Indian Journal of Science and Technology, *Vol 8(20), DOI:10.17485/ijst/2015/v8i20/52680, August 2015*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Centralised Enhanced forward Error Correction Mechanism on the Contention Window to Improve the Transmission Quality in Vehicular AD Hoc Networks

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Abstract

Background: Vanet the recent emerging technology in the recent industry has grabbed the attention with advanced techniques and extricate framework of sophisticated equipments. Initially absence of an infrastructure in this network has communication constraints for the nodes involved therein. Adding to this the dynamic topology makes the network more vulnerable for potential targets of security and reliability of data diffusion within these nodes. The communication standard i.e. 802.11p have some optional channel rejection in the Orthogonal Frequency Division Multiplexing in the Physical layer which motivated to work on the reliability methods of data dissemination. **Methods:** To start with the hidden terminal issues of these networks have to be addressed which can be resolved by frame capture. This frame capture quality in turn is determined by the Contention window of the Physical layer. Hence an adaptive mechanism that involves forward Error correction (AFEC) which helps to overcome packet losses in an efficient way in midst of channel fluctuation, burst packet loss. The results are simulated in NS2 (2.34) with static packet size of 512 bytes. **Findings:** The experimental results demonstrated that the FEC mechanism is more adaptive in adjusting and controlling the data redundancy across the network for static and dynamic channel fluctuations. The redundancy rate was further reduced with an adaptive technique on the Contention Window size, which had considerable effects of every transmission on the delay, through put and jitter. The centralized FEC algorithm is set on an adaptive platform where each vehicle updates its back off window size at the end of each Observation Time depending on the priority of the message received. The feasible part of this algorithm is that it can be implemented on the MAC layer, which has a Reception Module. Consequently, the proposed mechanism under various network conditions performs well in terms of QoS for emergency messages than the conventional methods for a less volume of data. **Application/Improvements:** The algorithm can be analyzed from a traffic scenario of two-way highway and rural areas. The progress of the work can also be carried out for multimedia messages.

Keywords: Contention Window, Data dissemination, Forward Error Correction Mechanism, QoS of message, Vanets

1. Introduction

The IEEE 802.11p in the Wireless Access in Vehicular Environment (WAVE) the specified standard for MAC in V2V communications uses the basic mechanism of the Distributed Co-ordination Function (DCF) which was originally designed for low mobility networks has an inefficiency for a high mobility communication in Vanets by Alasmary[1]. More over the performance of the 802.11p immaterial of the network depends on the number of communicating nodes, type of data traffic, back off procedure, scheduling optimization, channel estimation & equalization, mobility affection and carrier sensing range as said by Miao[2]. It was also observed by that the 802.11p showed a constant back off window size which had an unguaranteed throughput in the V2I framework as put forth by Wang[3].

According to Chen Y[4] et al while studying the performance of the 802.11 MAC in a single hop network found that the delay was always satisfied when compared with the Packet Delivery Ratio (PDR) decreased considerably with the increase in the number of nodes.

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Also Bilstrup K[5] found for emergency messages the Self Organized Time Division Multiple Access (STDMA) outperformed the Carrier Sense Multiple Access (CSMA) of the MAC layer of 802.11p.

It was observed by Rob Havelt[6] that IEEE 802.11p uses a fully standard complicate OFDM frame encoders in digital complex base-band representation that uses the USRP Version 2 as digital to analog front-end to up-convert and transmit them in the 5.9 Ghz band that has been allocated for Dedicated Short Range Communication (DSRC) for vehicular applications.

2. Related Work on Frame Capture

The effectiveness of an algorithm and the proposed methodology is judged with the Quality of service that is well explained by. Li J[7] for Adhoc networks. Here the author initiates the QOS from QoS aware routing technique with a Positional Attributes based Next hop Determination Algorithm (PANDA) next he implements QoS from the routing protocol by a Location Aided Knowledge Extraction Routing (LAKER) and finally addresses the end-to-end requirements by propounding an Adaptive Per Hop Differentiation (APHD) schemes. Ward L[8] has attempted to study the intelligence of the transportation system using the IEEE 802.11p standard and propounded that the contention window do have vital role in determining the quality of service.

