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Spectrum Efficiency of Modulation Schemes for Network Optimization in 5GHz Dense Environments

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ABSTRACT

For reliable data transmission, 802.11ax standard employs various orders of modulation schemes with a forward error correction method performing different coding rates (CR). Higher-order modulation schemes can enhance the data rate, but at the same time increasing the possibility of data corruption and bit error occurrence. Moreover, in wireless communications, each modulation scheme can be used with different guard intervals and channel bandwidths. A shorter guard interval increases the data rate at the cost of increasing the interferences and data loss. A longer guard interval solves the issue but at the cost of the performance reduction due to wasting the useful bandwidth. With regards to channel bandwidth, although wider channels increase the data rate, they are subject to more signal interference. This can get even worse in the high-density deployment of 802.11ax where many users are placed in close distance and the signal interferences are strong. Thus, aside from the modulation orders and coding rates parameters, the efficiency of modulation schemes relies on the channel bandwidth and guard interval which demands the proper selection of these parameters. Consequently, this work proposes a simulation model to optimize the performance of the 802.11ax network regarding the modulation schemes under high-density conditions. The model includes all available modulation schemes and their corresponding coding rates along with the channel bandwidth and guard interval. The model is further implemented and the most efficient values for performance optimization are determined on the basis of bit error rate, throughput and its efficiency, end-to-end delay, loss ratio, and jitter.

Keywords: Bit error rate (BER), coding rate, forward error correction (FEC), performance optimization

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INTRODUCTION

The high-efficiency wireless (HEW) 802.11ax standard officially launched at the end of 2019 to improve wireless communication in dense environments where a large number of users are transmitting data simultaneously on the same connection link. To achieve the objectives, the standard employs different parameters, among which is higher-order modulation schemes compared to the previous wireless standards (Otsuka et al., 2019). The modulation algorithms encode data bits into symbols and transmit them using a carrier signal by modifying its properties. In order to provide the reliability of the data, the modulation schemes employ the forward error correction (FEC) method with different coding rates (CR). The FEC adds redundant information to control occurring errors in the data and the CR is a fraction that determines how much of the data is redundant (Vijay & Malarkodi, 2019; Bellaltaa & Szott, 2019). The CR is denoted as the ratio k/n which indicates that for every k bits of useful information, the coder generates n bits of data, of which n-k are redundant.

The 802.11ax standard includes a variety of modulation schemes with different coding rates as follows (Vijay & Malarkodi, 2019; Adame et al., 2019):

- The binary phase-shift keying (BPSK) with two different symbols and one bit per symbol. It includes a single coding rate of 1/2.
- The quadrature phase-shift keying (QPSK) with four different symbols and two bits per symbol. It includes two different coding rates of 1/2 and 3/4.
- The quadrature amplitude modulation (QAM) with the following variants:
    - The 64-QAM encodes data with 64 different symbols and six bits per symbol. It includes 2/3, 3/4, and 5/6 coding rates.
    - The 256-QAM encodes data with 256 different symbols and eight bits per symbol. It includes 3/4 and 5/6 coding rates.
    - The 1024-QAM encodes data with 1024 different symbols and ten bits per symbol. It includes 3/4 and 5/6 coding rates.

Theoretically, increasing the number of symbols in modulation schemes will increase the overall speed because more bits of data are transmitted per each symbol. However, this happens at the cost of receiver sensitivity and range reduction. The sensitivity shows how well a device can receive the signals, hence, reducing the receiver sensitivity increases the possibility of data corruption and bit error rate (BER) that indicate the loss of data and the number of bit errors per unit of time, respectively (Naik & Reddy, 2017). Furthermore, in wireless communications, each modulation scheme can be used with different guard intervals and channel bandwidths. Practically, aside from the modulation orders and coding rates, the efficiency of modulation schemes relies on channel bandwidths and guard intervals.

The guard interval is the time spacing between the symbols to avoid inter-symbol interference. The 802.11ax standard supports short, medium, and long guard intervals (Deng et al, 2017). Utilizing a shorter guard interval, on one hand, increases the data rate (the rate at which the data is transmitted), but on the other hand, it increases the symbols interferences due to reducing the spacing between the symbols and hence results in higher data loss. In the 802.11ax network, any type of data with different requirements is transmitted over for which the guard interval value is set regardless of the type. In this context, if the data is real-time, a shorter guard interval can increase the interferences and cause data loss, for which the real-time data has zero tolerance (D-Link, 2013). In order to solve this issue, the longer guard intervals can be utilized in the networks but at the cost of performance reduction due to allocating useful bandwidth as the space between the symbols instead of using them for data transmission (Vijay & Malarkodi, 2019). Thus, a choice has to be made on high dense deployment of 802.11ax to determine and apply the proper guard interval based on the network requirements regarding the specific modulation schemes. The channel bandwidth is the other parameter affecting the efficiency of the modulation schemes in the network as it controls the rate of data transfer. The 802.11ax standard provides wide and narrow channels (Vijay & Malarkodi, 2019; Deng et al, 2017). Although utilizing wider channels will provide higher data rates and consequently, optimize the overall network performance, they are subject to more signal interference. This can get even worse in the high-density deployment of 802.11ax where many users are placed in close distance and the signal interferences are already high. In this context, it is essential to determine the efficiency of all available channel bandwidths and identify the best selection for high-density 802.11ax network in conjunction with the specific modulation schemes.

