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USING JOINT ADAPTATION OF TRANSMISSION POWER AND CONTENTION WINDOW SIZE IN IMPROVING VANET PERFORMANCE

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Abstract- In this paper we present a novel format for vibrant adaptation of transmission power and contention window (CW) Size for information propagation in Vehicular Ad-hoc Networks (VANETs). The anticipated format uses a shared approach to adapt transmission power at the physical (PHY) layer and quality-of-service (QoS) parameters at the medium access control (MAC) layer and incorporates the Enhanced Distributed Channel Access (EDCA) mechanism of 802.11e to implement a priority based vehicle-to-vehicle (V2V) communication. In this paper, an algorithm for joint adaptation of transmission power and contention window to improve the performance of vehicular network in a cross layer approach is used. The high mobility of vehicles in vehicular communication results in the change in topology of the Vehicular Ad-hoc Network (VANET) dynamically, and the communication link between two vehicles might remain active only for short duration of time. In order for VANET to make a connection for long time and to mitigate adverse effects due to high and fixed transmission power based on estimated local traffic density, while the CW size is adapted according to the instantaneous collision rate to facilitate service differentiation. In the interest of promoting timely propagation of information, VANET advisories are prioritized according to their urgency and the EDCA mechanism is employed for their dissemination.

Keywords- Vehicular Networks, VANETs, Broadcast, Contention Window Adaptation, Message Differentiation, Transmission Power Adaptation, QoS, Medium Access Control Protocol, 802.11e EDCA, Intelligent Transportation System.

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Introduction

We are witnessing an inimitable junction of Vehicular Ad-hoc Networks (VANET) and Intelligent Transportation Systems (ITS) which is on the edge to bring about a innovatory leap by making our roadways and streets safer and the driving experience more enjoyable [1]. Intelligent Transportation Systems (ITS) have been developed to improve the safety, security and efficiency of the transportation systems and enable new mobile applications and services for the traveling public. Working with the fielded ITS infrastructure, VANET is expected to boost the consciousness of the traveling public by aggregating, propagating and disseminating up-to-the-minute information about impending traffic-related measures. In vehicular communication, message propagation and dissemination occur with vehicle-to-vehicle and/or vehicle-to-infrastructure communication. The message forwarding and propagation should be done in small amount of time. Incase if traffic incident occurs, all the vehicles on the road benefit from appropriate and accurate information diffusion allowing the drivers to make informed decisions. The message forwarding and propagation should be done in small amount of time. Therefore, reliability and low delay are extremely important factors for VANET applications to propagate and disseminate the message to the region of interest. Due to high-speed mobility, V2V and V2I communication links have a tendency to be shortlived. Moreover, one of the best ways of propagating traffic-related advisories towards a particular region is some form of (controlled) broadcast transmission by increasing the transmission range in meager traffic conditions such as in rural areas or in urban areas where the application penetration ratio is low ,increases the duration of communication links but in intense traffic conditions (e.g., areas with a high penetration ratio, urban areas, or traffic jams) increasing the transmission range may produce high network overhead in VANET. Therefore in order to address these problems, dynamic adaptation of transmission power is crucial .In addition, in order to propagate emergency messages in a timely manner, the vehicular network for an intelligent transportation system must sustain some form of message differentiation, similar in strength to service differentiation for QoS in the contention based channel access mechanism EDCA of 802.11e [4]. Messages related to accidents should propagate to target regions on time so that further congestion and possible accidents can be avoided. This work is motivated by the fact that the fixed transmit power and the QoS related parameters for prioritized messages do not improve the performance for the vigorously changing topology of VANETs. Therefore the vibrant adaptation of joint transmission power and contention window in vehicle-to-vehicle communication is needed to achieve superior performance according to the local density of vehicle in a cross layer approach.

The paper is organized as follows: In Section 2, we present the overview of 802.11e EDCA and the problem statement. We present the scheme for dynamic adaptation of joint transmission power and contention window scheme in Section 3. In Section 4, we deal with the algorithm for joint power and CW adaptation. Finally, the conclusion is presented in Section 5.

Overview of EDCA Mechanism of IEEE 802.11E and its Problem Statement in VANET

We now briefly summarize the EDCA mechanism as defined in the 802.11e standard. EDCA controls the access to the wireless channel on the basis of the Channel Access Functions (CAF's). The IEEE 802.11 standard plays a major role in wireless networking. The fundamental access mechanism of IEEE 802.11 is applicable to VANET communications, which use IEEE 802.11p [5], a modified version of IEEE 802.11a. Due to their simplicity, scalability, flexibility and cost effectiveness, wireless local area networks (WLAN) based on IEEE 802.11 are among the most widely deployed WLAN technologies. It is widely known that the baseline IEEE 802.11 standard does not provide for the service differentiation necessary for supporting QoS for time critical data such as voice traffic in WLAN [12,13]. In order to address the issue of service differentiation the IEEE 802.11e standard [4] specifies the distributed contention-based channel access mechanism, referred to as EDCA. The EDCA is available in the ad-hoc mode where no transportation is available. The EDCA scheme relies on CSMA/CA along with a slotted Binary Exponential Backoff (BEB) mechanism for contention-based channel access [4] and supports MAC-level QoS and prioritization of different data/traffic by defining multiple Access Categories (ACs) with different CW and Arbitration Inter Frame Space (AIFS) values.

