LATENCY REDUCTION IN PACKET FORWARDING AND BEACONING IN VEHICULAR AD HOC NETWORKS

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This dissertation is dedicated to my family for their endless support and encouragement, especially my treasured parents.

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ABSTRACT

Vehicular Ad Hoc Networks (VANETs), is a special type of MANET in which vehicles can communicate with each other. One of the main limitations associated with this type of network is to deal with delay which is very crucial aspect. In VANETs, a proper maintenance of communication is cumbersome and topology is also not stable. Thus researchers relay more on geographical routing protocols than topology routing protocols. In geographical or position based routing protocols delay is still one of the main concerns. In this study, this problem (delay) has been addressed by introducing an efficient mechanism. In order to avail the objectives of this research, two ideas have been proposed. First, a packet forwarding method has been developed in order to reduce the latency of GeOpps routing protocol. Second, an efficient beaconing interval method has been developed by taking into account of the fuzzy logic approach on the basis of experimental results. In order to validate proposed methods, multiple experiments were carried out with different scenarios and then their outputs were compared with standard protocols. The results show that in the beaconing protocol, the use of proper parameters in fuzzy system can help to enhance the performance of the network in terms of load and also delay. Furthermore, applying the result of beaconing in GeOpps routing protocol caused it to perform better. The Modified GeOpps (MGeOpps), is associated with benefit of less processing in order to find the next node. Hence, it obtains good results in packet delivery ratio and less delay in packet transmission. The overall end-to-end delay is 2% less than the GeOpps routing protocol.

ABSTRAK

Vehicular Ad Hoc Networks (VANETs), adalah sejenis Manet khas di mana kenderaan-kenderaan boleh berkomunikasi antara satu sama lain. Salah satu kelamahan utama yang dikaitkan dengan jenis rangkaian ini adalah pengurusan kelewaden yang merupakan aspek penting. Dalam VANETs, satu penyelenggaraan komunikasi yang bait betul adalah rumit dan topologi juga tidak stabil. Justeru, pengkaji-pengkaji lebin bergantung kepada protokol penghantaran geografi daripada protokol penghantaran topologi. Dalam protokol-protokol penghantaran geografi atau berdasarkan kedudukan kelewatan masih salah satu daripada kebimbangan-kebimbangan utama. Dalam kajian ini, masalah ini (kelewatan) telah ditangani dengan memperkenalkan satu mekanisme yang cekap. Bagi mencapai objektif-objektif kajian ini, dua idea telah dicadangkan. Pertama, satu kaedah penghantaran paket telah dibangunkan untuk mengurangkan kependaman daripada penghantaran GeOpps protokol. Kedua, satu kaedah cekap selang penunjuk telah dibangunkan dengan mengambil kira pendekatan kaburan logik berdasarkan keputusan-keputusan eksperimen. Bagi pengasahan kaedah-kaedah yang telah dicadangkan, pelbagai eksperimen-eksperimen telah dijalankan dengan senario-senario berbeza dan kemudian keputasan-keputasan nya dibandingkan dengan protokol-protokol piawai. Keputusan-keputusan menunjukkan bahawa penunjuk-penunjuk protokol, penggunaan parameter-parameter yang betul dalam sistem kaburan boleh membantu untuk meningkatkan prestasi rangkaian dari segi-segi beban dan juga kelewatan. Tambahan pula, penggusaan hasil penunjuk dalam panghantaran protokol GeOpps telah menyebabkan ia untuk melaksanakan dengan lebih baik. pengubahsuaian GeOpps (MGeOpps), dikaitkan dengan faedah mengurangi pemprosesan untuk mencari nod seterusnya. Oleh itu, ia mendapat keputusan-keputusan yang baik di dalam nisbah penghantaran paket dan mengurangkan kelewatan dalam penghantaran paket. Koseluruhan kelewatan hujung-ke-akhir adalah 2% kurang daripada penghantaran protokol GeOpps.