Rochim and Sari (2016) studied the fifth-generation mobile networks (5G) and examined the efficiency of higher-order modulation schemes in these networks. The performance of 1024-QAM and 4096-QAM with 1/3, 1/2, 2/3, and 3/4 coding rates were compared with QPSK to 256-QAM. The results were obtained in terms of bit error rate, whereas 802.11ax HEW network, channel bandwidths, guard intervals, and other performance metrics were not taken into account. The QPSK to 256-QAM modulation schemes over 802.11ac networks were investigated in Khan et al. (2016). The functionality was investigated for different channel bandwidths from 20 to 160 MHz as a function of payload size and the number of stations. The SNR and error rates were measured for comparison purposes, though 802.11ax networks, guard intervals, and other metrics were not evaluated. Weller et al. (2019) compared the throughput performance of 1024-QAM with 256-QAM in 802.11ax. Despite that, other modulation schemes, channel bandwidths, and performance metrics were not implemented. The effectiveness of modulation schemes was evaluated in Masiukiewicz (2019) to compare 802.11ax throughput with 802.11ac and 802.11n by varying the channel bandwidth as 40, 80, and 160 MHZ. However, measurement of other metrics and also the implementation of the narrower channels, including 20MHz and 40MHz were not verified. The BPSK to 256-QAM modulation schemes were evaluated in Hoefel and Bejarano (2016) over the 802.11ax network. The measurement results with regard to error rates and SNR were provided, nonetheless, implementation of other higher-order modulation schemes and performance metrics were not available. A testbed was set up by Codau et al. (2017) for the throughput evaluation of modulation schemes in the 802.11ac network. However, the experimental evaluation did not include 802.11ax and other essential performance measurements. Likewise, a testbed was also presented in Sheshadri and Koutsonikolas (2017) over 802.11ac to obtain the loss ratio in the presence of modulation schemes. The performance of 802.11af standard over 6MHz channel bandwidth was analyzed in Brioso et al. (2018). The efficiency of BPSK to 256-QAM modulation schemes were measured in connection with throughput. However, 802.11ax and other performance metrics were not included. Assessment of LTE cellular network was provided in Naik and Reddy (2017) to determine the performance under different modulation schemes, including QPSK, 16-QAM, and 64-QAM. The SNR results as a function of bit error rate were presented without regard to guard intervals, other metrics, higher-order modulations, and 802.11ax networks. The MATLAB simulator was used in Ghosh (2016) for the analysis of LTE modulation schemes, including QPSK, 16-QAM, and 64-QAM. The SNR and BER results were obtained, but no evaluation over 802.11ax was performed. Rochim and Sari (2016) took into consideration the efficiency of BPSK to 64-QAM modulation schemes in 802.11ac and compared them with those of 802.11n. However, the performance assessment of 802.11ax with its available modulation schemes was not verified. The possible modulation schemes in 802.11ax for vehicle-use were implemented in Akbilek et al. (2018). The performance of the schemes was compared regarding the SNR and error rate. However, the assessment did not involve channel bandwidths, guard intervals, and other performance metrics such as throughput, loss ratio, end-to-end delay, and jitter.

From the related works, there is a lack of a comprehensive study to identify the performance of all available modulation schemes for the 802.11ax network in relation to the available channel bandwidths and guard intervals. Thus, on the basis of this background, this work proposed a model to initially identify the efficiency of the available modulation schemes in line with all the channel bandwidths, coding rates, and guard intervals for the 802.11ax network and determine the best-suited selections for performance optimization under high-density conditions. Three main contributions of this work are: first, to examine different orders of all available modulation schemes in line with coding rates and identify the best selections, second, to assess the performance of all the available guard intervals and identify the best-suited values, third, to resolve the significance of channel bandwidths on performance variations and determine the best values for performance optimization. The rest of the work is organized as follows. Section 2 provides details regarding the simulation model and parameters. Section 3 presents the results and Section 4 concludes the work.

MATERIALS AND METHODS

This work proposed a model to optimize the performance of 802.11ax networks in high dense deployment regarding the efficiency of modulation schemes. The model developed an 802.11ax network in the 5GHz spectrum frequency band using the network simulator version 3 (NS3.29). The network included an 802.11ax-enabled access point to which 100 users were connected to create a high-density area. Furthermore, the network included an application server which generated data at the rate of 2Mbps. The data was transmitted from the application server to all the users simultaneously in a downlink direction. A simplified presentation of the simulated 802.11ax is provided in Figure 1.

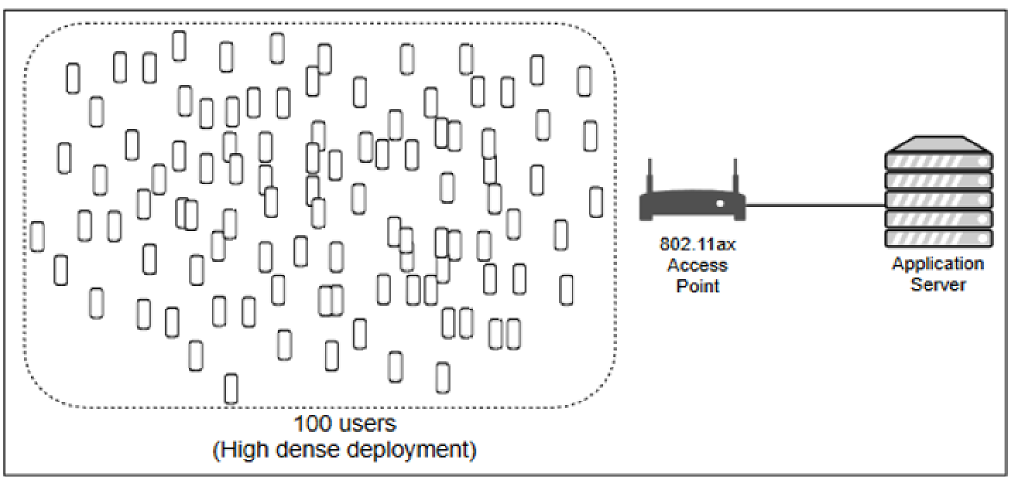

Figure 1. The 802.11ax simulation environment

For encoding of the data, the model included all modulation schemes that were supported by the 802.11ax standard. The modulation algorithms (MA) supported by the model and the corresponding coding rates (CR) are as follows:

- MA=BPSK, CR=1/2.
- MA=QPSK, CR=1/2 and 3/4.
- MA=16-QAM, CR=1/2 and3/4.
- MA=64-QAM, CR=2/3, 3/4, and 5/6.
- MA=256-QAM, CR=3/4 and 5/6.
- MA=1024-QAM, CR=3/4 and 5/6.

Furthermore, in 802.11ax, each modulation scheme can be used with different guard intervals and channel bandwidths. Thus, the model supports the following channel bandwidth (CW) and guard intervals (GUI):

- CW= 20MHz, 40MHz, 80MHz, and 160MHz.
- GUI=800ns, 1600ns, and 3200ns.

The internet protocol (IP) at the network layer used by the model to transmit the encoded data was version 6 (IPv6) due to offering more IP addresses which were required in dense networks with large number of devices. Moreover, the propagation loss model was Friis and the propagation delay was Constant Speed. The number of transmitting and receiving spatial streams was one as defined by default in the 802.11ax standard. The model evaluation was done based on BER, end-to-end-delay, packet loss ratio, and throughput and its efficiency. The throughput efficiency was measured as the difference between the application and simulation throughputs (Masiukiewicz, 2019). A summary of the main simulation parameters is provided in Table 1.

Table 1
Simulation parameters

Parameter name	Parameter description
Network standard	802.11ax
Radio band frequency	5GHz
User density	100 users (high-density)
Modulation schemes	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM
Corresponding FEC coding rate	1/2, 3/4, 2/3, 5/6
Propagation loss model	Friis
Propagation delay	Constant Speed
Traffic pattern	UDP Streaming
Network protocol	IPv6
Application data rate	2Mbps

RESULTS AND DISCUSSIONS

This section presents the results from the implementation of the model and determines the proper parameter selection for the performance optimization of 802.11ax with dense users.

BPSK with 1/2 Coding Rate

The binary phase-shift keying modulation scheme with two different symbols and one bit per symbol using 1/2 coding rate was implemented with all four channel bandwidths and three available guard intervals. The results are provided in Figure 2.

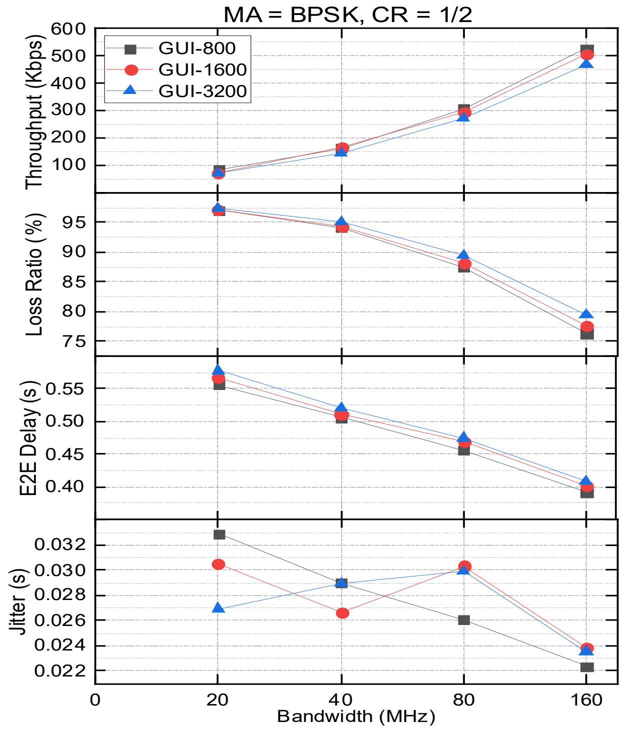

Figure 2. BPSK scheme with 1/2 coding rate

As we mentioned, the application data rate was 2Mbps in all the simulation scenarios. Comparing this rate with the archived throughput by BPSK showed that the algorithm was not able to provide a high-level performance for the end-users. Moreover, based on the results we observed that changing the guard interval from small to larger values did not significantly affect the performance of real-time applications. In contrast, the results confirmed a significant effect of the wider channels on the performance improvement of the end-users. In this context, the least performance was achieved by 20MHz channel bandwidth while 160MHz channel resulted in the best performance. When channel bandwidth was selected 20MHz, the functionality of BPSK compared to application data rate reduced to about 5% which was extremely low. In contrast, using 160MHz under high-density conditions provides 25% functionality for the end-users of real-time applications. Thus, although the result shows the inefficiency of the BPSK modulation scheme in high dense areas, the algorithm performed better when wider channels are used. The throughput efficiency of BPSK relating to the channel width and the guard interval index is provided in Table 2.

