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PERFORMANCE EVALUATION OF IEEE 802.11AC WIRELESS NETWORKS WITH QOS FOR MULTIMEDIA APPLICATIONS

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Abstract

The development of technologies related to wireless communication caused the worldwide utilization of (WLANs). IEEE 802.11ac offers several optimizations in the physical and MAC layers to make effots in higher throughput and optimized reliability. Consequently, (QoS) is a main method for efficaciously improving the performance of wireless networks. It is widely utilised in numerous real-time applications, like audio and video stream, while preserving network reliability and fairness. This work stresses on analysing the impacts of QoS on the performance of IEEE 802.11ac WLANs, particularily in both terms (throughputting and delaying). By employing the new software (Riverbed Modeller 18.5), three different numbers of nodes (4, 12, and 24 nodes) with unitary topologies are effectively modeled and efficaciously simulated to meticulously detect the WLANs performance for innumerable MIMO configurations. The simulation findings uncovered that applying QoS applications with a bandwidth of 80 MHz can improve throughput and delay performance. The better improvements in QoS (throughput and delay) values are acquired in the greatest number of nodes (24 nodes). For MIMO (3×3) spatial streaming, the improvement values are (98.2%) and (49.5%) for velocity (throughput) and latency (delay), respectively.

Keywords: Bandwidth, IEEE802.11ac, Riverbed v.18.5, Wireless LAN, QoS.

Introduction

Few years ago, (WLAN) transformed, and became a focal point of our everyday routines. Out of the most powerful wireless technologies, (Wi-Fi), based on the IEEE802.11 WLAN standard, has been able to fulfill users' increasing needs for different services [1]. Thus, the 802.11 standard evolved from IEEE802.11n/a/g to 802.11ac in a bid to provide very maximal throughputting (VHT) progressively more necessary. The IEEE 802.11ac standard achieved most of the enhancements to the IEEE802.11 protocol physical (PHY) and media access control (MAC) layers. These efficasioully improved WLAN performance in speed (throughputting), coverage, and trustworthiness [2, 3]. The enrichments to the PHY layer of 802.11ac involve multiple-input multiple-output (MIMO) spatial streams, increased channel bandwidth (80 and 160MHz), different modulation and coding schemes (265-MCS), and short guard interval (400-SGI) [4, 5]. The MAC layer is supported by encomapssing block acknowledgement (BA) and frame accumulation to decearse MAC overhead [6, 7]. 802.11ac provides data rates of up to (1560Mbps) in wave 1 and (6240Mbps) in wave 2, compared to (54 and 600Mbps) in 802.11a/n [8]. IEEE802.11ac updated the QoS feature of the previous standard (802.11e) [9]. The QoS technique can be utilised via enhanced distributed channel access (EDCA) to solve the contending issue between users (nodes) of the WLAN [10]. In the research paper, the IEEE802.11ac work is analysed as well as inspected under various conditions (including QoS deployment, number of users, and MIMO) when channel BW 80MHz, blocking-acknowledgement (BA), and framing aggregation are enabled using the later version of the Riverbed (OPNET) modeler (v18.5), which supports the later standard of the 802.11 family (AC standard).

The current paper is structured into: The work related in Sect-2. In Sect-3, the tools and methodology (i.e 802.11ac key attributes, theoretical performance, and parameters with modelled networking scenarios) are expounded. The simulation results of throughputting and delaying for QoS deployment and MIMO configurations are mentioned in Section 4. Lastly, Section 5 presents the conclusion.

1. LITERATURE REVIEW

Myriade of research inspected and evaluated the performance 802.11ac standard for different factors on the WLAN efficiency. For efficasiouly improving QoS for time-sensitive applications in WLANs, the researcher in [11] investigated the possibilities of the IEEE802.11e standard. In [12], the authors evaluated the execution of the 802.11ac standard by using omnet++ under various parameters, such as 1–8 antennas, service scheduling activation, and 20 MHz bandwidth. Their findings revealed that increasing the number of antennas and activating service scheduling (QoS) improved network performance. The best performance improvement values in the 45-node number are 56.1 and 94.4 for delay and throughput, respectively. In reference [13], the authors developed a multi-level scheduler with rapid throughput that employs a machine learning method to identify the transmission channel. This scheduler supports dynamic bandwidth allocation, improves QoS performance, and keeps the competition fair between nodes that want to access the channel. Over three distinct frame aggregation strategies, the authors [14] compared the MAC performance of 802.11 (n and ac) by using the Omnet++ network simulator. Based on their findings, 802.11ac with an 80 MHz and one SS configuration achieves a 28% higher maximum throughput than 802.11n with a 40 MHz and two SS configurations. In [15], the authors analyzed and verified the performance of the 802.11ac networking standard by using a network simulator (NS-3) under various variables, such as antennas 1–8 SS and dynamic channel bonding (DCB) 160, 80, and 40 MHz technology, and their influence on networking. Their simulation findings revealed that increasing the number of antennas and enabling DCB improved network performance. The best performance improvement values in the 48-node number are 46.61% and 87.3% for delay and throughput, respectively. In [16], the researchers uncovered channel-bond aggregation to effectively optimize the WLANs performance, and their findings uncovered that channel-bond aggregation outclasses by 15% and 20%, respectively.

