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VAPT: VANET Adaptive Power Transmission Nodes Connectivity

by

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LIST OF ABBREVIATIONS

AIFS	Arbitration Inter-frame Space
BR	Bit Rate
CBR	Channel Busy Ratio
CBSDA	Cluster Based Semantic Data Aggregation
CCA	Cooperative Collision Avoidance
CH	Cluster Head
CM	Cluster Members
CSMA	Carrier-Sense Multiple Access
CW	Contention Window
DCF	Distributed Coordination Function
DEM	Differential Equation Method
DSRC	Dedicated Short-Range Communication
DTRA	Dynamic Transmission Range Assignment
DV	Distance Vectors
EDCA	Enhanced Distributed Channel Access
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing
HaFL	Heuristic and Adaptive Logic Scheme
IEEE	The Institute of Electrical and Electronics Engineer
ITS	Intelligent Transportation System
LLC	Logical Link Control
LS	Link State
MAC	Medium Access Control
MANET	Mobile Ad-Hoc Network
NR	Newton Raphson
OBDR	Optimized Broadcast-based Directional Routing
OBU	On Board Unit
OFDM	Orthogonal Frequency-Division Multiplexing
OSI	Open System Interconnection
PAB	Position-based Adaptive Broadcast
PDR	Packet Delivery Ratio
PDU	Packet Data Unit

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PHY	Physical
PLCP	Physical Layer Convergence Protocol
PMA	Physical Medium Access
RSU	Road Side Unit
SNR	Signal to Noise Ratio
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VANET	Vehicular Ad-Hoc Network
WAVE	Wireless Access for Vehicular Environment
WLAN	Wireless Local Area Network

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LIST OF SYMBOLS

P	Power
T_{sim}	Simulation time
T_D	End-to-end delay
d_{trans}	Transmission delay
d_{prop}	Propagation delay
d_{proc}	Processing delay
d_{queue}	Queuing delay
$\sum P_{rcvd}$	Total packet received
$\sum P_{sent}$	Total packet sent

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VPDP: VANET Penyesuaian Daya Penghantaran Persambungan Nod