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LIST OF ABBREVIATIONS

AFBR	-	Adaptive Fuzzy Beacon Rate
C2C	-	Car-to-Car
C2I	-	Car-to-Infrastructure
CBR	-	Current Beacon Rate
DGPS	-	Differential Global Positioning System
GeOpps	-	Geographical Oppurtunistics
GF	-	Greedy Forwarding
GPS	-	Global Positioning System
GPSR	-	Greedy Perimeter Stateless Routing
ITS	-	Intelligent Traffic System
IVC	-	Inter-Vehicle Communication
LL	-	Low-density-Low-speed
LN	-	Low-density-Normal-speed
LH	-	Low-density-High-speed
MANET	-	Mobile Ad hoc Network
MGeOpps	-	Modified Geographical Opportunistics
NBR	-	New Beacon Rate
NP	-	Nearest Point
NPGF	-	Nearest Position Greedy Forwarding
PDAs	-	Personal Digital Assistants
PDN	-	Percentage of Directional Neighbour vehicles
PGB	-	Preferred Group Broadcast

RSU	-	Road Side Unit
RVC	-	Road-Vehicle Communication
SUMO	-	Simulation Urban MObility
TP	-	Transmission Power
V2I	-	Vehicle-to-Infrastructure
V2V	-	Vehicle-to-Vehicle
VANETs	-	Vehicular Ad Hoc Networks
VS	-	Vehicle Status

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Vehicular ad hoc networks (VANETs) is a special type of MANET in which communication is among vehicles which is known as Vehicle to Vehicle communication (V2V)and between vehicles with roadside wireless units or Vehicle to Infrastructure(V2I). This network, have become large because of supporting wireless products that get more popular and can now be used in vehicles such as personal digital assistants (PDAs), laptops and mobile phones (Paul *et al.*, 2012; Zeadally *et al.*, 2012).In this type of networks, rather than moving at random, vehicles tend to move in an organized fashion and with more speed that has encountered researchers with many problems due to rapid changes in topology and link connectivity(Blum *et al.,* 2004).

Due to high mobility and rapid topology changing of VANETs, lowest delay in transmitting information is required to avoid many problems such as disconnection and have an efficient network in terms of packet delivery ratio, connection establishment and routing. In order to avoid mentioned problems researchers have studied this network (VANETs) and proposed different techniques. In other words, different type of protocols were proposed by different authors, Topology based protocols and Position based protocols(Altayeb and Mahgoub, 2013), that here the main concern is about the position or geographic based routing protocol. According to this protocol, each node knows its own and neighbours node geographic position by Global Positioning System(GPS)(Agarwal and Saxena, 2013; Kuo and Fang, 2013).Being able to forward packets to the most qualified node is one of the crucial issues in VANETs routing protocols. Hence, different type of forwarding has been proposed, e.g. greedy and perimeter forwarding(Karp and Kung, 2000), intersection forwarding(Sun *et al.*, 2010), node's destination based forwarding where navigation suggested routes is used to select the forwarding node(Leontiadis and Mascolo, 2007).

In compare with other normal type of networks, VANETs is more challenging due to its mobility. Once an opportunity of sending packet to a proper node is missed, it might not be taken for second time. The reason is that specific node can go out of the coverage area and therefore it is out of access. Transmitting packets process needs to consider many issues such as density, velocity, direction and node's destination to avoid severe problems such as Local Maximum, delay and packet loss.

This study focused on delay in routing protocol in VANETs. Particularly, the research undergoes an investigation on packet forwarding and beaconing in order to reduce delay of delivering packets to destination. GeOpps routing protocol, is selected as benchmark which is very close to this work in terms of the idea for packet forwarding.

1.2 Problem Background

In the following sections, two issues are highlighted that are one of the main concerns of researchers to increase the efficiency of VANETs. The factor that is causing the importance of these issues is delay. Therefore, this research investigates two key challenges that are as follows;

- Delay in packet forwarding
- Delay in beaconing interval

Therefore, the next subsections are elaborated as a way to discuss these main domains.