Table 2
BPSK throughput efficiency comparison

CW (MHz)	Efficiency, η (%)		
	GUI=800ns	GUI=1600ns	GUI=3200ns
20	4.19	3.68	3.45
40	8.13	8.23	7.23
80	15.31	14.66	13.68
160	26.37	25.28	23.30

QPSK with 1/2 and 3/4 Coding Rates

This section implements the quadrature phase-shift keying with four different symbols and two bits per symbol. Since the scheme supports two distinct coding rates including 1/2 and 3/4, the model implements both of them in line with four existing channel bandwidths and three guard intervals. The results of 1/2 and 3/4 coding rates are provided in Figure 3 (left) and (right), respectively.

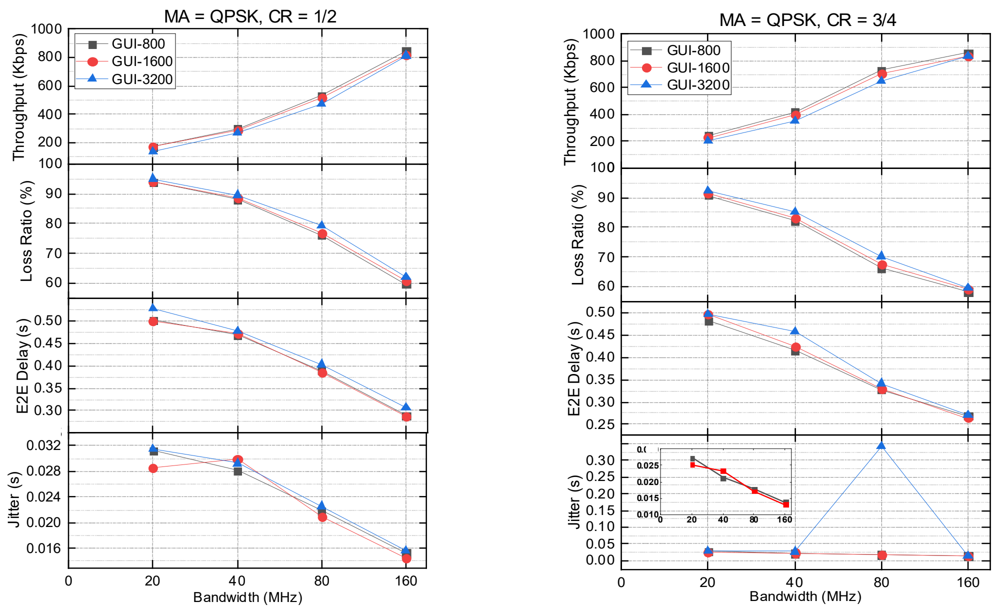

Figure 3. QPSK scheme with 1/2 (left) and 3/4 (right) coding rates

Regardless of the coding rates, the QPSK results showed its better performance compared to BPSK as it provided 40% improvement of the application data rate at the best consideration. Moreover, the results are consistent with BPSK in the context of better performance of the end-users with wider channels, unlike guard interval values which do not have a considerable effect. The comparison over the 1/2 and 3/4 coding rates shows that when QPSK algorithm was used with 3/4 coding rate, real-time applications provided better services for the end-users in terms of throughput, delay, and loss ratio. However, jitter results showed otherwise for 80MHz channels which provided significantly high jitter values compared to other bandwidths and compared to 1/2 coding rate. This proved that using 80MHz channels for jitter-sensitive applications in high dense 802.11ax was not efficient as it highly degraded the performance of these services. The throughput efficiency of QPSK with 1/2 and 3/4 coding rates relating to the channel width and guard interval is provided in Table 3.

Table 3

QPSK throughput efficiency comparison

CR	CW (MHz)	Efficiency, η (%)		
		GUI=800ns	GUI=1600ns	GUI=3200ns
1/2	20	8.42	8.47	6.80
	40	14.91	14.51	13.53
	80	26.60	25.86	23.60
	160	42.19	40.96	40.69
3/4	20	12.20	11.29	10.24
	40	20.77	19.78	17.61
	80	36.47	35.44	32.51
	160	43.09	41.95	41.65

16-QAM with 1/2 and 3/4 Coding Rates

This section implements the quadrature amplitude modulation scheme with 16 different symbols and four bits per symbol. The scheme supported two distinct coding rates including 1/2 and 3/4, hence, the model implemented them for the available channel bandwidths and guard intervals for the high dense deployment of 802.11ax. The results from the implementation of 16-QAM with 1/2 and 3/4 coding rates are provided in Figure 4 (left) and (right), respectively.

The obtained results show interesting findings. It was observed that while increasing the order of modulation from 4 (QPSK) to 16 (16-QAM) did not affect the widest channels (160MHz), it enhanced the performance of the narrower channels including 20, 40, and 80MHz. This is because the 802.11ax in the model is under highly dense conditions with 100 users that are exchanging heavy loads of real-time traffic simultaneously on the network. This will bring the network to its ultimate capacity and cannot go beyond that. The level of performance improvement of the narrow channels increased, even more, when 3/4 coding rate was utilized by the 16-QAM scheme compared to 1/2 coding rate. In this context, different guard interval values provide a close level of performance and their variations do not considerably change the experience of the end-users. Thus, when utilizing the 16-QAM scheme in the high dense deployment of 802.11ax network, deploying the 3/4 coding rate with 80 and 160MHz channel bandwidth is best-suited with any available value for the guard interval. The throughput efficiency of 16-QAM with 1/2 and 3/4 coding rates relating to the channel width and guard interval is provided in Table 4.

