

Dynamic Congestion Control Algorithm for Vehicular Ad-hoc Networks

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Abstract

Vehicular Ad Hoc Network (VANET) has received increased attention from scholars and industries in recent years. Meanwhile, Congestion control remains the major concern for VANET application due to its characteristics such as bandwidth limitation, fast change of topology and lack of central coordination. Researchers have proposed a number of solutions to overcome these challenges and also to reduce congestion in VANET environment. These solutions are based on packet generation rate, transmit power control, utility function, carrier sense threshold or a combination of them. In this paper, the existing congestion control approaches is classified into three main classes, namely, proactive, reactive and hybrid. Besides, we propose and implement an algorithm by which carrier sense (CS) threshold or MaxBeaconingLoad (MBL) value can be assigned dynamically for fine-tuning the Distributed Fair transmits Power Adjustment for VANETs (D-FPAV) congestion control approach. In addition to optimal channel bandwidth usage, the proposed algorithm can be used in any situation considering traffic and non-traffic conditions.

Keywords: *Beacon messages, Congestion control, Event-driven messages, IEEE 802.11p, VANET, Vehicular networks*

1. Introduction

The networks with the absence of any centralized or pre-established infrastructure like access points in managed wireless networks or routers in wired networks are called Ad hoc networks [1]. Such wireless ad hoc networks can be categorized via their application, such as Wireless Mesh Networks (WMN), Mobile Ad Hoc Networks (MANET) Wireless Sensor Networks (WSN), and Vehicular Ad hoc Networks (VANETs). VANET is a particular type of MANET, that vehicles play the role of nodes in it. As opposed to MANET, vehicles move on predefined roads and velocity depends on the speed signs. What is more, these vehicles also have to follow traffic signs and signals [2]. Thus, VANETs moving pattern is regular and more manageable. Considering providing comfort and safety to the road users, VANET can be regarded as one of the influencing areas in advancement of the intelligent Transportation System (ITS). VANETs applications can be classified into three main categories [3] which are:

1. Safety Applications [4] such as Post Crash Notification(PCN), Slow/Stop Vehicle Advisor(SVA), Road Hazard Control Notification(RHCN), Emergency Electronic Brake Light(EEBL), Cooperative Collision Warning(CCW)

2. Convenience Applications [4] such as Parking Availability Notification (PAN), Congested Road Notification (CRN)

3. Commercial Applications [4] such as Remote Vehicle Personalization/ Diagnosis, Service Announcements, Real Time Video Relay and Content Map Database Download.

The Federal Communication Commission (FCC) assigned a frequency spectrum to VANETs wireless communication. Later In 2003, a dedicated short range communications (DSRC) was established by the commission. For providing public safety and private application, the DSRC as communication service employs the 5.850-5.925 GHz band [5]. The IEEE establishes a working group for Wireless Access in Vehicular Environments (WAVE) standard [6] or IEEE 802.11p to provide DSRC for VANETs communication. The design of dedicated short range communications (DSRC) is a system which has numerous channels. The Federal Communication Commission (FCC) categorize this spectrum into seven channels of 10 Mhz. Service Channels (SCH) comprise six of these channels and the remaining one is known as Control Channel (CCH) [7]. The CCH channel is used for safety messages, however, WAVE-mode short messages and non-safety services are anticipate to be supplied from the SCH channels [8, 9]. The basic target of VANET is to increase safety of the road users and comfort of the passengers. There are many challenges in VANET that have to be resolved to offer reliable services such as routing, security, and quality of service. Due to many issues such as Inaccurate State of Information, dynamically Varying Network Topology, Absence of Central Coordination, Hidden Terminal Problem, Limited Resource Availability Error Prone Shared Radio Channel, and Insecure Medium, therefore, supporting Quality of Service (QoS) is a challenging task. Many approaches are proposed to improve the QoS in VANETs. Congestion control is one of the solutions which will be highlighted in this article. Remain part of the article is arranged as follows:

In next section, congestion problem in VANETs is explained as well as related work which proposed to solve the mentioned problem and its shortages. Congestion control classes which are proactive, reactive and hybrid as well as their characteristics and taxonomy of congestion control algorithms in VANETs is illustrated and defined in Section 3. Section 4 discusses shortly about D-FPAV congestion control algorithm. In Section 5, we introduce dynamic D-FPAV algorithm for solving the mentioned shortages of D-FPAV algorithm. Section6 presents the simulation results which performed to evaluate the effectiveness of our proposed dynamic congestion control algorithm. At the end, Section7 includes the conclusion of this paper as well as future work.

