Performance Comparison of Video Traffic Over WLAN IEEE 802.11e and IEEE 802.11n

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Abstract— **This paper reviews the fast deployment of Wireless Local Area Networks (WLANs) and the ability of WLAN to support real time services. Stringent quality of service (QoS) and high throughput requirements has come into force. We compare the QoS support in the IEEE 802.11e to 802.11n standard. The 802.11n frame aggregation mechanism provides a better video traffic transmission performance such as throughput, delay and packet lost. The 802.11e mechanism allows prioritized medium access for applications with high QoS requirements by assigning different priorities to its four access categories. The 802.11n implemented frame aggregation to get high throughput and low delay transmission. We evaluate the performance of both 802.11 standards by implementing real time audio and video traffic using Network Simulator-2 (NS 2) simulation. Parameters such as throughput mean delay and packet lost have been calculated and graphs have been plotted. Simulation results show that 802.11e mechanism provides satisfactory service differentiation among its four access categories. With frame aggregation mechanism in 802.11n, network delay has been effectively decreased to better support real-time audio and video transmissions**

Keywords – Performance Comparison; 802.11e; 802.11n; Throughput

I. INTRODUCTION

In recent years, IEEE 802.11 standard has emerged as the dominating technology and is vastly used in Wireless Local Area Networks (WLANs) [1]. Low cost, ease of deployment and mobility support has resulted in the vast popularity of IEEE 802.11 WLANs. WLAN can be easily deployed in hot-spot zones of airports, hotels, office, and residence homes. With ever increasing popularity of multimedia applications, people want voice, audio and video services through WLAN connections. Unlike the traditional best effort data applications, multimedia applications require quality of service (QoS) support such as guaranteed bandwidth, delay and packet lost. The legacy 802.11, 802.11b, 802.11a/g can provide up to 2 Mbps, 11 Mbps and 54 Mbps data rates. However, the achievable throughput of a WLAN is less than half of the physical layer (PHY) raw data rate because of the protocol overheads, (UDP, TCP, IP, medium access control (MAC), physical (PHY) preamble, interframe spaces (IFSs), acknowledgment (ACK) and backoff time, etc. As both the MAC layer and the PHY layer of 802.11 [2] are designed for best effort data transmissions, the original 802.11 standard does not take QoS into account. Hence to provide QoS support IEEE 802.11 standard group has specified a new IEEE 802.11e standard. IEEE 802.11e supports QoS by providing differentiated classes of service in MAC layer; it also enhances the physical layer so that it can deliver time sensitive multimedia traffic, in addition to traditional data packets [3].

The IEEE 802.11e standard introduces the Hybrid Coordination Function (HCF) as the MAC scheme. While backward compatible with Distributed Coordination Fuction (DCF) and PCF, HCF provides stations with prioritized and parameterized QoS access to the wireless medium. HCF combines aspects of both the contention-based and the contention free access methods, where the contention-based channel access mechanism in HCF is known as the Enhanced Distributed Channel Access (EDCA) and its contention free counterpart is known as the HCF Controlled Channel Access (HCCA).The EDCA is an extension of the conventional distributed coordination function (DCF) [3]. It provides prioritized QoS services which classify all the traffics destined MAC layer to multiple Access Categories (ACs). Also differentiate the chance to get a transmission opportunity (TXOP) using unequal channel access parameters.

In response to the demand for higher performance WLANs to support multimedia applications such as voice and video, the standard group has specified a new IEEE 802.11n standard to provide over 100 Mbps throughput at the MAC data Service Access Point (SAP) via PHY and MAC enhancement [5]. An IEEE 802.11n WLAN can operate with physical layer raw data rate up to 200-600 Mbps by using Multiple-Input Multiple-Output (MIMO) technology, modified encoding and optional channel binding scheme. To efficiently improve the SAP throughput, two main MAC enhancement mechanisms have been proposed to reduce the protocol overhead (1) frame aggregation and (2) bidirectional transmission [6]. These mechanisms eliminate the need to initiate a transmission for every MAC frame in the legacy 802.11 and thus reduce the transmission overheads and improve the throughput efficiency. In our work, we compare the performance of 802.11e to 802.11n on accommodate video traffic.

