ENHANCED SNR-BASED ADMISSION CONTROL ALGORITHM FOR VEHICULAR AD-HOC NETWORK

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For Allah the only God, for my beloved parents, family, and my friends...

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ABSTRACT

Vehicular Ad-hoc Network (VANET) becomes a fundamental subcategory of mobile ad-hoc networks that provides vehicles to communicate with each other and with roadside infrastructure smartly. Data traffic in VANET can be categorized into safety and non-safety, where safety is a very critical point and non-safety is related to entertainment. Various VANET performance challenges are considered in terms of Quality of Service (QoS) which cause performance degradation as performance anomaly where high rates of vehicles wait for the low rates of vehicle transmitting time and starvation problem where some vehicles cannot transfer their data. Three main achievements have been accomplished. Starting with the impact of the increasing vehicle speed on performance anomaly problem consequences has been investigated. Followed by high-speed effects on data delivery is illustrated and how 802.11p has outperformed 802.11 in terms of data delivery is also demonstrated. Lastly, starvation problem is investigated where results showed increased data loss when vehicle nodes unable to deliver data correctly. Finally, a QoS-aware Signal to Noise Ratio (SNR) admission control mechanism (QASAC) is proposed to handle the performance anomaly problem while maintaining the QoS levels for high and low traffics. This can result in wasting throughput and cause data loss. The investigation results show that 802.11p has enhanced the number of dropped packets up to 70%. Also, the 802.11p end to end delay has decreased up to 12% less than the results of the 802.11 MAC protocol. The packet delivery ratio has been enhanced by up to 41% by 802.11p. The starvation problem investigation phase shows that 802.11p perform better than 802.11 which mainly affected by the increased speed of the vehicle. QASAC assigned different SNR values to different vehicles group based on the sending SNR values and in each group. Unlike recently proposed admission control in VANET networks, the proposed architecture differentiate between both high priority and low priority traffic QASAC has been compared against the latest SNR based admission control mechanism. QASAC has enhanced the performance of data delivery up to 23% in terms of data dropping rates for high priority traffic.

ABSTRAK

Rangkaian Sementara Kenderaan (VANET) menjadi subkategori asas rangkaian sementara bergerak yang menyediakan kenderaan untuk berkomunikasi antara satu sama lain dan dengan infrastruktur tepi jalan dengan cara pintar. Lalulintas data dalam VANET boleh dikategorikan sebagai lalulintas selamat yang sangat kritikal dan lalulintas tidak selamat yang berkaitan dengan hiburan. Pelbagai cabaran prestasi VANET dipertimbangkan dari segi Kualiti Perkhidmatan (QoS) yang menyebabkan kemerosotan prestasi sebagai prestasi janggal di mana kenderaan berkadar tinggi harus menunggu masa penghantaran kenderaan berkadar rendah dan masalah kelaparan di mana beberapa kenderaan tidak dapat menghantar data mereka. Ini boleh mengakibatkan pembaziran daya pemprosesan dan kehilangan data. Dalam tesis ini, tiga pencapaian telah berjaya diperolehi. Dalam bahagian pertama, kesan kelajuan kenderaan kepada masalah prestasi janggal telah disiasat. Kenderaan berkelajuan tinggi memberi kesan kepada penghantaran data telah digambarkan dan bagaimana 802.11p dapat mengatasi 802.11 dari segi penghantaran data telah ditunjukkan. Dalam bahagian kedua, masalah kelaparan telah disiasat di mana keputusan menunjukkan peningkatan kehilangan data apabila nod kenderaan tidak dapat menghantar data dengan betul. Dalam tesis ini, mekanisme kawalan kemasukan nisbah isyarat kepada hingar (SNR) QoS-sedar (QASAC) dicadangkan untuk menangani masalah prestasi janggal sambil mengekalkan tahap QoS untuk jenis lalulintas yang berbeza. Keputusan penyiasatan menunjukkan 802.11p telah meningkatkan bilangan paket yang jatuh sehingga 70%. Tambahan lagi, penangguhan hujung ke hujung 802.11p telah menurun sehingga 12% berbanding keputusan protokol MAC 802.11. Nisbah penghantaran paket telah dipertingkatkan sehingga 41% oleh 802.11p. Fasa penyiasatan masalah kelaparan menunjukkan bahawa 802.11p memberikan prestasi lebih baik berbanding 802.11 terutamanya disebabkan oleh peningkatan kelajuan kenderaan. QASAC telah memberikan nilai SNR berbeza kepada kumpulan kenderaan berbeza berdasarkan penghantaran nilai SNR dan dalam setiap kumpulan. Tidak seperti kawalan kemasukan yang diusulkan baru-baru ini dalam rangkaian VANET, senibina yang