2. Related work

There are two types of messages to enable safety applications [10]. On the one hand, cooperative awareness messages (CAMs), also known as beacons, are broadcasted periodically by all nodes on the control channel, in order to receive and provide status information on presence, geographical position and movement of neighboring nodes, and service announcements to/from those nodes. On the other hand, emergency messages which are event-driven will be transmitted in the case that an abnormal or hazardous condition is noticed, in order to inform surrounding nodes about it [10]. The real challenge regarding this beaconing activity will be to control the load in the channel in order to stay away from channel congestion. The following facts support this statement. As outlined in the introduction, a single 10-MHz wide channel is employed to exchange safety messages. IEEE 802.11p offers the data rate which [11] range from 3 to 27 Mb/s. In this case, the ones in the lower range are more preferable for safety applications because of the strength they show against interferences and noises [12]. Based on previous studies [13-14] and Final Report of

Vehicle Safety Communications Project [15], apparently, numerous messages in every second from every single vehicle are required so that the desired accuracy for safety applications is provided. Moreover, because of fading and collisions, to get overcome the influences of packet losses additional transmission repetitions can be regarded. Lastly, considering recent studies [16], security-related overhead (for example digital certificates) will result in the large size of safety related messages, *i.e.*, between 250 and 800 bytes. A simple calculation simply displays the fact that (for instance, with 100 neighboring nodes which sends ten 500-byte packets in every second) the load which is generated could be a lot greater than the bandwidth available [17]. Therefore, there is a demand for utilizing some methods to limit and control the load and congestion on the control channel, since the exchange of beacon messages alone can saturate the channel. In [18], researchers defined MBL as a threshold of above-mentioned mechanism but they assumed that threshold of MBL is set to a fixed level. Accordingly, optimal bandwidth usage of the control channel cannot be achieved through assigning a fixed MBL value in some cases, such as:

- By having a fixed MBL value, a specific bandwidth will be scheduled for sending event driven messages. This result in having wastage in the control channel bandwidth in times of not having notable number of event-driven messages to send or;
- When a few numbers of beacons are needed to be sent because of slow change of network topology in traffic jams on the streets or highways.

Another important issue to understand in D-FPAV approach is the tradeoff between accuracy of channel load estimation on a vehicle, and additional overhead which is put on the channel. In order to optimally tune the above described tradeoff, the design decisions in the following lines should be made: How often the status of neighboring vehicles is needed to be forwarded, with which transmission power the information must be transmitted and what range of neighbors must be included. The authors found that piggybacking aggregate status information (position of surrounding vehicles) in 1 out of 10 beacon messages resulting in the best compromise between control overhead and effectiveness of congestion control. They used the above mentioned approach in order to reduce the overhead, but it can still grow to 40 percent, compared to the actual application-layer data [17].

3. Taxonomy of Congestion Control Algorithms for VANETs

The major classification criterion considers the information based on the congestion control mechanisms deriving from their decision to adjust the transmission parameters. The first class is reactive congestion control, which uses explicit feedback, *i.e.*, first-order feedback with regards to the desired result about the channel congestion status to decide whether and how an action should be carried out. Owing to their nature, measures to lessen channel load are taken only after a congested situation has been detected. The second class is proactive congestion control which employs models that try to estimate transmission parameters based on information such as the number of nodes in the vicinity and data generation patterns. Such transmission parameters will not lead to congested channel conditions; meanwhile it provides the desired application-level performance. In particular, such mechanisms typically employ a system model to estimate the channel load under a given set of transmission parameters, and making the use of optimization algorithms to determine the maximum transmit power and/or rate setting that will adhere to a maximum congestion

limit [10]. The third class is hybrid congestion control which tries to combine the advantages of both proactive and reactive approaches.

The relative advantages and disadvantages of proactive vs. reactive approaches can be discussed here. Given their ability to prevent congestion, proactive approaches are very appealing for vehicular environments where radio communications are primarily used for safety applications. The performance of such safety applications would be seriously threatened by congested channel conditions. However, proactive approaches come with two major drawbacks. First, in order to estimate the expected load generated by neighboring vehicles, such approaches require a communication model that maps individual transmission power levels to determine carrier sense ranges. However, this mapping is reasonable only as long as it reflects the average propagation conditions of the wireless channel. Accordingly, propagation conditions should be either dynamically estimated as the vehicle moves which is very difficult to do in a real-life scenario, or they should be statistically estimated to build specific profiles for different environments, *e.g.*, urban and highway. Second major drawback of proactive approaches is the need to carefully estimate the amount of generated application-layer traffic in a certain period of time. Although in some cases this is possibly practical (*e.g.*, in the case of applications built on top of periodic beacon exchange), accurate application-layer traffic estimation is a challenging task in general.