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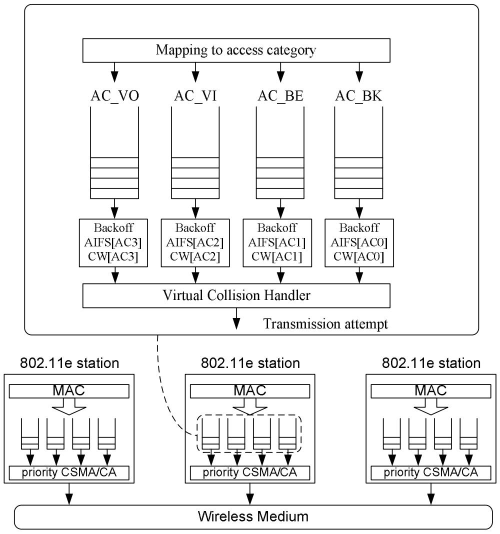

Figure 1. Four access categories in IEEE 802.11e [6].

TABLE 1. 802.11E EDCA PARAMETER SET

Priority	AC	Designation	AIFSN	CWmin	CWmax
3	AC_VO	Voice	2	7	15
2	AC_VI	Video	2	15	31
1	AC_BE	Best Effort	3	31	1023
0	AC_BK	Background	7	31	1023

This paper is organized as follows; Section II describes basic theory of WLAN IEEE 802.11e and WLAN IEEE 802.11n. In Section III, we evaluate video transmission performance over 802.11e and 802.11n using ns-2 simulation and perform the performance comparison evaluation of the simulation results. Finally, Section IV concludes the paper.

II. BASIC THEORY

A. IEEE 802.11e

IEEE 802.11e EDCA is designed to enhance the 802.11 DCF (Distributed Coordination Function) mechanism by providing a distributed access method that can support service differentiation among different classes of traffic. EDCA classifies traffic into four different AC as illustrated in Figure 1 [7]. The four access categories include AC _VO (for voice traffic), AC_VI (for video traffic), AC_BE (for best effort traffic), and AC _BK (for background traffic). To simplify the notations, AC_VO assign as AC3, AC_VI as AC2, AC_BE as AC1, and AC_BK as AC0. Each AC has its own buffered queue and behaves as an independent backoff entity. The priority among ACs is then determined by AC-specific parameters, called the EDCA parameter set. The EDCA parameter set includes minimum Contention Window size (CWmin), maximum Contention Window size (CWmax), Arbitration Inter Frame Space (AIFS), and Transmission Opportunity limit (TXOPlimit). The preferred values of each mechanism parameters that the standard recommends are shown in Table 1 [7].

Figure 2 demonstrates the operations in 802.11e EDCA. To achieve differentiation, instead of using fixed DIFS (Distributed Interframe Space) as in 802.11 DCF, EDCA assigns higher priority ACs with smaller CWmin, CWmax, and AIFS to influence the successful transmission probability (statistically) in favor of high-priority ACs. The AC with the smallest AIFS has the highest priority, and a station needs to defer for its corresponding AIFS interval. The smaller the parameter values (such as AIFS, CWmin and CWmax) the greater the probability of gaining access to the medium. Each AC within a station behaves like an individual virtual station: it contends for access to the medium and independently starts its backoff procedure after detecting the channel being idle for at least an AIFS period. The backoff procedure of each AC is the same as that of DCF. When a collision occurs among different ACs within the same station, the higher priority AC is granted the opportunity to transmit, while the lower priority AC suffers from a virtual collision, similar to a real collision outside the station.

