Cognitive Intelligence with Adaptive MAC Vehicular Ad-Hoc Network Optimization

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Abstract **- Successful and timely data delivery in evolutionary Vehicular Ad-Hoc Network (VANET) for Intelligent Transportation System (ITS) are particularly challenging due to the unique characteristics of VANET, such as fast topology change and frequent disruptions. The current VANET schemes use static parameters in an ever changing VANET topology, which results in lack of adaptability. Due to the fast topology change and frequent disruptions in VANET, a cognitive and adaptive VANET Medium Access Control (MAC) scheduling optimization protocol scheme, which is able to change its transmission parameters, to suit different topology change in VANET is preferable. In the proposed Adaptive VANET MAC, namely AdMAC, change of signal to noise and interference ratio (SINR) is proposed as an indicator to represent VANET transmission environment and traffic density. The change of SINR is then used to determine the VANET MAC contention window size. Simulation is conducted under congested and non-congested traffics, in the urban map of Kuala Lumpur, Malaysia. Results show that the proposed AdMAC has better adaptability, in terms of packet success rate and average delay.**

Index Terms – Vehicular Network, Intelligent Transportation System, Optimization, Mobile Communication, Decision Systems, Artificial Intelligence

I. Introduction

In VANET, vehicles drive randomly with high mobility under fast topology change and frequent disruptions [1]. The current existing schemes in VANET use parameters that do not consider transmission reliability, transmission stability, interference and traffic conditions, to optimize contention window size [2]. In order to ensure VANET suffers less packet collisions and achieve minimum delay, VANET MAC parameters have to be adaptive and optimized, to ensure VANET MAC transmission performance is maintained, under ever changing topology and frequent disruptions [3]. Currently, VANET is governed by IEEE802.11p with Enhanced Distributed Channel Access (EDCA) priority scheme [4]. The default IEEE802.11p scheme is still very much static, which makes it less feasible, under varying VANET transmission environments.

Therefore, in the following paper, an adaptive VANET MAC, namely AdMAC is proposed. The main contributions of this research work are listed below. Firstly, change of SINR is proposed as traffic condition, transmission environment and transmission stability indication. Secondly, contention window size which affects transmission performance in VANET is adapted according to traffic condition, transmission environment and transmission stability, with the use of change of SINR. Thirdly, the proposed AdMAC is shown to be adaptable and optimized, under varying simulation conditions, congested and non-congested traffic, with lower average delay and higher packet success rate. Simulation is conducted under realistic VANET environment with urban Kuala Lumpur, Malaysia map. The detailed AdMAC scheme is explained in the following sections.

The rest of the paper is organized as follows. Section 2 discusses the related work. In Section 3, the proposed AdMAC is explained in detail. Section 4 presents the simulation scenario and parameters. Section 5 analyses the results, and discusses the findings. Section 6 concludes the research work.

II. Related Work

VANET is the main component towards realizing Intelligent Transportation Systems (ITS) [5]. Various works have been proposed to ensure adaptive and optimized VANET MAC. In the following section, these literature works are critically analysed.

In [6], a joint adaptation is proposed where the transmission power is adapted based on estimated local vehicle density, whereas the contention window size is adapted based on the instantaneous collision rate. The proposed method however, ignores the surrounding interference and transmission reliability, which makes it less adaptable to varying VANET transmission environment.

VANET MAC has to be able to cope with short connection lifetimes, fast changing topologies caused by vehicle mobility, high node density, quality demands, harsh propagation environments and heterogeneous traffic nature [7]. In [8], a cognitive VANET MAC is proposed where a close distance range transmission is given higher priority, by assigning shorter contention window size. In order to achieve higher radio channels reliability in VANET MAC, in [9], a Reliable Time Division Multiple Access (TDMA) based on One-hop Broadcast (RTOB) is proposed. A metric named Cover Ratio (CR) which is more appropriate than the conventional Packet Delivery Ratio (PDR) is used to evaluate reliability of transmission packets. However, the proposed method does not perform well in the ever changing VANET MAC environments due to its lack of transmission stability indication, making it less adaptable.

In [10], minimum cost utilization is used to determine the priority of the transmission in VANET MAC. A centralized online algorithm is proposed to find the lower bound on the cost of utilization of the RSUs for a given set of subscriptions and events presented. However, this method increases the complexity of the system, making it time consuming, hence incurs higher delay.

