

Performance Analysis of Zigbee Based Network Topologies Through Modulation Techniques

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ABSTRACT Due to vast range of applications in managing, monitoring, and automating homes, industries, and other workplaces. Standard IEEE 802.15.4 based zigbee has recently attracted the interest of the research and academic communities. In addition to these Zigbee has some great intrinsic qualities, such as low energy consumption and inexpensive. ZigBee network topologies should be chosen depending on application and performance needs. As a result, this paper analyse the performance of ZigBee network for star, tree, and mesh topologies by changing the modulation method of transceivers. The research was carried out using the OPNET Modeler to simulate required scenarios. The goal is to see effect of modulation techniques and Zigbee topologies on the performance evaluation parameters MAC throughput, MAC delay, and end-to-end delay. The result shows that highest MAC throughput is 431898.599999 bits per second achieved for tree topology when transceiver's modulation technique is set to QPSK. The lowest MAC

delay is 0.015866 second and lowed end to end delay is 0.026300 second for mesh topology when transceiver's modulation technique is set to FSK2. The effect of BPSK modulation technique over different topologies is almost same.

Keywords: IEEE802.15.4, Opnet, BPSK, FSK, QPSK.

I. INTRODUCTION

Sensor devices that monitor environmental conditions make up Wireless Sensor Networks (WSNs) to measure temperature, pressure, pollution, vibration, and more. These sensors are connected to one another through a wireless network [1, 2]. WSNs, Battery life, bandwidth, and computational power, on the other hand, have limitations and concerns [2]. As a result, efforts are underway to design novel routing algorithms in order to broaden the scope and scalability of WSNs or improve power and energy utilisation [1, 2]. Finally, due to the widespread usage of WSN, an industry standard, IEEE 802.15.4, as well as the Zigbee protocol [1, 2], were created. Zigbee's strong features, as well as its specifications, have helped it gain wide adoption for personal area networks, which are essential in WSNs. The following are some of the functions that ZigBee technology may provide: [1, 3]:

1. Long Battery Life
2. Low data rate, and
3. Economical price
4. High efficiency and reliability

This work presents a simulation investigation on the effectiveness of various modulation algorithms and network topologies for Zigbee networks. The research looked at end-to-end latency, throughput, and delay.

II. OVERVIEW OF MODULATION TECHNIQUES

A sinusoidal signal has three important characteristics amplitude(v), frequency(f), and phase(θ). These characteristics Amplitude Modulation, Frequency Modulation, and Phase Modulation are the three basic modulation techniques based on these qualities. Amplitude shift keying, Frequency shift keying, and Phase shift keying are the digital versions of these signals based on these modulation techniques [4, 5, 6]. Many different modulation techniques can be constructed by intermixing different available three core strategies. For example, a Quadrature phase shift keying modulation mechanism can be created by two BPSK signals carried with orthogonal carriers [4].

Amplitude shift keying (ASK)

ASK [4, 5, 6] is a kind of amplitude modulation that encrypts digital data by varying the amplitude of carrier waves. The digital message is solely mapped to the carrier wave's amplitude fluctuations. The keying is the foundation of ASK. On-off keying(OOK) is a specific type of ASK.

Frequency shift keying (FSK)

FSK is a frequency modulation technique that uses discrete carrier wave frequency shifts to transmit digital data. The most basic type of FSK is binary FSK, often known as BFSK. To transport binary data, BFSK consist of different pair of frequencies. [4, 5, 6]

The receiver in the FSK merely listens for particular frequency fluctuations over a number of periods. As a result, FSK is lesser noise sensitive than ASK. The FSK technique, on the other hand, has a number of disadvantages, including larger spectrum and higher bandwidth. FSK technique creates sidebands, on both sides of the carrier wave. It's possible that this will cause interference with neighbouring channels. Minimum Shift Keying is used to decrease the sidebands. MSK is an FSK variation that is more spectrally efficient. A side from that, frequency transitions can be smoothed out using Gaussian frequency-shift keying (GFSK)[4, 5, 6].

Frequency Shift Keying-2

FSK-2 is a technique in which digital data is transferred via discrete carrier wave frequencies 1 & 2 shifts and provides the modulated output waveform.

Phase shift keying (PSK)

PSK is a type of technique that conveys data by modifying the phase parameter of the carrier wave. The carrier signal's frequency and amplitude remain consistent, which is critical. The most basic type of PSK is binary phase-shift keying. In many situations, BPSK is employed as a robust method. In 802.11 WSN, multiple techniques are employed based on the transmission rate, but the broadcast of header of each frame is always using BPSK to acknowledge successful transmission. BPSK alters the carrier 180° for change of each binary state.

In BPSK technique, phase change occur at zero sites[4,5, 6].

