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Analysis for Modulation and Coding Scheme with Data Rate Traffic Over IEEE 802.11AC and 802.11N in Wireless Multimedia

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ABSTRACT This paper discusses wireless traffic consisting of various types of data packets. Regardless of the type of data being sent and received, the transmission can suffer from latency problems. The wireless multimedia standard enables the service provider to prioritize voice, video, best-effort, and background data by adding differentiated services code point value to the internet protocol header. This effectively allows network users to benefit from optimal network performance while using various applications with different latency and throughput requirements. In this paper, we conducted a study of five use-cases over two common wireless standards, IEEE 802.11n and IEEE 802.11ac. The study was carried out by prioritizing, respectively, voice, video data packets, with lowest priority assigned to best-effort data packets. The best-effort traffic can have more bandwidth than the voice or video. Under each use case, we evaluated the impact of additional network load on video streaming.

KEYWORDS WMM, DSCP, QoS, voice, video, data packets, best-effort.

I. INTRODUCTION

INTERNET usage has dramatically increased over the past years. The world has come closer together with new opportunities, competitive technologies, and speed-hungry networks. To keep up with the demanding technologies, there is always a constant need to improve the speed with which the data streaming is delivered over wireless networks. As the dimension, resolution, and the processing speed of devices keeps improving, there is a constant need for faster delivery of data packets over wireless networks. Buffering of data streaming has been one of the main issues we faced.

This has been resolved to a large extend by the use of Wireless Multimedia (WMM), wherein the data streams are divided into 4 priorities so that users' needs are met depending on the choice of his/her priority. The IEEE 802.11 WMM standard protocol implemented not only optimizes data traffic but also ensures that important data packets like voice and video are given higher priority. WMM maintain the priority for real-time applications that are time-critical using quality of service (QoS). WMM define four categories of queuing in the order of priority [9]:

1. Voice: Data packets with the highest priority such as VoIP.
2. Video: Second highest priority given such that video applications have the least buffering while streaming.
3. Best-effort: Data packets of medium importance.
4. Background: Least priority queuing for applications which are not time-critical.

II. PRELIMINARIES AND RELATED WORKS

Architecture in WMM networks under limited network capacity, this set of technology especially attracts the ability to run high priority applications and traffic. This has been accomplished by QoS, through capacity allocation and differentiated handling to selected network traffic. This allows the network administrator to control the amount of bandwidth provided to this application or traffic flow and to determine the order in which packets are processed. Parameters used to measure QoS are latency (delay), jitter (variance in latency), and bandwidth (throughput) and error rate [3]. This makes QoS especially important for real-time broadband traffic, such as voice over IP (VoIP), video conferencing, and video on demand, which are highly sensitive to delay and jitter. These applications, with maximum latency limits and minimum bandwidth requirements, are called “inelastic”. To implement QoS the following three key methodologies can be followed [9]:

- Best-effort QoS: Is basically no QoS. Traffic is steered on a first-come, first served premise. Information is dealt with similarly paying little mind to delicate traffic or typical traffic. Best-effort is anything but difficult to execute and is versatile, for example, the default conduct of switches. The web advances traffic on a Best-effort premise [3].
- Integrated Services (IntServ) QoS: This is also known as hard or end-to-end QoS. When in need of a specific level of service, IntServ QoS requires an application to signal [2]. By reserving or allocating resources end-to-end for the application, an admission control protocol responds to this request. The request is denied if resources cannot be reserved for that particular request. Every device end-to-end must support the IntServ QoS protocol(s) [3].
- Differentiated Services (DiffServ) QoS: Was intended to be an adaptable QoS arrangement. Traffic types are marked to identify their classification after they are organized into specific classes. On a per-hop basis, depending on the traffic’s classification, policies are then created to provide a specific level of service. DiffServ QoS, although flexible and scalable in enterprise environments, is considered soft QoS, as it does not absolutely guarantee service, like Integrated Services QoS. DiffServ QoS does not enforce end-to-end allocations and does not employ signaling [3]. Wi-Fi multimedia network by prioritizing data packets according to four categories, WMM enhance QoS on a network. Priority levels can be changed by network administrators as they see fit. The network QoS is not accessible if an application or operating system does not support WMM. Therefore, it is necessary that multimedia applications support WMM so that they can take advantage of QoS functionality, as the appropriate priority level to data packets is assigned by the QoS. The traffic they generate is treated as best-effort and receives a priority lower than voice and video [5]. The Categories of WMM are the following ones:

1. Voice: The highest quality of concurrent VoIP calls and minimal latency is made possible by giving voice parcels the most elevated need.

2. Video: WMM prioritize video by setting video bundles in the subsequent level. This would prioritize the video over all other data traffic. This in turn enables support for one high definition (HD) Television stream on a wireless local area network or three to four standard definition (SD) Television streams.

3. Best-effort: Those legacy devices or applications that lack QoS standards are contained in the best-effort data packets.

4. Background: Consists of print occupations, record downloads, and other traffic that does not experience the ill effects of expanded inertness [9].

III. PURPOSE AND OBJECTIVES OF THE RESEARCH

WMM is an improvement to the media access control address sublayer that helped to add QoS functionality to Wi-Fi networks. After waiting for a random backoff time and if no equipment is transmitting at that given time, then a client’s device transmits. An opportunity for all the equipment to transmit can be achieved by this collision avoidance method. This collision avoidance method gives all the devices the opportunity to transmit [5]. The disadvantage is that during high traffic demand conditions, the performance of all devices gets affected as the networks get overloaded. The experiment was conducted at INEA S.A. It analyzes how the WMM network affects the throughput of streams having the voice, video and best-effort priorities. Further in the experiment, five use-cases are considered showing how the video priority, at a certain rate, behaves upon transmission of best-effort priority, voice priority, or both the priority streams together.