2. MATERIALS AND METHOD

2.1. IEEE802.11ac (VHT-WLAN) primary features:

a. Deployment of QoS

The IEEE802.11ac standard introduced the hybrid coordination function (HCF) as an improved media accessing function that utilizes both accessing methods: HCF (HCCA) and optimized disseminated canal accessing (EDCA) [9, 17]. The primary properties of HCF could be the incorporation of the transmitting chance concept (TXOP), that refers to a specific period during which (QoS) aware station (Q-STA) is permitted for transmitting a bundle of frames. The TXOP limit is the highest allowable value for the TXOP, which is determined by the QoS-enhanced access point to regulate latency [18].

In IEEE 802.11ac, the Dynamic Bandwidth Channel Allocation (DBCA) is used to Calculate the required width of the channel based on the transmitted data. This allows for the reservation of the required Transmission Opportunity (TXOP). EDCA incorporates four distinct buffers, also known as Information stacks, with varying access categories in each QoS sensitivity. The primary purpose of EDCA is to facilitate the distinction of traffic. Traffic categories (TCs) refer to the service flows that are given priority, each TC is designated a contention window (CWmax and CWmin) according to its priority. Each access category (AC) is treated as an independent DCF terminal and has its specific access parameters (AIFS, TXOP, CWmax, and CWmin), the access point (router) consistently transmits these parameters through the beacon interval. Enhanced-DCA implements two strategies to facilitate network traffic distinction: 1) Inter-frame space termed arbitration IFS (AIFS) for each access category (AC), as illustrated in figure 1(a). 2) Technique assigns collision windows of varying sizes to each access category (AC). Because the high access category (AC) priority has a smaller window size, it can transmit frames related to this access category before those related to other ACs with larger window sizes. When the back-off process is initiated, the back-off time is selected randomly from the range of (1, CW) [10, 19], in QoS terms, each AC can send a QoS demand to the access point, which includes the highest frame size and average data rate. After receiving the demand, the AP performs admissions control to determine the grant of the request. The period that authorized data is allowed to use the channel is determined by accepting or rejecting the request [20]. Figure 1(b) illustrates the scheduled service queues in the EDCA system. These queues, including video, voice, background, and best-effort, operate on a first-in-first-out (FIFO) basis. Each queue is assigned a priority level (ACS).

This paper considers the HCF of the IEEE802.11ac standard, specifically focusing on the TCS (ACS) for video, audio, best effort, and background traffic. Table 1 illustrates the QoS attributes for these different categories.

Table 1. QoS factors

Traffic	AC	CWmax	CWmin	AIFSN	TXOP (ms)
Background	3	1023	31	3	3.264
Besteffort	2	1023	31	7	3.264
Video	1	31	15	2	6.016
Voice	0	15	7	2	6.016

