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REAL-TIME PREDICTIVE ANALYTICS FOR CATALYTIC CONVERTER HEALTH: A CLOUD-NATIVE IOT APPROACH TO URBAN EMISSION MITIGATION

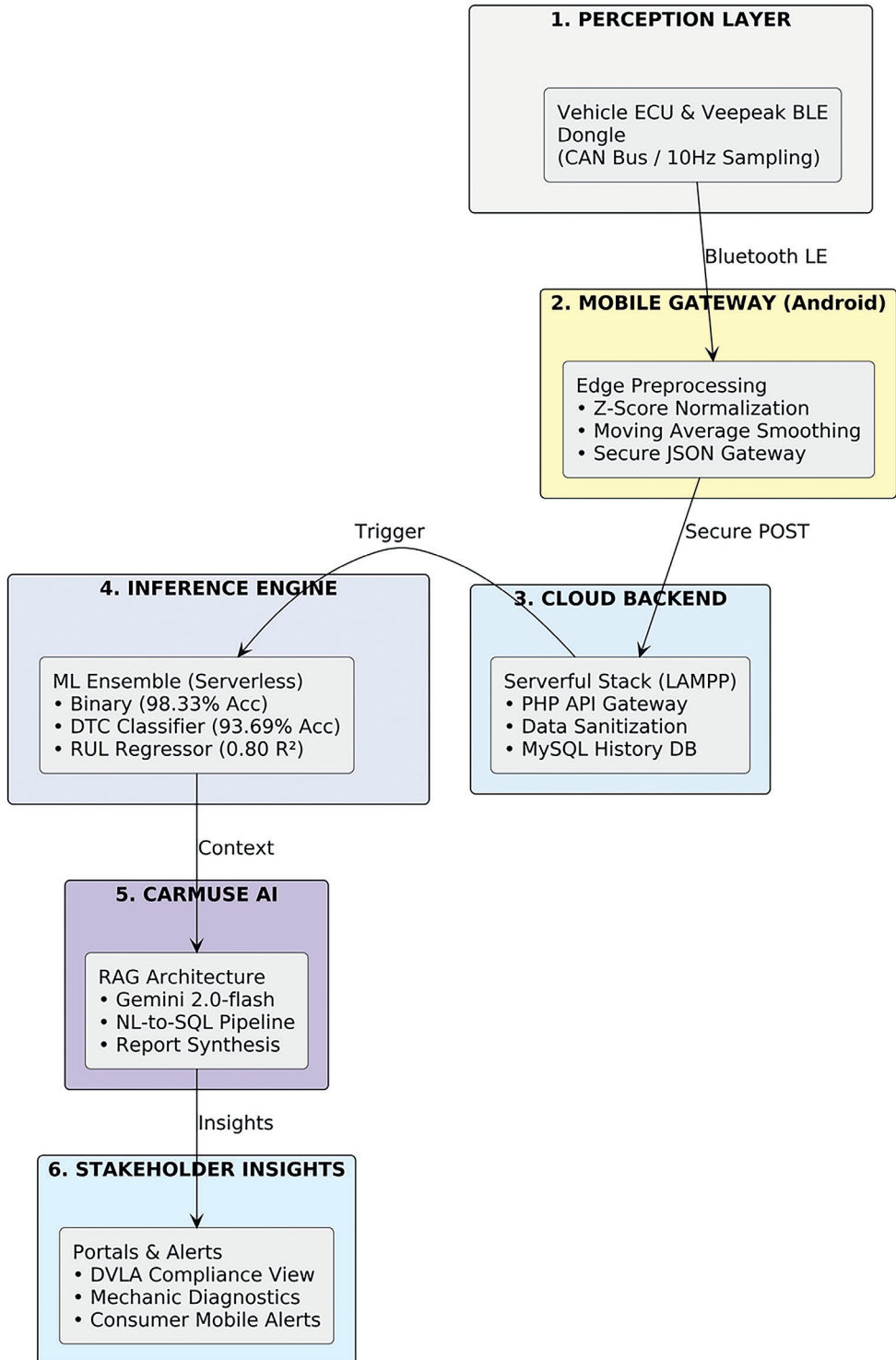
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Abstract – Vehicular emissions are a primary driver of air pollution in urban centres like Accra, Ghana, where ageing fleets and poor maintenance lead to frequent catalytic converter failure. Real-time monitoring of these components is largely absent in consumer-facing technology, leading to reactive repairs and prolonged environmental impact. This research presents "CatalyticGreat+", an integrated IoT platform for the proactive tracking and predictive maintenance of catalytic converters. The system utilises a Veepeak OBD-II Bluetooth Low Energy (BLE) dongle to capture telemetry from the vehicle's Electronic Control Unit (ECU). Data is processed via a native Android application and transmitted to a hybrid cloud architecture. The backend leverages serverless Google Cloud Functions to host three machine learning models: a binary classifier for fault detection (98.33 % accuracy), a multi-class trouble code classifier (93.69 % accuracy), and an ExtraTrees regression model for predicting Remaining Useful Life (RUL) in hours ($R^2 = 0.8061$, MAE = 2.22h). A unique contribution of the platform is "CarMuse," a Retrieval-Augmented Generation (RAG) AI that enables non-technical stakeholders, such as DVLA personnel, to query vehicle datasets using natural language. System evaluation under high-load conditions (500 concurrent users) demonstrated a throughput of 82 requests per second with sub-second inference. These results prove that low-cost IoT telemetry and serverless computing can effectively democratize emissions monitoring. This framework provides a scalable roadmap for moving from reactive to predictive maintenance, potentially reducing the collective carbon footprint of urban vehicle fleets in resource-constrained environments.

Keywords – Air quality; catalytic converters; cloud computing; Internet of Things (IoT); machine learning; predictive maintenance; Retrieval-Augmented Generation (RAG)



Hybrid cloud-native architecture for real-time vehicle telemetry and AI-driven predictive maintenance