IEEE standards 802.11n and 802.11ac [1, 3], have been used to analyze and study the three priorities. All the computers used in the experiment are loaded with Kali Linux. Traffic Identifier indicates a 3-bit field in the QoS Control field of the 802.11 wireless media access control frame. The 8 values of this field correspond to eight user priorities [4]. Wireshark it is an application that analyzes network packets. The wireshark application captures network packets and then displays that packet data as detailed as possible [6]. In the experiments conducted, the filters used are as follows:

- wlan.qos.tid==0 (shows the throughput of best-effort stream)
- wlan.qos.tid==5 (shows the throughput of video stream)
- wlan.qos.tid==6 (shows the throughput of voice stream)
- wlan_radio.data_rate (we use this filter in ”Y Filed” and select ”AVG (Y Field)” from ”Y-Axis” to show date rate of packets the system can transmit)
- wlan_radio.11n.mcs_index (we use this filter in ”Y Filed” and select ”AVG (Y Field)” from ”Y-Axis” to show the average type of MCS used in 802.11n standard)
- wlan_radio.11ac. MCS (we use this filter in ”Y Filed” and select ”AVG (Y Field)” from ”Y-Axis” to show the average type of MCS used in 802.11ac standard).

Monitor mode exclusive to wireless networks, the wireless adaptor can monitor and capture network traffic using this mode. The traffic can be captured without restriction from any wireless network in the area [7]. IPerf is a tool that measures the bandwidth of the traffic and subsequently measures its performance. It can create TCP and user datagram protocol (UDP) data streams and can produce standardized performance measurements for the throughput of a network in one or both directions [8]. Therefore, IPerf has been used in the experiment as a traffic generator to simulate two more data streams.

IV. PROPOSED METHOD

The servers and the devices at the customer premises are configured as shown in Fig. 1. Depending on the use-case - one, two, or three servers are set up. The servers are connected to the router through a switch. The output data from router is distinguished at the optical line terminal (OLT) and reaches the optical network terminal (ONT). The data traffic is transmitted from the servers to the ONT by fiber optic whereas the data from ONT is received at the end-users terminal via Wi-Fi [10].

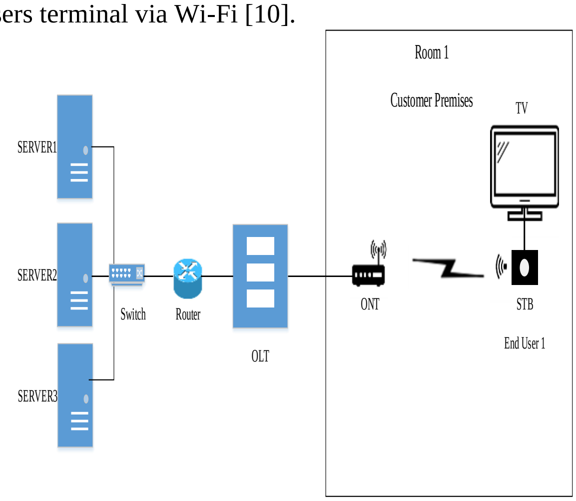

Figure 1. Network layout

Server is set-up initially, we connect one of the computers with the server. The value of the differentiated services code point (DSCP) server is set to the video priority upon receiving the commands shown in Fig. 2. from that particular computer. The video priority is achieved by following the commands:

- sudo iptables –t mangle –F (to remove the previous DSCP value),
- sudo iptables –t mangle –A OUTPUT –m Tcp –p TCP –sport 5001 –j DSCP --set-dscp-class cs4 (to use TCP and set the DSCP value).

This command sets the Linux firewall (named: iptables) to modify the outgoing traffic from the server. The modification sets the DSCP fields in the IP header to class cs4, which corresponds to the decimal value of 32 (video priority) [11, 12].

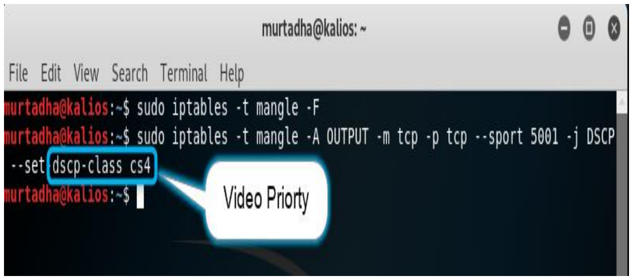

Figure 2. Command prompts to prioritize video streaming network layout

Similarly, the value of DSCP for the server can be set according to the preferred priority (voice, video, or best-effort). The values of DSCP are as shown in Table 1 [4-14].

Table 1. Characteristics of Wi-Fi multimedia access category & Class Selector

DSCP Value (Bin)	DSCP Value (Dec)	WMM Access Category	CS	TID
001 000	8	Background	CS1	1
010 000	16		CS2	2
000 000	0	Best-Effort	CS0	0
011 000	24		CS3	3
100 000	32	Video	CS4	4
101 000	40		CS5	5
110 000	48	Voice	CS6	6
111 000	56		CS7	7

Huawei ONT device is being used in our experiments. As the network is a fiber optical network, we employ ONT. It is a network interface device that receives and sends data between the client's system and the server systems as shown in Fig. 3. The parameters in ONT are initially set-up as follows [13-14]:

- Set the channel to 120
- Set the Channel width to 20 MHz
- Choose mode 802.11n or 802.11ac

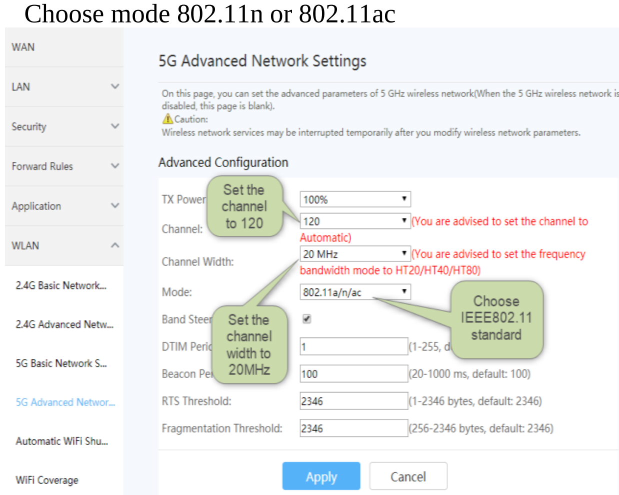

Figure 3. Main window of ONT

V. CASE STUDY

In the first use-case, priority is given only for video streaming. In the second use-case, we add the best-effort stream in addition to the video streaming. The third use-case takes into consideration the voice, and video streaming priority. The fourth use-case is carried out with three priorities: video, voice and best-effort. For the fifth use-case, the fourth set-up is repeated. However, the end-user with higher priority (i.e. voice) is moved farther away from the ONT such that it receives lower signal strength as compared to the other two priorities streaming [15].

