IMPROVEMENT OF SELF-ORGANIZING TIME DIVISION MULTIPLE ACCESS IN VEHICULAR AD-HOC NETWORKS

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A dissertation submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Computer Science)

Faculty of Computing
Universiti Technologi Malaysia

MARCH 2014

This work is dedicated to my beloved parents, my father “Sabir Arif Hama Murad” and my mother “Bafraw Hama Sidiq Saeed” for their resilience in insisting to educate me amidst the absolute poverty in which they raised me.

ACKNOWLEDGEMENT

In The Name Of Allah, Most Gracious, Most Merciful

First and foremost, I must be thankful to Allah for finishing the research and I would like to express my sincere thanks and appreciation to my supervisor **Dr. Mohammad Abdur Razzaque**, for his precious guidance, encouragement, constructive criticisms, advice, knowledge and motivation. Without his continual support and interest, this project report would not have been that same as presented here.

I would like to thank to all my family members for their prayers and all their supports and encouragements. I am also grateful to my all friends, especially Dr. Kayhan Zrar Ghafoor, who never give up their support to me.

Besides, I would like to thank the authority of Universiti Teknologi Malaysia (UTM) for providing me with a good environment and facilities.

ABSTRACT

Vehicular ad-hoc network (VANET) is a subclass of mobile ad-hoc network (MANET) with the key difference of frequently changing mobility pattern and network topology. It can provide both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications thereby can greatly improve the safety and efficiency of road traffic. Media Access Control (MAC) is one of the key protocols for VANET in providing real-time services. Self-Organized Time Division Multiple Access (STDMA) is one of the MAC protocols for VANETs. The main problem of STDMA (MAC) protocol is delay. In this research, we proposed a scheduling algorithm to surmount this delay and improve the performance of STDMA MAC protocol, by allocating additional time slots for all nodes in the emergency service category. In the proposed algorithm we divide the available bandwidth between two different service classes: best effort and real time. There are two different counters, which count the number of allocated slots to users of different classes. The highway scenario is selected to model the vehicle traffic patterns. Simulation results show that for different number of nodes the proposed scheme has improved the delay by 23% and throughput by 4% compared to STDMA. For different values of speed it has shown 24% lower delay and 23% higher throughput than STDMA. In addition, result show that our proposed protocol outperforms the conventional one CSMA/CA in terms of delay and throughput.

ABSTRAK

Vehicular Ad-hoc Network (VANET) adalah subkelas *Mobile Ad-hoc Network* (MANET) yang mempunyai perbezaan utama iaitu corak mobiliti dan jaringan topologi yang sering berubah. Ia membolehkan komunikasi kenderaan-ke-kenderaan (V2V) dan kenderaan-ke-infrastruktur (V2I), maka ia meningkatkan keberkesanan keselamatan dan kecekapan trafik jalan raya . Media Kawalan Akses (MAC) merupakan salah satu protokol utama bagi VANET dalam menyediakan perkhidmatan dalam waktu nyata. *Self-Organizing Time Division Multiple Access* (STDMA) adalah salah satu protokol MAC bagi VANETs dimana masalah utama protokol STDMA (MAC) adalah kelewatan. Kajian ini mencadangkan algoritma penjadualan untuk mengatasi kelewatan ini dan meningkatkan prestasi protokol STDMA (MAC) dengan memperuntukkan slot masa tambahan bagi semua nod yang tertakluk dalam kategori perkhidmatan kecemasan. Dalam algoritma yang dicadangkan, ia membahagikan lebar jalur yang ada di antara dua perkhidmatan bagi kelas yang berlainan iaitu usaha terbaik dan waktu nyata. Terdapat dua kaunter yang berbeza untuk mengira bilangan slot yang diperuntukkan kepada pengguna kelas yang berlainan. Senario lebuhraya dipilih untuk memodelkan corak trafik kenderaan. Keputusan rangkaian simulasi menunjukkan bahawa nombor nod yang berbeza bagi skim cadangan melambatkan sebanyak 23% and pemprosesan sebanyak 4% berbanding STDMA. Untuk nilai yang berbeza kelewatan kelajuan sebanyak 24% lebih lambat dan 23% lebih tinggi pemprosesan daripada STDMA. Di samping itu, keputusan menunjukkan bahawa protokol cadangan melebihi keupayaan konvensional CSMA/CA dari segi kelewatan dan pemprosesan.

