Computer Networks 108 (2016) 15–28

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

Prioritizing and scheduling messages for congestion control in vehicular ad hoc networks

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ARTICLE INFO

Article history:
Received 3 July 2015
Revised 25 May 2016
Accepted 21 June 2016
Available online 12 July 2016

Keywords:
Congestion control
Message priority
Meta-heuristic techniques
Queue scheduling
Tabu search
Vehicular ad hoc networks

ABSTRACT

Vehicular Ad Hoc Networks (VANets) is considered as a technology which can increase safety and convenience of drivers and passenger. Due to channel congestion in high density situation, VANets' safety applications suffer of degradation of performance. In order to improve performance, reliability, and safety over VANets, congestion control should be taken into account. However, congestion control is a challenging task due to the special characteristics of VANets (e.g. high mobility, high rate of topology change, frequently broken rout, and so on). In this paper, DySch and TaSch strategies are proposed. Those strategies assign priorities to the safety and service messages based on the content of messages (static factor), state of network (dynamic factor) and size of messages. DySch and TaSch strategies schedule the messages dynamically and heuristically, respectively. Their performance is investigated using highway and urban scenarios while the average delay, average throughput, number of packet loss, packet loss ratio, and waiting delay in queues are considered. Simulation results show that DySch and TaSch strategies can significantly improve the performance of VANets in comparison to the best conventional strategies. Employing the proposed strategies to control congestion in VANets helps increase reliability and safety by giving higher priority to the safety messages.

1. Introduction

Vehicular Ad hoc Network (VANet) is a sort of Mobile Ad hoc Network (MANet) that aims at employing wireless technologies within Intelligent Transport Systems (ITSs). Dedicated Short Range Communication (DSRC) defines protocols and standards for conducting the Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications in VANets. VANet has special characteristics such as high rate of topology change, high mobility of nodes, high nodes density, sharing the wireless channel, and frequently broken rout. Those special characteristics in VANets give rise to some challenges in data transferring and scheduling [1–4].

When the channels are saturated due to the increasing number of vehicles, congestion happens in the networks. In other words, when the vehicles send messages simultaneously in high density situations, the shared channels are easily congested. Congestion indeed leads to overload the Medium Access Control (MAC) channels, increases the packet loss and delay, and consequently decreases the performance of VANets. Therefore, congestion should be controlled for enhancing the reliability of VANets [5–8]. Congestion control strategies aim at controlling the load on the shared channels and provide a fair channel access among the vehicles. Various strategies have been designed in each layer of network communication to control the congestion in VANets. Some of these strategies, which are designed for MAC layer, define priority for the messages and schedule them in different communication channels [9,10]. Data prioritizing and scheduling help serve more requests, reduce download delay and packet loss, and so on [11,12].

DSRC uses a 75 MHz bandwidth at 5.9 GHz for performing V2V and V2I communications and transferring the safety and service messages in VANets. DSRC employs IEEE 802.11p and IEEE 1609 standards for managing the performance of network by Wireless Access in Vehicular Environment (WAVE) systems. IEEE 1609.4 standard is also used to implement multi-channel in VANets. The DSRC bandwidth is composed of eight channels that consist of six 10 MHz service channels (SCH) for non-safety communications, one 10 MHz control channel (CCH) for safety communications, and one 5 MHz reserved channel for future uses. Fig. 1 shows channel allocation within DSRC. Normally, the control and service communication channels are used for different prioritized messages. Control channel is used to transmit high priority safety messages including emergency and beacon messages, and service channels are used to transmit low priority service messages [4,13,14].

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http://dx.doi.org/10.1016/j.comnet.2016.06.027
1389-1286/

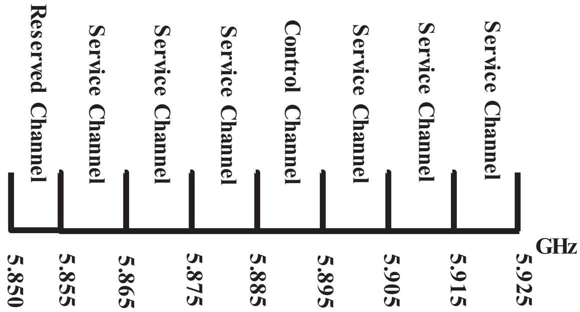

Fig. 1. DSRC channel allocation [13].

Table 1
CW boundaries for each kind of the message in EDCA.

Messages	CW_{min}	CW_{max}	AIFS
Background	CW_{min}*	CW_{max}*	7
Best Effort	CW_{min}	CW_{max}	3
Video	$(CW_{min}+1)/2-1$	CW_{min}	2
Voice	$(CW_{min}+1)/4-1$	$(CW_{min}+1)/2-1$	2

* CW_{min}=15 and CW_{max}=1023 as the default in DSRC [17–19].