Research efforts in the literature mainly focus of improving VANET MAC. However, with the ever changing transmission environment and frequent disruptions in VANET [11] [12], an adaptable MAC [13] [14], that is capable of performing reliable packet transmission in a timely manner, in varying fast topology change is important [15] [16]. Therefore, in the proposed AdMAC, the use of change of SINR as an indication of transmission reliability, interference and traffic density, is proposed to determine the contention window size. The proposed AdMAC is explained in detail in the following sections.

III. The Proposed Adaptive VANET MAC (AdMAC)

In this section, an Adaptive VANET MAC (AdMAC) is explained in detail. The current default IEEE802.11p uses static parameters in an ever changing VANET transmission environment as shown in Table 1, where typical aCWmin=15 and aCWmax=1023 are usually chosen [15] [17]. However, nodes in VANET are highly mobile moving in unpredictable transmission environment. Therefore, VANET MAC should be made adaptable to the transmission conditions, to ensure efficient packet transmission, by achieving higher packet success rate and lower delay.

In the proposed AdMAC, change of SINR is used to monitor the transmission environment. In order to ensure adaptive VANET MAC, contention window size is adapted according to the transmission environment, indicated by change of SINR. The contention window size is usually depicted by a range of values indicated by minimum and maximum contention window size, depending on data type. The contention window size is then randomly chosen, with the condition that the chosen size must be within the allocated minimum and maximum contention window size.

TABLE 1
DEFAULT IEEE802.11P CONTENTION WINDOW SIZE

	Priority Levels	**Data Type Designation**	**Default IEEE802.11p CWmin**	**Default IEEE802.11p CWmax**
High	4	Access Category Voice (AC_VO)	(aCWmin+1)/4-1	(aCWmin+1)/2-1
	3	Access Category Video (AC_VI)	(aCWmin+1)/2-1	aCWmin
	2	Access Category Best Effort (AC_BE)	aCWmin	aCWmax
Low	1	Access Category Background (AC_BK)	aCWmin	aCWmax

TABLE 2
THE PROPOSED ADAPTIVE VANET MAC (ADMAC)

Change of SINR	**The Proposed AdMAC Maximum Contention Window Size (AdMAC CWmax)**	**The Proposed AdMAC Minimum Contention Window Size (AdMAC CWmin)**	**The Final AdMAC Contention Window Size as compared to the Default IEEE802.11p**	**Reason**
SINR Increases (Non-congested traffic or ideal transmission environment)	Default CWmax *0.5	Default CWmin *0.5	Decreased	Reduce waiting period between packet transmission so that more packet transmissions can take place
SINR Same	Default CWmax	Default CWmin	Same	Transmission is in good condition, maintain CW
SINR Decreases (Traffic congestion or non-ideal transmission environment)	Default CWmax *2	Default CWmin *2	Increased	Increase waiting period between packet transmission to reduce packet collision

Since low contention window size during traffic congestion results in high packet collision, whereas a high contention window size during non-congested traffic results in low packet transmission, therefore, the contention window size should be adapted according to the traffic transmission environment. In the proposed AdMAC, if change of SINR indicates non-congested traffic or ideal transmission environment, the contention window size is reduced in order to reduce the waiting period before next packet transmission can take place.

On the other hand, if the change of SINR indicates congested traffic or non-ideal transmission environment, the contention window size is increased in order to increase the waiting period between transmissions, to prevent packet collision. Alternatively, if the change of SINR remains the same, it represents good transmission environment, hence the contention window size remains the same. The parameter values are selected based on simulated results. Figure 1 describes the proposed AdMAC algorithm in detail.

```
Algorithm: Adaptive VANET MAC (AdMac)
foreach Time do

Calculate Change of SINR

If (Change of SINR = positive)
AdMAC CWmax = Default CWmax * 0.5;
AdMAC CWmin = Default CWmin* 0.5;
Randomly choose a value between AdMAC CWmin and AdMAC
CWmax;

else if (Change of SINR =negative)
AdMAC CWmax = Default CWmax * 2;
AdMAC CWmin = Default CWmin* 2;
Randomly choose a value between AdMAC CWmin and AdMAC
CWmax;

else
Contention Window Size = Remains the same;

end
end
end
```