In terms of noise interference, PSK techniques is being less laible to noise than ASK, but it acquires the same bandwidth as the ASK modulating technique. PSK demodulation needs a signal comparison of same phase to a sine carrier, which makes the demodulator more challenging [4, 5, 6].

PSK modulation includes Quadrature phase-shift keying, 8-PSK, 16-PSK, and M-PSK. All these modulation techniques work on the similarly with defined principle ; the only difference is that the phase shifts are smaller, allowing for more bits to be sent at the same carrier frequency [4, 5, 6].

III. ZIGBEE MODULATION TECHNIQUES AND TOPOLOGIES

The physical layer of the 802.15.4 standard offers three frequency bands, which use the Direct Sequence Spread Spectrum (DSSS) access mode: 245.0 MHz (16 channels), 915 MHz (10 channels), and 868 MHz(1 channel). In the 2450 MHz frequency band, Offset Quadrature Phase Shift Keying (O-QPSK) is utilised for modulation, whereas Binary Phase Shift Keying (BPSK) is used in the 868/915 MHz bands (BPSK)[7].

At 2.4 GHz, O-QPSK modulation is employed in Zigbee technology.

The O-QPSK modulation technology overcomes BPSK modulation's drawbacks, such as signal 180° mutation and phase ambiguity. Furthermore, the use of DSSS (Direct Sequence Spread Spectrum) addresses the issue of ASK modulation anti-interference[8].

As mentioned in [1,] Zigbee supports three topologies: star, mesh, and tree.

IV. SIMULATION SETUP AND RESULT ANALYSIS

To investigate system behaviour modelling and simulation are being used. In this paper, OPNET is used for modelling communication networks that includes a development environment and a lot of features. We simulate ZigBee networks: star, tree, mesh structure in three different scenarios and each having 3 different cases based on modulation techniques used. We employ 7 ZigBee nodes as shown in figure 1, which are configured as follows: 1 coordinator, 1 Router, and 5 End Devices.



Fig.1. Zigbee Network

Scenario1: Analysis of Star Topology by varying the modulation method

By varying the modulation methods, the behaviour of the star topology is analysed in this case scenario. When creating the star topology network the modulation method was set to BPSK, QPSK, and FSK2 for case 1, 2, and 3 respectively. Table 1 shows the values of different evaluation parameters at simulation time 594.0s.

Table 1. Values of different evaluation parameters for star topology network at simulation time 594.0s.

Case	Modulation Technique	MAC Delay	MAC Throughput	End to End Delay
1	BPSK	0.019074	272059.919999	0.030816
2	QPSK	0.0190764	272347.919999	0.028401
3	FSK2	0.019108	272555.280000	0.029827

