

ZigBee: Simulation and Investigation of Star and Mesh Topology by Varying Channel Sensing Duration

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ABSTRACT

ZigBee was developed by IEEE 802.15.4 Task Group and ZigBee Alliance. ZigBee (IEEE 802.15.4-2006 standard) is a category in the IEEE 802 family and ZigBee alliance is responsible for ZigBee standard which uses the transported services of the 802.15.4 network specification therefore ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks. ZigBee devices are often used in mesh network form to transmit data over longer distances, passing data through intermediate devices to reach more distant ones. This allows ZigBee networks to be formed ad-hoc, with no centralized control or high-power transmitter/receiver able to reach all of the devices. In this research paper, the effect of channel sensing duration on star and mesh topologies is analyze by varying Channel Sensing duration by using OPNET Modeler. The performance is compared in terms of Data Traffic send, Data Traffic Received and Mac Delay.

Keywords

ZigBee, WSN, Topology, IEEE 802.15.4, OPNET, Star, Mesh.

1. INTRODUCTION

A wireless sensor network is a special Ad-Hoc network comprises spatially distributed autonomous device using sensor are distributed randomly in wide area [1, 2, 3, 14]. WSN can be generally described as a collection of sensor nodes organized into a cooperative network that can sense and control the environment enabling interaction between persons or embedded computers and the surrounding environment [12, 13]. A typical sensor node contains three C's are collection, computation and communication unit based on the request of sink, gathered information will be transmitted wireless network [5]. ZigBee is developed by ZigBee alliance which has hundreds of members companies (Ember, Freescale, Chipcon, Invensys, Mithsubishi, CompXs, AMI semiconductors, ENQ semiconductor) from semiconductor and software developers to originally equipments manufacturers. ZigBee and 802.15.4 are not the same. ZigBee is a standard base network protocol supported solely by the ZigBee alliance that uses the transported services of the IEEE 802.15.4 network specification [5]. ZigBee alliance is responsible for ZigBee standard and IEEE is for IEEE 802.15.4. It is like TCP/IP using IEEE 802.11b network specification [6].

1.1. Applications of WSN

WSN are used in many fields like [15,13,5]:

- Area monitoring
- Environmental/Earth monitoring
- Air quality monitoring
- Forest fire detection
- Landslide detection
- Water quality monitoring
- Natural disaster prevention
- Machine health monitoring
- Data logging
- Industrial sense and control applications
- Water/wastewater monitoring
- Agriculture
- Greenhouse monitoring
- Structural monitoring
- Passive localization and tracking
- Smart home monitoring

1.2. The Structure and Research Platform of Zigbee Wireless Sensor Network

There are three types of nodes in ZigBee wireless sensor network: coordinator, router, and device [7,8]. The coordinator is responsible for intelligent network, selecting, suitable channel to create a network and adding child node to the network established. There is only one coordinator to complete these tasks in a network. Because the distance between two nodes in end-to-end transmission is limited, a kind of device, route node is needed to forward information transmission. The three types of nodes above are the concept of network layer and there deployment decide the ZigBee network topology, ZigBee networks can achieve the following three forms of network topology: Star network, Tree Network, Mesh Network [7, 9] are the developed from the concept of peer-to-peer topology in IEEE 802.15.4 [10].

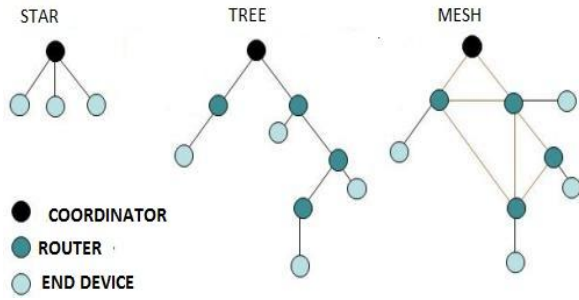


Figure 1 Star, Mesh and Tree Topology

In Star topology nodes are connected to a single hub node. If a communication link is cut its only effect on one node. However if the master node fail whole the network is fail [1]. In mesh topology all nodes are connected with each other and advantage of mesh topology is that if one communication link is cut it does not effect on other links. In tree topology the master connected to one or more child node that are one level lower in the hierarchy with point to point link between each of the end nodes and the master (coordinator).