In yet another work by Van Wijngaarden[9] where he attempted to study the frame capture issues in IEEE 802.11p and concluded that the capture behavior is dependent on the arrival time of the frames in compliance with the Physical Layer Convergence Protocol (PLCP). It is observed that frame capture is very important whilst resolving the hidden terminal problems in vehicular Adhoc networks. Han C[10] and his colleagues in proposing an analytical model for the throughput of the Enhanced Distributed Channel Access (EDCA) found that different Contention Windows (CW) and Arbitration Interframe Space (AIFS) do play a vital role for the channel access also approved by Han[11] and Song[12].

As observed by Havelt[6] it has been clearly stated that proper mitigation techniques need to be deployed for preventing interference that include Synchronized transmissions, Synchronizing Time Division Multiple Access (TDMA), Maintaining specified separation between antennas, Changing power levels to reduce signal levels at the potential interference points, Operating at different frequencies and alternating channels. It is also mentioned in the requirements to accomplish vehicle data transfer to reduce interference many installation characteristics are to be followed among which using a separate channel from the two channels used in the intersection eliminates the remaining interference potential by Havelt[3].

The Mobility impact of the vehicles on the performance of IEEE 802.11p MAC protocol was studied and two different solutions were propounded for adapting the same using the mobility parameters like Transmission time and the relative speed based on the service priorities. It was observed that both the schemes reduced the contention level, which thereby reduced the collision, packet dropping rate and increasing the throughput.

Sun[13] as a performance study of IEEE 802.11p for vehicle-to-vehicle communication using opnet found that the IEEE standard is less costly than the other communication standards like RR-ALOHA or D-MAC. It is also found 802.11p uses Orthogonal Frequency Division Multiplexing (OFDM) and Enhanced Distributed Channel Access (EDCA) to cope with the changing communication environment and to provide priority based services.

A cluster based multi channel communication scheme to best use the DSRC channels was proposed by Su.H[14]. The vehicles were presumed to have DSRC transceivers, which made them, work simultaneously on the two channels viz. Control channel and Service channel for a stipulated time period. Once the cluster head is selected it uses one of its transceivers using contention free TDMA-MAC to collect the safety message during the first sub-period and deliver the messages along with the control packets to other nodes

Rawashdeh[24] proposed yet another cluster based media access technique separately for intra-cluster and inter-cluster communication where again the control channel is used to deliver safety data and service channel for both safety and non safety messages. The service channel is divided into Cluster Member Period (CMP) where the nodes sent its status, safety messages and any other advertisement while during Cluster Head Period (CHP) is meant to process all received messages and respond to requests. This hybrid method avoids inter-cluster interference and found that the cluster density and delay are directly proportional.

3. Proposed Architecture

The IEEE 802.11 have clear specification for Physical (PHY) and Medium Access Control (MAC) for wireless area networks in which the MAC has a Distributed Co-ordination Function (DCF) access method which is a carrier sense multiple access with collision avoidance (CSMA/CA). The 802.11 specification also supports yet another Point Co-ordination Function (PCF) which is a centralized MAC protocol supporting collision free and time bounded services. The DCF technique of packet transmission is a two way handshake i.e. a Request-To-Send (RTS) is sent for every packet that has to be transmitted and the receiving node of that packet responds by sending a Clear-To-Send (CTS) packet after which the real transmission of data starts. But as it is carrier sense the transmitting node first sense whether the medium is busy, if so it waits for the DCF interframe space (DIFS) to be idle for a chosen backoff counter (the amount of time the station must wait until it is allowed to transmit). This backoff counter is given by:

Back-off Time = rand (0, CW) x slot time

Which is frozen when the medium is busy and has a sequential decrease only when the medium is idle. This process is repeated until the backoff counter reaches to zero and the station is allowed to transmit. This idle period of the medium after the DIFS period is the Contention window (CW) as given in Figure 1. This CW is initially assigned the minimum size which is denoted by CW_{min} which is doubled each time the station experiences a collision until the CW reaches a maximum i.e. CW_{max} which remains the same in spite of more collisions. Once the transmission is successful CW is reset to the initial value of CW_{min}. There are chances of the packet being discarded if it cannot transmit after certain number of retries.