Reactive approaches, which do not suffer from the drawbacks that accompany proactive mechanisms, have the notable disadvantage of undertaking control actions only after a congested channel condition has been detected. Considering that sometimes it is needed to recover from a congested channel situation, this means that reactive approaches expose safety-related applications to the risk of not being able to fulfill their design goal, due to the poor (temporary) performance of the underlying radio channel. Another disadvantage of reactive approaches is that important design goals such as fairness and packet prioritization are more difficult to achieve than in a proactive approach.

We remark that fairness is important in vehicular networks to ensure that all vehicles in the network have similar opportunities to communicate with nearby nodes. In fact, if congestion control were obtained by sacrificing; say, a specific node in the network is forced to set its transmission power to a very low value, this node would not have a chance to communicate with nodes in its surrounding which will consequently impair application-level performance. Most importantly, in safety-related applications, every vehicle in the network should be able to receive fresh information about the status of the other vehicles in its surrounding, along with communicating its own status to the surrounding vehicles. For this reason, fairness becomes a major design goal in safety-related applications. As for prioritization, providing a strict prioritization of different classes of packets is an important requirement for vehicular networking, which is partly addressed in the drafted IEEE 802.11p standard by adopting the enhanced distributed channel access (EDCA) mechanism defined within IEEE 802.11e [10].

The main objective of this paper is fine-tuning the D-FPAV algorithm, which is a proactive congestion control algorithm, and it will be described in details in next section. Proactive, reactive, hybrid congestion control approaches which are proposed for VANETs will be summarized in Table 1. We have done this taxonomy based on the above definitions and information which was available in the literature. The references mentioned in the table can be used for more information.

Table 1. Classification of Proposed Congestion Control Approaches for VANETs

Class	Approach	Reference	Packet rate	Utility function	Transmit Power	Access priority	Carrier sense threshold	Smart rebroadcasts
Proactive	VCWC	[19]	✓	×	×	×	×	×
	UBPFCC	[20]	×	✓	×	✓	×	×
	DPBS	[6]	×	✓	×	✓	✓	×
	Cross-layer CC	[21]	×	×	✓	✓	✓	✓
	BRR-EPA	[22]	×	×	✓	✓	×	×
	Application based CC	[23]	✓	×	✓	×	×	×
	D-FPAV	[18]	×	×	✓	✓	✓	×
Reactive	Power or Rate based CC	[24]	✓	×	✓	×	✓	×
Hybrid	Power – Rate combined CC	[25]	✓	×	✓	×	✓	×
	CF for CC	[26]	×	×	×	×	×	✓
	AICC	[27]	✓	×	✓	×	×	×

4. Dynamic D-FPAV Algorithm

In this part, the D-FPAV approach is presented [18], which is a proactive distributed congestion control in vehicular environments. D-FPAV achieves congestion control by varying the node transmission power, where a node's transmit power setting depends on predictions of application-layer traffic and the observed number of vehicles in the surrounding. The following designs goals are reached through this algorithm which employs transmit power control. Congestion control: through periodic beacon exchange the load on the medium produced is limited by congestion control. Fairness: Maximize the smallest amount of transmit power value over all transmission power levels which are allocated to nodes. This shapes the vehicular network under Constraint 1. Prioritization: assign higher priority to event-driven emergency messages when compared to the priority of periodic beacons. Solving the problem in the following lines in a fully distributed environment is the purpose of DFPV [18]. Beacons Max-Min Tx Power Problem (BMMTxP) is defined as a Given set of nodes $N = (u_1, u_2, \dots, u_n)$ in $R = [0, 1]$ and a value for the MBL, determine a PA, *i.e.*, PA, in a way that the minimum power of transmit that the nodes employed for beacons is maximized and the experience load on the network at the nodes stays under the MBL. Formally,

$$\max_{PA \in \mathcal{PA}} (\min_{u_i \in N} PA(i)) \quad (1)$$

Subject to

$$BL(PA, i) \leq MBL \quad \forall i \in \{1, \dots, n\} \quad (2)$$

Where, PA is the set of all possible PAs. The following elements builds the D-FPAV: 1) implementing the algorithm of FPAV [28] at every node with the collected information from the beacons which was received; 2) swapping transmit power control values which are locally computed among vehicles in the surroundings; and 3) choosing the lowest power level among all those computer locally and by surrounding vehicles. The D-FPAV algorithm is summarized in below.