2. EXPERIMENTAL SETUP

In these experiment two topologies of ZigBee WSN was compared by changing channel sensing duration. These two topologies are Star and Mesh. In the basic Star topology scenarios consist of 15 ZigBee end devices and one coordinator as shown in fig 2. The basic mesh and tree topologies scenario consist of 15 ZigBee end devices, 8

Table 1: Coordinator's Network Layer Parameter

Mac Layer Parameter	
Minimum value of the back-off exponent in the CSMA/CA	3
Maximum no. of back-off in the CSMA/CA	4
Channel sensing duration (sec)	5,10,15,20
Physical Layer Parameter	
Data Rate (kbps)	250
Receiver Sensitivity (db)	-85
Transmission band (Ghz)	2.4
Transmission Power (W)	.05
Application Layer Parameter	
Packet interval time/type (sec/constant)	1
Packet size/type	1024/constant

Zigbee routers and one coordinator as shown in fig 3. In actual star topology scenario we used 100 ZigBee end devices and one coordinator and in mesh we used 100 ZigBee end devices, 8 ZigBee routers and one coordinator.

Table 2: Coordinator's The Mac, Physical and Application Layer Simulation Parameters

Maximum no. of children	255
Maximum no. of routers	10
Route discovery time	10

OPNET Simulator [16] was used to carried out performance of Star, Mesh, and Tree ZigBee Topologies. We used OPNET modeler, because OPNET modeler provides a comprehensive development environment supporting the modeling of communication network and distributed systems [1]. OPNET modeler provides better environment for simulation, data collection and data analysis [16]. The Simulation parameters used in our scenario for coordinator are shown in Table 1 and Table 2.

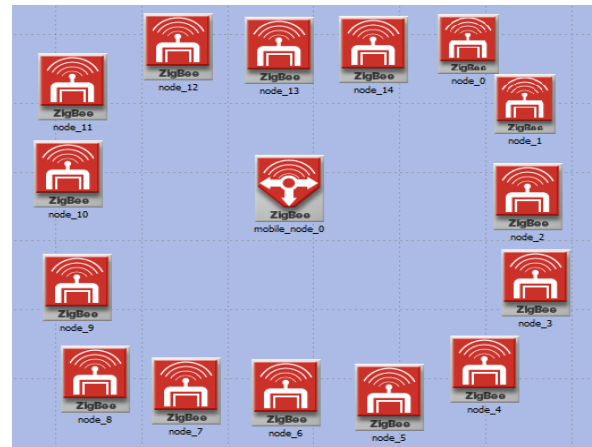


Figure 2: Star

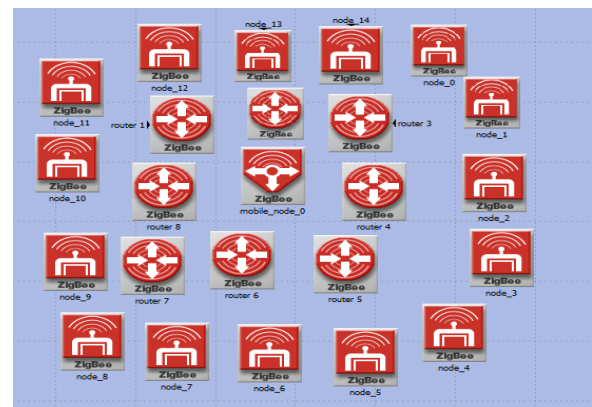


Figure 3: Mesh

In this research, the matrices measured are Delay, Load and Retransmission Attempt.

3. RESULTS

3.1. Data Traffic send

This statistics include all the traffic that is sent by the MAC via CSMA-CA. It does not include any of the management or the control traffic, nor does it include ACKs. Fig. 4, fig. 5, fig. 6 and fig. 7 shows the Data Traffic send for both mesh and star for different channel sensing duration.

These Figures shows that as the channel sensing duration increased the data traffic send for Mesh and Star is decreased. These figures also show that the data sent by star is more than mesh.