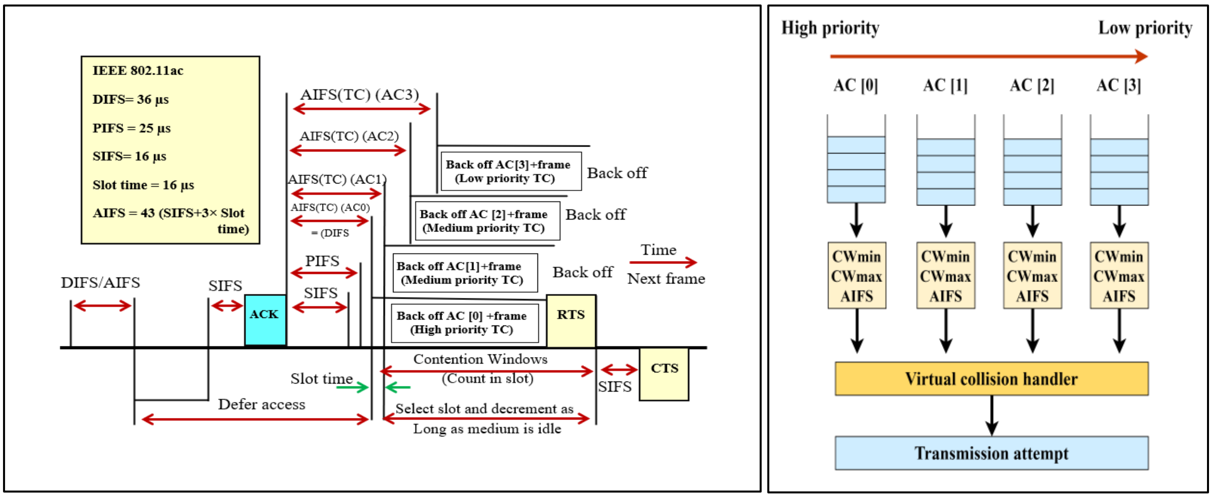


Figure 1. (a) EDCA timing diagram and (b) EDCA access categories [10]

b. *MIMO and Frame Aggregation*

The layer, particularly, the physical one, (MIMO) antenna technology of IEEE 802.11ac related to communication undoubtedly optimizes spectrum efficacy and rises throughputting via supporting 1 to 8 MIMO antenna systems with higher channel BW (80 MHz and 160 MHz) and modulation level (256 QAM) in Waves 1 and 2 [21, 22]. The system of MIMO, particularly, antenna's, at the IEEE 802.11ac physical layer makes use of triple processing methods to effectively optimize the performance of WLAN: (i) (SDM), also renowned of being 'space multiplexation', is a way empowering at-the-same-time transmitting and receiving of varying signals for max-speed data transferring (adopted in this work paper). The core configuring related to such methods is expressed in figure 1. (ii) (STBC), broadly expressed as space diversification, serves as methods to enhance the steadfastness or range of transmitting over dwindling chanals. (iii) (LDPC) channelling coding intends optimizing the code gains for MIMO-OFDM communication and make up maximal data percentage (throughputting) requirements as rising up opposition for signalling interferring [23, 24].

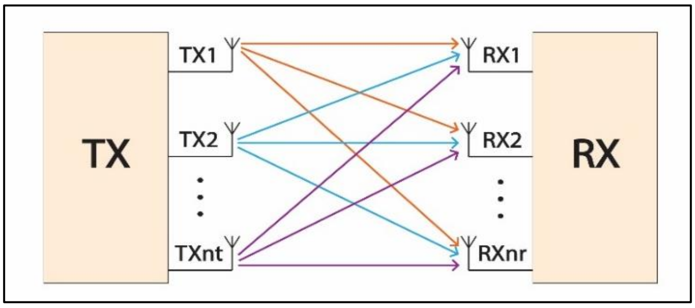
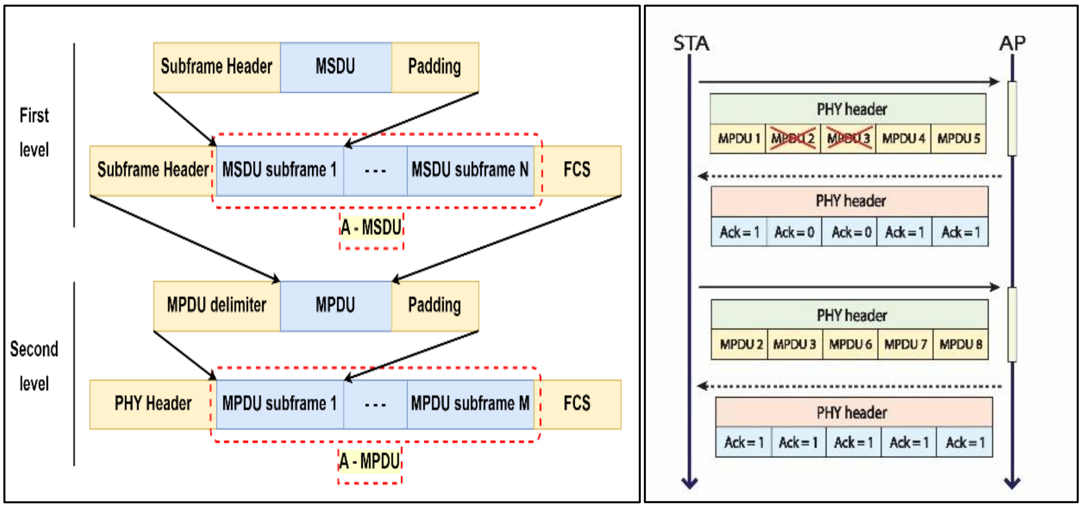