ABSTRAK

Kebelakangan ini, Rangkaian Ad-Hoc (VANET) kenderaan telah mendapat perhatian yang ketara di mana ia dijangka dapat menyokong aplikasi keselamatan dan penggunaan Internet untuk mengakses aplikasi berkaitan. Aplikasi keselamatan memainkan peranan penting untuk mengelakkan kemalangan jalan raya. Walaupun dalam kes kemalangan itu tidak dapat dielakkan, aplikasi ini sekurang-kurangnya dapat mengurangkan kesan kemalangan. Matlamat utama VANET adalah untuk menyediakan keselamatan kepada penumpang dan pertukaran mesej keselamatan masa nyata adalah salah satu isu yang paling penting dalam VANET. Aplikasi keselamatan merupakan applikasi kelewatan sensitif dan mereka bergantung pada komunikasi antara kenderaan. Di VANET, perubahan pesat dalam mobiliti kenderaan yang cepat dan kerap membuat topologi yang sangat dinamik. Disebabkan ini, VANET menghadapi cabaran dalam mengekalkan hubungan. Oleh itu, dengan menggunakan kuasa penghantaran tetap di VANET, ia akan memberikan kesan buruk kepada sambungan. Kuasa penghantaran adalah berkadar terus dengan julat penghantaran. Menggunakan kuasa penghantaran / julat penghantaran tetap membawa kepada banyak kelemahan; contohnya, apabila kenderaan diedarkan secara padat, lebih banyak nod perlu berkongsi medium, menyebabkan peningkatan kesesakan dan perlanggaran yang menyebabkan penangguhan dan mengurangkan kapasiti rangkaian. Di samping itu, tetingkap pertentangan (CW) dan bit rate (BR) juga memainkan peranan penting dalam proses penghantaran. Menggunakan saiz CW yang lebih besar akan mengurangkan kehilangan paket, dengan itu meningkatkan 'throughput' dan PDR. Walau bagaimanapun, saiz CW yang lebih besar akan meningkatkan kelewatan. Sedangkan untuk BR, kelewatan dapat diminimalkan dengan menggunakan BR yang lebih tinggi, tetapi akan mengurangi PDR dan 'throughput'. Ini disebabkan BR yang lebih tinggi menghasilkan kadar penghantaran cepat yang meningkatkan kehilangan paket. Oleh itu, kerja penyelidikan ini dicadangkan untuk mengatasi masalah ini. Objektif utama penyelidikan ini adalah untuk mencadangkan mekanisme kawalan kuasa baru bagi mengekalkan sambungan rangkaian yang dapat mengurangkan kelewatan dan penggunaan tenaga dan memperbaiki PDR. Mekanisme VANET Penyesuaian Daya Penghantaran (VPDP) yang dicadangkan, mengubah lapisan MAC dengan menggunakan pengoptimuman luar talian. Pengoptimuman luar talian ini menggunakan algoritma Berbeza Evolusi (DE) untuk memeriksa tiga parameter (kuasa penghantaran, BR, dan CW) dan untuk mencari nilai optimum mereka. Nilai optimum ini kemudian digunakan untuk mengoptimumkan prestasi rangkaian. Untuk mencapai matlamat penyelidikan ini, eksperimen yang meluas telah dijalankan untuk menyiasat bagaimana nilai pemboleh ubah kuasa penghantaran boleh mempengaruhi penyambungan rangkaian dalam pelbagai senario VANET dan beban lalu lintas parameter. Hasilnya menunjukkan bahawa mekanisme pengoptimuman VPDP yang dicadangkan dapat meningkatkan prestasi pelbagai senario VANET. Senario lebuh raya dalam simulasi saiz paket yang berbeza menunjukkan peningkatan prestasi tertinggi dalam jangka masa kelewatan dan penggunaan tenaga. Di mana, kelewatan meningkat sebanyak 55.07% secara purata dan penggunaan tenaga meningkat sebanyak 54.44% secara purata. Manakala bagi nisbah

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penghantaran paket (PDR), peningkatan tertinggi ialah 17.35% secara purata ditunjukkan oleh senario hibrid dalam simulasi kadar paket yang berlainan. Kemudian, peningkatan tertinggi untuk 'throughput' adalah 17.78% secara purata, juga ditunjukkan oleh senario hibrid dalam simulasi kadar paket yang berlainan.

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VAPT: VANET Adaptive Power Transmission Nodes Connectivity

ABSTRACT

Recently, vehicular Ad-Hoc Network (VANET) has received considerable attention where its safety applications and Internet users accessing related application are expected to be supported. Safety applications play an important role to avoid road accidents. Even in the case if the accident is unavoidable, these applications can at least minimize the impact of accidents. The main goal of VANET is to provide safety to passengers and the real-time safety message exchanging is one of the most important issues in VANETs. Safety applications are a delay-sensitive and they mainly rely on reliable inter-vehicle communication. In VANET, the rapid and frequent changes in vehicle mobility create a highly dynamic topology. Due to this, VANET faces challenges in maintaining the connectivity. Therefore, by using fixed transmission power in VANET, it will give adverse effects on the connectivity. Transmission power is directly proportional to transmission range. Using fixed transmission power/transmission range leads to many disadvantages; for example, when vehicles are distributed densely, more nodes have to share the medium, causing more contentions, collisions, resulted to delays that reduce network capacity. In addition, the contention window (*CW*) and bit rate (*BR*) also play a significant role in the transmission process. Using a bigger size of *CW* will reduce the packet loss, hence increase the throughput and Packet Delivery Ratio (*PDR*). However, the bigger size of *CW* will increase the delay. While for *BR*, the delay can be minimized by using a higher *BR*, but it will reduce the *PDR* and throughput. This is due to the fact that higher *BR* resulted in fast transmission rate which increases the packet loss. Hence, this research work is proposed in order to overcome these problems. The main objective of this research is to propose a new power control mechanism to maintain network connectivity that can minimize the delay and the uses of energy and improve the *PDR*. The proposed VANET Adaptive Power Transmission (VAPT) mechanism modified the MAC layer by applying offline optimization using Differential Evolution (DE) algorithm to inspect three parameters (transmission power, *BR*, and *CW)* and to find their optimum value. These optimum values are then used to optimize the network performances. To achieve the objective of this research, extensive experiments were conducted to investigate how the variable value of transmission power can influence the connectivity of the network in different VANET scenarios and traffic load parameters. The results show that the proposed VAPT optimization mechanism improves the performance of multiple VANET scenarios. The highway scenario in different packet size simulation shows the highest performance improvement in terms of delay and energy consumption. The delay is improved by 55.07% in average and the energy consumption is improved by 54.44% in average. While for the *PDR*, the highest improvement is 17.35% in average is shown by hybrid scenario in different packet rate simulations. Then, the highest improvement for throughput is 17.78% in average, also shown by the hybrid scenario in different packet rate simulations.

