DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Advanced Research

JUNE 2021

Project Title:
Connected and Automated Vehicle (CAV) Application Development

Task Number: 3427

Start Date: January 1, 2020

Completion Date: April 1, 2021

Task Manager:
Pradeepa Pannirselvam
Transportation Engineer (Electrical)
pradeepa.pannirselvam@dot.ca.gov

Software and Hardware Systems for Autonomous Smart Parking Accommodating both Traditional and Autonomous Vehicles

Develop a solution for parking congestion integrated with autonomous vehicles.

WHAT WAS THE NEED?

Current parking infrastructure suffers from congestion as the number of vehicles circulating in urban areas is growing and expansion is not a cost-effective solution. In parallel, developments in autonomous vehicle technology mean that driverless vehicles are predicted to be in circulation by the 2020s and makeup 40% of vehicle travel by the 2040s. Expected benefits of autonomous vehicle travel include reduced congestion through vehicle sharing and reduced walking distance for passengers who can be dropped off chauffeur-style by autonomous vehicles. Given that this new technology has the potential to exacerbate existing congestion issues, it is necessary to develop a solution for parking congestion integrated with autonomous vehicles.

WHAT WAS OUR GOAL?

The goal of this project is that this system will: 1) be scalable and include multiple lots across a metropolitan area, 2) operate in real time, and 3) communicate securely with autonomous vehicles over Dedicated Short Range Communication (DSRC).

WHAT DID WE DO?

This project addressed the issue by providing a full-stack solution including sensors to monitor occupancy, Fog systems to perform local data pre-processing, radios to communicate with autonomous vehicles, and cloud-based software to predict occupancy. This solution is divided into 3 main subsystems which include the Parking Tracker Fog System (PTFS), a wireless sensor network, and a Cloud-based server.

Caltrans

Caltrans provides a safe, sustainable, integrated and efficient transportation system to enhance California's economy and livability.

The PTFS refers to the local IoT module and is equipped with DSRC technology for Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication. It is responsible for generating useful information about occupancy and vehicle classes based on data collected from the wireless sensor network or data directly received from autonomous vehicles over DSRC. For the wireless sensor network, a tested system of MEMSIC IRIS sensor motes equipped with Passive Infrared Sensor (PIRs) is used because they have demonstrated compatibility with multi-hop networks that allow for sensor connections over a greater distance.

To facilitate DSRC between the PTFS and autonomous vehicles, Ettus B210 Software Defined Radios (SDRs) is used to communicate using the V2X standard: IEEE 802.11p. The novel contribution to the ongoing issue of parking congestion is this DSRC solution for integrating autonomous vehicles into Intelligent Transportation Systems (ITS). A Cloud-based server is the final subsystem and is responsible for collecting data across multiple PTFSs to be inputted into a machine learning model trained to predict occupancy in parking structures. To validate the algorithms employed, parking scenarios is simulated and the performance of the system in terms of response time and accuracy was evaluated. DSRC solution was also evaluated based on criteria including latency and accuracy.

To summarize, the major research tasks accomplished are the following:

- A wireless sensor network using MEMSIC IRIS sensor motes for mounted ultrasonic sensors and PIRs that has comparable performance to established systems in was developed.
- A Fog computing system, the PTFS, that will aggregate data and use it to classify vehicles and determine occupancy in addition to communicating with autonomous vehicles over DSRC using installed radios was developed.
- PTFS's software defined radios for connecting over DSRC with autonomous vehicles in V2V and V2I communication was customized.

WHAT WAS THE OUTCOME?

The work throughout this project showcased hardware and software implementation of a smart parking system that can communicate with both traditional and connected vehicles alike. This comes as a step towards evolving the existing parking infrastructures to accommodate the estimated wide-scale adoption of autonomous vehicles and connected vehicles, which would require real-time information about available parking services. In this regard, PTFS was developed that can establish communication through traditional wireless communication and DSRC, which is the expected communication technology for connected vehicles.

This system is illustrated in Figure 1. The model parking structure is shown in Figure 2 and the simulation model is shown in Figure 3. Several experiments were conducted through simulations and Hardware setup demos to assess the reliability of the parking information exchange in real-time for both traditional and DSRC-based communications. Finally, this work could be foreseen as being scalable to multiple parking spaces, each represented through its own PTFS, and all PTFSs are managed through a central cloud that can alleviate the smart parking services to a city-wide level and complement it with parking occupancy predictions.

WHAT IS THE BENEFIT?

The results will contribute important information for the design of Autonomous Smart Parking Accommodating both Traditional and Autonomous Vehicles.

IMAGES

Figure 1: Hardware-in-the-loop Structural Diagram

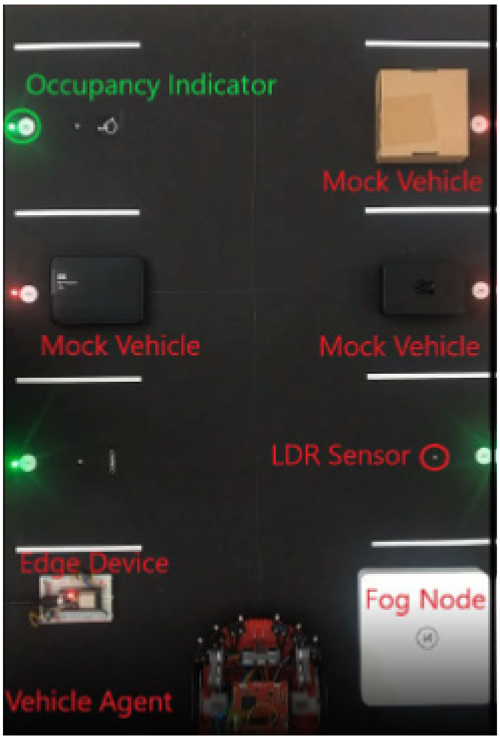

Figure 2: Model Parking Structure

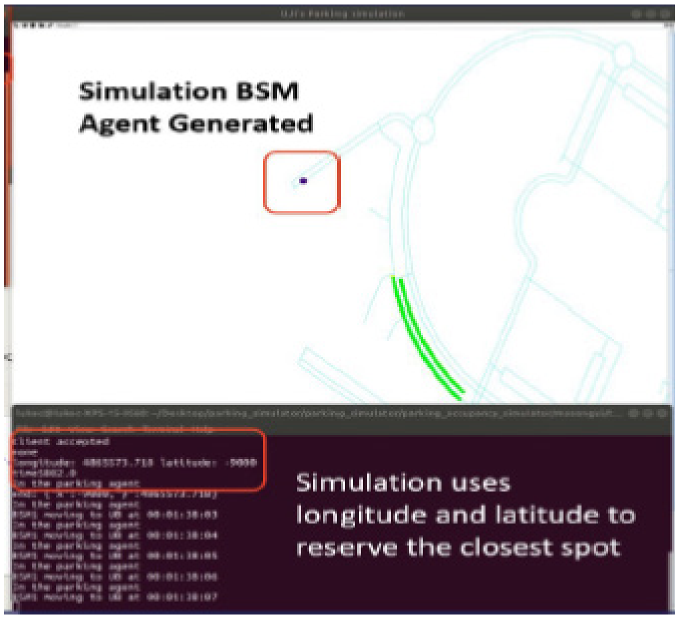

Figure 3: Simulation Model