<u>Graduate Research Plan Statement -</u>
Advanced Vehicle-Weather Applications using Edge Computing

Background: Microclimates suffer a serious impact on driving. This includes snow, ice, heavy rain, and other kinds of inclement weather that create rapidly changing road conditions. Dynamic road conditions require the vehicle's driving assistant system to react accordingly to ensure efficiency and safety. For example, a drone can be more energy efficient if its route planning algorithm considers real-time wind vector data, and a car should adjust its braking control system parameters to drive safely on snow-asphalt joint pavement[4].

Problem: There lacks an effective method to sense microclimate in a realtime fashion. On one hand, existing sensors on smart vehicles are vulnerable to weather conditions and provide low accuracy under adverse weather conditions [6]. On the other hand, the traditional approach for sensing microclimate by weather stations and satellites suffer from high processing latency and cannot provide useful information to drivers or autonomous vehicle systems fast enough to be considered real-time. As a result, one of the most critical issues in the development of autonomous vehicles and driver assistance systems is their poor performance under adverse weather conditions, such as rain, snow, fog, and hail[3].

Unique Insight: The system I propose to build will benefit from our latest insight concerning the fusion of data from different *types* of sources, which can provide high-accurate microclimate data with a high enough QoS that realizes real-time responses (i.e., adjusting the necessary stop distance). By surveying research literature, I found that different sensors provide their own distinct perspective on microclimate. For example, smart road sensors can be used to provide accurate observations on some microclimate parameters; some car-mounted sensors (i.e., camera, radar, temperature sensor) provide direct information about the weather, while other car-mounted sensors provide indirect information that can be used to infer the weather (e.g., the braking system parameters and the motion sensor readings can be used to infer road slipperiness); and mobile sensors provide information about the driver's concentration levels, which can also be used to infer weather conditions.

Research Questions:
1. How to adapt to dissimilar execution environments? Cars are moving fast on road neworks, which brings high resource dynamicity to the proposed system (i.e., number of nodes in a network, types of sensor data provided). However, the driving assistant applications require a real-time degree of QoS (i.e., latency, reliability, accuracy) to provide the required functionality. *Hence, how can we translate all heterogeneous inputs into a homogeneity to guarantee the necessary QoS for a real-time weather application?*

2*. How to extract meaningful information from sensor data in a real-time fashion?* There are three primary network tiers by which we can transmit and extract data: through the cloud, through core network devices, and through edge/user devices. Currently, we are refining the IoT to take advantage of each of those tiers using a multi-tier data transmission and processing approach in order to save network resources and improve QoS for application services[7].

Approach and Methods:
1. Understand the requirements: Collect information from engineers working on autonomous driving (Ford, GM, other Detroit-area automotive companies) to gain an understanding on the requirements on latency, accuracy, and granularity for autonomous/assisted driving vehicle systems.
***2. Build a emulator testbed*:**
a) *Define data collection methods***:** Stationary sensors, road sensors, mobile sensors, car-mounted sensors, nearby weather stations, and other nodes available in the edge network will be used to collect

data. The data will be aggregated to an edge server for analysis and oversight of all devices in the edge network. Use of current autonomous vehicle and weather emulators can be incorporated to help understand how sensor data can be collected.

b) *Collect data under different weather conditions to create a dataset:* A set of data will be collected and used to help in the QoS analysis of the data used for the real-time vehicle weather application.

c) *Applying data processing algorithms on the edge server:* The dataset collected can be used in autonomous vehicle emulators for testing and further analysis of how to build the algorithms to analyze and make sense of all of the data when it is available at various times, and that meet the weather application QoS requirements.

3. Test different scenarios and find the gap: Various scenarios will be tested using the built emulator in order to find the gap between the defined algorithm built to process the data, and the QoS of the weather application.

4. Build a system that works best for most scenarios: Based on the results from step 3, I will build a system and adapt the data analysis algorithm to work with all tiers (cloud, network core, edge) and with all types of sensor data so that a weather application will function for a vehicle system and meet the latency, granularity, and accuracy requirements. See figure 1.