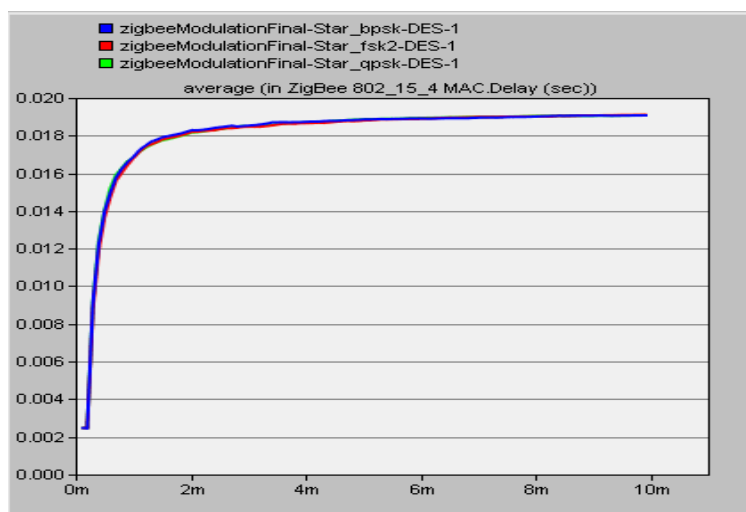


Fig. 2: MAC Delay for Star Topology Network

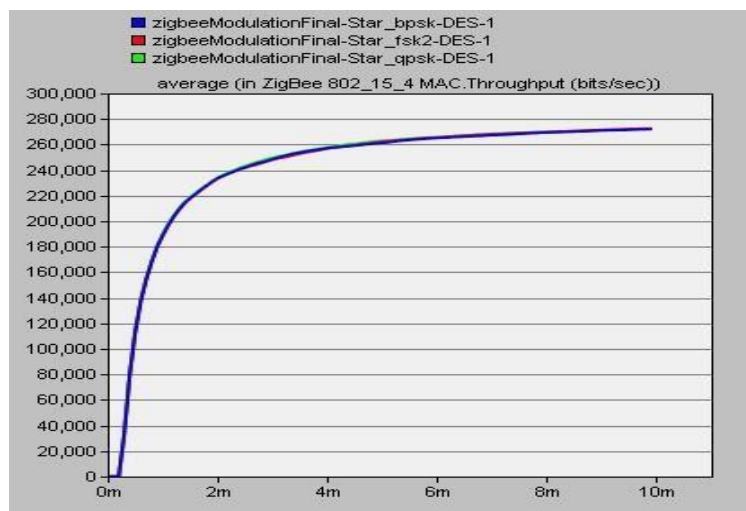


Fig.3: MAC Throughput for Star Topology Network

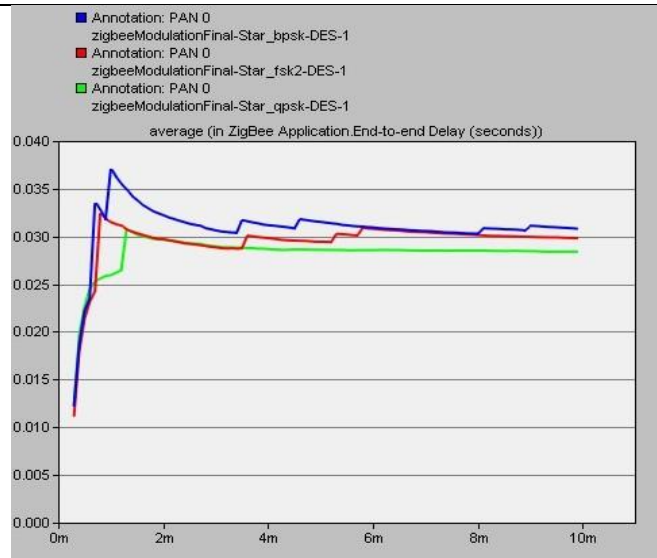


Fig.4 : Star Topology Network- End to End Delay

As demonstrated in table 1 and figures 2, 3, and 4, the MAC latency and throughput are nearly same for all modulation approaches, however the end-to-end delay in a star topology network is highest for BPSK modulation and lowest for QPSK modulation.

Scenario 2: Analysis of Tree Topology by varying the modulation method

By varying the modulation methods, the behaviour of the tree topology is analysed in this case scenario. When creating the star topology network the modulation method was set to BPSK, QPSK, and FSK2 for case 1, 2, and 3 respectively. Table 2 shows the values of different evaluation parameters at simulation time 594.0s.

Table 2. Values of different evaluation parameters for tree topology network at simulation time 594.0s.

Case	Modulation Technique	MAC Delay	MAC Throughput	End to End Delay
1	BPSK	0.0190742	272059.919999	0.030816
2	QPSK	0.020866	431898.599999	0.029198
3	FSK2	0.019071	272313.359999	0.031718

