Zigbee network parameters effectness on control system behavior Assistant Professor Eng. Saad

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Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 23 May 2021

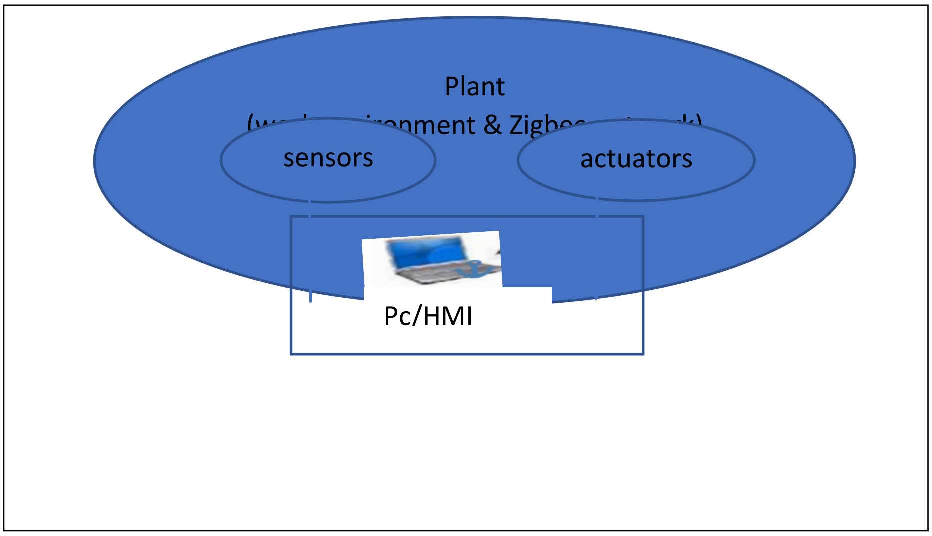
Abstract In this paper, we perform extensive network evaluation by creating different scenarios (using different topologies), to observe the effect of some parameter at MAC and application layers such as rate of data transmit, delay, throughput and end to end delay with three promising topologies in ZigBee (sensor/actuator) network. This paper aims to leverage wireless devices for NCSs in industrial applications. To achieve this, industrial area was chosen (Path along the bank of the Medical City at Tigris river) to implement and simulate the proposed network and demonstrate the impact of these parameters by (Using OPNET IT Guru Academic Edition) network simulation tool.The goal is to highlight the effect of Zigbee network parameters in the two layers (Mac and PHY) on the (sensor gather data) to the control center and return a control signal to a controller device(actuator) set to perform a specific function in an attempt to reach the highest performance in industrial system have been chosen and achieve the stability state of this industrial systems.Results of three ZigBee topologies (star, mesh & mesh1 and tree) showed that star topology is more efficient and best suited compared with mesh and star topologies for IEEE 802.15.4/ ZigBee standard due to measured parameters (Average end to end delay (second), Average Data dropped rate (bits/second)) that showed highest results for star topology as well (see Comparative performance table).

Keyword: Zigbee parameters, sensor, actuator, WNCS, PABTR**.**

1. Introduction

Zigbee network is used because it is specially designed for low cost, low data rate and low-power consumption wireless personal area networks (WPANs). Its mesh topology of network makes this network best suited for industrial automation. Sensor and actuator are supposed to use in the system but In this era of revolution technology, the industrial automation system deals with advanced automation control technologies to have better control performance over complex processes, to increase reliability, productivity, and quality while minimizing the production cost, process control industries must be driven by integrated controllers with high distributed control capability, but it is un available

In this paper, in depth details of the industrial automation transformer parameters control system will be discussed. As can be seen from Figure (1) the proposed system consists of IEEE802.15.4 / Zigbee, which compromised from three part (coordinator - router - end-devices (sensor or actuator), environment can be applied Zigbee network on it (The Banks of Tigris river) our (plant)



2. flow chart of gather data and send signal in proposed system:

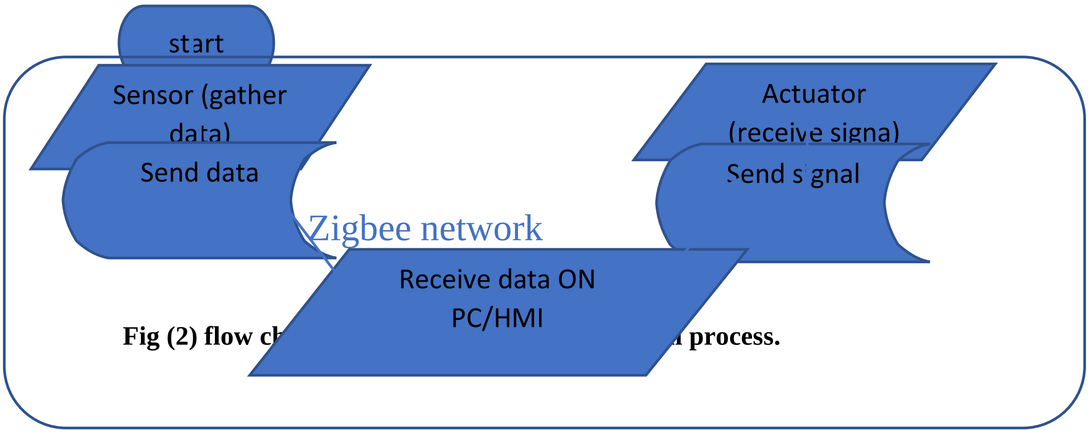


Fig (2) flow ch … process.

The goal of this chapter is to present NCS, highlight the characteristics in relation to wireless network and finally describe and make comparison between effect of Zigbee network parameters for main topologies are used.

NCS is one in which sensors, controllers and actuators exist in a spatially distributed manner. Sensor to controller, controller to actuator loops is reliant on real time communication network which could be either wired or wireless, with the later(wireless) is being the focus of this thesis.

OPNET contain fixed parameters which shown below Tab (1), the other will be shown with each scenario will be done.

Table (1) Fixed application traffic and parameters for the physical, MAC and application layer

Physical layer parameters	
Data rate (kbps) (W)	250
Receiver sensitivity (db)	-85
Transmission band (GHz)	2.4
Transmission power	0.05
MAC Parameters	
ACK wait duration	0.05
Number of Retransmission	5
Application layer parameters	
Packet interval time/ type (sec/constant)	1
Packet size/type (bits/constant)	1024

3. Implementation Case study:

Another site has been chosen is (Path along the bank of the Medical City at Tigris river) in Baghdad city. Riverbed Modeler version 17.5 is used for designing and implementation of ZigBee network (OPNET). We have considered an environment (Tigris bank) having many and many of kilometers and the parameters involved in the water quality determination such as the pH level, turbidity, temperature and water speed is measured in the real time by the sensors that send the data to the base station for(control/monitoring), so the designed network consists of fixed devices because it will work permanently (at least till now). however, sensor to collect data and actuator to take a action will be supposed after put them in along the river.

The comparative analysis involves global throughput, MAC delay, data dropped rate and end to end delay as the parameters can affect on industrial system. In this simulation the overall scenario has been considered taking ZigBee Coordinator (Fixed), ZigBee Router (Fixed), ZigBee end device (Fixed) in every configuration. At first, scene for work environment will be displayed to understand it and familiarity different conditions that can be valuable for our work Fig (3).

