AN EFFICIENT SAFETY SYSTEM FOR VANET USING ENHANCED MESSAGE DISSEMINATION PROTOCOLS WITH CHANNEL PERFORMANCE CONTROL

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By

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ABL	Active Beacon List
AC	Access Categories
AIFS	Arbitration Inter Frame Space
AIFSN	Arbitration Inter Frame Space Number
AODV	Ad hoc On-Demand Distance Vector routing
ASV	Advanced Safety Vehicle project
AWGN	Additive White Gaussian Noise
C2C	Car to Car communications
C2CCC	Car 2 Car Communication Consortium
C2I	Car to Infrastructure communications
CA	Certificate Authority
CANoe	CAN Software Network Design
CBB	Contention Based Broadcast
CBF	Contention Based Forwarding
CCA	Central Certificate Authority
CCB	Coded-Cooperative-repetition Beacon
CP	Collision Probability

CRL	Certificate Revocation List
CRNT	Coded Repetition Neighbor Table
CSMA	Carrier Sense Multiple Access
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTB	Clear To Broadcast
DB-DIPC	Delay-Bounded Dynamic Interactive Power Control
DRP	Distributed Revocation Protocol
DCF	Distributed Coordination Function
DE	Differential Evolution
DIFS	DCF Inter Frame Space
DSR	Dynamic Source Routing Protocol
DSRC	Dedicated Short Range Communications
DT	Distance Table
EDCA	Enhanced Distributed Channel Access
EDR	Event Data Record
EMDV	Emergency Message Dissemination for Vehicular network
ES	Evolutionary Strategy
FC	Foreign Certificate

FCC	Communications Commission
FPAV	Fair Power Adjustment for Vehicular environments
FCC	Federal Communications Commission
IPv6	Internet Protocol version 6
GA	Genetic Algorithm
gBest	Global Best
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
IVC	Inter -vehicle Communications
LCA	Local Certificate Authority
LT	Life Time
LBB	Location Based Broadcast
LCCL	Local Cluster Certificate List
MAC	Media Access Control
MANET	Mobile Ad hoc Networks
MATLAB	Matrix Laboratory
MBL	Maximum Beaconing Load

MIB	Management Information Base
NCCL	Neighbor Cluster Certificate List
NT	Neighbor Table
pBest	Personal Best
PNT	Piggybacked Neighbor Table
OFDM	Orthogonal Frequency Division Multiplexing
RC2CRL	Revocation using Compressed Certificate Revocation Lists
RSU	Road Side Unit
RTB	Request To Broadcast
RTPD	Revocation of Tamper-Proof Device
SA	Simulated Annealing
SBP	Smart Broadcasting Protocol
SIFS	Short Inter-Frame Space
SL	Sequence List
SN	Sequence Number
Simulink	Simulation and Model-Based Design
TDMA	Time Division Multiple Access
TPD	Tamper Proof Device

TS	Time Stamp
PHY	Physical Layer
PSO	Particle Swarm Optimization
PBPC	Particle swarm optimization Beacon Power Control
PCBB	Particle swarm optimization Contention Based Broadcast
UMB	Urban Multi–hop Broadcast
UN	United Nations
VANET	Vehicular Ad hoc NETworks
VII	Vehicle Infrastructure Integration initiative
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
VNT	Vehicle Network Tool
VSC	Vehicle Safety Consortium
WAVE	Wirelesses Access in Vehicular Environment
WME	WAVE Management Entity
WSMP	WAVE Short Message Protocol

SISTEM KESELAMATAN YANG BERKESAN BAGI VANET MENGGUNAKAN PROTOKOL PENYEBARAN MESEJ YANG DIPERTINGKAT DENGAN KAWALAN PRESTASI SALURAN

ABSTRAK

Perkembangan pesat rangkaian komunikasi wayarles / tanpa wayar dalam beberapa tahun kebelakangan ini memungkinkan terjadinya komunikasi kenderaan ke kenderaan (V2V) dan komunikasi kenderaan ke infrastruktur (V2I) dalam rangkaian sementara mobil (MANET). Ia juga mendorong perkembangan teknologi baru yang disebut sebagai rangkaian sementara vehikular (VANET), yang bermatlamat mencapai keselamatan jalan raya, infotainmen, dan suatu pengalaman memandu yang amat selesa. Ia boleh membantu dalam mereka bentuk sistem keselamatan untuk mengelak berlakunya kemalangan dalan raya dalam dua cara: 1) pemancaran secara berkala (isyarat) daripada semua kenderaan yang memaklumkan pemilik kenderaan lain tentang status semasa mereka, dan 2) penyebaran mesej kecemasan bagi memaklumkan kepada kenderaan lain untuk mengelak bahaya yang ada.

Tesis ini mencadangkan suatu sistem keselamatan yang berkesan bagi VANET dengan mereka bentuk protokol dan teknik komunikasi untuk membolehkan maklumat berkaitan keselamatan dapat dihantar dengan jayanya. Justeru, tiga protokol berdasarkan mekanisme kawalan kuasa, pertelagahan, dan kedudukan dicadangkan bagi membentuk data lalu lintas, supaya mesej dapat diterima dalam kebarangkalian serta kebolehpercayaan yang tinggi).

Pertama, kaedah CRNT (Coded Repetition Neighbor Table) dicadangkan,

bertujuan meningkatkan kesedaran tentang rangkaian untuk membolehkan kenderaan dalam rangkaian mengetahui situasi rangkaian semasa dan mengesan pergerakan kenderaan yang lain. Kedua, kaedah PCBB (Particle swarm optimization Contention Based Broadcast) ditawarkan bagi penyebaran mesej kecemasan yang cepat dan berkesan dalam suatu kawasan geografi yang sama.

