Volume: 13 Issue: 06 Pages: 5159-5168(2022) ISSN: 0975-0290

# Evaluation of Mobile ZigBee Technology Performance with Simulation Techniques

**Ojo Jayeola Adaramola**
Department of Computer Engineering, Federal Polytechnic Ilaro, Ogun State, Nigeria.
ojo.adaramola@federalpolyilaro.edu.ng
**Jamiu Rotimi Olasina**
Department of Computer Engineering, Federal Polytechnic Ilaro, Ogun State, Nigeria.
jamiu.olasina@federalpolyilaro.edu.ng

**ABSTRACT**

**ZigBee technology adaptation and use is an emerging wireless communication technology with low power consumption and long battery life. These technology applications include controlling industrial systems, automating home systems, embedded sensing, and many more. Due to ZigBee's low bit rate and low transmission rate, it is necessary to investigate how ZigBee will perform in a heterogeneous situation using a simulation approach. This paper goes on to describe the design and modelling of mobile ZigBee networks with 5, 10, 15, 20, and 25 nodes to evaluate and compare the performance of this wireless sensor network for star topology networks over time. For the resourceful operation of WSN, mobile ZigBee networks with 5, 10, 15, 20, and 25-star topologies were considered. Certain network parameters such as throughput (bits/sec), delay (sec), end-to-end delay (sec), traffic sent (bits/sec), and traffic received (bits/sec) were explored and compared for smooth WSN operation when ZigBee communication protocol was used and modelled with the OPNET simulator. After evaluating all of the required parameters for various scenarios, an acceptable result was obtained for the mobile ZigBee WSN.**

Keywords - **Mobile ZigBee, Network Parameters, OPNET, Star Topology, Wireless Sensor**

Date of Submission: May 20, 2022 Date of Acceptance: Jun 04, 2022

## 1. INTRODUCTION

The ad hoc capability of wireless sensor networks (WSNs) comes with robustness, fault tolerance, and the ability to be presented for a large coverage, contrary to the primitive type of sensor network that required prearranged locations [1]. As a result of the convenient and systematic use of the wireless network in offices, homes and campuses, the wireless personal area network (ZigBee) has become a supporting technology that provides a solution for easy signal distribution by tapping into its scalability [2] and low power consumption benefits [3], [4]. Instead of laying down cables, wireless technology is commonly employed in today's world. In educational, industrial, and private contexts, wireless communication is utilized to gather data or fulfil specified tasks. The three basic C's of a characteristic wireless sensor are communication modules, computation, and collection. [5]. Over the last decade, WPAN and WLAN technology have seen substantial growth [6].

However, this emerging technology when compared with Bluetooth in the application process had higher network flexibility, a higher number of nodes, low power and a better transmission range was recorded [7]. Security and lower communication links are also provided by this wireless communication protocol [8]. ZigBee is available in three forms to include ZigBee coordinator configured to form the topology type, transmission channel selection and initialize the network. An intermediary ZigBee router connects other nodes to the network, and ZigBee end devices communicate with the coordinator or router [9]. Also, ZigBee topologies such as star topology, mesh and tree topology were well-classified [10].

ZigBee standard functions at a three-band frequency of 2.4 GHz band of 250 kbps maximum data rate, 868 MHz bands of 20 kbps data rate and 915 MHz band of 40 kbps data rate [6], [9], [11]. Furthermore, environmental and physical conditions like humidity, temperature and pressure can be collected by deploying a great number of WSNs in a zone of interest. Many simulation models such as OMNeT++, Avrora, ATEMU, TOSSIM, NS-2, J-Sim, EmStar, and OPNET were recently developed by different researchers to implement network technology. But in comparison with other simulators, OPNET performed better in terms of suitability for study and modelling network environments, investigating protocols, practical network communication, and the behaviour of OPNET simulator in the real-life scenario [12].

However, the efficacy of network characteristics such as latency (sec), throughput (bits/sec), end to end delay (sec), traffic received (bits/sec), and traffic sent (bits/sec) was examined to measure the validity of the mobile Zigbee network. The rest of this article can be organized as follows: The first section provides an overview of ZigBee technology, section 2 discussed the literature related to work using ZigBee technology, and section 3 described the method used for the implementation of the research work in OPNET environment, section 4 presented the results obtained in the work and the analysis of each of the results, while section 5 concluded the work with the future directions.

## 2. RELATED WORK

This aspect revealed the trends in ZigBee technology as regards wireless sensor network (WSN), and the effort put together by various researchers to uncover the practicality of the technology. This was unveiled to allow researchers to tap into hidden features of this technology to further make an appreciable technical contribution that will enhance a positive impact on society.

[13], many physical experiments on ZigBee technology were carried out. This was done to observe the performance and effects of interference on the device under several conditions, such as outdoor environment, indoor environment, and co-existence of Bluetooth. The experiment was performed in a physical setting and there was an observation on the performance of the ZigBee device as its signal degraded in both outdoor and indoor settings. [14], also proposed a smart monitoring system to control the operation of doors of various rooms, lighting systems and also appliances on campus in an OPNET simulation environment. Four parameters comprising delay, load, throughput and packet delivery ratio were compared in tree and mesh topologies for performance evaluation. Based on their conclusion, mesh topology performed better as regards packet delivery ratio (PDR) and delay while optimal performance was achieved in tree topology in respect of throughput and load. They further stressed that the result obtained will help the network designers to model and decide on a superlative scenario for their task in future.

[15], analyzed the performance of three types of ZigBee topology (star, tree and mesh topologies) for different sizes of nodes using Riverbed Modeler 17.5 academic edition. Three network metrics considered for the analysis were the number of hops, end-to-end delay, and throughput. A higher delay was observed in a star topology with 40 nodes, and also higher throughput was witnessed in a mesh topology with 40 nodes. From the perspective of end-to-end delay and throughput, he observed that mesh design provided the optimal results, while tree design performance superlatively matched the number of hops with scenarios having higher nodes. More also, an investigative performance of the mobile device utilizing ZigBee protocol with a different number of nodes and distances was considered. Three scenarios were modelled with personal area network (PAN) 1, 2 and 3 having 2mW of transmission power in an OPNET simulation environment. The parameter chosen were throughput, traffic received and data drop. The results obtained indicated that the mobile node linked to PAN 1 for some minutes and disconnected to connect to PAN 2 for some minutes and further disconnected to link to PAN 3. From the result obtained, data dropped at its lowest rate for the best simulation period [16].