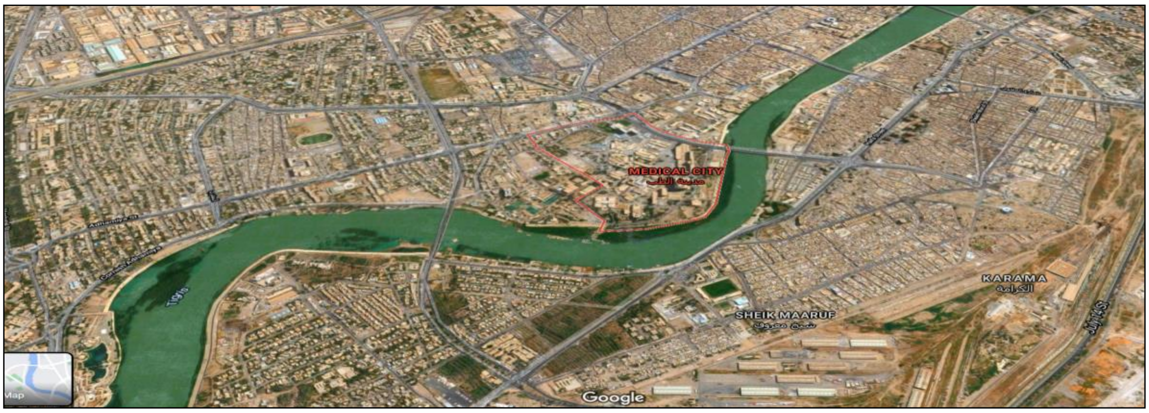
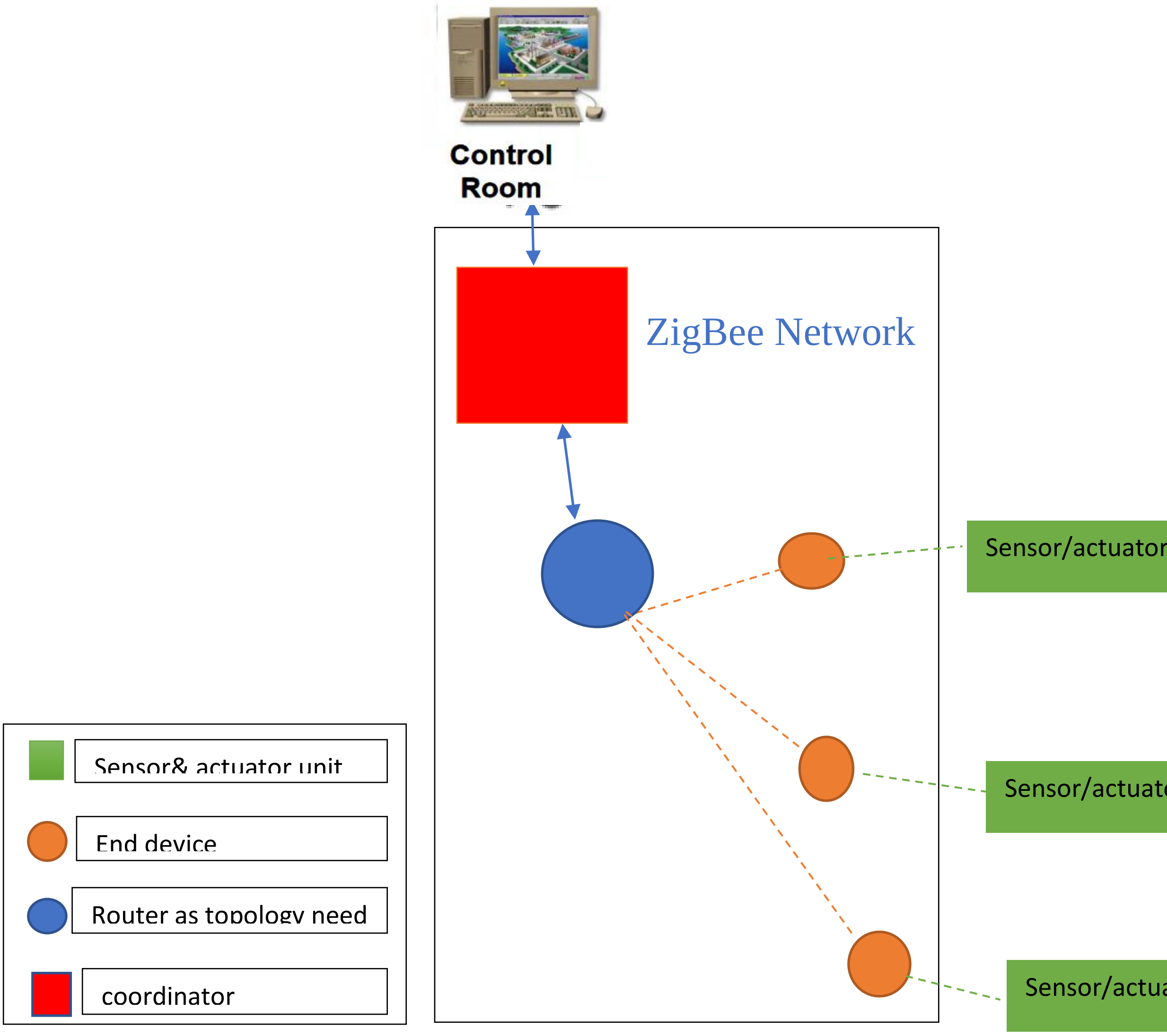


Fig (3) (industrial area have been chosen PABTR)



Fig(4) Block diagram Zigbee based wireless sensor network for the monitoring & controlling system case study

A sensor unit is basically consisting of several sensors used to detect the predetermined parameters that indicate the quality of water. In this work, four types of sensor; pH level, temperature, water speed sensor and that senses the acidity of basicity of the water.

Algorithm : End Node Algorithms		
Input	RX Data. / command received from coordinator to end devices (gather data)	
Out put	TX Data. / end nod response (send gather data)	
start		
Step 1	Check serial buffer if nothing, (go to start)	
Step2	Assign buffer content to RX (receive port) data	
Step 3	If RX data = “read X” go to step (6)	
Step 4	If RX data = “on X” then go to step (7)	
Step 5	If RX data = “off X” go to step (1)	
Step 6	Store in TX data node number (x)	
Step 7	Store analog water temperature	Store analog (X data has been read) according sensor type
Step 8	Store analog water speed flow value	
Step9	Store analog PH level	
Step10	Send TX data. /(Transmit port) send response from end device to coordinator	
	END	

Algorithm(1): End nod Algorithm:

Algorithm(1): Coordinator Node Algorithms

A/ PABTR with long thin tree topology:

In this scenario long thin topology (tree topology) will be applied and simulate by OPNET simulator as shown below Fig (6). Here one type can be applied to implement our network (so coordinator node, router nod and end devices node (sensor /actuator) respectively will be used.

Algorithm : Coordinator Node Algorithms	
Input	TX Data
Out put	TX Data "packet information from nodes (sensors)
start	
Step 1	Create Net Work (build Zigbee network).
Step2	Add of PAD ID.
Step 3	check if end nod asks to join.
Step 4	if Read TX Data =" " go to step (3)
Step 5	if Read TX Data =" x" go to step (6)
Step 6	check XBEE serial buffer
Step 7	if serial buffer = " " go to step (6).
Step 8	store responds of node in TX Data.
Step9	Send "read for X Data" TX. / command from coordinator to end nodes (actuator or sensors)
Step10	go to step (3).
Step11	END

Fig (6) long thin topology (tree topology)

EXPERIMENTAL SETUP:

Table 2 General Configuration Parameter (long thin (tree topology)

N. O	Attributes	Value
1	Topology Type	Long thin (tree)
2	Number of Nodes	33
3	Number of Coordinators	1(at the head of path)
4	Number of Router	16
5	Packet Interval Tim	Constant (1.0)
6	Packet Size (bits)	Constant (1024)
7	Simulation Duration (sec)	3600
8	Trajectory	Vector

As see, the number of used nodes almost reached (31), and the Coordinator node was at the beginning of the path to represent the tree's topology, all nodes distributed along the river bank (sensor) to gather data (feedback) then send signal ((sensor/actuator) as control system) to do required action.