Ketiga, kaedah PBPC (Particle swarm optimization Beacon Power Control) dicadangkan, bertujuan mengurangkan pelanggaran paket yang terhasil daripada mesej berkala untuk mengawal beban pada saluran, di samping memastikan bahawa kebarangkaian penerimaan mesej yang tinggi dalam jarak yang selamat daripada kenderaan pengirim mesej. Dengan menggunakan versi Vehicular Networks Toolbox yang terkini daripada simulator, maka merit daripada semua pendekatan serta sinergi mereka ditunjukkan. Keputusan simulasi menunjukkan bahawa PBPC mampu menambah baik kadar penerimaan mesej isyarat serta meningkatkan kebarangkaian penerimaan mesej kecemasan melalui suatu julat jarak yang lebih luas di antara pengirim dang penerima. PCBB pula mampu meningkatkan penghantaran maklumat kecemasan melebihi 70% kepada semua nod yang terletak dalam kawasan geografi yang sama. Di samping itu, ia juga membolehkan mesej kecemasan mencapai jarak yang lebih jauh, yang memberi manfaat kepada kenderaan yang datang menerima maklumat penting. Apabila PCBB digunakan dalam gabungan dengan CRNT dan PBPC, maka keberkesanan serta kelengahan penyebaran adalah dianggap telah ditambah baik. Sebagai kesimpulan, PBPC mampu menambah baik prestasi saluran dengan mengawal beban saluran yang terhasil saripada mesej isyarat, mengurangkan pelanggaran paket sebanyak 50%.

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ABSTRACT

The rapid development of wireless communication networks in recent years has made vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications possible in mobile ad hoc networks (MANETs). It has also led to the development of a new technology called vehicular ad hoc network (VANET), which aims to achieve road safety, infotainment, and a comfortable driving experience. It can support safety systems designed to avoid road accidents in two ways: 1) periodic transmissions (beacon) from all vehicles that inform neighbors about their current status, and 2) dissemination of emergency messages to warn other vehicles to avoid the danger.

The intent of the thesis is to propose an efficient safety system for VANET by designing communication protocols and techniques to provide the means for successful transmission of safety-related information. Therefore, three protocols based on power control, contention, and position-based mechanisms are proposed to shape data traffic, such that messages are received with high probability and reliability where they are relevant.

First, a method Coded Repetition Neighbor Table (CRNT) is proposed, which aims to increase the network awareness to enable the network vehicles to know about current network situations and detect other vehicle movements. Second, a method

called Particle swarm optimization Contention Based Broadcast (PCBB) is offered for fast and effective dissemination of emergency messages within a geographical area to distribute the emergency message. Third, a method called Particle swarm optimization Beacon Power Control (PBPC) is proposed, which aims to decrease the packet collision resulting from periodic messages leading to the control of the load on the channel while ensuring a high probability of message reception within the safety distance of the sender vehicle.

Using the latest version of Vehicular Networks Toolbox from Matlab simulator, the merits of all the approaches, as well as of their synergies are demonstrated. Simulation results show that PBPC is capable of improving the reception rates of beacon messages and increasing the probability of reception of emergency messages over a wide range of distances between sender and receivers. PCBB enhances the delivery of the emergency information to all nodes located in a geographical area by more than 70%. Furthermore, it enables the emergency message to reach greater distances, thus benefiting the incoming vehicles receiving the important information. When PCBB is used in combination with CRNT and PBPC, the dissemination efficiency and delay are considerably improved. Finally, PBPC is capable of improving the channel performance by controlling the channel load resulting from the beacon messages, reducing packet collision by 50%.

CHAPTER 1

1.1 Introduction:

The rapid development in wireless communication networks in recent years has made vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications possible in mobile ad hoc networks (MANETs). This development has given birth to a new type of high mobile MANET called vehicular ad hoc network (VANET), creating a fertile area integrating elements of research on road safety, efficient driving experience, and infotainment (information and entertainment). Creating an efficient safety system on the road is a very important and critical concern for humans today.

Nearly 1.3 million people die as a result of road traffic accidents annually, and more than 3000 deaths each day are reported. More than half of the people involved in the accidents were not travelling in a vehicle; moreover, the number of persons injured was 50 times greater than the number of recorded deaths each day (WHO, 2011). Malaysia has a very high traffic accident fatality rate of 26 people per 100,000, and 6,300 fatal accidents occur annually (Accidents, 2011). The number of vehicles in 2004 is approximately 750 million globally (Raya et al., 2006), increasing annually by 50 million (Worldometers, 2011a). Today, the estimated number of vehicles exceeds one billion, increasing the possibility of more crashes and deaths on the roads. According to the World Health Organization (WHO) (2011), road traffic accident is the fifth leading cause of death in the world, and each year, 2.4 million die from traffic related accidents (WHO, 2011). Traffic congestion wastes time and fuel, thus, there is an urgent demand to develop efficient safety systems. The new techniques in this system should aim to make the intelligent vehicle think, communicate with other vehicles, and act to prevent accidents. To implement such a system, vehicle manufacturers have begun to equip their vehicles with devices enhancing safety, such as small range radars, night vision, light sensors, rain sensors, navigation systems, and the Event Data Record (EDR) resembling the Black-Box. Vehicles gain more fresh information when they communicate (talk) with each other and inform each other of any probable danger; they may even respond to that danger in a cooperative manner. However, VANET is still at the early stages of deployment, and real and intensive research pertaining to necessary safety solutions is still limited. This research gap prevents VANET from achieving its main goal of creating an efficient safety system on the road.

Research in VANET technology has evolved into two categories, namely, inter-vehicle communications and road side units (RSUs) (see Figure 1.1). Inter-vehicle communications represents communications between vehicles, whereas RSUs are placed on various locations, such as roads, signs, and parking areas. Inter-vehicle communications is more technically challenging because this must be supported even when vehicles are stopping and when they are moving (Lee et al., 2010). Intra-vehicle communications represents communications occurring within a vehicle; these enable vehicle diagnostics wherein a technician can plug a tester into a port in the vehicle network in order to examine the operational state of various components of the vehicle and gather other information (e.g., fluid levels and engine performance). The current thesis focuses on inter-vehicle communications, especially cooperative driving. One of the major efforts dedicated to VANET was launched in 2011 where the United Nations (UN) Road Safety Collaboration has developed a global plan for the Decade of Action for Road Safety 2011–2020. The categories of activities include building road safety, improving the safety of road infrastructure, and broader transport networks; the plan also aims to develop safer vehicles and enhance the behavior of road users (WHO, 2011).

The current thesis aims to achieve better safety system by deploying techniques capable of enhancing the performance of the VANET system, while ensuring successful reception of emergency and status information under all network conditions. Special attention is given to the challenges presented in scenarios where dense traffic has a high level of channel saturation, causing long latency and increasing the packet collision and channel load.