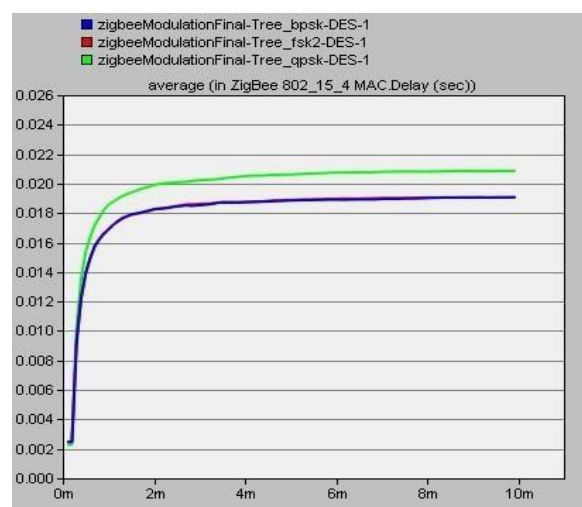


Fig.5:MAC Delay for Tree Topology Network

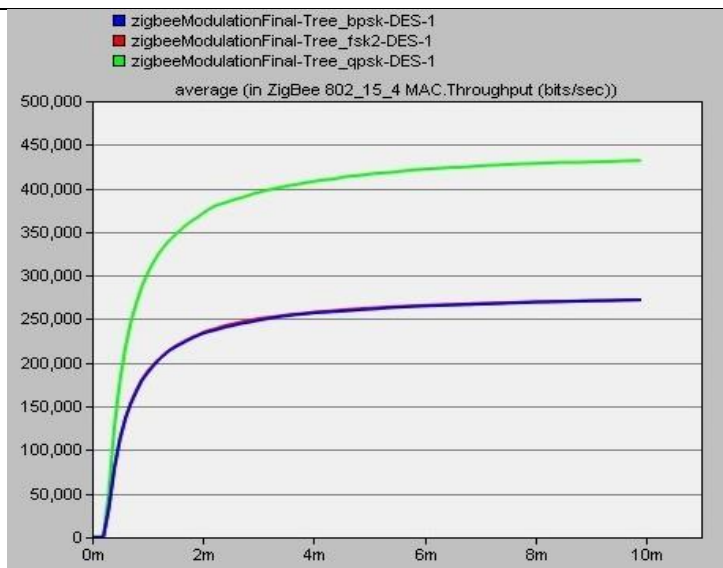


Fig.6: MAC Throughput for Tree Topology Network

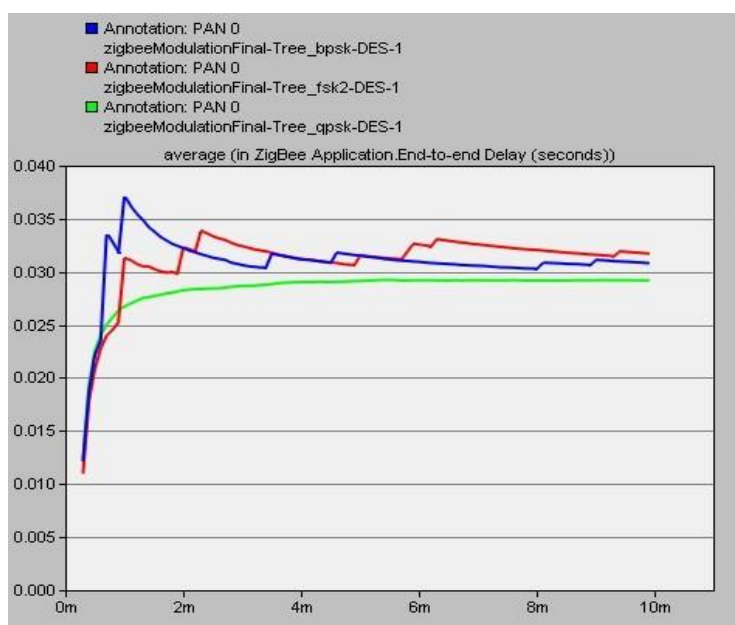


Fig. 7: End to end delay for Tree Topology Network

As shown in table 2 and fig 5, 6, and 7 the MACdelay and MACthroughput is higher for the QPSK as compare to others. The end to end delay is highest for PSK2 modulation method and lowest for QPSK method in tree topology network.

Scenario 3: Analysis of Mesh Topology by varying the modulation method

By varying the modulation methods, the behaviour of the mesh topology is analysed in this case scenario. When creating the mesh topology network the modulation method was set to BPSK, QPSK, and FSK2 for case 1, 2, and 3 respectively. Table 3 shows the values of different evaluation parameters at simulation time 594.0s.

Table 3. Values of different evaluation parameters for mesh topology network at simulation time 594.0s.

Case	Modulation Technique	MAC Delay	MAC Throughput	End to End Delay
1	BPSK	0.019074	272059.919999	0.030816
2	QPSK	0.019068	272267.280000	0.031735
3	FSK2	0.015866	217581.84	0.026300