Fig. 1: The Proposed AdMAC Algorithm

IV. Simulation

Simulation for the proposed AdMAC is conducted with Omnet++, Vehicles Network Simulation (Veins), Simulation of Urban Mobility (SUMO) and open google map applications [18]. The simulation is modelled with inattentive drivers in the dense inner-city of Kuala Lumpur where vehicles drive at their comfortable speed as shown in Figure 2. Traffic obstructions are introduced by stopping the lead vehicle. Vehicles travel along the shortest route to a fixed sink node. Two different simulation environments, congested and non-congested traffic are simulated to test the adaptability of the proposed AdMAC scheme. Table 3 shows the simulation parameters.

TABLE 3
TRAFFIC PARAMETERS

Parameter	Value
Packet arrival rate, λ	0.01s – 0.001s
Number of vehicles, Φ	500 - 1000
Packet size	512 bytes
Transmitted power	19 dBm

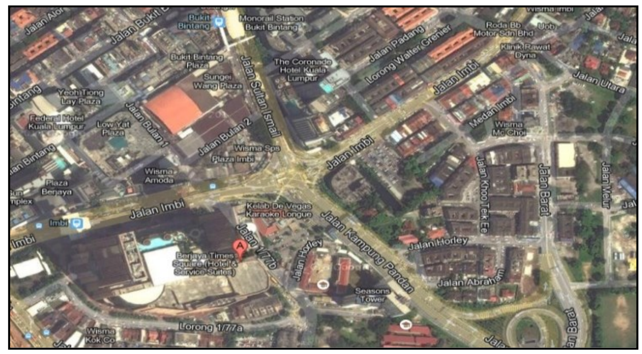

Figure 2: Kuala Lumpur, Malaysia City Centre Map (An Urban Area)

V. Result and Discussion

From Figure 3 to Figure 6, it can be observed that the proposed AdMAC scheme achieve lower delay and higher packet success rate as compared to the default IEEE802.11p scheme and the reference scheme in [6]. The default IEEE802.11p scheme uses static parameters in varying VANET transmission environment. The parameters are not adapted according to the varying transmission environment which results in inappropriate assignment of parameters during transmission. This results in degradation of transmission performance, in terms of average delay and packet success rate, under varying transmission environments; congested and non-congested traffics.

Alternatively, the reference scheme in [6] uses an estimated calculation of packet collision rate method to determine its contention window size, which results in transmission parameter inaccuracy. Under varying transmission environment, the reference scheme in [6] is shown to be underperformed as compared to the proposed AdMAC scheme, due to its incapability to be adaptive under varying VANET transmission environment. Therefore, the reference scheme in [6] is shown to achieve lower packet success rate and higher delay, as compared to the proposed AdMAC scheme. In Figure 5 and 6, it can be observed that the reference scheme in [6] is only able to achieve slightly better results as compared to the default IEEE802.11p scheme, under congested traffic. However, the reference scheme in [6] achieved the same packet success rate and average delay, as the default IEEE802.11p scheme, under non-congested traffic. Hence, using the reference scheme in [6] under non-congested traffic is highly discouraged as it would incur higher computational complexity yet achieving the same results as the default IEEE802.11p scheme.

On the other hand, from figure 4 to figure 6, the proposed AdMAC is able to achieve better performance in terms of packet success rate and average delay, regardless of transmission environments depicted by, non-congested traffic and congested traffic, with simple algorithm. The proposed AdMAC detects the traffic conditions with the use of change of SINR, and adjust its contention window size according to traffic conditions. This results in better performance, in terms of packet success rate and average delay, as the parameters are adapted according to the transmission suitability, making the proposed AdMAC adaptive and optimized.