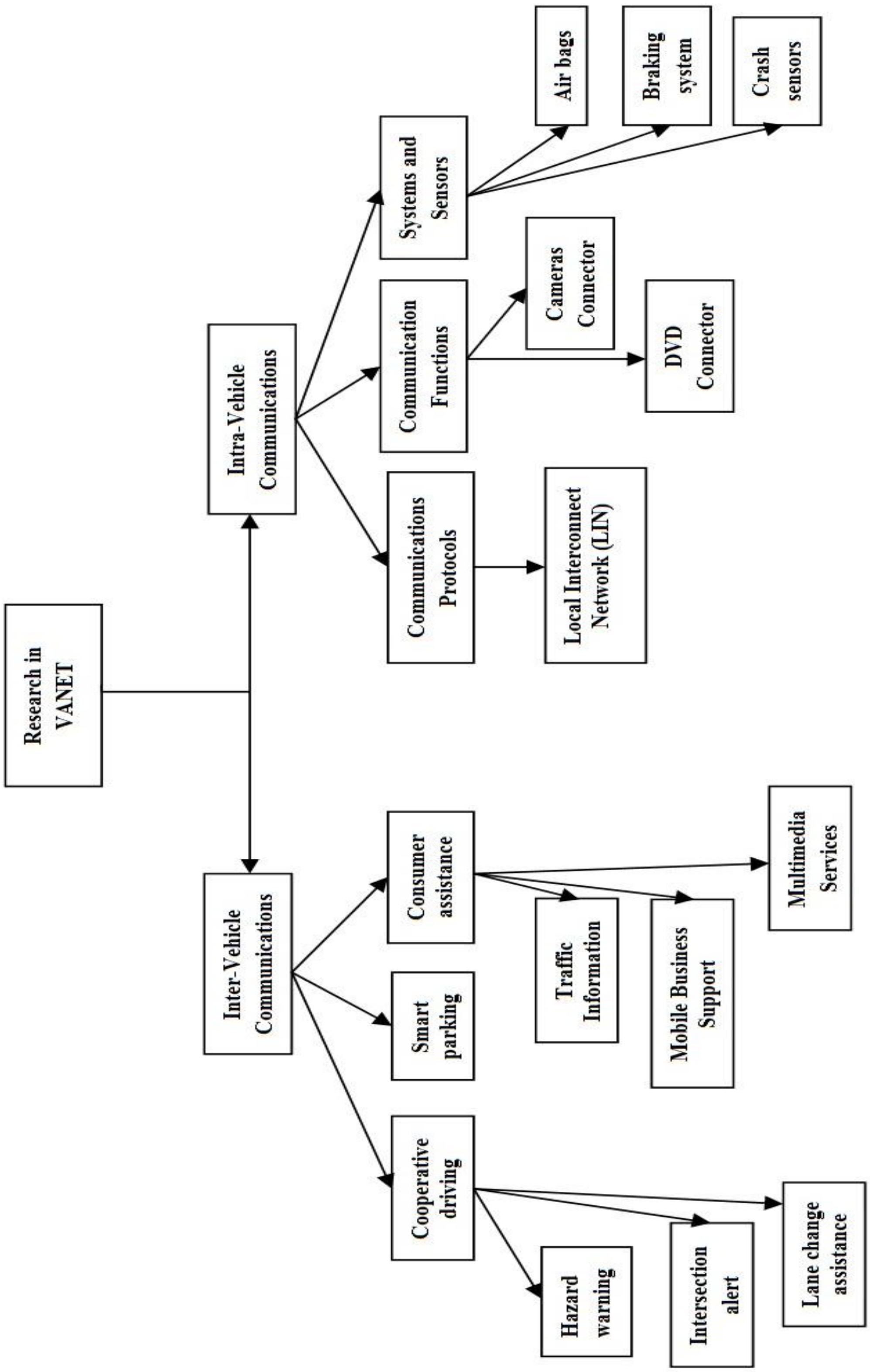

Figure 1.1: Research in VANET.

1.2 Research Background

Wirelesses access in vehicular environment (WAVE) is a multi-channel approach, designed by the Federal Communications Commission (FCC), reserved for one control channel from 5.855 to 5865 GHz, for high availability, low latency vehicle safety communications (Commission, 2008). Furthermore, WAVE represents the first VANET standard published in 2006. An enhancement was required on IEEE 802.11 standard to support applications from the Intelligent Transportation Systems (ITS), a branch of the U.S. Department of Transportation. The result showed the 802.11p standard, which was approved on July 2010 (Grouper, 2011). The 802.11p standard is meant for VANET communication and uses dedicated short range communications (DSRC) spectrum; it is divided into eight 10 MHz channels with only one control channel for safety application communication. VANET safety applications depend on the exchange of safety information among vehicles (C2C communication) or between vehicle to infrastructure (C2I Communication) using the control channel (see Figure 1.2). VANET safety communication is implemented in two ways, namely, periodic safety message (hereby called beacon) and event-driven message (hereby called emergency message), both sharing only one control channel. The beacon messages are messages containing status information about the sender vehicle, such as position, speed, heading, and others. Beacons provide fresh information about the sender vehicle to the surrounding vehicles in the network, updating them of the status of the current network and predicting the movement of vehicles. Beacons are sent aggressively to neighboring vehicles at 10 messages each second. In turn, this causes an increase in channel collision that the control channel cannot tolerate, especially when dense traffic occurs in small geographic areas. Therefore, it is necessary to formulate strategies to control the channel load resulting from packet collision and efficiently utilize the channel limited resources, especially during high dense vehicular traffic situations (Figure 1.2).