IEEE 802.11e EDCA defines a TXOPlimit as the time interval during which a particular station can initiate transmissions. During this period, defined by a starting time and a maximum duration, stations are allowed to transmit multiple data frames from the same AC continuously within the time limit defined by TXOPlimit [7]. In 802.11e EDCA the higher priority ACs have a longer TXOPlimit, while lower priority ACs have a shorter TXOPlimit. Priority differentiation used by EDCA ensures better service to high priority class while offering a minimum service for low priority traffic [8]. Although this mechanism improves the quality of service of real-time traffic, the performance obtained is not optimal since EDCA parameters cannot be adapted according to the network conditions.

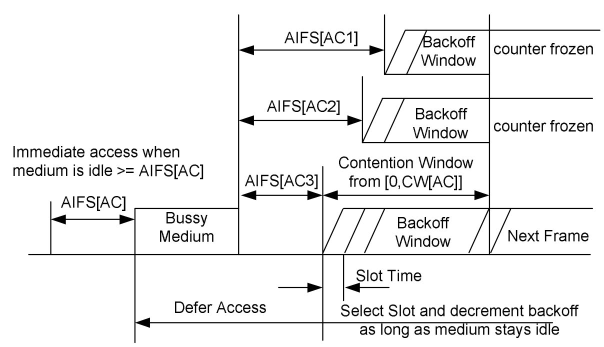

Figure 2. IEEE 802.11e EDCA mechanism [6].

B. IEEE 802.11n

Although 802.11e adds the support of QoS, TXOP and block ACK, the inefficiency of channel utilization in legacy 802.11 MAC is not fully solved. To satisfy the need of the

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high-speed wireless network access today, the major target of IEEE 802.11n is to provide high throughput mechanism while allowing the coexistence of legacy 802.11 devices. To meet the requirements of high throughput, two possible methods can be applied. One is increasing the data rate in the physical layer (PHY layer), and the other is increasing the efficiency in the medium access layer (MAC layer) [9]. Based on the foundation of 802.11a/b/g/e, numerous new features in PHY and MAC layers are introduced to enhance the throughput of IEEE 802.11n WLAN [10].

To achieve high throughput in 802.11 wireless networks, the most commonly used method is to increase the raw data rate in the PHY layer. Legacy 802.11 PHY layer uses Single-Input Single-Output (SISO) system in 20 MHz bandwidth channel with one antenna. IEEE 802.11n expands the channel bandwidth to 40MHz to increase the channel capacity, and operates in OFDM scheme with the Multi-Input Multi-Output (MIMO) technique [9].

Aggregation mechanism is the key feature to improve the 802.11 MAC transmission efficiency. Aggregation can enhance efficiency and channel utilization. The aggregation mechanism combines multiple data packets from the upper layer into one larger aggregated data frame for transmission [11]. Overhead in multiple frame transmissions is reduced since the header overhead and interframe time is saved. Aggregation scheme achieves higher system gain for application scenarios with small packets, for example, VoIP.

Some frame aggregation mechanisms are illustrated in Figure 3 [6]. In Figure 3(a), a train of N PHY frames are sent one by one with no IFS. These frames can be transmitted to one or multiple destinations, and each destination station acknowledges the received frame in the same order after a short IFS (SIFS). In Figure 3(b), each destination station sends an ACK immediately after a SIFS when it successfully receives a frame.

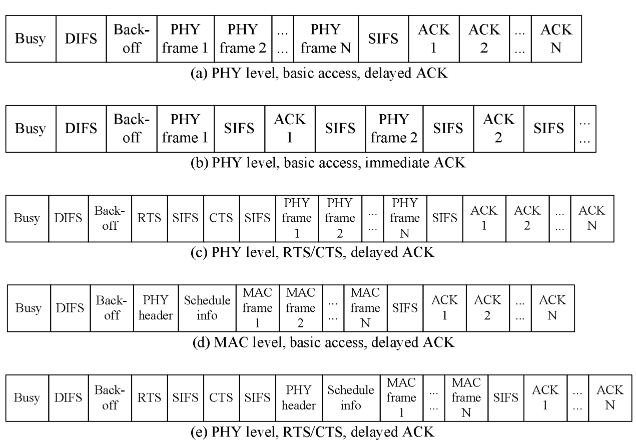

Figure 3. IEEE 802.11n Frame aggregation mechanisms [6].

