A Simulation Study of Block Acknowledgements and TXOPs under Varying Channel Conditions

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Abstract— The acknowledgment schemes of legacy 802.11 do not support optimized performance due to high overheads. The performance further deteriorates for real time traffic. Transmission opportunity (TXOP) mechanism and Block Acknowledgements (Acks) were later introduced to facilitate improved performance in 802.11e. In this paper we aim to prove the effectiveness of both TXOP and Block Ack and analyze their effects under varying channel conditions through simulations carried out in NS-2.

Index Terms:
Keywords-component; 802.11e, Block acknowledgement schemes, Transmission opportunity.

I. INTRODUCTION

User demands to access multimedia applications while on the move has made IEEE 802.11 as their ultimate choice. This has been made possible due to the continuous provision of multiple higher data rates by using various modulations and channel coding schemes [1]. Among the 802.11 standards 802.11e is the most popular choice as it supports QOS requirements of time sensitive applications such as voice and video by introducing priority mechanisms. The MAC protocol of 802.11e is called Hybrid Co-ordination Function (HCF). It incorporates both contention based Enhanced Distributed Channel Access (EDCA) (DCF is legacy 802.11) and HCF Controlled Channel Access (HCCA) (PCF in legacy 802.11). In addition 802.11e introduces the concept of Transmission Opportunity (TXOP) which is defined as the time duration when a station may transmit multiple frames in contrast to 802.11 where a node can transmit a single frame only and wait for receiving the acknowledgement as implemented in ARQ stop and wait protocol. 802.11e also introduced four different acknowledgement mechanisms [2] including Block ACK and No ACK mechanisms [3].

A. *Acknowledgement Mechanisms*

In normal ACK, every frame is acknowledged with an ACK frame after a short inter frame (SIF) duration. Acknowledgement time out takes place similar to ARQ mechanisms. The normal Block ACK consists of a setup phase, data transfer phase and a tear down phase. After the setup phase the sender can transmit multiple frames. When it wants to get an acknowledgement, it sends Block ACK request (BAR). The Receiver after receiving the BAR responds with Block ACK frame (BA). This is referred to as immediate acknowledgement. [1].
Another type of Block ACK is called delayed acknowledgement; if the receiver feels that there is not enough time to send BA, it responds with a normal acknowledgement and then sends BA in the subsequent TXOP giving it the highest possible priority [5]. Finally, No acknowledgement defines a procedure where a received MAC protocol data unit (MPDU) is not responded with any acknowledgement.

B. *EDCA*

Quality of Service (QOS) in 802.11e is ensured through EDCA. Various wireless stations depending upon their traffic needs contend for the channel. There are two types of contention; contention with in a node among different traffic types like voice, video etc and between the nodes. Various traffic types are defined as Access Categories (ACs). Each AC has different contention parameters. In EDCA inter frame space is called AIFS (Arbitration Inter Frame Space). Smaller AIFs indicate high priority. The other parameters to distinguish traffic types are Contention Windows (CWmin and CWmax). Some of the default values for various parameters defined for 802.11e Standard are shown in Table 1. [11]

Table 1 Default values 802.11e Standard

Traffic Type	**AC**	**AIFSN**	**CW_{min}**	**CW_{max}**	**TXOP Limit**
Voice	**0**	**2**	**7**	**15**	**3.2 ms**
Video	**1**	**2**	**15**	**31**	**6.01ms**
Best Effort	**2**	**3**	**31**	**1023**	**0**
Background	**3**	**7**	**31**	**1023**	**0**

C. *TXOP*

TXOP is the time duration during which a wireless node can transmit multiple packets separated by SIF interval. TXOP is indicated by starting time and the duration. A TXOP of 0 value indicates that node can transmit only one frame.

II. Related Work

There have been considerable efforts to analyze the newly proposed acknowledgement schemes. For example a scheme called Burst ACK has been studied in [4] where one station gets access to the channel; frames are transmitted with out SIF interval but each frame is responded with an acknowledgement. Ideal case throughput and delay of Block Ack schemes were studied in [5]. The saturation throughput of Block Ack schemes was analyzed in an infrastructure network assuming that the channel is error free in [1]. The performance analysis of Block acknowledgement schemes were studied in [6] with respect to noisy channels. In [3] the authors have compared three acknowledgment schemes with respect to the number of stations, MAC protocol data unit (MPDU) length, PHY mode and bit error rate (BER).