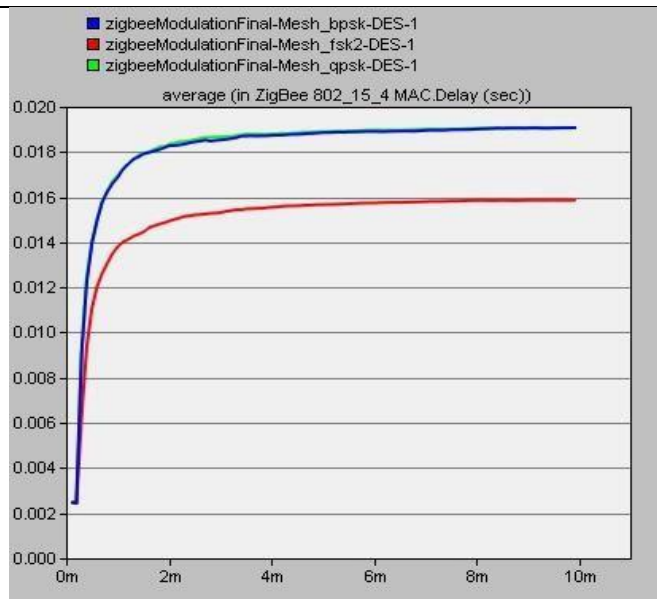


Fig. 8:MAC Delay for Mesh Topology Network

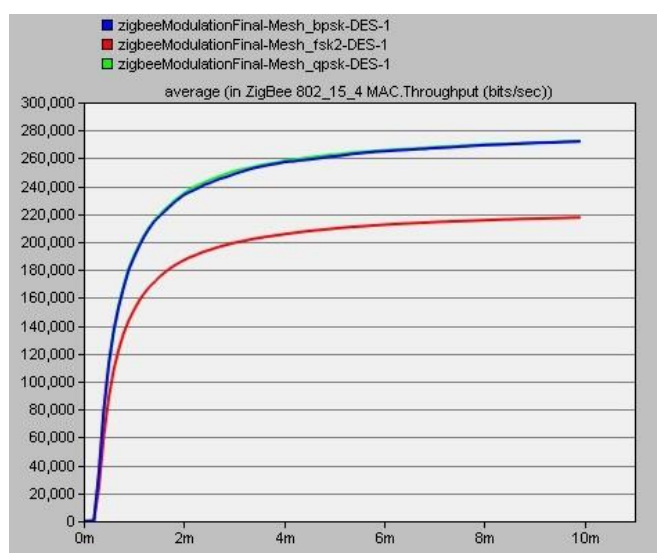


Fig.9: MAC Throughput for Mesh Topology Network

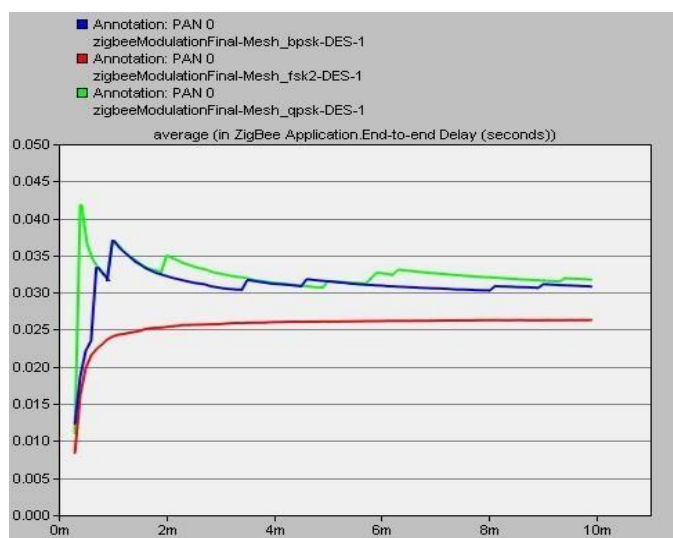


Fig. 10: Mesh Topology Network- End to end delay

As shown in table 3, figure 1, 2, and 3, the MAC delay and MAC throughput is lowest for the FSK2 as compare to others. In a mesh topology network, the end-to-end delay is largest for QPSK modulation and lowest for FSK2.

V. PERFORMANCE ANALYSIS AND EVALUATION OF STAR, TREE, AND MESH TOPOLOGY

Using simulation results, we compare and analyse the star, tree, and mesh topologies in this section as shown in section 4.

MAC Delay

Table 4 shows that MAC delay is lowest for mesh topology when modulation technique is FSK2 whereas MAC delay is highest for tree topology when modulation technique is QPSK.

Table 4: MAC delay in star, tree, and mesh topology for different modulation techniques

Case	Modulation Technique	Star	Tree	Mesh
1	BPSK	0.019074	0.019074	0.019074
2	QPSK	0.019076	0.020866	0.019068
3	FSK2	0.019108	0.019071	0.015866

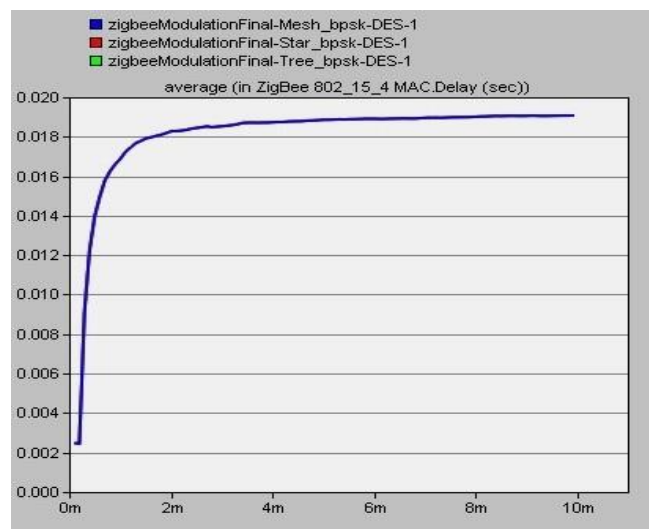


Fig. 11: Comparison of MAC Delay of various topology networks when transceivers used BPSK modulation

As shown in figure 11 MAC delay is almost same for all topologies when transceivers modulation is set to BPSK.