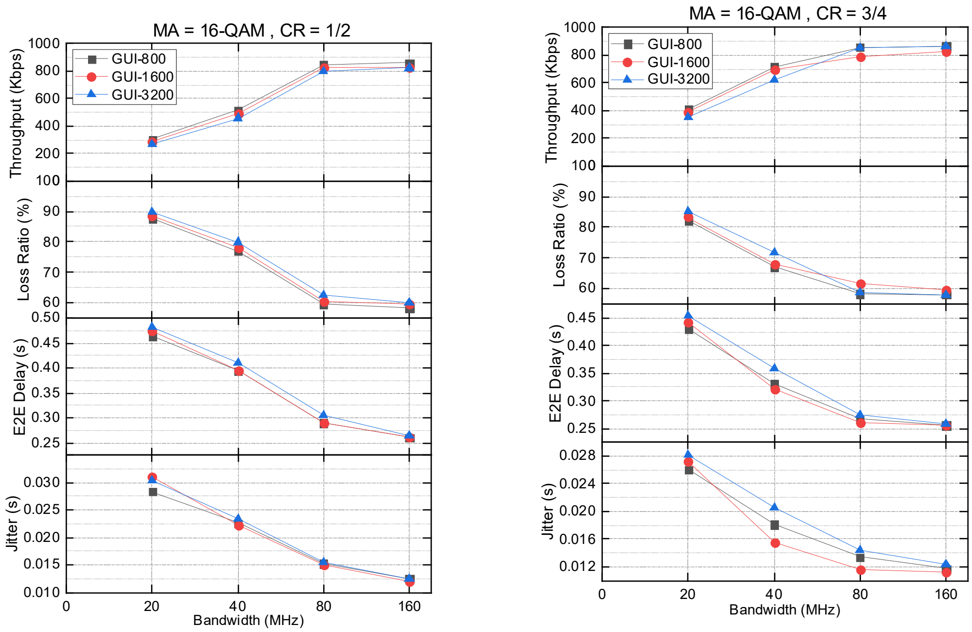

Figure 4. 16-QAM scheme with 1/2 (left) and 3/4 (right) coding rates

Table 4

16-QAM throughput efficiency comparison

CR	CW (MHz)	Efficiency, η (%)		
		GUI=800ns	GUI=1600ns	GUI=3200ns
1/2	20	15.12	14.32	13.21
	40	25.86	24.73	22.89
	80	42.24	41.41	39.78
	160	43.05	41.49	41.17
3/4	20	20.54	19.45	17.52
	40	35.73	34.92	31.05
	80	42.92	39.32	42.90
	160	43.13	41.55	43.14

64-QAM with 2/3, 3/4, and 5/6 Coding Rates

This section increases the order of the quadrature amplitude modulation scheme to 64 different symbols and six bits per symbol while the possible coding rates are 2/3, 3/4, and 5/6. The model implemented the three coding rates in accordance with the four available channel bandwidths and three guard intervals. The results from the implementation of 64-QAM with 2/3, 3/4, and 5/6 coding rates are provided in Figure 5 (left), (middle), and (right), respectively.

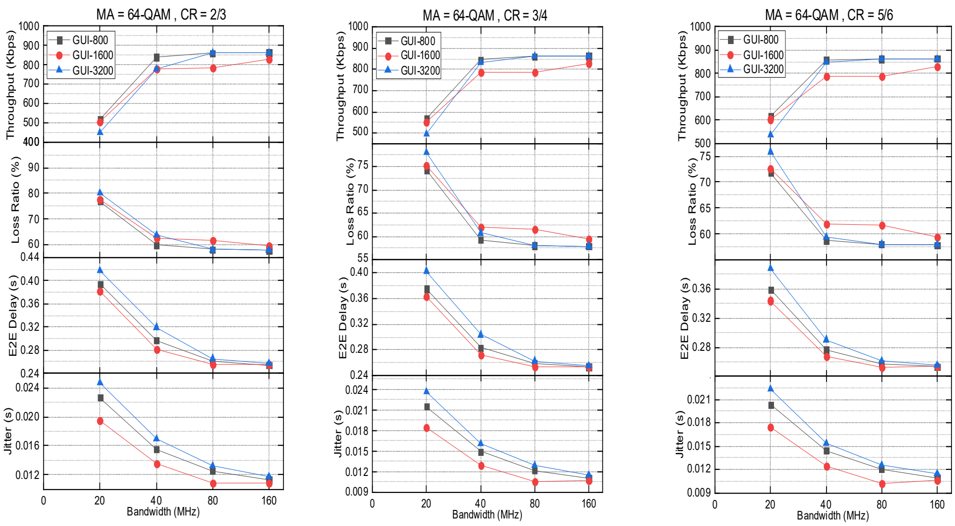

Figure 5. 64-QAM scheme with 2/3 (left), 3/4 (middle), and 5/6 (right) coding rates

The results show the efficiency of 64-QAM scheme to enhance the performance achieved by the narrower channels to a level close to wider channels. In this context, the 40MHz channel achieved similar performance as 80 and 160MHz channels. Moreover, unlike before, different values of guard intervals result in different performance achievements under similar conditions. The longer guard interval value increases delay and jitter to which real-time applications have zero tolerance. Additionally, increasing the guard interval decreases the throughput and increases loss ratio which is not suitable for high-speed demand applications. With regard to different coding rates, they do not considerably change the performance. The end-users' experience using 2/3 coding rate is at a similar level as 3/4 and 5/6 coding rates. Therefore, to enhance the performance of high-density 802.11ax networks using 64-QAM, employing 40, 80, and 160 MHz channel bandwidth with the shortest guard interval (800ns) is the best combination while coding rate's impact is not significant. The throughput efficiency of 64-QAM with 2/3, 3/4, and 5/6 coding rates relating to the channel width and guard interval is provided in Table 5.