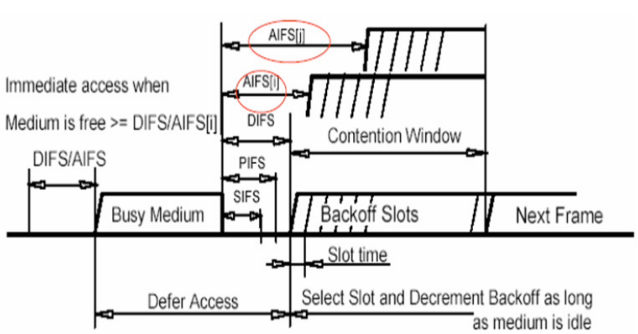

Figure 1. Contention Window in 802.11 [18]

This is always an issue to guarantee on the QoS requirement of the messages especially when it comes for emergency. In this regard many techniques have been put forth to enhance the MAC performance in EDCF. One such method is suggested by Yunli Chen[4] where a Optimal Contention Window (OCW) is propounded in which the traffic is classified into traffic categories and it is assumed that each station always has a packet available for transmission with no capture and experiences a back off. It is also assumed that each packet collides with constant and independent probability *p* and for each packet the average back off counter is W/2. Each packet has its arbitration interframe space (AIFS) and its minimum CW which helped to determine the back off counter. In the OCW the focus is on the CW which aids to provide a priority measure to the packets i.e. to the messages in turn. The federal communication committee claims as propounded by Li[16] is that it is mandated to have the seven-channel band plan to the DSRC for the vehicle communication which is divided into seven channels i.e.Ch 172, Ch174, Ch176, Ch178, Ch180, Ch182, and Ch184 as given in the Figure 1.

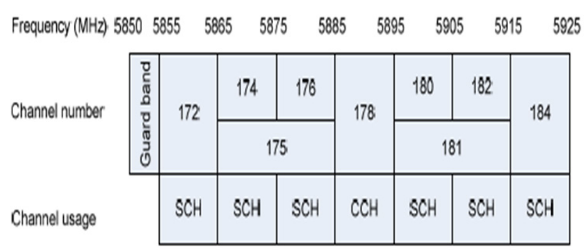

Figure 2. Channel Allocation in DSRC [18]

From the Figure 2 it is clear that Ch178 is the dedicated control channel that is being used to deliver safety messages and announcements. Ch172 is the high-availability and low latency channel for vehicle safety and high-priority applications. The remaining five channels are the service channels. It was found Van Eenennaam M[17] that the typical handshake mechanism did have a overhead on the channel switchover especially in Vanets. To overcome this 802.11p introduced the Wave BSS where the node broadcast one message and a demand beacon, which contains all information that is required for the receiving node like position, speed, acceleration and direction of the node, which is sent at regular interval i.e. 100ms. The Distributed Co-ordination Function in the MAC is shown in Figure 3.

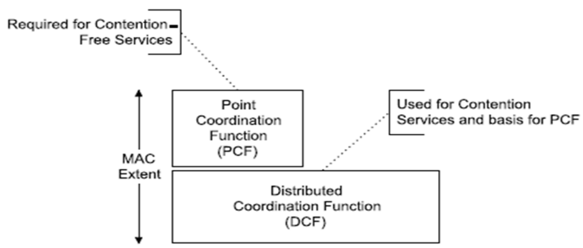

Figure 3. Distributed Coordination Function18[18]

4. Adaptive Packetization Technique

In this technique we are adhering to the packet recovering technique used by the wired network. The unavoidable packets are recovered by using Automatic Repeat Request (ARQ) or Forward Error Correction (FEC). The difference between these is that in the former the missing packets are retransmitted during timeouts or explicit receiver request but in the latter the packet loss is prevented by transmitting redundant information that is required to rebuild the missing data. When it comes for multimedia or a dynamic network like vanets retransmission incurs considerable delay hence in such situation FEC is handy. Hence in an infrastructure network the Access Point (AP) is a good place for adding the FEC mechanism but in our infrastructure-less the RSUs are the best place to implement the FEC algorithm.

