A Simulation Study of the Car-to-X Communication Based Merge Traffic Control in Freeway Work Zone

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1 Introduction

In recent years, the development of information and communication technologies has paved the way for the development of Advanced Driver Assistant Systems (ADAS) on the road. The Car-to-X communication is a very important technology within ADAS. Through the wireless communication among vehicles (i.e. Car-to-Car communication) as well as between vehicles and roadside infrastructures (i.e. Car-to-Infrastructure communication), the drivers can receive information that extends well beyond their visual range [1]. Traffic managers can get more traffic information as well, which helps them establish and/or improve effective control strategies. The Car-to-X communication thus brings great benefits in terms of higher traffic safety and efficiency.

Due to some technical issues (e.g. lack of standard communication protocol) from the automobile and infrastructure manufacturers, this technique is currently still on a developing state. Since the use of this technology greatly depends on its market penetration, time is still needed to fully enjoy its benefits. However, at this stage, it is important for the public to get information about the advantages of this technology, which in return will contribute to its acceptance and implementation in the future.

For this purpose, the authors are motivated to study the impact of such Car-to-X communication on specific situations. Due to the shortage of Car-to-X field applications, it is quite costly and time consuming to get real traffic data in order to carry out a proper empirical analysis. Therefore, a microscopic traffic simulation tool (VISSIM) is employed in our study to model the potential applications and their impacts on traffic. This paper focuses on a merge traffic control application for freeway work zones. During the simulation, the drivers are advised to maintain certain speed limits and/or follow specific merging procedures based on the traffic conditions provided by other vehicles and roadside units (RSU). In addition, scenarios with different penetration rates of the Car-to-X system are designed and investigated. The simulation results show that Car-to-X communication can bring substantial improvements in the performance of traffic around freeway work zones.

2 Merge traffic control in freeway work zone

Typically there are two strategies [2] for the control of merging traffic in freeway work zones: the early merge traffic control and the late merge traffic control.

The early merge traffic control is the conventional approach. It aims at encouraging drivers to merge as early as possible before they reach the mandatory merging point. The control signs providing the information about the lane drop are placed significantly upstream of the lane drop itself. This control strategy reduces the potential conflicts or frictions among the drivers merging at the last minute. As a result it reduces the accident rates close to the merge area and guarantees the through flow.

The late merge traffic control is just the opposite strategy of the early merge. It advocates that drivers should stay on their lane and merge as late as they can. With this strategy the control signs are still placed upstream, but they advise drivers to use all the lanes until the mandatory merging point. The idea is to fully utilize the capacity of the lanes as much as possible. This can shorten the queue along the road and reduce the possibility of blocking exits upstream of the work zone.

Due to the variation of traffic, it is not reasonable to just keep one of those two strategies all the time. The control strategy in real life should be dynamic rather than static: the traffic control should be adaptable to the traffic conditions. Therefore the Car-to-X communication can be a proper application for this control scheme. Through the Car-to-X communication network, the traffic conditions can be updated to the control center in real time. Similarly, different driving advices provided by the control center can be broadcasted to each vehicle according to its status on the road. The drivers are informed to merge early or late accordingly. In addition, the information regarding the speed and distance to the front vehicle can be propagated from one vehicle to another, with the objective of increasing the traffic safety and efficiency.

3 Implementation

The microscopic traffic simulation tool VISSIM has been further developed in its recent version to support the Car-to-X communication function. Through programming with the API module, the vehicles in VISSIM simulation can communicate with the external control program and receive the control commands regarding their speed, position on the road, etc. In this study, a scenario of a lane drop (from three lanes to two lanes) due to a work zone has been designed in VISSIM. The length of the work zone has been set to 500 meters, although such length setting should not affect the results. It is supposed that the work zone condition will last for one hour, after that the restriction is deactivated. By changing different parameters such as the speed limit, suggested merging point and Car-to-X equipment installation rate, different simulation outcomes (e.g. queue length, flow rate, average travel time) are generated. In addition, a random number generator is employed to simulate the misbehavior. For example, some drivers may ignore the received early merge instruction and continue to the very end.

4 Results

The simulation results are post-processed for analysis purposes. The results show that by adopting the Car-to-X communication in the freeway work zone, a smooth gradual change of speed can be achieved upstream of the work zone.

The early merge traffic control strategy works well with low flow rate: the number of stops is less while the traffic flow through the work zone suffers just small reductions. The late merge traffic control strategy leads to shorter queue length in the simulation when the input flow is high. As expected, it prevents the blockage of the upstream exit.

Furthermore, comparing with the conventional control method which uses fixed points of merge signs, the simulation results show that both strategies work better with the Car-to-X communication system. This most likely happens because by adopting the Car-to-X communication, the control strategy is more adaptable to current traffic states, and hence outperforms the traditional non-dynamic control methods. In addition, the simulation results show that the improvement of traffic flow is significant only after a minimum penetration threshold is achieved.

References

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