According to [4] a station with QoS implements four access categories (ACs) and there is a set of EDCA parameters associated with each AC. These parameters include AIFS [AC] and CW with its minimum and maximum value CWmin [AC] and CWmax [AC], respectively. Each AC from every station independently starts a backoff timer after detecting that the channel is idle for an AIFS [AC] interval and competes with other ACs for channel access and the opportunity to transmit. For each AC, the backoff period is selected from a uniform distribution over [0,CW [AC]]. The CW size is initially assigned CWmin and doubles when transmission fails, up to CWmax. then the CW reached CWmax the CW size is re-initialized, and the process is repeated. When an application is admitted, it has a number of QoS parameters. If two or more backoff timers within the same station finish backoff at the same time, there will be a virtual collision which will be solved by the station's internal scheduler. It should be noted that MAC protocols for VANET have to consider different types of traffic messages as well as a speedily changing network topology. For example, it is highly enviable for emergency messages related to traffic incidents on the roadway to have higher priority than other messages in order to get speedy channel access, and thus prioritization of different messages according to their urgency is an important requirement in VANET. Using dynamic adaptation of transmission power along with that of the contention window combines the advantages of both methods. Hence the message propagation and dissemination occur with high throughput and low delay for priority messages. The algorithm used in this paper uses a cross layer approach as the algorithm adapts the transmission power (in PHY-layer) and contention window size (in MAC-layer) to enhance the performance of vehicular communication.

Prioritization of Messages and Transmission Power Adaptation

In this section, we describe how transmission range and transmission power are calculated based on local density of vehicles and network conditions, and how different messages are assigned different priorities based on their urgency.

Transmission Range and Transmission Power

One of the starting points investigation was provided by the following expression derived in Artimy [8] for the transmission range (TR) based on the estimated local vehicle density

$$TR = min\left\{L(1-K),\sqrt{\frac{L\ln L}{K}}+\alpha L\right\} \tag{1}$$

Where,

is a constant from traffic flow theory [8] ,

L is the length of the road segment over which the vehicle estimates its initial local vehicle density, And

K is the local vehicle density for a given vehicle, calculated as the ratio K = of the actual number (AN) of vehicles on the road present within its transmission range to the total number (TN) of vehicles that can be there on the road for current transmission range. The given vehicle counts its neighboring vehicles based on the sequence number acknowledgement received from them and evaluates the K value by taking the ratio of total reachable neighbors to the maximum possible number of vehicles on the given road segment.

Prioritization of Messages

As discussed in Section 2, the IEEE 802.11e EDCA has the service differentiation to provide QoS for different types of messages: voice traffic, video traffic, best effort traffic and background traffic [4]. To incorporate the EDCA mechanism in VANET we categorize the different messages according to their urgency and delay requirements [7] as listed in Table 1.

Table 1- Message Priorities [7]

Priority(traffic in EDCA)	Messages in VANET
Priority 1: (Voice - AC(3))	Accident messages, etc.
Priority 2: (Video - AC(2))	Accident indication messages
Priority 3: (Best-effort - AC(1))	Warning related messages
Priority 4: (Background - AC(0))	General messages

The different access categories in EDCA will have different QoS parameters associated with them. Table 2 gives the QoS parameters corresponding to the ACs in 802.11e EDCA. The higher the access category number, the higher the channel access or transmission opportunity will be. That means the CWmin value for AC (3) will be the least among all ACs. The backoff counter drawn uniformly from [0, CW[AC]] will have an initial value of CWmin, implying that AC (3) will get the highest transmission opportunity over others. Moreover, high priority classes in turn use a shorter inter frame spacing (IFS) and a smaller CW size so that they will get preferential treatment over lower priority classes. Each vehicle will have four different queues, one for each priority class with a virtual collision handler to handle internal collisions.

Table 2- Priority Specific Parameters [4]

AC	CWmin	CWmax	AIFS
0	CWmin	CWmax	2
1	CWmin	CWmax	1
2	(CWmin+1)/2 1	CWmin	1
3	(CWmin+1)/4-1	(CWmin+1)/2	1

Contention Window Size Adaptation

In order to support message differentiation for diverse types of messages listed in Table 2 the size of the CW in Table 2 should also be adapted taking into account the fact that vehicles that have higher priority messages should not get the chance to be greedy while higher priority messages should not be waiting for a long time for the opportunity to transmit. We note that a vehicle attempting to get transmission opportunity must wait for the channel to remain idle for the duration of the AIFS before starting its back-off timer. We also note that holding channel access for a long time for higher priority messages may result in a delay in message propagation which will not be able to notify or prevent incidents on the roadway such as congestion and traffic-jam buildups. Therefore, to alleviate these difficult effects the adaptation of QoS parameters for different access categories is essential.