First in this section for the DCF-CSMA we explore the transmission probabilities that optimize its performance as suggested by Yedavalli K[18] for every successful packet transmission. In the proposed method instead of the window based backoff method the same is determined by the transmission probability p such that the station transmissions probability is *p* and the idle time is *1-p* for the subsequent time slot when the medium is also busy. The time interval between two consecutive successful transmissions is defined as epoch. Thus the average Transmission Time at an epoch *E* [TT] is given by:

$$E\,[TT] = E\,[T_{total\ idle}] + E\,[T_{collision}] + E\,[T_{success}] \quad (1)$$

where = *E* [$T_{total\ idle}$] is the average time in idle between two consecutive transmission of the medium, *E* [$T_{collision}$] is the total time of collision and *E* [$T_{success}$] is the successful transmission time length at the end of the transmissions. As it has a constant probability of transmission *p* within an epoch the *total idle* between any two consecutive packet transmissions is to have the same mean value. It is also observed that the decision to transmit in a given time slot after sensing the medium to free is independent of the previous free channel senses and the number of collisions is independent of the total idle time which makes us arrive at the given two equations.

Let the delay be *D* incurred between two successive transmissions which is given by

$$D = \frac{1-(1-p)^{n}}{n\,p(1-p)^{n-1}} - 1 \quad (2)$$

Where *n* is the contending node in the network. With a constant packet size *L, D* the length of DIFS and the time slot for p-persistent CSMA for IEEE 802.11p having a standard propagation length t_{time} above equation for the total collision time reduces to

$$D = \left(\frac{1-(1-p)^{n}}{Np(1-p)^{n-1}} - 1\right)(L+D) \times t_{time} \quad (3)$$

The same way the delay for the idle time for n given contending nodes is given by (4)

$$T_{idle} = \frac{(1-p)^{n}}{1-(1-p)^{n}} \quad (4)$$

Hence the same for a packet size *L, D* the length of DIFS along with the delay is calculated by the equation (5)

$$T_{coll} = \left(\frac{1-(1-p)^{N}}{Np(1-p)^{N-1}}\right) - 1\left(\frac{(1-p)^{n}}{1-(1-p)^{n}}\right) \times t_{time} \quad (5)$$

Similarly the time spent for a success transmission is given by the equation (6)

$$T_{success} = (L + D)\,.\,t_{time} \quad (6)$$

Therefore the average Transmission Time (T) at an epoch *E* [TT] is deduced from the equations (3) (5) and (6) to as given in Eqn. (7)

$$T = E[TT]\left(\frac{(L+D)-(L+D-1).(1-p)^{n}}{n.p(1-p)^{n-1}}\right) \times t_{time} \quad (7)$$

For each packet the average back off counter is CW/2 and the successful transmission period has T slots. The collision period (C) includes the average transmission time (T) the Delay (D) and the propagation time t_{time}. The packet waits for *p.CW*/2 transmissions before its back off counter decreases to 0 and the average transmission period is *p*.C + (1-*p*)T. The packet will try for a 1/(1-p) times before it is successfully transmitted. Hence the delay (D) is given by

It is found by Chen Y[4] that the average delay will decrease then the CW increases from 16 and when it reaches the minimum D and CW will increase hand in hand. It was also observed in the calculation for given n = 20, t_{time} =0.01 , CW=104 the delay D = 25.09 and when gradually the CW was increased to 331 the delay remained the same. Hence, to have an optimal transmission quality it was decided to fix the CW to 331.

The effects of the CW size changes after every successful transmission on delay, throughput and jitter by Han[11] and Khalaj A[20,]. It is also observed that when the CW size remains larger the better was the throughput in spite of high jitter in heavy loads. Whenever the packet collides, a method is deployed where instead of resetting CW size to its minimum size after any successful transmission it is set to half of its current size which intuitively reduced the variation in the back off window and delay. In yet another method he tried the same technique but by deploying different reduction in CW size in four different tests and its influence in the performance on three traffics data, audio and video. Test 1: same as above Test 2: $CW = CW_{min} + (CW_{current} - CW_{min})/4$ Test 3 : $CW = CW_{min} + (CW_{current} - CW_{min})/2$ and Test 4 : $CW = CW_{min} +3 (CW_{current} - CW_{min})/4$. It is found that keeping CW size larger did provide high throughput and better fairness in heavy load especially in heavy load. More over it is also observed that the Test1 and Test2 suited well for multimedia and Test3 and Test4 for data traffic provided high throughput. Hence, it was decided to stick to the Contention Window size either to Test3 or Test4.