dicadangkan membezakan di antara kedua-dua lalulintas keutamaan tinggi dan keutamaan rendah QASAC telah dibandingkan dengan mekanisme kawalan kemasukan SNR terkini. QASAC telah meningkatkan prestasi penghantaran data sehingga 23% dari segi kadar kejatuhan data untuk lalulintas keutamaan tinggi.

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LIST OF SYMBOLS AND ABBREVIATIONS

AP	Access Point
ARF	Auto Rate Fallback
C2C-CC	CAR to CAR Communication Consortium
CARC	Context Aware multi Rate Control
CoCA	Cooperative Channel Assignment
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTB	Clear to Broadcast
CTS	Clear to Send
CW	Contention Window
DCF	Distributed Coordination Function
DIFS	Distributed Inter-Frame Spacing
DRCA	Data-Rate adaptive Channel Assignment
DSRC	Dedicated Short Range Communication
EDCF	Enhanced Distributed Coordination Function
EDT	Estimated Delivery Time
FCC	Federal Communication Commission
FPAV	Fair Power Adjustment for Vehicular environments
GPS	Global Positioning Systems
ICA	Identical Channel Assignment
ITS	Intelligent Transportation Systems
LBB	Location Based Broadcast
MAC	Media Access layer
MANET	Mobile Ad-hoc Network
MMAC	Multi-channel MAC
MOAR	Multiband Opportunistic Auto Rate
MRMC	Multi-Rate Multi-Channel
MTR	Minimum Transmission Range
MUP	Multi-radio Unification Protocol
OAR	Opportunistic Auto Rate
OBU	On-Board Units
OFDM	Orthogonal Frequency Division Multiplexing
OSM	Open Street Map
PCF	Point Coordination Function
QASAC	QoS Aware SNR based Admission Control protocol
QoS	Quality of Service

RA-ARF	Rate Adaptation algorithm - Auto Rate Fallback
RBCA	Rate-Based Channel Assignment
RTS	Request to Send
RTB	Request to Broadcast
SAC	SNR-based Admission Control protocol
SIC	Successive Interference Cancellation
SNR	Signal to Noise Ratio
SUMO	Simulation of Urban Mobility
TRPSA	Transmission Rate-based Packet Size Adjustment
UDI	Uplink-Downlink Interference
UMB	Urban Multi-hop Broadcast
V2I	Vehicle to Infrastructure
V2R	Vehicle to Roadside
V2V	Vehicle to Vehicle
VANET	Vehicular Ad-hoc Networks
VSC	Quality Vehicle Safety Communication System
WAVE	Wireless Access in Vehicular Environments
WLAN	Wireless Local Area Networks
WMN	Wireless Mesh Networks

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Recently, Vehicular Ad-hoc Networks (VANET) becomes more popular and widely deployed all over the roads across the world. Most of modern cars are equipped with wireless modules which provides vehicles to communicate with each other's and with communication control points [1]**.** Enhancing inter-vehicle communication and roadside communication is considered as the most popular wireless communication research topics [2]. VANET allows road vehicles to notify other vehicles about traffic jams, sudden stops and other hazardous road conditions [3]. The huge number of expected benefits of VANET and the number of supporting vehicles are likely become the most realized implementation of mobile ad-hoc networks where a short range of IEEE 802.11 can be used for vehicles communications using suitable radio interface technology [4]. However, which mainly a new standard has been developed for both physical and MAC layer which is IEEE 802.11p standard, [5] which mainly developed to meet the requirement of communication between vehicles. IEEE 802.11p is an approved amendment to the IEEE 802.11 standard which provides wireless Access in Vehicular Environments (WAVE). Enhancements were applied to 802.11 to support Intelligent Transportation Systems application [6].

The fundamental difference that can be encountered between Mobile Ad-hoc Network (MANET) and VANET is the absence of infrastructure in the case of MANET [7]. VANET on the other hand includes access points locations along the road sides and these vehicles access the services based on predefined infrastructure. VANET implementation encounters different challenges. One of the most critical challenges is adjusting Quality of Service (QoS) parameters [8]. Quality of Service is one of the main requirements for data delivery which means providing the required level of efficient data delivery requirements such as the acceptable level of network throughput, delay, jitter and drop rate [9].