[17], designed and carried out a substantiation model for wireless sensor networks to ascertain nodes that were not working in a distributed wireless sensor network. The quality of services (QoS) considered were throughput, end-to-end delay, and load for the star, mesh and tree topologies. The outcome in the OPNET simulation environment revealed that the number of corrupt nodes rises with a growth in the number of nodes on one target and the amount of corrupt nodes drops with an increase in the number of targets. And also concluded that each of the topologies was better on different QoS considered when compared in terms of their performance. The behaviour of ZigBee in the OPNET simulation environment for nuclear medicine was also examined to discover radiation display, and infection in the manufacture, problem-solving, and healing area. Different scenarios for the three topologies were modelled and configured via load, end-to-end delay, and throughput as network metrics. The research was conducted to determine the most appropriate combination of topologies to be used out of recommended network architectures [18].

[19], suggested fixed and mobile nodes ZigBee networks for consideration of the various quality of services (QoS) such as end-to-end delay, throughput, MAC delay and MAC load in a different environment of OPNET 17.5. The results obtained from the simulation environment showed that the ZigBee network with fixed nodes outperformed the ZigBee network with a mobile node in terms of throughput, MAC delay and end-to-end delay while good performance was observed in the ZigBee network with a mobile node as regards the MAC load.

The performance of network parameters such as delay (sec), which represents the time it takes a bit of information to transit from one transmission point to another along the channel, was examined in this research effort for 5,10,15,20, and 25; throughput indicates the rate of data processing and transport from one location to another is measured bits/sec; end to end delay is the amount of time required a packet to travel from sender to the receiver over a network and is measured in seconds; traffic received indicates the amount of data travelling through a network at any one time is measured in bits per second and traffic sent (bits/sec) represents the average byte or packet delivered to the transport layer in a network to assess the evaluations of a mobile Zigbee network.

## 3. METHODOLOGY

The performance was conducted in a simulation setting, using the OPNET simulator. In this environment, mobile nodes were constructed considering star network topology. The performance evaluation of mobile ZigBee technology was studied based on three ZigBee devices, the Coordinator, Router, and End Device. In this study's findings, different scenarios were modelled in a star network, utilizing various ZigBee node sizes considering 5, 10, 15, 20, and 25 ZigBee nodes, each with a single ZigBee coordinator for configuration. The ZigBee coordinator attributes were configured based on some parameters as shown in Table1 below.

**Table 1: ZigBee Coordinator Attributes for Star Network Topology**

| S/N | ZigBee coordinator attributes parameters | Values |
|---|---|---|
| 1. | Network Parameters | Default Star Network |
| 2. | PAN ID | Auto Assigned |
| 3. | Number of Nodes | 5, 10, 15, 20, 25 |
| 4. | Designation | Random |
| 5. | Packet Interval Time | Constant (1.0) |
| 6. | Packet Size | Constant (1024) |
| 7. | Start Time | Uniform (20, 21) |
| 8. | Stop Time | Infinity |
| 9. | Network Metrics | Delay, Throughput, End-to-End Delay, Traffic Sent, Traffic Received |

According to Fig. 1, one coordinator, one router, and three end devices were modelled and the scenario was arranged in a star-like topology.

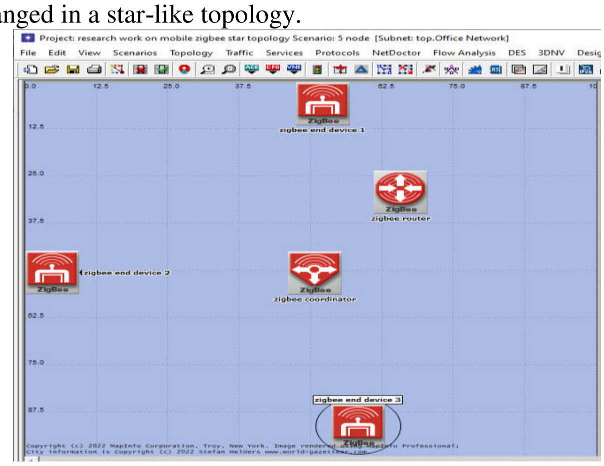


**Figure 1: five (5) mobile nodes**

Fig. 2 considers ten nodes to include one coordinator, two routers, and seven end devices, and the scenario was arranged in a star-like topology.

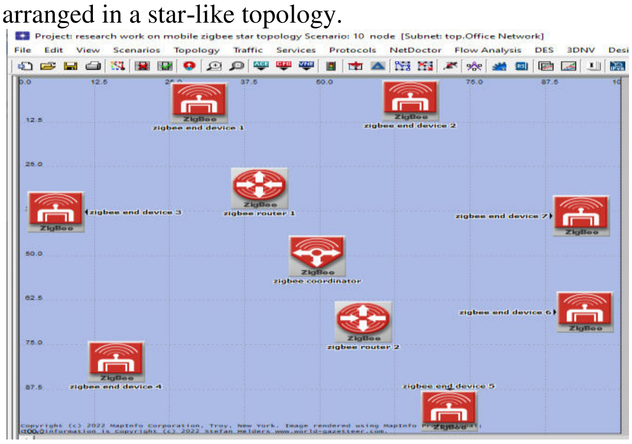


**Figure 2: ten (10) mobile nodes**

The Fig. 3 scenario was created by modelling fifteen nodes, which included one coordinator, three routers, and eleven end devices.

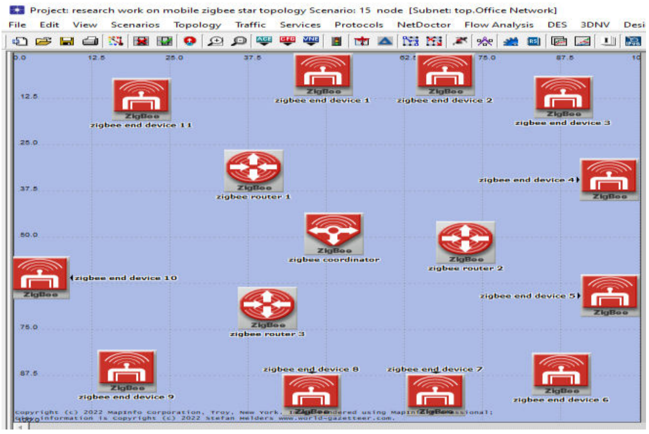


**Figure 3: fifteen (15) mobile nodes**

Fig. 4 depicts a scenario with twenty ZigBee nodes: one coordinator, four routers, and fifteen end devices. All the nodes were arranged to form a star topology.