A. USE-CASE ONE PRIORITY FOR VIDEO. FIRST PRIORITY USE-CASE OR ONE PRIORITY USE-CASE

The priority is set for video at the server. ONT and Set-Top Box (STB) is set-up in the same room. The wireless connection is established between ONT and STB (end-user 1). The STB is physically connected to the TV. Hence the video stream (TID = 5) between ONT and STB is obtained. The network traffic between ONT and STB is captured via Wireshark. This can be seen in Fig. 4 [16, 17].

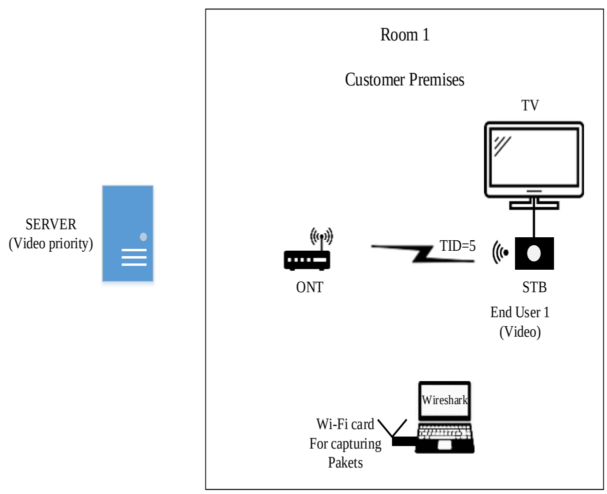

Figure 4. Main window of ONT

B. USE-CASE TWO PRIORITY FOR VIDEO AND BEST-EFFORT. SECOND PRIORITY USE-CASE OR TWO PRIORITIES USE-CASE

Two servers are set-up in such a way that video is given priority at server 1 and best-effort (default) at server 2 (IPerf). ONT, STB & laptop are set-up in the same room. The wireless connection is established between ONT and the two end-users [15, 16].

End-user 1 (STB) is given video priority and best-effort priority for end-user 2 (laptop). In this use-case, we can have two streams. First stream gives priority for video (TID = 5), Second stream for best-effort (TID = 0). This set-up is as shown in Fig. 5.

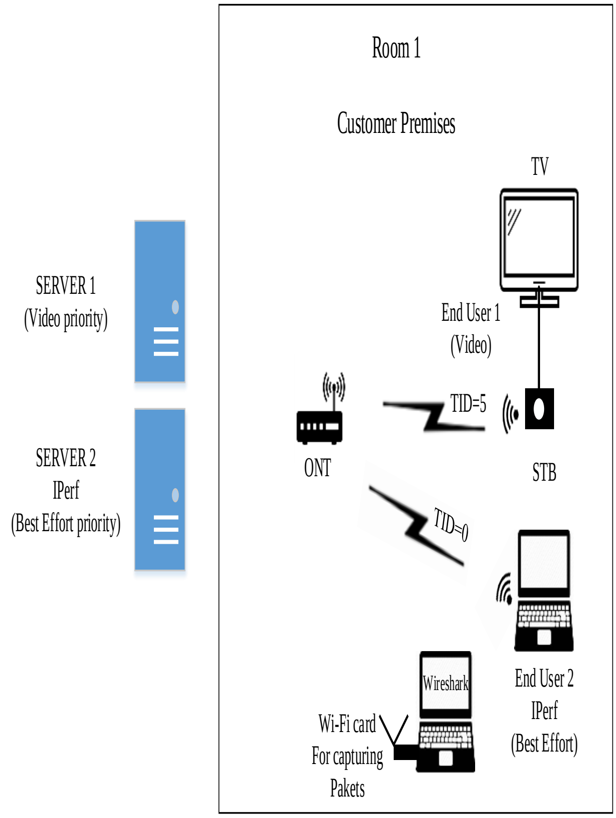

Figure 5. Representation for use-case 2

C. USE-CASE THREE PRIORITIES FOR VIDEO AND VOICE. THIRD PRIORITY USE-CASE OR THREE PRIORITIES USE-CASE

Two servers are set-up in such a way that video is given priority at server 1 and voice priority at server 2 (IPerf). ONT, STB & laptop are set-up in the same room [18, 19].

The wireless connection is established between ONT and the two end-users. End-user 1 (STB) is given video priority and end-user 2 (laptop) is given voice priority. Hence, in this use-case, we can have two streams.

First stream gives priority for video (TID = 5), Second stream for voice (TID = 6). This set-up is as shown in Fig. 6.

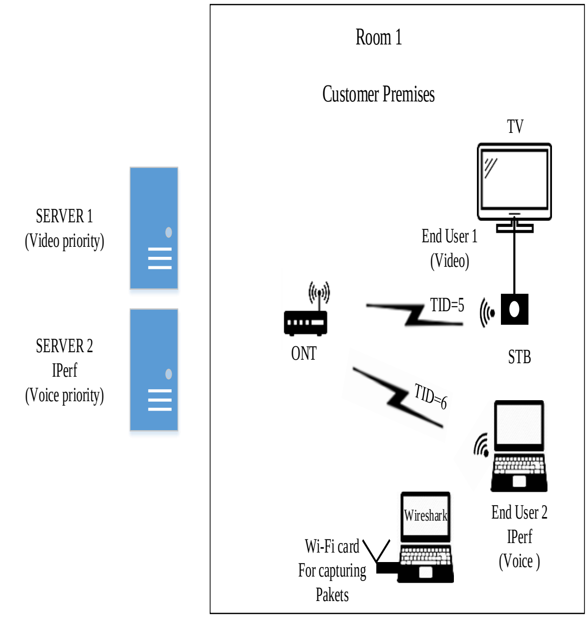

Figure 6. Representation for use-case 3

D. USE-CASE FOUR PRIORITIES FOR VIDEO, BEST-EFFORT, AND VOICE. FORTH PRIORITY USE-CASE OR FOUR PRIORITIES USE-CASE

In this use-case, we utilize three servers. Video is given priority at server 1, best-effort at server 2, and voice at server 3. Just as in use-case1, all the end-users are set-up in the same room. The wireless connection is established between ONT and the three end-users. End-user 1 (STB) is given video priority, best-effort priority for end-user 2 (laptop), and voice priority for end-user 3. Therefore, in this use-case, we can have the following three streams. First one for video (TID = 5), second for best-effort (TID = 0), third for voice (TID = 6). This set-up is as shown in Fig. 7 [19].

