Performance Evaluation of MAC Protocols in VANETs

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Abstract

Vehicular Adhoc Network (VANET) is an example of Mobile Adhoc Network (MANET) that uses moving cars as nodes in a network to create a mobile network. They are popular for life safety applications and internet access applications. There is a no. of issues which are to be resolved for the VANETs and Media Access Protocols (MAC) is one of them. In this paper we will discuss about the performance of 802.11 based MAC protocols i.e. PCF and EDCF. We analyzed the performance of PCF and EDCF protocols in terms of delay and throughput for different types of traffic which are voice, video, HTTP and remote login. The two protocols show different delay and throughput for each type of service during simulation. The simulator OPNET modeler 14.5 has been used to simulate the protocols over same scenario. The simulation results shown that the EDCF protocol performs better than PCF in VANETs.

Keywords: VANET, MAC, PCF, EDCF, OPNET.

1. INTODUCTION

Vehicular networks consist of large no. of vehicles which are autonomous and self organizing and involve themselves as servers and/or clients for exchanging and sharing information. Communication in VANETs may be of two types: Vehicle-to-Vehicle (V2V) versus Vehicle-to/from-Infrastructure (V2I) These vehicles will require an authority to govern them, each vehicle can communicate with other vehicles using short radio signals DSRC (Directed Short Range Communication- 5.9 GHz), for range can reach 1Km, this communication is an Ad hoc communication that means each connected node can move freely, no wires required, the routers used are called Road Side Unit (RSU). The RSU works as a router b/w the vehicles on the road and connected to other n/w devices and it is also known as infostation. [2] Each vehicle has OBU (On Board Unit), this unit connects the vehicle with RSU via DSRC radios, and another vehicle is TPD (Tamper Proof Device), this device holding the vehicles secrets, all information about the vehicles like keys, driver identity, trip details, speed etc.

VANET is a new technology and there are a no. of issues which are to be resolved for it, these issues includes data segmentation & re-assembling, MAC protocols, building better simulations, bit bate & power consumption. We are considering MAC protocols in this paper.

The safety applications of VANETs require better Quality of Service (QoS) in terms of delay and throughput. To provide better QoS, the protocols have been compared and analyzed so that the results will help to design the new VANETs and modified MAC protocols for them. The IEEE 802.11 based MAC protocols have been considered because of their popularity and ease of implementation. The two protocols are based on CSMA/CA contention free method and do not require synchronization between the vehicles.

The paper is organized as follows: section II describes the MAC Protocols in detail. Section III analyses the performance of two protocols in terms of delay and throughput for various types of services. Finally, section IV concludes the paper.

2. MAC Protocols

Media Access Control protocols such as TDMA, FDMA, or CDMA are difficult to implement for VANET. For any of these protocols to be used either time-slots, channels, or codes need to be dynamically allocated, which requires synchronization that is difficult to achieve in a network where the nodes have a high degree of mobility.

The objective of the media access control protocol is to arbitrate the access to the shared medium, which in this case is the wireless channel. If no method is used to coordinate the transmission of data, then a large number of collisions would occur and the data that is transmitted would be lost. The ideal scenario is a MAC that prevents nodes within transmission range of each other from transmitting at the same time, thus preventing collisions from occurring. Equally important, the media access control must be fair, efficient, and reliable. [3] Moreover high reliability and low latency are the major requirements of the VANETs. So MAC protocols should be able to fulfill these requirements. [4]

The major problems that a MAC protocol for VANETs has to solve are to:

I. Transmission Collisions
II. The Hidden Terminal Problem
III. Exposed Node Problem

The methods Request to Send (RTS) and Clear to Send (CTS) are used to solve these problems.

2.1 Point Coordination Function (PCF)

The point coordination function is a centralized, polling-based access mechanism which requires the presence of an Access Point (AP) that acts as Point Coordinator (PC) to provide contention-free frame transfer for processing time-critical information transfers. PCF uses the point coordinator (PC) as the polling master. [6] At the beginning of the contention-free period (CFP), the point coordinator has an opportunity to gain control of the medium In the PCF mode, time is divided into superframes. Each superframe consists of a contention period where DCF is used and a contention-free period (CFP) where PCF is used. The CFP is started by a beacon frame sent by the PC using DCF.

