A Review of Congestion Control Algorithm for Event-Driven Safety Messages in Vehicular Networks

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Abstract

Congestion control algorithm in Vehicular Networks (VANETs) has been extensively studied. However, most of congestion control algorithms are not directly applicable to uni-priority of event-driven safety messages. The event-driven safety messages have stringent requirement on delay and reliability. The uni-priority of event-driven safety messages are caused by the traffic of the same priority, typically the warning messages of safety applications from different transmitters. The uni-priority messages should be schedule before the node starts the transmitting process. In dense network, a large number of vehicles broadcast a beacon messages at a high number of frequency. Then the Control Channel (CCH) easily congested. It's very important to keep the CCH channel free from congestion to ensure timely and reliable delivery of event-driven safety messages [9, 20]. Hence, this study takes a closer look at existing congestion control algorithms to solve congestion problems because it affects the performance of safety messages. The study further exposes the weaknesses and advantages of some of these congestion control algorithms which can assist researchers to tackle the inherent problems of congestions in VANETs. This paper also concludes with a planned future research for disseminating uni-priority of event-driven safety messages while solving congestion problems.

Keywords: *VANETs, Event-Driven Safety Message, Control Channel, Uni-Priority, IEEE 802.11p*

1. Introduction

VANETs are composed of vehicles equipped with advanced wireless communication devices and self-organized networks built up from moving vehicles. The VANETs tends to operate without any infrastructure or legacy client and server communication. Each vehicle equipped with communication devices will be a node in the VANETs and allow to receive and send other messages through the wireless communication channels. This network will provide wide variety of services such as Intelligent Transportation System (ITS). The safety application is one of the most crucial application in ITS. For example, if a vehicle detects road accident, it will inform other neighboring vehicles about this road accident. The safety messages must to be delivered to each neighboring node with almost no delays.

The safety messages can be categorized into two categories; beacon and event-driven messages. The vehicles are supposed to issue beacon messages periodically to announce other vehicles about their situations such as speed, positioning and direction. These periodic messages are used by neighboring vehicles to become aware of their surrounding and to avoid potential dangers [6, 20]. The event-driven safety messages are generated when an abnormal condition or an imminent danger is detected, and disseminated within a certain area with high priority [20]. The event-driven safety messages should be delivered to neighboring node with high reliability and limit time. A single delayed or lost message could result in loss of life [8, 20].

The Federal Communication Commission (FCC) allocated a frequency spectrum for VANETs wireless communication. The Commission then established Dedicated Short Range Communications (DSRC) Service in 2003. The DSRC is a communication service that uses the 5.850-5.925 GHz band for the use of public safety and private applications [5].

In order to provide DSRC for VANETs communication the IEEE is currently working on the IEEE 802.11p or Wireless Access in Vehicular Environments (WAVE) standard [14]. The original 802.11 protocols are not suitable for VANETs because of high vehicular mobility, faster topological changes, requirements of high reliability and low latency for safety applications. The DSRC was designed into multi-channel system. The FCC divided the spectrum into seven each with 10 to 20 MHz channels which six were identified as Service Channels (SCH), and one was identified as the Control Channel (CCH), as shown in fig. 1. The CCH channel is used for safety messages, but non-safety services and WAVE-mode short messages are expected to be provided in the six service channels [10, 13].

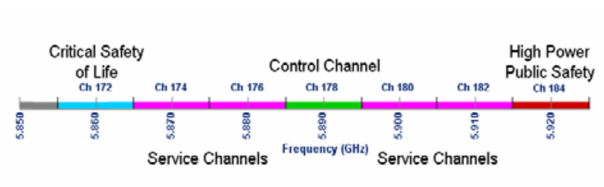

Fig. 1 The Seven Channels of DSRC

In dense network, a large number of vehicles broadcast beacon messages at a high frequency, the CCH channel will easily congested. The periodic messages are broadcast may lead to broadcast storm/blind flooding problem in VANETs [6, 16, 18]. It is very important to keep the CCH channel free from congestion in order to ensure timely and reliable delivery of event-driven safety messages [19, 20]. In order to avoid congestion of CCH channel and delay of event-driven safety message, a reliable and efficient congestion control algorithm is needed [9, 14, 20].