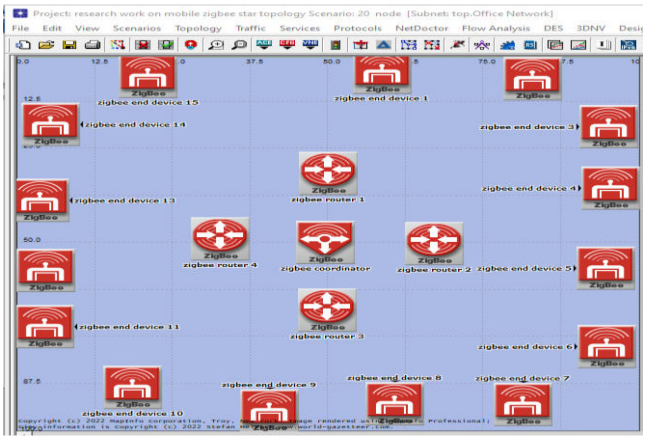


**Figure 4: twenty (20) mobile nodes**

Fig. 5 shows twenty-five ZigBee nodes, including one coordinator, five routers, and nineteen end devices. A star topology was created by arranging and configuring these mobile nodes.

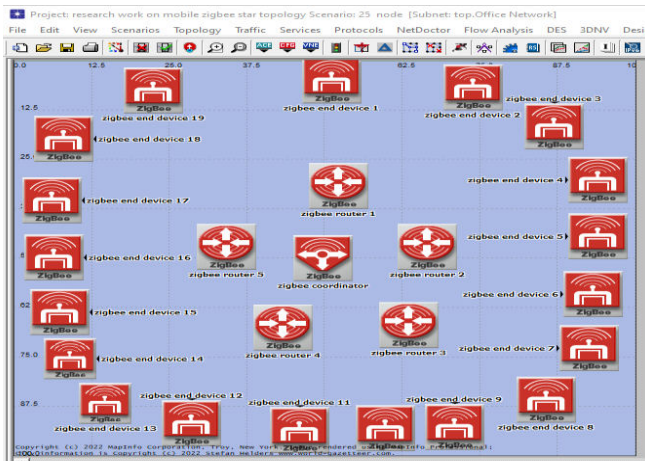


**Figure 5: twenty-five (25) mobile nodes**

Volume: 13 Issue: 06 Pages: 5159-5168(2022) ISSN: 0975-0290

## 4. RESULTS AND ANALYSIS

In terms of money and time, simulation and modelling are important tools in the development and evaluation of systems. The simulation displays the system's anticipated performance under various scenarios based on its simulation model. As a result, the simulation model aims to discover an adequate model and predict how well the real system would perform. For the simulation, we used OPNET Modeler 14.5, a leading modelling and computational platform. This simulation software comes with a complete software platform for modelling communication protocol and networking devices, many other features and also guidelines on how to model the ZigBee protocol using OPNET modelling techniques. Initially, we looked at the network metrics that were taken into account for each scenario, such as delay, throughput, end-to-end delay, traffic sent and traffic received, and compared each parameter for each star topology scenario. For each of the five scenarios, five tables were created to show the behaviour of all network metrics, while another five tables were considered to show a comparison of the network metrics in each scenario.

As shown in Table 2, the star topology for a five-node network was compared with various parameters such as delay (sec), throughput (bits/sec), end-to-end delay (sec), traffic sent (bits/sec), and traffic received (bits/sec) over a 60-second time frame at a 10-second interval. Based on our observation from the table, the delay increased from 0 sec to 30 sec and further decreased from 40 sec to 60 sec. Throughput grew over time, the end-to-end delay remained nearly constant throughout the simulation, and more packet was received from the traffic sent.

**Table 2: Star Topology for Five (5) Nodes**

| STAR TOPOLOGY NETWORK | | | | | |
|---|---|---|---|---|---|
| **Time (sec)** | Delay (sec) | Through put (bits/sec ) | End-to-End Delay (sec) | Traffic Receive d (bits/sec ) | Traffic Sent (bits/sec ) |
| 0 | 0.00586 | 3599.1 | 0.01071 | 2091.6 | 2275.6 |
| 10 | 0.006095 | 7763.1 | 0.01071 | 3969.6 | 3969.9 |
| 20 | 0.006106 | 7882 | 0.0107 | 4030.9 | 4030.9 |
| 30 | 0.006112 | 7923.2 | 0.0107 | 4030.9 | 4031.4 |
| 40 | 0.006111 | 7943.2 | 0.0107 | 4062.5 | 4062.5 |
| 50 | 0.006108 | 7956.1 | 0.0107 | 4069.2 | 4069.2 |
| 60 | 0.006107 | 7963.9 | 0.0107 | 4073.2 | 4073.2 |

Fig. 6 depicts the graph of various network parameters for 5 mobile ZigBee nodes when plotted against time using analytical tools. As it can be seen in the graph, network delay and end-to-end delay remained at minimal levels, this indicated that little delay was experienced across the network and the time taken to transmit data between the mobile ZigBee nodes was little. There was no significant difference between traffic sent and traffic received as this indicated a little packet loss during transmission and this does not have much impact on the communication process. Also, the rate at which data has been processed and communicated between the nodes changes and increases with time for the throughput. The behaviours of each network parameter for 5 mobile ZigBee are compared and presented in Fig. 6 below.

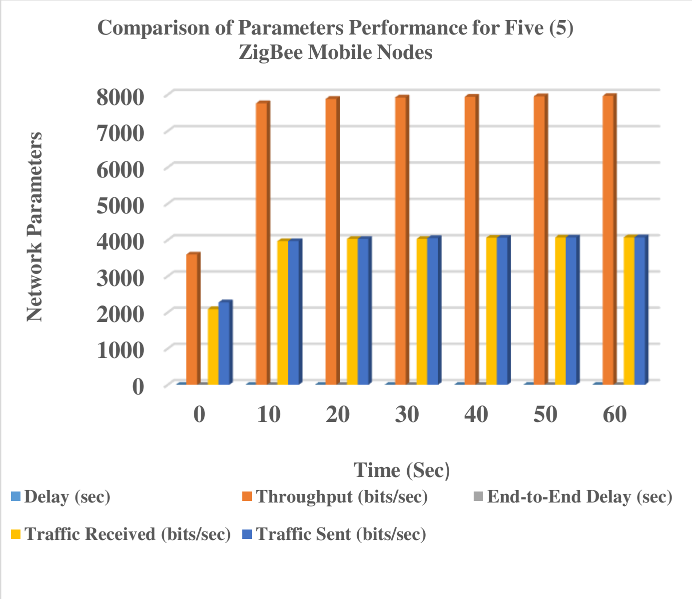


**Figure 6: parameters comparison for five (5) ZigBee mobile nodes**

Table 3 depicts a star topology for a ten-node network that compared various parameters such as delay (sec), throughput (bits/sec), end-to-end delay (sec), traffic sent (bits/sec), and traffic received (bits/sec) over a time range of 0 sec to 60 sec at a 10-sec interval. With time, delay (sec), throughput (bits/sec), and end-to-end delay (sec) all increase, and as more packets were sent, fewer packets are received.