Table 5

64-QAM throughput efficiency comparison

CR	CW (MHz)	Efficiency, η (%)		
		GUI=800ns	GUI=1600ns	GUI=3200ns
2/3	20	25.86	25.12	22.42
	40	42.05	38.88	38.95
	80	43.05	39.32	43.09
	160	43.14	41.55	43.22
	20	28.39	27.59	24.69
3/4	40	42.36	39.33	41.64
	80	43.11	39.36	43.12
	160	43.19	41.52	43.20
	20	30.87	30.17	26.81
5/6	40	42.85	39.31	42.39
	80	43.12	39.35	43.16
	160	43.16	41.55	43.18

256-QAM with 3/4 and 5/6 Coding Rates

This section increases the order of quadrature amplitude modulation to 256 different symbols and eight bits per symbol with the existing coding rates as 3/4 and 5/6. Accordingly, the model implements the 256-QAM modulation scheme with the two available coding rate, four channel bandwidths, and three guard intervals. The results for 3/4 and 5/6 coding rates are presented in Figure 6 (left) and (right), respectively.

The results show different findings than before. For all the previous modulation schemes in the model ranging from BPSK to 256-QAM, increasing the bandwidth of channel results in increasing the performance so that the highest performance is achieved by 160MHz channel. However, the results prove otherwise in 256-QAM algorithm. When 256-QAM used 3/4 coding rate, the highest performance in terms of throughput and loss ratio was achieved for 40 and 80 MHz channel bandwidths. However, with reference to delay and jitter, the best performance belongs to the 160MHz channel. Thus, with 3/4 coding rate, for the bandwidth demanded applications the 40 and 80 MHz channels were suitable while for delay-sensitive application, 160MHz channel was suited more. Turning now to 5/6 coding rate appeared some similarities and some differences with 3/4 coding rate. While the best channel bandwidths for 256-QAM with 3/4 coding rate were 40 and 80 MHz, for 5/6 coding rate, the best channel bandwidths are 20, 40, and 80 MHz for bandwidth-demand applications. Moreover, for delay-sensitive applications, like before, using 160MHz channels were more suitable. With respect to guard interval, the 5/6 coding rate was less sensitive to guard interval values while in 3/4 coding rate using a shorter guard interval improved the performance. The throughput efficiency of 256-QAM with 3/4 and 5/6 coding rates relating to the channel width and guard interval is provided in Table 6.

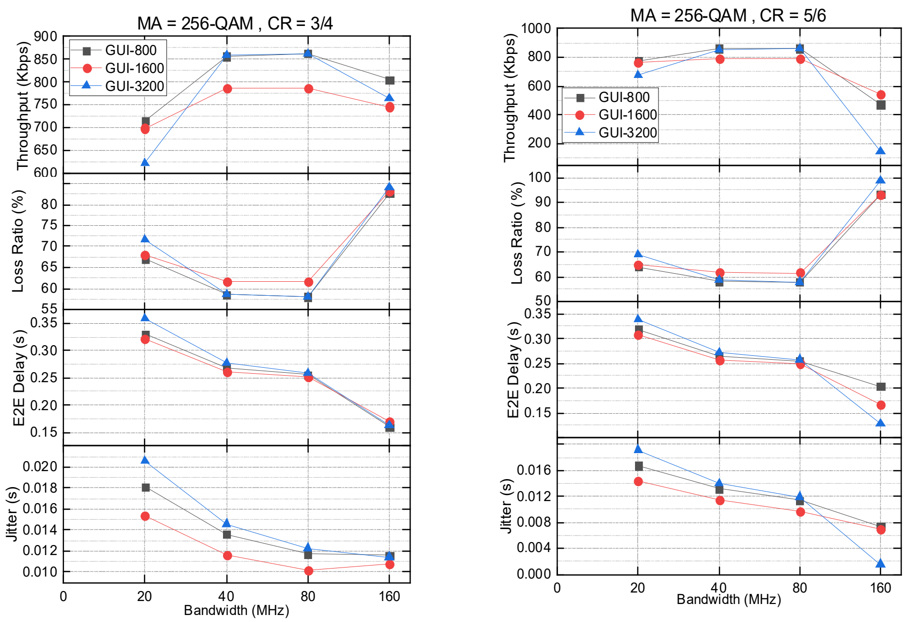

Figure 6. 256-QAM scheme with 3/4 (left) and 5/6 (right) coding rates

Table 6
256-QAM throughput efficiency comparison

CR	CW (MHz)	Efficiency, η (%)		
		GUI=800ns	GUI=1600ns	GUI=3200ns
1/2	20	35.72	34.92	31.05
	40	42.84	39.36	42.92
	80	43.12	39.37	43.14
	160	40.25	37.30	38.23
3/4	20	38.82	38.10	33.70
	40	43.06	39.36	42.81
	80	43.14	39.38	43.21
	160	23.56	27.21	7.21

1024-QAM with 3/4 and 5/6 Coding Rates

The last modulation scheme supported by the proposed model was 1024-QAM which had 1024 different symbols, ten bits per symbol, and two coding rates as 3/4 and 5/6. The model took all these parameters into account and implemented them to identify the most suitable values to be used in the high dense deployment of 802.11ax networks. The results for 3/4 and 5/6 coding rates are provided in Figure 7 (left) and (right), respectively.