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CHAPTER 1: INTRODUCTION

1.1 Research Background

The rapidly increasing numbers of vehicles over the globe nowadays have considerably increase its governing problems. One of the problems that need to be addressed at priority is vehicle collision. Every year, millions of people are suffering from non-fatal injuries ("WHO | Road traffic injuries.," 2016) which caused disability and limiting their daily activities. The lives of millions people are also cut short due to the increasing number of traffic crashes which is caused lack of inefficient transportation management systems. Therefore, it is very important to align things when it comes to traffic on roads so that fatal injuries due to accidents can be avoided. Recently, Vehicular Ad-Hoc Network (VANET) has received considerable attention from research communities where safety applications and Internet users accessing related application on the road are expected to be supported (Chai et al., 2013). Safety applications which are the applications for vehicles safety that warns drivers through sound or light indication when dangerous situations or events occur in the vicinity, play an important role to avoid road accidents. Even if the accident cannot be avoided, these applications can at least minimize the catastrophic impact from accidents. Safety applications are delay-sensitive and they mainly rely on reliable communication between the vehicles (Technol, 2015). VANET is a mobile ad hoc network designed to provide communications among vehicles (Boukerche, 2008) and it is infrastructure less and does not need to be centralized. The connection between the nodes in VANET are established when their location is inside the transmission range of each other. The main aim of VANET is to provide safety to passengers and therefore, the exchanging of real-time

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safety messages is one of the most important concerns in VANETs. There are two main reasons of exchanging these messages (Technol, 2015):

1) Awareness of the environment (Periodic Messages)
2) Detection of an unsafe situation (Event-Driven Messages)

Periodic messages are information that are repeatedly transmitted at a specific time interval, which aim to give awareness of the environment to the drivers on the road. For instance, a vehicle is announcing its current state or a road side unit (RSU) is broadcasting the status of a traffic light. On the other hand, the event-driven messages are information that is transmitted when a certain event occurs. It is a detection of an unsafe situation. For example, when a traffic accident is detected, the vehicle will generate a message to inform or warn other vehicles about the accident. This is important as other vehicles can take a precaution step from the warning messages and avoid to travel on the affected path.

In VANET, rapid and frequent changes in vehicle mobility creates a highly dynamic topology (Q. Le Van, Minh and Yang, 2013) and due to that fact, VANET faces challenging task in maintaining connectivity. Therefore, using fixed transmission power in VANET may adversely affect the connectivity. Since transmission power is directly proportional to transmission range, deploying fixed transmission power/transmission range may lead to many disadvantages. When the vehicles are sparsely distributed, using fixed transmission power, some vehicles cannot reach their neighbours which are outside of their transmission range. This leaves such vehicles in isolated state.

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The density of mobile nodes (vehicles) has a great impact on VANET's performance by influencing some factors such as capacity, routing efficiency, delay, and robustness (MM Artimy, 2007),(Van Minh, MingChuan, & Qing, 2012). The mobile node's density might vary from one location to another location caused by limitations in the transportation network, traffic controls, or fluctuations in speed, thus disturbing the homogeneous distribution of nodes. Therefore, transmission power control is the dominant factor that affects VANET usability and performance. If the protocols in VANET are not designed to handle such condition, it will give a huge impact on the degradation of the network's performance. Therefore, in order to mitigate these adverse effects in high node density of VANET, controlling the communication range of the nodes can be used. The communication range can be controlled by adjusting the transmission power (M Artimy, 2006).