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AAS	-	Advanced Antenna System
AIS	-	Automatic Identification Systems
ALOHA	-	Abramson's Logic of Hiring Access
BE	-	Best Effort
CDMA	-	Code Division Multiple Access
CET	-	Chanel Empty Time
CM	-	Competitive Message
CSMA	-	Carrier Sense Multiple Access
CSMA/CA	-	Carrier Sense Multiple Access with Collision Avoidance
CTS	-	Clear-to-Send
DCC	-	Decentralized Congestion Control
DCF	-	Distributed Coordination Function
DSRC	-	Dedicated Short Range Communications
FDMA	-	Frequency Division Multiplexing Access
FSM	-	Finite State Machines
FTP	-	File Transfer Protocol
GPS	-	Global Position System
GUI	-	Graphical User Interface
HTTP	-	Hypertext Transfer Protocol
IEEE	-	Institute of Electrical and Electronics Engineers
IP	-	Internet Protocol
ITS	-	Intelligent Transportation Systems
LAN	-	Local Area Network
MAC	-	Medium Access Control
MANETs	-	Mobile Ad Hoc Networks
NCTUns	-	National Chiao Tung University
NED	-	Network Description Language

NI	-	Nominal Increment
NS	-	Nominal Slot
NS2	-	Network Simulator 2
NSS	-	Nominal Start Slot
NTS	-	Nominal Transmission Slot
OMNET++	-	Optical Micro-Networks Plus Plus
OPNET	-	Optimized Network Engineering Tool
PPR	-	Probability of Packet Reception
QoS	-	Quality of Service
RR-ALOHA	-	Reliable Reservation ALOHA
RT	-	Real Time
RTS	-	Request-to-Send
S-ALOHA	-	Slotted-ALOHA
SI	-	Selection Intervals
SINR	-	Signal-to-Interference-and-Noise
STDMA	-	Self-organizing TDMA
TCP	-	Transmission Control Protocol
TDMA	-	Time Division Multiple Access
TraNS	-	Traffic and Network Simulation
UDP	-	User Datagram Protocol
V2I	-	Vehicle-to-Infrastructure
V2R	-	Vehicle to Roadside
V2V	-	Vehicle to Vehicle
VANETs	-	Vehicular Ad Hoc Networks
VDL	-	VHL Data Link
VeSOMAC	-	Vehicular Self-Organizing MAC
WAVE	-	Wireless Access for Vehicular Environments
Wi-Fi	-	Wireless Fidelity
WiMax	-	Worldwide Interoperability for Microwave Access
WT	-	Waiting Time

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CHAPTER 1

INTRODUCTION

1.1 Introduction

One of the subgroups of the mobile ad hoc network (MANET) is the vehicular ad hoc network VANET (Bhagchandani and Sharma, 2013). VANET supports Intelligent Transportation Systems (ITS) for improving road safety, reducing traffic conjunction. Even though ITS provides any benefits, this technology requires reliable and real-time communications. Unfortunately, most of the existing communication protocols failed to realize this requirement. As a result, the protocols have a high transmission delay (Blum *et al*., 2004 and Liu *et al*., 2009). The development of (VANETs) can be defined as one of the emerging areas of application of ad-hoc network technology. There are two kinds of communications in VANETs, i.e. Vehicle-to-Vehicle (V2V) and Vehicle-to-Roadside (V2R). All these communications greatly relied on IEEE 802.11b. Instead, both new standards of IEEE 802.16 (WiMAX) and IEEE 802.11p are promising (Bibhu and Singh, 2012).

The medium access control (MAC) protocols can be used to provide real-time and reliability necessities. Most of the traditional MAC protocols focus on one of the reliabilities or real-time communication criterias. For example, the Carrier Sense Multiple Access (CSMA) protocol and IEEE 802.11p for VANETs (Hartenstein and Laberteaux, 2008). Although the mobility of the nodes can be supported by CSMA based MAC protocol, they are not collision-free and unbounded delay (Rezazade *et* *al*., 2011). Therefore, they are not appropriate for delay sensitive transactional applications (Eichler, 2007). An efficient and reliable medium access control (MAC) protocol is needed to evade the transmission collisions in mobile ad hoc networks MANETs (Menouar *et al*., 2006).

