ITS- 802.11p TABANLI HAREKETLİ ARAÇLARIN HABERLEŞMESİ

ITS- 802.11p BASED VEHICULAR COMMUNICATION

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Başkent Üniversitesi
Lisansüstü Eğitim Öğretim ve Sınav Yönetmeliğinin
ELEKTRİK-ELEKTRONİK Mühendisliği Anabilim Dalı İçin Öngördüğü
YÜKSEK LİSANS TEZİ
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ÖZ

ITS- 802.11p TABANLI HAREKETLİ ARAÇLARIN HABERLEŞMESİ

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Başkent Üniversitesi Fen Bilimleri Enstitüsü
Elektrik-Elektronik Mühendisliği Anabilim Dalı

Günümüzde kablosuz haberleşmenin uygulama alanları, farklı arayüzler sunarak genişledi. Bu uygulamalardan biri olan Akıllı Ulaşım Sistemi(ITS, güvenli haberleşme ve trafik yönetiminin geleceğinde hayati rol oynayacaktır. Özellikle kentsel bölgelerde, haberleşme yoğunluğu aşırı artar ve bu durum kullanıcılar için haberleşme ağının doygunluğa ulaşmasına neden olur. Doygun bir haberleşme ağında paketlerin çarpışma olasılığı çok artar. Paketlerin çarpışma olasılığındaki artış, işlenen veri miktarının üstel olarak azalmasına neden olur. Bu durum, IEEE 802.11 standardına ait MAC'ın en iyi bilinen problemlerindendir. Bu tezde, paketlerin çarpışma olasılığının artışı problem ile başa çıkabilmek ve işlenen veri miktarını arttırabilmek için CEA ve DEA algoritmalarını mevcut IEEE 802.11p protokolünde yer alan MAC katmanında geliştirme modeli olarak önermekteyiz.

Bu tezin amacını, kısaca, doygun ağ haberleşmesinde, paket çarpışmalarını azaltmak, işlenen veri miktarını arttırmak ve paket çarpışmasını kontrol etmek için, haberleşme kanalının bir önceki durumu ve aktif olarak haberleşmekte olan kapsama alanındaki düğüm sayısı bilgilerine bağlı olarak, MAC katmanında kullanılan geri-çekilme (backoff) mekanizması üzerinde hareket halinde güncelleme yapılması olarak özetleyebiliriz.

Anahtar Sözcükler: Güvenli Haberleşme, paket çarpışması, doygun ağ haberleşmesi, paket çarpışmasının kontrolü, CEA, DEA, geri çekilme algoritmaları, IEEE 802.11p

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ABSTRACT

ITS- 802.11p BASED VEHICULAR COMMUNICATION

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Nowadays, wireless communications have spread to many application areas by serving different interfaces. Intelligent Transportation System is one of them which will play vital role for the future of safety communication and traffic management. Especially in the urban regions the communication density increases highly which causes saturated network for the vehicles. In the saturated network the collision probability increases abruptly that leads to exponential decrement of the throughput which is the well known problem of IEEE 802.11 standard MAC. In this thesis, to overcome with this problem and to increase the throughput, we propose two enhancement models such as CEA and DEA algorithms in MAC-layer protocol which is based on IEEE802.11p standard. Basically we update the back-off mechanism on the fly according to the knowledge of the previous state of the channel and the number of the active nodes within communication range in order to reduce the packet collision, to increase the throughput and to control congestion in the saturated network.

Keywords: safety communication, packet collision, saturated network, CEA, DEA, congestion control, backoff algorithms, IEEE 802.11p

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ITS	Intelligent Transportation Systems
WAVE	Wireless Access in Vehicular Environment
DSRC	Dedicated Short Range Communications
OBU	On Board Unit
RSU	Road Side Unit
CBR	Constant Bit Rate
CW	Contention Window
CEA	Centrelazed Enhancement Algorithm
DEA	Distributed Enhancement Algorithm
VT	Virtual Transmission Time
OI	Observation Interval
PHY	Physical
MAC	Medium Access Control
ETSI	European Telecommunications Standard Institute
FCC	Federal Communications Commission
OSI	Open System Interconnection
WME	WAVE Management Entity
WSMP	WAVE Short Message Protocol
UDP	User Datagram Protocol
TCP	Transport Control Protocol
QoS	Quality of Service
EDCA	Enhanced Distributed Channel Access
ASTM	American Society for Testing and Materials
EIRP	Effective Isotropic Radiated Power
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications
DCF	Distributed Coordinaton Function
DIFS	Distributed Interframe Space
SIFS	Short Interframe Space
AIFS	Arbitrary Interframe Space
CCH	Control Channel
SCH	Service Channel
RTS	Ready to Send
CTS	Clear to Send
UTC	Universal Time Coordinated
AC	Access Categories
BK	Background Traffic Category
BE	Best Effort Category
VI	Video Category
VO	Voice Category
BEB	Binary Exponential Backoff

1. INTRODUCTION

Growing demand for information effects the evolution of the wireless communication Technologies based on hardware and software. The wireless communication technology and industry proceeds with respect to the current requirement of humanbeing. For the wireless communications, the key points are being mobile and ubiquitous in this era. Vehicular communication serves for these requirements entirely. The vehicular communication can play an essential role to develop the driving safe paradigm which is being much bigger concern for the humanbeing. Beside we foresee that the mobile data traffic is growing so fast that there will be an allocation problem to provide mobile spectrum for clients and servers. ITS(Intelligent Transportation System) is one of the application area to meet the needs for safety drive. The aim of ITS is increasing the efficiency of road traffic as a summary. To achieve this goal, there are Wireless Access in Vehicular Environment systems which use IEEE802.11p and ASTM 2213 for the PHY and MAC layers in their protocol stacks. According to OSI- layer structure, we will focus on the IEEE 802.11p standard which is used for Dedicated Short Range Communication. The Dedicated Short Range Communication determines operating parameters for PHY and MAC layer such as communication range, operating frequency, data rate. DSRC Band, provides very high data transfer rates in circumstances where minimizing latency in the communication link and isolating relatively small communication zones are important. [1]

In the vehicular communication, there are some common problems like other wireless communications systems. The most popular ones are hidden terminal problem and packet collisions. In order to overcome hidden node terminal problem, the MAC-layer uses RTS/CTS method which is used for handshaking while transmitting and receiving packets. However, even we overcome the hidden node problem, the packet collision can decrease the throughput significantly. Because too much vehicles on the road means too much collision. To mitigate the collision of packets, the MAC-layer uses back-off scheme. In [19], it is mentioned that the capturing the previous channel status impacts the collision probability. In [20], the method to handle with the low performance of IEEE 802.11's MAC protocol in terms of throughput is using adaptive backoff scheme such as adaptive binary exponential backoff which is based on estimation of the number of active stations in the network and adjusting optimal backoff window size according to this online information. In this thesis, we evaluate the performance of alternative backoff algorithms (CEA and DEA) in a saturated network which were proposed in [12]. CEA utilizes the similar metholody with the [20]. The second algorithm, DEA, is based on the information of the previous state of the channel as it is in [19]. Beside in [21], it is proposed that to optimize the contention window size, the number of idle slots can be used to lead the high throughput. By composing both of propositions, [19] and [21] DEA can be implemented. The alternative backoff algorithms, CEA and DEA, were compared with the IEEE 802.11p standard back off scheme in the simulator environment. As a simulator, we used NCTUns [16]. The NCTUns is a network simulator which has a open source code that gives you the oppurtinity for modifying easily and modular implementation. Hence, the enhancement of backoff algorithms were implemented in MAC module.

IEEE 802.11p occupied MAC-layer has the exponential back off mechanism. But when the number of vehicles increase or with high data rate packet collisions occur much more so that the original IEEE 802.11p back-off algorithm cant handle with the agressive packet traffic. As a result the throughput decreases abruptly. The goal of this thesis is to prove the effect of selection of backoff algorithms with respect to dynamism of the road traffic. In Sec. 2, we introduce the ITS, WAVE, DSRC, IEEE 802.11p concepts. Then in Sec. 3, we mention about PHY and MAC-layer protocol of 802.11p with their features, In Sec 4 we propose two different algorithms with their analytical backgrounds to control the congestion and maximize the throughput. In Sec. 5 we show the results related with the new back-off mechanisms, make conclusions about the simulation results and future work.

2. SAFETY DRIVE CONCEPT AND VEHICULAR COMMUNICATION

2.1. ITS

ITS is the system consisting of human, road and vehicles. For coordination among human, road and vehicles, wireless communication technology connecting human, road and vehicles is necessary to exchange information each other. [2]
As an formal expression:"Intelligent Transport Systems and Services (ITS) are defined as "any system or service that makes the movement of people or goods more efficient and economical, thus more 'intelligent'" [3].
ITS service and applications can use in various areas such as electronic tolll collection, homeland security, safety service by navigating the driver or sharing the instantenous traffic information for the traffic management.

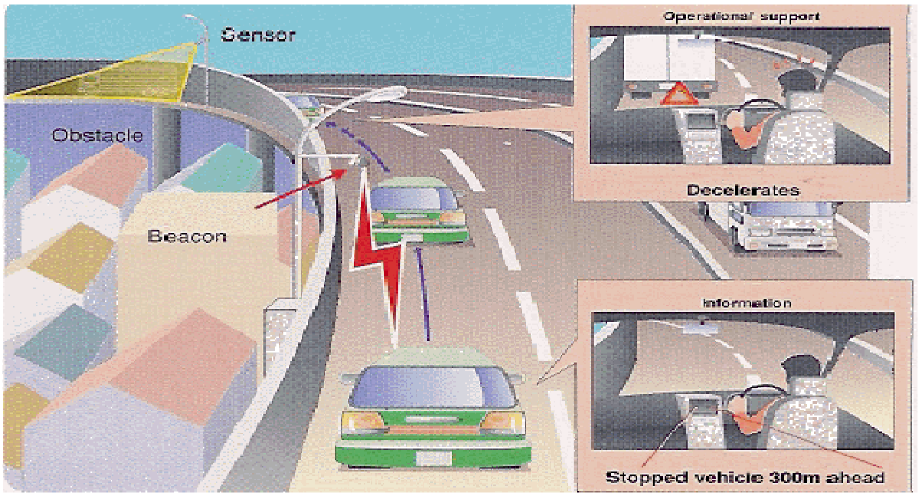

Figure 1 ITS-Roadside Infrastructure Based Warning Systems

2.2. WAVE

In order to support various safety and commercial applications in vehicular environments, the IEEE 1609 and IEEE 802.11p [3] task groups developed an IEEE 802.11 WLAN based vehicular communication system, known as Wireless Access in Vehicular Environments (WAVE). This system works on the 5.9GHz ITS frequency band regulated by 2, where IEEE 802.11p standard specifies the Physical layer (PHY) and the basic MAC. All above layers of WAVE are regulated by the IEEE 1609 standard family. [5]

