Designing CSMA/CA Mechanism in MATLAB

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In this report, the implementation and design specifications of CSMA/CA mechanism in MATLAB will be explained clearly. Afterwards, the results of the simulation is going to be analyzed.

1. INTRODUCTION

Carrier-sense multiple access with collision avoidance (CSMA/CA) is a multiple access mechanism for wireless local area networks. Basically, each clients has to wait some time to access the channel. Before accessing channel, each client must control the medium whether there is a packet from other clients, or not. Only if there is no packet in the medium, the clients prevent from collision. The time that each client wait is determined with a random number system; which means each client generates a number and obtains a $Backoff\ Time$ as can be seen in Equation 1. Let R be a random number between $(1, CW)$, the Backoff Time t_{bo} is calculated from R and the Slot Time t_{st} which is a sensible time period for changing due to WIFI standards[**article**] [1].

$$t_{bo} = R \cdot t_{st} \tag{1}$$

To obtain reliable comparison of UORA and CSMA/CA mechanisms, the implementation of CSMA/CA in MATLAB was a necessity. At that point, the design specifications of CSMA/CA have been determined properly so that the result of the simulation have to be comparable with measurements. On the other hand, in terms of throughput, different scenarios and collision, the result is going to be analyzed.

2. THE DESIGN SPECIFICATIONS

Although, this simulation focuses on uplink data transfer, the main goal is to simulate channel access mechanism in a proper way; which means the design specifications do not include the different data transmission methods for clients' data traffic. In terms of data packet, to observe access mechanism in a more decent way; data packet is determined as a constant for entire case.

A. Modulation Type and Data Rate

A constant and stable modulation method 256-QAM has been chosen in simulation. Also, there are lots of documentation, test results and measurements about 256-QAM in IEEE802.11ac. In VHT MCS Index (Very High Throughput Modulation and Coding Scheme); the baud rate, symbol rate, data rate etc. change with channel bandwidth. Therefore, to form a stable test environment for CSMA/CA, a constant channel bandwidth has been decided on 160 Mhz and coding rate as 5/6, which means the VHT MCS Index level of the simulator is 9. In the lights of the information about 256-QAM in the Table 1, it is possible to verify the data rate of 256-QAM[3].

$$R_b = \frac{1}{t_s + t_{gi}} \tag{2}$$

$$R_d = R_b \cdot n_s \cdot \log_2 M \cdot R_c \tag{3}$$

Let R_b be bit rate of the 256-QAM, the symbolling period t_s of 256-QAM varies with channel bandwidth. The t_{gi} guard interval for a symbol is a deterministic value. Due to interference conditions, it is possible to increase the time to clearer detection. On the other hand, n_s denotes the number of the subcarrier in a 160Mhz channel while M is the number of the modulation level. Finally, the coding rate R_c depends on channel coding[2].

$$R_b = \frac{1}{3.2s + 0.4s} = 277,777.777 \tag{4}$$

$$R_d = 277,777.777 \cdot 468 \cdot 8 \cdot 5/6 = 866.666 Mbps \tag{5}$$

Table 1. MCS Index for 802.11ac

MCS Index	Modulation	Coding	Data Rate in Mbps
8	256-QAM	3/4	780
9	256-QAM	5/6	866.7

B. Constant Packets and Time Spaces

As mentioned earlier, the client needs to control medium to complete data transmission. To make controlling easier, the clients and access points (AP) have to send Request to Send (RTS) and Clear to Send (CTS) packets. In Fig.1, it is possible to observe that there is an acknowledgement (ACK) packet with RTS and CTS. Also, by means of Distributed Coordination Function (DCF), CSMA/CA includes time spaces such as DCF Interframe Space (DIFS)and Short Interframe Space (SIFS) to eradicate the problem of noise interference in the medium. The DIFS and SIFS is calculated from Slot Time is the minimum sensible time in a network system[4].

Although the size of CTS, RTS and ACK packets can vary during the transmission, slot time, SIFS and DIFS are constant.

