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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 for event-driven safety messages. The event-driven safety messages have stringent requirement on delay and reliability. A single delayed or lost of event-driven safety messages could result in loss of life. In dense network, a large number of vehicles broadcast a beacon messages at a high number of frequencies, the Control Channel (CCH) will easily congested. It's very important to keep the CCH channel free from congestion. Hence, this study takes a closer look at existing congestion control algorithms to solve congestion problem because it affects the performance of event-driven safety messages. In this paper, we propose the congestion control algorithm for event-driven safety messages. The effectiveness of the proposed congestion control algorithm is evaluated through the simulations.

Keywords: **VANETs; IEEE 802.11p; CSMA/CA; Congestion Control; Event-Driven Safety Messages.**

1. Introduction

VANETs are composed of vehicles equipped with advanced wireless communication devices without any base stations. Each vehicle equipped with VANETs device will be a node in the ad-hoc network and can receive and relay others messages through the wireless network. This type of networks can provide wide variety of services such as safety applications (Khabazian, et al. 2008; Li, et al. 2009). Basically, the safety applications can be categorized in two (2) types; 1) periodic (beacon) and 2) event-driven safety messages.

The periodic safety message exchange is preventive in nature, and its objective is to avoid the occurrence of dangerous situations. The periodic safety message may contain information regarding the position, direction, and speed of vehicles, the event-driven safety message may be generated as a result of a dangerous situation or when an abnormal condition is detected such as road accident (Khabazian, et al. 2008; Li, et al. 2009). The event-driven safety messages disseminated within a certain area with high priority and need to be deliver to each neighbor with almost no delays. Both of these safety messages will send through one single channel kwon as Control Channel (CCH). The Federal Communications Commissions (FCC) has allocated the frequency spectrum between 5.580 and 5.925 GHz for Dedicated Short Range Communication (DSRC) in VANETs. The DSRC spectrum is divided into seven (7) 10MHz channels range from 3 to 27 Mbps. The central channel is the control channel (CCH), which is restricted to safety communications only (Zhang, et al. 2007).

In dense network, a large number of vehicles broadcast beacons safety messages at a high frequency or event-driven messages are broadcast multiple times, then the CCH communication channel will easily get congested. This situation will decrease a throughput while delay is increasing significantly. On the other hand, the simplest way of broadcasting beacon safety messages to all nodes is by using blind flooding. Each node that receives the packets will rebroadcast this packet and will lead the broadcast storm.

VANETs based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) scheme (Campolo, et al., 2009; Li, et al. 2009; Wang, et al. 2008). Because of the shared wireless medium, blindly broadcasting the packet may lead to frequent contention and collisions in transmission among neighboring nodes. Moreover, a node can experience very long channel access delays due to the risk of the channel being busy during its listening period messages (Bilstrup, et al., 2008). This will affect the reliability and the performance of safety applications.

The rest part of the paper is organized as follows: In section 2, states the related previous works on congestion control in VANET. Section 3 states our proposal of the congestion control algorithm. The performance evaluation of the proposed congestion control algorithm is given in section 4 with simulation results.

2. Related Works

Some of researchers challenge on develop congestion control in VANETs were introduced in (Bouassida & Shawky, 2008; Wischhof & Rohling, 2005; Zang, et al. 2007; Zhang, et al. 2007). In research paper (Bouassida & Shawky, 2008), they developed a congestion control approach based on the concept of dynamic priorities-based scheduling. They evaluate dynamic priority factor based on: node speed consideration, message utility consideration and message validity consideration. This approach requires context exchange between neighbour nodes, which generates a communication overhead. In addition, research in (Bouassida & Shawky, 2008) not addresses the problem of broadcast storm.

On other hand, the congestion control algorithm for event-driven safety messages was developed in (Zang, et al. 2007). This congestion control approach evaluated the performance of the Safety Electronic Brake Light with Forwarding (EEBL-F). Research in (Zang, et al. 2007) set the predefined threshold in their congestion control algorithm based on channel usage level. Each device periodically senses the channel usage level, and detects the congestion whenever the measured channel usage level exceeds the predefined threshold. Measuring the channel usage level is too difficult to analyse under realistic environment due of the different traffic load.