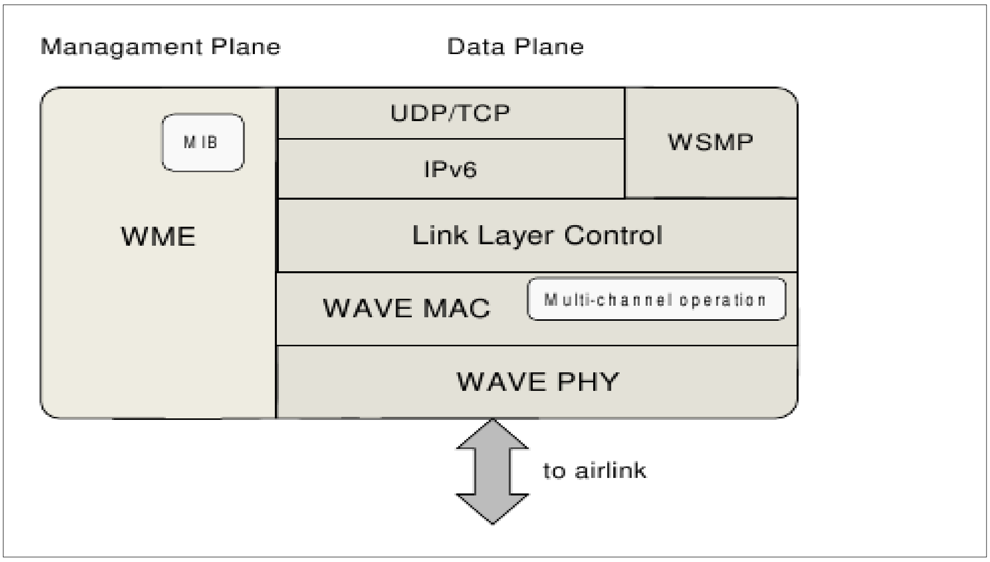

Figure 2 WAVE System-Protocol Stack

As it is seen in Figure 2, the WAVE-System-Protocol Stack consists of two main parts. One of them is Management Plane, other one is Data Plane.
Management Plane is used to configure and manage the system with WME(WAVE Management Entity).

Data Plane is used to deliver data. It includes two communication protocols, IPv6 and WAVE Short Message Protocol. WSMP is a low overhead protocol designed to optimize WAVE operation, which permits applications to control physical parameters such as the transmission power, the data rate and the channel number.
On top of IPv6, although both TCP (Transport Control Protocol) and UDP (User Datagram Protocol) are supported, the latter one is expected to be used by most applications due to its low overhead and latency. [5]
In IEEE 1609.4, the multichannel operations are implemented such as channel routing, user priority, channel coordination, MAC Service Data Unit data transfer.

Beside for the prioritization of applications, it includes eight levels of priority category which is the enhancement version of IEEE802.11e(QoS).

2.3. DSRC

Wireless technologies can support road safety applications by two means: by the periodic transmission of 'status' messages of each node and by the dissemination of 'hazard' messages once a potential danger has been detected [5]. DSRC is a short to medium range communication service that supports both Public Safety and Private operations in roadside to vehicle and vehicle-to-vehicle communication environments such as accident avoidence, intersection coordination, danger warning. [1]

The Dedicated Short Range Communication (DSRC) standards group devised a channel switching scheme that includes a control channel in order to support a site licensing system for roadside transponders, a general priority system for applications, and still use the full spectrum of the DSRC band. The spectrum is divided into several channels: control channels and service channels. The basic concept is that the control channel will support very short announcements or messages only, and any extensive data exchange will be conducted on service channels . [6]

In 1999, the U.S. Federal Communication Commission allocated 75 MHz of Dedicated Short Range Communication (DSRC) spectrum at 5.9GHz to be used exclusively for vehicle-to-vehicle and infrastructure-to-vehicle communications.

The DSRC spectrum is divided into seven 10 MHz wide channels. Channel 178 is the control channel, which is generally restricted to safety communications only. The two channels at the edges of the spectrum are reserved for future advanced accident avoidance applications and high-powered public safety usages. The rest are service channels and are available for both safety and nonsafety usage. [7]

"DSRC" has different meanings, different technical characteristics and different operating frequencies around the world in the transportation sector. It is closely linked with IEEE802.11p which describes the lower layers of DSRC [6]. In Figure 3, we can see the connection between IEEE 802.11p module and DSRC.

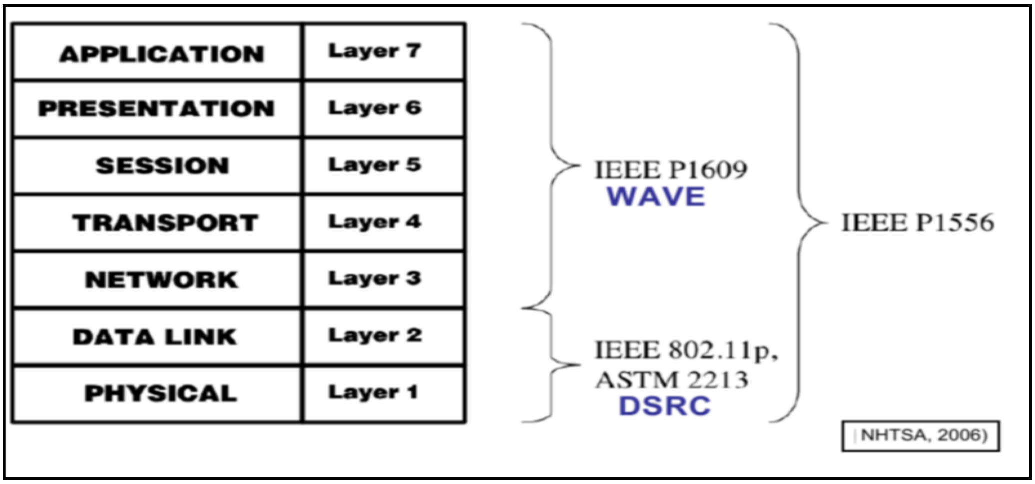

Figure 3 WAVE and DSRC Protocol Stack within OSI-Model

All knowledge and complexities related to the DSRC channel plan and operational concept are taken care of by the upper layer IEEE 1609 standards. In particular, the IEEE 1609.3 standard covers the WAVE connection setup and management [6]. The IEEE 1609.4 standard sits right on top of the IEEE 802.11p and enables operation of upper layers across multiple channels, without requiring knowledge of PHY parameters [7]. IEEE 802.11p addresses the physical layer and medium access control layer (MAC) called 802.11p module.

2.4. Overview of IEEE 802.11p Module

The FCC ruling for IEEE802.11p Wireless Access in Vehicular Environment (WAVE) is based on the ASTM (American Society for Testing and Materials) standard E2213-03 where the 5.9 GHz (5.850-5.925) band is divided into seven 10 MHz channels (one control and six service) at power levels up to 44.8 dBm (30 Watts) EIRP for road side units (RSUs) and 33 dBm (2 Watts) EIRP for on board units (OBU) [6]. The Physical and MAC- layer's details are mentioned in the next section.

3. FEATURES OF PHY AND MAC LAYER in IEEE802.11p

3.1. Physical Layer

The Physical Layer based on 8022.11p is a variation of the OFDM based IEEE 802.11a standard. The IEEE 802.11a PHY employs 64- subcarrier OFDM. 52 out of the 64 sub-carriers are used for actual transmission consisting of 48 data sub-carriers and 4 pilot sub-carriers. The pilot signals are used for tracing the frequency offset and phase noise. The short training symbols and long training symbols, which are located in the preamble at the beginning of every PHY data packet, are used for signal detection, coarse frequency offset estimation, time synchronization, and channel estimation. A guard time GI, is attached to each data OFDM symbol in order to eliminate the Inter Symbol Interference introduced by the multi-path propagation. In order to combat the fading channel, information bits are coded and interleaved before they are modulated on sub-carriers. IEEE 802.11p PHY takes exactly the same signal processing and specification from IEEE 802.11a except for the following changes:

1. Operating frequency bands for IEEE 802.11p are 5.9 GHz American ITS band. The 75 MHz are divided in seven 10 MHz channels and a safety margin of 5 MHz at the lower end of the band. The center channel is the control channel, on which all safety relevant messages are broadcasted. The remaining channels are used as service channels, where lower priority communication is conducted after negotiation on the control channel As an option two adjacent service channels may be used as one 20 MHz channel. The European frequency regulation Conférence Européenne des Administrations des Postes et des Télécommunications (CEPT) is currently working on a similar frequency allocation.
2. In order to support larger communication range in vehicular environments, four classes of maximum allowable Effective Isotropic Radiated Power (EIRP) up to 44.8 dBm (30W) are defined in IEEE 802.11p. The largest value is reserved for

use by approaching emergency vehicles. A typical value for safety relevant messages is 33 dBm.

3. To increase the tolerance for multi-path propagationeffects of signal in vehicular environment, 10 MHz frequency bandwidth is used. As the result of reduced frequency bandwidth, all parameters in time domain for IEEE 802.11p is doubled comparing to the IEEE 802.11a PHY. On the onehand this reduces the effects of Doppler spread by having a smaller frequency bandwidth; on the other hand the doubled guard interval reduces inter-symbol interference caused by multi-path propagation.
4. As a result of the above the data rate of all PHY modes is halved. [8]

The following comparison table for 802.11p and 802.11a Physical Layer parameters are shown in Table 1.

Table 1 802.11p and 802.11a PHY Layer-Parameters Comparison

Parameters	**802.11a**	**802.11p**
Channel Bandwidth	20 MHz	10 MHz
Frequency	5.0 Ghz ISM Band	5.850-5.925 MHz
Data Rate	6-54 Mbps	3-27 Mbps
Modulation	BPSK OFDM, QPSK OFDM, 16-QAM OFDM, 64-QAM OFDM	BPSK OFDM, QPSK OFDM, 16-QAM OFDM, 64-QAM OFDM
Error Correction Coding	Convolutional Coding-K=7	Convolutional Coding-K=7
Coding Rate	1/2,2/3,3/4	1/2,2/3,3/4
Number of Subcarriers	52	52
OFDM Symbol Duration	4.0 µs	8.0 µs
Guard Period	0.8 µs	1.6 µs

3.2. MAC LAYER

The MAC layer of 802.11 is responsible for providing equal access to the shared, unreliable wireless media and reliable data transfer over the same. Although it is shared, no two transmissions can occur at the same time, since both transmissions would probably fail because of interference. Access to the shared media is regulated with the CSMA/CA scheme based on DCF(Distributed Coordination Function) . [9] The DCF implies following sequence :

1- When a frame arrives at the MAC layer to be transmitted the status of the channel must be checked.

