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History Based Contention Window Control in IEEE 802.11 MAC Protocol in Error Prone Channel

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Abstract: Problem statement: IEEE 802.11 Medium Access Control (MAC) protocol is one of the most implemented protocols in this network. The IEEE 802.11 controls the access to the share wireless channel within competing stations. The IEEE 802.11 DCF doubles the Contention Window (CW) size for decreasing the collision within contending stations and to improve the network performances but it is not good for error prone channel because the sudden CW rest to CW_{min} may cause several collisions. **Approach:** The research to date has tended to focus on the current number of active stations that needs complex computations. A novel backoff algorithm is presented that optimizes the CW size with take into account the history of packet lost. **Results:** Finally, we compare the HBCWC with IEEE 802.11 DCF. The simulation results have shown 24.14, 56.71 and 25.33% improvement in Packet Delivery Ratio (PDR), average end to end delay and throughput compared to the IEEE 802.11 DCF. **Conclusion:** This study showed that monitoring the last three channel status achieve better delay and throughput that can be used for multimedia communications.

Key words: IEEE 802.11, MAC protocol, back off algorithm, contention window, error prone channel

INTRODUCTION

Mobile Ad Hoc Network (MANET) is a very popular field in these years. This technology is useful for ubiquitous environment in offices, hospitals, campuses, factories, airports and other various places. Since all transmitting stations in ranges, share the wireless medium we need to control medium access within contending stations. Study group 802.11 was formed and introduced IEEE 802.11 standard. This standard provides detailed MAC and Physical Layer (PHY) specification for WLAN. The IEEE 802.11 defines two modes of MAC protocol: Distribution Coordination Function (DCF) mode that is used for ad hoc networks and Point Coordination Function (PCF) mode that is useful for infrastructure-based networks. The DCF is necessary while supporting PCF is optional (Crow *et al*., 1997; Deng and Chang, 1999). In the study, present research on the DCF and corresponding enhanced schemes. In the DCF scheme, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is used for minimizing the effect of collision on the performances of the network. IEEE 802.11 uses Request-To-Send (RTS)/Clear-To-Send (CTS) mechanism in order to decrease the overhead caused by frame collision and hidden terminal effects. RTS/CTS mechanism fixes the channel before the data transmission. Figure 1 and 2 illustrate the data transmission with or without using RTS/CTS (Crow *et al*., 1997).

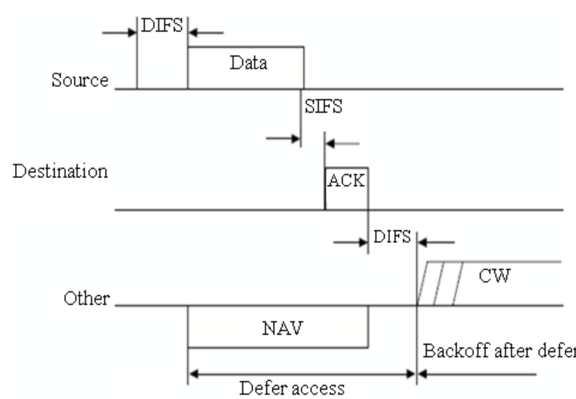

Fig. 1: Data transmission without RTS/CTS

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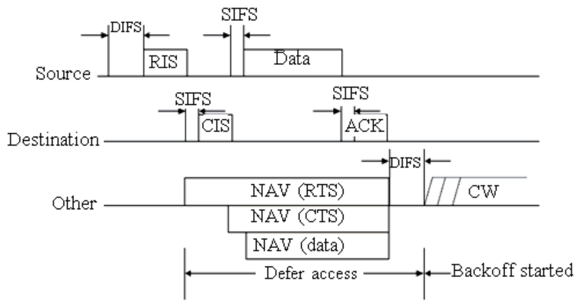

Fig. 2: Data transmission with RTS/CTS

According to the DCF, each station which has a data packet for transmission sends RTS packet to receiver. Upon receipt of the correct packet, the receiver waits for a Short Inter Frame Space (SIFS) interval and transmits a CTS packet if the channel is found idle. Moreover, the frames RTS and CTS involve the information about transmission duration which is utilized for updating a Network Allocation Vector (NAV) that shows the period of time in which the channel will remain busy. According to the DCF, when a station has a packet to transmission, at first checks the channel status if it finds the channel idle for Distributed Inter Frame Space (DIFS) period then a Slotted Binary Exponential Backoff (BEB) procedure chooses a random backoff interval value uniformly in [0,CW-1]. The 802.11 DCF sets $CW = CW_{min}$ and it is doubled with transmission failure up to a predefined maximum (CW_{max}). If the channel is sensed idle, backoff timer keeps running but when the channel is sensed busy the backoff algorithm pauses the timer. (When other station initiates the data transmission) the backoff timer resumed when the channel is sensed idle again for more than DIFS. When the backoff timer expires, the station is allowed to transmit a data packet at the next slot.