5. Centralized Enhanced Forward Error Correction Algorithm

The centralized enhanced forward error correction algorithm is explained in Table 1 which is based on the Forward error correction techniques as propounded by Gandikota[21], Flardh[22] and Longzhe[23]. The results were evaluated through simulations in NS-2. The following are the simulation settings to which the algorithm is adopted.

- Every vehicle is subjected to a CBR traffic with packet size 512 bytes.
- All transmitting vehicle is able to hear all others i.e. there is no hidden terminal problem
- Simulation length is 20 secs and the number of nodes is fixed for 78
- The algorithm is simulated only for a normal and emergency messages where the CW has an increasing factor of 2.5
- T^i_{busy} is the busy state of the channel
- The transmission range is about 70m and the largest distance of a vehicle to the base station is 20 m.

Table 1. Algorithm

Algorithm Centralized Enhanced FEC
$CW = CW_{init}$
while v is in T do
if end of *ith* OI then and emergency=1
$r^i_{busy} = T^i_{busy} / T_{oi}$
$\alpha_i = r^i_{busy} - r^{i-1}_{busy}$
if $\lvert \alpha_i \rvert > \lvert CW_{min} \rvert$ then
if $\lvert \alpha_i \rvert > 0$ and less than α_{thres} then
$CW = CW_{min} + (CW_{current} - CW_{min})/2$
endif
else if v is still in T and $\lvert \alpha_i \rvert$ =< α_{thres}
AND still emergency = 1
send beacon using FEC
$CW_{min} +3 (CW_{current} - CW_{min})/4$
endif
else
CW remains unchanged
endif
elseif emergency=0
Use previous CW and keep observing
$T^i_{busy} = T^i_{busy} + T^i_{newbusy}$
Endif
Endwhile

The centralized FEC based algorithm starts from the assumption of an Observation Interval (OI) which is much larger than the average Transmission Time (*T*). The algorithm is set on a stage where each vehicle updates its back off window size at the end of each OI. At any interval of time *i* the station compares its current busy proportion with the previous one and the difference is computed as α_i another variable α_{thres} is introduced which is always checked for the value of 331 which is initially set to CW_{min}. This updating of the CW is based on heuristic that the number of vehicle size increases so the CW also has to. The algorithm can be easily implemented on the communication component of each vehicle as the MAC layer has a Reception Module, which identifies the end of each OI by counting the number of ACKs received.

6. Numerical Results

We have simulated and compared our algorithm mentioned in the previous section to evaluate its performance with regards to the CW size during emergencies for throughput, delay and jitter as these parameters have a major role in the performance metric for vehicular safety communication by Eichler[24] and Jafari[25]. The model was simulated initially by increasing the number of nodes gradually from 5 to 75 for a data packet of 512 bytes with beacon messages which helped us to estimate the performance under heavy load. The parametric estimation for delay and throughput is only considered. The parameters considered for the simulation results is given in Table 2.

Table 2. Simulation parameters

Parameter	Normal Message	Emergency Message
CW_{min}	31	31
CW_{max}	1023	1023
IFS	90 us	90 us
CW increasing factor	2	2.5
Flow rate	120 KBps	120KBps
Beacon size	400	400 bytes
Scheduling	FIFO	FIFO
MAC	802.11	802.11

It was observed that there was not much of a change in the delay upto a load of 40 but when the load increased the emergency message had a 40 percent less delay compared to the normal message with a gradual increase of 10 per loads, which is seen in the Figure 4. When the load increases there tends to a linearity of delay with the messages.

In regards of throughput, the results can be visualized in Figure 5. We see here that the throughput was much better for emergency than the normal ones. The throughput did show a gradual decline over a certain period when the load increased gradually. It was also observed that the throughput did have a steep fall and become linear when the load increased i.e. there was not much of increase in the throughput after there was a increase in the nodes up to 90.

From Figure 6 the jitter is observed to much better for the emergency rather than the normal ones.

To conclude the results for the normal message is compared with the normal data traffic of the work of Khalaj[20] for a delay and throughput. Our algorithm did show a 30percent improvement than the Second Proposed Algorithm (SPA) of [20]. The error delivery of urgent messages was found only 0.11percent for every 100 messages delivered.