However, time spaces may have a different values due to WIFI standards. Furthermore, there is a limit for DATA packets, but aggregated data transmission mechanism is used for huge data traffic; which is not included in the simulation. To form more realistic results, in the simulation, the limit is exceeded. At that point, for the packets size, an average value for each packet type has been determined and used in the simulation. Additionally, the values of IEEE802.11ac for DIFS, SIFS and Slot Time have been used in the simulation. The duration for the packets and time spaces can be found in Table 2 and 3[2].

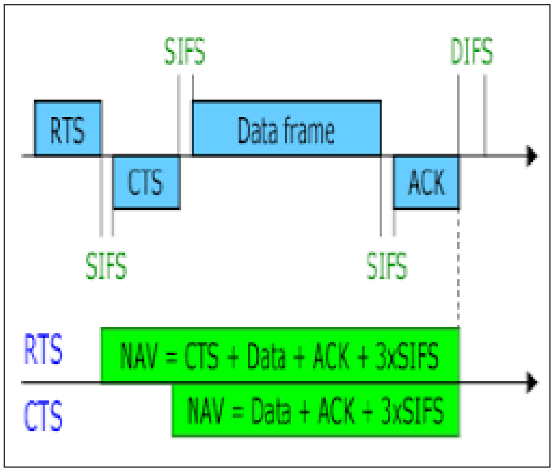

Fig. 1. RTS/CTS Scheme

Table 2. Time Duration for Time Spaces

Time Spaces	Time
$SlotTime$	$9\mu s$
$SIFS$	$16\mu s$
$DIFS$	$34\mu s$

Table 3. Time Duration for RTS/CTS packets

Packets	Time
RTS	$52\mu s$
CTS	$34\mu s$
ACK	$28\mu s$
$Max.DataDuration$	$305.1\mu s$

C. Contention Window Mechanism

As aforementioned, each clients generates a random number to determine the value of the random backoff interval is chosen from an interval called the Contention Window (CW), which lies between two preconfigured values, CW_{min} and CW_{max}. Random numbers are generated with *randi* function which is a buildin function in MATLAB, the function generates Pseudorandom integers from a uniform discrete distribution. For IEEE802.11ac standard, CW_{min} is equal 16 and CW_{max} is equal to 1024. In the simulation, when collision happens, CW values of collided clients increases exponentially as in Algorithm 1[5].

Algorithm 1. Contention Window Mechanism

procedure CW(Collision is detected.)
  $MinBackOff = min(BackOff[\,]$ ▷ the minimum backoff in this process.
  CW_k; ▷ contention window array
  $BackOff_k$; ▷ randomly generated backoffs
  $NumberOfUser = size(BackOff[\,])$; ▷ the number of users
  for $k \leftarrow 1$ to $NumberOfUser$ **do**
    if $BackOff_k = MinBackOff$ **then**
      $CW_k = 2 \cdot CW_k$;

D. Simulation Inputs

The program does not include specific clients with ID. It works as a queue for transmission. The user needs to specify the the time in seconds that a client starts transmission and its data load in MB as can be seen Figure 2.

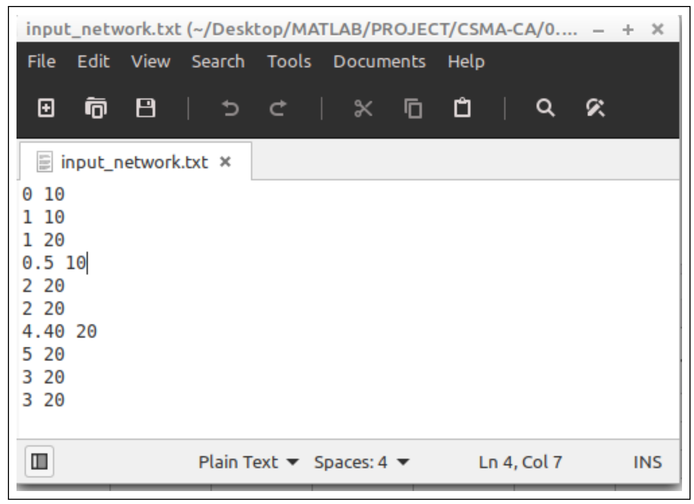

Fig. 2. Input Format of the program

E. Channel Control

If there is no client in the medium, programs check the medium in every 0.01 second. However, when there is further user in the input network, it terminates itself. Then, the simulator informs the user about current situation.