The purpose of this study is to reveal the strong and weak points of some of these congestion control algorithm so that researchers can come up with broader algorithm to tackle the inherent problems of congestions in VAENTs. This study focused on uni-priority of event-driven safety message congestion. The uni-priority message is caused by the traffic of the same priority, typically the warning messages of safety applications from different transmitters. According to [19], if there are many nodes with the same priority to transmit, the collisions may occur. Furthermore, in real life various reactions from drivers will happen, its will generate multiple event-driven safety messages.

The rest of this paper is structured as follows. The rest part of the paper is organized as follows: In section 2, network congestions in wireless ad hoc networks is shortly reviewed. Section 3 discusses various congestion control algorithms and some implementation strategies in VANETs. Section 4 concludes the paper with outlooks on the future work.

2. Wireless Ad Hoc Network Congestion

Wireless ad hoc network is a decentralized wireless network. The wireless ad hoc network does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed wireless networks. Instead, each node participates in routing by forwarding data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity. Every node in wireless ad hoc network can become aware of the presence of other nodes within its range. The wireless ad hoc networks can be further classified by their application such as Mobile Ad Hoc Networks (MANET), Wireless Mesh Networks (WMN), Wireless Sensor Networks (WSN) and Vehicular Networks (VANETs).

Wireless ad hoc is prone to network congestion due to the mobility of nodes, synchronization difficulties in self-coordination, and the limited capacity of the wireless channels [22, 3]. Therefore, node in wireless ad hoc may experience low throughput and long latency under the circumstance of network congestion.

One of the important aspects in wireless ad hoc networks is to maintain the efficiency network operation while preventing degradation of wireless channels communication [3, 24]. They were proposed the congestion control algorithm as solution. The major goal of congestion control mechanism is simply to use the network as efficiently as possible by attaining the highest possible throughput while maintaining a low loss ratio and small delay [17].

3. Congestion Control Algorithms in VANETs

In VANETs, many of studies focused to control the load of wireless channels over congestion control algorithms such as [7, 9, 11, 14]. The main purpose of congestion control algorithm is to control the load of traffic conditions and the performance of wireless communication channels will be increased.

Research in [11] was proposed congestion control algorithm focused on comfort applications such as browsing Internet. However, our study concern about dissemination of the safety messages especially event-driven safety messages. The successfully dissemination of event-driven safety message is very crucial and can save our life. If a vehicle detects dangerous stuff such as a sharp object fallen from a construction truck on the road, it will notify other vehicles behind to avoid the object. The safety message must to be delivered to others node with high reliability and without delays.

Researches in [9, 14] concentrated on safety messages. However research in [9] focused only on the performance of the Emergency Electronic Brake Light with Forwarding (EEBL-F) safety application. This congestion control algorithm should be testing on other event-driven safety applications such as pre-crash sensing and lane change warning. Research in [14] also focused on safety messages but this research didn't separate safety messages into beacon and event-driven safety messages. As mentioned, the event-driven safety message is most important and should be delivering on time with high reliability.

Some of researchers consider the utility of packets as an important part in congestion control algorithm such as [11, 14]. Research in [11] proposed a novel concept for utility-based congestion control and packet forwarding in VANETs. This protocol called as decentralized Utility-Based Packet Forwarding and Congestion Control (UBPFCC) is implemented on top of the IEEE 802.11 MAC protocol. The congestion control algorithm uses an application specific utility function and encodes the quantitative utility information in each transmitted data packet in a transparent way for all users within a local environment. A decentralized algorithm then calculates the average utility value of each individual node based on the utility of its data packets and assigns a share of the available data rate proportional to the relative priority. This congestion control algorithm evaluated priority message based on utility and packet size, it will reduced performance of disseminating of event-driven safety messages.

Research in [14] applied message utility one of dynamic factor, according to the number of its retransmitting by the neighborhood. For example, if a node X has to send message A but at the same time node X receives the same message A sent by another node. The node X should change the message A based on dynamic factor. The higher priority message is given to the smaller covered zone. Furthermore research in [14] evaluated priority with based on other factors such as node speed and message validity. The result showed that the delay of event-driven safety message is 50 ms in the worst scenario. This result is critical because pre-crash sensing safety application message need to disseminate to adjacent nodes within 20 ms.

Furthermore research in [14] also developed a congestion control algorithm and then adapt dynamic priorities-based scheduling. The purpose of dynamic priorities-based scheduling is to ensure high priority packets to be sent first without delay while medium and low priority packets will be rescheduling. In fact with EDCA, the message has been given based on its content such as critical or not.