1.2.1 Packet Forwarding

As aforementioned about the importance of VANET networks in safety and traffic control, a lot of efforts have been done to make this technology efficient. To use advantageous of this technology there is a need of proper routing protocol for transmitting information between vehicles with a lowest delay. Despite many studies have been conducted to come up with an efficient routing protocol in VANETs, still there are deficiencies, delay is the one of the crucial issues in routing that must be addressed(Nzouonta *et al.*, 2009; Wang *et al.*, 2010; Chen *et al.*, 2011; Jayachandran *et al.*, 2012; Khan *et al.*, 2012; Paul *et al.*, 2012; Schwartz *et al.*, 2012; Wu *et al.*, 2012a; Wu *et al.*, 2012b; Yu *et al.*, 2012; Wen and Rhee, 2013; Zhang *et al.*, 2013).Communications in VANETs are arranged into two groups, Car to Car (C2C) and Car to Infrastructure (C2I)(Shen *et al.*, 2009).The C2I routing protocols are composed of two subgroups that have gained more attentions than others which are Topology-based and Geographical-based(Sharef *et al.*, 2013).

This study is focused on the geographical-based in which the positions of nodes are considered into account for packet forwarding(Agarwal and Saxena, 2013).The final position of each node helps to make decision to which the packet is better to be sent. Each node is equipped with GPS system so that they can determine their destination and also be suggested by best path to the determined destination. Some algorithms have had a good contribution in enhancing routing protocols such as the earlier ones known as GPSR(Karp and Kung, 2000) and then improved of this routing protocol known as GPSR J+(Lee *et al.*, 2007),GPSR+AGF(Naumov *et al.*, 2006) and E-GPSR(Fenhua and Min, 2010). Furthermore, GPCR(Lochert *et al.*, 2005), GRANT(Schnaufer and Effelsberg, 2008), CAR(Naumov and Gross, 2007), A-STAR(Seet *et al.*, 2004) and STBR(Forderer, 2005), are in the same category of Geographic-based routing protocol.

Regarding to different types of routing protocols, many angles of routing protocols have been covered but having one comprehensive efficient routing protocol is still researcher's concern.

However, link state routing protocols provide route maintenance and low latency (Altayeb and Mahgoub, 2013), it does not work very well when the network is immense. In VANETs, since the network mobility is high and topology is not constant link state routing protocols are not applicable because maintaining a connection is a cumbersome task. Therefore, failing in packet forwarding causes delay and also packet drop. Rather than that, uncontrolled flooding leads to many unnecessary dissemination, which may cause the so called broadcast storm problem (Tseng *et al.*, 2002). As the size of a network grows, various performance metrics start suffering from the increasing load (Li *et al.*, 2001; Tseng *et al.*, 2002; Naumov and Gross, 2005) that prevents successful performance of the network. As a result, since topology-based routing protocols establish a path to destination and VANETs are not stable networks; sequentially change due to the high mobility, then topology-based routings cannot afford a good performance. In consequence, geographical routing protocols have been proposed in which the routing is based on the position of nodes.

All geographic routing protocols have exploited position information of navigation systems to route packets properly(Sukumaran *et al.*, 2013).Greedy routing protocols, mentioned before, are a type of geographical routing protocols that sends the packet to a node that is closest to ultimate destination. Greedy Perimeter Stateless Routing protocol (GPSR) (Karp and Kung, 2000), For example, considered only the closeness of neighbours to destination and when the packet stuck in local maximum it uses the perimeter method to get out of this situation. High probability of being in local maximum and relaying only on the closeness of the neighbours to destination makes this routing protocol unreliable in which delay is relatively high(Paul *et al.*, 2012). GPCR(Karp and Kung, 2000), uses coordinators to direct packets to destination in which junctions are the dominant places where the forwarding decision are taken which is not promising to be a proper way of forwarding packet for the following reason; the scalability of the network is not considered so when the network is sparse, performance decrease dramatically(Lin *et al.*, 2010; Altayeb and Mahgoub, 2013). In this regard, it is highly possible that packets face local maximum so then delay is the result of a routing nevertheless the main concern of this routing protocol is declining delay.

Using GPS suggestion, best node and route can be found to direct the packet to the destination. In Geographical Opportunistic routing (GeOpps) (Leontiadis and Mascolo, 2007), next node is selected based on three principles as follow(Altayeb and Mahgoub, 2013); first, in the neighbourhood the closest node to destination is identified. Nodes, calculate the shortest time to destination. Finally, packet is sent to a node is closest to destination and take shortest time to get to destination. Calculating the overall distance of neighbours from their current location to the nearest point to destination and then from that point to destination is the criteria for finding the best node. The need of time for doing this strong processor is the weakness of this routing protocol.