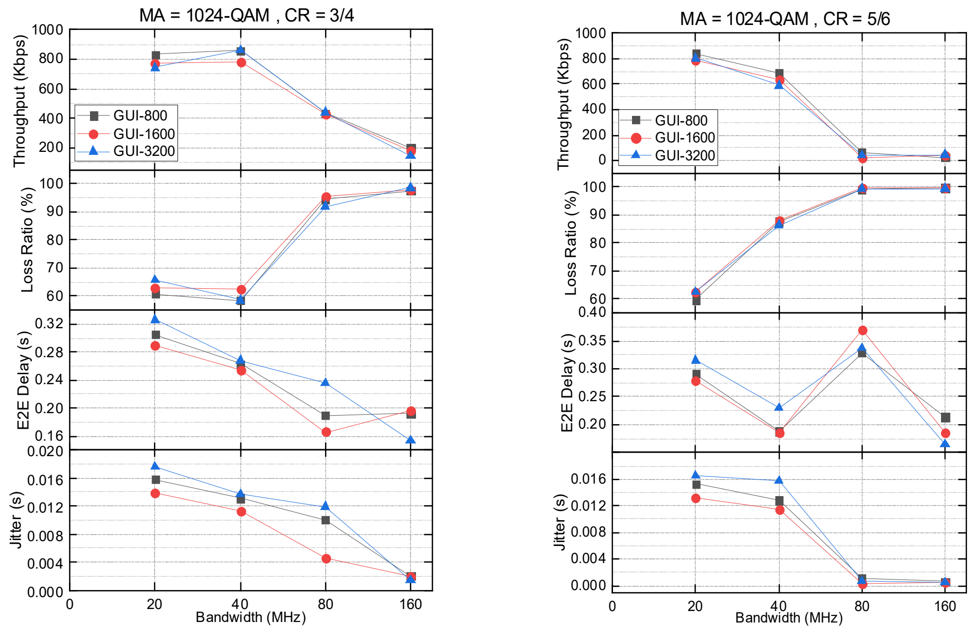

Figure 7. 1024-QAM scheme 3/4 (left) and 5/6 (right) coding rates

The above results prove that very high order modulation is not suitable for high-density areas that utilize wider channels for higher speed. Regardless of the coding rate value, two narrower channels, 20 and 40 MHz bandwidths fulfilled a better throughput and loss ratio performance compared to the wider 80 and 160 MHz channels. Furthermore, in 3/4 coding rate, a similar throughput and loss ratio values were achieved by 20 and 40 MHz channels while in 5/6 coding rate, the 80 and 160 MHz channels achieved similar throughput and loss ratio. In contrast, with respect to delay and jitter results, the wider channels can meet the demand of delay-sensitive applications as they provide less delay and jitter values. The best delay and loss ratio performance for 3/4 coding rate was achieved by 80 and 160 MHz channels while for 5/6 coding rate, the least delay belongs to 40 and 160 MHz. In this context, the jitter results of 80 and 160 MHz channels provided equal results. Like before, the lower coding rate is more responsive to guard interval values. For 3/4 coding rate, the longer guard intervals reduced the performance to a higher extent than in 5/6 coding rate. The throughput efficiency of 1024-QAM with 3/4 and 5/6 coding rates relating to the channel width and guard interval is provided in Table 7.

Table 7
1024-QAM throughput efficiency comparison

CR	CW (MHz)	Efficiency, η (%)		
		GUI=800ns	GUI=1600ns	GUI=3200ns
1/2	20	41.63	38.87	37.19
	40	43.03	39.28	43.02
	80	21.69	21.27	22.03
	160	10.05	9.04	7.24
3/4	20	42.17	39.24	40.27
	40	34.59	31.98	29.50
	80	3.06	0.86	2.00
	160	1.20	2.01	2.25

Bit Error Rate (BER) Occurrence

In this section we compare the bit error rate (BER) comparison of all the modulation schemes. The results are provided in Figure 8.