III. Problem Definition

Wireless networks are not only complex but also sensitive to a variety of features which makes them some what unpredictable. They are highly dependent on atmospheric conditions, and may get affected even by man-made and natural obstacles. Additionally, drastic movement of nodes makes them even more unpredictable. All the above ingredients lead to dropping of packets and high delays; these have pronounced affect on applications that have stringent QOS requirements. Prior to the introduction of the QOS characteristics in wireless standard that was introduced in 802.11e, all frames were supposed to be acknowledged which resulted in high overhead and therefore reduced throughput irrespective of network conditions. Adverse environmental conditions make the performance even worse. However, it is envisaged that the TXOP mechanism introduced in 802.11e along with Block ACK would certainly assist in overcoming the delays, reduce overheads and increase throughput. The effects of acknowledgement schemes especially the Block Ack and Normal Ack mechanisms in various network and environmental conditions for different applications both real time and non real time traffic are being studied and analyzed.

IV. Simulation

Simulations in NS2 were carried out to using Casetti [10] model for implementing 802.11e Standard. This model was chosen for simulations as it was very well defined as compared to other models. The Casetti model has the following properties:

1) It can implement both Normal ACK as well as Burst Model

2) In burst model the number of frames N can be defined

3) HCCA mode can be implemented. However, this is not required in our case so it was disabled

4) TCP and UDP traffic can be generated

5) TCP traffic can be greedy as well as ON/OFF model

Following are some of the chief parameters that can be defined and specified as desired:

1) Bandwidth
2) CWmin and CWmax
3) TXOP limit
4) Either 802.11b or 802.11e
5) Queue length
6) Perr (Average error probability)
7) Access categories

However one the major drawback of this model is that Trgraph and NAM can not be run.

V. SIMULATION PARAMETERS

The simulation was conducted with the following parameters:

1) Band Width = 54 Mbps
2) Number of nodes = 2(BS & WN)
3) Burst BB & Burst BG 2000 (no of slots for error model)
4) Traffic both TCP (greedy) and UDP
5) Packet size of TCP = 1000 bytes and UDP = 250 bytes
6) NA and BA both conducted
7) HCCA disabled
8) TXOP limit Various
9) Perr (error probability) Various

A. *Topology*

Two nodes that is one Base Stations (BS) and one Wireless Node (WN) were deployed to run TCP and UDP traffic as under:

TCP – from WN to BS

UDP – from BS to WN

B. *Simulation Results*

Simulations were run under 5 different Bit Error Rates (BER) which were 0.01, 0.1, 0.2, 0.5 and 0.9. Various parameters were changed to ascertain the validity of Casetti implementations of 802.11e and study the affects of varying channel conditions. Simulations were carried out with both Normal Acknowledgement (NA) and Block Acknowledgement (BA) mechanism.

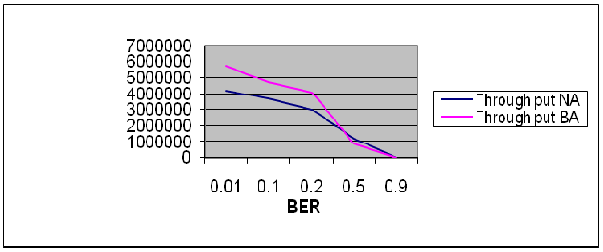

Figure 1: TCP Throughput in NA Vs BA modes

Figure 1 shows the throughput in NA and BA mode. It increases in burst mode, however, the difference reduces as BER increases. This is due to the fact that at significantly high BER, the throughput is drastically reduced due to bit errors and the difference between NA and BA becomes negligible. It validates the concept that in poor channel conditions BA is not really useful.