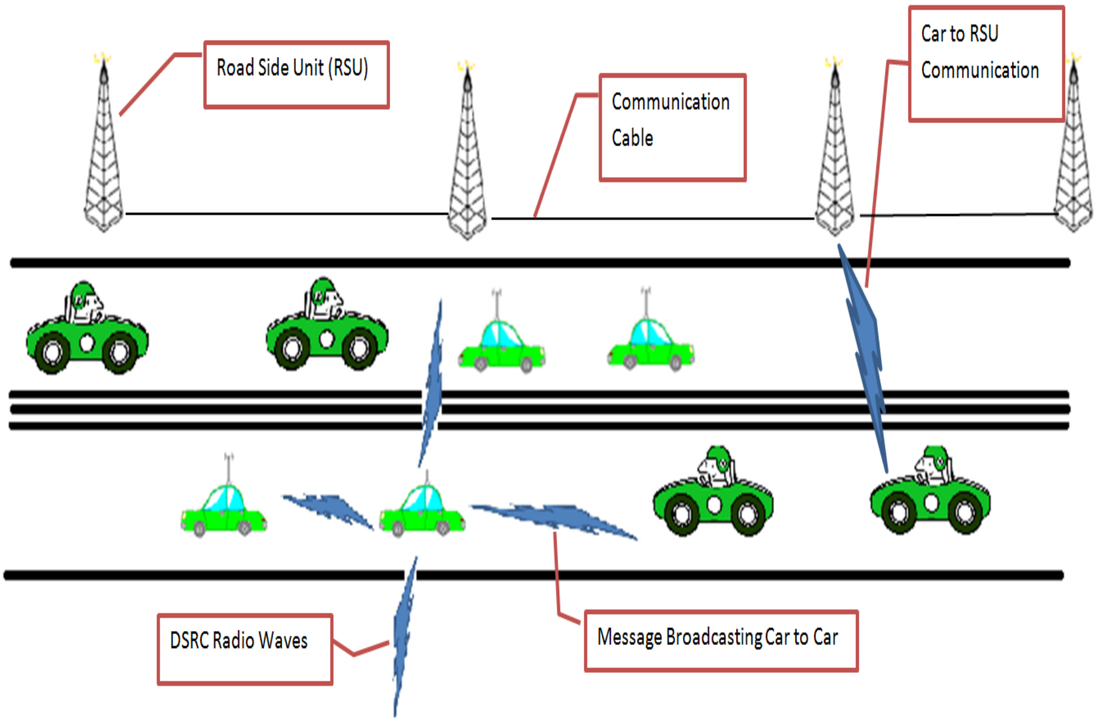

Figure 1.2: VANET Structure.

The VANET structure controlling beacon messages could be executed by transmission power control or message repetition control. Sending the message on high full power may cause the message to reach longer distances, thereby increasing the channel load, whereas sending in low power enables the message to reach only very short distances. Emergency messages are messages sent by a vehicle when it detects a potential dangerous situation on the road. This information should be disseminated to inform other vehicles about a probable danger that could affect the incoming vehicles. VANET is a high mobile network, in which nodes are moving in speeds exceeding 120 km/h. Even if the vehicles are far from the vehicle sending the emergency message, they eventually reach the danger because there high speed traveling at 33.33 m/s. To avoid the potential danger, every millisecond counts.

In 2008, a serial crash involving 250 vehicles occurred on the highway between Dubai and Abu Dhabi, resulting in three deaths and 277 injured people, including 10 seriously wounded victims. Another serial vehicular accident on the same highway happened on the 2nd of April 2011 involving 127 vehicles, killing one and injuring 61others (Figure 1.3) (Emaratalyoum, 2011). When the first crash occurred, there should have been a technique to warn the incoming and speeding vehicles about this danger, and such early warning could have saved lives and money. Sending an alarm to incoming vehicles, especially those moving at high speed, bad weather conditions and low road visibility, could help avoid accidents.

Figure 1.3: Dubai highway crashes 2011, (emaratalyoum, 2011)

Emergency messages in VANET are broadcast on a frequency, and all vehicles inside the coverage area should receive the message. The coverage area is not enough because it hardly reaches a distance of 1000 m (which is the DSRC communication range) caused by attenuation and fading effects. Vehicles still far from the danger area should receive this critical information to avoid danger. Furthermore, the probability of message reception can reach 99% in short distances, and can even be as low as 20% at half of the DSRC communication range (Moreno, 2004). Therefore, a technique to increase the emergency message reception with high reliability and availability is needed.

1.3 Problem Statement:

This thesis focuses on the problems related to the VANET safety system as discussed in Section 1.2. The main research question is “How can better safety system in VANET be achieved in terms of improved performance, efficiency, reliability, and availability?”

The sub questions include

1- How can the overall VANET system performance in terms of collision, delay, and network visibility, which is described by distance sensed, be improved?

2- How to increase the number of vehicles that receive the emergency message in high speed mobile environment?

3- How can the progressive load on the channel resulting from beacon messages sent aggressively by vehicles in dense traffic situations be controlled?

1.4 Research Objectives

1. To achieve an efficient VANET safety system that can disseminate safety information within a wider range with less delay and lower channel collision. This is can be one by a) providing vehicles extended information about other vehicles in the network; b) achieving fast and efficient emergency message transmission and increase reception percentage by more than 50% (compared to exiting protocols); and c) improving system performance and the capacity to lower the channel collision resulting from the beacon messages by 50%.
2. To evaluate the proposed VANET safety system via simulation and comparison against the performance of the existing approaches.

1.5 Research Contribution

Three main protocols are proposed, with the aim of building an efficient safety system in VANET: increasing network visibility, performance of emergency message system, and safety message dynamic power control.

This thesis proposes a new mechanism – called Coded Repetition Neighbor Table (CRNT) –, the goal of which is to increase the network visibility of each vehicle on the road by having more information warning the drivers of vehicles ahead before they reach the danger site.

To improve the emergency message system's performance, the thesis proposes a new protocol – called Particle swarm optimization Contention Based Broadcasting (PCBB) – to increase the percentage of emergency message reception with low channel load and short delay. This protocol broadcasts the emergency message in multi-hop broadcast fashion, after which the multi-hop forwarders are selected before the original message is sent.

To optimize and improve the channel performance, a dynamic transmission power control protocol is also proposed– called Particle swarm optimization Beacon Power Control (PBPC) – to adjust the transmission power of the beacon message that has been aggressively sent by all vehicles on the road at a frequency of 10 times/second.

The main contribution of this thesis is achieved by deploying the three protocols altogether, so that network visibility is enhanced and vehicles can have better awareness of the network. This work also contributes to current literature by allowing vehicles to receive better information about the channel and neighbors before transmitting beacon or emergency messages, more control over the load on the channel, thus resulting in decreased packets collision, and higher performance and priority for the emergency message transmission. Producing a stable safety system with higher availability, reliability, and performance and achieving the safety system the main goal of the VANET. The performance of the proposed protocol has been studied using Matlab commercial software. The software selected has superior performance compared with others.