Research in [20] proposed transmit power control in their framework of congestion control algorithm. Research on this area has been increase researchers to study especially from [16]. The purpose of transmit power control to maximize energy consumption and connectivity for point-to-point communications. Generally, a higher data rate usually requires a higher transmit power from a sender, thus may cause a higher interference to other nodes. The congestion control via dynamic transmit power control, which are usually periodical one-hop broadcast messages, can restrict the channel usage level and dynamically reserve a fraction of bandwidth for the safety application. The original idea is to control the transmit power of low priority messages and keep the transmit power of the highest priority traffic [16]. Research in [9] also proposed congestion control via dynamic transmit power control. They adjusted the transmit power for all packet types and study the impacts of transmit power control on the congestion problem in VANET. With increased transmit power level, the IEEE 802.11p physical layers (PHY) is able to provide communications within a distance from 100m to 1km in vehicular environments. This congestion control algorithm need places equipped with Road Site Units (RSUs).

Researches in [9, 20] were proposed smart/efficient rebroadcast scheme algorithms to prevent the congestion channels problem by limiting the forwarded packets. The blindly broadcasting beacon messages will causes a lot of redundancy packets and lead the broadcast storm problem. Smart rebroadcasting scheme from [20] operates only vehicles on the same lane and located behind the accident vehicle will forward the event-driven safety message. The vehicles only forward event-driven safety message after their successful reception of this event-driven safety message from front vehicles. In real scenarios, when accident happened it's also involve other lanes. The researchers in [20] also proposed efficient rebroadcasting in their concepts and framework of congestion control. The efficient rebroadcasting will reduce the transmission rate with minimum overhead.

Some of congestion detection methods are introduced in congestion control algorithm such as event-driven detection, measurement-based detection and MAC blocking.

3.1 Event-Driven Detection Method

The event-driven detection method was adapted in [9, 14]. With this event-driven detection method, each node applies the brute force queue freezing for all MAC transmission queues except for the safety queue with the highest priority. For example, when a node detects event-driven safety message either generated at its own application layer or received from another device, it will launch the congestion control immediately to guarantee the delivering of event-driven safety message [9].

3.2 Measurement-Based Detection Method

In the measurement-based detection method, each device periodically senses the channel based on the predefined thresholds such as channel usage level [9], number messages queue [14] and channel occupancy time [7]. The predefined threshold play important role in the performance of the wireless network by monitor and detect congestion of communication channels. The predefined threshold will be measure by metrics above. For example in [9] applied channel usage level as threshold. With this method, each device periodically senses the channel usage level, and detects the congestion whenever the measured channel usage level exceeds the predefined threshold. However research in [7] was set channel occupancy time as predefined threshold. If channel occupancy time measured at a node in CCH channel is longer than a given predefine threshold, all beacon messages will be blocked immediately. Research in [14] set a queue length in SCHs channels as threshold. If the queue length of comfort applications exceeds a predefine threshold, congestion is indicated and the preceding node is notified in order to decrease its transmission rate. To ensure performance of event-driven safety message, they should control CCH communication channel compared to SCHs channels.

3.3 MAC Blocking Detection Method

The MAC blocking detection mechanism is used for immediate and aggressive control of beacon message transmissions to mitigate congestion, and also adaptive traffic rate control is used for congestion avoidance. The MAC blocking detection method applied in [7]. For example, if MAC blocking happens at a node due to excessively long channel occupancy time, the channel is considered as congested for event-driven safety messages. The congestion signal is sent to the application layer, triggering traffic rate control actions.

4. Conclusions and Future Works

In this paper, we tried to expose the strong and weak points of some of these existing congestion control algorithms in VANETs. We conclude that many of these of congestion control algorithms are found will solved congestions problems in VANETs. However, most of proposed congestion control algorithms not focusing on event-driven safety message. Furthermore these congestion control algorithms are not addressed on uni-priority of event-driven safety message congestion. In real situation, various reactions from drivers will generate multiple event-driven safety messages. The uni-priority message of event-driven safety messages also generated from different transmitters. The nodes with same high priority packets need to schedule before start transmitting process.

In future work, we will propose framework for congestion control for disseminating uni-priority of event-driven safety messages. We also plan to verify and evaluate performance of our proposed congestion control algorithm using network simulator such as NS-2.

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