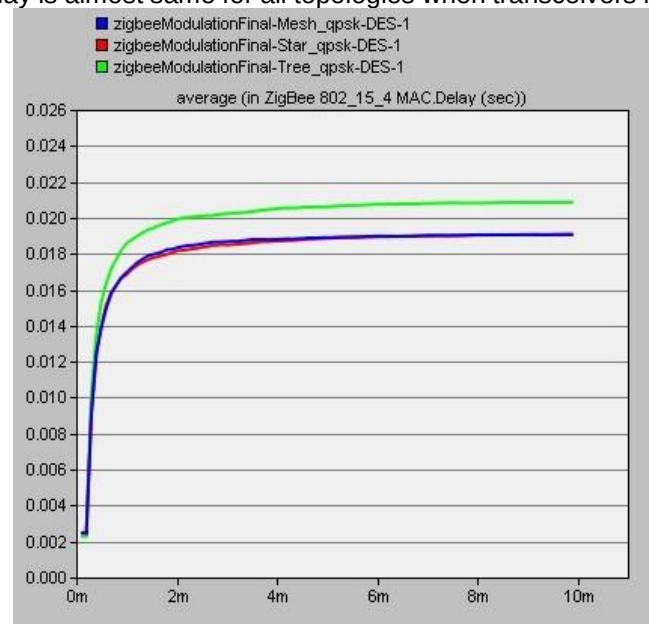


Fig.12 : Comparison of MAC Delay of various topology networks when transceivers used QPSK modulation

As show in figure 12 the MAC delay is higher in tree topology network as compared to other topologies.

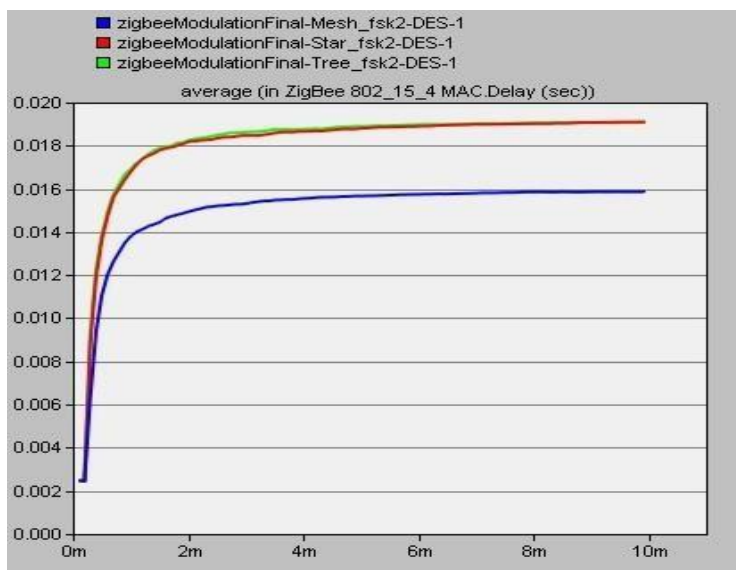


Fig.13: Comparison of MAC Delay of various topology networks when transceivers used FSK2 modulation

As show in figure 13 the MAC delay is lower in mesh as compare to other topology network.

MAC Throughput

Table 5 shows that MAC throughput is same for all topology when modulation technique is BPSK. MAC throughput is highest for tree topology when modulation technique is QPSK. MAC throughput is lowest for mesh topology when a modulation technique is FSK2.

Table 5: MAC throughput in star, tree, and mesh topology for different modulation techniques

Case	Modulation Technique	Star	Tree	Mesh
1	BPSK	272059.919999	272059.919999	272059.919999
2	QPSK	272347.919999	431898.599999	272267.280000
3	FSK2	272555.280000	272313.359999	217581.84

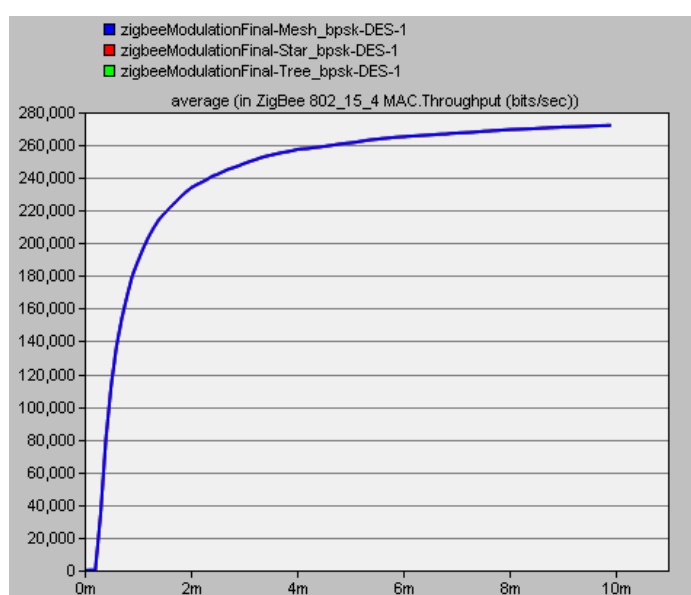


Fig.14: Comparison of MAC throughput of star, tree, and mesh topology networks when transceivers used BPSK modulation

As show in figure 14 the MAC throughput is almost same in all topology networks.