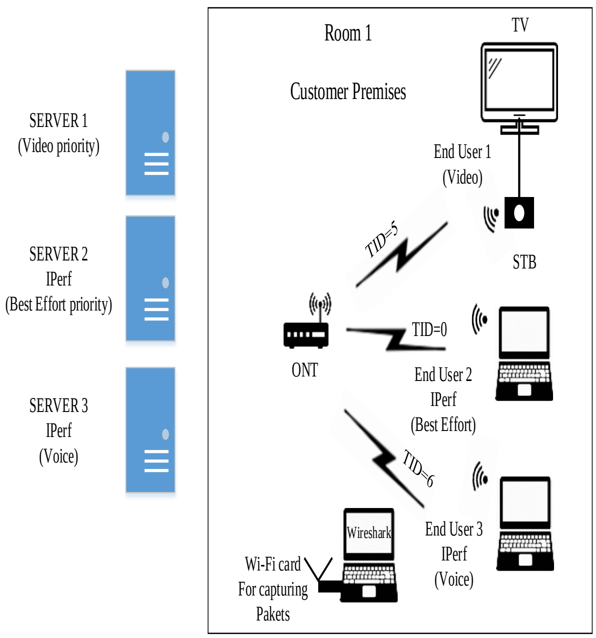

Figure 7. Representation for use-case 4

E. USE-CASE FIVE PRIORITIES FOR DIFFERENT COMBINATIONS VIDEO, BEST-EFFORT, AND VOICE FORMULAE. FIFTH PRIORITY USE-CASE OR FIVE PRIORITIES USE-CASE

The use-case 5 is similar to use-case 4. The end-users 1 and 2 are set-up in the same room. The third end-user (voice priority) is positioned in a different room, farther away from the ONT, to observe its effects on the traffic. Therefore, in this use-case, we can have the following three streams. First one for video (TID = 5), second for best-effort (TID = 0), third for voice (TID = 6). This set-up is as shown in Fig. 8 [20, 21].

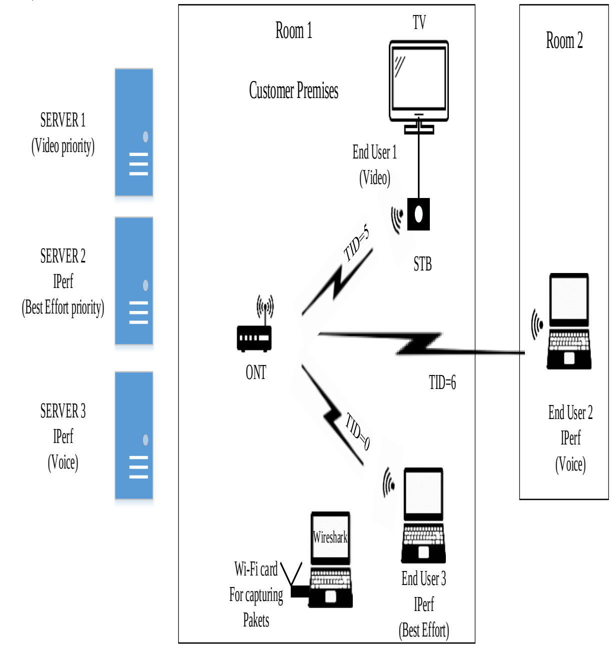

Figure 8. Representation for use-case 3

These five use-cases are repeated by changing the mode from 802.11ac to 802.11n. The video streaming priority is analyzed thus, by placing it in different combinations of data traffic environments as outlined in the five use-cases.

VI. SIMULATION RESULTS AND DISCUSSION

The results of WMM give an understanding of how the high priority stream performs in traffic containing other priority streams. In effect, this also helps us to manage the traffic which has different priority streams. The Wireshark application helps capture the traffic between ONT and the client. Selecting one packet would display the information of that packet in a more detailed form. Upon observing the packet details, for the standards, 802.11n and 802.11ac, three of the parameters were seen to have fluctuating values. Hence, we discuss these two parameters modulation and coding scheme (MCS), throughput. The standard 802.11ac supports 256 QAM. Modulation while the previous standards do not. MCS helps us to understand the type of modulation, number of spatial streams, and coding scheme used in the packet [20, 21].

A. USE-CASE ONE EVALUATION THROUGHPUT OF THE VIDEO DATA STREAMING

In this case, we are going to see the throughput of the video stream only. It is shown in Fig. 9. The video streaming is seen to be transmitted smoothly since there are no high priority streams in our traffic.

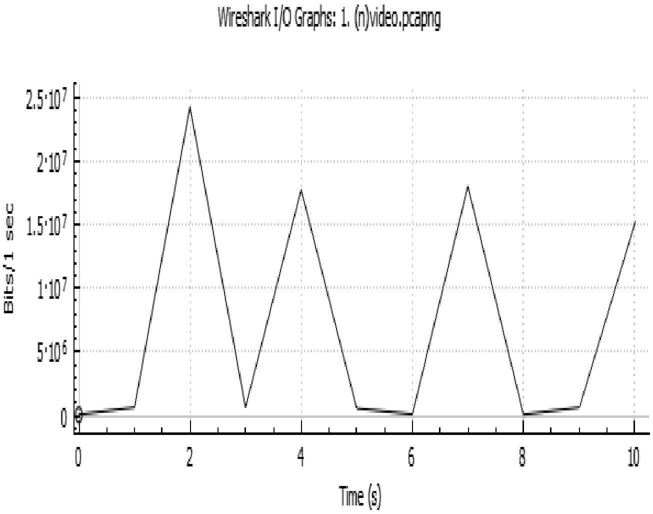

Figure 9. Video throughput for use-case 1

Fig. 10 shows the maximum data rate that the system can transmit with ideal conditions while streaming video data packets under the standards, 802.11n and 802.11ac. For 802.11ac the throughput is higher than 802.11n.