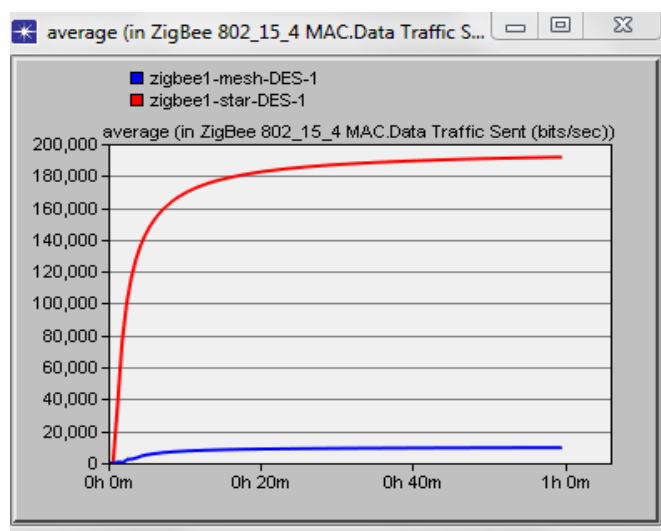


Figure 4: Data Traffic Send for channel sensing duration = 5 sec

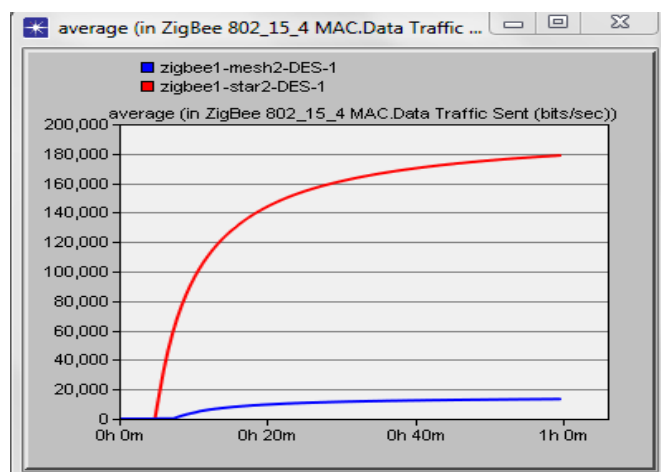


Figure 5: Data Traffic Send for channel sensing duration = 10 sec

Table 3: Data Traffic Send for channel sensing duration at 5 and 10 sec

Data Traffic Send for channel sensing duration = 5 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	7,610.1604	169,877.9629
20	8,838.8634	182,857.7206
30	9,252.2135	187,120.2701
40	9,470.9640	189,470.9836
50	9,611.4745	190,952.1254
60	9,691.3822	191,790.5533
Data Traffic Send for channel sensing duration = 10 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	4,360.8888	102,144.7134
20	9,833.5428	145,293.0984
30	11,563.1111	162,090.2264
40	12,504.7385	170,244.1111
50	13,077.4705	175,558.4209
60	13,415.1533	178,746.6911