Frequent VANET topology changes and the vehicles high speed make the task of maintaining QoS parameters complicated, in contrast to wired networks where it only it describes in terms of delay and throughput [8]. Vehicle high mobility and state information required for routing procedure add more difficulties for reliable QoS mechanisms [10].

To meet the requirements of high mobility and speed, various advances were proposed in wireless communication mechanism to support advanced safety of vehicle applications [11]. Dedicated Short Range Communication (DSRC) [12] is short to medium communication range service which supports both private and safe communication. DSRC was proposed to provide reliable, safe and high rate Vehicle to Vehicle (V2V) and Vehicle to Roadside (V2R) communication, which can minimize latency inside a relatively small communication zone [13]. New application communication class was enabled to increase the overall efficiency and safety of the traffic system.

The problem of performance anomaly mainly happened in carrier sensing multiple access/collision avoidance-based WLANs where each node has the same opportunity to access the channel, and the channel utilization by a node can be defined as the ratio between the transmission time of the node and the total transmission time of all other nodes. Then, nodes transmitting at high transmission rates obtain the same throughput as the nodes transmitting at low transmission rates [14]. On the other hand, the starvation problem means that specific node does not have the chance to transmit its data while it has been waiting for other node to complete its data transmission. Starvation problem mainly occurs in mobile networks where networks node change their location by time, the node miss his chance while waiting where its destination become unreachable and thus data can be loss. As shown in Figure 1.1, node 1 and node 2 have two different data rates where node 1 has 54 Mbps and node 2 has 6 Mbps. Node 1 complete its data transmission in shorter time, however node 2 takes longer time to transmit its data due to smaller data rates and node1 has to wait for node 2 to complete its transmission to start again. On the other hand, if node 1 become out of the range of access point (AP) while he is waiting for node 2 to its complete data transmission, then starvation problem is occurred, and node 1 data is not sent to the required destination.

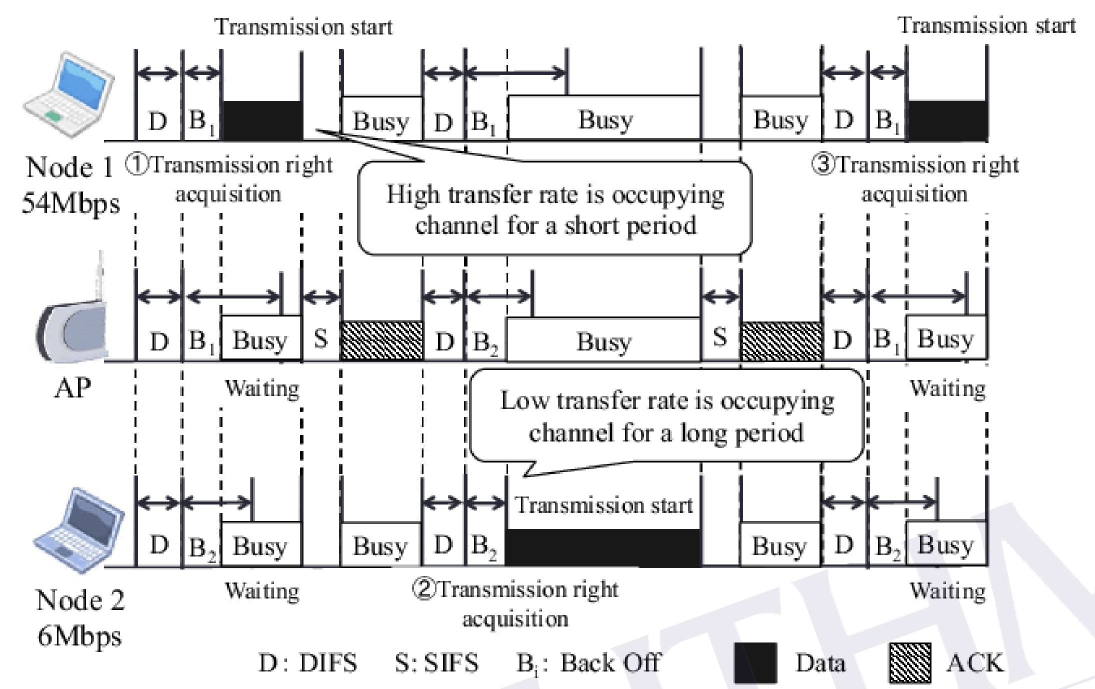

Figure 1.1: The performance anomaly problem

Admission control is an access control-based approach which allow or prevent vehicle to send data to road side units based on specific parameters. One of the used parameters is the signal to noise ratio (SNR) which is defined as the ratio between the signal powers of the sending vehicle against the power of the noise around that vehicle. Lower SNR values indicate weaker signal power and thus lower data rates [15].