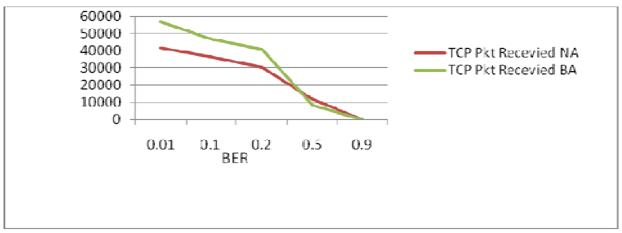

Figure 2: TCP Packets Received in NA Vs BA mode

In Figure 2 the numbers of TCP packets received in NA and BA modes are shown. The number of packets received in BA mode as expected is higher as compared to NA mode. However, at BER 0.9 which is an extremely high BER, there is no significant difference in the number of TCP packets received between the two cases, as expected based on previous analysis.

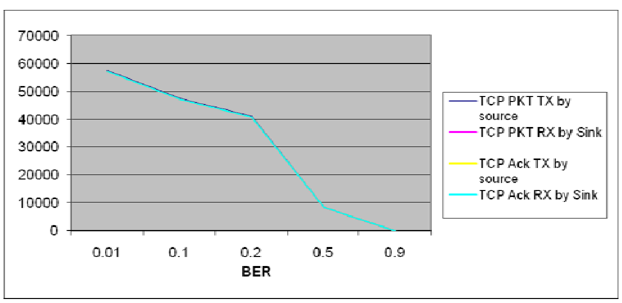

Figure3: TCP and its ACK Packets in BA mode

Figure 3 shows TCP packet sent by the source and received by the destination and its ACK sent by the receiver and received by the destination. There is downward trend in number of packets BER increases. Similar trend is seen in NA mode also.

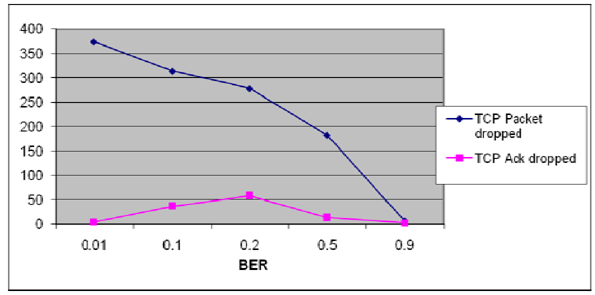

Figure 4: Dropped TCP and its ACK Packets in BA mode

Figure 4 shows the dropped TCP packets transmitted and their Ack. The loss is less in smaller sized Ack packets as the larger TCP packets are affected more by poor channel conditions (higher BER) as compared to smaller packets. Similar trend is analyzed in NA mode.

It was analyzed that trend was different with UDP packets. An enormous increase in number of UDP transmitted packets at MAC layer was seen at higher BER. This is due to the fact that the frames were being timed out and retransmitted again. However, Ack frames being in smaller in size were not that much affected and packet dropped rate was less (not shown). Similar trend was seen in both BA and BA-10 (N set to 10 in TXOP).

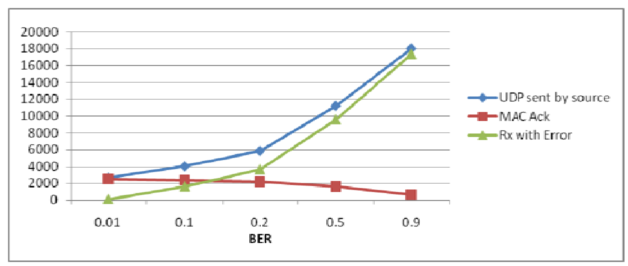

Figure 5: UDP Packets and their Acks at NA, BA and BA-10 mode

Another important trend was analyzed in the above mentioned figure. It was seen that the number of UDP packets sent by the source, their MAC Ack, packets dropped and other parameters in all 3 cases that is in NA, BA and BA -10 were identical. It is due to the fact that large enough buffer size and TXOP value (5 msec) all the packets are getting through and as such there is no difference in the various readings

C. TXOPs Analysis

In 802.11e TXOP is a very important concept to achieve efficiency. In this case, a sending station can send multiple packets and may receive ACK for each and every packet or a cumulative ACK if BAR and BA are implemented. In the case where each packet is initially acknowledged, it is still quite efficient as only the 1st packet contends for the media. TXOP can be implemented both for contention based as well as contention free traffic. For contention based traffic the protocol is EDCA-TXOP. The TXOP is defined by the time interval during which multiple frames can be sent. A TXOP set to 0 implies that only one MSDU can be transmitted in one transmit opportunity.