Figure 2. MIMO-SDM technique

The Medium Access Control (MAC) layer could improve performance via introducing frame-aggregation mechanisms. The mechanism consolidates many upper-layer data packets into a large data framing in purpose of transmitting. Also, save header overhead and inter-frame time to reduce multiple-frame transmission overhead. The aggregation approach transmits several Aggregate-MAC Service Data Units (A-MSDU) as one Aggregate-MAC Protocol Data Unit (A-MPDU); the first level A-MSDU has a length of 11,454 bytes, and the second level A-MPDU has a length of 1,048,575 bytes, as in Figure 3(a) [25]. The MAC layer also integrates block acknowledgement. To confirm the correct reception of each frame, the recipient sends a block acknowledgement, indicating that it is possible to broadcast frames with no recognizing each single unicastting frame, as in Figure3(b) [7][26][27].



(a) (b)

Figure 3. (a) Levels of frame aggregating. (b) BA with aggregation [25]

2.2. IEEE 802.11ac Theoretical performance

The theoretical maximal throughputting (transfer velocity) and duration of delaying (latency) could be specified by formulae (1) and (2), provided by [12, 15].

$$Throughput_{(bits/_{sec})} = \frac{N_{DS} \times N_{SS} \times N_{Bits\,per\,symbol} \times CR}{T_{OFDM}} \quad (1)$$

$$Delay_{(second)} = \frac{Max\ A{-}MPDU\ Length}{Max\ DR} \quad (2)$$

Where: N_{DS} is Data subcarriers (234 for 80MHz), N_{SS} is MIMO Spatial stream (SS) number (1 to 3), N_{BPS} is symbol bits number (eight for 256-QAM), T_{OFDM} stands for the timing of OFDM symbol (3.6 µs), CR is the coding rate (3/4), Max A−MPDU is the 2nd aggregation level (1048575 bytes).

Table2. Illustrates the theoretical (throughputting in Mbps) and (delaying in Sec) for channel BW 80MHz

Table 2. Theoretical performance

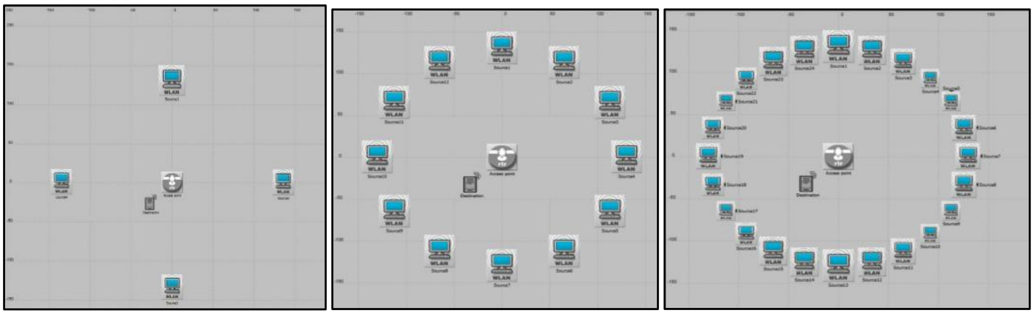
MIMO	**Throughput (Mbps)**	**Delay (Sec)**
1×1	390	0.0215
2×2	780	0.01075
3×3	1170	0.00716

2.3. IEEE 802.11ac Theoretical performance

Three scenarios (disseminated uniformly) with numerous numbers of nodes (4, 12, and 24 nodes) do evaluations for (VHT-WLAN) depending highly on IEEE802.11ac as shown in Figure4. The recommended scenarios are effectively demonstrated and replicated by modern software (Riverbid v.18.5), which supports the later standard (AC) with channel bandwidth (80MHz) and many different factors, as illustrated in Table 3. In the modeling process, many assumptions were used, as described below:

- We selected an area of 150 * 150 m^2, placed the router in the center, and distributed the users evenly throughout the network.

- We have enabled the frame aggregation mechanism and block acknowledgement.
- Table 1 displays the TXOP and CWs.
- The power threshold for received packets is -100 dbm.
- No network hidden terminal is assumed.
- DIFS, SIFS, and slot time are 34, 16, and 9 µs, respectively.