In addition, this research fails to notice important issues which are uni-priority and reliability. The uni-priority congestion is caused by the traffic of the same priority, typically the warning messages of safety applications from different transmitters.

In a similar study in (He, et al. 2010), they proposed congestion control algorithm for DSRC based on safety applications. However, they just assumed the CCH channel is successfully reserved for event-driven applications without testing the successfully rate for event-driven safety messages. In this research, they set the channel occupancy time as threshold. If channel occupancy time measured at a node in CCH interval is longer than a given threshold, all beacon safety messages will be blocked immediately in the remainder of that CCH interval and the CCH interval followed to reduce channel load and reserve space for event-driven safety messages. Measuring the channel with the channel occupancy time is too difficult to analyse needs the proper rate control design.

3. The Congestion Control Algorithm

In this section, we propose the congestion control algorithm in VANET. The propose congestion control algorithm divided into two main parts; congestion detection and control and rebroadcast algorithm. The congestion detection and control used two methods of congestion detection such as event-driven detection and measurement-based detection method. The flowchart steps for proposed congestion control algorithm are demonstrated in Fig 1.

3.1 Event-Driven Detection and Control

The event-driven detection method monitors the event-driven safety message and decides to start the congestion control algorithm whenever event-driven safety message is detected or generated. The congestion control will launch immediately the queue freezing method for all MAC transmission queues except for the event-driven safety message. In order to send event-driven safety message with the minimum delay, the lower priority messages such as beacon messages emission is freeze. Currently, the event-driven detection method has been used in the existing of congestion control algorithm (Zang, et al. 2007).