D-FPAV Algorithm: (algorithm for node u_i)

INPUT: all the nodes' status in $CS_{MAX}(i)$

OUTPUT: assigning a power, $PA(i)$, for node u_i , such that the resulting power assigned is optimal

BMMTxP solution

Based on the nodes' status in $CS_{MAX}(i)$,

 Compute the maximum common tx power level P_i such that the MBL threshold is not violated at any node in $CS_{MAX}(i)$

 Broadcast P_i to all nodes in $CS_{MAX}(i)$

 Receive the messages with the power level

 from nodes u_j such that $u_i \in CS_{MAX}(j)$; store the received values in P_j

 Compute the final power level:

$$PA(i) = \min \{ P_i, \min_{j: u_i \in CS_{MAX}(j)} \{ P_j \} \}$$

Our methodology for fine-tuning the D-FPAV algorithm is to employ dynamic MBL value instead of a fixed value. The implementation is based on the combination of transmitting power control and message generation rate. Using Dynamic MBL value makes the algorithm adjustable based on traffic or non-traffic and event-driven or non-event-driven message conditions. The conditions on the streets and highways can be classified into two main categories; when there is traffic and when there is no traffic. Heavy traffic in the streets and highways can be detected from beacons information and based on vehicles speed. Based on above mentioned conditions, four different states are generated, namely, non-traffic and event-driven, non-traffic and non event-driven, traffic and event-driven, traffic and non-event-driven. However, the last state may not be generated due to the fact that the event-driven message is issued in the case of abnormal conditions. Thus, piggybacked beacons generation rate and MBL value can be decreased to 1 out 15 (instead of 1 out of 10) and $bandwidth/3$, respectively, when there is traffic or MBL value can be increased up to the maximum bandwidth of the channel when there is no traffic and no event-driven messages around and also, it can be set to $2 \times bandwidth/3$ when there is no traffic although there are event-driven messages around. Vehicles topology (location) will change slowly due to heavy traffic in the streets. In this situation, using the proposed approach can decrease the number of piggybacked beacons and consequently, the control channel overhead, which is already mentioned, can be reduced. Moreover, needless to say that traffic happens when there is an abnormal condition in a street. Therefore, in this situation, event-driven messages should have higher priority than beacon messages. Through the proposed methodology, more bandwidth will be reserved for transmitting event-driven messages in the case of traffic. As a result, the probability of receiving event-driven messages will be raised as well as their reception range. In the next paragraphs, the procedures for detection of traffic in the streets and assigning the MBL value dynamically are explained in details.

Procedure: findTraffic (for node u_i)

According to the status of the nodes in $CS_{MAX}(i)$ and neighbor table of u_i

 Compute the neighbor vehicle speed

 If 80% of neighbor vehicles' speed $< 30\text{km/h}$

 Then there is traffic in the highway (street) and return true

 Else return false

Procedure: dynamicMBL (for node u_i)

 If findTraffic = true

Piggyback the information every 15 beacons
Return $MBL = Bandwidth/3$
If findTraffic = false and no event-driven
Piggyback the information every 10 beacons
Return $MBL = Bandwidth$
If findTraffic = false and event-driven
Piggyback the information every 10 beacons
Return $MBL = 2*Bandwidth/3$

Therefore, the effect of MBL value on existing D-FPAV algorithm should be investigated, prior to implementation, in order to find the best value for each condition of our proposed algorithm. Therefore in next section, its effect will be investigated via simulation.

5. Experiment

In the evaluation of the wireless communications, the aspect of the using suitable models and their accurate configuration plays a significant role. Since NS-2 [29] is an extensively used network simulator is employed as the simulator in our paper. NS-2.33 version is the network simulator which was used for our experiment. To consider a real-life scenario as well as a dynamic network topology, a scenario has been used which has 7km long with relatively considerable traffic density. 141 vehicles travel at speed of not less than 4m/s (=14.5km/h) and not more than 33m/s (=120km/h) which is the highest speed in many countries. The highway has three lanes and the average vehicle density for each kilometer is 20. This scenario is illustrated in Figure 1.

