Intersection Collision Avoidance System Architecture

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Abstract - In this preliminary paper we propose new intersection collision avoidance architecture. This system allows vehicles to establish secure links with roadside unit installed at the intersection before entering the furthest point where vehicles start to share their current state with the roadside unit. Early link establishment is chosen to maximize the opportunity of advanced notification for collision warnings.

I. INTRODUCTION

Recent studies have reported that more than 30% of all crashes in the United States are due to intersection collisions [1]. To reduce the number of accidents, new developed systems must be able to detect and prevent accidents in real time. The Dedicated Short Range Communication (DSRC) technology will be used widely to overcome this problem.

DSRC interfaces between different types of equipment that are located inside vehicles and at the roadside. Equipments inside vehicles are called On-Board Unit (OBU), and equipments at the roadside are called Roadside Unit (RSU). DSRC uses seven non-overlapping 10 MHz channels. One of these channels is called Control Channel. This channel is used to send safety messages, establish links between equipments, and send advertisement messages. The other six channels are called Service Channels and can be used for non-safety data.

The goal of this paper is to use the DSRC technology to build an intelligent intersection traffic system (IITS). The IITS allocates transmission windows to all vehicles approaching the intersection, and sends poll requests to each vehicle during its allocated window. The vehicles share their status information as a response to the poll request. The IITS allows vehicles to establish secure links with the RSUs installed at the intersection before entering the region, where they must exchange their status information. Three different methods have been considered to design the IITS system. This paper presents a brief description of all three methods. Detailed performance analysis of these three techniques along with advantages and disadvantages of each method will be presented in our future full paper.

This paper is organized as follows, Section II presents problem definition and system overview, Section III contains system design and protocol architecture. Finally, Section IV contains conclusion and future work.

II. PROBLEM DEFINITION AND SYSTEM OVERVIEW

Safety messages must be generated and sent to reach all vehicles within an allowable latency of 100 msec [2]. Consider the scenario where the DSRC technology is used to implement intersection collision avoidance system. In this scenario the RSU communicates with all vehicles approaching the intersection. The RSU receives information from vehicles on the service channel and sends warning messages on the control channel. Since DSRC technology allows only one channel to operate at a time, the vehicle either listens to the service channel or listens to the control channel [3].

As vehicles approach the intersection they must establish secure links with the RSU via control channel by exchanging their digital certificates (Establishing secure links takes more time than exchanging normal messages). After that, vehicles start to interact with the RSU by sharing their data and receiving the intersection’s condition messages from the RSU via service channel. If the traffic density and the arrival rate of the vehicles become high, the RSU might not be able to generate warning messages within the specified latency, and at the same time continue collecting information from all vehicles within the communication range. Moreover, the increase of vehicles' density results in increase of the packet loss. Hence, the challenge is to build a system that allows the RSU to offer safety services on time, collect information from all vehicles within an allowable latency and reduce packet loss.

A. Intersection Region

Fig. 1 shows a Four-leg signalized intersection area. The RSU is installed at the center of the intersection. The area is divided into: Control Channel Zone (CCHZ) with \( d_1 \) meters diameter; Service Channel Zone (SCHZ) with \( d_2 \) meters diameter. When vehicles enter CCHZ, OBUs communicate with the RSU on the control channel using the ad hoc mode.

On the approach to the intersection and at a specific distance (SCHZ), the OBUs send requests via the control channel to notify the RSU for the OBUs to be added to the RSU’s polling list. The OBUs keep receiving polling requests and responding to them on the service channel until they leave

Figure 1. Intersection area, RSU is in the center of intersection, CCHZ is the control channel zone, and SCZ is the Service channel zone.
the intersection. When the OBUs leave the intersection they notify the RSU to remove them from the polling list.

B. Messaging System

We assume that a warning message dictionary is embedded in all OBUs and RSU. Each message is identified by its unique ID. We assume that one byte of ID is enough to represent all messages. The sender needs to insert the ID of the message so that the receivers can identify the message.

The system has three types of messages: status, warning and polling messages. Status and warning messages can be sent by vehicles and IITS, while polling messages are sent by the IITS only. Vehicle’s Status Message (VSM) will be sent by vehicle when it receives poll request from the IITS. VSM carries information about the state of the vehicle, i.e. velocity, acceleration, position, and so on. VSM can also include an additional field that contains the ID of a warning message, i.e. a vehicle might enable this field if it can’t stop on the red light, and send it to the IITS which will rebroadcast it to other vehicles. IITS’s Status Message (ISM) will be sent periodically every $T$ sec. ISM contains all the dynamic information about the intersection, i.e. the status of the current signal light, time remaining to switch to the next light state, and so on. Polling messages (PM) will be sent by the IITS to all vehicles in the SCHZ only. PM contains three fields: the MAC address of the vehicle that must respond by sending VSM, the ACK frame to the vehicle polled in the previous window, and the ID of a possible warning message to alert the driver to slow down.

III. SYSTEM DESIGN AND PROTOCOL ARCHITECTURE

To build the system, three methods have been considered: Competition based, Shared Channel, and Dedicated Channel methods. In the competition based, the RSU and the vehicles compete for the media to send their data. This method might have high packet loss and high latency for vehicles and RSU if the density of vehicles at the intersection is high. In the Shared Channel method, the IITS has one RSU that shares service and control channels by switching between them every $T$ sec. As shown in Fig. 2, the control channel period is divided into contention free period and contention period. In the contention free period the IITS sends warning messages, ISM messages, and polled vehicles list every $T$ sec. In the contention period, vehicles compete to establish secure links, to notify the IITS when they enter the SCHZ, and to notify the RSU when they leave the intersection. The service channel period is divided into fixed size windows. During this period, each vehicle in SCHZ is polled individually. The RSU sends PM to the vehicle and the vehicle responds by sending VSM during its allocated window. This method is suitable when the number of lanes per road is small, and the arrival rate of vehicles is low. In the Dedicated Channels method, two RSU will be installed at the intersection, one is dedicated to the service channel and we call it RSU_SRV, and the other is dedicated to the control channel and we call it RSU_CTL. Both RSUs will be operating at the same time. Vehicles inside the SCHZ will communicate with the RSU_SRV via service channel, and at the same time vehicles outside SCHZ will communicate with the second RSU_CTL via the control channel. Fig. 3 shows one system cycle. The cycle starts with a control and a service channel working in parallel. The control channel period is similar to the control channel period in the shared channel method. At the same time, during the service channel period, vehicles receive poll requests from the IITS and respond to them. As shown in Fig. 4, the IITS polls vehicles imminent to collision (Vehicle imminent to collision is the vehicle that is close to the edge of the intersection) more than once during a single cycle. Frequent polling helps in reducing the distance traveled by the vehicle after issuing a slow down message. At the end of this period, vehicles in SCHZ must switch to the control channel to receive warning messages during the contention free period. This method is attractive at high traffic density intersections.

IV. CONCLUSION AND FUTURE WORK

In this paper, we introduced an IITS in which the intersection zone is divided into CCHZ and SCHZ. We also proposed three methods of interacting between vehicles and RSU. In our future work, we will evaluate these methods and study the influence of vehicles’ density on CFP and CP length.

REFERENCES