- ➢ if the channel is sensed idle at this point and during a DIFS (DCF Interframe Space) time interval, the station can proceed with the transmission.
- ➢ if the channel is busy, or becomes busy during that interval, the transmission is deferred using the backoff mechanism.
  - → The backoff mechanism first sets the backoff timer with an integer random number of slots within [0,CW], where CW is the contention window size. The backoff timer is decremented by one unit for each slot time interval (SlotTime) that no medium activity is indicated until reaching 0.
  - → If the medium becomes busy before the backoff timer reaches 0, the process is suspended until the medium becomes idle again.

2- After a transmitted frame a new backoff is performed even if there is no other frame waiting to be sent. This ‘post’ backoff ensures that the transmitting station will not have priority over any other waiting station, if any.

3- If it is a unicast communication; destination station sends the Acknowledge Frame as a fixed period of time after the reception of the DATA frame, which is referred to as short interframe space (SIFS).

4- If it is a Service Channel(SCH), RTS (Ready To Send)/ CTS(Clear to Send) is used.

- ➢ The station intending to transmit a DATA frame, can send first an RTS frame to reserve the medium for the complete exchange.

After reception of RTS Frame, the destination station must wait for a SIFS period of time and then answer with a CTS frame.

- The DATA frame, can then be sent after another SIFS period from the moment the CTS frame is received. [5]

The illustration of this sequence can be seen in Figure 4.

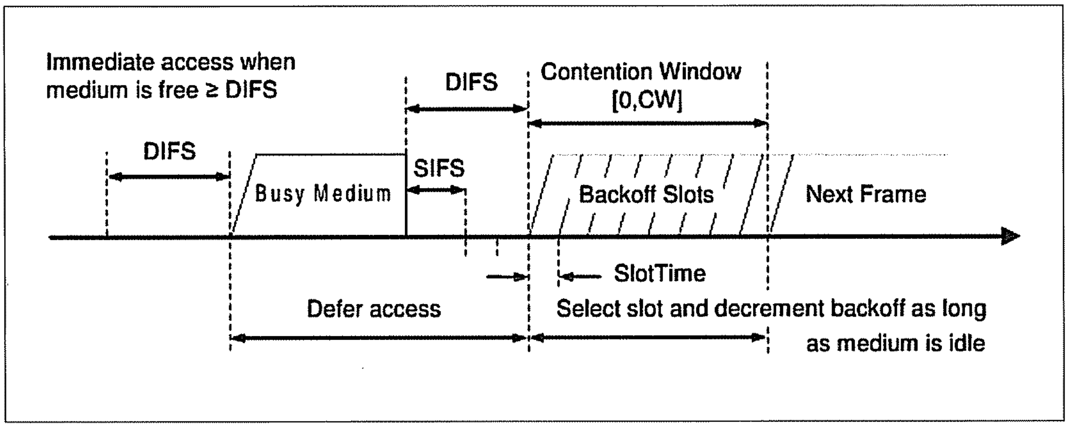

Figure 4 Distributed Coordination Function in CSMA/CA Scheme

3.2.1 Multi-channel concept

The multi channel operations can be used for safety and non-safety applications. In DSRC band WAVE System, there are two types of channels which are SCH(service channel)and CCH(control channel). Control channels are used for system control, management frames with high priority danger warning messages. Unlike, service channels are used for non-safety applications such as sending video and voice data. The channel coordination between service channels and control channel among WAVE devices are synchronized via GPS which is based on universal time coordinated (UTC). Each UTC second is split into 10 Synch intervals. And each synch interval is composed of alternating like the following conditions:

- For CCH Intervals: All devices monitors the CCH

- For SCH Intervals:All devices can monitor only one SCHs but may switch to another one. [10]

3.2.2 Prioritization for channel access in 802.11p

The prioritization method for 802.11p is the extension of 802.11e Enhanced Distributed Channel Access (EDCA) Quality of Service[13]. Therefore, application messages are categorized into different ACs (Access Categories). There are four available access categories which are BK(Background Traffic),has the lowest priority, VI(Video),the highest priority, BE(Best Effort and VO(Voice). Within the MAC layer, a packet queue exists for each AC. During the selection of a packet for transmission the four ACs content internally. The selected packet then contends for the channel externally using its selected contention parameters. The contention parameters used for the EDCA-Application Categories are shown in Table 2.

Table 2 EDCA Parameters for 802.11p

AC	CWmin	Cwmax	AIFS
BK	aCWmin	aCwmax	9
BE	(aCW min+1)/2-1	aCWmin	6
VO	(aCW min+1)/4-1	(aCW min+1)/2-1	3
VI	(aCW min+1)/4-1	(aCW min+1)/2-1	2

Cwmin and CWmax values are calculated by giving following values:
aCWmin = 15 and aCWmax = 1023.
Each AC has to wait at least its AIFS slots, plus additional slots determined by the selected Contention Window (CW) value in 802.11p.
AIFS time is written as:

$$t_{aifs} = AIFS * t_S \tag{1}$$

Contention Window duration is written as:

$$t_{CW} = CW * t_S \tag{2}$$

where $t_S = 13\ \mu s$

t_S : Time slot that the MAC utilizes to define the DCF interframe space and to decrement in steps the backoff interval. It is computed as the sum of:

i) the minimum time necessary to assess whether the medium is busy,
ii) the maximum time required by the PHY to switch from receiving state to start transmitting a frame, iii) the AirPropagationTime, and iv) the nominal time that the MAC needs to process a frame and prepare its response.

The comparison table for 802.11p and 802.11a according to MAC- layer parameters can be seen in Table 3.

Table 3 MAC-Layer parameters comparision for 802.11p and 802.11a

Parameters	**802.11a**	**802.11p**
Time Slot SIFS Time	9 µs 16 µs	13 µs 32µs
CWMin	15	15
CWMax	1023	1023

3.2.3 Backoff algorithms and contention window

The particularity of 802.11p back-off process is that the back-off is decremented slot by slot[17]. If the medium becomes busy during this process, the decrementation process is stopped and will be resumed as soon as the medium becomes free again with the remaining number of slots. When the back-off value reaches 0 the frame is emitted. For each new frame, a new random slot number is drawn.

The integer number of back-off time slots is uniformly drawn in an defined interval called contention window. The algorithm used by 802.11p to make this contention window evolving is called Binary Exponential Back-off (BEB). After each successful transmission, the contention window is set to [0, $CW_{min} - 1$] (its initial value). When i successive collisions occur, the contention window is set to [0; min(1024, $2^i * CW_{min} - 1$)]. If i > 7, the contention window is set to its initial value. It is the retry limit of the BEB algorithm.

4. ALTERNATIVE BACKOFF ALGORITHMS

4.1. The Collisions Problem in WAVE

The original 802.11p protocol includes the BEB algorithms method as a backoff mechanism which is mentioned in the previous section and EDCA parameters to determine the priority for the messages. However in big cities or rural areas, the packet traffic can be more agressive which decreases the throughput cuz of increasing of collisions. To analyze the problem, we model the collisions probability and throughput with the following equations[13]:

The Collisions Probability for a single hop network:

$$N_p = t_i / (t_{aifs} + t_w + t_{packet}) \tag{3}$$

where

t_i :throughput calculation interval,

t_w :Waiting Time with respect to each AC's selected CW value,

t_{packet} :Packet Duration,

Np :Throughput for each AC during one time interval

The collisions occur if at least two nodes have the same CW values. Thus the probability of collisions is related with the number of different CW values which can be calculated for the combinations of N Nodes:

$$CW_{TOTAL}(N_t) = cw^{N_t} \tag{4}$$

where N_t : Total number of sending nodes,

Then, the probability of a collision can be written as for multiple sending:

$$P_{Coll}(N_t, cw) = (N_t / CW_{TOTAL}) * \sum_{i=1}^{cw-1} (cw - i)^{N_t - 1} \quad (5)$$

By using Equation 3, we consider that, the way of reducing the probability of the collisions can be done by increasing the Contention Window size. However according to Equation (1), the increasing of the window size causes the reducing of the throughput. Thus we need an optimum contention window size that can reduce the probability of collisions while making the throughput decrease slightly.

4.2. CEA Algorithm

4.2.1 Slotted p-persistent CSMA scheme

A p-persistent IEEE 802.11p protocol differs from the standard protocol only in the selection of the backoff interval. Instead of the binary exponential backoff
used in the standard, the backoff interval of the p-persistent IEEE 802.11p protocol is sampled from a geometric distribution with parameter p. Moreover in [14] it can be shown that theorical throughput limit of IEEE802.11 can be achieved by changing backoff interval dynamically by using optimal p value.
The backoff interval of p-persistent CSMA is determined by the transmission probability p such that a station chooses to transmit with probability p and stays idle with probability 1 − p in each subsequent time slot when the medium is sensed busy.

The model is based on the assumption that for each transmission attempt
a station uses a backoff interval sampled from a geometric and distribution with parameter p= 1/(E[B]+1) which equals to 1/p=(CW+1)/2 for 802.11p and implies the window based backoff mechanism.