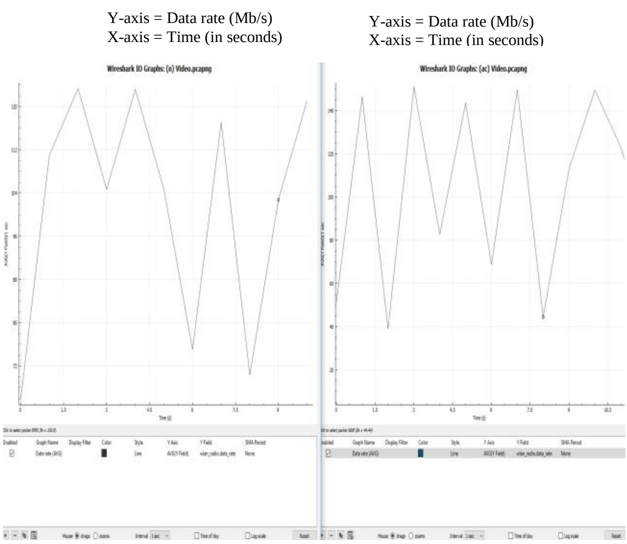

Figure 10. Data rate for use-case 1 (802.11n & ac)

In Fig. 11, left-hand side plot (by 802.11n) shows the average MCS value as 14, i.e., the packets use 64-QAM. The right-hand side plot (by 802.11ac) shows that the packets use an average value of MCS 8. This essentially means that it uses 256-QAM.

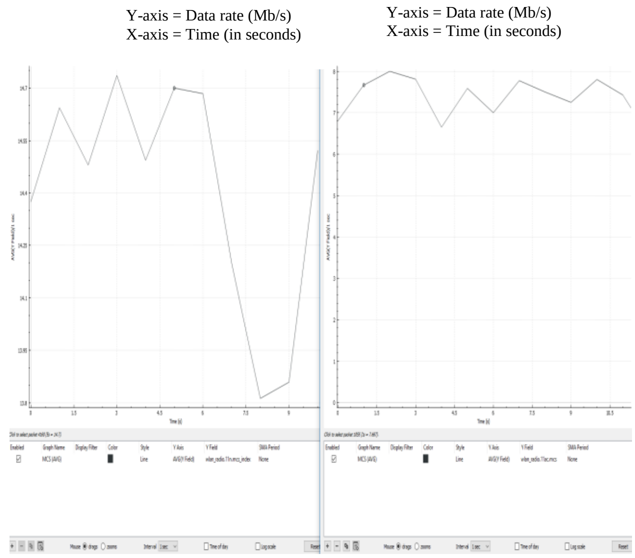

Figure 11. MCS for use-case 1 (802.11n & ac)

B. USE-CASE TWO EVALUATION THROUGHPUT FOR VIDEO AND BEST-EFFORT DATA STREAMING

In this use-case, we have two different priorities: video and best-effort. The throughput for video and best-effort streaming is shown in Fig. 12. The traffic is captured when the video packets start transmitting. The packets of best-effort are transmitted for a certain time period (starting time t= 7 sec and ending time t = 18 sec).

The video priority stream is relatively the same even when subjected to a data streaming of best-effort. Upon calculating the throughput in the first phase, before streaming data packets with best-effort priority, we obtain the mean throughput 8 Mb/s. When the traffic has both streaming data packets, i.e., best-effort priority and video, the throughput for video packets is 8.6 Mb/s.

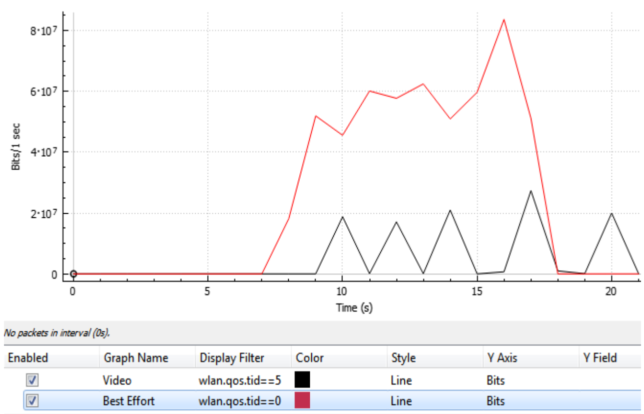

Figure 12. Video and best-effort streaming for use-case 2

The data rate of 802.11ac is higher than that for 802.11n. Under 802.11ac, the data rate was recorded at 150 Mb/s. For the standard 802.11n, the data rate was noted at 128 Mb/s. This can be seen in Fig. 13.

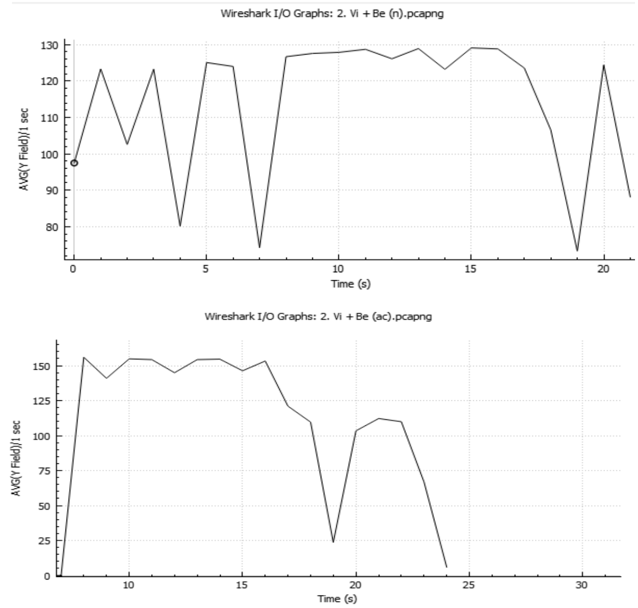

Figure 13. Data rate for use-case 2 (802.11n & 802.11ac)

In Fig. 14, left-hand side plot (by 802.11n) shows the average MCS values 14 and 15, i.e., the packets uses 64-QAM. Right-hand side plot (by 802.11ac) shows that the packets use an average value of MCS 8. This essentially means that it uses 256-QAM.