(a) (b) (c)

Figure 4. Simulating Scenarios of WLANs (a)4, (b) 6, and (c) 24 nodes.

Table 3. The factors values

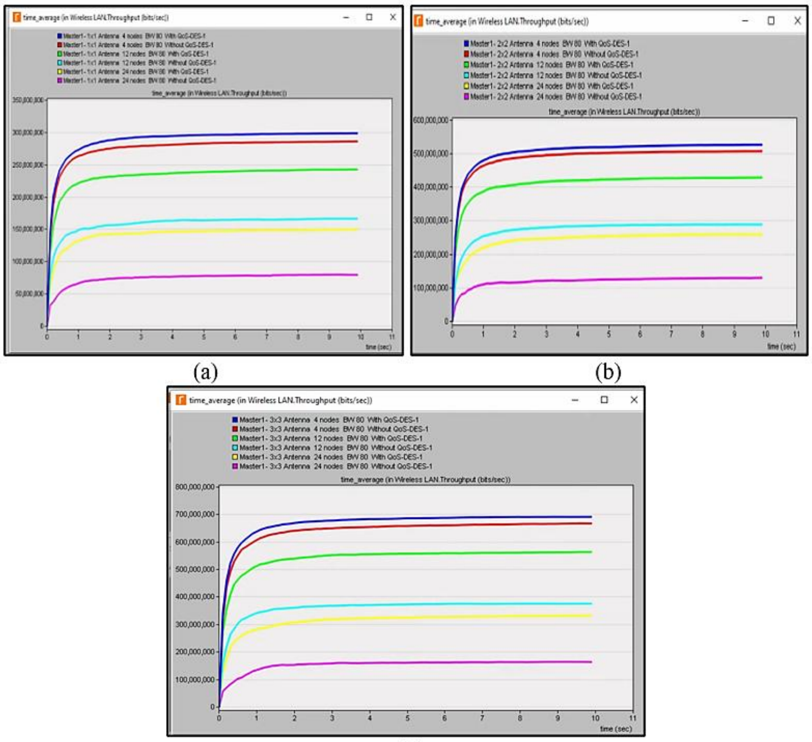
factors	Values
Physical attributes	IEEE802.11ac
Bandwidth and Band	80 MHz and 5 GHz
MIMO configurations	1, 2 and 3 SS
Data rate	1170 Mbps
Guard interval	400 ns
Transmitting power	0.1 Watt
Buffer length	2048000 bits
Packet length	2048 bytes
AMPDU and AMSDU aggregation	1048575 and 11454 bytes
Files info	High load
Voicetype and Videotype	(G.711 e. s.) and (30 frame/sec - 352x240 pixel)
RTS-threshold	512/None and enabled CTS (bytes)
Simulation timing	10 sec

3. RESULTS AND DISCUSSION

We have analysed and investigated the WLAN performance using Riverbed v18.5, focusing on dual metrics: throughputting and delaying, as illustrated in Fig5, and 6. The detection action of IEEE802.11ac WLAN performance takes into account various factors such as the high channel bandwidth (80 MHz), different MIMO configurations (1, 2, and 3), spatial streams, node numbers, and with & without QoS deployment:

3.1. Throughput

Fig5(a-c) uncovers the deviations in throughput among diverse MIMO (1×1, 2×2, and 3×3) antenna systemization. The correlationship among the throughput and the count of MIMO antenna systems is crystal clear; because the count of streaming goes up, the throughput rises up too. However, if nodes hieghten up, the datum ratio (throughput) goes down. It absolutly arises as the router (access point) transmits a larger number of data packets, increasing the probability of bottlenecking, colliding, and ultimately losing packets. Without QoS deployment and for (1×1) and (3×3) MIMO configurations, the average throughput values are (286.2, 166.6, and 85.9 Mbps) and (665.3, 376, and 164.1 Mbps). when applying the QoS deployment, the throughput performance is improved, and the average values are (298.9, 242.8, and 149.9 Mbps) and (697.9, 563.9, and 325.4 Mbps) for 4, 12, and 24 node numbers, respectively. The high-node scenario (24 nodes) achieves a better enhancement in QoS throughput values. For 3×3 MIMO, the improvement values are (4.9%, 49.9%, and 98.2%) for 4, 12, and 24 node numbers, respectively.



(a) (b)

(c)

Figure 5. Average throughput performance for (a)1x1 (b)2x2 and (c)3x3 spatial streams.