All vehicles are synchronized by Coordinated Universal Time (UTC) to operate multi-channel on a single radio transceiver in VANets. The UTC is obtained based on information acquired from Global Positioning System (GPS) or the other vehicles. The vehicles adjust their time based on UTC and synchronously switch between CCH and SCH intervals. The IEEE 1609.4 WAVE protocol results in high delay to deliver high priority safety messages due to periodically switching between the channels [15,16].

To solve this issue, Enhanced Distributed Channel Access (EDCA) mechanism was considered in DSRC. EDCA assigns priorities to the messages such that the high priority messages have a higher chance to be sent. In other words, the high priority messages wait less than the low priority messages to occupy channel. This is accomplished by determining a shorter Contention Window (CW) and Arbitration Inter-Frame Space (AIFS) for high priority messages, as shows in Table 1 [17–19].

As it was mentioned before, when the number of vehicles increases, the control and service channels overload, and consequently congestion happens in the network that leads to increase delay and packet loss. Congestion in control channel can also occur when load of beacon messages increases due to high vehicle density. In this situation, safety messages (especially emergency messages) cannot be properly transmitted due to deficiency in the messages scheduling. It should be also noted that the scheduling in VANets is faced to some challenges because of sharing wireless communication channel, and employing multi-channel technology with single-radio transceivers. Therefore, an efficient scheduling is required to have more safe and reliable VANets [7,20,21].

In this paper, two congestion control strategies are presented to prioritize and schedule the safety and service messages. The proposed strategies consist of priority assignment unit, and message scheduling unit. The priority assignment unit assigns priority to each message based on static and dynamic factors. Then, the message scheduling unit reschedules the prioritized messages in the control and service channel queues. The performances of the proposed strategies are evaluated using various performance metrics including number of packet loss, packet loss ratio, average delay, and average throughput. The rest of the paper is organized as follows. Section 2 reviews the existing congestion control and messages scheduling strategies in VANets. Section 3 proposes the new strategies to control congestion that prioritize and schedule the messages. Section 4 applies the proposed strategies in a highway and urban scenarios and discusses the obtained results.

2. Background and related works

Congestion Control strategies are employed to achieve high communication reliability and bandwidth utilization within the networks. Generally, there are two types of congestion control mechanisms in networks: 1) open-loop mechanism that avoids the congestion before it happens, and 2) closed-loop mechanism that controls the congestion after it happens [22]. Congestion control strategies in VANets can be classified in to three categories: 1) controlling the power of transmissions, 2) controlling the rate of transmissions, and 3) prioritizing and scheduling the messages in communication channels [20].

The prioritizing and scheduling the messages is a very common open-loop congestion control strategy in communication channels. Some performance metrics should be considered to increase efficiency of message scheduling in VANets such as fairness, reliability, responsiveness, time constraint, data size, service ratio and data quality [23]. In the following, some existing algorithms to schedule the messages for transferring through the channels are introduced.

First-In First-Out (FIFO) algorithm is one of the simplest scheduling algorithms. In FIFO, the earliest arrival request is served first. Longest Wait Time (LWT) and Maximum Request First (MRF) algorithms schedule the messages based on the deadline of messages in the broadcast environment. Longest Total Stretch First (LTSF) algorithm considers a stretch metric for reducing waiting time. The stretch metric is defined as the ratio of request response time to its service time. First Deadline First (FDF) algorithm serves the most urgent requests, but it does not consider the service time for data. In Smallest Data Size First (SDF) algorithm, the data with smallest size serves first. However, the urgency of messages is not considered in SDF [23].

Maximum Quality Increment First (MQIF) algorithm schedules the messages based on Quality of Service (QoS) and Quality of Data (QoD) factors that consider the responsiveness and staleness of data, respectively. Least Selected First (LSF) algorithm gives opportunity to the messages that had least opportunity to be served before. Finally, D∗S algorithm defines priorities of messages based on Deadline (D) and Size (S) of message [23]. In the rest of this section, some of the proposed congestion control strategies in VANets are presented.

Torrent-Moreno et al. [24] developed a distributed congestion control strategy called Distributed-Fair Power Adjustment for Vehicular environment (D-FPAV). In this strategy, after congestion detection, the beaconing transmission range is dynamically tuned based on vehicle density. However, when transmission range of beacon messages is decreased in congestion situation, the probability of receiving the beacon messages in far distances reduces. Therefore, the performance of applications that need information through beacon messages is disrupted.

Bai et al. [25] proposed Context Awareness Beacon Scheduling (CABS) strategy to control congestion that may occur due to the high broadcasting rate of beacon messages within dense vehicular networks. The proposed congestion control strategy was a distributed strategy. CABS scheduled the beacon messages dynamically by employing piggybacked context information in beacon messages like velocity, direction and position. Then, a time slot was assigned to each node using TDMA-like transmission. Although CABS improved channel access delay and packet reception rate by scheduling the beacon messages, MAC layer interworking was not considered during adjusting time slot to each node.

Taherkhani and Pierre [26], proposed Uni-Objective Tabu search (UOTabu) congestion control strategy in order to increase reliability of applications in VANets. In this strategy, the congestion