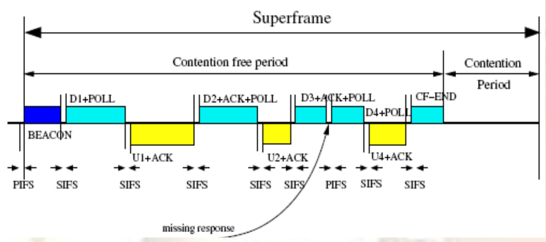

Fig.1. Structure of Superframe

The CFP may vary from superframe to superframe, as the base station has to contend for the medium. Once the CFP starts, the PC polls each station in its polling list (the high priority stations) when they can access the medium. To ensure that no DCF stations are able to interrupt this mode of operation, the inter frame space between PCF data frames (PIFS) is shorter than the DIFS. To prevent starvation of stations that are not allowed to send during the CFP, there must always be room for at least one maximum length frame to be sent during the contention period. [5]

The PC polls the stations in a round-robin fashion. A polled station always responds to a poll. If there is no pending transmission, the response is a null frame containing no payload. If the CFP terminates before all stations have been polled, the polling list is resumed at the next station in the following CFP cycle. A typical medium access sequence during PCF is shown in Fig. 1. A station being polled is allowed to transmit a data frame. In case of an unsuccessful transmission, the station retransmits the frame after being repolled or during the next Contention Period.

2.2Enhanced Distributed Co-ordination Function (EDCF):

The 802.11 legacy MAC does not support the concept of differentiating frames with different priorities. Basically, the DCF is supposed to provide a channel access with equal probabilities to all stations contending for the channel access in a distributed manner. However, equal access probabilities are not desirable among stations with different priority frames.

With the EDCF, a station cannot transmit a frame that extends beyond a time interval called EDCF transmission opportunity (TXOP) limit. If a frame is too long to be transmitted in a single TXOP, it should be fragmented into multiple frames. We also introduce and evaluate a mechanism called the contention-free burst (CFB) that allows a station to transmit multiple MAC frames consecutively as long as the whole transmission time does not exceed the EDCF TXOP limit, which is determined and announced by the access point (AP). [7] The emerging EDCF is designed to provide differentiated, distributed channel accesses for frames with 8 different priorities (from 0 to 7). Each QoS data frame carries its priority value in the MAC frame header. An 802.11e STA shall implement four access categories (ACs), where an AC is an enhanced variant of the DCF 0. Each frame arriving at the MAC with a priority is mapped into an AC as shown in Table I. Note the relative priority of 0 is placed between 2 and 3. This relative prioritization is rooted from IEEE 802.1d bridge specification.

Table I Priority to Access Category Mappings

Priority	Access Category (AC)	Designation (Informative)
1	0	Best Effort
2	0	Best Effort
0	0	Best Effort
3	1	Video Probe
4	2	Video
5	2	Video
6	3	Voice
7	3	Voice

Basically, an AC uses AIFSD[AC], CWmin[AC], and CWmax[AC] instead of DIFS, CWmin, and CWmax, of the DCF, respectively, for the contention process to transmit a frame belonging to access category AC. AIFSD[AC] is determined by

$$AIFSD[AC] = SIFS + AIFS[AC] * SlotTime ,$$

where AIFS[AC] is an integer greater than zero. Moreover, the backoff counter is selected from [1, 1+CW [AC]], instead of [0, CW] as in the DC .Fig. 2 shows the timing diagram of the EDCF channel access.

The values of AIFS[AC], CWmin[AC], and CWmax[AC], which are referred to as the EDCF parameters, are announced by the AP via beacon frames. The AP can adapt these parameters dynamically depending on network conditions.

Basically, the smaller AIFS[AC] and CWmin[AC], the shorter the channel access delay for the corresponding priority, and hence the more capacity share for a given traffic condition.

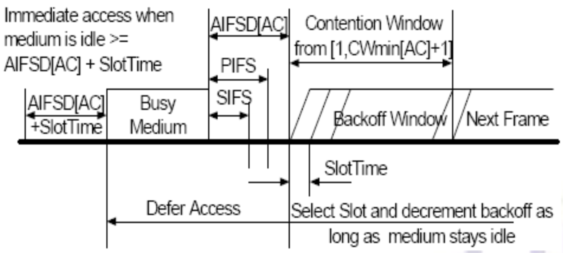

Fig.2.IEEE 802.11e EDCF Channel Access

Fig. 3 shows the 802.11e MAC with four transmission queues, where each queue behaves as a single enhanced DCF contending entity. When there is more than one AC finishing the backoff at the same time, the collision is handled in a virtual manner. That is, the highest frame among the colliding frames is chosen and transmitted, and the others perform a backoff priority with increased CW values.