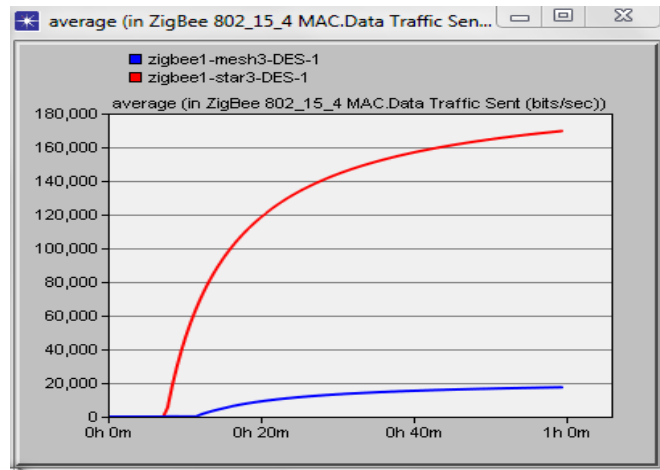


Figure 6: Data Traffic Send for channel sensing duration = 15 sec

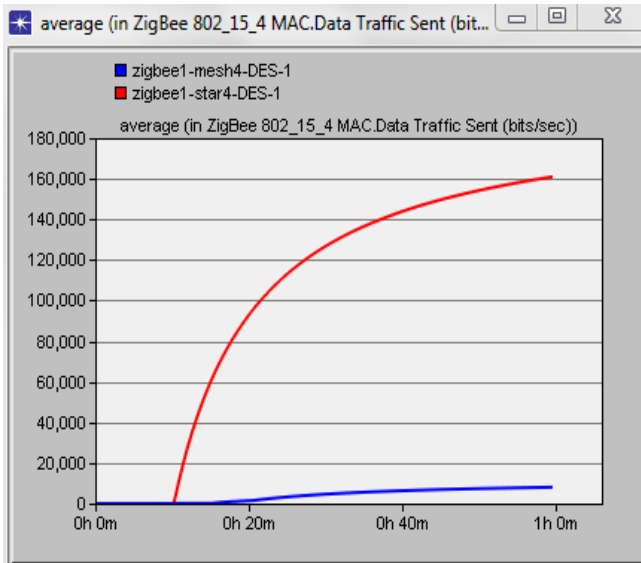


Figure 7: Data Traffic Send for channel sensing duration = 20 sec

Table 4: Data Traffic Send for channel sensing duration at 15 and 20 sec

Data Traffic Send for channel sensing duration = 15 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	108.00	48,207.6790
20	9,373.8285	120,092.2539
30	13,275.6949	145,057.2521
40	15,408.1470	157,107.3529
50	16,695.1947	164,896.6431
60	17,461.362	169,612.2666
Data Traffic Send for channel sensing duration = 20 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	30.00	55.7407
20	1,479.1492	95,241.0095
30	4,635.2244	128,316.6923
40	6,366.00	144,324.1633
50	7,404.4653	154,665.4614
60	8,027.5866	160,908.2488

3.2. Data Traffic Received

It represents the total traffic successfully received by the MAC from the physical layer in bits/sec. This includes retransmissions. Fig. 8, fig. 9, fig. 10 and fig. 11 shows the Data Traffic Received for both mesh and star for different channel sensing duration. From these Figures it is clear that as the channel sensing duration increased the data received is decreased. These figures also show that the data received in Star is more than Mesh.