Maximizing throughput may require a large aggregation frame with length longer than that specified in standard (4095 bytes). On the other hand, it is suggested that the total length of the aggregation frame should be smaller than a threshold since some huge frames may cause unfairness among stations. In addition, long data frames will result in large collision time and thus reduce the transmission efficiency when collision probability is high. In legacy 802.11, the optional Request To Send/Clear To Send (RTS/CTS) is proposed to improve the transmission efficiency when the frame size is larger than a threshold (0–2347 bytes). However, RTS/CTS in legacy 802.11 is employed by a pair of sender and receiver for unicast transmission and is not suitable for the downlink aggregation mechanism which may involve multiple destination stations. Therefore, modified RTS/CTS function can be used with downlink aggregation to reduce collisions resulting from large data frames, as shown in Figure 3(c).

The above three mechanisms are PHY level aggregations. The PHY overhead can be reduced through MAC level aggregations, which are shown in Figure 3(d) and 3(e) for basic access mode and RTS/CTS mode, respectively. With these two mechanisms, N MAC frames for different destinations can be aggregated into one PHY frame [6]. After the (shared) PHY preamble and header, destination stations receive the scheduling information, based on which they can determine the time to receive the MFs if there is any. Using downlink multi-destination aggregation, the AP only needs to contend once to transmit an aggregated frame to multiple MNs, in contrast to multiple contentions and transmissions without frame aggregation.

III. Experimental Results

The purpose of this paper is to evaluate the comparison of the traffic video over IEEE 802.11e and over IEEE 802.11n. All simulation is conducted with ns-2 [12], where to simulate 802.11e we use modules from NKCU Taiwan based on ns-2.28 [13] and to simulate 802.11n we use AFR modules [14] from Hamilton Institute Ireland based on ns-2.30 [15]. Figure 4 shows the topology configuration used in our simulation. The topology consists of a multimedia server that connects to a WLAN Access Point (AP); an AP connects to a mobile node using 802.11e or 802.11n.

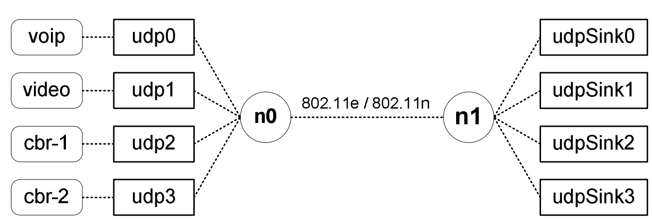

Figure 4. Simulation topology.

The performance of 802.11e and 802.11n can be evaluated from the receiving traffic through the wirelessly connected multimedia server (n0) and mobile node (n1). Several major metrics to compare performance between 802.11e and 802.11n are:

- Throughput, the traffic size through a link in a selected range of time, where :

$$Throughput = \frac{\sum packet}{\sum time} \times 8/1000 \quad Kbps \qquad (1)$$

- Delay, the mean of times in receiving side due the different received for every packet, where :

$$Delay = \sum_{i=1}^{m} \frac{(t_i^{recived} - t_i^{send}}{m} \quad (ms) \qquad (2)$$

- Packet lost, the percentage of lost of packet when received at receiving side compare to transmit packets where :

$$Packetlost = \left[\frac{\sum packet_{send} - \sum packet_{received}}{\sum packet_{send}} \right] \times 100\% \ (3)$$

A. Simulation Setup

In this section, we use ns-2 simulator to evaluate the performance of IEEE 802.11e and IEEE 802.11n. We choose 802.11 as the PHY layer, and the PHY data rate is set to 1 Mbps, 11 Mbps and 54 Mbps. The simulation parameters are shown in the Table 2.