For different node numbers and varying MIMO configurings, Table 4 uncovers the average throughput (in Mbps) and improvement values. It is important to note that as the number of antennas heightens up, the throughput improvement values increase. This undoubtedly might be attributed to the effectiveness of the MIMO technique at the physical layer of the 802.11ac typical.

Table 4. Average throughput values (in Mbps)

	4 users			12 users			24 users		
MIMO	No-QoS	QoS	Imp-rove%	No-QoS	QoS	Imp-rove%	No-QoS	QoS	Imp-rove%
1×1	286.2	298.9	4.4	166.6	242.8	45.7	80.6	149.9	85.9
2×2	506.4	529.8	4.6	289.3	429.4	48.4	135	259.3	92
3×3	665.3	697.9	4.9	376	563.9	49.9	164.1	325.4	98.2

3.2. Delay

Figure 6(a-c) illustrates the varieties in delaying among myriad of antenna systems (1×1, 2×2, and 3×3) SS. The latency (delaying) decreases as the count of MIMO antenna systemization goes up. Yet, as the count of nodes goes up, the latency rises. Lacking QoS and for (1×1) and (3×3) MIMO configurations, the overall values of delaying are (0.02931, 0.05035, and 0.10407 sec) and (0.0126, 0.02231, and 0.05111 sec) for 4, 12, and 24 node numbers, respectively. When the QoS deployment is implemented, the latency (delaying) performance is enriched (i.e., lower delay), and the average delay values are (0.02806, 0.03454, and 0.05596 second) and (0.01201, 0.01487, and 0.02577 second) for 4, 12, and 24 node numbers, respectively. the better enhancement in the QoS delay values is acquired in the high-node scenarios (24 nodes). For 3×3 MIMO, the improvement values are (4.6%, 33.3%, and 49.5%) for 4, 12, and 24 node numbers, respectively.

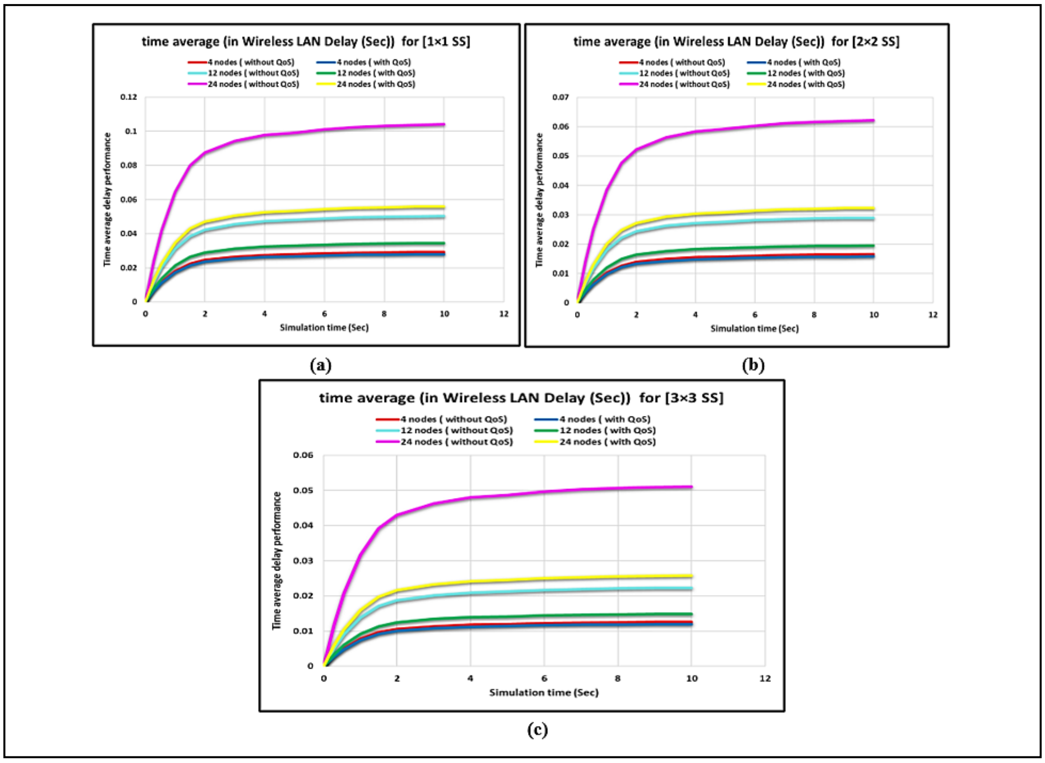


Figure 6. Average delay performance for (a)1x1 (b)2x2 and (c)3x3 spatial streams.