In VANET, the network connectivity cannot be maintained by a fixed transmission range due to the non-homogeneous distribution of vehicles and the conditions of traffic that rapidly change (M. Artimy, W. Robertson, 2005). Therefore, a dynamic transmission range is needed to maintain the connectivity in non-homogeneous networks to take advantage of power savings and increased capacity (M. Artimy, W. Robertson, 2005),(Ukkusuri & Du, 2008).

The main focus of this research is to propose a new, dynamic power control mechanism to maintain network connectivity while at the same time minimize the uses of the energy. The proposed mechanism modified the MAC layer to inspect three parameters which are transmission power (*Tx*), bit rate and contention window (*CW*) which are then optimized using Differential Equation (DE) optimization algorithm to

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optimize network performance. The details explanations about this method are discussed in Chapter 3. To achieve the objective of this research, extensive experiment were conducted to investigate how the mechanism can influence the connectivity of the network in different VANET scenarios and traffic load parameters.

1.1.1 Overview of VANET

In the early 1990s which is the beginning of research on VANETs, different wireless technologies have been considered to support Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication with the main aim to support cooperative safety applications (Campolo, Molinaro, & Scopigno, 2015).

The nodes in VANET are use d in On Board Units (OBUs) which are stations that are installed in vehicles (Rezha, Siadari, & Soo Young Shin, 2012) to communicate directly with each other or with the help of an infrastructure (intermediate nodes) such as router or Road Side Unit (RSU) (Barskar, 2015). VANET forms a dynamic topology due to the high speed of the vehicles and requires real time packet transfer for efficient communication (Kanwar, 2014). The RSUs are connected to the backbone network for facilitating internet access.

The VANET's technology is based on IEEE 802.11 wireless standard which is the fundamentals for Wireless Local Area Network (WLAN), Wi-Fi, Mobile Ad-Hoc Network (MANET) as well as VANET (Bhattacharjee & Pal, 2011). This technology has appeared as the key underlying technology in the realization of an Intelligent Transportation System (ITS). The ITS is the application that provide an information to

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the traveller in order to increase the safety and efficiency of the road transportation system. The IEEE 1609 family of standards for Wireless Access for Vehicular Environment (WAVE) is defined to support applications for ITS (Shahzad A. Malik, Shah, & Shahid A. Khan, M. Jahanzeb, 2010).

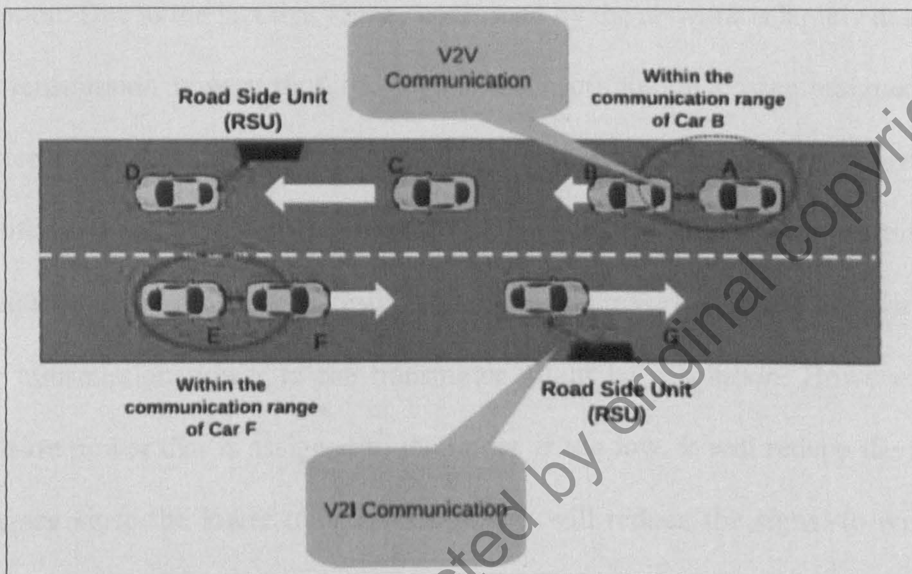

Figure 1.1 Illustration of VANET
Source: (Rehman, Khan, Zia, & Zheng, 2013)