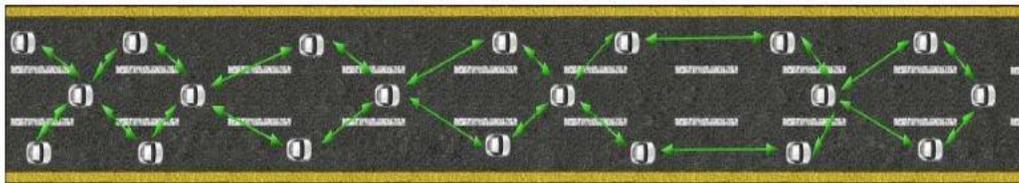


Figure 1. Vehicles Scenario for 1 km

There are several other parameters which are designed to perform the scenarios in the simulation. The packet generation rate which is selected for beacons is 10 packets per second which is seen as a suitable value in order to provide accurate data for the safety system [13]. The sizes of packets for all beacons are set at 500 Bytes. This size is the reasonable packet sizes in VANETs because of security issues [16]. Because of their robustness, the BPSK [30] modulation schemes of OFDM-based wireless LAN technologies, which are shown like 802.11p, are advisable. A 3Mbps data rate has been chosen because of the lowest SNR requirement that is 4dB. In D-FPAV implementation, MBL value will be assigned to different fixed values such as 0.5Mbps, 1Mbps, 1.5Mbps, 2Mbps, 2.5Mbps, and 3Mbps to investigate the MBL effect on this algorithm as well as to find the best value for each condition of our proposed algorithm in methodology section. In the CS range, rather than the number of nodes, the MBL threshold is vented in relation to megabits per second. Nevertheless, both measures that are the packet size and the packet generation rate (assumed to be the same for all the nodes) are equal and recognized. Finally, communication range (CR) is set to 500 meter at maximum transmit power. The maximum CS range, considering these configuration parameters, is 664 meter. Table 2 shows the most important configuration parameters which used in these simulations.

Table 2. Configuration parameters in our simulation

PARAMETER	VALUE
Message generation rate of beacon and event-driven	10 messages per second
Size of message	500bytes
Communication range	500m
Radio propagation model	Nakagami model
Vehicle density	20 vehicles per kilometer
Number of vehicles	141 vehicles
802.11p data rate	3Mb/s
D-FPAV algorithm	On, Off
MBL	0.5Mb/s, 1Mb/s, 1.5Mb/s, 2Mb/s, 2.5Mb/s, 3Mb/s
Communication protocol	UDP
Simulation time	200s
Number of lanes	3 lanes
Minimum node speed	4m/s (=14.5km/h)
Maximum node speed	33m/s (=120km/h)

As described in the scenario of the highway, all vehicles have been adjusted to transmit beacon messages with the rate which has already been prescribed. The event-driven messages are transmitted through one particular node situated around the middle of the 7km long road. For event driven messages sending, the same rate as beacons (10 packets/s) is used. They resend at the highest transmit power. The metric used for analyzing MBL effect on D-FPAV is the probability of the event-driven and beacon messages effective reception when considering the distance. The reception probability is employed to evaluate D-FPAVs efficiency in reaching a suitable prioritization for safety-related messages, which is attained via rising the correctly reception probability of event-driven messages simultaneously as not lowering the correctly reception probability of beacons near to the sender. For investigating D-FPAV performance, two main simulation setups are considered which are D-FPAV-On and D-FPAV-Off. In the D-FPAV-Off mode, every one of the beacons is transmitted with maximum power (CR = 500 m), owing to the fact that no power control is in place. Conversely, in the D-FPAV-On mode, beacons are transmitted by using the transmit power as calculated by D-FPAV.

6. Simulation Results

6.1. The Best MBL Values for Dynamic D-FPAV

Figure 2 shows the obtained results from the simulation for event-driven messages reception probability with D-FPAV-Off and D-FPAV-On by various values of MBL. By comparing the curves in Figure 2, the chance of properly receiving an event-driven message with D-FPAV-On with different MBL values, like 0.5 Mbps, 1 Mbps, *etc.*, are higher than the results in D-FPAV-Off. The distance between the sender and on the CR probably depends on the volume of the increase in reception. From the observation of the results, an intermediate range of distances (about 100m-600m with CR = 500m) in which the increase of the reception

probability is more considerable in D-FPAV-On mode. As an example, with CR = 500m which is employed in our simulation, the correctly reception probability of an event-driven message at a distance of 350m from the sender is about 0.46 with D-FPAV-On with 2Mbps for its MBL value, while it is only about 0.21 with D-FPAV-Off, corresponding to almost 130 percent increased. The trade off for obtaining a higher probability of receiving event-driven messages is a decreased probability of receiving beacon messages.