The IEEE 802.11e defines a transmission opportunity (TXOP) as the interval of time when a particular STA has the right to initiate transmissions. Along with the EDCF parameters of AIFS[AC], CWmin[AC], and CWmax[AP], the AP also determines and announces the limit of an EDCF TXOP interval for each AC, i.e., TXOPLimit[AC], in beacon frames. During an EDCF TXOP, a STA is allowed to transmit multiple MPDUs from the same AC with a SIFS time gap between between an ACK and the subsequent frame transmission. We refer this multiple MPDU transmission to as "Contention-Free Burst (CFB)."

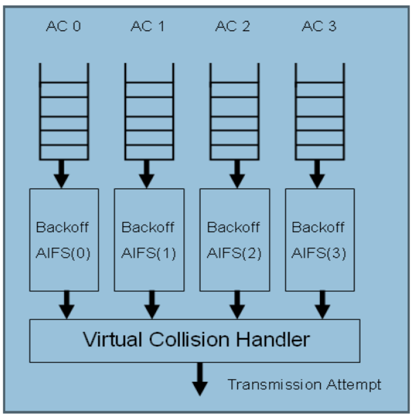

Fig.3. Four access categories (ACs) for EDCF

Fig.4 shows the transmission of two QoS data frames during an EDCF TXOP, where the whole transmission time for two data and ACK frames less than the EDCF TXOP limit is announced by the AP. As multiple MSDU transmission honors the TXOP limit, the worst-case delay performance is not be affected by allowing the CFB. We show below that CFB increases the system throughput without degrading other system performance measures unacceptably as long as the EDCF TXOP limit value is properly determined.

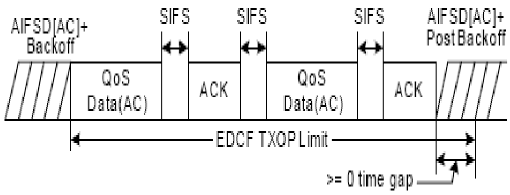

Fig.4. CFB timing structure

3. Simulation Evaluation

There exists a no. of simulators which can be used for network simulation. The popular simulators are: NS2, OPNET, OMNET, MATLAB etc. This research is conducted using discrete event simulation software known as OPNET Modeler 14.5 OPNET is Optimized Network Engineering Tool. In this simulator, number of parameters is available to study the performance of network. Various parameters like end to end delay, throughput, retransmission attempts and data dropped etc. These parameters are known as performance metrics.

We have modeled a no. of scenarios in which the wireless stations have been configured with PCF and EDCF functionalities separately. Moreover, these scenarios are also distinguished in case of type of service that runs in the scenario i.e. voice, video, HTTP and remote login. To compare the performance of two protocols, these protocols have been implemented in the network model having AP which is connected to the backbone and it acts like an RSU and it represents the V2I communication of VANETs. To evaluate the performance of EDCF protocol for different types of services, it is implemented in pure adhoc network which represents the V2V communication in VANETs.

The EDCF protocol classify all the traffic types into four classes which corresponds to AC (0), AC(1), AC(2) and AC(3) respectively and for each of these classes different applications have been configured in the application profile of the EDCF configured scenarios. Table II describes it in detail.

Each simulation scenario consisted of 50 nodes which were arranged randomly. The routing protocol AODV has been enabled in each scenario which is reactive in nature. All simulations are run for 200 seconds.

Table II Access Categories by EDCF

Access Category	Application Configured	Designation
AC(0)	HTTP(Heavy)	Background
AC(1)	Remote Login(Light)	Excellent Effort
AC(2)	Video Conferencing	Interactive Multimedia
AC(3)	VoIP	Interactive Voice

3.1Comparison of PCF and EDCF

The two protocols have been compared in terms of delay and throughput for voice and HTTP types of services because these are the most important types in VANETs applications.

3.1.1Delay for Voice

Fig.5 shows the delay offered by two protocols which is constant and zero in case of PCF protocol throughout the simulation. And for EDCF, it is constant and zero for a time period but after that it increases gradually. It means that delay offered by EDCF is much more as compared to PCF. Hence PCF must be preferred over EDCF for a greater no. of nodes in infrastructure based VANETs.