Simulations were also conducted for varying TXOPs values and it was noted that by increasing the TXOPs, a saturation state is reached at a certain TXOP value, after which further increasing the value of TXOP has no effect on the number of packets being transmitted as shown in figure 6.

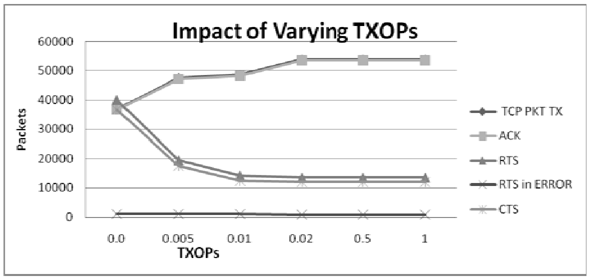

Figure 6: Impact of varying TXOPs

Impact of varying BER with the TXOP of 0.005 and 0.0 was analyzed and it was found that there is considerable reduction in number of packets at TXOP = 0 as only one MSDU is sent in each TXOP as explained above. Effects on various parameters are shown in Figure 12 and 13.

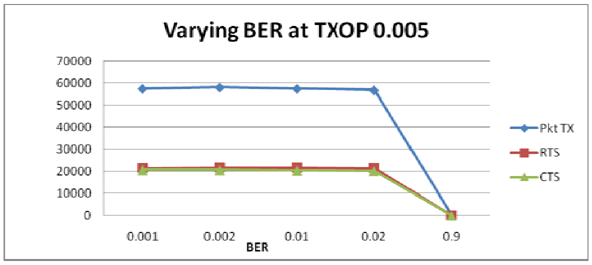

Figure 7: Effects of BERs with TXOP 0.005

It can be seen in above figure that RTS packets are much less than the packet transmitted as multiple packet can be transmitted in TXOP (0.005). The number of CTS packets is less than RTS packets as all RTS packet can not get through. Sudden drop in packets can be seen after BER 0.02 as channel conditions are getting poor.

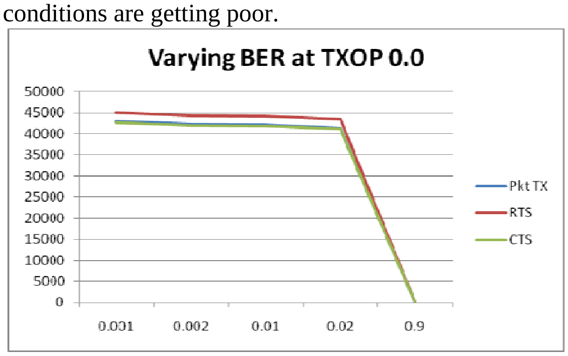

Figure 8: Effects of BERs with TXOP 0.0

It can be seen in figure 8 that number of RTS is even more than the TCP packets transmitted but number of CTS are almost similar to number of TCP packets. It is due the fact that some of the RTS packets could not get through and this number increases as the channel conditions deteriorates except at BER 0.9 when over all very few packets could get through.

VI. CONCLUSIONS

In this paper we simulated the 802.11e using Casetti model in EDCA mode only and validated its performance by observing the TCP packets transmission and reception in NA and BA mode under varying channel conditions and found it to be accurate. It was seen that higher BER leads to poor utilization of channel. It was also analyzed that Block Ack in TCP was found highly effective. On the contrary it hardly had any effect on UDP traffic under same TXOP as the statistics in all 3 cases that are NA, BA and BA-10 were found identical. It was analyzed that a TXOP value of 5 msec is high enough to affect any change. It was analyzed that increased TXOP value does not have any effect once a threshold value is reached. However number of packets gets reduced in TXOP value of 0 as only one MSDU can be sent. In addition, TCP packets are almost equal to the number of RTS packets as a node has to contend the channel for every packet it wants to transmit.

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