After receiving correct data packet by receiver, the receiver waits for SIFS time then transmits a positive Acknowledgment (ACK) to the sender. If the sender receives the ACK packet correctly then resets the CW size to the CWmin and drops the data packet. Otherwise, sender increases the CW size and attempts to retransmission until CWmax is reached (Deng and Chang, 1999).

In the literature, numerous papers have been conducted on improving the performance of IEEE 802.11 DCF by modifying the CW value (Natkaniec and Pach, 2000; Kim *et al*., 2008). We can categorize these papers into two groups. One group modifies the CW size with static scale and the other group changes the CW dynamically based on the current network condition.

Several papers introduce decreasing the CW value with static scale. In (Natkaniec and Pach, 2000; Moura and Marinheiro, 2005) authors suggested the Double Increment Double Decrement (DIDD) backoff scheme that decreases gradually after a successful packet transmission (Bharghavan *et al*., 1994).Proposes a backoff algorithm known as MILD (Multiple Increase Linear Decrease), which multiplies the CW by 1.5 on a packet transmission failure and decreases on a successful transmission linearly. MILD works well when the network load is heavy but does not work well when the network load is light because it consumes quite long time to return to the appropriate state. In (Song *et al*., 2003), the CW is increased by backoff factor r_I and backoff factor r_D is used for decreasing the CW size. In (Deng *et al*., 2008; Kim *et al*., 2008), the authors suggested a mechanism to modify the CW size based on the number of active stations that is estimated by monitoring the current channel status. In this group of papers, the node has to use complex computations for estimating the number of active nodes which are undesirable for the wireless ad hoc networks.

In our scheme, we introduce a simple approach to slowly modify the CW value based on the history of packet lost in the network. We use static scale from group one for modifying the CW value but we take into account the history of packet lost accurse in the channel.

MATERIALS AND METHODS

We propose a novel backoff mechanism, in which the history of packet lost is taken into account for CW size optimization. The packet lost involves packet collision and channel error. The mechanism checks the last three states of transmission, and optimizes the CW size based on the following Table 1 (0 indicates a collision and 1 indicates a successful transmission without collision).

In this study, we utilize two parameters x and y, that are used to update CW value. We check the channel and if the packet lost rate is increased because of channel error or collision, we increase the CW size for decreasing the packet lost and when the packet lost rate of the channel is decreased we decrease the CW size slowly for increasing the throughput. The CS (Channel State) is three elements array that is updated upon each transmission trial, i.e. each time the station transmits the packet successfully and receives the acknowledgement (ACK for data and CTS for RTS packets) or when the packet becomes collide because of channel error or collision. When we store the new channel state, the oldest channel state in the CS array is removed and the remaining stored states are shifted to the left.

Table 1: CW estimation algorithm in HBCWC

CS state	CW range
000	CW = CW*(x*y)
001	CW = CWmin
010	CW = CW*(x*y)
011	CW = CWmin
100	CW = CW*(x*y)
101	CW = CWmin
110	CW = CW*(y/x)
111	CW = CWmin

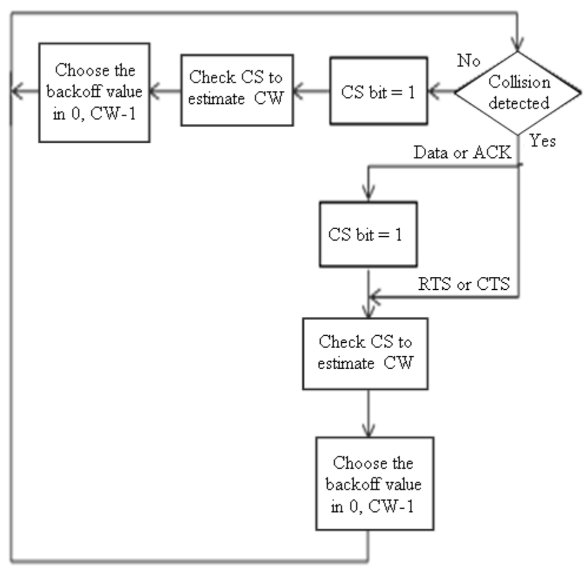

Fig. 3: Operation of HBCWC

In this mechanism, we have four variables, CW, x, y and CS array that are initialized in this way:

$$CW = CWmin \tag{1}$$

$$x = 1.1 \tag{2}$$

$$y = 1.9 \tag{3}$$

$$CS = 000 \tag{4}$$

Figure 3 shows the operation of HBCWC. The station transmits a packet and if the packet lost occurs in data or ACK packet because of channel error or collision then a channel state bit will be set to ‘0’ and the CS array is checked and new backoff value is chosen. Otherwise, if the packet lost occurs in RTS and CTS packet, only the CS array is checked and new backoff value is chosen.

In addition, when the station transmits the packet without any error the CS array will be set to ‘1’ and the new backoff value is chosen based on the CS array.