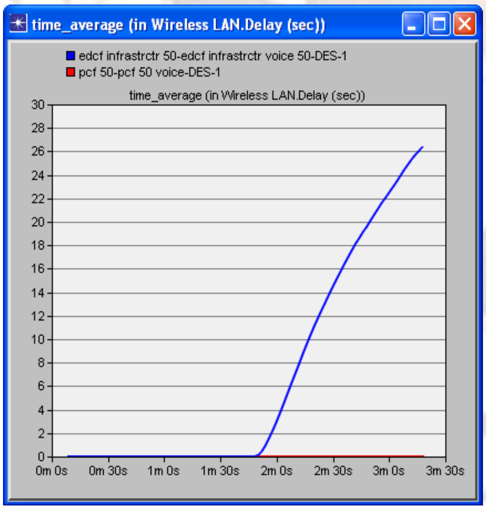

Fig.5.Delays by PCF and EDCF for Voice

3.1.2 Throughput for Voice

The Fig. 6 shows that for EDCF, throughput of EDCF is much better than PCF. As PCF shows maximum value of 3000 bits/sec, decreases after that and then comes to zero. On the other hand, EDCF gives maximum throughput of 9000 bits/sec.

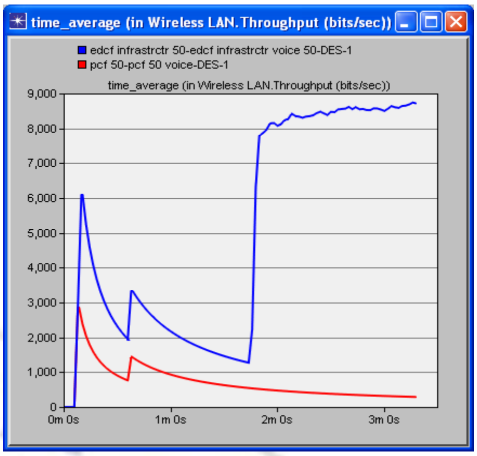

Fig.6.Throughputs of PCF & EDCF for Voice

3.1.3 Delay for HTTP

In Fig.7, for a particular time period, the delay of both protocols is constant and near about zero. After that, the delay increases gradually for both protocols but delay for PCF is much more than that of EDCF.

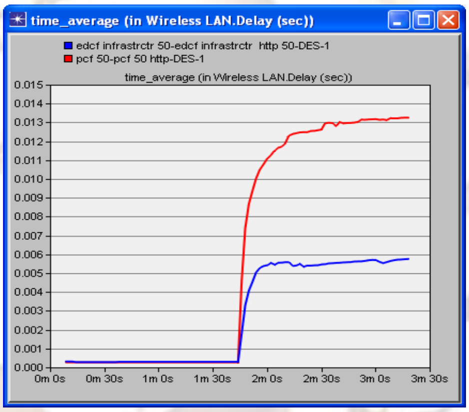

Fig.7.Delays by PCF and EDCF for HTTP

3.1.4 Throughput for HTTP

Initially, the throughput for EDCF is slightly greater than PCF and does not change very much. But after some period of time, throughput for both protocols increase sharply and they overlaps. After that, throughput increases gradually for both protocols but EDCF offers slightly greater than that of PCF.

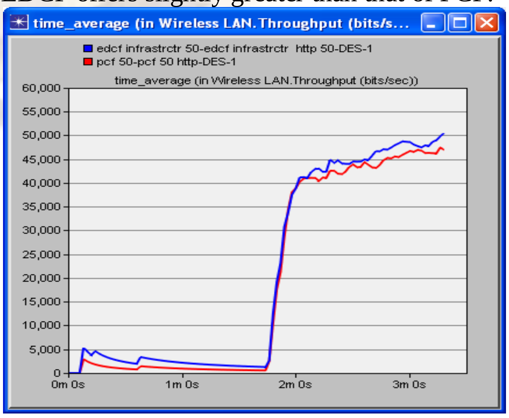

Fig.8.Throughputs of PCF and EDCF for HTTP

3.2 Performance of EDCF Protocol for Different Types of Services

The various services which have been taken are voice, video, HTTP and remote login. The performance has been evaluated in terms of delay, throughput, data dropped and retransmission attempts. The results are as follows:

3.2.1 Delay of EDCF

In Fig.9, there is no delay for the services HTTP and Remote login throughout the simulation. For video, the delay increases gradually and at a low rate. And for voice applications, the delay is maximum among all applications till the end of the simulation.