**Table 3: Star Topology for Ten (10) Nodes**

| STAR TOPOLOGY NETWORK | | | | | |
|---|---|---|---|---|---|
| **Time (sec)** | Delay (sec) | Through put (bits/sec ) | End-to-End Delay (sec) | Traffic Receive d (bits/sec ) | Traffic Sent (bits/sec ) |
| 0 | 0.006517 | 9242 | 0.01328 | 4096 | 4551.1 |
| 10 | 0.006766 | 19961.4 | 0.01354 | 8931.6 | 9923.9 |
| 20 | 0.006788 | 20207.7 | 0.01359 | 9069.7 | 10077.5 |
| 30 | 0.006801 | 20369.5 | 0.01361 | 9117.5 | 10130.6 |
| 40 | 0.00681 | 20427.5 | 0.01363 | 9140.7 | 10156.3 |
| 50 | 0.006814 | 20458.5 | 0.01363 | 9155.8 | 10173.1 |
| 60 | 0.006817 | 20478.5 | 0.01364 | 9164.8 | 10183.1 |

Fig. 7 shows a graph of some network metrics displayed against time using analytical tools for ten (10) mobile ZigBee nodes. As shown in the graph, network delay and end-to-end delay were both kept to a minimum, indicating that there was little delay across the network and that data transmission between mobile ZigBee nodes took very little time. There was little statistical difference between traffic transmitted and traffic received, indicating that there was some packet loss during transmission, but this does not have much consequence on the communication process. In addition, for throughput, the rate at which data is processed and transferred between nodes fluctuates and rises over time. Fig. 7 compares and displays the behaviour of each network parameter for ten mobile ZigBee devices.

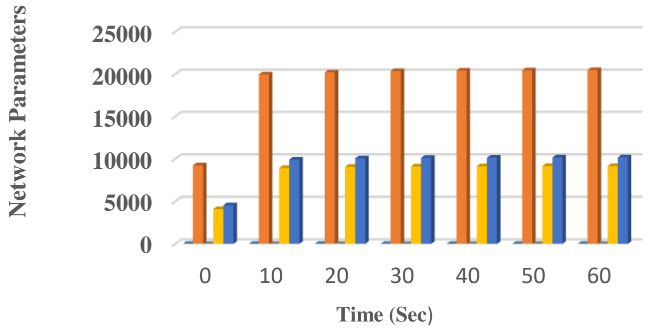


**Figure 7: parameters comparison for ten (10) ZigBee mobile nodes**

Table 4 shows a star topology for a 15-node network where delay (sec), throughput (bits/sec), end-to-end delay (sec), traffic sent (bits/sec), and traffic received (bits/sec) were compared over a time range of 0 sec to 60 sec at a 10-sec interval. With time, delay (sec), throughput (bits/sec), and end-to-end delay (sec) all increase, and as more packets are sent, almost the same packets are received.

**Table 4: Star Topology for Fifteen (15) Nodes**

| STAR TOPOLOGY NETWORK | | | | | |
|---|---|---|---|---|---|
| **Time (sec)** | Delay (sec) | Throughput (bits/sec) | End-to-End Delay (sec) | Traffic Received (bits/sec) | Traffic Sent (bits/sec) |
| 0 | 0.00881 | 14376.4 | 0.01842 | 6371.6 | 6826.7 |
| 10 | 0.00954 | 31051.1 | 0.01911 | 13893.5 | 14885.9 |
| 20 | 0.00956 | 31527.6 | 0.01915 | 14108.4 | 15116.2 |
| 30 | 0.00957 | 31692.5 | 0.01915 | 14179.8 | 15234.5 |
| 40 | 0.00958 | 31722.4 | 0.01917 | 14218.9 | 15234.5 |
| 50 | 0.00958 | 31824.3 | 0.01917 | 14242.3 | 15259.6 |
| 60 | 0.00958 | 31855.4 | 0.01918 | 14256.4 | 15274.7 |

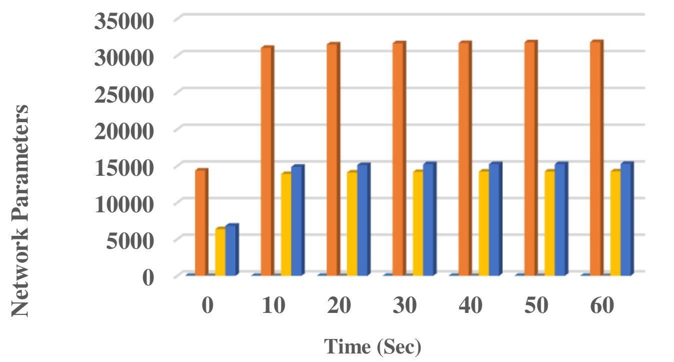


**Figure 8: parameters comparison for fifteen (15) ZigBee mobile nodes**

Fig. 8 displays a graph of certain network characteristics plotted against time for ten (15) mobile ZigBee nodes using analytical tools. Network delay and end-to-end delay were both kept to a minimum. There was a small statistical difference between traffic transmitted and traffic received, implying that some packet loss occurred during transmission, although this had little effect on the communication process. For the throughput, the rate at which data is processed and sent changes and grows over time. Fig. 8 compares the performance of each network parameter for fifteen mobile ZigBee devices.

Star topology for twenty nodes networks was presented and compared in Table 5 based on delay (sec), throughput (bits/sec), end-to-end delay (sec), traffic sent (bits/sec), and traffic received (bits/sec) over a 60-second time frame at a 10-second interval. Delay (sec), throughput (bits/sec), and end-to-end delay (sec) all increase as time passes, and as more packets are sent, more packets are received.

**Table 5: Star Topology for Twenty (20) Nodes**

| STAR TOPOLOGY NETWORK | | | | | |
|---|---|---|---|---|---|
| **Time (sec)** | Delay (sec) | Throughput (bits/sec) | End-to-End Delay (sec) | Traffic Received (bits/sec) | Traffic Sent (bits/sec) |
| 0 | 0.00851 | 19447.3 | 0.0178 | 8618.7 | 9102.2 |
| 10 | 0.01002 | 42207.5 | 0.02009 | 18853.9 | 19847.9 |
| 20 | 0.01015 | 42785.6 | 0.02031 | 19146.4 | 20154.9 |
| 30 | 0.01019 | 43009.9 | 0.0204 | 19247.6 | 20261.2 |
| 40 | 0.01022 | 43118.7 | 0.02046 | 19296.6 | 20312.7 |
| 50 | 0.01024 | 43189.4 | 0.02048 | 19328.5 | 20346.1 |
| 60 | 0.01024 | 43231.8 | 0.02049 | 19347.6 | 20366.2 |

Using analytical tools, Fig. 9 shows a graph of delay (sec), throughput (bits/sec), end-to-end delay (sec), traffic

Volume: 13 Issue: 06 Pages: 5159-5168(2022) ISSN: 0975-0290

sent (bits/sec), and traffic received plotted against time for twenty (20) mobile ZigBee nodes. As shown in the graph, both network and end-to-end delays were reduced to a minimal, implying that there was little delay across the network and that data transmission between mobile ZigBee nodes was swift. There was a little difference between traffic sent and received, showing that little packet loss happened during transmission. The rate at which data is processed and transferred changes and grows with time in terms of throughput. Fig. 9 shows how each network setting performs for twenty mobile ZigBee devices.