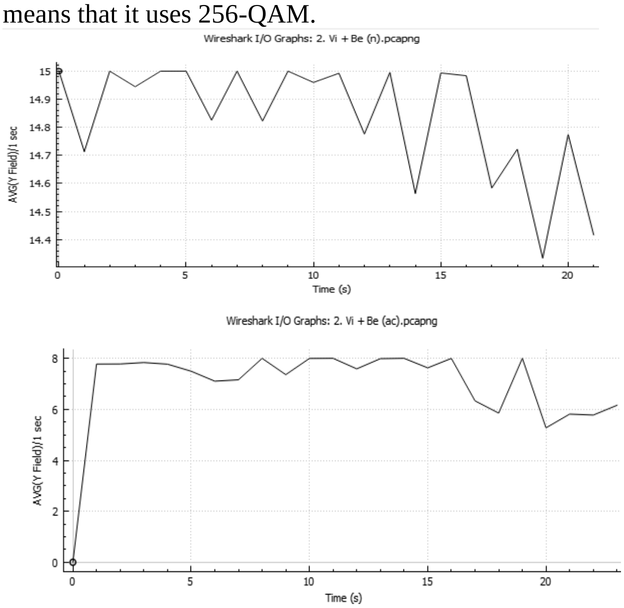

Figure 14. MCS for use-case 2 (802.11n & ac)

C. USE-CASE THREE EVALUATION THROUGHPUT FOR VIDEO AND VOICE DATA STREAMING

In this use-case, we have two different priorities video and voice. The throughput for video and voice streaming is shown in Fig. 15. The traffic is captured when the video packets start transmitting.

The packets of voice are transmitted for a certain time period (starting time t= 14 sec and ending time t = 25 sec). The video priority stream is not as smooth as it was before the voice stream. Upon calculating the throughput in the first phase, before streaming data containing voice priority, we obtain the mean throughput for video data packets as 8.7 Mb/s. When the traffic has both the streaming, i.e., video priority and voice the mean throughput of the video data packets is 7 Mb/s.

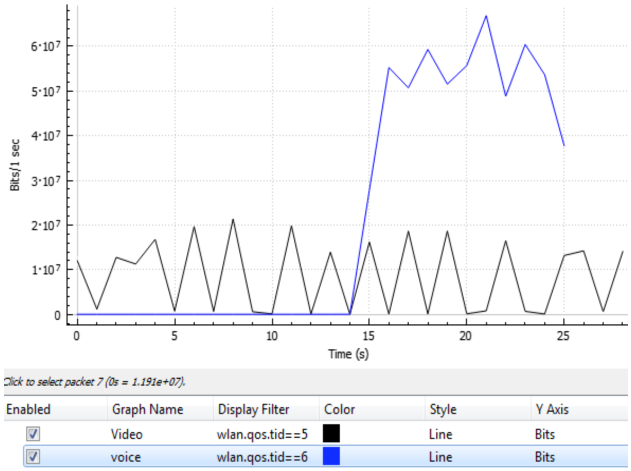

Figure 15. Video and voice streaming for use-case 3

In Fig. 16, the data rate of 802.11n drop to 50 Mb/s while the peak value was noted at 130 Mb/s. For 802.11ac the data rate was registered at 155 Mb/s.

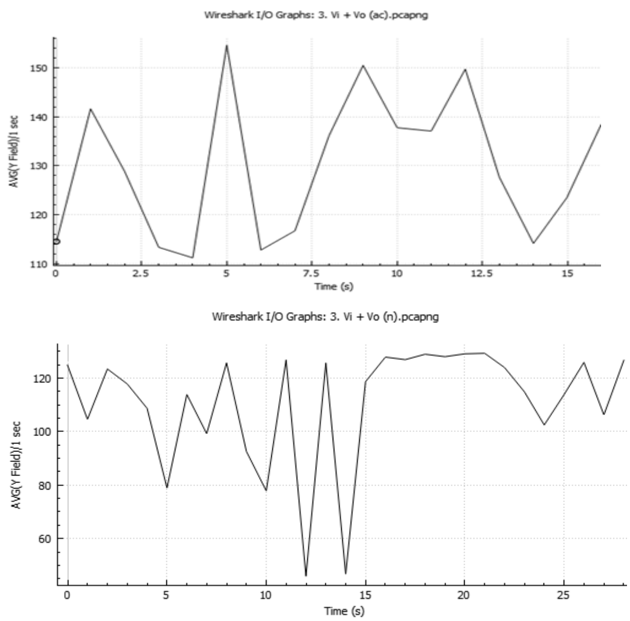

Figure 16. Data rate for use-case 3 (802.11n &ac)

In Fig. 17, left-hand side plot (by 802.11n) shows the average MCS values 14 and 15, i.e., the packets use 64-QAM. Right-hand side plot (by 802.11ac) shows that the packets use an average value of MCS 8 (256-QAM).

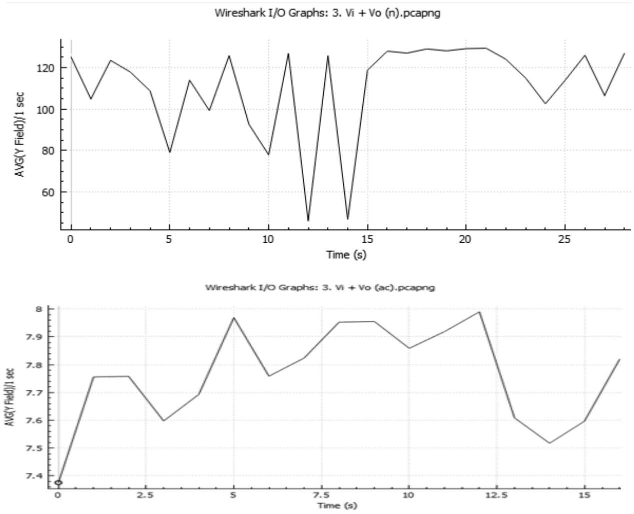

Figure 17. Data rate for use-case 3 (802.11n &ac)

D. USE-CASE FOUR EVALUATION THROUGHPUT FOR THE VIDEO AND BEST-EFFORT DATA STREAMING

In this use-case, we have three different priorities video, voice, and best-effort. The throughput for the video and best-effort streaming is shown in Fig. 18. The traffic is captured when the video packets start transmitting. The packets of best-effort are transmitted for a certain time period (starting time, t= 3 sec, and ending t = 20 sec) and the voice packets are transmitted at a different time interval between t= 6 sec and t = 15 sec. The drop of the high priority traffic from 60 Mb/s to 30 Mb/s could be explained by the fact that WMM provides only statistical preference, but not the strict priority.