4.2.2 Virtual Transmission Time

To control and observe the channel capacity during communication, we need a time duration which includes all process such as being idle, collisions and succesful packet transmissions. The time interval between two consecutive succesful tranmission is defined as virtual transmission time [11]. The virtual transmission time consists of idle times, collisions times and a single successful transmission time. Idle times are defined as the time in which the channel is free, collisions times are defined as the time in which more than one node attempts to tranmit and a single succesful transmission time occurs when the packet is received by the destination node which marks the end of virtual transmission time.Because of the geometric backoff assumption, all the process are regenarative corresponding to the virtual time[14]. Then for each renewal period the maximum throughput of the channel can be calculated as:

$$Throughput_{max} = E[L_{packet}]/E[VT] \tag{6}$$

where $E[L_{packet}]$: Average Length of the packet,

$E[VT]$:Average length of the renewal period (virtual tranmission time), then

$$E[VT] = E[T_{TotalIdle}] + E[T_{TotalCollision}] + E[T_{Success}] \tag{7}$$

where $E[T_{TotalIdle}]$: Expected number of total idle time slots,

$E[T_{TotalCollision}]$: Expected number of total collision time slots,

$E[T_{Success}]$: Expected number of time slots of a succesful tranmission,

The idle periods during the virtual tranmission time are i.i.d(identical independent distributed) variable with the same mean value, more over the above processes are independent from the previous state of the channel state during a virtual transmission time. Hence, From [11], $E[T_{TotalIdle}]$ can be written as:

$$E[T_{TotalIdle}] = (E[N_{Coll}] + 1) * E[T_{Idleperiod}] \qquad (8)$$

where $E[N_{Coll}]$: Expected number of collisions during the virtual transmission time, $E[T_{Idleperiod}]$:Expected number of idle time slots during the virtual tranmission time, $E[T_{TotalCollision}]$ can be written as:

$$E[T_{TotalCollision}] = E[N_{Coll}] * E[T_{Collisionperiod}] \qquad (9)$$

where, $E[T_{Collisionperiod}]$: Expected number of collisions time slots at each collision.
From [14], the following lemma is written as:

Lemma 4.2.2.1: $E[N_{Coll}] = (1-(1-p)^M)/(M*p*(1-p)^{M-1} - 1$ (10)

$$E[T_{Idleperiod}] = ((1-p)^M/(1-(1-p)^M)) * t_{slot} \qquad (11)$$

Proof: Let's define P_{Coll} as the probability that a collision occurs conditioned to at least one transmission in the time slot and $P_{Success}$ as the probability of a succesful tranmission, then the following equations can be written:

$$P_{Coll} = P\{TransmittingStations \geq 2 \mid TransmittingStations \geq 1\}$$

$$P_{Coll} = (1-(1-p)^M - M*p*(1-p)^{M-1})/(1-(1-p)^M) \qquad (12)$$

where M is the number of transmitting stations,

$$P_{Success} = P\{TransmittingStations = 1 \mid TransmittingStations \geq 1\}$$

$$P_{Success} = (M * p * (1-p)^{M-1})/(1-(1-p)^{M}) \quad (13)$$

$$P\{N_{Coll} = i\} = P_{Coll}^{i} * P_{Success} \quad (14)$$

where i=0,1,2,... and $P\{N_{Coll} = i\}$: distribution of the number of the collisions in a virtual time.

By using Equation (12) and Equation (11) in Equation(14) we obtain the Equation (10).

For the calculation of $E[T_{Idleperiod}]$; Let's define P_{Idle} as the probability that the number of stations which transmit is 0 in a time slot. Then, by using transmission probability of a station with p

$$P_{Idle} = (1-p)^{M} \quad (15)$$

Hence, $1-P_{Idle}$ is the probability of at least one station that tranmits in a time slot which leads to; $1-P_{Idle} = 1-(1-p)^{M}$. Thus, we obtain Equation(11) by using Equation(15) in the Equation (16).

$$E[T_{Idleperiod}] = t_{slot} * [1-(1-p)^{M}] * \sum_{i=1}^{\infty} [i * (1-p)^{M}]^{i} \quad (16)$$

$$E[T_{Idleperiod}] = ((1-p)^{M} /(1-(1-p)^{M})) * t_{slot} \quad (16)$$

From Equation(8), we have the below equation:

$$E[T_{TotalIdle}] = (E[N_{Coll}] + 1) * E[T_{Idleperiod}] \quad (8)$$

then by using Equation (10) and Equation(11),

$$E[T_{TotalIdle}] = \frac{(1-(1-p)^{M})*(1-p)^{M}}{(1-(1-p)^{M})*(M*p*(1-p)^{M-1})}*t_{slot} \qquad (8)$$

By algebraic manipulation Equation(8) can be written as:

$$E[T_{TotalIdle}] = ((1-p)/(M*p))*t_{slot} \qquad (8)$$

Similarly From Equation(9), we have the below equation

$$E[T_{TotalCollision}] = E[N_{Coll}]*E[T_{Collisionperiod}] \qquad (9)$$

then by using Equation (10) and fix length of the packet, Equation(9) can be writen as:

$$E[T_{TotalCollision}] = \frac{(L+D)*t_{slot}*((1-(1-p)^{M})-M*p*(1-p)^{M-1})}{M*p*(1-p)^{M-1}} \qquad (9)$$

Because of the length of the packet and DIFS which are constant; expected number of time slots of a succesful tranmission can be written as:

$$E[T_{Success}] = (L+D)*t_{slot} \qquad (17)$$

Thus, Substituting Equation(8), Equation(9) and Equation(17) in Equation(7), we obtain the following equation:

$$E[VT] = \frac{(L+D) - ((L+D-1)*(1-p)^{M})}{M*p*(1-p)^{M-1}} * t_{slot} \qquad (7)$$

As it is seen in the Equation(4), the optimum tranmission probability can maximize the throughput while minimizing the average length of the renewal period. Hence during the communication, if we find an optimum value for tranmission probability in a virtual transmission time, then we can maximize the throughput.

To find the optimum transmission probability, we assume that packet and DIFS lengths are constant and known. Thus we use p value as a minizer to find the $Throughput_{max}$.

To find p value which minimizes the Equation (5) becomes an nonlinear optimization equation can be written as:

$$p_{opt} = \arg\min_{p} \{E[VT]\} \qquad (16)$$

Assuming that a 802.11p occupied Road Side Unit(RSU) knows the number of the trasmitting vehicles(OBUs) which are in communicating range as a center, the RSU broadcast this information periodically and each vehicle can use this information to find their optimum transmission probability to update their Contention Window size [12].

The CEA (Centralized Enhancement Algorithm) includes following steps:

```
1-While the current OBU is in the communication range
 1.1 If RSU broadcasts the number of concurrent transmitting vehicles
   a)Calculate $p_{opt}$
   b)Set $CW_{Min}$ =$CW_{Max}$ = CW=2-$p_{opt}$ /$p_{opt}$
 1.2 else
   a)Use previous CW
2-endif
3-endwhile
```

4.3 CEA Algorithm Simulation Results

The simulations are evaluated in NCTUNS [15]. To compare the proposed algorithms with the original 802.11p back off algorithm, we have made some modifications in the mac module of NCTUns.

Simulation Setup

Table 4 Simulation Setup-Parameters

Stack-Module Parameters		
Channel Model	**PHY- Layer**	**MAC-Layer**
Propagation Model: Theoretical/Pathloss Model: Two_Ray_Ground	Data Rate: 3 Mbps	Time Slot: 13 µs
Antenna Height:1.5 (m)	Transmission Power: 28.8 dBm	SIFS Time : 32µs
PathLoss:2 (Free Space Propagation)	Receiver Sensitivity: -82.0 dBm	CWMin: 15
Others: (Default Values)		CWMax: 1023

Scenario-1: 802.11p Original Protocol-Saturated and Non Saturated Network

To make sure that the Network is Saturated,

It is proposed that in [18], for one-hop network, simply lets suppose that all vehicles(OBUs) transmit to one base station(RSU). Then the saturation limit is defined as below:

$$N_t * \lambda \le \mu_c \qquad (17)$$

$$\mu_c = \frac{1}{(t_{DIFS} + t_{packet})} \qquad (18)$$

where t_{DIFS} : DIFS time and t_{packet} :Packet Duration, where N_t :Number of Transmitting OBUs, λ :Packet Arrival Rate for an OBU, μ_c :Maximum Departure Rate of the Network

According to above equation, when the number of transmitting vehicles increases or μ_c decreases it is obvious that network will be saturated. The simulations results are in packet sending configurations that implies saturated network according to above equation.

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)
Network Arrival Rate:0.4 Mbps (Non Saturated Channel)
Network Arrival Rate:2 Mbps (Saturated Channel)
The number of Vehicles:{1,2,4,8,10,12,16,20}
The Transmitting Range between Vehicles: 1000 (m)
The Largest Distance between OBUs and RSU : 500 (m)
The Vehicle Speed:50 km/h

According to above scenario configuration, the results are seen in Figure-5 and Figure-6 (Theorical results)