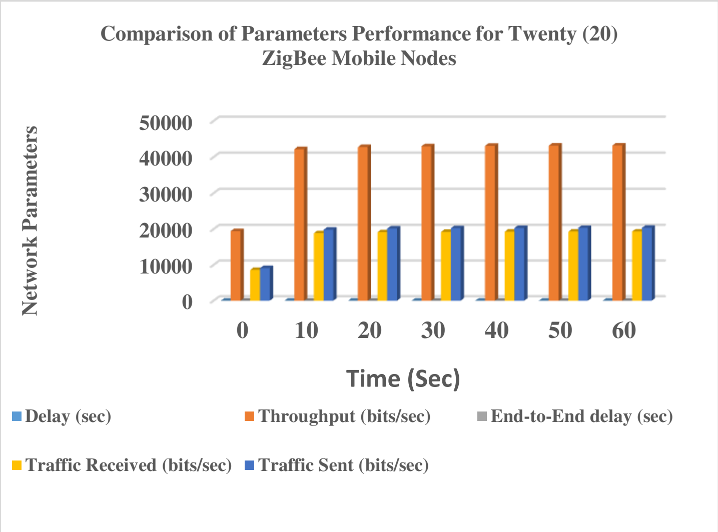


**Figure 9: parameters comparison for twenty (20) ZigBee mobile nodes**

In Table 6, a twenty-five-node network's star topology was compared using delay (sec), throughput (bits/sec), end-to-end delay (sec), traffic sent (bits/sec), and traffic received (bits/sec) over a 60-second time frame at a 10-second interval. According to our findings in Table 6, the delay (sec), throughput (bits/sec), and end-to-end delay (sec) all increase with time, and as more packets are sent, more packets are received.

**Table 6: Star Topology for Twenty five (25) Nodes**

| STAR TOPOLOGY NETWORK | | | | | |
|---|---|---|---|---|---|
| **Time (sec)** | Delay (sec) | Through put (bits/sec) | End-to-End Delay (sec) | Traffic Received (bits/sec) | Traffic Sent (bits/sec) |
| 0 | 0.01042 | 24136.9 | 0.02141 | 10922.7 | 11377.8 |
| 10 | 0.01143 | 52208.5 | 0.02244 | 23857.4 | 24809.9 |
| 20 | 0.01151 | 52921.4 | 0.02258 | 24185.9 | 25193.7 |
| 30 | 0.01153 | 53187 | 0.0226 | 24313.4 | 25321.1 |
| 40 | 0.01155 | 53332.3 | 0.02264 | 24375.2 | 25390.9 |
| 50 | 0.01156 | 53419.4 | 0.02266 | 24415.4 | 25432.7 |
| 60 | 0.01157 | 53471.7 | 0.02267 | 24439.5 | 25457.8 |

Fig. 10 plots latency (sec), throughput (bits/sec), end-to-end delay (sec), traffic sent (bits/sec), and traffic received (bits/sec) against time for twenty five (25) mobile ZigBee nodes using analytical tools. Both network delay and end-to-end delays were reduced to a minimum, as seen in the graph, meaning that there was little delay across the network and data transfer between mobile ZigBee nodes was quick. There was a little variation in traffic delivered and received, indicating that there was little packet loss during transmission. In terms of throughput, the pace at which data is processed and transferred changes and grows with time. Fig. 10 depicts the performance of each network setup for twenty-five mobile ZigBee devices.

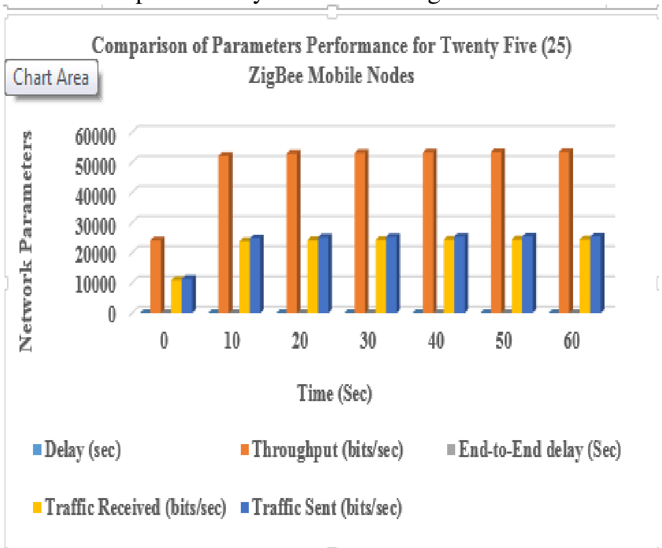


**Figure 10: parameters comparison for twenty-five (25) ZigBee mobile nodes**

In addition, in each of the scenarios, only one parameter was considered for effective performance comparison, and the results are presented in Tables 7–11 below.
Table 7 shows the delays (in seconds) for the five scenarios that were modelled in the OPNET environment, and Fig. 11 shows the graphical representation using analytical tools.

**Table 7: Delay (sec) for all the Scenarios**

| Time (sec) | Delay (sec) for 5 nodes | Delay (sec) for 10 nodes | Delay (sec) for 15 nodes | Delay (sec) for 20 nodes | Delay (sec) for 25 nodes |
|---|---|---|---|---|---|
| 0 | 0.00586 | 0.006517 | 0.00881 | 0.00851 | 0.01042 |
| 10 | 0.006095 | 0.006766 | 0.00954 | 0.01002 | 0.01143 |
| 20 | 0.006106 | 0.006788 | 0.00956 | 0.01015 | 0.01151 |
| 30 | 0.006112 | 0.006801 | 0.00957 | 0.01019 | 0.01153 |
| 40 | 0.006111 | 0.00681 | 0.00958 | 0.01022 | 0.01155 |
| 50 | 0.006108 | 0.006814 | 0.00958 | 0.01024 | 0.01156 |
| 60 | 0.006107 | 0.006817 | 0.00958 | 0.01024 | 0.01157 |

Fig. 11 shows the graph with all of the delays (sec) for different numbers of nodes compared. A scenario with 5 nodes resulted in a lower delay (sec), followed by a delay for 10 nodes, 15 nodes and finally, a scenario with 25

Volume: 13 Issue: 06 Pages: 5159-5168(2022) ISSN: 0975-0290

nodes resulted in a larger delay (sec). Even so, there were only minor differences in the delay (sec) for each scenario. This demonstrates that the higher the nodes, the length of time it takes for data to travel across the network from one transmission point to another, and the more time is spent doing so. This is presented in Fig. 11 shown below.