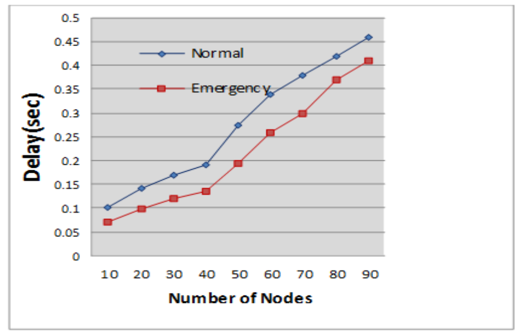

Figure 4. Delay of the messages.

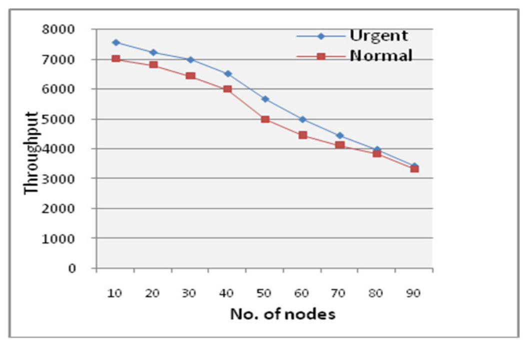

Figure 5. Throughput.

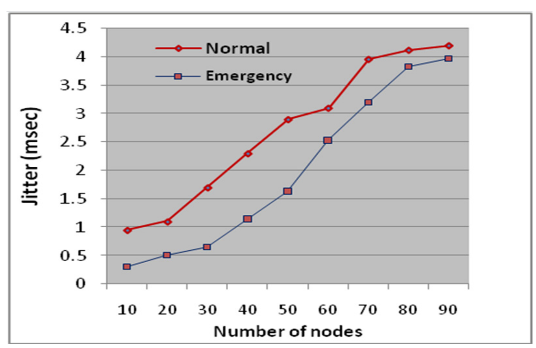

Figure 6. Jitter.

This results were compared with the earlier work of this research *PRIORITIZED DIRECTIONAL BROADCAST TECHNIQUE FOR MESSAGE DISSEMINATION IN VANETS* (PDBT)[26] for delay and throughput for normal messages. It is found that our CEFEC algorithm outcast the earlier more for a very normal message which is very much seen in Figure 7 and Figure 8.

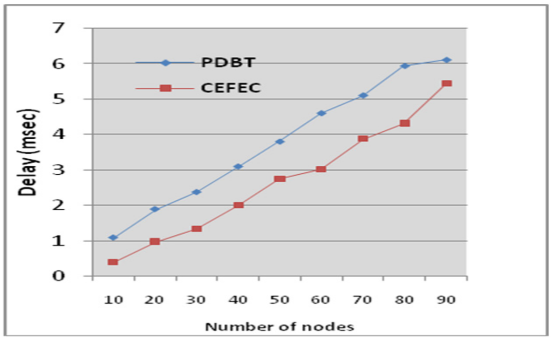

Figure 7. Delay comparison.

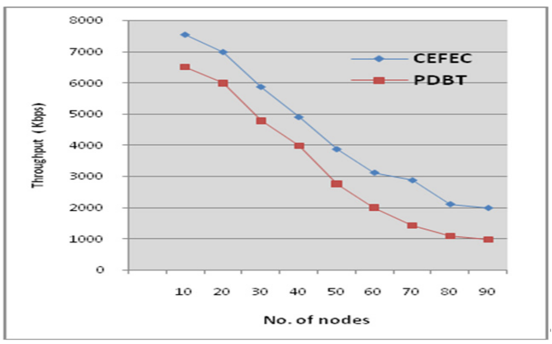

Figure 8. Through put comparison of PDBT and CEFEC.

7. Conclusion

It is observed that from the work that the Centralized Enhanced FEC algorithm had a successful transmission in cases of both emergency and normal messages with the adaptive FEC technique on the CW. The throughput remained larger and the delay was much low. The progress work is to analyze the packet drop on emergency messages on a two way highway and rural areas. The real time implementation of this project is going on with two laptops connected between two cars and disseminating messages of priority among them. The project has also been applied for sponsored funds.

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