1.2.2 Beaconing

In VANETs, vehicles need to know about other vehicles at their neighbourhood that are within each vehicle coverage area. Therefore, there is a need for an awareness message to disclose basic information about neighbours that is called beacon message (Paul *et al.*, 2012). There are two types of beaconing; constant beaconing and dynamic (adaptive) beaconing. The problem of using constant beaconing is as follows; first, in low density, low beacon rate cause delay to discover about neighbours and then reduces reliability. The other negative side of this method is that the high rate of beaconing leads the network to be overloaded(Thaina *et al.*, 2011). Regarding to these drawbacks of fixed beaconing message, adaptive beaconing seems necessary to reduce the impact of these problems on VANETs. In the following, first different approaches are investigated and then most related work to this study will be introduced.

Different approaches have been revealed in order to have optimal beaconing in terms of bandwidth load or delay. It is notified in many of research works that the beaconing consumes a big part of bandwidth, so they have tried to tune bandwidth consumption along reducing latency by proposing adaptive beaconing(Fukui *et al.*, 2002; Mittag *et al.*, 2009; Torrent-Moreno *et al.*, 2009; Cheng *et al.*, 2010; Samara *et al.*, 2010b; Schmidt *et al.*, 2010; Sommer *et al.*, 2010; Thaina *et al.*, 2011; Sebastian *et al.*, 2012). Adaptive beaconing can be categorized in 3 groups(Ghafoor *et al.*, 2013b); transmission power control, interval, and hybrid beaconing. In the following some of these approaches are elaborated.

To overcome scalability problem, a solution is proposed that considered vehicles that are ahead only (van Eenennaam *et al.*, 2010).In this method, only beacons are sent from vehicles that are in front of current vehicle are acknowledged. When a node received a beacon from in front node it transmits its beacon to in front vehicles. Consequently, the collision can be low, but the problem is that it ignores vehicles at behind that might be a big portion of the existing node in the coverage area of each node. Authors in (Schmidt *et al.*, 2010) intelligently described different situation and based on that they proposed situation-adaptive beaconing. They considered both accuracy and offered load that beacons imposed on the network. However, they did not evaluate and compare their method. Sending packet based on constant travelled distance and number of lane (Fukui *et al.*, 2002) are another mechanisms. Thereby, vehicles transmit more packets when they move faster. The other factor they considered is number of lane on the street; based on this idea, the more number of lanes are, the fewer packets are sent which is not reasonable. Having more lanes on the street cannot imply traffic conditions. Another scheme of adaptive beaconing is introduced in (Thaina *et al.*, 2011). Regarding to these authors, beacon messages are affected with two schemes. First, node's environment; composed of the density and network traffic. Based on this idea, when these two parameters, density and network traffic (number of nodes and buffered messages respectively), are high the beacon rate must be low and vice versa. The other parameter is the application requirements; each application requires different interval. When there is no need for high rate of message transmission, beaconing rate is set to low frequency. The problem to this study is that they did not take the velocity of vehicles into account which is very influential onto beacon transmission and in overall beacon ratio.

Authors in (Sebastian *et al.*, 2012) revealed an idea to adapt beaconing based on estimated channel load and danger severity of the interactions among vehicles. The objective of this research is to provide an optimized beaconing rate to improve collision prevention capability. According to this research, they tried to reduce delay by increasing beacon rate with respect to channel load. Since the main concern of this research is to improve collision prevention, in dense conditions the channel load is relatively high regarding to the high possibility of collision in this situations.

A fuzzy-logic is used to adapt beaconing rate (Ghafoor *et al.*, 2013a).The adaptive beacon rate in this approach considered the percentage of vehicles traveling in the same direction and status of vehicles as inputs of the fuzzy system. Two input parameters to fuzzy system are Percentage of Directional Neighbour vehicles (PDN) and vehicle Status (VS) which are used in inference engine to produce the new beacon; these parameters are used to make rules for fuzzy system in order to gain the pre-set beacon rate. In fact, taking into account merely two mentioned matrices cannot have proper output for the whole situations. Status, as an influential parameter, has a significant impact on output. In order to elaborate more this issue, see figure 1.1.