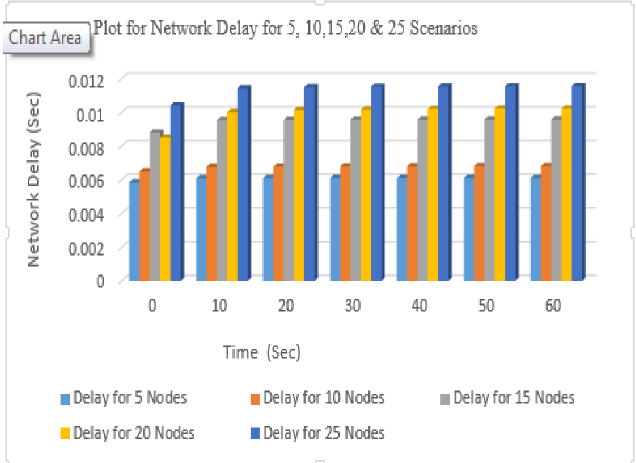


**Figure 11: comparison of delay (sec) for all the scenarios**

Table 8 shows the throughput (bits/sec) for the five scenarios that were modelled in the OPNET environment, and Figure 12 shows the graphical representation plotted using analytical tools.

**Table 8: Throughput (bits/sec) for all the Scenarios**

| Time (sec) | Throughput (bits/sec) for 5 nodes | Throughput (bits/sec) for 10 nodes | Throughput (bits/sec) for 15 nodes | Throughput (bits/sec) for 20 nodes | Throughput (bits/sec) for 25 nodes |
|---|---|---|---|---|---|
| 0 | 3599.1 | 9242 | 14376.4 | 19447.3 | 24136.9 |
| 10 | 7763.1 | 19961.4 | 31051.1 | 42207.5 | 52208.5 |
| 20 | 7882 | 20207.7 | 31527.6 | 42785.6 | 52921.4 |
| 30 | 7923.2 | 20369.5 | 31692.5 | 43009.9 | 53187 |
| 40 | 7943.2 | 20427.5 | 31722.4 | 43118.7 | 53332.3 |
| 50 | 7956.1 | 20458.5 | 31824.3 | 43189.4 | 53419.4 |
| 60 | 7963.9 | 20478.5 | 31855.4 | 43231.8 | 53471.7 |

Fig. 12 shows a graph plotted using analytical tools for throughput (bits/sec) for various node counts. This indicates the rate at which data is processed and transferred from one location to another. As can be seen from the graph, throughput increases as the number of nodes increases. This means that the lower the number of nodes, the lower the throughput (bits/sec), and the higher the number of nodes, the higher the throughput (bits/sec). Lower throughput was experienced with 5 nodes whereas higher throughput was experienced with 25 nodes as presented in Fig. 12 below. Though, the throughput increases in each scenario with time.

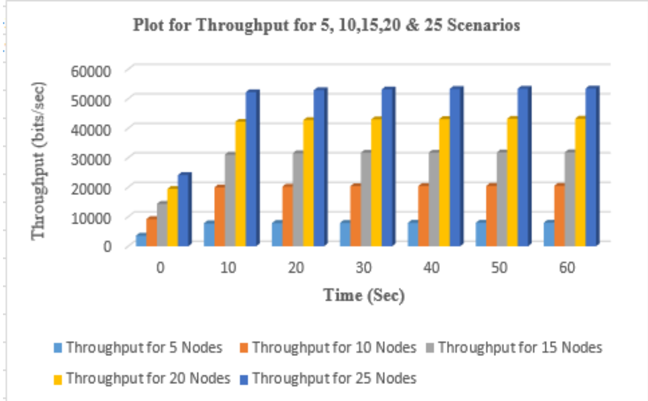


**Figure 12: throughput (bits/sec) comparison of all the scenarios**

The end-to-end delay (sec) for the five scenarios that were modelled in the OPNET environment is shown in Table 9, and the graphical representation plotted using analytical tools as shown in Figure 13

**Table 9: End-to-End Delay (sec) for all the Scenarios**

| Time (sec) | End-to-End Delay (sec) for 5 Nodes | End-to-End Delay (sec) for 10 Nodes | End-to-End Delay (sec) for 15 Nodes | End-to-End Delay (sec) for 20 Nodes | End-to-End Delay (sec) for 25 Nodes |
|---|---|---|---|---|---|
| 0 | 0.01071 | 0.01328 | 0.01842 | 0.0178 | 0.02141 |
| 10 | 0.01071 | 0.01354 | 0.01911 | 0.02009 | 0.02244 |
| 20 | 0.0107 | 0.01359 | 0.01915 | 0.02031 | 0.02258 |
| 30 | 0.0107 | 0.01361 | 0.01915 | 0.0204 | 0.02260 |
| 40 | 0.0107 | 0.01363 | 0.01917 | 0.02046 | 0.02264 |
| 50 | 0.01069 | 0.01363 | 0.01917 | 0.02048 | 0.02266 |
| 60 | 0.01069 | 0.01364 | 0.01918 | 0.02049 | 0.02287 |

A graph plotted using analytical tools for end-to-end (sec) for various node counts is shown in Fig. 13. End-to-end (sec) increases as the number of nodes increases, as shown in the graph. End-to-end (sec) decreases as the number of nodes decreases, and the end-to-end (sec) increases as the number of nodes increases. This indicates that as the node density on a network grows, the time it takes for a packet to travel from node to node grows. Therefore, there were larger differences in end-to-end delay (sec) between 5 nodes and 25 nodes, as shown in the graph in Fig. 13 below.