VANET is responsible for the communication between moving vehicles in a certain environment. The illustration of VANET is as shown in Figure 1.1. The V2V communication occurs when a vehicle communicates with another vehicle directly and V2I communication happens when vehicles communicate to an infrastructure such as a RSU.

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1.1.2 Adaptive Transmission Power versus Fixed Transmission Power in VANET

Adaptive transmission power is a technique that controls the level of power output of the node that is used for data transmission process. The aims of this technique are to improve the network performance and reduce interference as well as energy consumption. Due to the fact that energy consumed by the network is largely determines by the transmission power, thus the higher the transmission power assigned to the transmitter, the higher the energy consumed by the network. This in turn decreases the battery life span and increases the interference between the nodes that operating at the same frequency. To reduce the energy consumed and increase the battery life span, assign a lower transmission power to the transmitter might be a solution. However, if the transmission power that is assigned to the nodes is too low, it will reduce the network performance since the lower transmission power will reduce the signal-to-noise ratio (SNR) at the receiver and increase the probability of packet error. Therefore, by using adaptive transmission power which is a mechanism that controls the transmission power, it will manage the power level output of each node in Ad-hoc Network by taking into consideration the network constraints. The difference between fixed transmission power and adaptive transmission power can be seen in Figure 1.2(a) and Figure 1.2(b).

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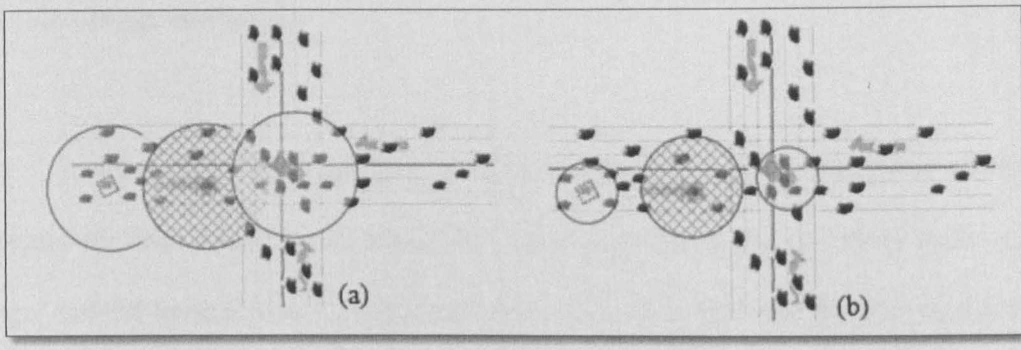

Figure 1.2 Figure (a) shows Fixed Transmission Power Mode and Figure (b) shows Adaptive Transmission Power Mode
Source: (Tian & Lv, 2012)

Figure 1.2(a) and (b) show the illustration of the fixed transmission power and adaptive transmission power. All nodes in fixed transmission power mode used the same value of power transmission and transmission range while the nodes in adaptive transmission power used different value of power transmission and transmission range according to the density of the network and the distance between nodes. Using adaptive power transmission, when the network density is high, the transmission power and transmission range will be low since the distance between the nodes are closed to each other and vice versa.

For this research project, a joint adaptation of transmission power, contention window (CW) and bit rate (BR) is proposed. The main idea of this proposed project is to find the best combination value of the transmission power, CW, and BR that can optimize network performance by using offline optimization method. However, the adaptive transmission power in this project's perspective depends on the CW and BR value. The proposed mechanism in this project finds the best combination value of the transmission power, CW, and BR that can optimize the network performance by using offline optimization method.

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