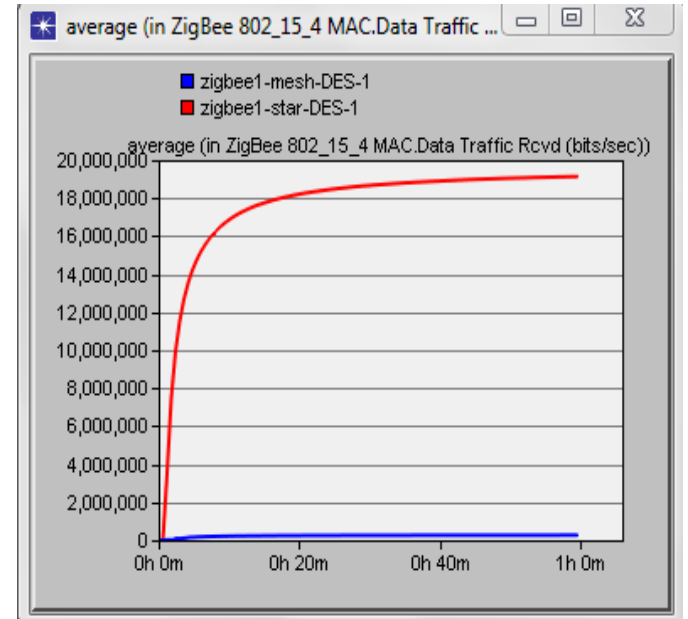


Figure 8: Data Traffic Received for channel sensing duration = 5 sec

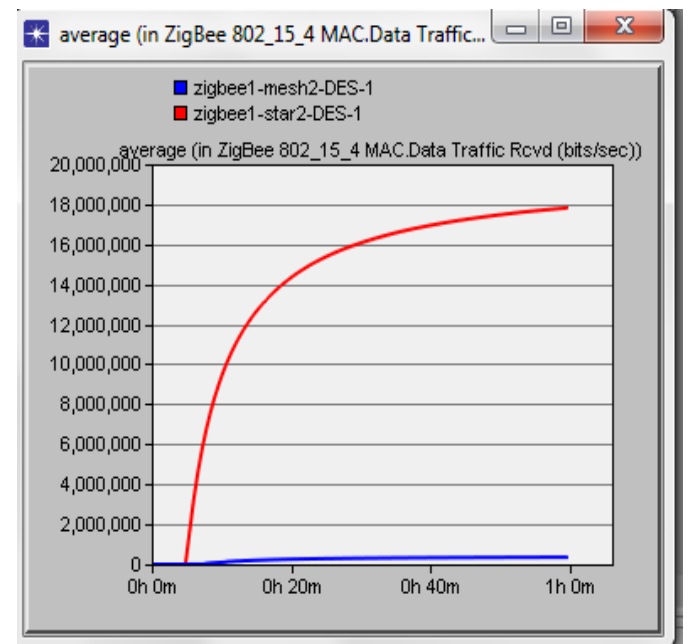


Figure 9: Data Traffic Received for channel sensing duration = 10 sec

Table: 5 Data Traffic Received for channel sensing duration at 5 and 10 sec

Data Traffic Received for channel sensing duration = 5 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	216,402.0123	16,938,086.79
20	244,701.6634	18,244,380.00
30	253,974.5620	18,690,455.70
40	258,242.9803	18,917,196.22
50	261.709.4196	19,054,157.70
60	263.393.16	19,137,481.86
Data Traffic Received for channel sensing duration = 10 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	100,744.0987	10,163,173.40
20	256,581.6380	14,476,311.63
30	304,390.8627	16,086,121.87
40	330,162.4771	16,970,296.65
50	345,388.8915	17,509,264.65
60	324,921.2192	17,817,948.42

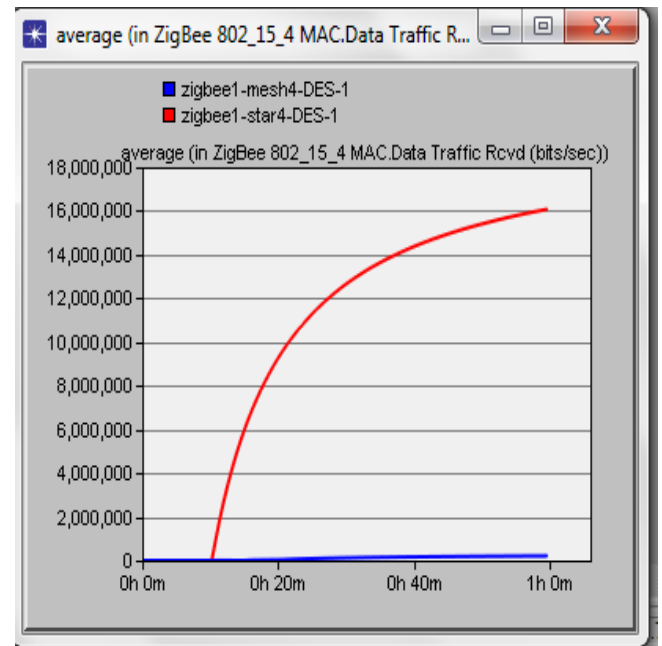


Figure: 11 Data Traffic Received for channel sensing duration = 20 sec

Table: 6 Data Traffic Received for channel sensing duration at 15 and 20 sec

Data Traffic Received for channel sensing duration = 15 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	3,320.3703	5,569,899.30
20	232,596.53	11,986,298.60
30	339,522.75	14,381,991.60
40	398,652.35	15,745,570.76
50	433,734.45	16,468,201.27
60	454,568.14	16,940,368.00
Data Traffic Received for channel sensing duration = 20 sec		
Time (in minutes)	Mesh (bit/sec)	Star (bit/sec)
10	467.1851	1,015.8641
20	33,776.8758	9,502,024.47
30	121,597.4945	12,676,330.94
40	167,121.7222	14,411,702.82
50	194,444.2526	15,445,727.00
60	210,907.1644	16,070,234.22