In our simulation we have considered three scenarios, namely scenario 1, scenario 2 and scenario 3. In each scenario all the stations are transmitting to the same destination. Scenario 1 and 2 consist of one VoIP connection, one video connection and two connections each of background traffic and best effort data. We use scenario 1 to evaluate the performance of IEEE 802.11e and scenario 2 to evaluate the performance of IEEE 802.11n. In scenario 3 we increased the video transmission rate to be known maximum throughput of 802.11e and 802.11n. The best-effort and background traffics have been created using CBR traffic with the sending rate of 256 Kbps. Consistent with 802.11e specifications, VoIP traffic is carried under AC1, video under AC2, background traffic under AC3 and best effort data under AC4. In every scenario, the video traffic starts at 5 secs,VoIP traffic starts at 0.1 sec, video at 10 secs, BK traffic starts at 20 secs and BE traffic starts at 15 secs.

B. 802.11e and 802.11n performance

We compare the performance of 802.11e and 802.11n mechanism by simulating the scenario 1 and scenario 2, having one VoIP connections, one video connection and two BK/BE connections each.

By comparing the Figure 5 and Figure 6, which plot the throughput of each traffic type, we observe that the throughputs of video and BE/BK data are significantly different from 802.11e and 802.11n, whereas the VoIP traffic is able to maintain its throughput in both cases. In Figure 5, we can observe that the throughput of video traffic drops from around 512 kbps to 400 kbps but still can get the throughput upto 500 kbps. This confirms that the video traffic is well served with the implemented QoS in 802.11e, while many video frames are dropped at the 802.11n where the throughput drops from 512Kbps to around 400kbps because 802.11n does not implement QoS. It can also be seen that the throughput of BE/BK traffic is low in 802.11e as compared to 802.11n because BE/BK have low traffic priority parameters.

TABLE 2. SIMULATION PARAMETERS

	Voice	Video	Background	Best Effort
Transport protocol	UDP	UDP	UDP	UDP
Access Category	AC1	AC2	AC3	AC4
Packet Size	160 bytes	1500 bytes	1500 bytes	1500 bytes
Sending rate	64 Kbps	512 Kbps	256 Kbps	256 Kbps

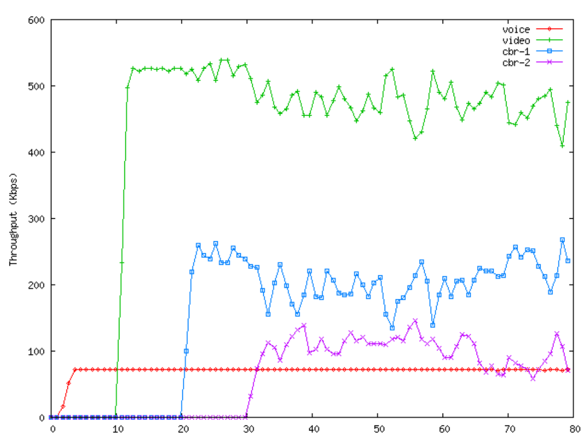

Figure 5. IEEE 802.11e throughput.

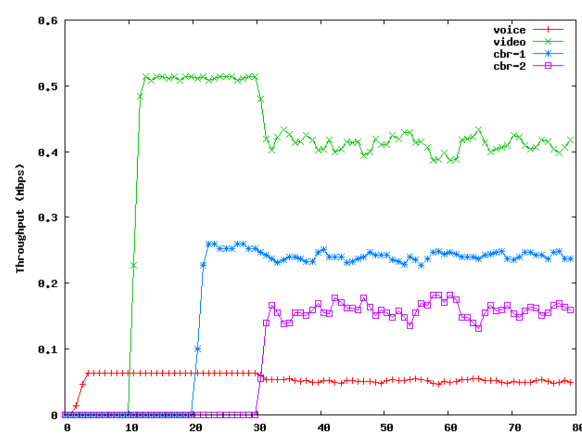

Figure 6. IEEE 802.11n throughput.