In this approach, the size of the CW may either increase or decrease, and CW adaptation is carried out by applying the well-known approach used in the IEEE 802.11 algorithms by which the size of window CW [AC] is varied by a factor of two. In other words, the window size is doubled if one has to increase the size, and is reduced by half if one has to decrease its size. The CW size will continue to increase until it reaches to maximum size of the window, CWmax [AC] after which it will be re-initialized to CWmin. Thus, in this approach the window size fluctuates according to the network conditions observed by a vehicle while in conventional 802.11 technologies the size of window remains fixed no matter what the network condition is.

We note that the increase in CW [AC] values (for all ACs maintaining the hierarchy of CW [AC] values as in EDCA [4]) when the network is congested, will give less opportunity for all ACs to reduce network load because of broadcast and rebroadcast. Similarly the decrease in CW [AC] values when the network has less or no collision, will give higher opportunity for all ACs The local state of the network can be determined as in [9] by using the record of sequence numbers corresponding to individual vehicles from which it receives messages. By using lost sequence numbers each vehicle can calculate the approximate percentage of lost frames sent by other vehicles to in a given period of time. The adaptation of CW size according to network conditions results in high throughput and lower delay for high priority messages, while lower priority messages also get channel access but with lower preference over higher priority ones [10].

Algorithm

From the methods discussed in the previous section, an algorithm [2,3] which adapts both transmitted power and CW size and which should be run by entity vehicles periodically to ensure that proper updates of transmission power and CW [AC] values occur according to the local vehicle density and the network condition respectively. In this algorithm, each vehicle calculates its own transmission power dynamically based on the local density in order to mitigate the adverse effects of high transmission power and to increase the duration of the communication link in case of low traffic density for inter-vehicle communication.

Transmission Power Adaptation

Primarily, individual vehicles start with an arbitrary transmission power and pay attention for information from other vehicles. Once a vehicle receives message packets from other vehicles, it starts to evaluate the sequence numbers and to count the vehicles around its locale. In order to mitigate the adverse effects of high transmission power and to increase the duration of the communication link vehicle dynamically adapts its transmission power based on the estimated local vehicle density. The vehicle density within its transmission range is calculated . Using the estimated vehicle density the algorithm calculates the transmission range using equation (1) and then sets up the corresponding transmission power. We note that maximum transmit power corresponding to maximum transmission range is selected when either the local vehicle density K is lower than some application-dependent threshold1 value or when the vehicle needs to transmit priority 1 messages.

CW Size Adaptation

Dynamic adaptation of CW size causes changes in the back-off counter so that periodically transmission of messages occurs according to the network conditions, namely the perceived collision rate and local vehicle density. The dynamic adaptation of the CW size is regulated by a threshold2 Value. Formally, the algorithm for the adaptation of transmission power is as follows:

Input

Maximum transmission range R value, traffic constant α from traffic flow theory [8] and threshold value1, and default CW[AC] values ACs [4] and threshold value 2

Output

Transmission power P corresponding to the calculated transmission range TR and adapted CW[AC] values ACs

while (“messages are received”) do

Algorithm1: Transmit power adaptation.

```
Foreach Time do
    K=estimated local vehicle density
    If K < threshold1 or (Highest priority message) then
        Assign transmission range TR equal to maximum value R;
    Else
        Calculate TR using equation (1);
    end
    Assign the suitable transmission power corresponding to calculated transmission range TR
end
```

Algorithm 2: CW size adaptation.

```
foreach Time do
    if estimated collision rate > threshold2 then
        Increase the corresponding CW [AC] values for all ACs
    else if estimated collision rate < threshold2 then
        Decrease the corresponding CW [AC] values for all ACs
    else
        Maintain corresponding CW [AC];
    end
    end
end
```

The proper picking of threshold value also plays a chief role for the algorithm. Algorithm 1 adapts the transmission range and eventually the transmission power, whereas algorithm 2 adapts the corresponding CW values for all messages, hence the transmission prospect or time to get channel access. In order to adapt the transmission power and the contention window dynamically, each vehicle runs both algorithms in a periodic manner so that the proper tuning of those values occurs according to the local density of vehicles and the network conditions.

Conclusion

In this paper, the algorithms (algorithm 1 and 2) for dynamic adaptation of joint transmission power and contention window according to the vehicle density and network traffic conditions in a cross layer approach to improve the performance is discussed. A scheme for reliable broadcast transmission in vehicular communication is discussed. The scheme incorporates the EDCA medium access mechanism of IEEE 802.11e in VANET to set priority for different messages according to their urgency, and consists of an algorithm by which individual vehicles with dynamism adapt transmission powers according to the estimated local vehicle densities and adjust CW [AC] for all ACs based on data collision rate on the network.

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