The HBCWC has extra memory space for CS array that is used for saving new variables and extra computations for five additional operations that are used to select the next CW size. The operations involve multiplication, shifting CS array to adding new variable, if conditional statement and memory read and write operations. We do not study the optimization of x and y and their effect on the performances. It could be a good future work.

RESULTS

Simulation model and parameters: We implement the proposed scheme in NS-2 simulator (version 2.28) (NS, 1995) and evaluate the performance of HBCWC in error prone channel and compare it to the IEEE 802.11 DCF. The results are showed for varied number of connections. Our simulation are based on a 1000×1000 m flat space and 50 wireless nodes are randomly distributed within this area. The simulation time was set to 600 sec. Each node generates CBR (constant bit rate) traffic with data payload size 512 bytes and data packet rate of 4 packets sec^{-1}. The propagation range and channel capacity is set 250 m and 2 Mb sec^{-1} for each node. We generate node mobility with random waypoint model. The minimum, maximum speed and pause time is selected 0 and 20 m sec^{-1} and 50 sec. We present the channel error with basic error model in NS-2. We assume that error unit and error rate is respectively packet and 0.1.

The metrics used in evaluating the performance of our scheme are as follows:

Packet Delivery Ratio: the Packet Delivery Ratio (PDR) which represents the ratio between the number of packets originated by the application layer source and the packets received by the final destination.

Average end to end delay: The average end to end delay which calculates the average time required to receive the packet.

Average throughput: The average throughput which is the amount of data successfully received in a given time period that it is measured in Kilo bits per sec (Kbps).

To investigate the effect of channel error, we define a channel error with Packet Error Rate = 0.1 (PER) and compare the result of channel error on the DCF and HBCWC. Figure 4-6 show the PDR, average end to end delay and throughput versus the number of connections in the network with channel error. We obtain that 24.14, 56.71 and 25.33% improvement for PDR, average end to end delay and throughput.

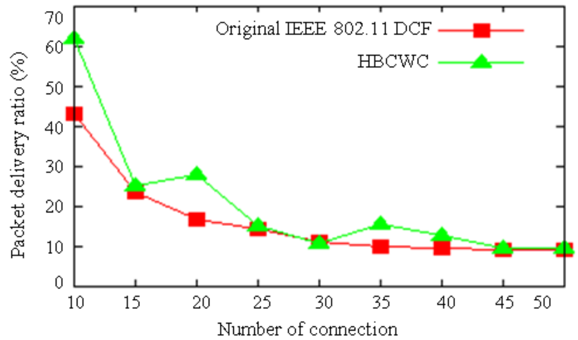

Fig. 4: packet delivery ratio

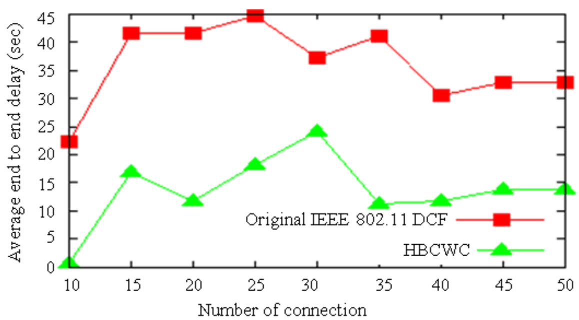

Fig. 5: average end to end delay

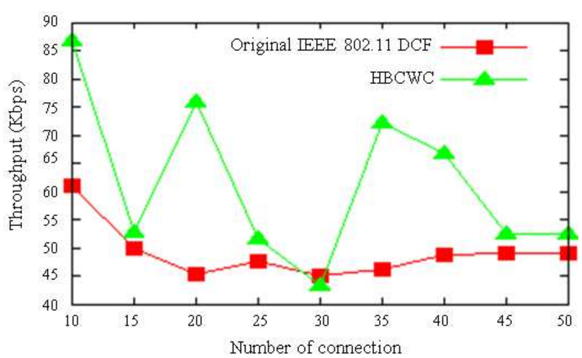

Fig. 6: Throughput

DISCUSSION

The purpose of the study was to decrease collision between contending stations with simple method and modify DCF mechanism when it reset CW to CW_{min}. We present the result of the effect of channel error on the HBCWC and IEEE 802.11 DCF performances. The channel error may cause data frames lost. In the IEEE 802.11DCF, when a data frame is corrupted by channel error, DCF doubles the CW size as collision without any attention to the channel condition. But in our scheme, we monitor the channel condition with taking the history of lost packet into account and modifying the CW size based on the channel condition.

CONCLUSION

In this study, we proposed a novel backoff algorithm to enhance the performances over error prone wireless ad hoc networks based on the IEEE 802.11 architecture. The basic idea is to check the channel condition and optimize the CW size based on that for combating channel error and obtaining better performances. Simulation results show that the HBCWC significantly improves the performances compared with the IEEE 802.11 in terms of PDR, average end to end delay and throughput over error prone network. We obtain 24.14%, 56.71% and 25.33% improvements in PDR, delay and throughput. For future work, we want to show the effect of the HBCWC parameters (x and y) on the performances.

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