For different node numbers and varying MIMO configurings, Table 5 unveils the average latency (in sec) and improvement values. It is important to note that there is a slight rise in the delay improvement values as the number of antennas rises. We can attribute this to the effectiveness of the MIMO technique at the physical layer of the standard.

Table 5. Average latency values (in Sec)

	4 users			12 users			24 users		
MIMO	No-QoS	QoS	Imp-rove%	No-QoS	QoS	Imp-rove%	No-QoS	QoS	Imp-rove%
1×1	0.02931	0.02806	4.2	0.05035	0.03454	31.4	0.10407	0.05596	46.2
2×2	0.01656	0.01583	4.4	0.02899	0.01953	32.6	0.06213	0.03235	47.9
3×3	0.0126	0.01201	4.6	0.02231	0.01487	33.3	0.05111	0.02577	49.5

4. CONCLUSIONS

In the current work, different node count scenarios (4, 12, and 24 nodes) were proposed for modelling and mimicking wireless LANs that were correspondent to the IEEE802.11ac standard. The new software (Riverbed v.18.5) is utilised to make evaluations and observing the performance related to the IEEE802.11ac standard-based WLAN. Such scenarios make use of widespread modelling operations to efficaously optimize networking performance. The findnings of mimicking unveiled that applying QoS applications with channel BW (80MHz) can improve throughput and delay performance. The highest node number (24 nodes) yields the best improvements in QoS (throughput and delay) values. For MIMO (3×3) spatial streams, the improvement values are (98.2%) and (49.5%) for velocity (throughput) and latency (delay), respectively. The results indicate that the QoS deployment with channel bandwidth (80MHz) achieved high throughput and a lower delay. Also, the scheduling services lead to a good enhancement in the performance of 802.11ac-WLANs, especially in high-intensity traffic loads.

5. REFERENCES

[1] U. Cisco, “Cisco Annual Internet Report (2018–2023),” *Cisco: San Jose, CA, USA*, vol. 10, no. 1, pp. 1–35, 2020.

[2] M. Gast, *802.11n: A survival guide*, no. 1. “O’Reilly Media, Inc.,” 2012.

[3] IEEE Standards Association, *Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput, IEEE Standard 802.11n-2009*, 2009.

[4] R. Karmakar, S. Chattopadhyay, and S. Chakraborty, “Impact of IEEE 802.11n/ac PHY/MAC High Throughput Enhancements on Transport and Application Protocols—A Survey,” *IEEE Communications Surveys & Tutorials*, vol. 19, no. 4, pp. 2050–2091, 2017, doi: 10.1109/COMST.2017.2745052.

[5] O. Bejarano and E. W. Knightly, “IEEE 802.11ac: From channelization to multi-user MIMO,” *IEEE Communications Magazine*, vol. 51, no. 10, pp. 84–90, 2013, doi: 10.1109/MCOM.2013.6619570.

[6] B. S. Kim, H. Y. Hwang, and D. K. Sung, “Effect of frame aggregation on the throughput performance of IEEE 802.11 n,” in *2008 IEEE Wireless Communications and Networking Conference*, 2008, pp. 1740–1744.

[7] N. Khalil and A. Najid, “Performance analysis of 802.11 ac with frame aggregation using NS3,” *International Journal of Electrical and Computer Engineering*, vol. 10, no. 5, p. 5368, 2020.

[8] M. S. Gast, *802.11 ac: a survival guide: Wi-Fi at gigabit and beyond*. “ O’Reilly Media, Inc.,” 2013.

[9] A. Andreadis and R. Zambon, “Qos enhancement for multimedia traffics with dynamic TXOPlimit in IEEE 802.11e,” in *Proceedings of the 3rd ACM Workshop on QoS and Security for Wireless and Mobile Networks*, Chania, Crete Island, Greece, 2007, pp. 16–22.

[10] I. Paudel, “QoS provisioning in future wireless local area networks,” Institut National des Télécommunications, 2015.

[11] V. Sharma, H. Singh, and J. Malhotra, “Performance Analysis of IEEE 802.11e (EDCF) and IEEE 802.11(DCF) WLAN Incorporating Different Physical Layer Standards,” *J. Inst. Eng. Ser. B*, vol. 93, no. 4, pp. 247-253, 2012, doi: 10.1007/s40031-013-0034-3.