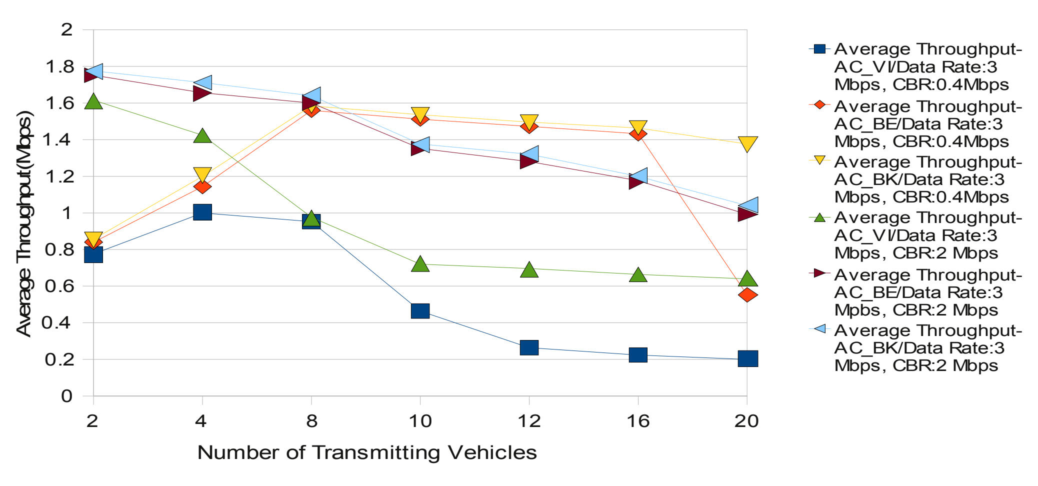

Figure 5 Saturated and NonSaturated Network with 802.11p Backoff Mechanism

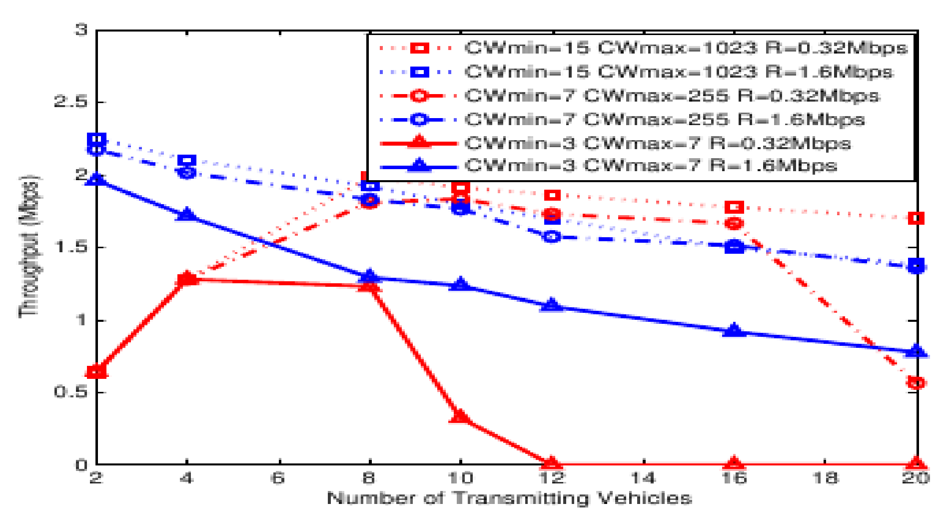

Figure 6 Theoretical Result for Saturated and Non Saturated Throughput

As it is seen in Figure-6 [12] and Figure-5, the network throughput decreases when the number of vehicles increases and network arrival rate is getting higher. The characteristic of the network is nearly the same, but the main difference between two figures are because of the OBU-RSU distance which increases the interference and decreases the number of the succesfully received packets. The second reason is the propagational model difference. For Figure-4 Nakagami model is used which is evaluated with NS-2 (See [12]) instead of Two Ray Ground Model which has been used in NCTUNS (See [16]). In Figure-4, because of using probabilistic model which is related with fading instensity factor m . The usage of probabilistic model may become challenge for CSMA process which causes the using time slot and increasing the collisiions probability, so it leads the throughput mitigation more abruptly than Figure-3. The Propagation models are described below:

Channel Model

a)The Nakagami Fading Model:

The Nakagami-m model derives the received signal strength from a multi-path environment where the different signal components arrive randomly because of the different propagation phenomena. It is used to estimate the signal amplitude at a given distance from the transmitter as a function of two parameters, Ω and m. The following expression describes the Nakagami probability density function

$$f_{amp}(x;m,\Omega)=\frac{2*m^{m}}{\Gamma(m)*\Omega^{m}}*x^{2*m-1}*e^{-\frac{m*x^{2}}{\Omega}} \tag{19}$$

where Ω defines the average received power at a specific distance; the value m identifies the fading intensity and depends on the environment and the distance to the sender; and Γ is the Gamma function.

When m is set to a positive multiple of 0.5 the Nakagami can be described by an Erlang distribution, which is how it is implemented in the simulator. (NS-2)

As it is seen from the Equation(18), the probabilistic models show a smoother decrease over the distance, with different decrease slopes depending on the chosen fading intensity.

The probabilistic behavior of the channel challenges the nodes coordination provided by the DCF mechanism: transmissions from neighboring nodes may suffer a high attenuation while further nodes' messages may suffer low attenuation. Furthermore, the resulting variance is accentuated with higher fading intensities, which may cause lower reception probabilities within the intended communication range but higher reception probability for larger distances.

b)Two Ray Ground Model

An approach to model multi-path propagation with calculation effiency is to calculate two propagation paths, the direct path and one reflected path [8].

The calculation is conducted for every combination of transmitter and receiver using the formula which makes deterministic is given with the following equation:

$$P_r = P_t * \frac{[1+\eta^2 + 2*\eta\cos(\frac{4*\pi*h^2}{d*\lambda})]}{4*\pi^2*(\frac{d}{\lambda})^{\gamma}} \qquad (20)$$

where η: is the reflection coefficent of the road,

λ: the wavelength,

h:Antenna Height

γ :Path-loss coefficent

d:Distance between transmitter and receiver

As it is seen in Equation(20), the phase shift is applied to reflected propagation path. Hence, when the distance becomes longer, the received power decreases which can cause the reducing of the the number of received packets though the interference gets lower.

Scenario-2: 802.11p Original Protocol-Fixed Network Arrival Rate

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:1.6 Mbps (Saturated Channel)

The number of Vehicles:{0,5,10,15,20}

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

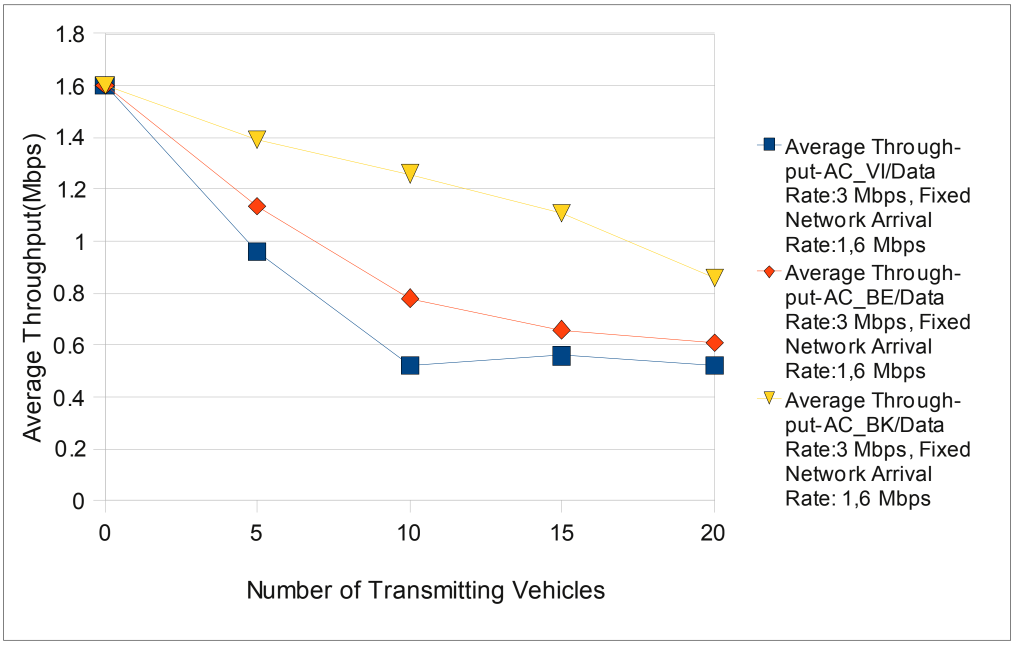

Figure 7 Saturated Network-Fixed Network Arrival Rate

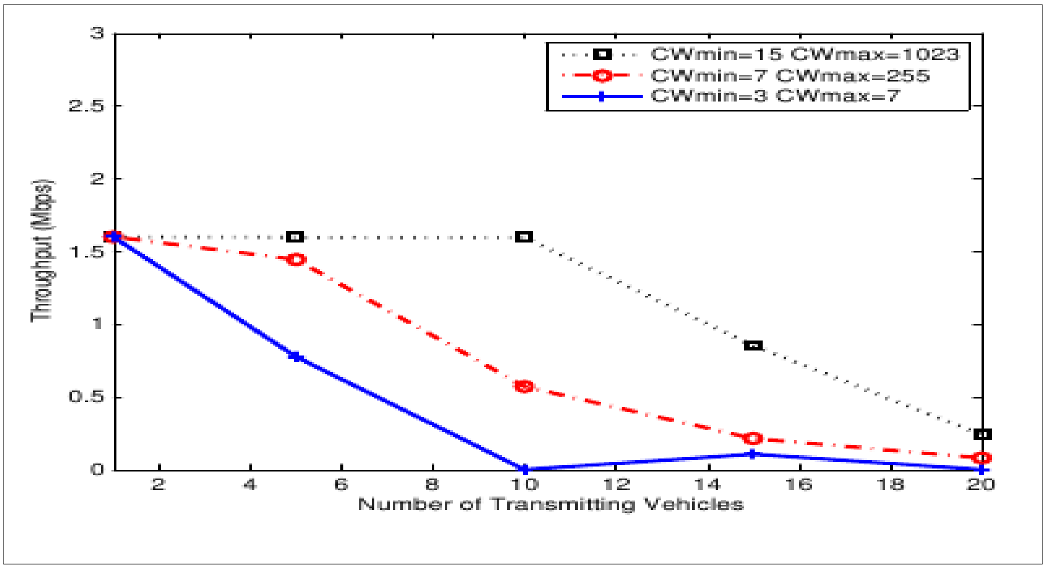

Figure 8 Theoretical-Result-Saturated Network-Fixed Network Arrival Rate

In Figure 7 and 8 [12], we can see that the fixed network arrival rate which saturates the network causes decreasing of the throughput. Beside it proves the importance of selection the Contention window size. Since, AC_BK, category of the background traffic, stays much more stable according to other contention window size which is related with the interval between Cwmin and Cwmax (15-1023). This interval gives advantage to choose numerous values with respect to BEB algorithm which is used as a backoff algorithm in 802.11p protocol.

Simulation result comparison with theoretical result [12] for AC_VI when the Transmission Power:16 dBm in both RSU and OBU can be seen in Figure 9:

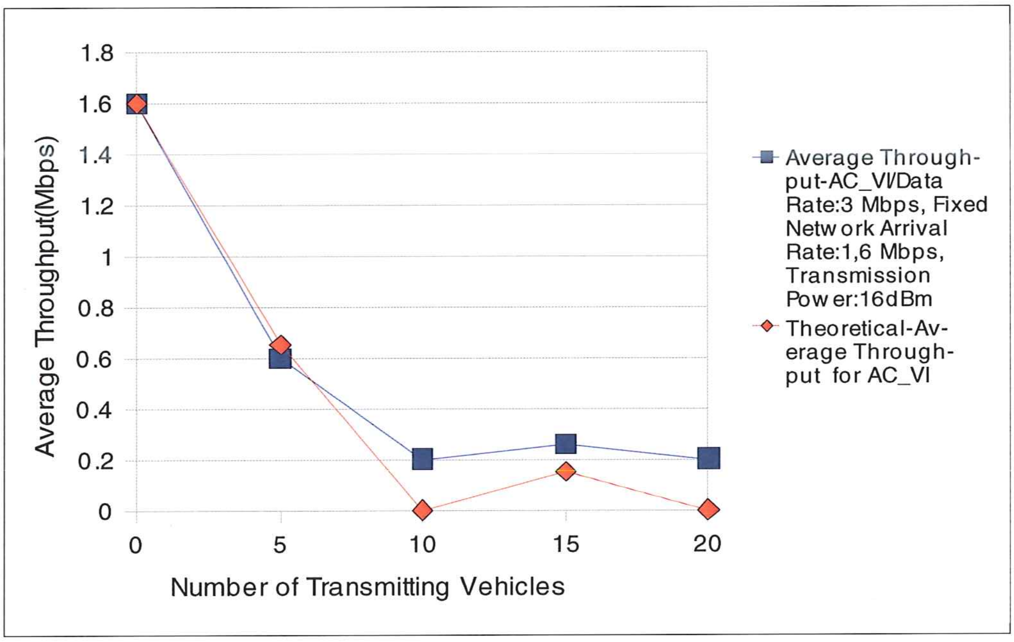

Figure 9 Theoretical Result Comparison for AC_VI with Fixed Network Arrival Rate

In Figure-9, by using NCTUns as a simulator, with the above parameter setting, theoretical results are closing to simulation results with the difference of 0.2 Mbps approximately. It shows that the transmission power and channel model plays important role for the reduction of the throughput.