1.6 Research Challenges

VANET devices or making any modifications on the MAC and physical layers, the main challenge in the preparation of this thesis is the absence of any VANET system in Malaysia. Only a few cities in the world have VANET devices running on the roads (Figure 1.2). Consequently, only few vehicles are equipped with VANET communication equipments (Figure 1.4), (Raya et al., 2006). Hence, if a message is transmitted within a network, it is presumed that only a limited number of vehicles can receive the communication. Therefore, it is necessary to exert massive effort to equip these vehicles with VANET devices.

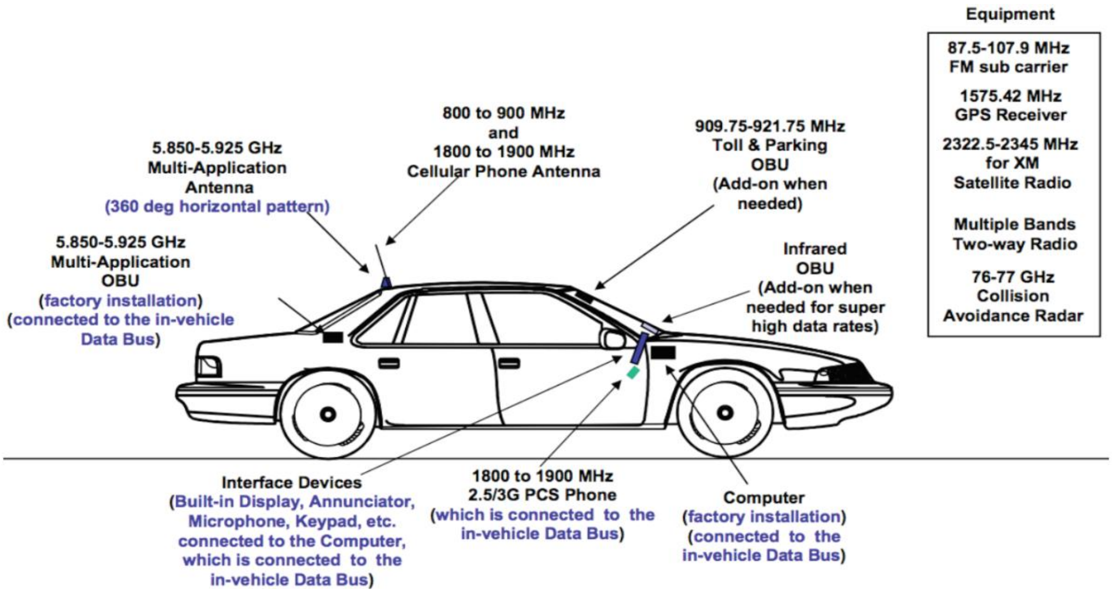

Figure 1.4: Future car equipped with VANET devices, (Gilbert Held, 2007).

1.7 Organization of Thesis

This thesis is structured as follows:

Chapter 2 presents VANET background information with physical layer and DSRC specification and sketch of channel bandwidth allocation, VANET communication challenges is also analyzed in details, furthermore, chapter 2 presents in detail a discussion and analysis of VANET protocols.

Chapter 3 presents the methodology of how the proposed protocols in this thesis are conducted.

Chapter 4 covers the architecture and simulation of the proposed protocols.

Chapter 5 covers an in-depth analysis and discussion of the proposed protocols and evaluates the performance of the protocols.

Chapter 6 presents the conclusion, and the future work.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses the VANET background, including its history, characteristics, and some technical aspects necessary to achieve safety system. Figure 2.1 shows the flow of the whole chapter. This chapter also discussed published methods and protocols related to the VANET safety system, such as increasing network visibility, previous efforts in the emergency message dissemination field, previous works on power control, and the particle swarm optimization (PSO) in VANET. This chapter presents in detail the emergency message dissemination for vehicular network (EMDV) and fair power adjustment for vehicular environments (DFPAV). The proposed protocols in this thesis will be compared to these two.

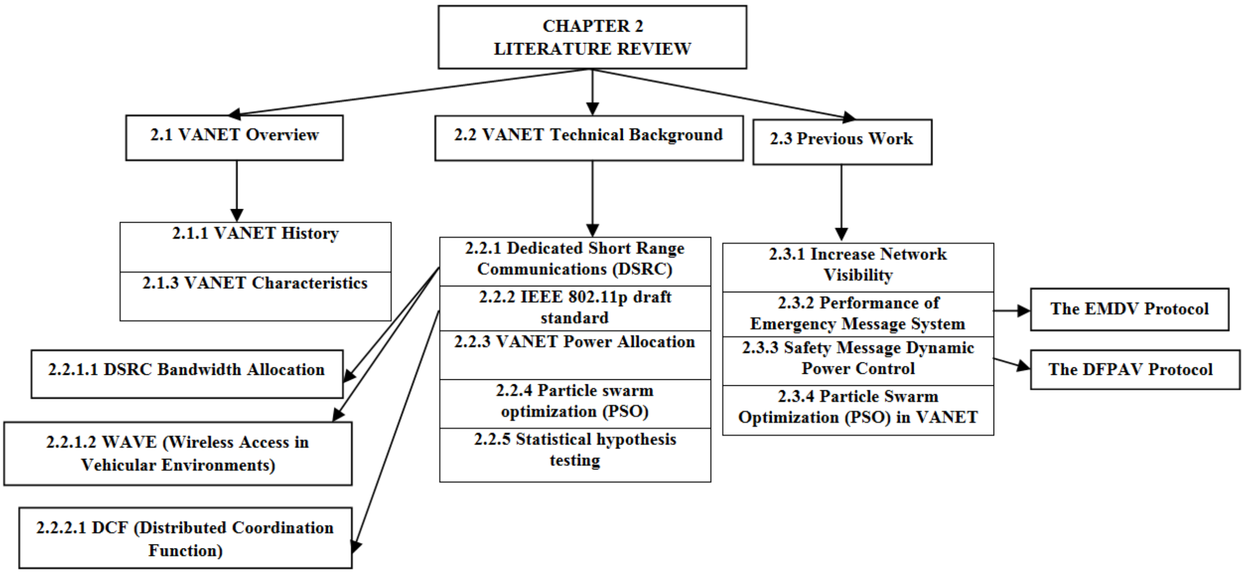

Figure 2.1: Chapter 2 flow diagram.