B/ PABTR with long thin star topology:

In this scenario long thin topology (Star topology) will be applied and simulate by OPNET simulator as shown below Fig (7). Here star topology was tried to simulated, so to implement our network the following nodes were used (coordinator node, router nod and end devices node (sensor /actuator) respectively will be used. Taking into account the position of the Coordinator's node in the middle.

Fig (7) long thin topology (Star topology)

EXPERIMENTAL SETUP:

Table 3 General Configuration Parameter (long thin (star topology)

N.O	Attributes	Value
1	Topology Type	Long thin (star)
2	Number of Nodes	31
3	Number of Coordinators	1(at the Middle of path)
4	Number of Router	16
5	Packet Interval Tim	Constant (1.0)
6	Packet Size (bits)	Constant (1024)
7	Simulation Duration (sec)	3600
8	Trajectory	Vector

As see, the number of used nodes almost reached (31), and the Coordinator node was at the middle of the path to represent the Star's topology, all nodes distributed along the river bank (sensor) to gather data (feedback) then send signal ((sensor/actuator) as control system) to do required action.

C/ PABTR with long thin mesh1 topology:

In this scenario long thin topology (Mesh topology) will be applied and simulate by OPNET simulator as shown below Fig (8). Here Mesh topology was tried to simulated, so to implement our network the following nodes were used (coordinator node, router nod and end devices node (sensor /actuator) respectively will be used. Taking into account the position of the Coordinator's node in the one side of the Tigris river while the nodes distributed on both banks.

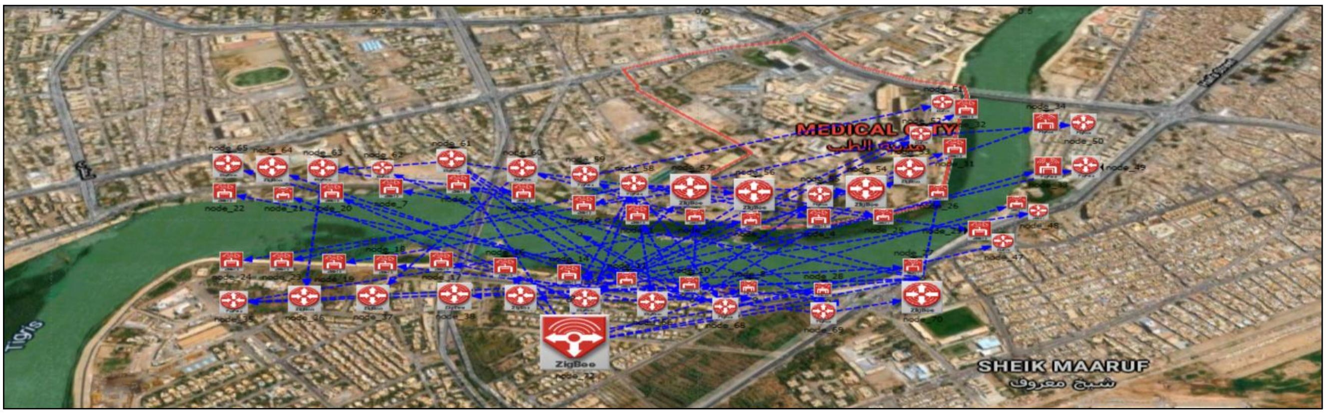


Fig (8) long thin topology (Mesh1 topology)

Table 4 General Configuration Parameter (long thin (mesh1 topology)

N.O	Attributes	Value
1	Topology Type	Long thin (mesh)
2	Number of Nodes	61(Both side of Tigris river)
3	Number of Coordinators	1
4	Number of Router	29 (behind nodes)
5	Distance	Part of 2 side
6	Packet Interval Tim	Constant (1.0)
7	Packet Size (bits)	Constant (1024)
8	Simulation Duration (sec)	3600
	Trajectory	Vector

As see, the number of used nodes almost reached (61) to cover both banks, and the Coordinator node was at (one bank) and the rest of nods were distributed as (30 nodes) for each bank to represent the Mesh 's topology, all nodes distributed Both banks of the river (sensor) to gather data (feedback) then send signal ((sensor/actuator) as control system) to do required action.

D/ PABTR with long thin mesh2 topology:

Here the same mesh1 topology were simulated but in different configuration and different distance on environment, to explained how change configuration (setup) maybe effect on behavior of network for same topology and then how effect on industrial automation. The mesh2 will be shown below.

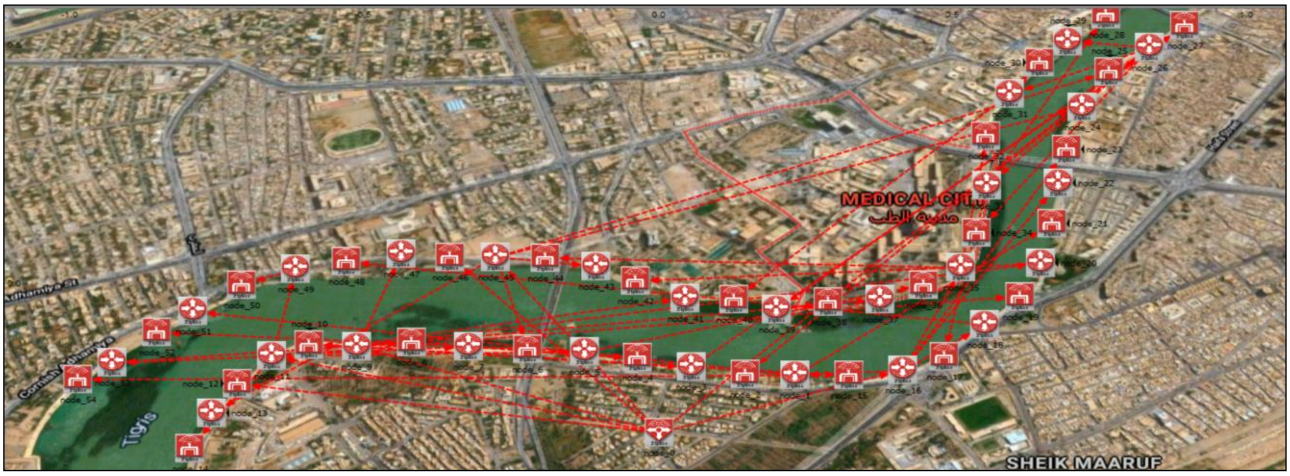


Fig (8) long thin topology (Mesh2 topology)

Table 5 General Configuration Parameter (long thin (mesh2 topology)

N. O	Attributes	Value
1	Topology Type	Long thin (mesh2)
2	Number of Nodes	54(Both side of Tigris river)
3	Number of Coordinators	1
4	Number of Router	26 (between node)
5	Distance	More than mesh1
6	Packet Interval Tim	Constant (1.0)
7	Packet Size (bits)	Constant (1024)
8	Simulation Duration (sec)	3600
9	Trajectory	Vector

As see, the number of used nodes almost reached (54) to cover long both banks nor like mesh1, and the Coordinator node was at (one bank) and the rest of nods were distributed as (27 nodes) for each bank to represent the Mesh 's2 topology, all nodes distributed Both banks of the river.

4. Result and discussion

Here scenario of difference topology will be applied and simulate by OPNET simulator on Path along the bank at Tigris river Taking into account long thin can be considered (a hybrid topology) because to position of coordinator give the topology different shape, as shown below

A/ Mesh topology result for (PABTR)

In this scenario mesh topology will be applied and simulate by OPNET simulator on Path along the bank at Tigris river, as can see the coordinator is located on one of the banks of the river, but not on both, parameters of this scenario will be shown below.