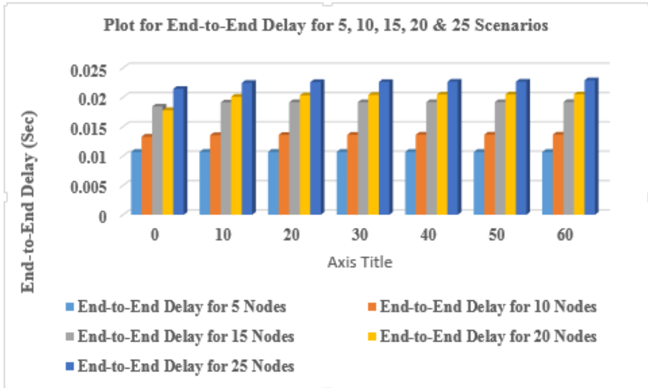


**Figure 13: end-to-end (sec) comparison of all the scenarios**

The traffic sent (bits/sec) for the five scenarios that were modelled in the OPNET environment is shown in Table 10 and the graphical representation using analytical tools is shown in Fig. 14.

**Table 10: Traffic Sent (bits/sec) for all the Scenarios**

| Time (sec) | Traffic send (bits/sec) for 5 nodes | Traffic send (bits/sec) for 10 nodes | Traffic sent (bits/sec) for 15 nodes | Traffic sent (bits/sec) for 20 nodes | Traffic sent (bits/sec) for 25 nodes |
|---|---|---|---|---|---|
| 0 | 2275.6 | 4551.1 | 6826.7 | 9102.2 | 11377.8 |
| 10 | 3969.9 | 9923.9 | 14885.9 | 19847.9 | 24809.9 |
| 20 | 4030.9 | 10077.5 | 15116.2 | 20154.9 | 25193.7 |
| 30 | 4051.4 | 10130.6 | 15234.5 | 20261.2 | 25321.1 |
| 40 | 4062.5 | 10156.3 | 15234.5 | 20312.7 | 25390.9 |
| 50 | 4069.2 | 10173.1 | 15259.6 | 20346.1 | 25432.7 |
| 60 | 4073.2 | 10183.1 | 15274.7 | 20366.2 | 25457.8 |

Fig. 14 depicts a graph depicting all traffic sent (bits/sec) for various numbers of nodes. A scenario with 5 nodes sent less traffic (bits/sec), while a scenario with 25 nodes sent more traffic (bits/sec). There were larger differences in the traffic transmitted for each scenario. This means that the average byte or packet sent to the transport layer in a network to measure the reliability of the mobile Zigbee network at a given moment in time differs. Fewer packets were sent by 5 nodes, more packets were sent by a scenario with larger numbers of mobile ZigBee nodes which increases with time as shown in Fig. 14 below

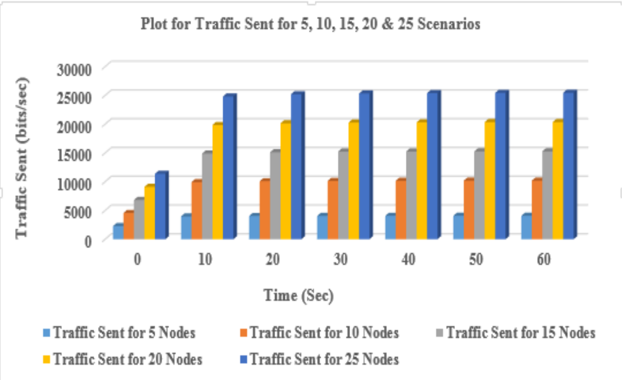


**Figure 14: traffic sent (bits/sec) comparison of all the scenarios**

Table 11 shows the traffic received (bits/sec) for the five scenarios that were modelled in the OPNET environment and Fig. 15 shows the graphical representation plotted using analytical tools

**Table 11: Traffic Received (bits/sec) for all the Scenarios**

| Time (sec) | Traffic Received (bits/sec) for 5 nodes | Traffic Received (bits/sec) for 10 nodes | Traffic Received (bits/sec) for 15 nodes | Traffic Received (bits/sec) for 20 nodes | Traffic Received (bits/sec) for 25 nodes |
|---|---|---|---|---|---|
| 0 | 5091.6 | 4096 | 6371.6 | 8618.7 | 10922.7 |
| 10 | 3969.6 | 8931.6 | 13893.5 | 18853.9 | 23857.4 |
| 20 | 4030.9 | 9069.7 | 14108.4 | 19146.4 | 24185.9 |
| 30 | 4030.9 | 9117.5 | 14179.8 | 19247.6 | 24313.4 |
| 40 | 4062.5 | 9140.7 | 14218.9 | 19296.6 | 24375.2 |
| 50 | 5069.2 | 9155.8 | 14242.3 | 19328.5 | 24415.4 |
| 60 | 4073.2 | 9164.8 | 14256.4 | 19347.6 | 24439.5 |

A graph plotted using analytical tools for traffic received (bits/sec) for various node counts is shown in Fig. 15. Traffic received (bits/sec) was lower in a scenario with 5 nodes, than in 10 nodes, 15 nodes, 20 nodes, and 25 nodes. This signifies that the amount of data travelling through a network at any particular point in time is different and thus further proved that the higher the nodes in a mobile ZigBee star topology, the more traffic will be received.

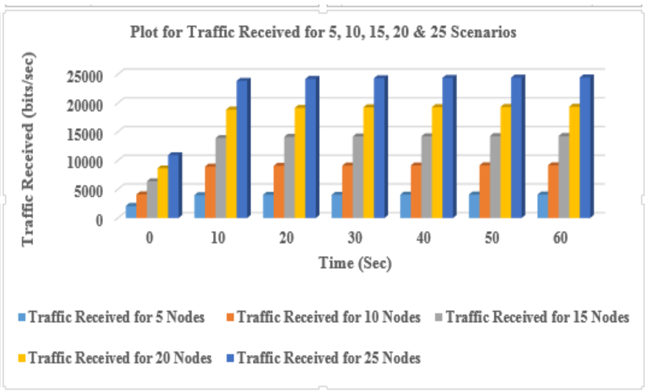


**Figure 15: traffic received (bits/sec) comparison of all the scenarios**

## 5. CONCLUSION

"OPNET 14.5", a renowned discrete-event network model and simulator, was chosen for this investigation because of its precision and advanced graphical user interface. The graphical representation was created using analytical tools. The delay (sec) in a scenario with five nodes is lower than in every other node. As the number of nodes grows, the delay (sec), throughput (bits/sec), end-to-end delay (sec), traffic sent (sec), and traffic received (sec) all increase. This means that for better signal transmission and reception using ZigBee technology, more nodes are required to achieve satisfactory results. This work could further be expanded by introducing more nodes and allowing researchers to compare performance in different mobile ZigBee topologies for efficiency.

Volume: 13 Issue: 06 Pages: 5159-5168(2022) ISSN: 0975-0290

## REFERENCES

[1] A., P., Abidoye, N., A., Azeez, A., O., Adesina, K., K., Agbele, & H., O., Nyongesa, (2011). Using Wearable Sensors for Remote Healthcare Monitoring System. *Journal of Sensor Technology*, *2011* (1), 22-28.