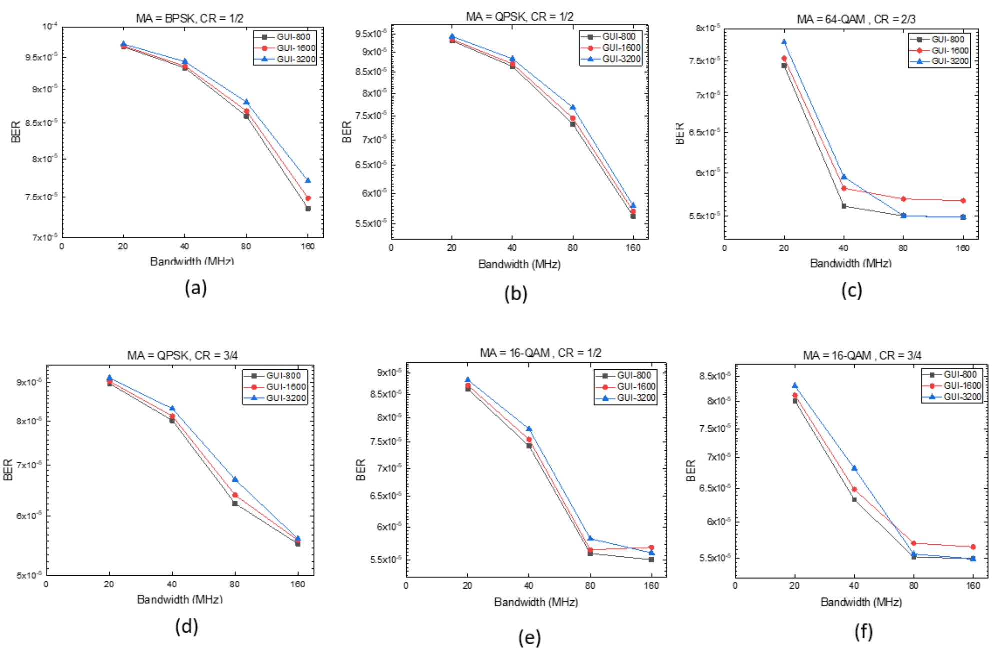

Figure 8. BER comparison of modulation schemes (a) BPSK-1/2, (b) QPSK-1/2, (c) QPSK-3/4, (d) 16-QAM-1/2, (e) 16-QAM-3/4, (f) 64-QAM-2/3

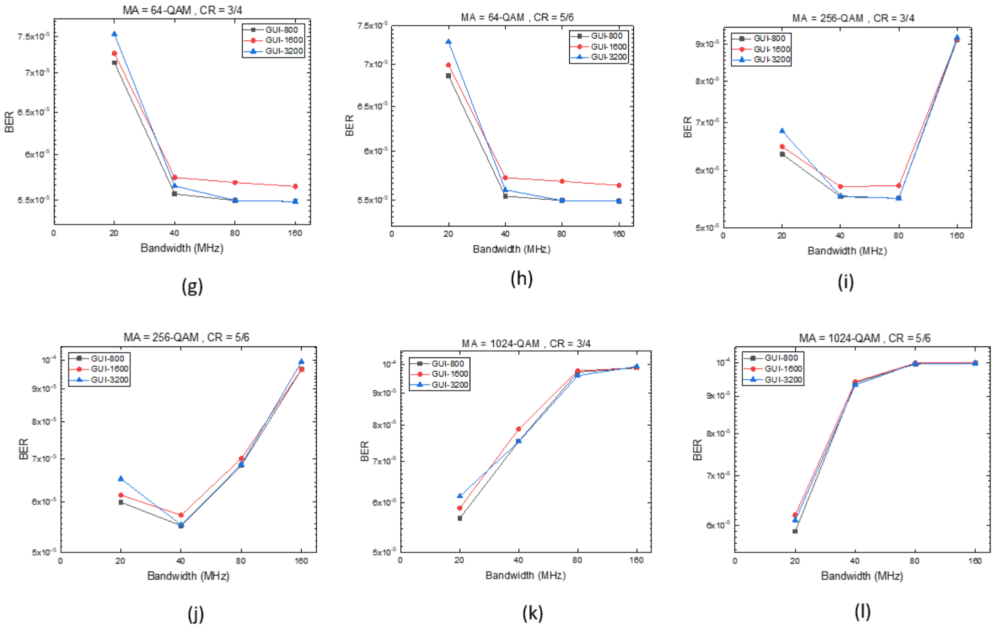

Figure 8(Continued). BER comparison of modulation schemes (g) 64-QAM-3/4, (h) 64-QAM-5/6, (i) 256-QAM-3/4, (j) 256-QAM-5/6, (k) 024-QAM-3/4, (l) 024-QAM-5/6

Typically, the acceptable BER values were below 10e-5 (Feukeu et al., 2013). Thereby, the above results show that all the obtained BER values were within the acceptable range. The results show a direct relationship between the order of modulation and BER reduction so that the worse BER values were obtained using the BPSK and the best values were obtained by the 1024-QAM with 5/6 coding rate. Concerning the channel width, for the lower order modulation from BPSK to 64-QAM, as the channel width increased, the BER decreased significantly. However, in the higher-order modulation from 256-QAM to 1024-QAM, the results were opposite so that lower BER values belonged to narrower channels.

CONCLUSIONS

This work proposes a model to optimize the performance of 802.11ax networks under high-density conditions regarding the available modulation schemes and their corresponding coding rates. The model further includes different combinations of guard interval and channel bandwidth parameters. The model is implemented and the results are measured to determine the proper values for the network optimization. The results show that utilizing wider channels and shorter guard intervals do not necessarily optimize the 802.11ax networks that are under heavy loads of a large number of users. The modulation schemes from BPSK to 64-QAM are able to improve the network performance in line with increasing the bandwidth of channels. In this context, the best performance is accomplished by 64-QAM with 40, 80, and 160 MHz channels with 5/6 coding rate. However, for higher-order modulation including 256-QAM and 1024-QAM, the results prove otherwise. In this regard, the least amount of data rate obtained by 256-QAM is attained for the widest channel as 160MHz. Likewise, the least data rate of 1024-QAM is gained for 80 and 160 MHz channels. Furthermore, on the basis of the results, we do not observe a significant effect of guard interval values on performance enhancement of high-density 802.11ax. Although the shorter guard interval can improve the overall performance to some extent, the level of improvement is not remarkable. With regard to the bit error occurrence, the BER results are consistent with others so that for the lower order modulation, from BPSK to 64-QAM, as the channel width increases, significantly better performance in terms of lower BER values is achieved. However, for the higher-order modulation i.e. 256-QAM and 1024-QAM, the lower BER values belong to the narrower channels.

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