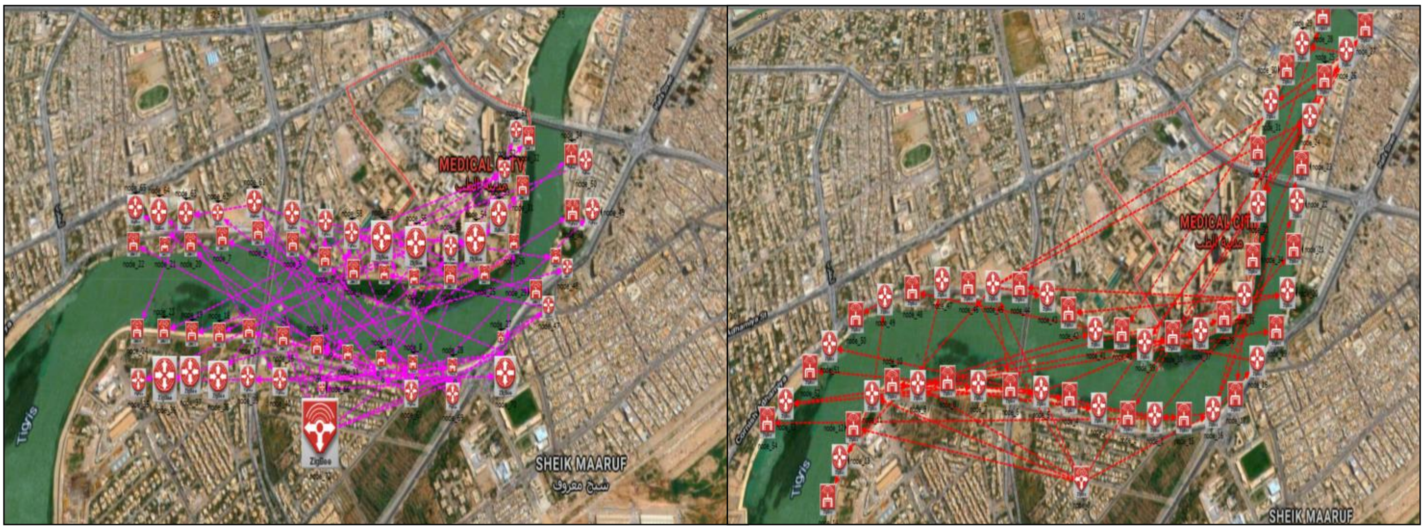


Fig (9) Scenario1, Mesh1 and mesh2 topology (throughput, delay, end to end delay and data drop)

B/ Star topology result for (PABTR):

In Star topology scenario which will