[2] R., Mahajanm, & S., Nair, (2013). Performance Evaluation of Zigbee Protocol Using Opnet Modeler for Mine Safety. *International Journal of Computer Science and Network (IJCSN), 2*(1), 62-66.

[3] N., V., Panicker, A., Sukeshkumar, S., M., Stephen, (2014). Patient Monitoring System using GSM and ZigBee Technology. *AMSE Journals –2014-Series: Modelling C; 75*(1), 13-21.

[4] S., Ritu, C., Yogesh, & S., Yudhvir (2010). Analysis of Security Protocols in Wireless Sensor Network. *International Journal of Advanced Networking and Application*s, 2(3), 707-713.

[5] P., Malhotra, & H., Sadawarti, (2014). Research on Performance Evaluation of Zigbee Wireless Sensor Networks using Various Parameters. *International Journal of Engineering Research & Technology (IJERT). 3*(4), 683-687.

[6] N., A., Hussain, & F., A., Yaseen, (2015). Performance Evaluation of Zigbee Routing Protocol under Various Conditions using OPNET Modeler. *International Journal of Computer Application. 117*(18), 25-31.

[7] T., Chandrasekhar, J., S., Chakravarthi, & V., Srikanth, (2013). Wireless Health Monitoring System Using ZigBee, *International Journal of Innovative Research in Science, Engineering and Technology*, *2*(11), 721-726.

[8] B., Thamilvalluvan, K., Periyasamy, M., A., Bennet, P., C., Sophia, P., J., Priya, R., Vijayalashmi, (2017). Zigbee Based Wearable Remote Health Care Monitoring for Patients. *International Journal of Pure and Applied Mathematics, 115*(8), 595-601

[9] O, J., Adaramola, & J., R., Olasina, (2018). Network Investigation and Performance Analysis of ZigBee Technology Using OPNET. *Journal of advanced in Computer Engineering Technology (JACET), 4*(4), 209-218.

[10] H., Kaur, & A., P., Bhondekar, (2015). Routing Protocols in Zigbee Based networks: *A Survey. April 2015, Conference: First international conference on electronics design innovations and technologies*. At: NITTTR, Chandigarh, India.

[11] G., H., Raghunandan, A., K., Akshata, & C.S., Hemika (2016). Performance Analysis of Different WSN Based Systems in Precision Farming. *International Journal of Advanced Networking and Applications*, 7(5), 2893-2898.

[12] X., Li, M., Peng, J., Cai, C., Yi, & H., Zhang, (2018). OPNET-Based Modeling and Simulation of Mobile Zigbee Sensor Networks. *Peer-to-Peer Networking and Applications, 9*(2), 414–423. https://doi:10.1007/s12083-015-0349-8

[13] T., Mujahid, & Z., Kartinah, (2015), Performance Evaluation of ZigBee in Indoor and Outdoor Environment, *9th International Conference on IT in Asia (CITA)* - Sarawak, Kuching, Malaysia, 1-7.

[14] A., A., Allahham, & M., A., Rahman, (2018). A Smart Monitoring System for Campus Using Zigbee Wireless Sensor Networks. *International Journal of Software Engineering and Computer Systems (IJSECS). 4*(1), 1-14.

[15] P., Mounika, (2018). Performance Analysis of Wireless Sensor Network Topologies for ZigBee Using Riverbed Modeler. *Proceedings of the Second International Conference on Inventive Systems and Control (ICISC* 2018), 1456-1459.

[16] A., Omar, S., Ibrahim& A., Dia, (2019). Evaluating the Performance of Nodes Mobility for Zigbee Wireless Sensor Network. *International Conference on Computing and Information Science and Technology and Their Applications (ICCISTA)* - Kirkuk, Iraq, 1-5.

[17] A., M., Almajidi, &· V., P., Pawar, (2019)/ A New System Model for Sensor Node Validation by Using OPNET. *Wireless Personal Communications*, 1-13. https://doi. 10.1007/s11277-019-06527-3

[18] R., I., Gomaa, (2020). Performance Analysis of Wireless Sensor Networks for Nuclear Medicine Applications. *Journal of Radiation Research and Applied Sciences. 13*(1), 714–720.

[19] I., N., Hossain, I., Md, & A., Rahman, (2022) A Comprehensive Analysis of Quality of Service (QoS) in ZigBee Network through Mobile and Fixed Node. *Journal of Computer and Communications, 10*, 86-99.

## AUTHOR'S PROFILE

**Mr**. **Adaramola Ojo Jayeola,** Has an M.Sc. degree in Computer Systems and the Network Engineering at the University of Greenwich, London in the United Kingdom in 2016, and M.Sc. in Electronics and computers engineering from Lagos State University, Nigeria, 2018. He is currently working as Chief Technologist in the Department of Computer Engineering at the Federal Polytechnic Ilaro, Ogun State, Nigeria. Adaramola is a member of the engineering professional body in Nigeria (Council for the Regulation of Engineering in Nigeria) and many societies and associations, which include: The Nigerian Institution of Professional Engineers and Scientists (NIPES), The

Volume: 13 Issue: 06 Pages: 5159-5168(2022) ISSN: 0975-0290

Nigerian Society of Engineering Technicians (NIST), The Society of Digital Information and Wireless Communication (SDIWC), the International Association of Engineers (IAENG), and the International Computer Science and Engineering Society (ICSES). His areas of interest are computer hardware and networking, wireless communication, routing protocols, vehicular ad-hoc networks, and ZigBee technology.

**Mr. Olasina, Jamiu Rotimi** holds M.Eng in Electrical and Information Engineering (Computer Engineering Option) from Covenant University, Ota, Nigeria. He Obtained B.Eng in Electrical and ComPuter Engineering, from Federal University of Technology, Minna, Nigeria. Jamiu also obtained National Diploma in Computer Engineering, from the Federal Polytechnic Ilaro, Nigeria. Engr. Olasina, J. R is a lecturer, in the Department of Computer Engineering, Federal Polytechnic Ilaro, Nigeria., and he also researches in the domain of software-defined radio, radio communication, cognitive radios, 5G technology, Data communication and networking, AI and Machine Learning, etc. Olasina is conversant with the use of Matlab, Python, Linux, GNU-Radio companion, etc. Olasina is a registered computer engineer with the Council for the Regulation of Engineering in Nigeria (Coren), The Nigerian Institution of Professional Engineers and Scientists (NIPES), and The Society of Digital Information and Wireless Communication (SDIWC), and the International Association of Engineers (IAENG).