3. SIMULATION RESULTS

In this section, the result graphs are going to be compared with theoretical results. Also, results with assumptions are going to be explained. The main goal is to reveal the pitfalls of CSMA/CA mechanism in detail. Firstly, the results start with the simulation of the given inputs in Fig. 2 and continue with the simulation of given input with higher data loads. Then, a scenario for a single client in a dense network with increasing number of clients will be simulated. Finally, in dense networks, the packet drops that collisions cause and throughput of the entire network will be analyzed.

A. The simulation of the given inputs

This scenario with respect to the given inputs in Fig. 2 has been formed to test program whether it works properly, or not.

Throughput and the number of collision are expected to have a consistency with theoretical values. In terms of throughput, we have a limited number of clients in this process. By the Birthday Paradox, with increasing number of clients, the probability to have collision increases. With few numbers of clients, the probability of collision is low and it is not expected to observe drops in throughput.

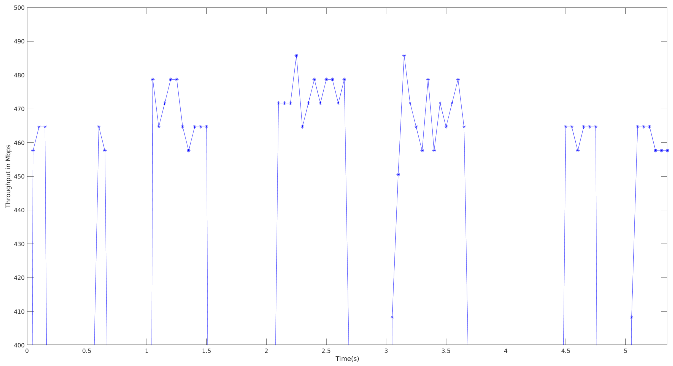

Fig. 3. Throughput vs Time Graph for Given Inputs

To complete data transmission in the mechanism, RTS/CTS mechanism checks the channel and prevents from collision. However, this requires lots of time; which is the main reason of throughput value in the Fig.3. Clients have to communicate with the Access Point to decide on when to access channel.

Although it is assumed that due to limited number of clients in the network, the drops in the throughput is not likely to happen; collisions cause to fluctuations in the throughput of the network as can be seen in both Fig.3 and Fig.4. However, it is possible to say that the precision of the graphs are high, a single collision has a huge impact on throughput.

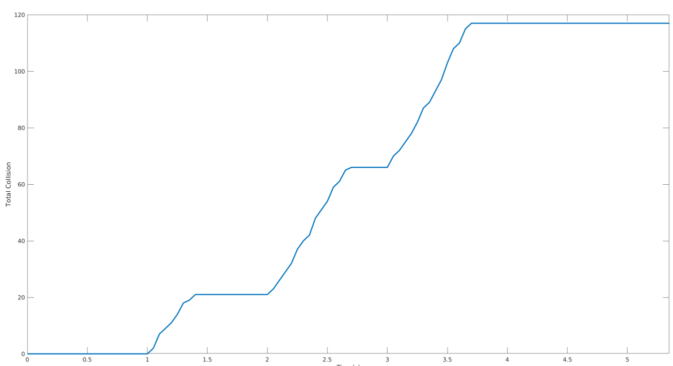

Fig. 4. Total Collision vs Time Graph

B. A Single Client in a Dense Network

In this part, the inputs are formed to simulate and observe a single user's throughput with increasing number of clients in a network. The expected result is that the throughput decreases with the number of user.

In Fig.5, as expected, the throughput of the first user decreases exponentially with new clients. The decrease in throughput is inevitable, the client shares the bandwidth with new clients; which requires linearly decrease. Collisions lead the throughput to drop exponentially. Also, in some of the cases, client did not have chance to access channel.