2.1 VANET Overview

2.1.1 VANET History

Vehicular Ad hoc Networks (VANET) is part of Mobile Ad Hoc Networks (MANET), see figure 2.2. This means that every node can move freely within the network coverage and stay connected without wires, each node can communicate with other nodes in single hop or multi hop, and any node could be Vehicle, Road Side Unit (RSU). The main difference between VANET and MANET is that VANET consists of high mobile nodes and usually having dense situations.

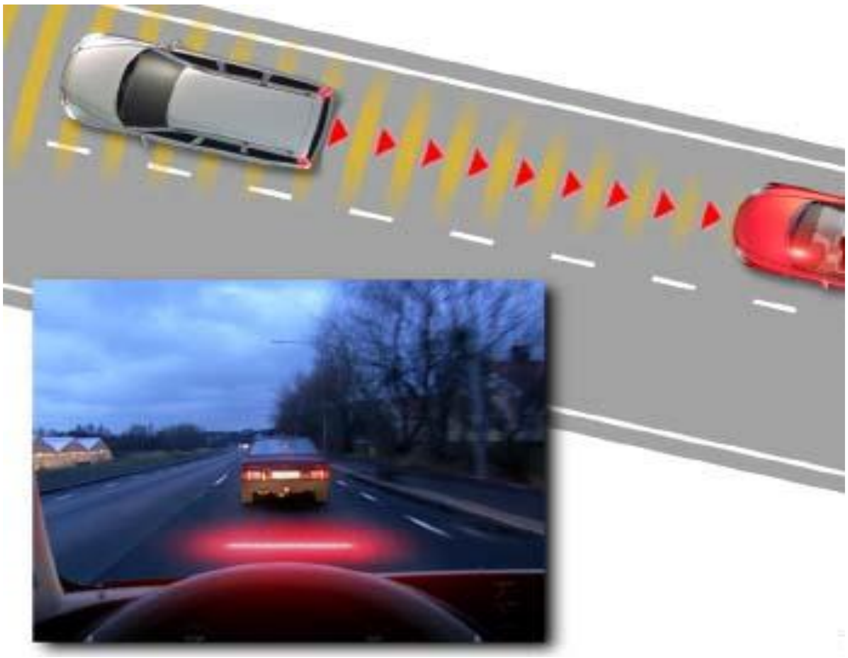

Figure 2.2: One of VANET applications.

In the year 1998, a team of engineers from Delphi Delco Electronics System and IBM Corporation proposed a network vehicle concept aimed to provide a wide range of applications (R. Lind et al., 1999). With the advancements in wireless communications technology, the concept of network car has attracted the attention from all over the world.

In the recent years, many new projects have been launched, targeting on realizing the dream of networking car and successful implementation of vehicular networks. The project Network On Wheels (NOW) (Abdalla et al., 2007) is a German research project founded by DaimlerChrysler AG, BMW AG, Volkswagen AG, Fraunhofer Institute for Open Communication Systems, NEC Deutschland

GmbH and Siemens AG in 2004, see figure 2.3. The project adopts an IEEE 802.11 standard for wireless access. The main objectives of this project are to solve technical issues related to communication protocols and data security for car-to-car communications. In this thesis, the outcome of this project is adopted and compared with the proposed protocols of this thesis.

NOW: Network on Wheels

Figure 2.3: NOW Network on Wheels project, (NOW, 2011)

2.1.2 VANET Characteristics

Although VANETs, is a part from MANETs, VANETs have some unique characteristics. These properties present considerable challenges and require a set of new especially designed protocols.

- Due to the high mobility of vehicles, vehicle's speed can exceed 120 km/h. resulting frequent and unexpected changes in VANET topology. Therefore, the communication link exists between two vehicles for very short time, especially when the vehicles are traveling in opposite directions. A one solution to increase the lifetime of links is to increase the transmission power, but increasing a vehicle’s transmission power will increase the channel load and degrades the system performance. The other solution is to have a set of new protocols employing a very low latency.

- Emergency message's latency, broadcasted messages is very critical to latency. Assuming, for example, that a vehicle is suddenly stopped, it should send a broadcast message to warn other vehicles about the probable danger.

Considering that the driver needs at least 0.70 to 0.75 sec to initiate his response (M. Green, 2000), the warning message should be delivered at very short latency.

- Although, the design challenge of protocols in wireless sensor networks is to minimize the power consumption, this is not a problem in VANETs, as Nodes in VANETs has rich power resources, but using the power for the transmission should be managed carefully to avoid causing increasing load to the channel, especially the control channel.

- Currently, only very small numbers of vehicles equipped with VANET devices. Thus, the benefits of the new technology, especially Vehicle 2 Vehicle applications, will not rise until many years. Moreover, the limited number of vehicles with equipped with VANET devices will lead to a frequent fragmentation of the network. Even when VANET is fully deployed, fragmentation may still exist in rural areas, therefore. Any VANET protocol should expect a fragmented network.

- Privacy and security have a crucial effect on the public acceptance of this technology. In VANETs, every node represents a specific person and the information stored in the vehicle's devices tells about his location, rout, identity and any other information that could be retrieved from the vehicle.

Any lack of privacy can ease a third party to steal critical information about the driver. However, from the other point of view, higher authorities should gain access to identity information to ensure punishment of illegal actions, where, there is a fear of a possible misuse of this feature. The manipulating with messages could increase false alarms and accidents in some situations defeating the whole purpose of this technology. (Manipulating and transmitting false emergency messages detection is out of the scope of the thesis).

Finally, the key difference between VANET protocols and any other form of Ad-Hoc networks is the design requirement. In VANETs, the key design requirement is to minimize latency with no prior topology information. However, the key design requirement of Wireless Sensor Network is to maintain network connectivity with the minimum power consumption.

Concluding, the main characteristics of VANETs can be summarized as follows (J. Guo et al., 2006):

- High mobility of nodes
- No prior information about the exact location of neighbor nodes.
- Predictable topology.
- Critical latency requirement, especially in cases of safety related applications.
- No problem with power.
- High possibility to be fragmented
- Crucial effect of security and privacy.

2.2 VANET Technical Background

2.2.1 Dedicated Short Range Communications (DSRC)

In this section, an overview of the overall 5.9GHz DSRC architecture is provided, which is an OFDM-based (Orthogonal Frequency Division Multiplexing) technology under development at the Institute of Electrical and Electronics Engineers

(IEEE) under the name of WAVE (Wireless Access in Vehicular Environments). WAVE includes IEEE P1609.0 (IEEE, 2006a), IEEE P1609.1 (IEEE, 2006b), IEEE P1609.2 (IEEE, 2006c), IEEE P1609.3 (IEEE, 2007a), IEEE P1609.4 (IEEE, 2006d), IEEE P1609.11 (IEEE, 2010).