be applied on Path along the bank at Tigris river.

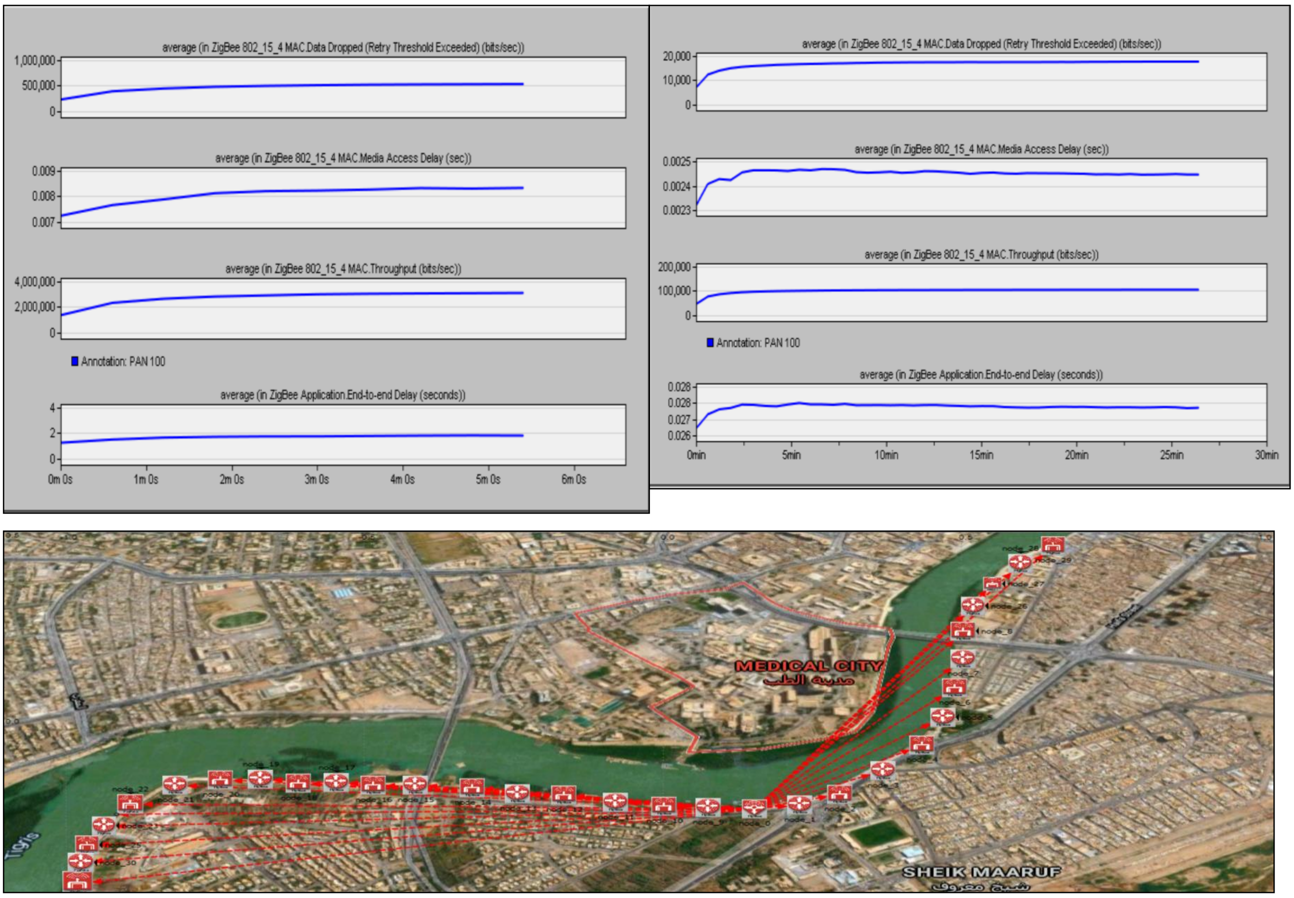
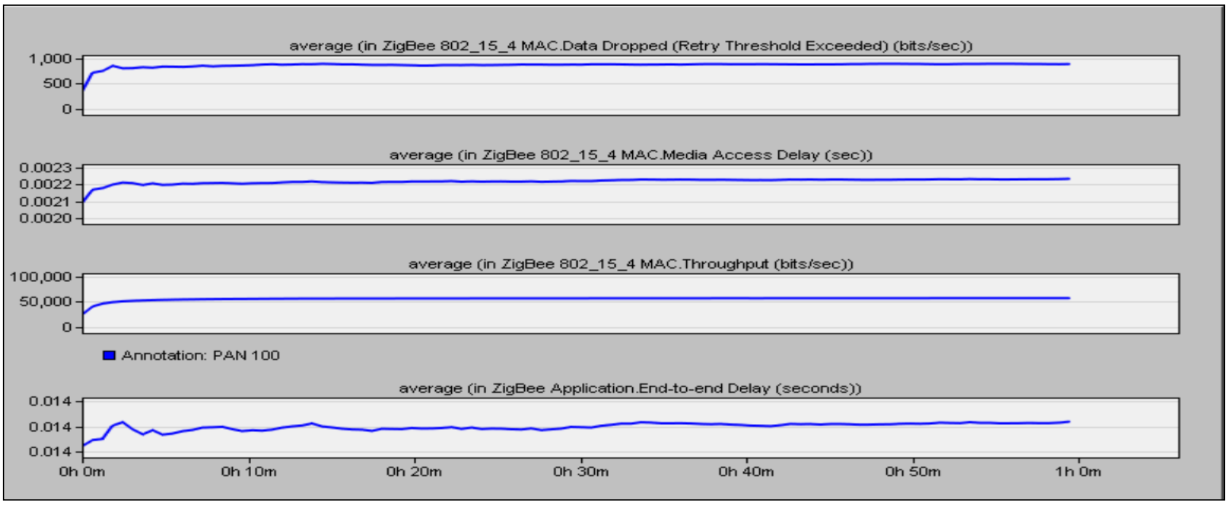
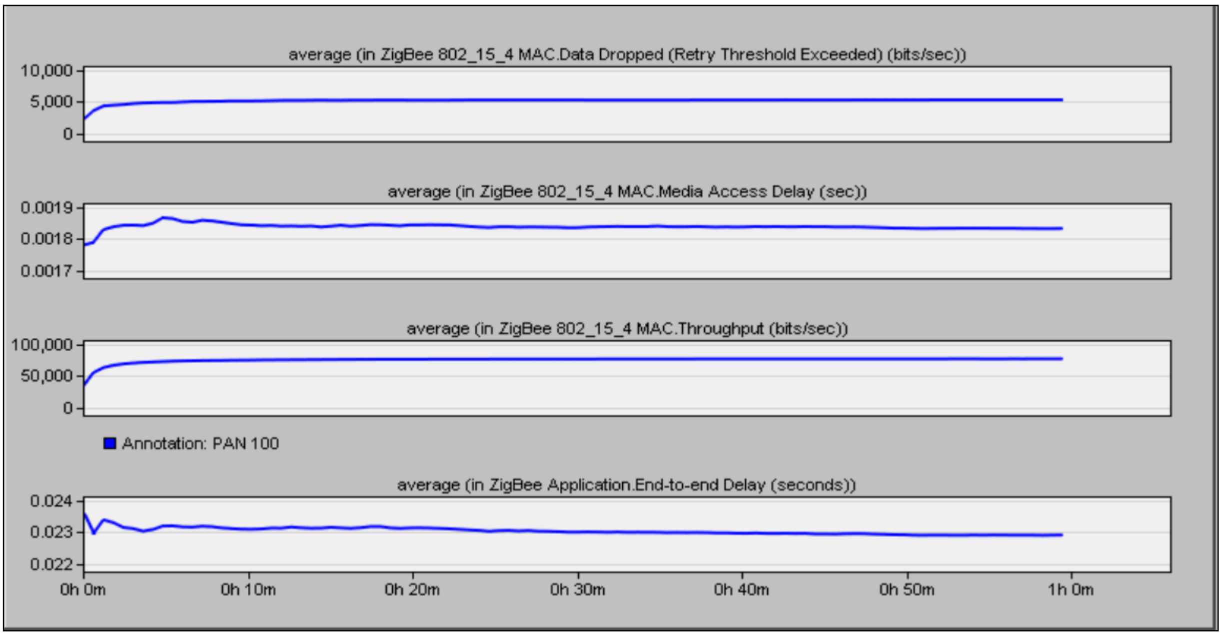
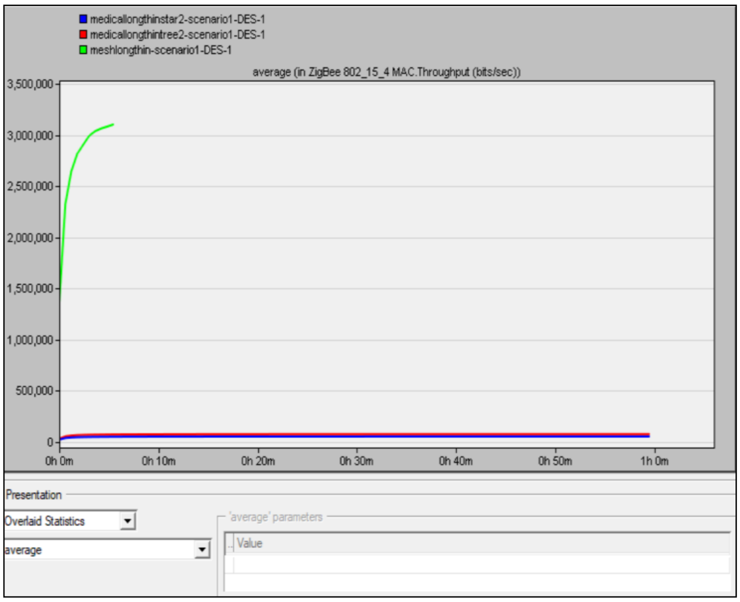