1.2 Problem Background

The medium Access Control (MAC) protocols are used in order to provide real-time and reliable communications (Katrin *et al*., 2009). MAC protocols for VANETs proposed in literature can be divided into two main categories: the contention-based MAC protocols, such as (Aloha, slotted Aloha, IEEE 802.11 Distributed Coordination Function (DCF) and Carrier Sense Multiple Access (CSMA), and the schedule-based MAC protocols, such as (FDMA, CDMA, VeSOMAC and TDMA) (Kumar *et al*., 2006; Yu and Biswas, 2007). Although the contention-based MAC protocols can support the mobility behaviour of the nodes, they have an unlimited delay in accessing the channel (Yu and Biswas, 2007). In addition, they are not collision-free. Therefore the reliability, which is the most important measure in these networks is not provided. Thus, these protocols are not the best to use in real-time and safety applications (Katrin *et al*., 2009; Yu and Biswas, 2007).

Nelson and Kleinrock (1985) formalized the concept of the spatial-TDMA scheduling problem. In order to maximize throughput and minimize delay, the aim of the classical form of this problem is to employ time slots as little as possible. Maximizing a weighted sum of the number of transmissions or finding the maximum number of transmission in a certain amount of slots are equivalent forms of mentioned problem (Quintas and Friderikos, 2012).

In STDMA, the problem that a node normally cannot concurrently receive from more than one node within its radio range or send and receive at the same time at a single hop. However STDMA has solved this issue by means of transmitting in periodical slots, which are called schedule with nodes or unidirectional (individual) links that are assigned to do so schedule (Chou and Li, 1991). Instead of trying to find a way to propose solutions to use the channels efficiently in different circumstances, most of the existing STDMA algorithms tried to find a solution for the existing problem. Although several distributed algorithms exist, none of them fulfilled these desired properties (Grönkvist, 2003).

According to (Bilstrup *et al*., 2009b) the authors evaluated the system for safety applications that have short data mutations, which is essential for reliability in highway cases. This system inevitably depends on GPS for feasible slot sharing and synchronization and STDMA cannot perform without GPS support (Bilstrup *et al*., 2009b). In a node overload case, nodes that are furthest apart, try to share slots, which cause slots to become overloaded. In this case, unless these slots are separated in space sufficiently, collisions will occur, which could lead to unbounded delays (Booysen, *et al*., 2011). The worst case with STDMA that can happen is the loss of synchronization (Sjöberg, 2009).

In terms of concurrently transmitting nodes, the probability of two or more nodes to have overlapping Selection Intervals (SI) is the STDMA's worst case, which has the probability of selecting same set of transmission slots (Bilstrup, *et al*., 2009a). (Sánchez, 2008) addressed a lot of STDMA-related research questions that aimed to solve the nonlinear optimization issue by means of "column generation" techniques that use Advanced Antenna Systems (AAS) to create the transmission schedule. However STDMA is very fair and efficient, its slower adaption in comparison with distributed approaches like CSMA/CA to network changes can be considered as its drawback.

STDMA's dependency on every single STDMA node to positioning system is its main drawback, which adds another actor to ensure safety and one more point to possible failures. In STDMA, collisions are subjected to happen intentionally and unintentionally. The unintended collisions occur when two transmitters set their n reuse factor to 0 at the same time and the same slot is allocated to them at the same time. The intended collision occurs when time slots are completely busy in a certain SI due to SDTMA allocation of the packet in the slot, which is engaged by the utmost vehicle (Cerezo Oliva, 2012). When the channel access delay of CSMA and STDMA are evaluating, it can be said that the minimum delay for CSMA is smaller than the minimum delay for STDMA, which, in the worst case, is random for CSMA and is known for STDMA, which is independent of channel type and network load (Khairnar and Kotecha, 2013).