Table 1.1: Fuzzy Rules Structure

Rule	IF		THEN
	Perce. of Direc.	Vehicle Status	BR_r
1	Sparse	Emerg.	VHigh
2	MDense	Emerg.	High
3	VDense	Emerg.	Medium
4	Sparse	NEmerg.	Medium
5	MDense	NEmerg.	Low
6	VDense	NEmerg.	VLow

In this figure, it can be seen the highest value for normal situation for transmitting beacon is medium rate which is not reasonable. The reason is, in sparse network nodes cannot miss any opportunity of finding a neighbour or a node in a proper position to forward the packet, but this method does not fulfil it. Finally, this methodology is benchmarked with two fixed beacon rate; 1 and 6 beacon/second.

A fuzzy method (Hassan *et al.*, 2013)is used for adjust beaconing frequencies in VANETs. This approach considered three metrics into account; packet carried time, number of neighbours, and speed. The fuzzy system is used to determine the next interval for sending message. In this approach, the member functions for fuzzy system are developed based on the three mentioned metrics as input. Finally, based on the member functions the desire outputs obtained that is said has better performance compare with fixed interval rate. For evaluating the proposed method four metrics are considered; packet delivery ratio, average end-to-end delay, routing overhead ratio, and total collision ratio. This mechanism has some shortcoming as follows; first, the packet carry time is not reasonable since in reality there is an expiration time for each packet that cannot go longer as it is considered in this article. The other problem is that the current vehicle always lacks of in front node's information. As a neighbour numbers that is one of the inputs to fuzzy system, only vehicles in front of the current node is counted. These vehicles must be in the same direction with the packet forwarder direction. Thus, these metrics cannot meet an efficient performance.

A predictive method is used (Schwartz *et al.*, 2013) to find neighbour's next positions. In this literature K position of the neighbours are predicted and if one of them satisfy the real position, the new beacon rate will be defer. Otherwise, it broadcasts its beacon message to the next slot. This method is based on prediction of node's position. Received node, predicts next positions of the node then if the predicted positions satisfy the feasibility condition, the proposed beacon rate control algorithm defers the broadcast of its beacon message to the next slot. In the other words, if the error is more than a value then it must broadcast another beacon to be able find the real position of the node. Otherwise without sending beacon the following position of the node is predictable.

Since beaconing helps updating the neighbour's table, it is very influential in improving the performance of VANETs network. An efficient interval can help vehicles have access to as fresh data as possible, there by vehicles have more accurate information about each vehicle that makes routing protocols more reliable. In this research, the proposed adaptive beaconing will be compare with proposed method in(Ghafoor *et al.*, 2013a).

1.3 Problem Statement

Many ideas have been proposed to tackle delay in VANETs routing protocols, but still there is a space for enhancement in latency. One of the causes of delayis from an inefficient beaconing and packet forwarding. Particularly, these problems can be categorized into two parts as follows;

- First, outdated information in neighbour’s table that show necessary information about current node’s neighbour situation. In other words, improper beaconing mechanism.
- Second, inability to find the proper node among neighbours of the current node. It can be said, an improper packet forwarding methodology is the reason of this problem.

In order to overcome aforementioned problems (delay in beaconing and packet forwarding), this study considers some crucial factors for both beaconing and packet forwarding that are as follows;

- Beaconing factors: density, velocity, and direction.
- Packet forwarding factors: density, position, and direction.

Toward selecting the best node among neighbours of the current node, there is a need for proper node selection algorithm. This algorithm must consider priorities on neighbours to find the most qualified node in order to be selected as a next forwarding node. Regarding to beaconing problem (delay), aforementioned parameters are used to conduct an experimental test to find an optimum interval times for VANETs networks in urban area.

1.4 Research Questions

This research enhances GeOpps routing protocol along finding a fair interval range in order to have an adaptive beaconing corresponding to the density of the network. The aforementioned issues lead to address the following questions:

1. How to adjust the interval of beaconing to reduce delay?
2. How to select next hop for delivering packet in a fair time to reduce delay?