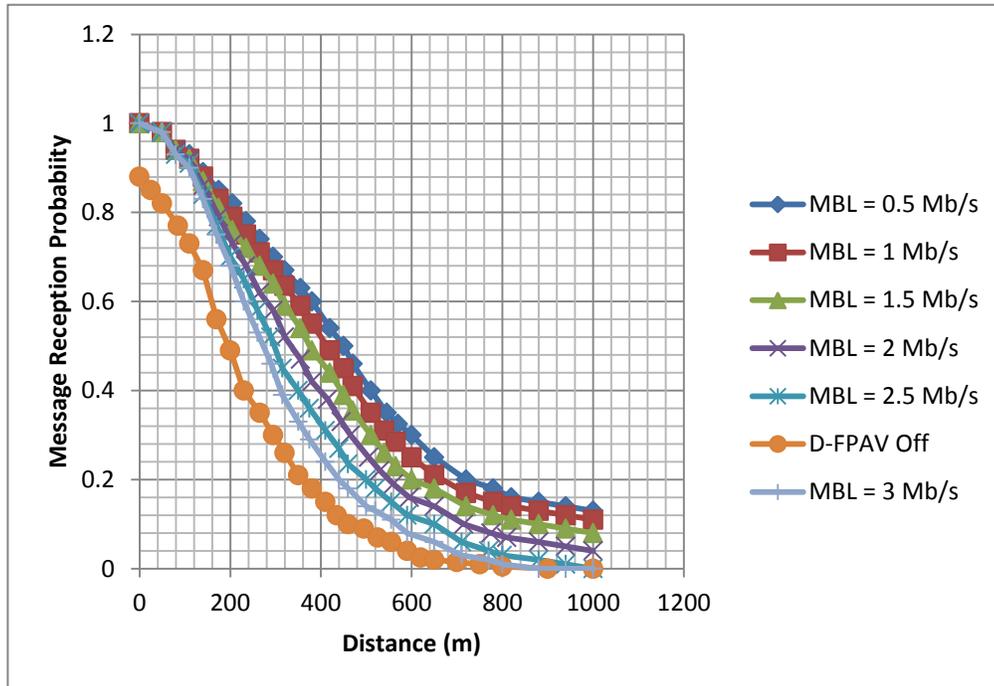


Figure 2. Successful Reception Probability of Event-driven Messages by Considering the Distance, for D-FPAV-Off and D-FPAV-On with Different MBL Values

The amount of this decrease is strongly dependent on distance and used MBL value which is illustrated in Figure 3: in the case that the receiver is extremely near to the sender (80 meter or less); the correctly reception probability of the beacon is the same as the case of D-FPAV-Off. For example, the probability of receiving of beacon message correctly at a distance of 50m from the sender is about 0.82 with D-FPAV-On with 1.5Mbps and 2Mbps for its MBL value and with D-FPAV-Off. In fact, the reception probability in D-FPAV-On is higher than D-FPAV-Off especially in near distances to the sender (for example, with distance below 60m). For example, the probability of correctly receiving of beacon message when the distance is 25m from the sender is around 0.92 and 0.93 with D-FPAV-On with 1.5Mbps and 2Mbps for its MBL value, respectively, while it is around 0.85 with D-FPAV-Off. After this distance, the probability is notably lesser than D-FPAV-Off. This lower probability for beacon reception is because of the lower transmitting power employed in sending beacons. This can be considered essential in order to lessen the beaconing load lower than the MBL threshold.

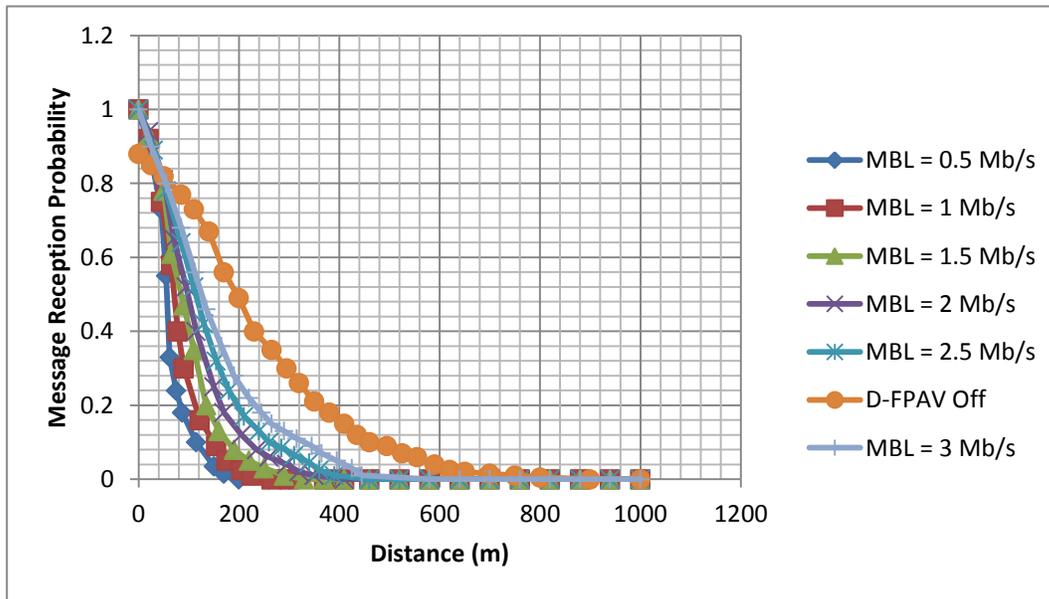


Figure 3. Successful Reception Probability of Beacon Messages by Considering the Distance, for D-FPAV-Off and D-FPAV-On with Different MBL Values