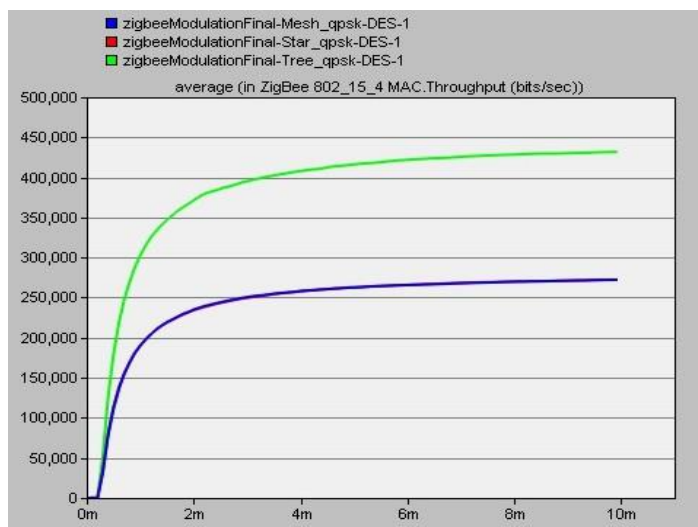


Fig.15: Comparison of MAC throughput of star, tree, and mesh topology networks when transceivers used QPSK modulation

As show in figure 15 the MAC throughput is higher in tree topology network as compared to other topologies.

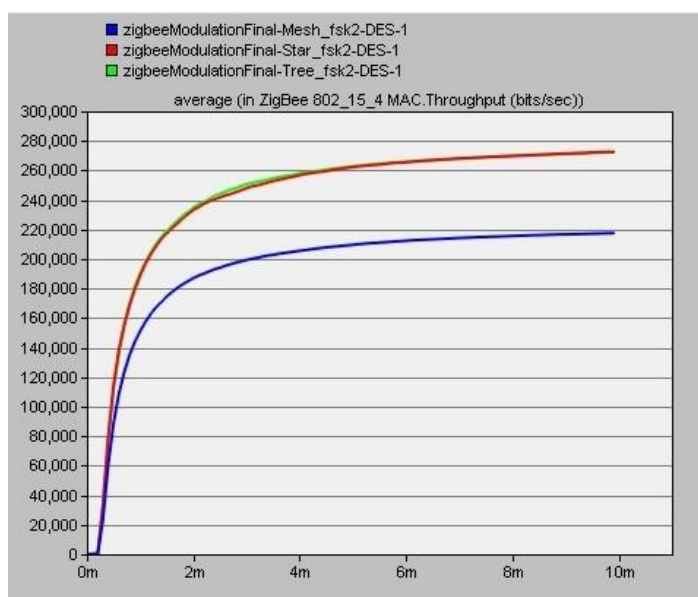


Fig.16: Comparison of MAC throughput of star, tree, and mesh topology networks when transceivers used FSK2 modulation

As show in figure 16 the MAC throughput is lower in mesh as compare to other topology network.

End to End delay:

Table 6 indicates that when the modulation technique is BPSK, the end-to-end latency is the same for all topologies. When the modulation mechanism is QPSK, the mesh topology has the longest end-to-end latency. When using FSK2 as a modulation technique, the mesh topology has the shortest end-to-end delay.

Table 5:MAC throughput for different modulation techniques in star, tree, and mesh topologies

Case	Modulation Technique	Star	Tree	Mesh
1	BPSK	0.030816	0.030816	0.030816
2	QPSK	0.028401	0.029198	0.031735
3	FSK2	0.029827	0.031718	0.026300