Therefore, there is no guarantee that the high priority traffic will not be affected by the low priority traffic. Upon calculating the throughput in the first phase, before streaming data packets with best-effort and voice priorities, we obtain the video throughput of 8.7 Mb/s. When the traffic has both video and best-effort streaming data packets, the video throughput is 8.6 Mb/s. With all the three priorities in the on the state, the video throughput is 6.9 Mb/s.

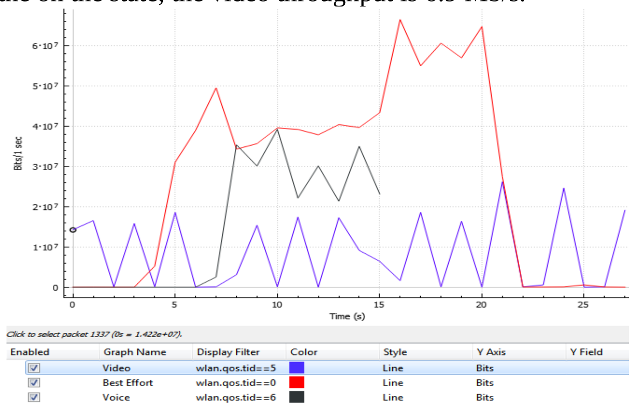

Figure 18. Video, best-effort and voice streaming for use-case 4

Fig. 19 shows the data rate while considering the three priority streaming by 802.11n and 802.11ac.

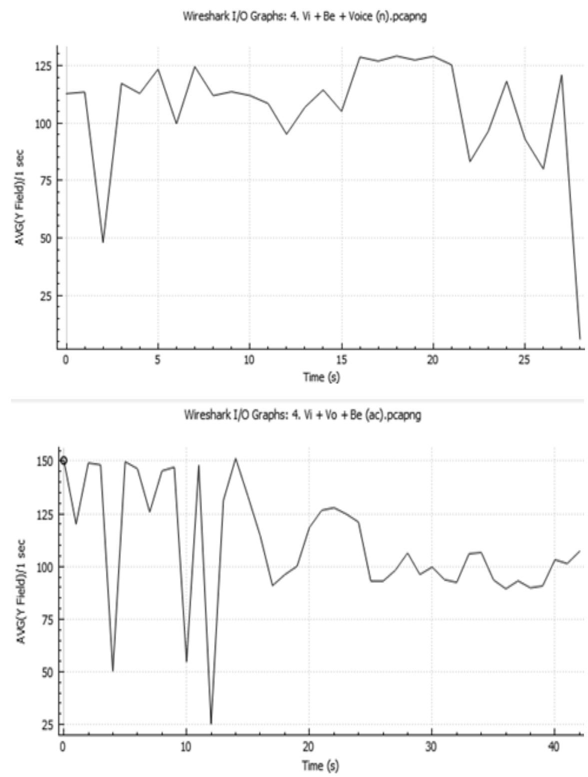

Figure 19. Data rate for use-case 4 (802.11n & ac)

Fig. 20 shows that with the 802.11ac standard results in a better modulation as compared to 802.11n standard.

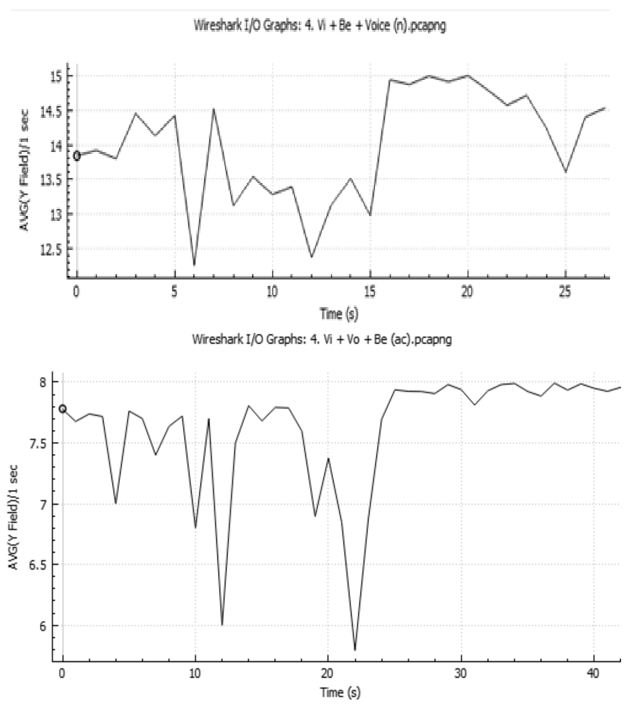

Figure 20. MCS for use-case 4 (802.11n & ac)

E. USE-CASE FIVE EVALUATION VIDEO, VOICE AND BEST-EFFORT DATA STREAMING

In this use-case, we have three different priorities video, voice, and best-effort. The traffic is captured when the video packets start transmitting. The priorities for voice, video, and best-effort are given as in previous use-cases. The packets of best-effort are transmitted for a certain time period (starting time t = 2 sec and ending time t = 32 sec) and the voice packets are transmitted at a different time interval between t = 11 sec and t = 29 sec. The signal strength for voice is significantly reduced as the end-user having voice priority is moved farther from ONT. However, owing to the low signal strength between ONT and the end-user with voice priority, the set priorities do not always follow the given priority levels. The outcome of this use-case is as shown in Fig. 21. Upon calculating the throughput in the first phase, before streaming data packets with best-effort and voice priorities, we obtain the video throughput of 7.9 Mb/s. When the traffic has both video and best-effort streaming data packets, the video throughput is 7.8 Mb/s. With all the three priorities in the state, the video throughput is 7.6 Mb/s.