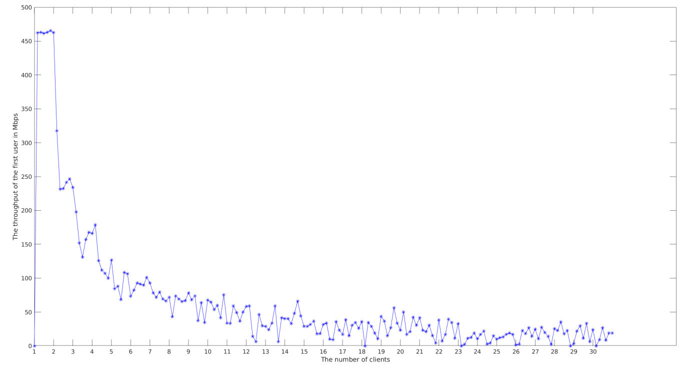

Fig. 5. Throughput of the 1st Client with Every New Clients

C. Collision Analysis

Collision avoidance possibles to maintain low-latency in the network. However, by the Birthday Paradox, it is obvious that with each clients, the probability to collide packets go up. At that point, it is ordinary to expect the collision per second to blow up but the Back Off Mechanism bring some kind of order to make the system stable. In other words, instead of collision, the clients face with long back off time. Therefore, the collision per second with every new client slowly goes up in Fig.6.

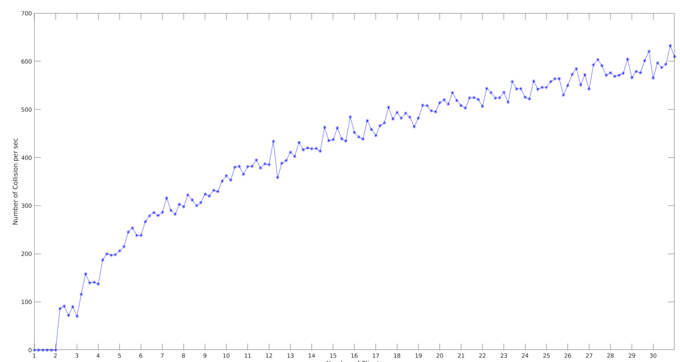

Fig. 6. Collision Characteristics of Dense Networks

D. Throughput with the Increasing Number of Clients

The main problem of CSMA/CA mechanism is packet loss due to collided clients; which causes to significant efficiency problems in dense networks. High latency and low throughput are the most undesired situations in the networks. The simulation has the ideal conditions, there is no noise in the air; all the nodes clearly hear other node, which means the hidden node problem does not occur. By taking into consideration of these circumstances, as can be seen in Fig.7, in a single spacial stream, it is possible to say that nearly %20 of throughput is lost in the network.

4. CONCLUSION

Due to multiple-device ownership and IoT devices, APs face with huge number of clients. As you can see in Fig.7, CSMA/CA mechanism does not propose a solution the huge traffic due to a great number of clients. On the other hand, bandwidth-hungry applications are getting more wide-spread. Also, augmented, virtual or mixed reality is the emerging technologies, which re-

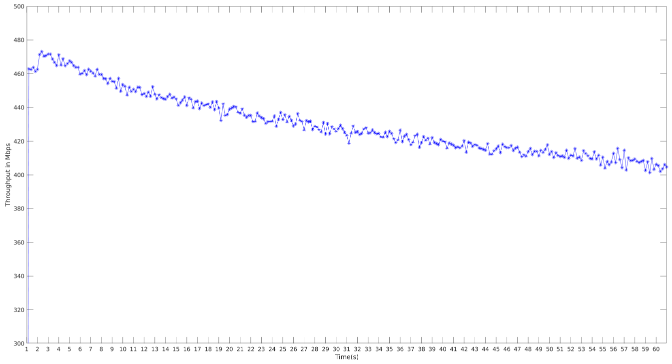

Fig. 7. Throughput with Increasing Number of Clients

quires low-latency. To respond these demands, Uplink OFDMA Random Access proposes a more efficient network.

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