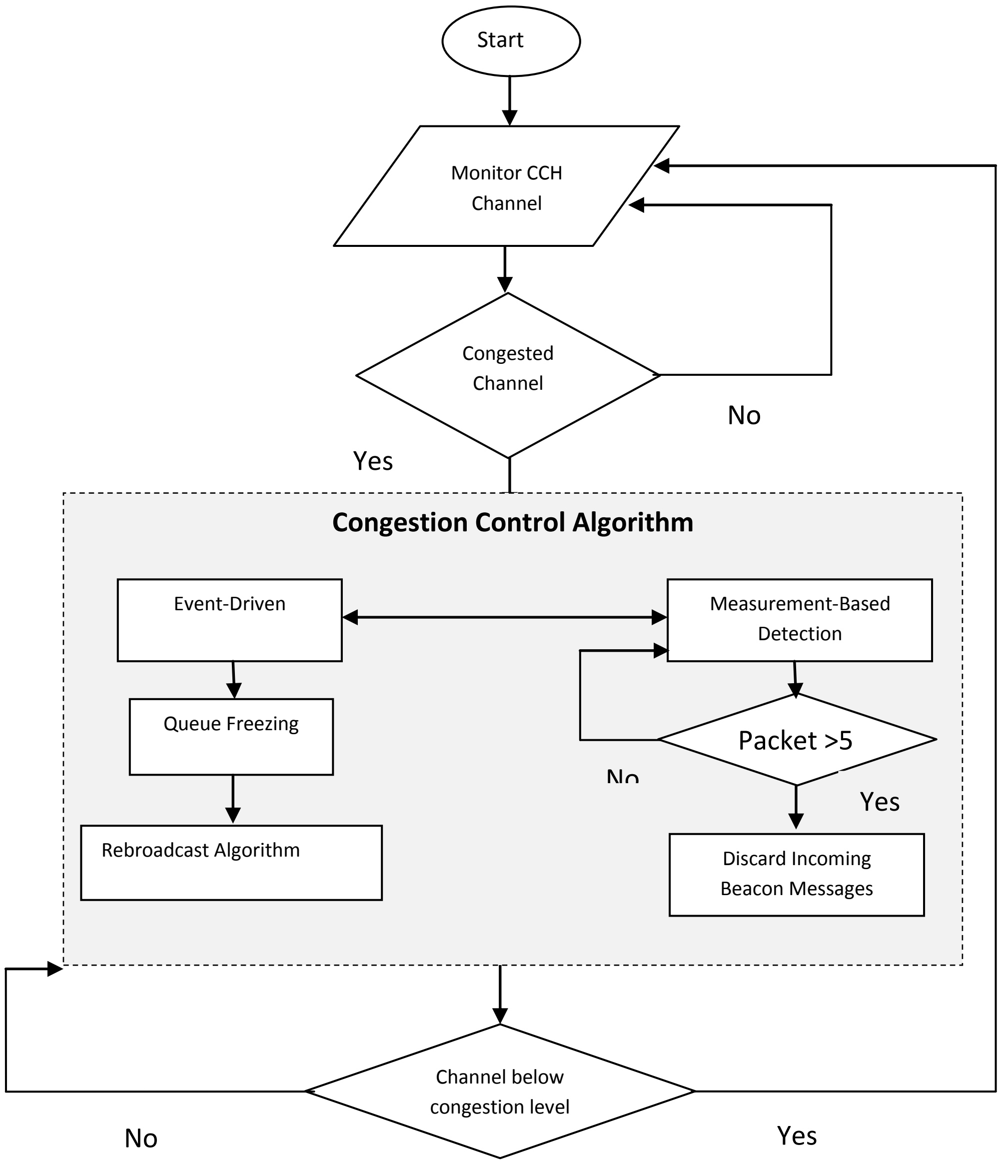

Fig. 1. Flowchart steps of the proposed congestion control algorithm

3.2 Measuremen-Based Detection and Control

The function of measurement-based detection is to monitor CCH communication channel based on packets queue. The node detects CCH communication channel is congested whenever the number of beacon safety messages in the queue exceeds a predefined threshold. If CCH communication channel was congested the congestion control algorithm will discard a further of beacon messages. Based on research (Hendriks, 2011) is concluded that a queue with a length of five beacon messages is sufficient to be used for 802.11p beaconing. The proposed congestion control algorithm will discard further a beacon safety messages whenever the length of packet queue more than five beacon safety messages.

3.3 Rebroadcast Algorithm

In this research, we proposed simple of rebroadcast algorithm consists of two types of broadcast phases; forward and makeup. In the first phase, the adjacent node considers have high priority to receive safety messages compare to other nodes in coverage area. While the forward phasing responsible delivering of event-driven safety messages to the adjacent node and also the farthest node for fast propagation. For instance, if the node (source) detected event-driven safety message, it will sends to nearest node called as (makeup/forwarder)**.** In the second phase, the makeup/forwarder will rebroadcast event-driven safety messages to all vehicles in communication range receive their messages. The transmission ranges are defined which is 400 meters.

4. Simulation Results

We examine the proposed congestion control algorithm through simulation experiments using Veins simulator. The Veins simulator make up of two distinct simulators, OMNeT++ for network simulation and SUMO for road traffic simulation. The simulation scenario is a 1500m x 1500m area of Los Angeles, extracted from the TIGER/Line database of the US Census Bureau. The simulation key parameters are summarized in Table 1.

Table 1: Simulation parameters

Parameter	Value
Simulation area	1500 m x 1500 m
Number of vehicles	150-250-350
Packet type	UDP
Node Speed	40-88 km per hour
Transmission range	400 m
Simulation time	300 s
Data packet size	512 bytes
MAC protocol	IEEE 802.11p

In this research, different experiments are conducted in different number of vehicle nodes which are 150 nodes sparse networks, 250 nodes for medium density networks and 350 nodes for dense networks. The fig. 2 illustrated the warning packets delay for event-driven safety messages in sparse network, fig. 3 for medium density networks and fig. 4 for high traffic density.

These experiments show that the number of vehicles is crucial and this factor has an impact on overall network performance. The result simulation showed whenever the number of vehicles is increased; the packets delay consistently increased. In sparse network, the performance of event-driven safety messages is excellent for proposed congestion control algorithm. However, in medium network the delay of event-driven safety messages increased dramatically, the maximum warning packets delay is 21 ms. In dense network, the result shows the performance of proposed congestion control still good, not exceed in worst cases 60 ms delays. However the performance of proposed congestion control dropped drastically from 20 % in sparse network to 11.9 % in dense network, because more nodes are blindly broadcast severe broadcast storm problem.