1.5 Research Aim

The main purpose of this study is to reduce the latency in two parts of routing protocol; those are packet forwarding and beaconing. Thus, the outcome of this research is a developed routing protocol with less delay. The proposed method is based on a work that has been done before, GeOpps. In a simple word can be said, an adjusting method is used in proposed method. The other important section of this research is adjusting beaconing rate to improve the efficiency of this method based on some factors that are mentioned before.

1.6 Research Objectives

The following objectives are in place to design improved GeOpps routing protocol:

1. To design an optimum beaconing mechanism in order to have efficiency on updating neighbour's table.
2. To develop the packet forwarding algorithm in adjusting manner in order to have less delay on packet delivery.
3. To evaluate the performance of the proposed packet forwarding and beaconing mechanism.

1.7 Research Contribution

In this research, delay is taken as a main challenge by reason of its impact on network efficiency. To alleviate delay, two issues are investigated as follows;

- **Packet forwarding**

  The main contribution of this research is to develop GeOpps routing protocol. Particularly, utilizing influential parameters such as; density, direction, position and destination in order to make a better decision for forwarding packets. The mechanism is used to develop this protocol (adaptive methodology), helps to reduce delay of packet delivery via using optimum route and eliminate overhead that is extra calculation to obtain shortest time to destination. The route is GPS suggestion that is the closest way to get to the destination. Thus, messages can be sent in the short time that is vital in vehicular safety and traffic control.

- **Beaconing**

  Rather than that, investigating about beaconing and recommend an adjusting interval specifically for urban areas helps hops to gain more updated information about neighbours and less position error. Regarding to this benefits, this protocol is more proper for this type of high mobility networks, VANETs.

Simply, it can be said that the contribution of this research is to have minimum delay in sending data to other nodes. Thus, it has an impact on safety and non-safety applications such as; traffic issue or warning message.

1.8 Scope of the Research

This research presents an enhanced packet forwarding mechanism and adaptive beaconing in VANETs to reduce the overall delay of routing protocol. More specifically the scope of this research is as follows:

1- The proposed protocol is limited to IEEE 802.11p standard.

2- The packet forwarding methodology development is confined in GeOpps routing protocol.

1.9 Significance of the Research

This research comprise of two significant parts; beaconing and packet forwarding. Sending beacon based on proper interval can enhance the performance of the VANETs network significantly. For this purpose, an experimental task is conducted in which a variety of possibilities regarding to the intervals (1-10 interval per second), velocities (5.6m/s, 8.3m/s, 11.11m/s, and 13.9m/s), densities (80, 110, 140, 170, and 210), are taken into account. The values for intervals is chosen based on the literature review as well as the densities (Schmidt *et al.*, 2010; Sommer *et al.*, 2011; Thaina *et al.*, 2011; Akbarifar *et al.*, 2012; Ghafoor *et al.*, 2013a; Schwartz *et al.*, 2013), but velocities except the 13.9m/s (State, 2013; Wikipedia, 2014) is selected randomly. Based on the obtained results from this part, an adaptive beaconing has proposed that cause less delay in beaconing.

Packet forwarding is another important issue that has been studied in this research. Based on the GeOpps routing protocol two ideas are proposed that adjust packet forwarding based on the different situations. The ideas are as follows;

- Omitting time calculation that is mentioned in GeOpps routing protocol. Regarding to this routing protocol, a minimum time that a packet would need to reach its destination is estimated(Leontiadis and Mascolo, 2007). This minimum time estimation is removed to help decreasing delay that caused by this computation.
- As mentioned before, packet forwarding mechanism is corresponded to density of the network. Based on this idea, when network is very dense, packets are sent without considering the closeness of neighbour hop’s destination to the packets destination. In other words, only the direction of hops is significant when the network is very dense.

1.10 Thesis Organization

Following chapters are organized as follows:

Chapter 2; It provides deep literature review about this study, background, routing protocols, problems, and possible solutions. In the end the possible solution is discussed and a comparative table of routing protocols is presented.

Chapter 3; Research methodology flow of this study is presented in this chapter. Test bed setup is explained in this part along with problem formulation based on literature review. In the end, it presents the mobility model and the protocol design is used in this study.

Chapter 4; describes the design details of introduced algorithm for routing protocol (GeOpps) and also interval of beaconing.

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