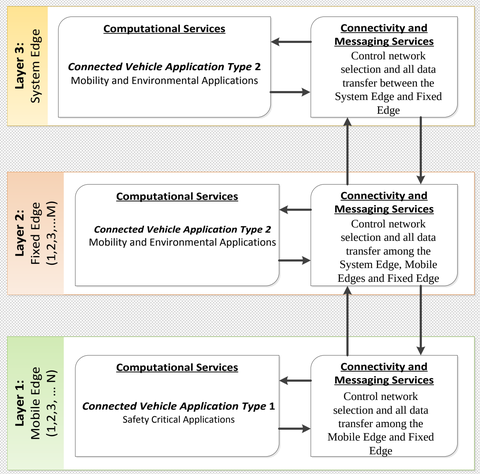
Development of Connected Vehicle Applications through an Edge-Centric Cyber-Physical System (CPS) Platform

Mizanur Rahman, Mhafuzul Islam, and Mashrur Chowdhury, Ph.D., P.E., F.ASCE

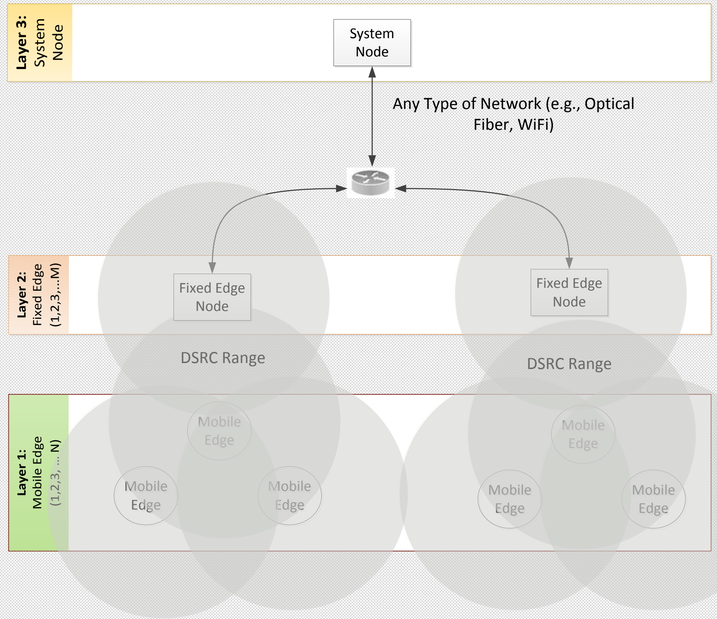
Introduction

- ▶Each vehicle in a Connected Vehicle (CV) system can wirelessly communicate and share data with other vehicles, infrastructures (e.g., traffic signal, roadside unit) and personal information devices; this constitutes a Cyber-Physical System (CPS).
- ▶A CPS with a centralized computing service cannot support real- time CV applications due to the often unpredictable network latency, high data loss rate and expensive bandwidth, especially in a mobile environment, such as the CV environment.
- ▶Edge computing is a relatively new concept for the CPS in which the resources for communication, computation, control, and storage are placed at different edges (e.g., fixed edge nodes at roadside infrastructure, system edge nodes (i.e., servers) at transportation center) in the CV system.
- ▶This edge-centric, distributed and layered CPS system is an appropriate choice to develop CV applications (e.g., queue prediction) with real-time feedback system.
- ▶The primary objective of this study is to develop and evaluate the performance of a traffic queue prediction algorithm with a real-time feedback system in an edge-centric CPS.
- ▶This queue prediction algorithm with a real-time feedback system is developed using machine learning approach and the algorithm
- ▶The queue warning algorithm was distributed in the edge-centric CPS that can run on different edge nodes of the system. This algorithm is developed using machine learning approach with a real-time feedback system.
- ▶The queue prediction algorithm was evaluated using SUMO (i.e., Simulation of Urban Mobility) and ns3 (Network Simulator 3) to illustrate the efficacy of the queue prediction algorithm on a roadway network in Clemson, South Carolina.