First, the current situation of the dedicated bandwidth allocation is presented. Afterwards, the IEEE 1609 will be described, and power allocation as required to understand the strategies and results obtained in following chapters, also the Intelligence in VANET will be described.

2.2.1.1 DSRC Bandwidth Allocation:

The Federal Communications Commission (FCC) in USA dedicated 75MHz band, between 5.850-5.925GHz. The microwave systems used in the five ranges due to their spectral environment and propagation characteristics, which are suitable to vehicular environments. Waves propagating in the 5.9GHz band can offer high data rate communications that reach distances between 300m to 1000m.

In order to serve several types of applications, the band is divided into eight channels 10MHz for each, as in WLAN systems, OFDM 20MHz channels suffered from inter-symbol interference caused by multi-path propagation, hence to reduce this interference the decision was to use of 10MHz channels for VANET communications, instead of the 20MHz (Standard, 2007), d this also will cover larger communication distances and will be more robust against fading. One of these channels is a control channel (5.885- 5.895GHz, Channel 178), and six service channels, and one 5MHz channel is reserved, see figure 2.4). The control channel is used to exchange the emergency messages as well as the beacon messages. The non-safety information exchange takes place on service channels.

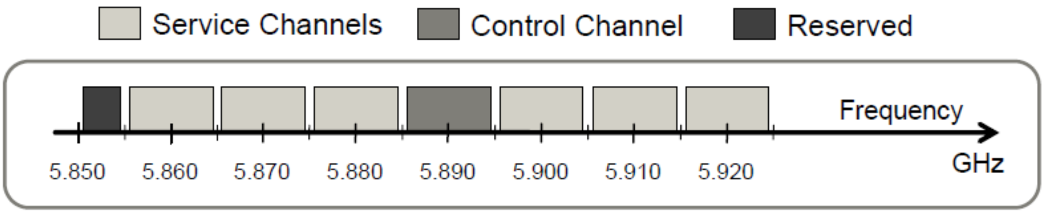

Figure 2.4: DSRC channel's allocation.

2.2.1.2 WAVE (Wireless Access in Vehicular Environments)

The WAVE standards define architecture, interfaces, messages, security, physical access and a standardized set of services and interfaces that enable secure Car-to- Car (C2C) and Car -to-infrastructure (C2I) wireless communications (IEEE, 2009). Together these standards provide the foundation for a broad range of applications in the transportation environment, including vehicle safety, automated tolling, enhanced navigation, traffic management. The EEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) consists of four path use standards, which have full use drafts under development and two unpublished standards under development. These draft standards combined the specifications of physical layer (PHY) and medium access control (MAC) prescribed in IEEE 802.11p.

2.2.2 IEEE 802.11p draft standard

IEEE 802.11p (IEEE, 2006a) is a form of 802.11a (IEEE, 1999) with a modified MAC and PHY to support low latency vehicular communications. The basic characteristics and functionalities are provided in the following.

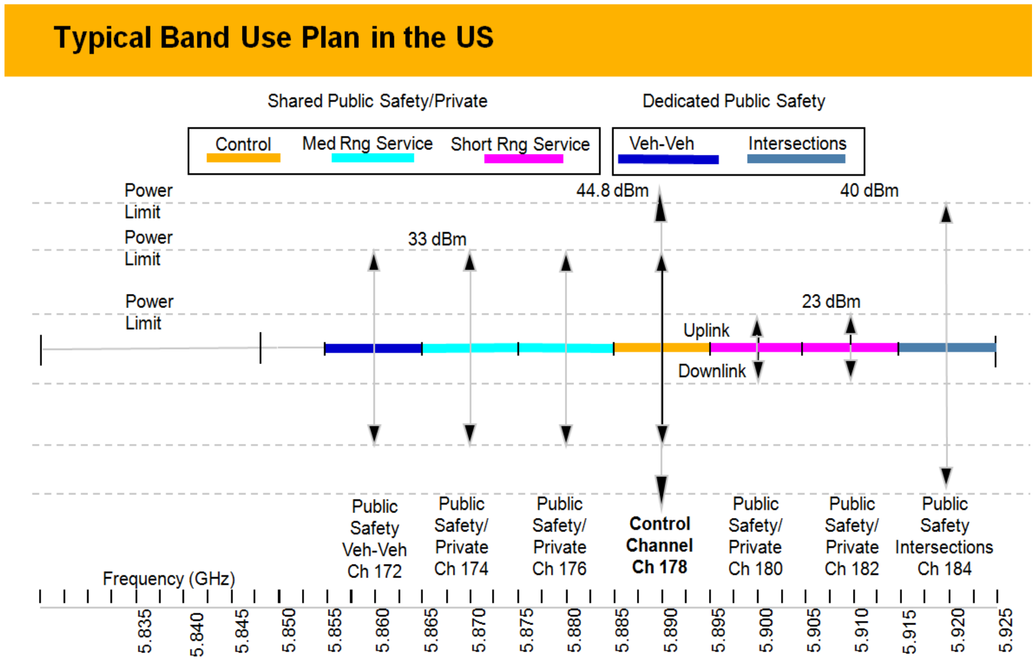

Figure 2.5: VANET power allocation.

With respect to the MAC specifications, it adapts the IEEE 802.11 (IEEE, 1997) standard for the requirements of WAVE environments. Due to the safety nature of WAVE communications, active scanning, passive scanning, or authentication and association procedures are not used. Moreover, it specifies that a WAVE device must monitor and operate on the control channel upon startup. WAVE devices can switch to service channels after the reception (or transmission) of a WAVE announcement frame.

The channel access mechanisms are, so far, inherited from IEEE 802.11 which specifies the DCF (Distributed Coordination Function) as the basic strategy in case of ad hoc communications. DCF is the leading channel access strategy used to exchange safety information among vehicles and is explained in more detail later in this section.

EDCA (Enhanced Distributed Channel Access) is supported in order to differentiate different priorities among applications.