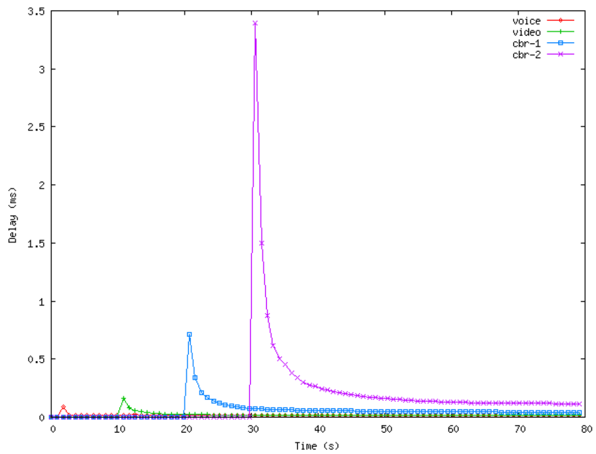

Figure 7. IEEE 802.11e delay.

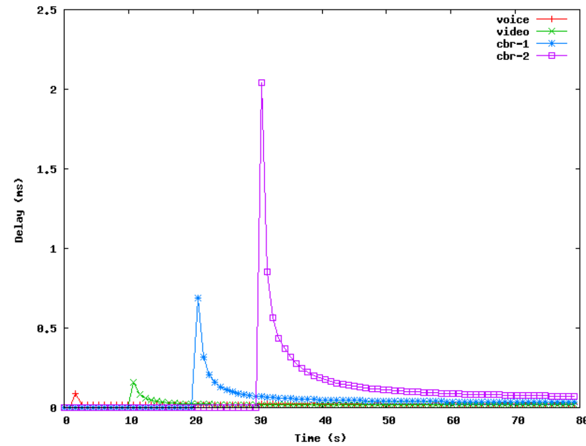

Figure 8. IEEE 802.11n delay.

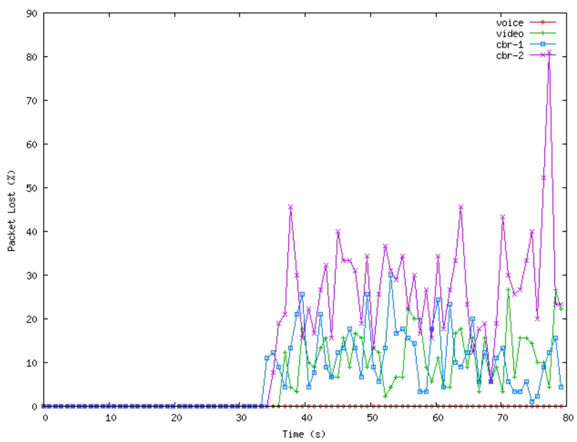

Figure 9. IEEE 802.11e Packet lost.

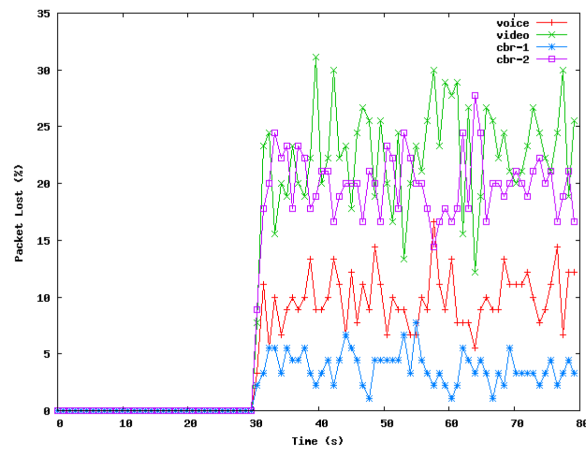

Figure 10. IEEE 802.11n packet lost.