1.2 Problem statement

Data communication in VANET mainly include two different types of traffic: safety and non-safety traffic. Quality of Service is very critical issue in safety application where data loss or delay cause catastrophic consequences. The location of the vehicle and its speed can directly affect the efficiency of data delivery [4]. Variant distances between vehicles and RSU and external noise cause channel qualities variance and different data rates. Intersections can be considered as the main location where issues in data transmission are increased due to higher channel dynamicity. Variant channel qualities also can be founded in intersections when it is compared with the situation where vehicles are moving on the road side. This mainly happened due to continuous existing of stopped vehicles as well as moving vehicles at intersections. In most cases stopped vehicle have better channel qualities than the moving vehicles [6]. Due to various channel conditions of the vehicles cause variant rates which mainly cause the performance anomaly problem which happens more apparently at intersections rather than the road sides.

Performance anomaly has been considered as one of the most critical issues related to wireless communication [16]. Performance anomaly is the condition where higher data rates devices have to wait for lower data rates devices to complete their data transmission which result in critical issues in a mobile network since higher rates devices cannot deliver their data correctly. The consequences of performance anomaly on data delivery of VANET safety application is much worse [17]. Recent researches proposed different approaches and mechanism to avoid performance anomaly problem by considering multiple interfaces, communication links, packet size and even full duplex communication. The consequences of variant vehicles speed on performance anomaly is not investigated in terms of different Wi-Fi MAC protocols. IEEE802.11 has been implemented as a standard protocol. However, a customized IEEE 802.11p has been designed for VANET requirements. The efficiency of handling performance anomaly problem for IEEE 802.11p over IEEE 802.11 is not investigated. It is required to illustrate how IEEE 802.11p can handle performance anomaly [18]. Higher speed mobility of VANET nodes can make the problem of performance anomaly more critical, where channel quality becomes much lower, providing lower data rates [19]. The results of higher speed vehicles movement have yet to be investigated in terms of performance degradation under performance anomaly problem. The consequences of a starvation problem also can be catastrophic, particularly in case of VANET safety application where human lives are on the line.

State of art mechanisms which are proposed to overcome performance anomaly. It mainly proposed a completely new approaches like using multiple interfaces or communication links. These approaches cause higher implementation overhead and in various cases starvation problems. In starvation problem low data rate vehicles cannot transmit their data despite its higher priority since vehicles are considered based on their data rates [20]. Starvation problem which is a direct consequence for performance anomaly can cause significant data loss. Starvation problem occurs when the high rate vehicles wait for low rate vehicles to transmit their data and while that happened, the high-speed vehicle become away from their destination and cannot send their own data. However, these results do not investigate in term of evaluation metrics. The advantages of IEEE 802.11p for handling performance anomaly also is not illustrated.

Recently proposed performance anomaly handling mechanism transmit the VANET traffic in the same manner regardless of its priority. The main reference recent paper [15] mainly depends on SNR for admission control, however this mechanism provide a single SNR threshold value for both low and high priority classes which make it not feasible for QoS handling. Admission control is one of the most efficient solution to overcome performance anomaly problem where vehicles that has an acceptable threshold data rate can only send data to limit the effect of low data rate vehicles. This threshold data rate is defined based on SNR values which measure the quality of wireless channels. However, admission control algorithm in [15] handle all data classes with the same threshold, so high priority traffic can be ignored to allow less priority traffic with the same data rate values. Handling performance anomaly in this manner is not QoS aware and can degrade the performance of data delivery. Moreover, recent performance handling mechanism is all implemented using the standard IEEE 802.11 for data communication. 802.11p has not been investigated where it was proposed to meet the requirements of VANET networks and vehicle mobility.