2.2.2.1 DCF (Distributed Coordination Function)

DCF is the channel access strategy used to exchange safety information among Vehicles. DCF is a form of CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance), see Figure 2.6. This medium access protocol says that the status of the channel must be checked every time when a frame arrives at the MAC layer to be transmitted. If the channel is sensed idle at this point and during a DIFS (DCF Inter frame Space) time interval, the station can proceed with the transmission. Else, if the channel is busy, or becomes busy during that interval, the transmission is deferred using the backoff mechanism.

The backoff mechanism is designed to avoid a collision with the station which is currently transmitting and with any other station, which may be also waiting for the medium to become idle.

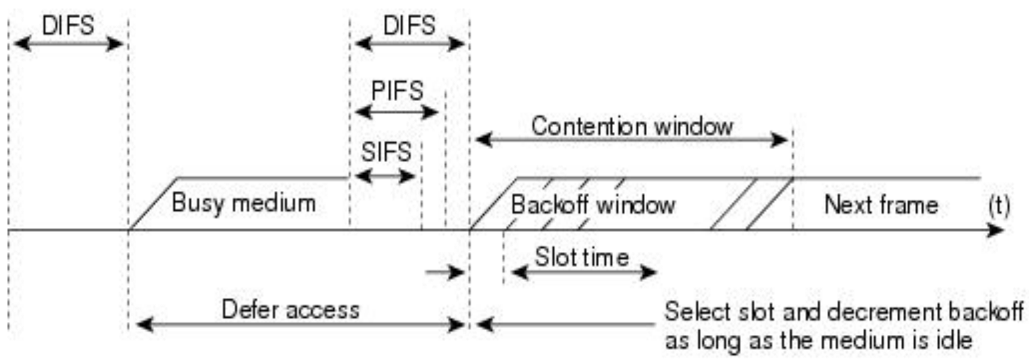

Figure 2.6: Distributed coordination function for channel access.

The backoff mechanism first sets the backoff timer with an integer random number of slots within [0, CW], were CW is the contention window size. The backoff timer is decremented by one unit for each slot time interval (SlotTime) until reaching 0. At this moment, the station can transmit. If the medium becomes busy before the backoff timer reaches 0, the process is suspended until the medium becomes idle again.

However, before the backoff mechanism return to the process of resuming or starting decrementing the backoff timer, the medium has to stay idle for the period of a DIFS.

After the frame had been transmitted a new backoff procedure is performed, even if there is no other frame waiting to be sent. This new backoff aims to clear any priority that the transmitting station has over any other waiting station.

2.2.3 VANET Power Allocation:

From a safety of life perspective, the communication in VANET has to be insured especially for the safety application, for traffic safety communication each vehicle will proactively send out periodic one-hop safety messages (Beacon) to establish mutual awareness. Furthermore, when a hazard situation is sensed, emergency messages will be sent out. As mentioned before, VANET control channel has limited bandwidth; hence control strategy must be adopted to avoid dense channel conditions like the broadcast storm problem, simply due to the transmissions of beacon messages. The control strategy is done by controlling the load resulted from packet collision imposed by beaconing messages to allow for reliable, efficient and low-latency transmissions of high-priority emergency messages. While in a TDMA-based approach, one would reserve specific slots for high-priority data (M. Lott, 2001), it is less straightforward to ‘guarantee’ a certain bandwidth for emergency messages in an IEEE 802.11 CSMA-based approach as it is assumed for this work.

VANET control channel is used for safety related messages and service announcements. Each vehicle sends beacons 10 times per one second which will cause a heavy load on the channel. Therefore, all vehicles will have to monitor the control channel often enough to receive all safety related information so that the safety applications achieve their goal.

In order to send the emergency message in high reliability and availability some conditions must be checked before doing the transmission to make sure that this message will reach its destination, and it will not increase the load on the channel, as sometimes message loss rates caused by MAC collision is between 20% and 40% (Mittag, 2008), these conditions like Transmission Power, Message Size, Network Status and Message Repetition.

The power limits prescribed by the Federal Communications Commission (FCC) for DSRC spectrum are as high as 33 dBm (Guan et al., 2007) for vehicle on board units, so that a desired communication range of 300 m for these safety messages can be easily reached in one hop as suggested by (Xu et al., 2005), while in (Moreno, 2007a) proved that the 1000 could be reached by one hop for beacon and emergency messages.

Sending safety messages in maximum power, will not guarantee that the message will reach for all the vehicles on the road, but guarantees to increase the load on the channel, especially in heavy traffic situations, in contrary, sending the message in low power will enable it to reach short distances, and it may not reach its destination. Furthermore, trying to reach a fixed transmission power for VANET is not practical due to high mobility and large variation of distances among vehicles. Therefore, there must be a dynamic technique to control the power of the safety message (beacon and emergency messages) to avoid packet collision and enables the emergency message to reach higher distances to warn all the vehicles that may benefit from this message.

2.2.4 Particle swarm optimization (PSO)

In computer science, particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, called particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's parameters. In PSO, the potential solutions fly through the problem space by following the current optimum particles.

Each particle keeps track of its coordinates in the problem space which is associated with the best solution (fitness) it has achieved so far. This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any neighbor particle. This value is called Global Best (gbest). When a particle analyzes the population as its topological neighbors, the best value is called Local Best (lbest).

The particle swarm optimization concept consists of, at each time step, changing the velocity of (accelerating) each particle toward its pbest and lbest locations. Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward pbest and lbest locations.

In the past several years, PSO has been successfully applied in many researches and application areas. It is demonstrated that PSO gets better results in a faster, cheaper way compared with other methods. One version, with slight variations, works well in a wide variety of applications. Particle swarm optimization has been used for approaches that can be used across a wide range of applications, as well as for specific applications focused on a specific requirement.

One of the reasons that makes PSO suitable for VANET as it is designed to deal with a large population of mobile nodes. Another reason that PSO is attractive is that there are few parameters to adjust. The PSO algorithm is as follows:

$Sv = lBestv * w + C1 * rand1 * (pBestv - lBestv) + C2 * rand2 * (gBestv - lBestv).$ (2.1), (neo, 2011).

$lBestv = pBestv + Sv.$ (2.2) (neo, 2011).

Where W: 0.1 to 0.5, C1= 2, C2= 2, rand: random number 0.1 to 1, pBest is the last lBest computed by the vehicle. w is the inertia weight of the particles, random 1 and random 2 are two uniformly distributed random numbers in the range [0, 1], and C1 and C2 are specific parameters which control the relative effect of the individual and global best particles.