Scenario-3: 802.11p Original Protocol-CEA Comparision

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Vehicles:{1,2,4,12,20,32,44}

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

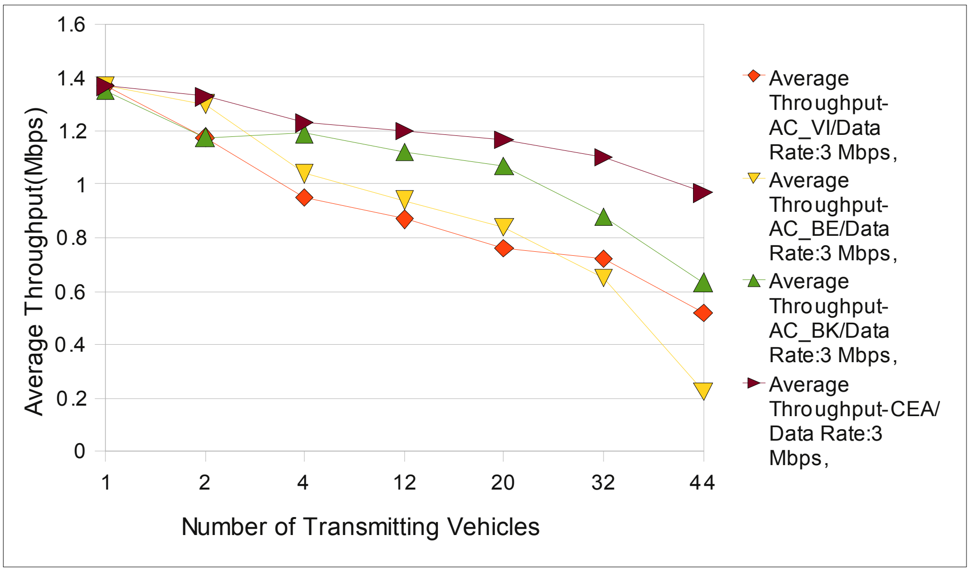

Figure 10 CEA Comparison with Original Protocol-Backoff Algorithm

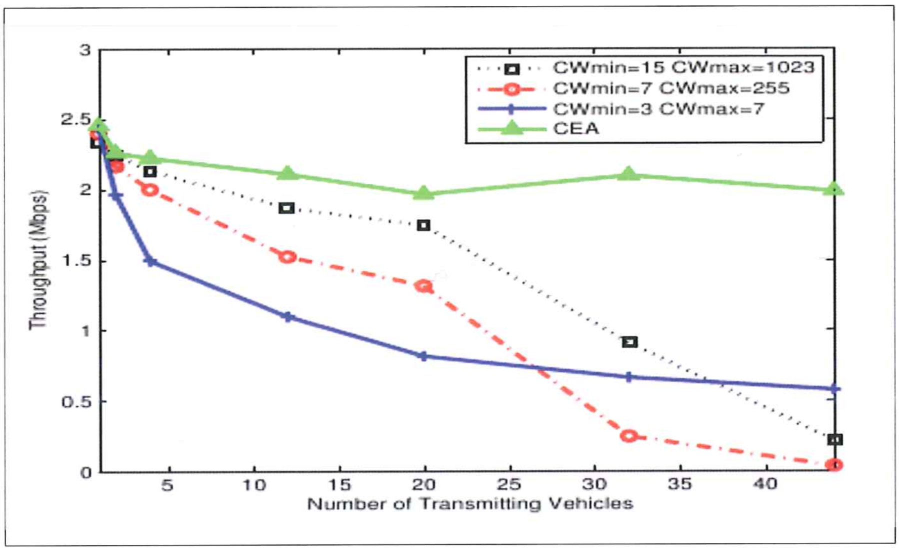

Figure 11 Theoretical Result-CEA Comparision with Original Protocol- Backoff Algorithm

As it is seen in Figure 10 and 11 [12], the back off algorithm which belongs to 802.11p protocol having problems when the number of vehicles increases, because the packet communication becomes more agressive, so the backoff algorithm with current EDCA parameters cant handle to reduce the collisions of packets. But with CEA algorithm, optimum tranmission probability handles with the packet collision better by using different CW values according to characteristic of the communication.

Scenario-4: 802.11p-CEA Payload Size Comparison

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Vehicles:{1,2,4,12,20,32,44}

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

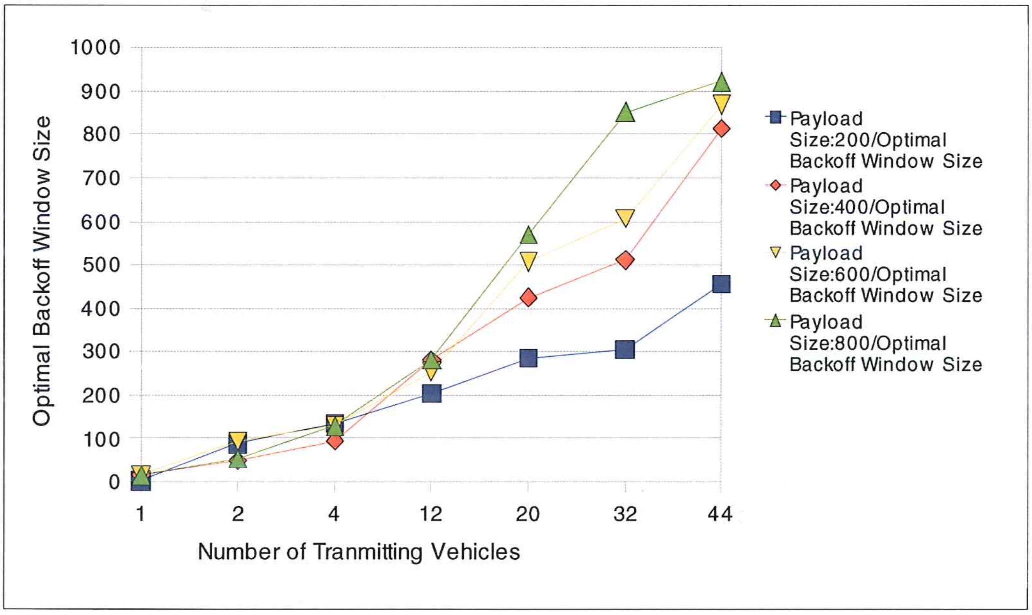

Figure 12 CEA-Payload Size Effect for Optimal Contention Window Size

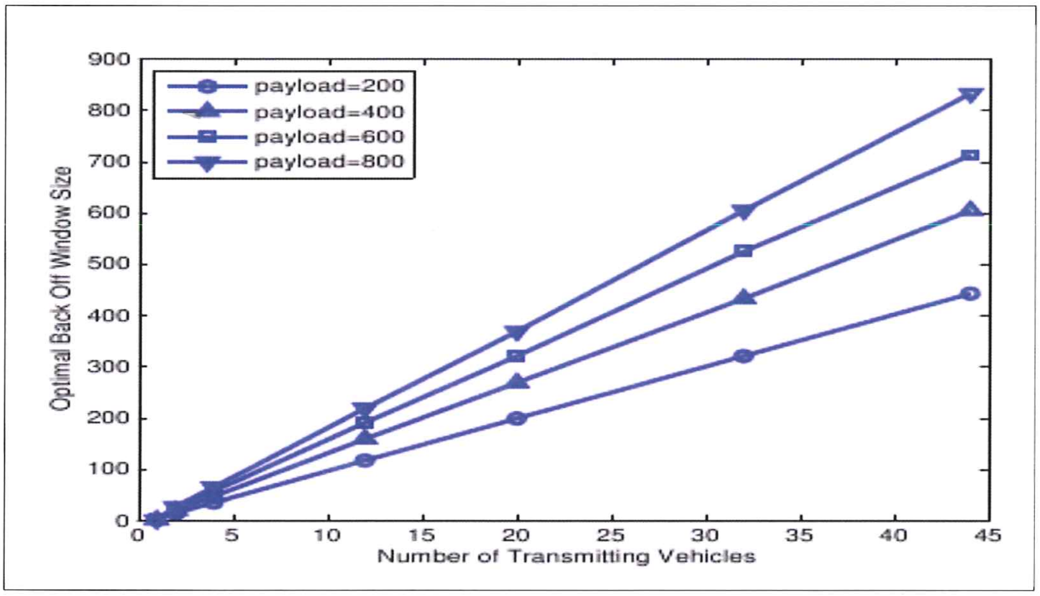

Figure 13 CEA-Theoretical Result Payload Size Effect

In Figure 12 and 13 [12], we can see that when the payload size gets bigger, the CEA back off algorithm calculates higher contention window size which increases the collision probability of packets.

4.4 DEA Algorithm

The knowledge of the number of transmitting vehicles is the key point to determine the 'most suitable' contention window size. In [14], the estimation of number of transmitting vehicles can be implemented by observing idle time within a virtual transmission time. However, the characteristic of the channel can be random which leads to have high estimation variance for backofff algorithm. Hence, instead of using one virtual transmission time, to reduce the randomness we can use more than one virtual transmission time which is called observation interval.

The DEA Algorithm is based on the observation interval instead of using only one virtual transmission time. The Contention window size is increased when the channel becomes much more busy unlike the when the channel gets less busy, the contention window size is minimized after each observation interval. To determine whether the channel is busy or not, we use a parameter which is called busy time ratio. And after each observation interval, busy time ratio is calculated by measuring the total busy time then busy time ratio is updated. This ratio is compared with the value of the previous observation interval which gives the amount of deviation from the previous state of the channel. By using this difference, the threshold value is calculated. The threshold value is used to determine the change of the busy time for the next observation interval. Threshold is compared with the latest amount of deviation of busy time to compute the new contention window size. If the difference is positive, it is sign of the increment of the transmitting vehicles. So the contention window is updated with the proportion of the latest amount of deviation of busy time to current threshold. If the difference is negative, it s the sign of the decrement of the transmitting vehicles in the communication range. Thus the contention is minimized with the with the proportion of the latest amount of deviation of busy time to current threshold.