1.3 Research objectives

VANET includes different priority traffic types where the latest proposed mechanism performance anomaly mechanism does not differentiate between them. In this research, a comprehensive investigation of the VANET data communication performance is provided, the main objectives of this research are:

1. To investigate the performance of 802.11p in handling performance anomaly problem for high speed vehicles.
2. To determine the performance degradation resulted from starvation problem.
3. To overcome performance anomaly by designing a reliable QoS aware SNR based admission control algorithm.

1.4 Research scope

The efficiency of data delivery in VANET is the main research field for this research. Performance anomaly is one of the critical performance issue in VANET. To solve the performance anomaly problem, a number of schemes have been presented in the literature. Most of them allow both nodes with high and low transmission rates to capture the channel for the same amount of time, i.e., the time fairness is sustained. By doing so, the throughput degradation of nodes with high transmission rates can be mitigated. The existing schemes can be classified into three categories: packet fragmentation [21], contention window adaptation [22], and packet aggregation [23].

VANET data traffic is divided into two main classes safety data which is related to accidents and traffic warning and non-safety data which is related to entertainment traffic such us video streaming and games. In SNR admission control mechanism, vehicles are divided into groups based on the measured SNR values where each group has a predefined threshold. In each group, two subclasses are defined based into different SNR threshold values to differentiate between high priority traffic like safety traffic and low priority traffic like non-safety traffic. High priority data SNR value is lower than low priority data. In this scenario, higher data can have higher precedence to be delivered and overcoming starvation problem, where low data priority with lower data rate cannot affect the data transmission which also tolerate performance anomaly.

Implementing a real environment for high speed vehicles with data communication is a complex mission where multiple simulator types are required. Performance investigation is carried out using different simulators to reflect the real environment of VANET. A traffic mobility simulator (SUMO) is used to simulate the mobility of real traffic patterns based on pre-selected maps, number of vehicles and vehicles speed. On the other hand, to simulate the network communication behavior, NS2 is used.

To evaluate proposed QoS aware SNR based admission control protocol performance, it is compared against the SNR-based admission control protocol (SAC) in Wi-Fi-based vehicular network proposed in [15]. Both algorithms is implemented using NS2 simulator. The same network topology which has been used in two previous performance evaluation scenarios is used which represent a real environment of VANET networks with different vehicles speeds. The main idea of the SAC protocol is to accept packets from vehicles depending on the SNR value of the received packet where a predefined threshold value is defined. However, this protocol does not differentiate between the priority of the traffic where both high and low priority data are handled in the same mechanism.

1.5 Research contribution

This main contribution of this research includes the following items:

1. Determine the efficiency of IEEE 802.11p in dealing with performance anomaly and investigate the advantages of it over standard IEEE 802.11 in case of high speed VANETs using various range of vehicles speed in terms of network evaluation metrics such as end to end delay, network throughput and packet delivery ratio.
2. Analysis the effect starvation problem for both standard IEEE 802.11 and IEEE 802.11p. Also, investigate how the network performance when vehicle travels with different speeds in term of starvation evaluation metrics.
3. Distinguish between handling performance anomaly problem for different classes of data priority for safety and non-safety application to deliver QoS for VANET traffic.
4. A QoS aware SNR admission algorithm to handle VANET traffic to handle performance anomaly based on data traffic priority and compare the proposed mechanism against recently proposed SNR admission control to illustrate its efficiency how it performs with different traffic priority classes.

1.6 Thesis outlines

The rest of the thesis is organized as follows. In Chapter 2, a comprehensive introduction to VANET technology is presented including VANET characteristics, challenges and applications. DSRC architecture and application are then illustrated, after that a literature review of mechanism proposed to handle performance anomaly is presented. A comprehensive review of related work where the advantages and drawbacks of each mechanism have been discussed. The research methodology is presented in Chapter 3, at the beginning, an introduction is presented for both performance anomaly and starvation problem is listed, after that the design of the proposed QoS SNR admission control mechanism is described in detail including the system model and the mechanism phases, the evaluation metrics used for measuring the performance is then defined. At the end of the chapter the simulation process is described including used simulators and how these simulators are integrated. In Chapter 4 the results are presented, at the beginning the simulation topology and parameters are listed, later the three main parts of simulations are presented: the results of different vehicle speeds and performance anomaly. Result comparison of starvation problem and the evaluation of QoS aware SNR based admission control against SNR admission control. In the last chapter conclusion and future work is presented.

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