Figure 2 and 3 show the effect of MBL value in performance of D-FPAV algorithm for event-driven and beacon messages, respectively. A MBL value which is smaller, limits the transmission power used for beacons, *i.e.*, it attains a stricter prioritization of event-driven messages over beacons. Facing smaller MBL, the average beacons transmission range is decreased and event-driven messages benefit the lesser load which will result in the higher probability of successfully being received from a distance. The obtained results with D-FPAV-On (lower probability of reception for beacons at medium-long distances, while higher reception probability at all distances for event-driven messages) satisfied the safety related messages requirement. Beacons are sent periodically and the data which they carried is mainly significant for the nodes in the vicinity to the sender. For this reason, in terms of safety messages, the lower reception probability of beacons in close distance is not vital. However, to avoid accidents and other hazards, the event-driven messages need an immediate reaction after being issues by the near and far distant vehicles. This will be fulfilled via the evidently greater probability of the reception of event-driven messages with D-FPAV-On with any MBL value, which is tested in our simulation, at all distances (close and far) from the sender. Therefore, we conclude that sending the safety related messages by D-FPAV-On is better than sending by D-FPAV-Off. Based on our findings, the MBL values assigned in each scenario have proven the effectiveness of algorithm to control the messages load in vehicular networks. As a result, the MBL values for different conditions, which are mentioned in our algorithm, are as follows: the MBL equals to 1Mbps when there is traffic in street (condition 1), 3Mbps when no traffic occurred and event-driven message to send (condition 2), 2Mbps when there is no traffic at least one event-driven message has to be sent (condition 3).

6.2. Dynamic D-FPAV vs. Fixed D-FPAV

Dynamic D-FPAV algorithm, in which MBL value will be assigned dynamically, shows different results with fixed D-FPAV algorithm. According to the results which are illustrated in Figure 4 and Figure 5, dynamic D-FPAV shows better throughput and reception probability in the case of beacon and event driven messages. Thus, dynamic D-FPAV can increase overall reception probability of packets in different conditions. Throughput is a metric which is described as the total number of received packets at destination out of total transmitted packets.

$$\text{Throughput (bytes/sec)} = \frac{\text{Total Number of Received Messages at Destination} \times \text{Packet Size}}{\text{Total Simulation Time}}$$

Thus, higher reception probability of beacon and event-driven messages means higher throughput in message delivery which depicted in Figure 4 and Figure 5. In Figure 4, it can be seen that the reception probability for beacon messages in dynamic D-FPAV is higher than fixed D-FPAV in all distances from the sender. For example, the correctly reception probability of beacon message at a distance of 200 m from the sender is about 0.6 and 0.2 with dynamic D-FPAV and fixed D-FPAV, respectively, corresponding to approximately 40 percent increased. This increase is due to allocate the more amount of bandwidth to beacon messages in dynamic D-FPAV against fixed D-FPAV algorithm. In Figure 5, it can be seen that the reception probability for event-driven messages in dynamic D-FPAV is higher than fixed D-FPAV in close distances from the sender (for instance, with distance below 400m). For example, the correctly reception probability of event-driven message at a distance of 200m from the sender is about 0.9 and 0.7 with dynamic D-FPAV and fixed D-FPAV, respectively, corresponding to approximately 20 percent increased. This result satisfies higher prioritization of event-driven messages which was one of the goals. After this distance, the correctly reception probability of event-driven messages in dynamic D-FPAV is same as fixed D-FPAV. The higher event driven reception probability is due to the lower generation rate and power of transmit used to send beacons in the dynamic D-FPAV algorithm, which used to decrease the beaconing load because of slow change of topology when there is traffic in highways.

