Adaptive Traffic Signal Control with Connected Vehicle Data

Master‘s Thesis of Hussein Bachir

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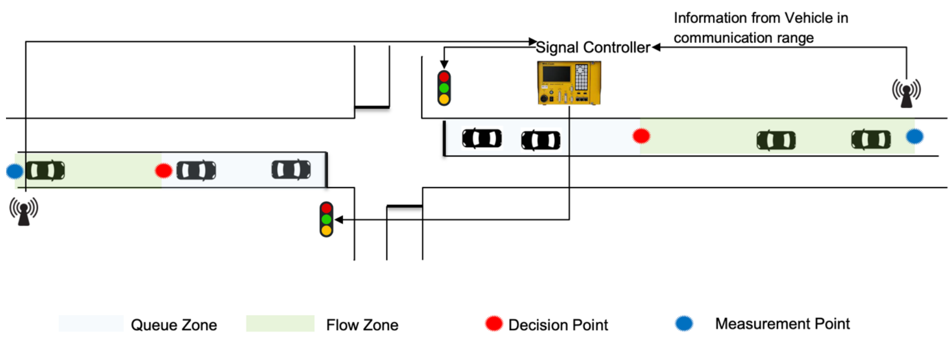
Introduction

The motivation for this research stems from the escalating traffic-related challenges, including congestion, attributed to the surge in urban vehicle ownership. Deficient synchronization of traffic signals has led to significant delays, with studies indicating up to 296 million hours of vehicle delay. Additionally, signalized intersections witness elevated accident rates, prompting the need for improved traffic signal operation. Conventional fixed timing control systems struggle to adapt to dynamic traffic conditions, necessitating the exploration of adaptive control methods. Connected vehicle technology offers a solution by enabling real-time data transmission, enhancing control system adaptability, and improving traffic flow efficiency, safety, and emission reduction. This thesis aims to develop a traffic control system integrating connected vehicle data, focusing on rule-based control's impact on control objectives such as minimizing delays, stop times, and queue lengths. It also explores the utilization of vehicle-to-everything (V2X) communication to optimize vehicle occupancy, address mixed vehicle traffic, and enhance public transport prioritization, thus advancing the effectiveness of adaptive traffic signal control.

Methodology

The control system comprises two detection points: the measurement point and the decision point, along a specific road section, along with a central control unit. These sensor points gather information from interconnected vehicles, including their speeds within a specified detection zone, proximity to the stop line, and average occupancy levels. Subsequently, this data is relayed through the vehicle's on-board modules to the central control unit, which utilizes various signal timing restrictions (e.g., minimum green timing, maximum green end time, amber time, and all-red duration) to determine whether an adjustment to the signal timing is necessary. This decision-making procedure involves reassessing traffic conditions every second based on these restrictions to ascertain the need for altering the signal stage. The data collected serve as the foundation for crafting the control algorithm, as will be expounded upon later. The two detection points effectively partition the road segment into delineated zones:



the queue zone, positioned between the stop line and the decision point, where the remaining queue after the minimum green time elapsed is evaluated, and the traffic demand in other parts of the intersection is scrutinized to determine the need for extending the green time. The flow zone, situated between the decision point and the measurement point, is where the vehicular traffic flow within the connection range of the intersection is analyzed, considering aspects like traffic flow, vehicle occupancy rate, and anticipated arrival time. Subsequently, this data is transmitted to the central control unit for further analysis. An exponential smoothing algorithm has been developed to predict the state of unequipped vehicles based on connected vehicles count and penetration rate.

Results