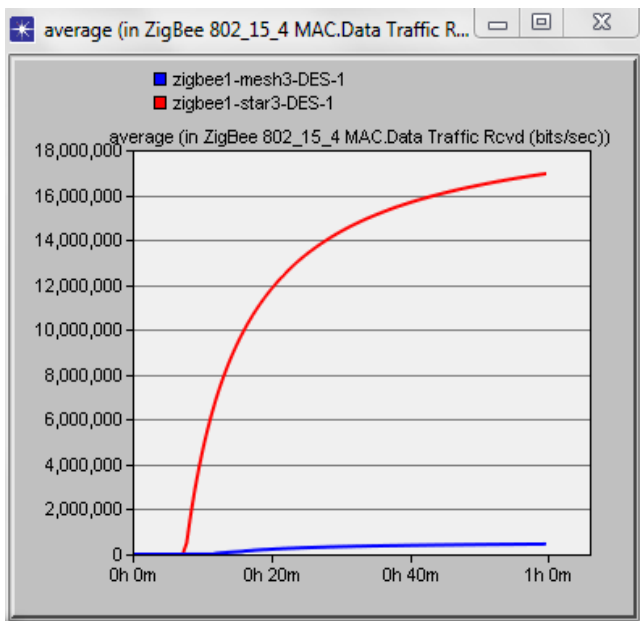


Figure 10: Data Traffic Received for channel sensing duration = 15 sec

3.3. Mac Delay

Represents the end to end delay of all the packets received by the 802.15.4 MACs of all WPAN nodes in the network and forwarded to the higher layer. Fig. 12, fig.13, fig. 14 and fig. 15 shows the Mac Delay for both mesh and star for different

channel sensing duration. From these figures it is clear that as channel sensing duration increased the delay also decreased.