In (Rezazade *et al*., 2011) a new MAC protocol STDMA for these vehicular networks is proposed, which entails the use of both contention-based and schedule-based MAC protocols. The proposed protocol is composed of two parts: initial state and steady state. In the initial state, nodes attempt to gain admission the channel through the use of a contention based MAC protocol. Within this state, each node transmits a competitive message, which is inclusive of the number of its allocated time slot after which the node waits for a waiting time (WT). After the WT time (which is equal for every node), the steady state, where each node knows the start time of its time slot, commences. Based on this, the nodes transmit their data in their allocated time slots and each node uses its time slot for *n* times, where *n* is equal for every node and is located within the competitive message. In order to allocate a time slot for themselves in this protocol, nodes gaining entrance to the network in the steady state have to wait until the next initial state. As a result, if these nodes are in possession of an important message, they cannot be satisfied by the proposed protocol because they are instead waiting for the initiation of the next initial state. It means that the node experience long delay.

1.3 Problem Statement

The vehicular ad-hoc networks (VANETs) can be considered as a special sort of MANETs with the key difference of frequently changes in mobility pattern and network topology (Bhagchandani and Sharma, 2013). The designing of MAC protocols for VANETs should provide real-time and reliable communications, which are essential for realising ITS applications. The existing MAC protocols for this kind of networks cannot achieve all of the mentioned objectives together (Rezazade *et al*., 2011). Hence, the hybrid protocol STDMA aims to achieve efficient and reliable (MAC) protocol for vehicular ad hoc networks VANETs, to consider (VANETs) the requirements by providing a balance between them. In addition, vehicles in emergency situations must send the information to alert the surrounding vehicles. However in the inter-vehicle communication particularly for emergency services, according to proposed STDMA MAC (Rezazade *et al*., 2011) protocol method, when nodes enter into the network in the steady state, they must wait until the next initial state in order to allocate a time slot for them. These nodes might have an urgent message while waiting for the next initial state, as at the beginning, the node experiences some delay. The main problem of this method is the urgent message problem. Users with urgent message have to wait for a long time if they arrive just after finishing the initial allocation state.

1.4 Research Question

1. How to improve (STDMA) MAC protocol to make an efficient hybrid protocol for vehicular environment?
2. How to make STDMA suitable for real-time application like VANETs?
3. How to evaluate the proposed protocol in simulation environments?

1.5 Research Objectives

The aim of this research is to develop an efficient MAC protocol in Vehicular ad-hoc network (VANETs). And the objectives are.

1. To improve an existing STDMA hybrid MAC protocols for VANETs.

2. To design an improved version of an existing STDMA hybrid MAC protocol to make STDMA suitable for real-time application.
3. To evaluate the proposed protocol in simulation environments.

1.6 Scope of the Research

This research will work on MAC protocol in VANETs. In particular, Hybrid STDMA MAC protocol will be modified to make it suitable for VANETs like real-time applications.

1.7 Research Contribution

An efficient and reliable MAC protocol for vehicular ad hoc network communication.

1. The modification and improvement of an existing STDMA hybrid MAC protocol for VANETs.
2. The evaluation of the proposed protocol in using performance metrics in simulation environments.

1.8 Research Significance

The importance of this research is to achieve an efficient and reliable vehicular communication. The medium access control (MAC) protocol provides distributed real time communication between nearby vehicle and between vehicles and the road-side equipment. The most important benefits are in terms of active safety, by using inter-vehicular communications. And vehicles can warn each other about a dangerous traffic situation, such as accident, icy road, oil stains and sudden break.

1.9 Research Organization

The organization of the thesis is as follows:

1. Chapter 1 provides the introduction to the study domain, basically an introduction to the vehicular ad-hoc networks (VANETs). Then it discusses problem background, problem statement, research objectives, research scope, research contribution and significant.
2. Chapter 2 provides an extremely literature review of the study area, background, explaining the contention-based, schedule-based and hybrid (MAC) protocols. Then, an overview of some network simulators.
3. Chapter 3 provides the research methodology flow used in this research and the simulation setup. This has been done by providing the general framework of the research represented via several stages.
4. Chapter 4 presents a discussion in details about the design of the proposed MAC protocol. In the end, it presents the process of implementation. Moreover, evaluation metrics explained.
5. Chapter 5 describes the simulation results that have been presented and discussed in order to evaluate the performance of the proposed method.
6. Chapter 6 presents the conclusion of this research with possible future work.

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