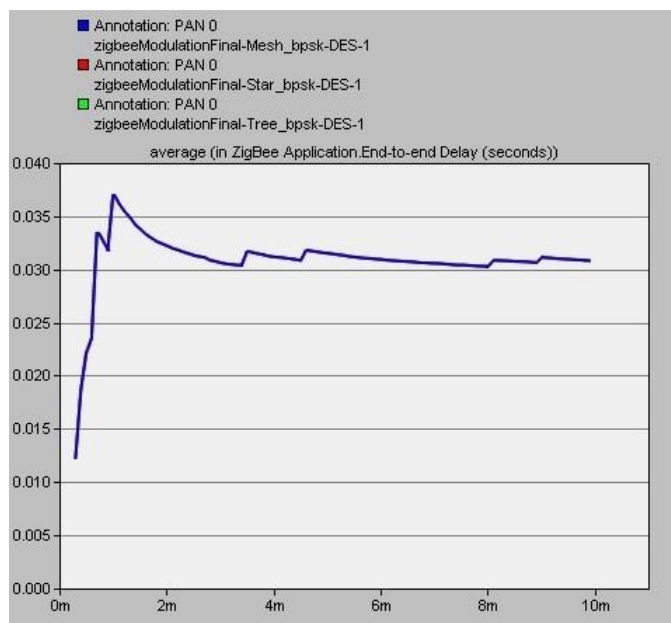


Fig.17: When transceivers used BPSK modulation- the end-to-end delay of star, tree, and mesh topology networks compared.

When the transceiver uses the BPSK modulation approach, the end-to-end delay is about the same in all topology networks, as shown in figure 17.

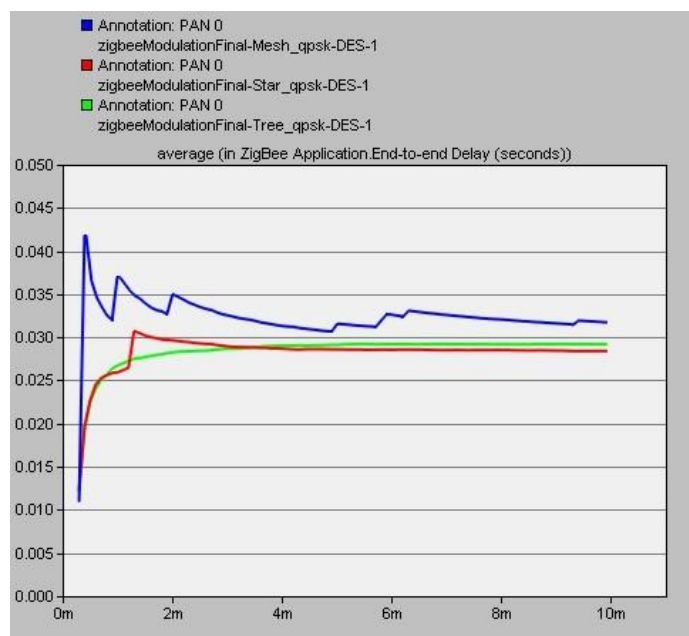


Fig.18: When transceivers used QPSK modulation- the end-to-end delay of star, tree, and mesh topology networks compared.

As seen in Figure 18, the mesh topology network has a longer end-to-end delay than the star topology network.

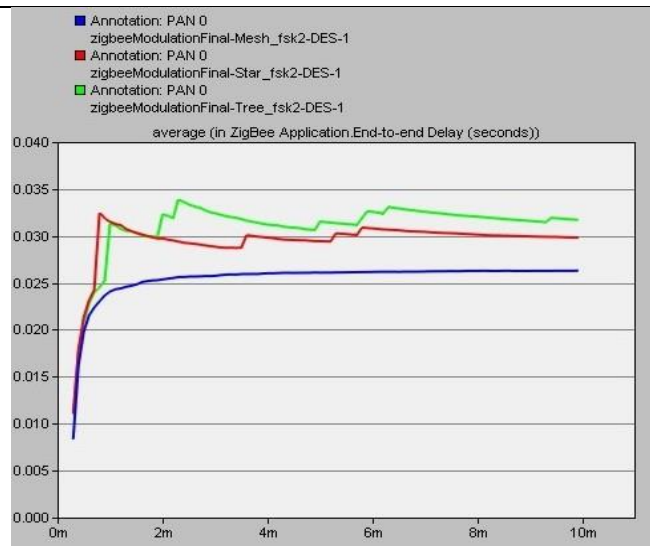


Fig.19: When transceivers used FSK 2 modulation- the end-to-end delay of star, tree, and mesh topology networks compared.

As seen in Figure 19, the mesh network has a lower end-to-end delay than the tree topology network.

VI. CONCLUSION

In this paper we demonstrate the effect of modulation techniques and topologies on Zigbee based network by analysing the evaluation parameters MAC delay, throughput, and end-to-end delay. For simulation same type and number of Zigbee nodes are used in all scenarios. The simulation time was 10 minutes. The values of evaluation parameters are recorded at simulation time 594.0s. The simulation results are shown and analysed in section 4 and 5 in detail. The findings show that MAC throughput is highest for tree topology when modulation technique is QPSK. When modulation technique is FSK2, mesh topology has a lesser MAC delay and end to end delay than tree and star topologies.

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