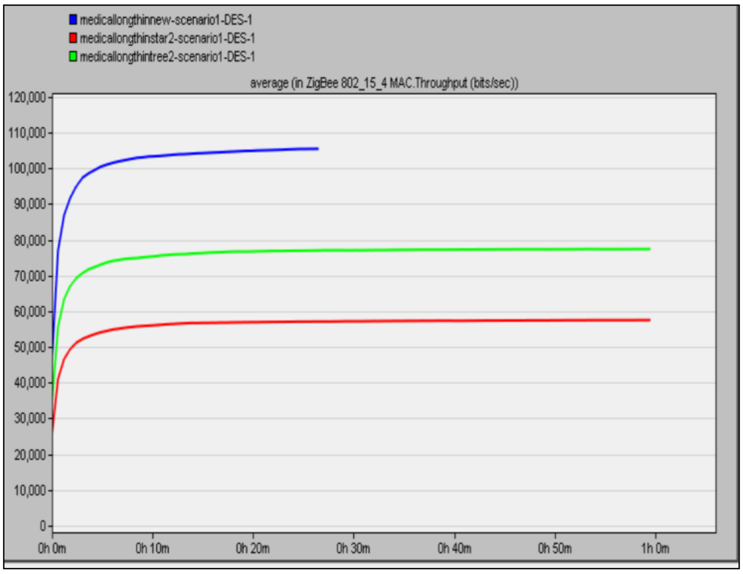
Fig (10) Scenario1 Mesh topology (throughput, delay, end to end delay and data drop)

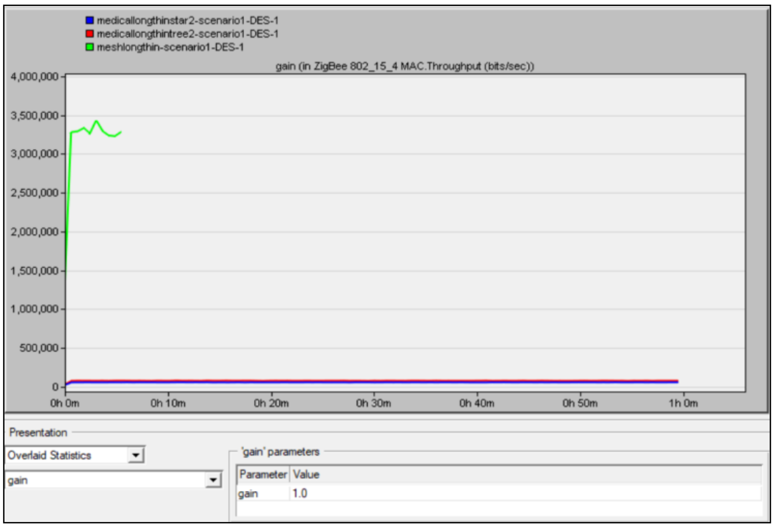


C/ tree topology result for (PABTR):
In tree topology scenario which will be applied on Path along the bank at Tigris river.