[12] Z. K. Farej and O. M. Ali, “On the evaluation of the IEEE 802.11ac WLAN performance with QoS deployment,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 24, no. 3, pp. 1618–1627, 2021, doi: 10.11591/ijeecs.v24.i3.pp1618-1627.

[13] R. Karmakar, S. Chattopadhyay and S. Chakraborty, “Learning Based Adaptive Fair QoS in IEEE 802.11ac Access Networks,” *2019 11th International Conference on Communication Systems & Networks (COMSNETS)*, Bengaluru, India, 2019, pp. 22-29, doi: 10.1109/COMSNETS.2019.8711461.

[14] E. H. Ong, J. Kneckt, O. Alanen, Z. Chang, T. Huovinen, and T. Nihtilä, “IEEE 802.11 ac: Enhancements for very high throughput WLANs,” in *2011 IEEE 22nd International Symposium on Personal, Indoor and Mobile Radio Communications*, 2011, pp. 849–853.

[15] Z. K. Farej and M. A. Hassan, “Analysis and Performance Evaluation of the Static and Dynamic Channel Bonding for the IEEE 802.11ac WLAN,” *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 17, no. 13, pp. 168–185, Jul. 2023, doi: 10.3991/ijim.v17i13.41601.

[16] V. Parashar *et al.*, “Aggregation-based dynamic channel bonding to maximise the performance of wireless local area networks (WLAN)”, *Wireless Communications and Mobile Computing*, vol. 2022, 2022.

[17] G. Cecchetti and A. L. Ruscelli, “Real-time support for HCCA function in IEEE 802.11e networks: a performance evaluation,” *Secur. Commun. Networks*, vol. 4, pp. 299–315, 2011.

[18] A. Ghafar, M. Kassim, N. Ya’acob, R. Mohamad, and R. Ab rahman, “QoS of Wi-Fi performance based on signal strength and channel for indoor campus network,” *Bulletin of Electrical Engineering and Informatics*, vol. 9, 10 2020.

[19] A. Refaat, M. Amed, W. Abed, and Q. Aish, “WLAN performance evaluation in different wireless access techniques (DCF, PCF, HCF),” *Periodicals of Engineering and Natural Sciences*, vol. 8, pp. 1297–1308, 09 2020.

[20] I. B. Arun, T. G. Venkatesh and B. Dappuri, "QoS provisioning with adaptive backoff algorithm for IEEE 802.11ac under multipacket reception," *2014 9th International Symposium on Communication Systems, Networks & Digital Sign (CSNDSP)*, Manchester, UK, 2014, pp. 826-830, doi: 10.1109/CSNDSP.2014.6923941.

[21] E. Charfi, L. Chaari, and L. Kamoun, “PHY/MAC enhancements and QoS mechanisms for very high throughput WLANs: A survey,” *IEEE Communications Surveys and Tutorials*, vol. 15, no. 4, pp. 1714–1735, 2013, doi: 10.1109/SURV.2013.013013.00084.

[22] A. T. Al-Heety, M. T. Islam, A. H. Rashid, H. N. A. Ali, A. M. Fadil, and F. Arabian, “Performance Evaluation of Wireless data traffic in Mm wave massive MIMO communication,” *Indones. J. Electr. Eng. Comput. Sci*, vol. 20, no. 3, 2020.

[23] S. R. Chaudhary, A. J. Patil, and A. V Yadao, “WLAN-IEEE 802.11 ac: Simulation and performance evaluation with MIMO-OFDM,” in *2016 Conference on Advances in Signal Processing (CASP)*, 2016, pp. 440–445.

[24] E. Ghayoula, M. H. Taieb, J.-Y. Chouinard, R. Ghayoula, and A. Bouallegue, “Improving MIMO systems performances by concatenating LDPC decoder to the STBC and MRC receivers,” in *2015 world symposium on computer networks and information security (Wscnis)*, 2015, pp. 1–6.

[25] O. Sharon and Y. Alpert, “A new aggregation based scheduling method for rapidly changing IEEE 802.11 ac wireless channels,” *arXiv preprint arXiv:1803.10170*, 2018.

[26] J. Govindarajan and C. Mohanapriya, “Study on real-time media congestion avoidance technique for video streaming over wireless local area network,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 15, no. 3, pp. 1535–1543, 2019.

[27] N. S. Ravindranath, I. Singh, A. Prasad, and V. S. Rao, “Performance Evaluation of IEEE 802.11ac and 802.11n using NS3,” *Indian J Sci Technol*, vol. 9, no. 26, pp. 1–8, 2016, doi: 10.17485/ijst/2016/v9i26/93565.