5. Test the system in real setups and make adjustments.

Logistics and Support:

1) Myself: Edge Computing research.
2)Weather tech company sensors: *LiveRoadAnalytics*.
3)Ford/automotive companies.
4)State of the Art CIS and Engineering research facilities at the University of Michigan-Dearborn (UM-D):
*Engineering Lab Building (2022).
-Multiple CIS laboratories.
*Institute for Advanced Vehicle Systems.
*Edge Computing researchers at UM-D:
*Dr. Zheng Song, IEEE best paper[1] on edge computing (2019).He runs Edge Computing courses and collaborates with graduate and undergraduate students on his research and runsa edge-computing user experience and testbed framework.

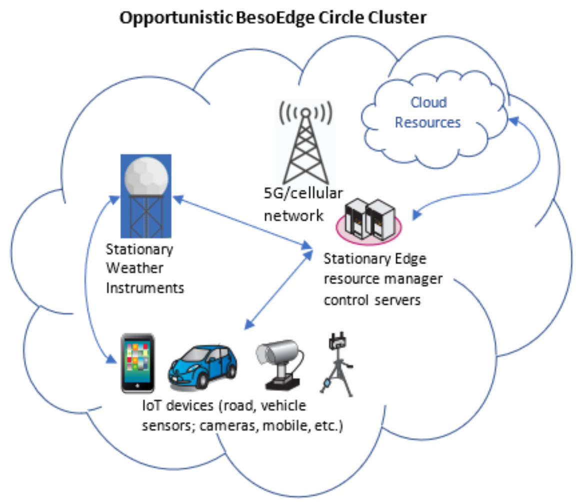

Figure 1

Intellectual Merit

1. autonomous driving. microclimate.
2. enhance the state-of-the-art of edge computing and IoT.
3. build a collaborative testbed for emulating sensor data in inclement weather to be used by autonomous driving stakeholders.

Broader Impacts

Research in edge computing in vehicle networks with weather sensor data can specifically keep drivers safe and advance the development of autonomous vehicles. This project involves the IoT, which all groups from all walks of life rely on. As such, there is no way such an undertaking can be done effectively without involving students and everyday users from all backgrounds. In the future, imagine a world where there is essentially always internet connectivity for all users - a world where there are so many devices that are all securely connected in a web that does not only rely on the internet core, but where every device (buildings, cameras, cell phones, smart watches, satellites, etc.) is always contributing and making so many applications possible. That is the vision for edge computing. As long as enough people are nearby, connectivity is practically guaranteed.

1. technical part: one sentence.
2. detroit. auto companies. advance the research on autonomous driving to bring jobs back to the region.
3. engineering education: this project can be used to train students how to process sensing data. benefit education. provide hands-on project opportunities to undergraduate students like me.
4. safety training: draw attention to safe driving at inclement weather.

References

[1] Z. Song and E. Tilevich. “A programming model for reliable and efficient edge-based execution under resource variability”. In 2019 IEEE International Conference on Edge Computing (EDGE), pages 64–71. IEEE, 2019.
[2] Srivastava, Kavita & Sharma, Sudhir. (2020). “Enabling Edge Computing in an IoT-Based Weather Monitoring Application”. 10.1007/978-981-15-2329-8_18.
[3] Zang, Shizhe, et al. "The impact of adverse weather conditions on autonomous vehicles: How rain, snow, fog, and hail affect the performance of a self-driving car." IEEE vehicular technology magazine 14.2 (2019): 103-111.
[4] Wang, Xinqun, et al. "Development of AEB control strategy for autonomous vehicles on snow-asphalt joint pavement." International Journal of Crashworthiness (2021): 1-21.
[6] Vargas, Jorge, et al. "An overview of autonomous vehicles sensors and their vulnerability to weather conditions." Sensors 21.16 (2021): 5397.
[7] Seyed Hossein Mortazavi, Mohammad Salehe, Carolina Simoes Gomes, Caleb Phillips, and Eyal de Lara. 2017. Cloudpath: a multi-tier cloud computing framework. In Proceedings of the Second ACM/IEEE Symposium on Edge Computing (SEC '17). Association for Computing Machinery, New York, NY, USA, Article 20, 1–13. https://doi.org/10.1145/3132211.3134464