medicallongthinstar2-scenario1-DES-1
medicallongthintree2-scenario1-DES-1
meshlongthin-scenario1-DES-1
average (in ZigBee 802_15_4 MAC.Throughput (bits/sec))
Presentation
Overlaid Statistics
average
'average' parameters
Value


medicallongthinnew-scenario1-DES-1
medicallongthinstar2-scenario1-DES-1
medicallongthintree2-scenario1-DES-1
average (in ZigBee 802_15_4 MAC.Throughput (bits/sec))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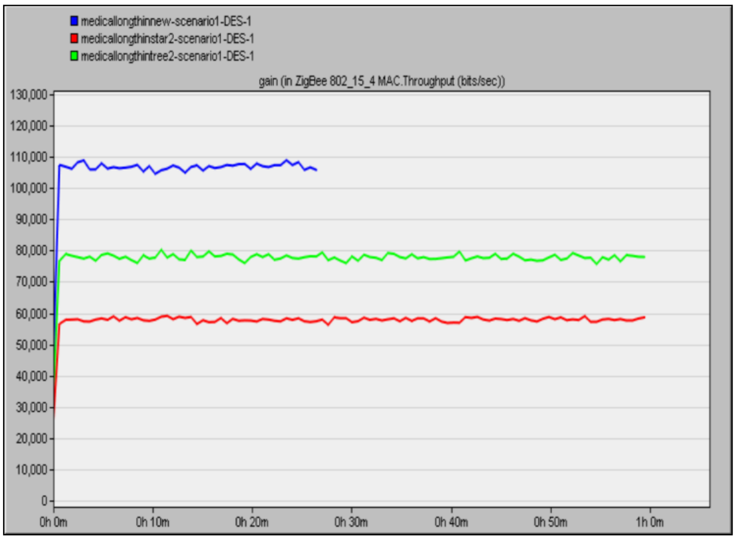
medicallongthintree2-scenario1-DES-1
meshlongthin-scenario1-DES-1
gain (in ZigBee 802_15_4 MAC.Throughput (bits/sec))
Presentation
Overlaid Statistics
gain
'gain' parameters
Parameter Value
gain 1.0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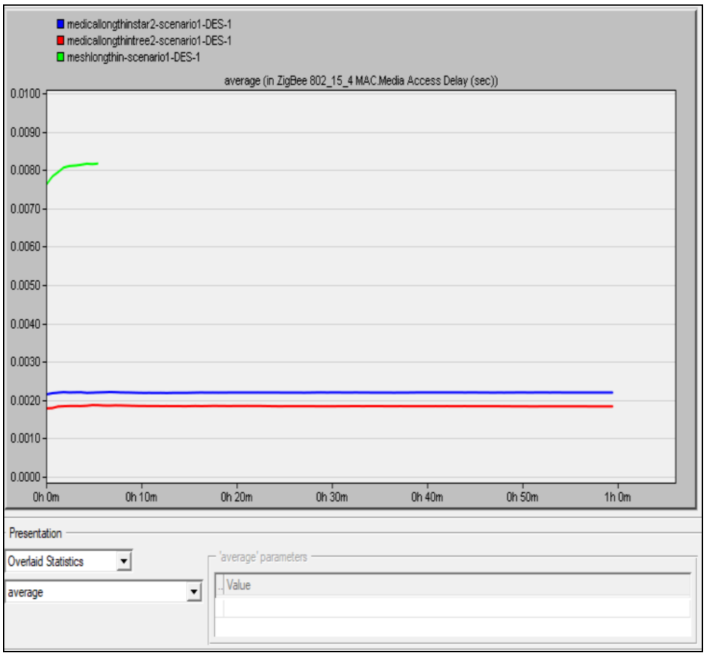
medicallongthinstar2-scenario1-DES-1
medicallongthintree2-scenario1-DES-1
gain (in ZigBee 802_15_4 MAC.Throughput (bits/sec))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meshlongthin-scenario1-DES-1
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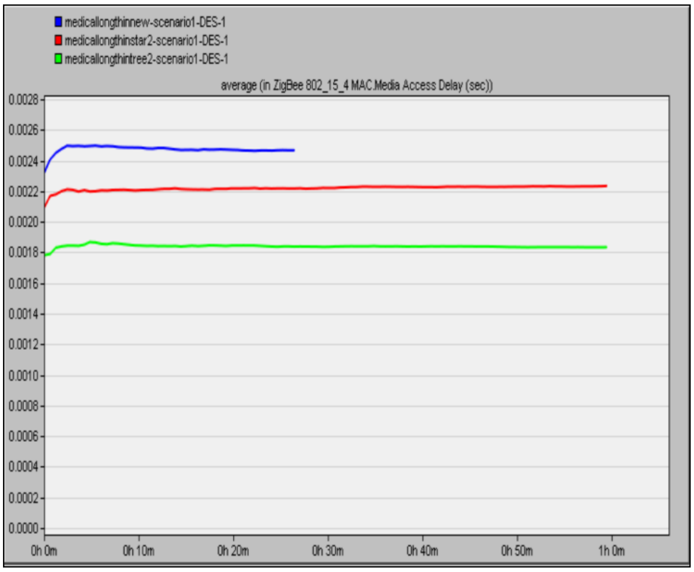
Presentation
Overlaid Statistics
average
'average' parameters
Value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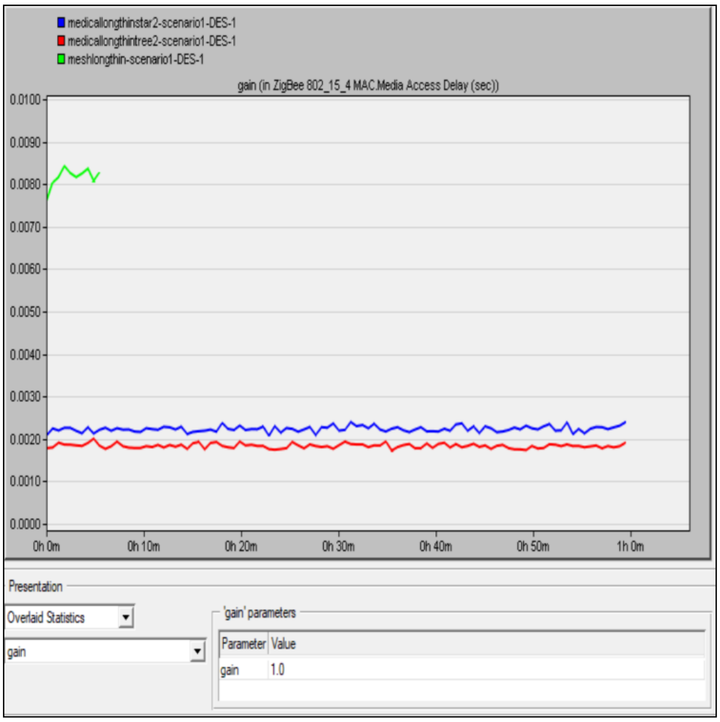
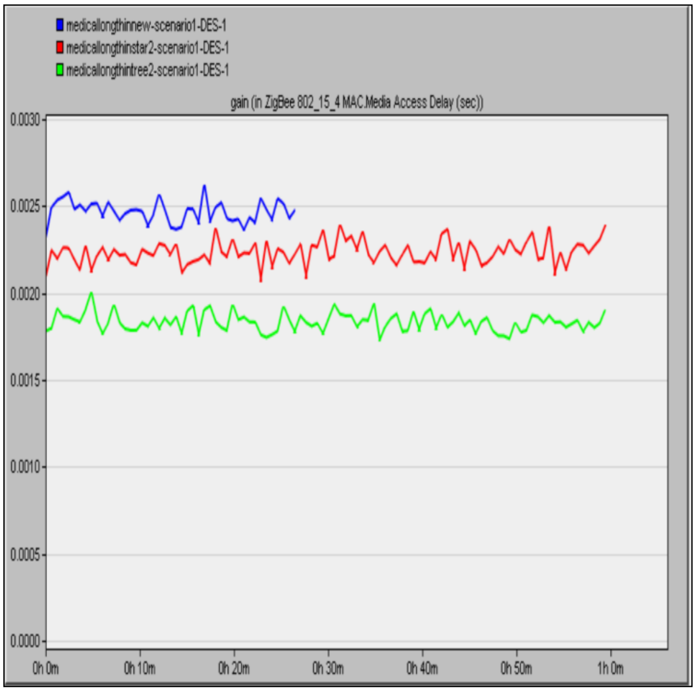
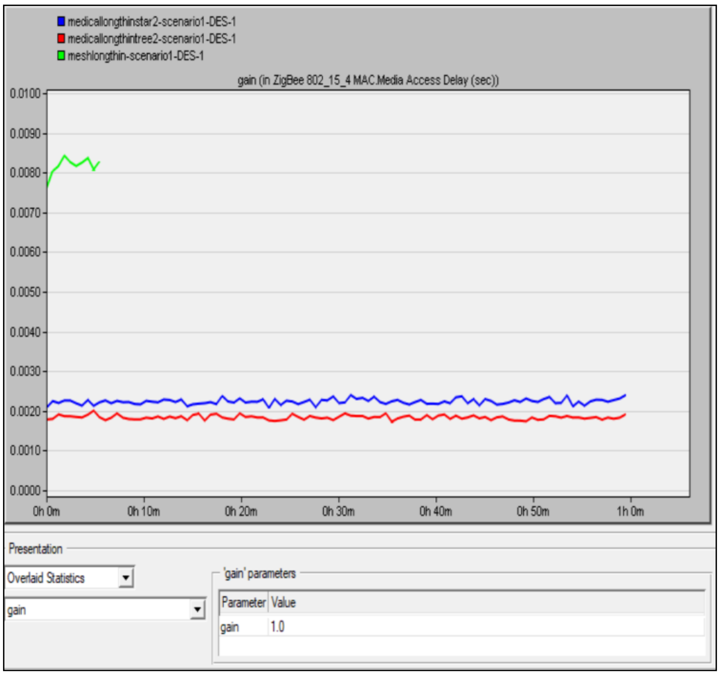
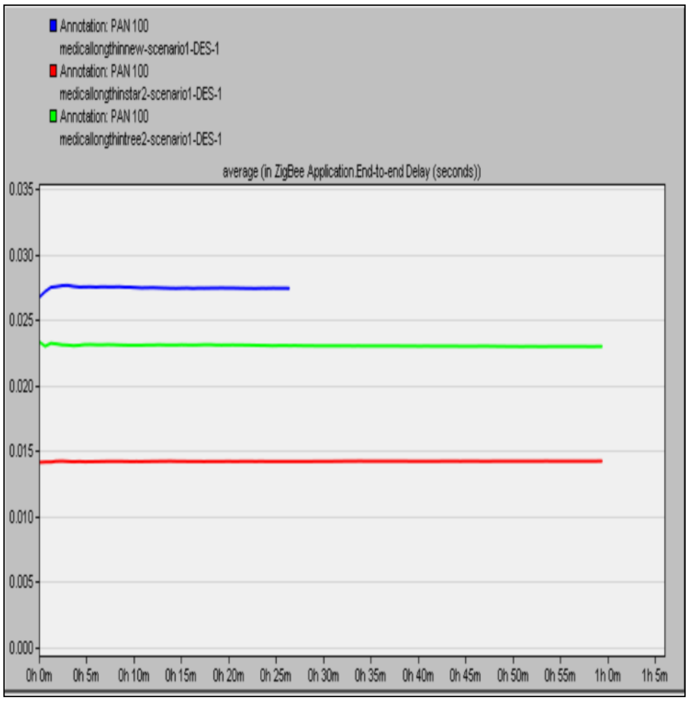
average (in ZigBee 802_15_4 MAC.Media Access Delay (sec))

