

Title Edge-Cloud Synergy for AI-Enhanced Sensor Network Data: A Real-Time Predictive Maintenance Framework

Author Names: Kaushik Sathupadi , Sandesh Achar ,M. Abdullah-Al-Wadud , Shinoy Vengaramkode Bhaskaran ,Jia Uddin

Abstract: Sensor networks generate vast amounts of data in real-time, which challenges existing predictive maintenance frameworks due to high latency, energy consumption, and bandwidth requirements. This research addresses these limitations by proposing an edge-cloud hybrid framework, leveraging edge devices for immediate anomaly detection and cloud servers for in-depth failure prediction. A K-Nearest Neighbors (KNNs) model is deployed on edge devices to detect anomalies in real-time, reducing the need for continuous data transfer to the cloud. Meanwhile, a Long Short-Term Memory (LSTM) model in the cloud analyzes time-series data for predictive failure analysis, enhancing maintenance scheduling and operational efficiency. The framework's dynamic workload management algorithm optimizes task distribution between edge and cloud resources, balancing latency, bandwidth usage, and energy consumption. Experimental results show that the hybrid approach achieves a 35% reduction in latency, a 28% decrease in energy consumption, and a 60% reduction in bandwidth usage compared to cloud-only solutions. This framework offers a scalable, efficient solution for real-time predictive maintenance, making it highly applicable to resource-constrained, data-intensive environments.

Keywords: sensor network; hybrid edge-cloud framework; predictive maintenance; K-nearest neighbors (KNN); long short-term memory (LSTM) network;

<https://doi.org/10.3390/s24247918>

<https://www.mdpi.com/1424-8220/24/24/7918>