The DEA Algorithm steps is given below:[12]

```
CW=CWinit
while the current Vehicle is in the communication Range
    if end of $i_{th}$ OI then
        $r^i_{busy} = T^i_{busy} / T^i_{OI}$
        $\alpha_i = r^i_{busy} - r^{i-1}_{busy}$
        if $|\alpha_i| > \alpha_{thresh}$ then
            if $\alpha_i > 0$ then
                $CW = CW \times (\alpha_i / \alpha_{thresh})$
            else
                $CW = CW / (|\alpha_i| / \alpha_{thresh})$
            end if
        else
            CW remains unchanged
        end if
        $T^i_{busy} = 0$
        $\alpha_{thresh} = (\alpha_{thresh} \times \alpha_{thresh} (i-1) + |\alpha_i|)/i$
        $Cw_{min} = CW_{max} = CW$
    else
        Use previous CW, keep observing
        $T^i_{busy} = T^i_{busy} + T^i_{newbusy}$
    end if
endwhile
```

4.5 DEA Algorithm Simulation Results

The simulation setup is the same with the previous section. The main difference is evaluation method for performance of DEA. Because of the deviation requirement according to busy time ratio. We use scenarios in which the number of transmitting vehicles change by time in the communication range. We add also the NON-ALG choice as an algorithm which means in all cases the CW_{init} value is used without doing any other backoff process to compare with the DEA in which the contention window size is unchanged with respect to the current busy time ratio.

Scenario-1: The Number of Transmitting Vehicles Change From 4 to 12

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Transmitting Vehicles: 4 (0-25 sec), 12 (25 -50 sec)

CW_{init} =40 (DEA and Non-ALG)

OI=1000 VT

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

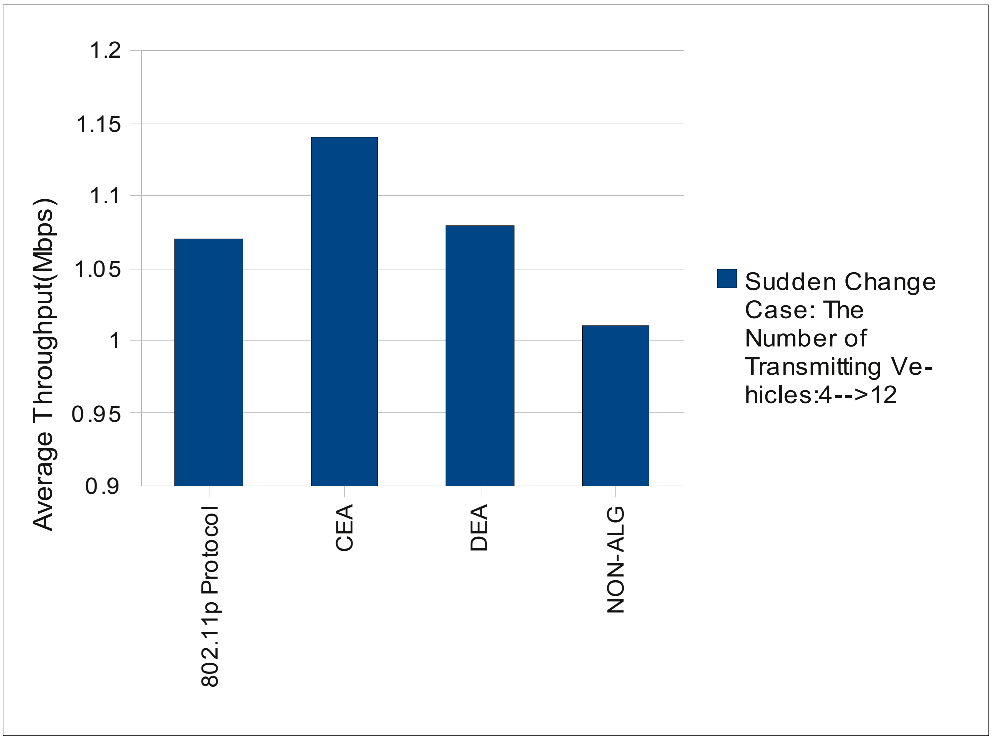

Figure 14 The Sudden Change Case at t=25, Transmitting Vehicles:4 -12

As it is seen in Figure-14, the CEA and DEA perform better than NON-ALG and 802.11p protocol. The usage of BEB algorithm increases the throughput much more than NON-ALG.

Scenario-2: The Number of Transmitting Vehicles Change From 4 to 16

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Transmitting Vehicles: 4 (0-25 sec), 16 (25 -50 sec)

CW_{init} =40 (DEA and Non-ALG)

OI=1000 VT

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

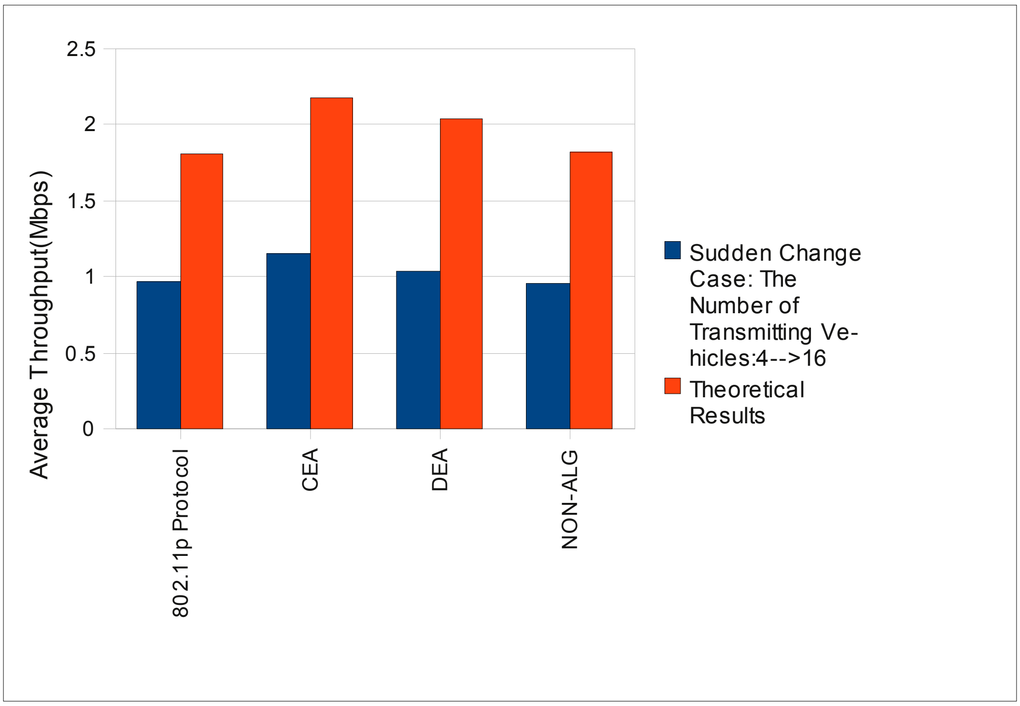

Figure 15 The Sudden Change Case at t=25, Transmitting Vehicles:4 -16

In Figure-15, theoretical part is from [12], it can be clearly seen that both of the Algorithm lead a better performance by adding 12 vehicles more in the current scenario.

Scenario-3: The Number of Transmitting Vehicles Change From 4 to 32

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Transmitting Vehicles: 4 (0-25 sec), 32 (25 -50 sec)

CW_{init} =500 (DEA and Non-ALG)

OI=1000 VT

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

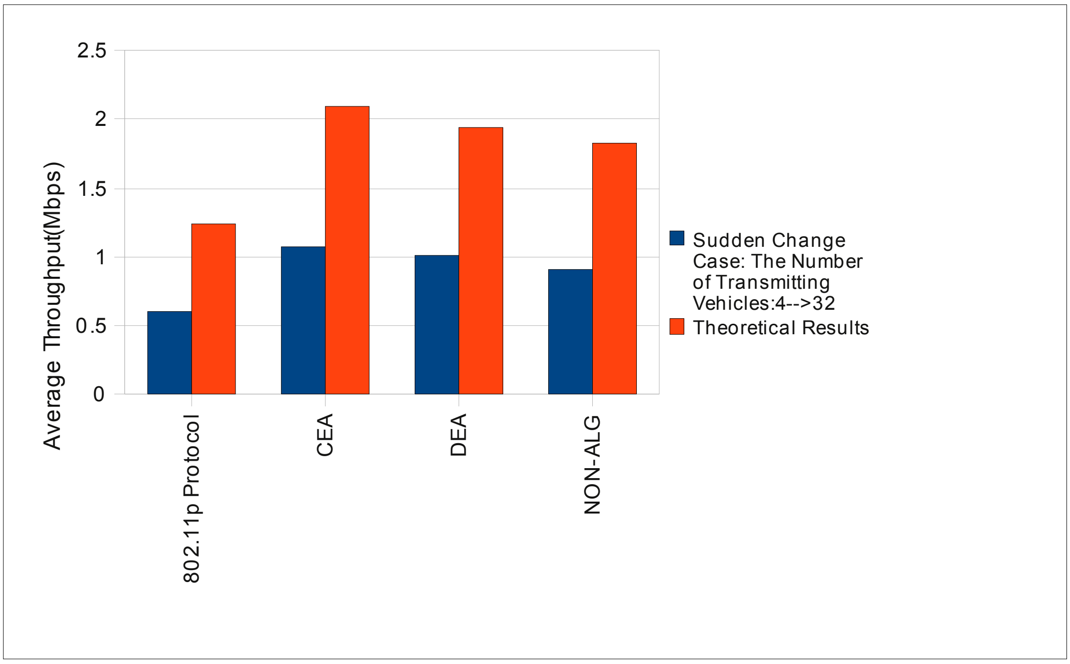

Figure 16 The Sudden Change Case at t=25, Transmitting Vehicles:4 -32

In Figure-16, theoretical part is from [12], the number of vehicles change from 4 to 32. This huge increment effect less CEA and DEA throughput, unlike the 802.11p backoff mechanism according to this randomness cant handle, so even NON-ALG implementation performs better.