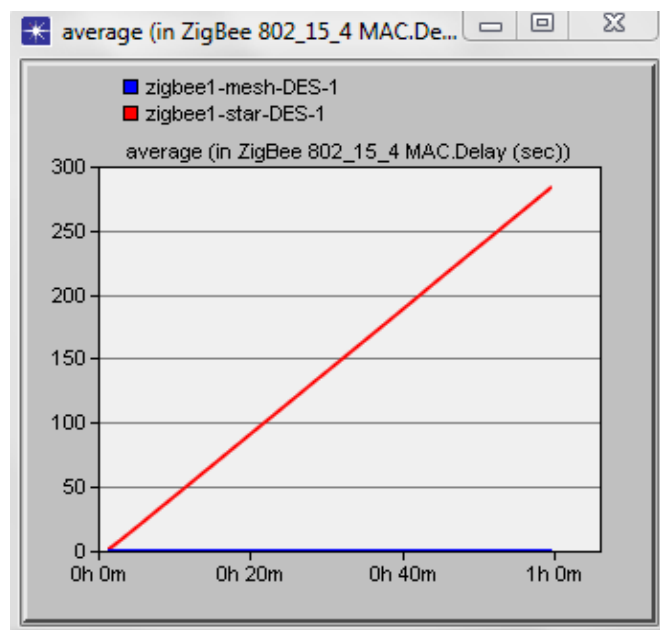


Figure 12: Mac Delay for channel sensing duration = 5 sec

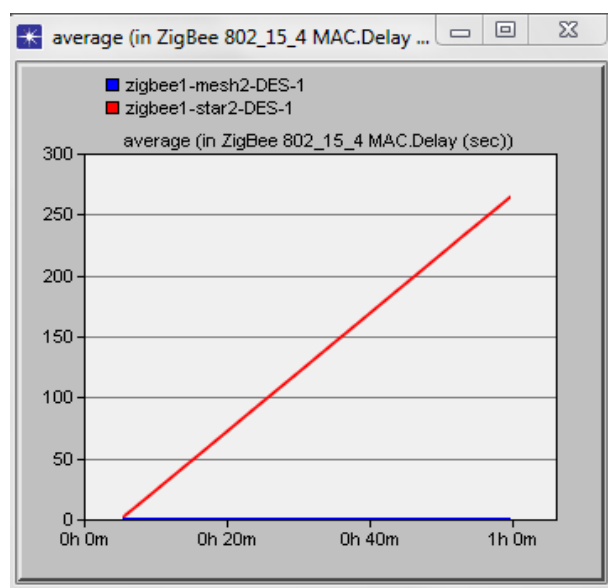


Figure 13: Mac Delay for channel sensing duration = 10 sec

Table7: Mac Delay for channel sensing duration at 5 and 10 sec

Mac Delay for channel sensing duration at 5 sec		
Time (in minutes)	Mesh (delay/sec)	Star (delay/sec)
10	0.0092	43.9157
20	0.0096	93.5187
30	0.0097	140.0805
40	0.0097	189.6977
50	0.0098	231.4577
60	0.0098	283.1066
Mac Delay for channel sensing duration at 10 sec		
Time (in minutes)	Mesh (delay/sec)	Star (delay/sec)
10	0.0088	24.9579
20	0.0089	74.4679
30	0.0090	120.9803
40	0.0090	170.5240
50	0.0090	220.0726
60	0.0090	263.7056

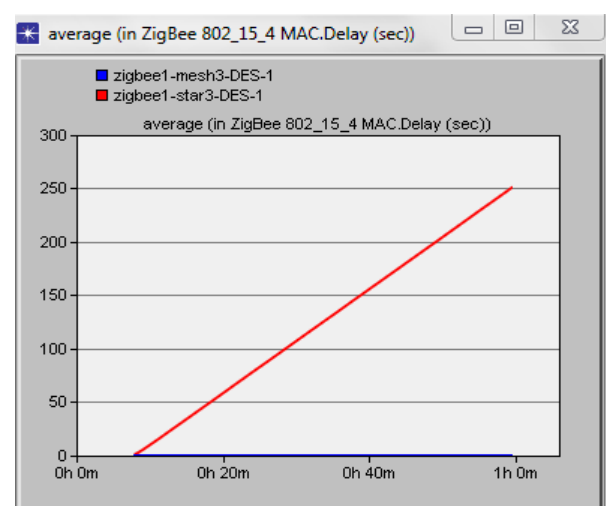


Figure 14: Mac Delay for channel sensing duration = 15 sec

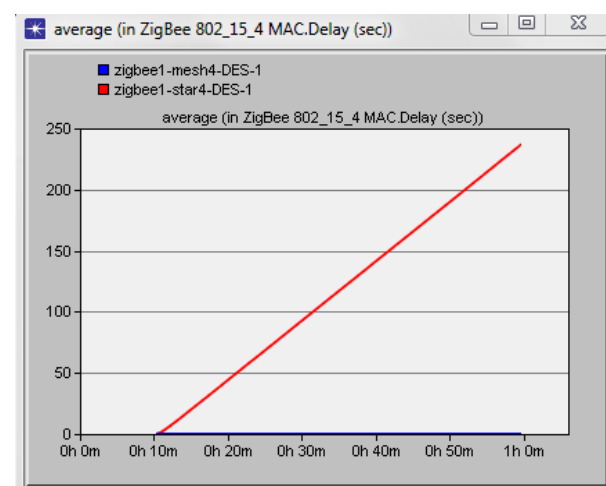


Figure 15: Mac Delay for channel sensing duration = 20 sec

Table8: Mac Delay for channel sensing duration at 15 and 20 sec

Mac Delay for channel sensing duration = 15 sec		
Time (in minutes)	Mesh (delay/sec)	Star (delay/sec)
10	0.0035	11.1601
20	0.0036	60.5928
30	0.0037	110.3152
40	0.0037	157.0421
50	0.0037	206.5918
60	0.0037	250.5439
Mac Delay for channel sensing duration = 20 sec		
Time (in minutes)	Mesh (delay /sec)	Star (delay/sec)
10	0.0026	0.0026
20	0.0027	46.5488
30	0.0027	96.0712
40	0.0028	142.7526
50	0.0028	192.2083
60	0.0028	236.0998

4. CONCLUSION

In this work we provided a versatile analysis of the characteristics of the IEEE 802.15.4 topology formation process using two possible topologies as well as the significant impact on the overall network performance using different parameters. Paper deals with the performance of Mesh and Star topology, which are compared by varying channel sensing duration from 5 sec to 20 sec. The result is analyzed in the terms of Data Traffic send, Data Traffic Received and Mac Delay. The result shows with increase in channel sensing duration the data sent and received in star is more but with greater delay than Mesh.

6. REFERENCES

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