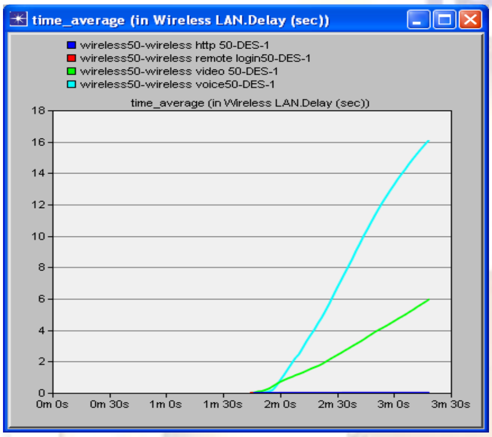

Fig.9. Delay of EDCF

3.2.2 Throughput of EDCF

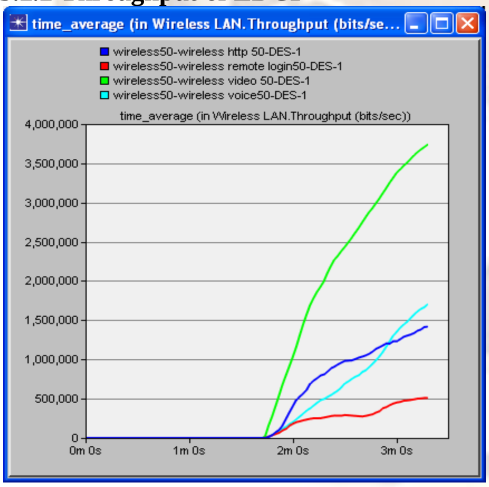

Fig.10. Throughput of EDCF

The Fig.10 shows the throughput for all traffic types which is maximum for video applications which is 4,000,000 bits/sec and even after this value it continues to increase. The throughput for all applications is zero and constant initially which causes overlapping of lines and then increases gradually for all. As compared to other applications, throughput of EDCF for Remote login is least. The throughput for HTTP greater than that of video but after some time reverse is there.

3.2.3 Data Dropped by EDCF

The Fig.11 represents the data dropped is zero and constant for HTTP and Remote login. For voice and video, the data dropped during transmission increases during simulation. For voice and video it increases sharply followed by gradual increases and after that becomes almost constant. Data dropped for video is maximum among all.

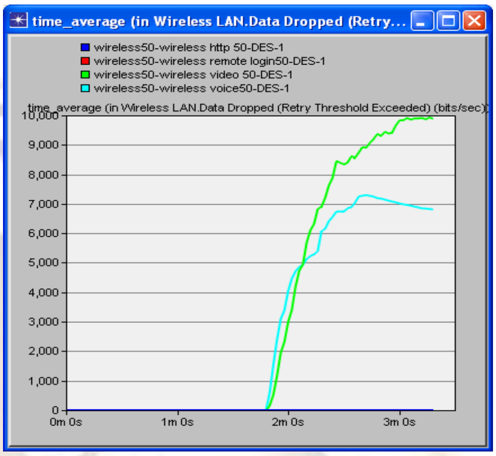

Fig.11 Data Dropped by EDCF

3.2.4 Retransmission attempts by EDCF

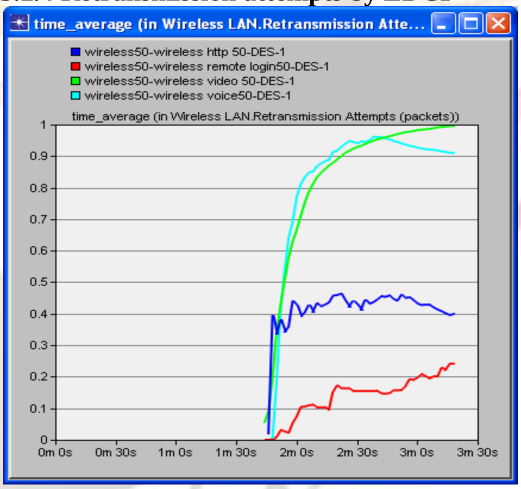

Fig.12 Retransmission attempts by EDCF

In Fig.12, for HTTP, the retransmission attempts increase gradually and for remote login they show sharp increase and become almost constant. But for real time applications, these attempts are more and they show sharp increase. But after that, these attempts start decreasing for voice and become almost constant for video. It concludes that retransmission attempts are maximum for video applications.

4. CONCLISION

The results obtained from the simulations show that EDCF performs better than PCF for different types of services. It provides less delay and more throughputs for delay sensitive applications such as voice and non-real time services such as HTTP. It is because EDCF provides efficient service differentiation which is not provided by PCF and hence can be efficiently adapted in VANETs. Due to service differentiation, the lower priority traffic types may be starved and never get transmitted. PCF may be adapted for delay insensitive applications as it shows better overall capacity and consider all traffic types equivalently. We have not considered the network conditions like fading and attenuation in the research work which can be the extension of this research.

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