Scenario-4: The Number of Transmitting Vehicles Change From 12 to 4

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Transmitting Vehicles: 12 (0-25 sec), 4 (25 -50 sec)

CW_{init} =500 (DEA and Non-ALG)

OI=1000 VT

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

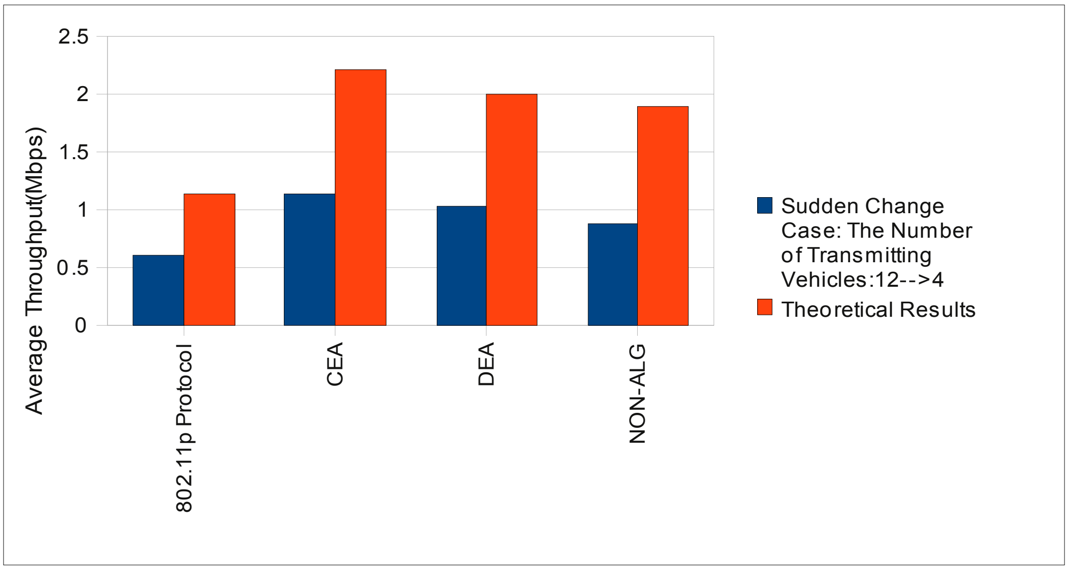

Figure 17 The Sudden Change Case at t=25, Transmitting Vehicles:12-4

In Figure-17, theoretical part is from [12], 8 transmitting vehicles decrease in the middle of the scenario, this decrement influence performance of 802.11p based backoff algorithm much more than others. As the previous before, the 802.11p based back off algorithm cant handle with the randomness of the channel. The

NON-ALG has also poor performance according to CEA and DEA. Hence this decrement is required contention window update, on the other hand in NON-ALG, there is only one Contention window for whole the simulation,so this value cant be enough to increase the throughput of the vehicles. But the initial value still make it to get better throughput according to 802.11p protocol based backoff algorithm.

Scenario-5: The Number of Transmitting Vehicles Change From 16 to 4

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Transmitting Vehicles: 16 (0-25 sec), 4 (25 -50 sec)

CW_{init} =500 (DEA and Non-ALG)

OI=1000 VT

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

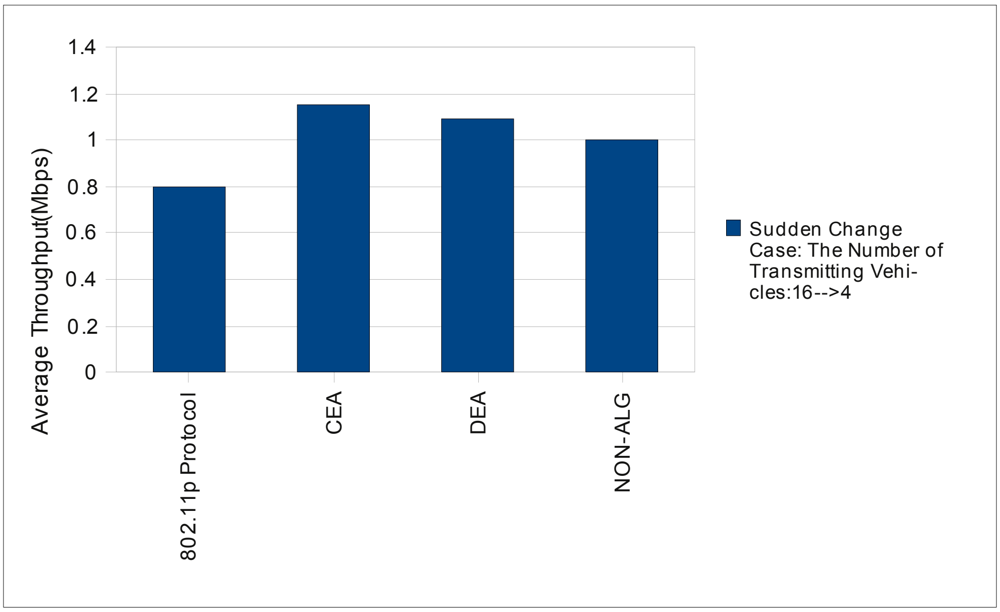

Figure 18 The Sudden Change Case at t=25, Transmitting Vehicles:16-4

In Figure-18, transmitting vehicles change from 12 to 4. This decrement makes similar effect with the Figure-14. The CEA and DEA handle with the sudden change of the channel better than NON-ALG and the 802.11p protocol based backoff algorithm.

Scenario-6: The Number of Transmitting Vehicles Change From 32 to 4

Scenario Configuration

Packet Sending Type: CBR(Constant Bit Rate)

Network Arrival Rate:3.2 Mbps (Saturated Channel)

The number of Transmitting Vehicles: 32 (0-25 sec), 4 (25 -50 sec)

CW_{init} =500 (DEA and Non-ALG)

OI=1000 VT

The Transmitting Range between Vehicles: 1000 (m)

The Largest Distance between OBUs and RSU : 500 (m)

The Vehicle Speed:50 km/h

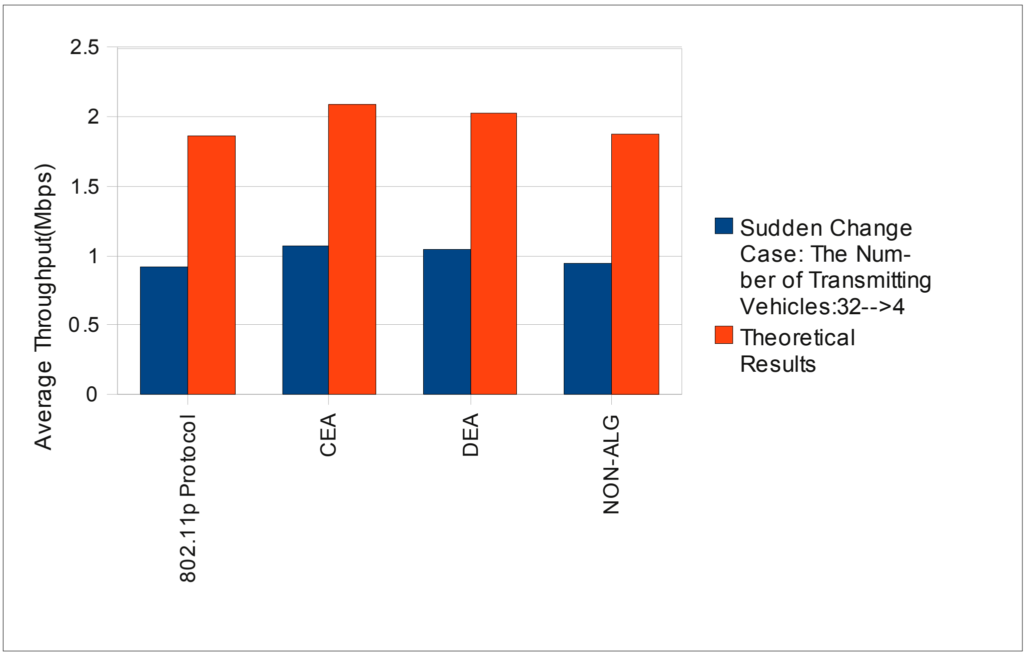

Figure 19 The Sudden Change Case at t=25, Transmitting Vehicles:32-4

In Figure-19, theoretical part is from [12], 28 vehicles stop communicating int he middle of the scenario. This decrement causes a contention window which is in large interval. Thus NON-ALG which uses only one value cant handle with this decrement. 802.11p backoff mechanism uses BEB algorithm. But the access category based min-max interval cant reduce the randomness of the channel to increase the throughput. The gain also decreases for CEA and DEA according to the other scenarious but still, because of observing and updating the contention window size with respect to this observation, they perform better than others.

5. CONCLUSION AND FUTURE WORK

The vehicular communication will have a key role for the road traffic management. To provide this, we need to design and implement systems and devices that can handle with the most hard road conditions such as high load network communications or with minimum delay the information sharing among vehicles. In order to achieve this we need robust and reliable designs and protocols. In this thesis, after simulation results, we consider that the current draft 802.11p standard is required improvement still in PHY and MAC layer. For example with multi transmitter or receivers, we could catch more signals with different phases and it would increase the amount of receiving messages. For the MAC-layer, current ACs cant manage with the saturated wireless network by using binary expontial backoff mechanism and it minimizes the throughput a lot instead of maximizing. So to overcome collision challenge and maximize the throuhgput in the saturated channel, we proposed two algorithms CEA and DEA. Both of them are based on the observation of channel till the packet is received successfully. These calculations and changing the contention window dynamically and adaptively make much more robust even in the highly increment of number of vehicles in the road traffic. The CEA algorithm could be implemented by using a sensor at each OBUs and thus they wouldnt need the knowledge of the number of vehicles in the communication range. But it would be more costly at the same time so, we use the sensor only in the Road Side Unit which sense the number of concurrent transmitting vehicles on the road and share this information with the whole OBUs within communication range. This time, when the number of vehicle change randomly, because of the characteristic of the algorithm, it cant adaptive easily hence for sudden change situations we proposed an another algorithm DEA. The implementation methodology is much more easier than CEA. Because whole stations have reception module in MAC-layer which can count the number of Acknowledge messages. And the observation interval can be defined easily in this way. The implementation is easier, but the calculation method has to be improved as we have seen in the figures. For example instead of calculation of average for threshold for the busy time proportion we can use a much more effective method by using neural network so that we can make better predictions for the next state of the channel. It would increase the performance of DEA algorithm. To increase the observation period, it acquires much more information about the characteristic of the channel hence we calculate for weight to compansate for the contention window which could mitigate the reduction of throughput abruptly.

The vehicles with high speed can communicate with 802.11p standard. But it shows that the phase-shifting is increasing and this delay influence performance of the proposed algorithms. Hence the calculation time for algorithms plays an important role to handle with this delay propogation.

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