In Figure 7 and Figure 8, we observe that VoIP and video delay performance is improved via 802.11n. We can see that when the BE/BK traffic starts at 20 secs and 30 secs, the voice frame delay and video frame delay have not increased in 802.11n as compared with 802.11e. Note that with 802.11n, the voice frame delay and video frame delay have better performance compared with 802.11e. It can also be seen that the delay for video traffic has improved in 802.11n as compared to 802.11e when all the traffic flows exist in the network. The delay for BE/BK traffic is also better in the 802.11n compared with 802.11e. In Figure 9 we observe that VoIP packet lost via 802.11e is the average zero percent compared to Figure 10 where VoIP packet lost drop to ten percent via 802.11n. Video packet lost is increased via 802.11n and compared to 802.11e.

These simulation results show that there is no service differentiation between the different types of traffic flows in 802.11n, which causes the QoS problem for multimedia applications when traffic load is high. The 802.11e mechanism provides differentiated channel access for different traffic types and can be expected that the 802.11e can support real-time applications with voice and video traffic with a reasonable quality of service.

C. *Comparison Analysis*

First we consider the scenario 1 and scenario 2, consisting of one VoIP connections, one video connection and two connections of each background traffic and best effort data. As mentioned above, the applications were start at different times so as to illustrate the impact of additional traffic streams on existing load. Figure 7 and Figure 8 show the delay performance of these traffic streams. The delay for VoIP frames is small (less than 1ms) from 0s to 0.1 ms, as it is the only traffic in the network so that it does not have to contend the channel with other sources. With the introduction of video traffic at 10ms, the delay for video frames increase to 0.2 ms whereas the delay for VoIP traffic is about 0.1 ms. It can be observed that when the BK/BE traffic is started at 20 secs and 30 secs, the delay for video and VoIP does not increased.

Next we simulate the scenario 3, in which we decrease the data rate from 1 Mbps to 0.5 Mbps. In Figure 11 the impact of decreasing the highest priority video connections can be seen on the delay performance of low priority traffic, when all the traffic streams present. The delay for video frames increases to 0.25s via 802.11e as compared to 0.15s via 802.11n, also the delay for video traffic via 802.11e at data rate 1 Mbps relatively same as via 802.11n. Thus, the impact of decreasing data rate can be seen on the delay performance of video traffic over 802.11e.

In scenario 3, we decrease the data rate of 802.11e and 802.11n to 0.5 Mbps. In figure 11 we observe that the decrease in low priority traffic does not have any negative impact on the delay of higher priority traffic. It can be seen that the delay for VoIP and video traffic is nearly same for both low BK/BE traffic and high BK/BE traffic. Comparing to data rate load change, decreases data rate in 802.11n load does not affect video delay in Figure 11 compare to decreases data rate in 802.11e, video delay relatively increase.

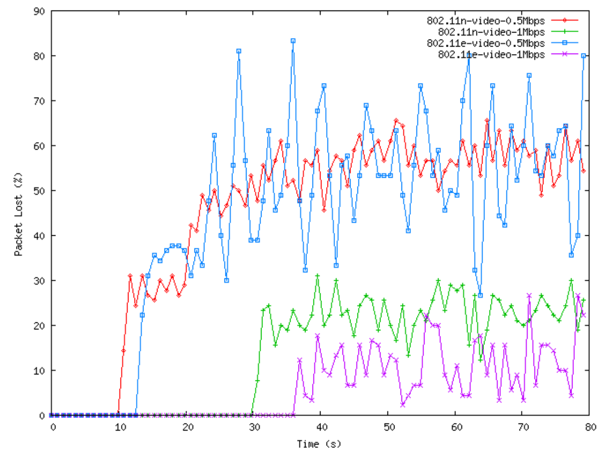

Figure 12. Packet lost comparison of 802.11e and 802.11n.