These results have been proved that an efficient congestion control algorithm with adoption of simple rebroadcast algorithm is efficient method for disseminating event-driven safety applications in dense network. The implementation of efficient congestion control is significantly increases the efficiency of disseminating of event-driven safety messages.

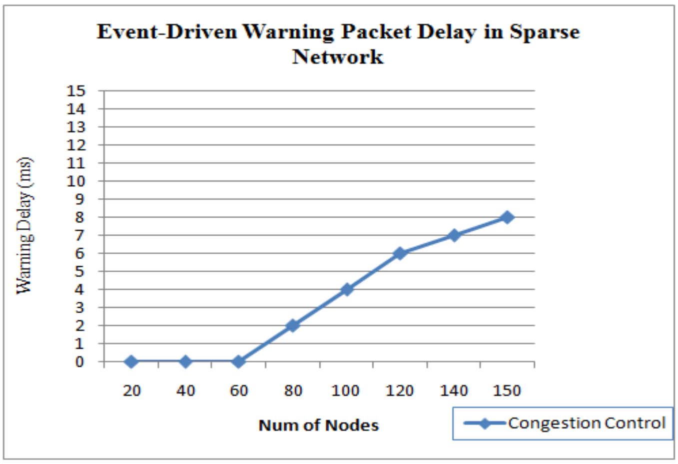

Fig. 2: Warning Packet Delay in Sparse Networks

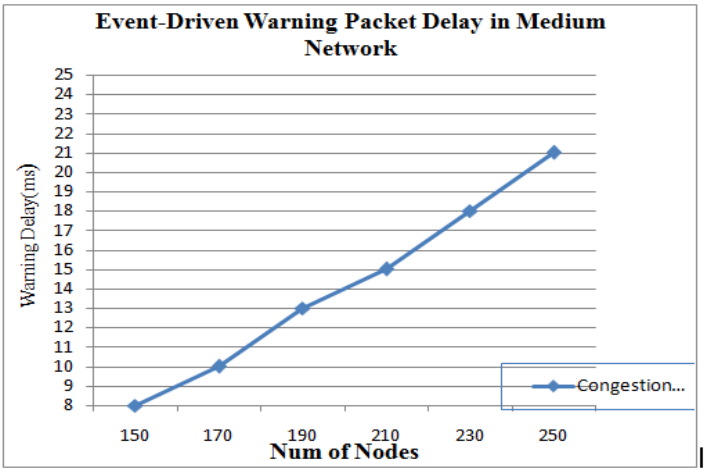

Fig. 3: Warning Packet Delay in Medium Networks

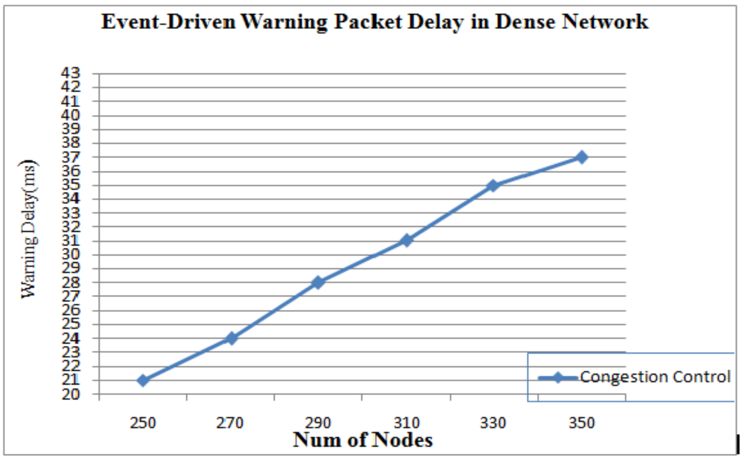

Fig. 4: Warning Packet Delay in Dense Networks

5. Conclusion

In dense network, a large number of vehicles send or generated beacons safety messages at a high frequency or event-driven messages are broadcast multiple times. This scenario will lead congestion in CCH communication channel and affect the performance of event-driven safety messages. Extensive and fair simulation results show that, the proposed congestion control performs the best in terms of warning packet delivery ratio. These results confirmed that the congestion control with adoption of rebroadcast algorithm is one of the best solutions for disseminating event-driven safety applications in dense network.

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