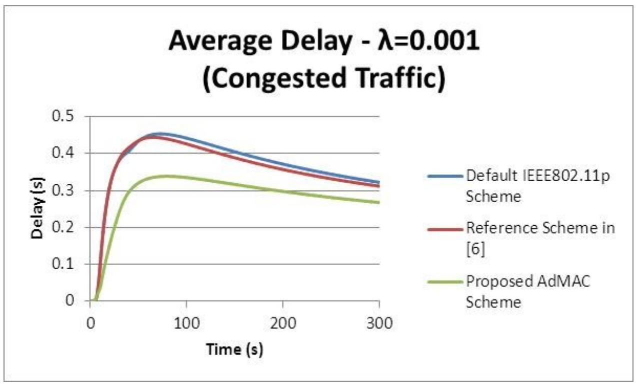

Fig. 3: Average Delay (λ=0.001) - Congested Traffic

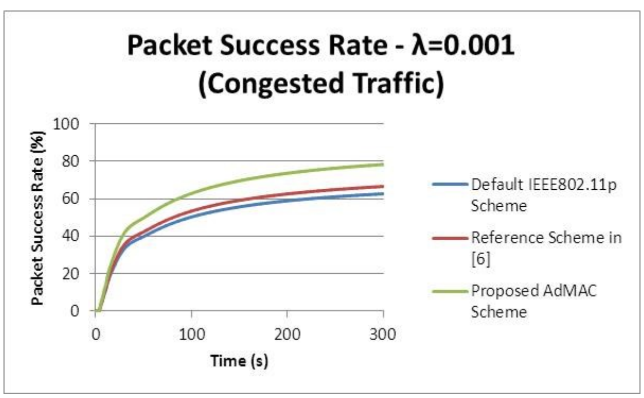

Fig. 4: Packet Success Rate (λ=0.001) - Congested Traffic

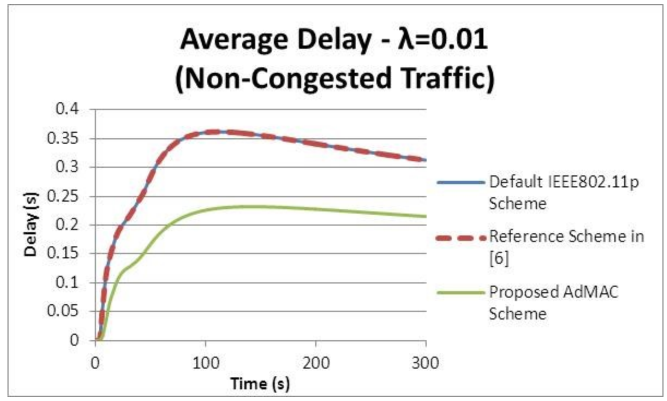

Fig. 5: Average Delay (λ=0.01) – Non-Congested Traffic

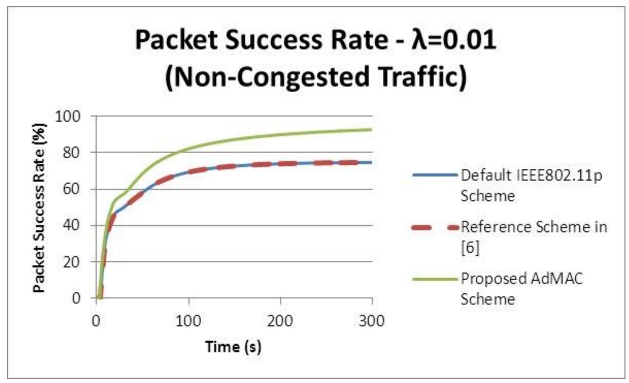

Fig. 6: Packet Success Rate (λ=0.01) – Non-Congested Traffic

VI. CONCLUSION

VANET is an emerging technology to ensure safety through communication between vehicles. The current VANET scheme shows lack of adaptability in an ever changing transmission environment due to its static parameters. Therefore, in this paper, a novel adaptive optimized scheduling protocol for MAC layer dynamic evolutionary VANET in intelligent transportation system (ITS), namely AdMAC is proposed. In AdMAC, change of SINR is used to determine traffic density and transmission environment. The change of SINR is then used to set the contention window size for packet scheduling. High contention window size is given to unviable transmission conditions to allow packets to clear before next transmission takes place, whereas low contention window size is given to good transmission conditions to allow more packet transmissions to take place. Simulation is conducted under congested and non-congested traffic in an urban Kuala Lumpur, Malaysia map, with the use of Omnet++, SUMO, Veins and open google map applications. Results show that the proposed AdMAC shows better adaptability and optimization, under varying transmission environment, with improved packet success rate and lower average delay.

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