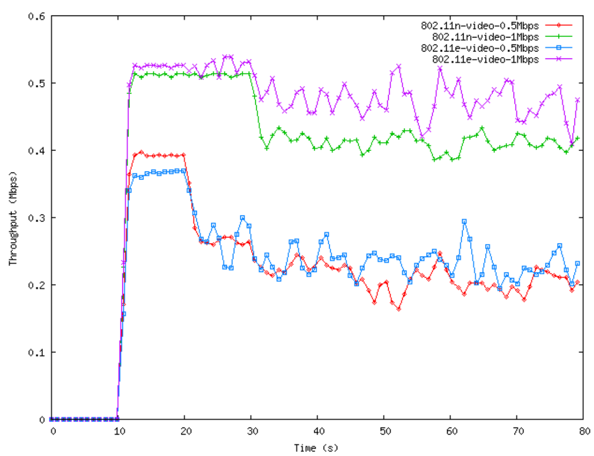

Figure 10. Throughput comparison of 802.11e and 802.11n.

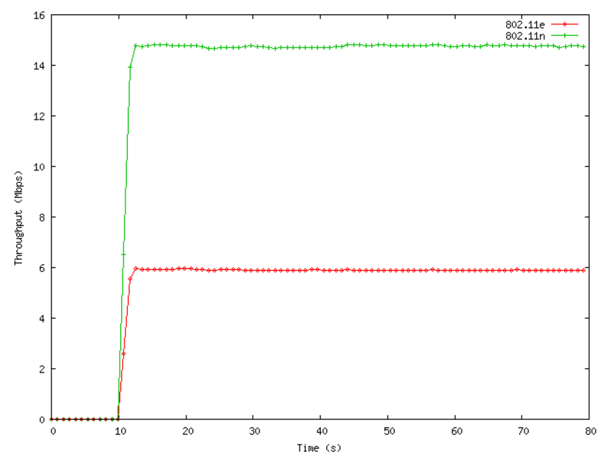

Figure 13. Maximum throughput comparison of 802.11e and 802.11n.

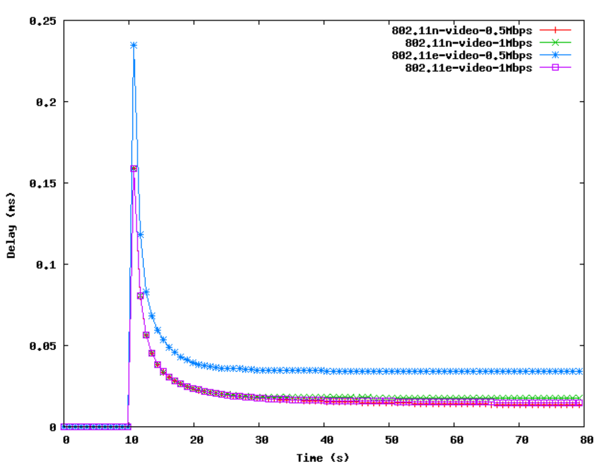

Figure 11. Delay comparison of 802.11e and 802.11n

IV. CONCLUSION

In this paper, we have evaluated the 802.11e and 802.11n mechanisms to transmit video traffic over WLAN. Through our simulations, we compared the 802.11e with the 802.11n in order to show that 802.11e provides differentiated channel access for different traffic types and is better equipped than 802.11n to handle real time applications with stringent QoS requirements likes VoIP and video. We conclude that with heavily loaded traffic connections under non-negligible background traffic, the 802.11n mechanism is not able to provide QoS guarantee. However, it can give better delay performance compared to 802.11e.

Our simulation result shows that 802.11n have better total throughput of 15 Mbps compared with 802.11e which only has 6 Mbps. We found out that 802.11n must implement QoS mechanism to support video to get a stable throughput during transmission.

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