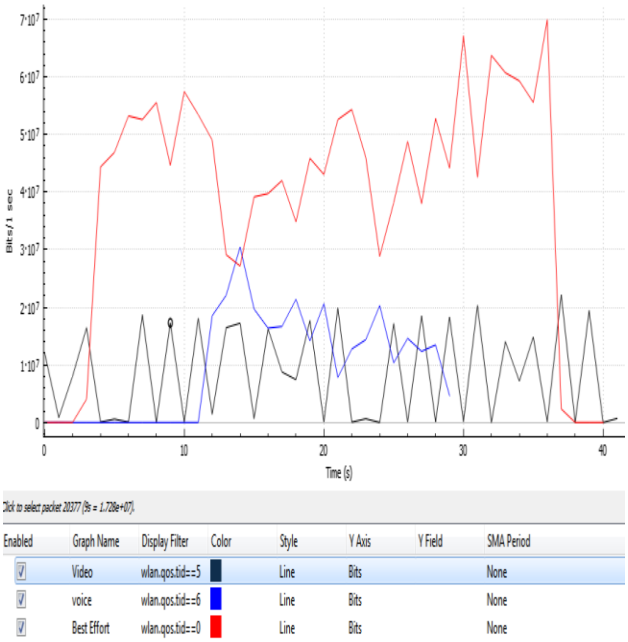

Figure 21. Video, voice and best-effort streaming for use-case 5

Fig. 22 shows the variation of data rate with time for use-case 5 for the standards 802.11n and 802.11ac. The data rate closely follows a constant high value when the end-users are all close to the ONT. When the end-user with voice priority is moved away from ONT, the average data rate is seen to be oddly distributed.

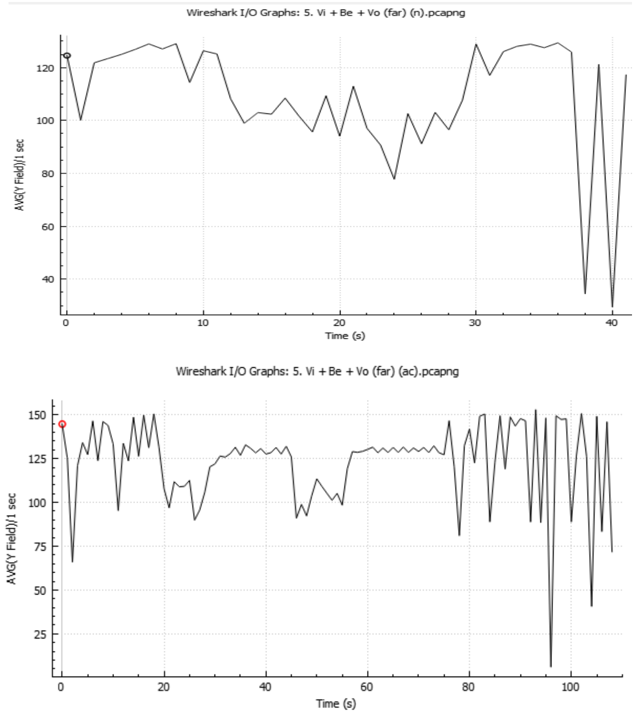

Figure 22. Video, voice and best-effort streaming for use-case 5

Fig. 23 shows that the average MCS value drops from 15 to 11 with 802.11n. This means that 802.11n utilizes different types of QAM modulation (16-QAM and 64-QAM). With 802.11ac, the packets use 64-QAM and 256-QAM for modulation.

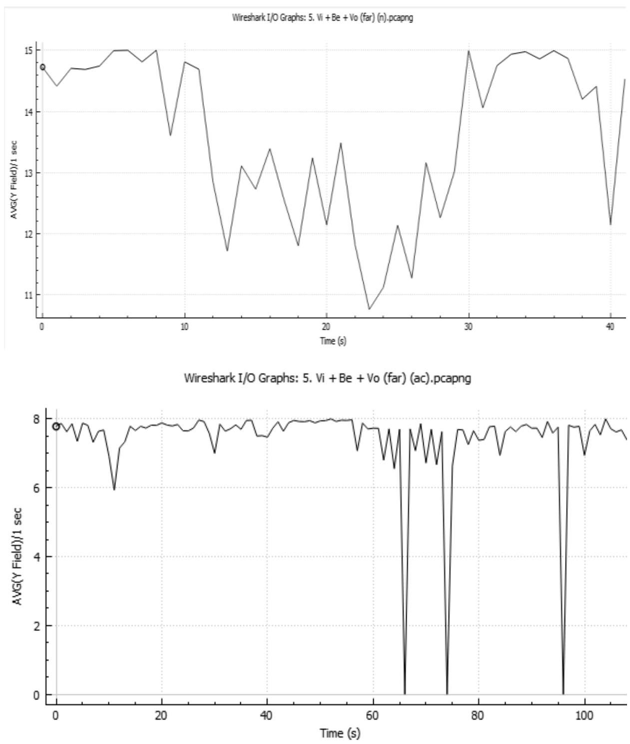

Figure 23. MCS for use-case 5 (802.11n & ac)

VII. CONCLUSION

We have evaluated the performance of video streaming in the five use-cases considered. The experiments were conducted over the two modes 802.11ac and 802.11n. The WMM work providing statistical priority not the strict priority and therefore there is no guarantee that the high priority traffic will not be affected by the low priority traffic. The best-effort traffic can have more bandwidth than the voice or video. However, once the WMM are functioning, the best-effort traffic should not kill/stop the higher priority traffic. We noticed that 802.11ac gives higher average data rate than 802.11n. The throughput for 802.11ac is higher than that of 802.11n. Most data packets use 256 QAM in 802.11ac mode while 64 QAM in 802.11n. Enabling WMM and utilizing 802.11ac will deliver a high throughput to the specific streaming category.

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