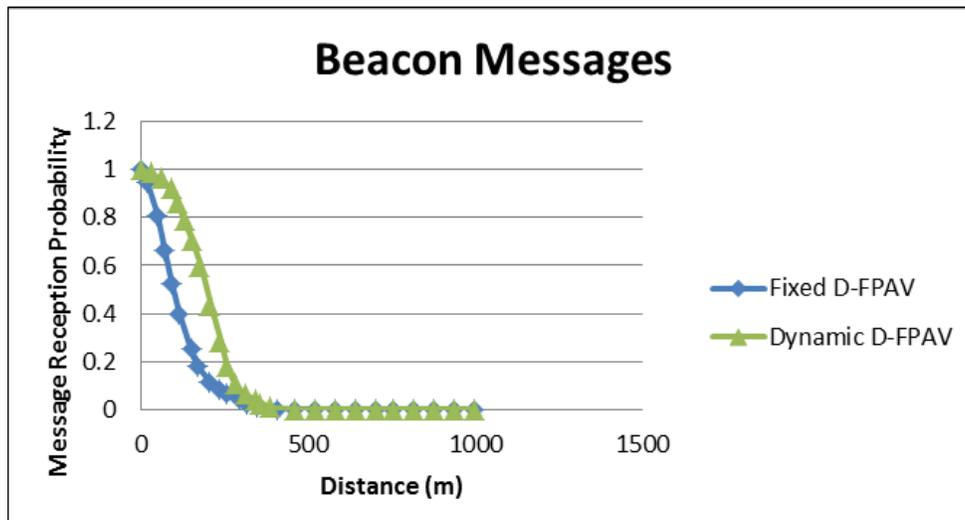


Figure 4. Successful Reception Probability of Beacon Messages by Considering the Distance, for Fixed D-FPAV and Dynamic D-FPAV

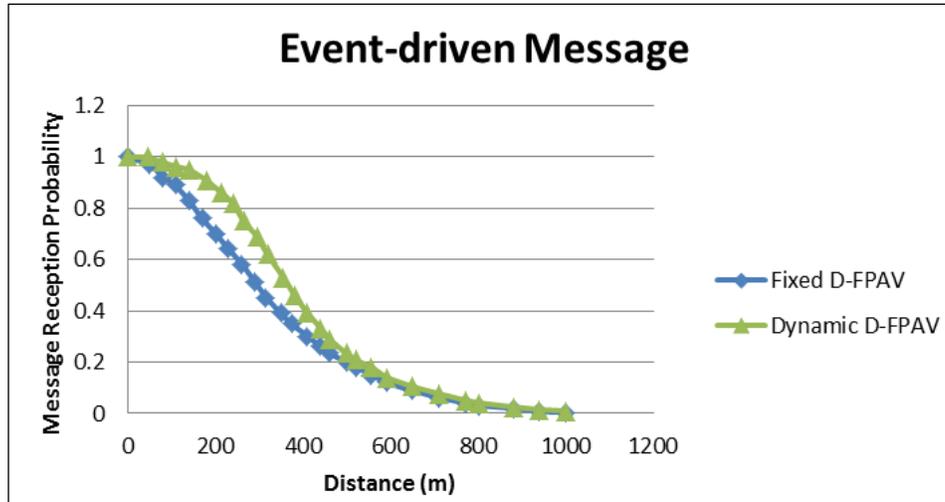


Figure 5. Successful Reception Probability of Event-driven Messages by Considering the Distance, for Fixed D-FPAV and Dynamic D-FPAV

7. Conclusion

In this paper, we have discussed about congestion problem which is one of the major challenges in VANETs. This issue is affected by the limited bandwidth in VANET standard, IEEE 802.11p. The algorithms proposed in this paper are classified into three main classes, namely, proactive, reactive, hybrid. Packet generation rate, utility function, transmit power control, access priority, carrier sense threshold, smart rebroadcast are the main characters, which are used in the proposed algorithms to alleviate the above-mentioned problem. D-FPAV is improved by investigating through several simulation scenarios. In this algorithm, safety related messages are classified into beacon and event-driven messages. It is based on maximization of minimum transmit power level for all nodes in CS range to get fairness between nodes, until beacon messages load is placed under the MBL threshold. This approach worked very well; however, it has two shortcomings, which is mentioned in problem statement section of this paper.

We proposed an algorithm based on the combination of transmit power control and message generation rate to solve the problems. Our algorithm is based on dynamic MBL assignment regarding to streets or highway conditions (traffic and non-traffic conditions). To find the best MBL value for each condition, D-FPAV algorithm is implemented in network simulator NS-2 and different values are assigned to MBL. Best MBL values for each condition are found and consequently, are explained in results section based on the obtained results from NS-2. After modifying the D-FPAV algorithm by adding our proposed algorithm to it via simulating in NS2, the dynamic MBL assignment effects in this algorithm have been investigated. The obtained results lead us to prove our claim of solving the mentioned problems. Our results showed that dynamic D-FPAV has better throughput and message reception probability than fixed D-FPAV by considering the reception of beacon and event-driven message. Furthermore, in addition to considering the effectiveness of dynamic D-FPAV algorithm, different scenarios should be simulated such as high speed vehicles which would be remained for the future work.

Acknowledgments

The authors would like to thank Ministry of Higher Education (MOHE) Malaysia and University of Malaya that funded this project under HIR-B000009.

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