Thesis Defense

Computer Science Master's Program

"FLAIR: A Fog-Native Workload Placement Framework for QoS-Aware Scheduling in Smart Manufacturing"

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Abstract:
Smart manufacturing environments utilize a variety of heterogeneous IoT sensors that continuously stream large volumes of data. To detect and mitigate critical events such as fires or accidents in real time, this data must be promptly analyzed by machine learning (ML) image classifiers. These classifiers are typically deployed on fog computing nodes located within the manufacturing warehouse facilities to ensure low-latency responses and to protect data privacy. Although fog nodes offer a better alternative to remote cloud data centers for such latency-sensitive tasks, they are often resource-constrained and highly sensitive to the composition of workloads, particularly in heterogeneous environments where multiple types of classification tasks run concurrently on the same fog node. To address this challenge, this thesis proposes FLAIR (Fog Layer Architecture with Intelligent Routing), a fog-native workload placement framework that ensures latency-based Quality of Service (QoS) requirements are met for real-time classification tasks. FLAIR integrates a data-driven predictive model for estimating the response time of new tasks, a Digital Twin mechanism that simulates co-location scenarios to assess resource utilization, and a lightweight, threshold-based algorithm that automatically places new classification tasks on suitable fog nodes to ensure that they meet QoS requirements. Experimental evaluations on an AWS-based testbed show that FLAIR consistently outperforms traditional Queuing Network Models (QNM), particularly in heterogeneous deployments, reducing the mean absolute percentage error (MAPE) from 39.56% to 6.43% and avoiding task placements that would otherwise violate QoS constraints. These results underscore FLAIR's effectiveness in supporting latency-critical ML tasks within the dynamic and resource-limited fog infrastructure of smart manufacturing environments.

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