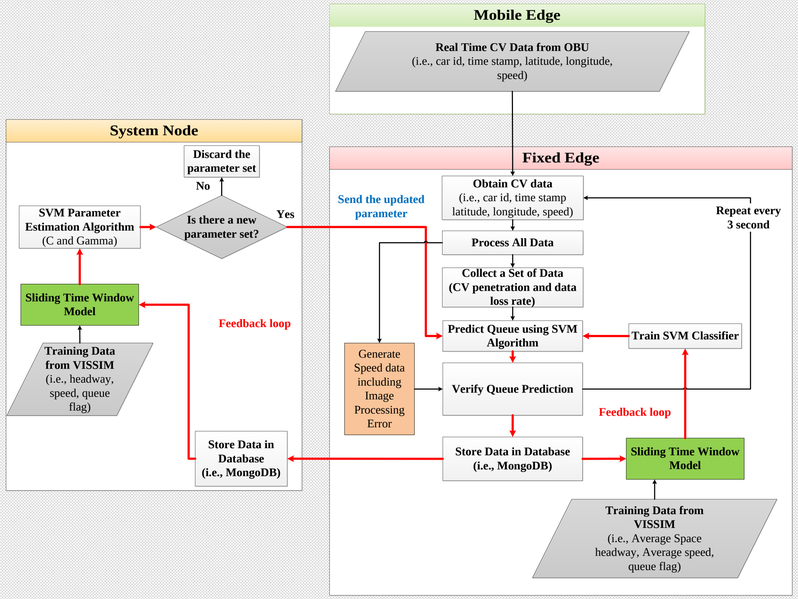


Edge- centric CPS framework for CV applications

Method



Communication networks in the edge-centric cyber-physical system in CV environment

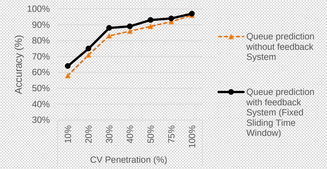


Adaptive queue prediction algorithm in the edge-centric CPS.

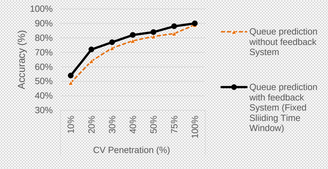
Experimental Scenarios and Resutls

Experimental Scenarios for with and without Feedback System

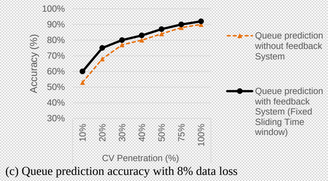
Experimental Scenario	Data Loss Rate (%)	CV Penetration (%)
Scenario 1	2	10, 20, 30, 40, 50, 75, 100
Scenario 2	4	10, 20, 30, 40, 50, 75, 100
Scenario 3	8	10, 20, 30, 40, 50, 75, 100
Scenario 4	16	10, 20, 30, 40, 50, 75, 100



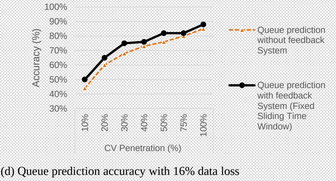
(a) Queue prediction accuracy with 2% data loss



(b) Queue prediction accuracy with 4% data loss

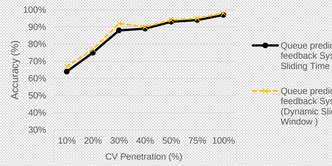


(c) Queue prediction accuracy with 8% data loss

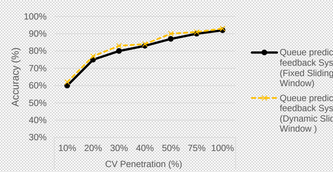


(d) Queue prediction accuracy with 16% data loss

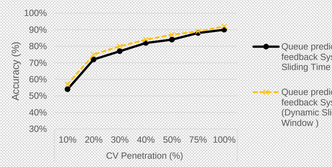
Queue prediction accuracy varying the CV penetration levels and data loss rates with and without the feedback system



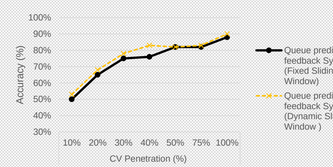
(a) Queue prediction accuracy with 2% data loss



(b) Queue prediction accuracy with 4% data loss



(c) Queue prediction accuracy with 8% data loss



(d) Queue prediction accuracy with 16% data loss

Comparison of queue prediction accuracy varying the CV penetration levels and data loss rates between Fixed Sliding Time Window and Dynamic Sliding Time Window for the feedback system

Conclusions

The performance of the queue prediction algorithm of edge-centric CPS was measured with and without feedback system in terms of accuracy with varying CV penetration levels and data loss rates. The analysis revealed that queue prediction using the feedback system (i.e., adaptive queue prediction algorithm) has a higher accuracy compared to without a feedback system.