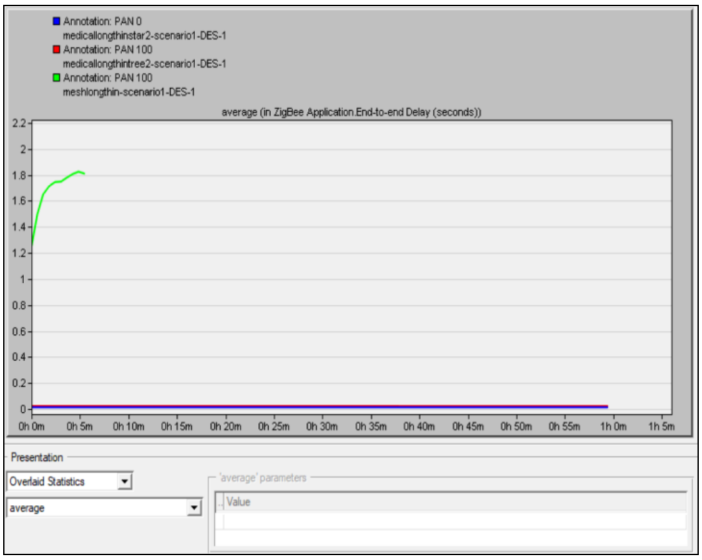








c/ End to End Delay: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Annotation: PAN 100
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Annotation: PAN 100
meshlongthin-scenario1-DES-1
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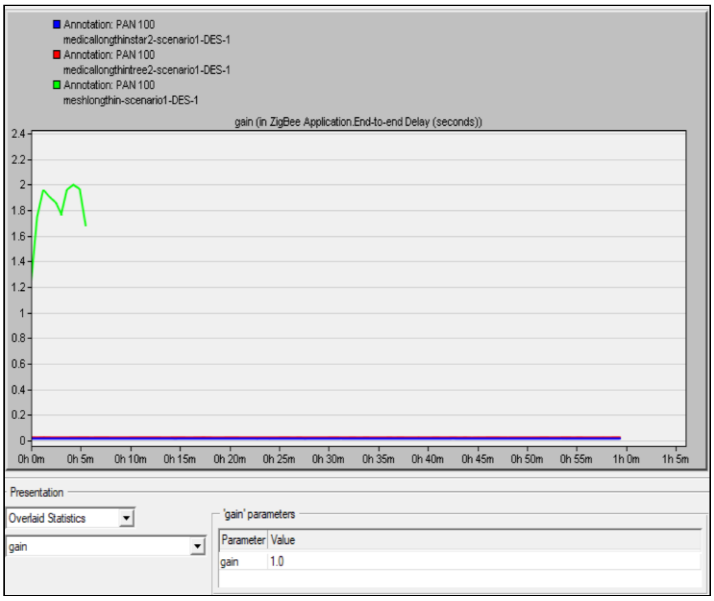
Presentation
Overlaid Statistics
average
'average' parameters
Value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Annotation: PAN 100
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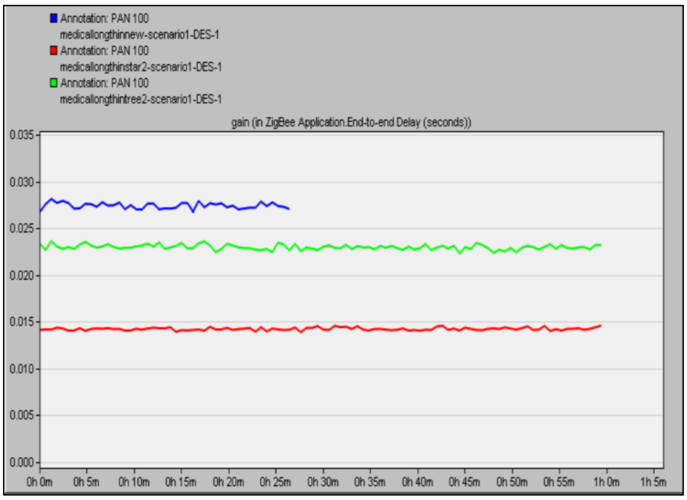
Annotation: PAN 100
meshlongthin-scenario1-DES-1
gain (in ZigBee Application.End-to-end Delay (seconds))
Presentation
Overlaid Statistics
gain
'gain' parameters
Parameter Value
gain 1.0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Annotation: PAN 100
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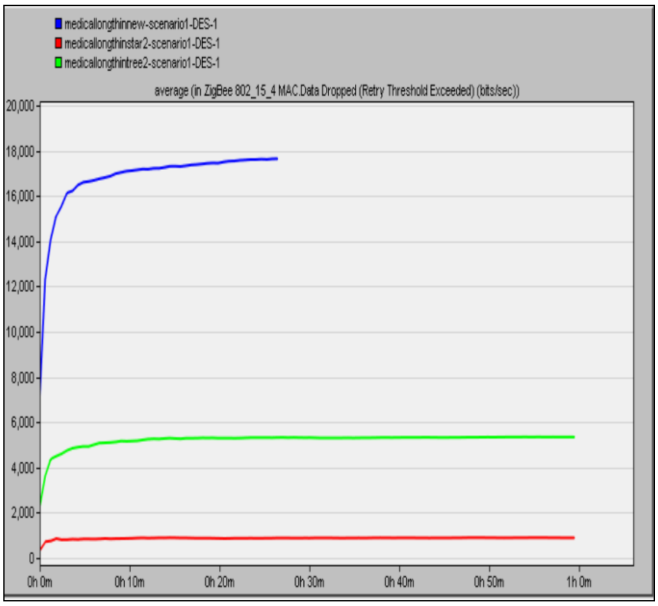
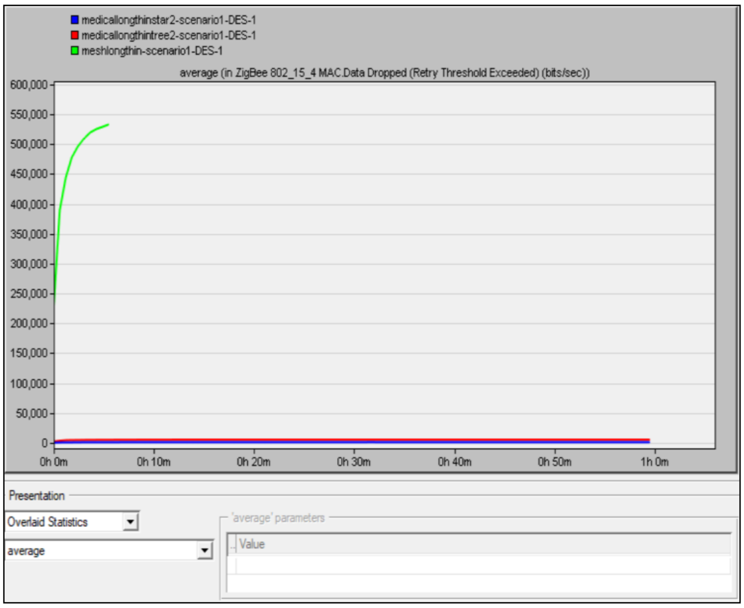
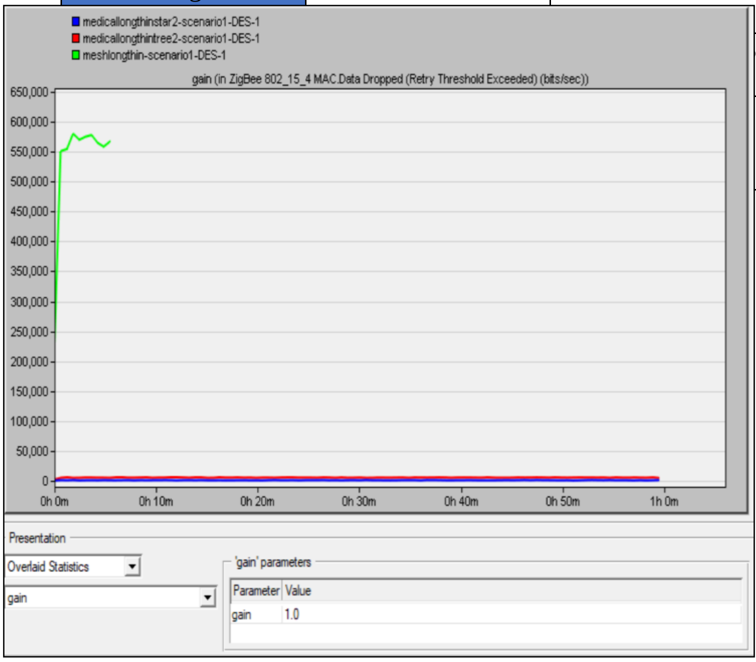
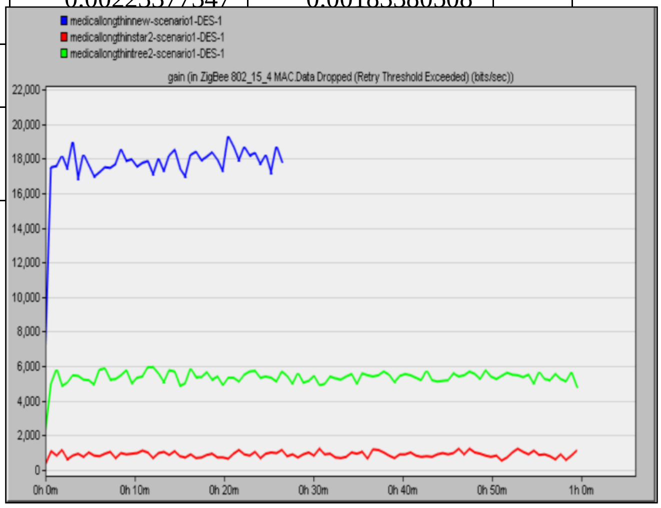
Annotation: PAN 100
medicallongthintree2-scenario1-DES-1
gain (in ZigBee Application.End-to-end Delay (seconds))


medicallongthinnew-scenario1-DES-1
medicallongthinstar2-scenario1-DES-1
medicallongthintree2-scenario1-DES-1
average (in ZigBee 802_15_4 MAC.Data Dropped (Retry Threshold Exceeded) (bits/sec))


medicallongthinstar2-scenario1-DES-1
medicallongthintree2-scenario1-DES-1
meshlongthin-scenario1-DES-1
average (in ZigBee 802_15_4 MAC.Data Dropped (Retry Threshold Exceeded) (bits/sec))
Presentation
Overlaid Statistics
average
'average' parameters
Value

	Senario1(mesh) topology	Senario1.2(mesh) topology	Senario2(star) topology	Senario3(tree) topology	
Average Throughput (bits/second)	3102388	105376	57544	77427	
Average MAC	0.00816511875	0.00246684417	0.00223377347	0.00183380508	





D/ Data drop:

6. Comparative performance table control parameter affective:

Here we add anew thing re simulate same mesh topology then we compare it with all topologies were used, what are discovered is the result for same scenario were be differ according to No. of nods , distance was covered and the nature of topology.

References

1. N. Boughanmi etal. 2009, Wireless Networked Control System using ZigBee/IEEE 802.15.4, Proceedings of the 13th IFAC Symposium on Information Control Problems in Manufacturing Moscow, Russia, June 3-5, 2009
2. Raul K. Mansano et al.2014, The Benefits of Soft Sensor and Multi-Rate Control for the Implementation of Wireless Networked Control Systems, www.mdpi.com/journal/sensors.
3. Galloway, B.; Hancke, G.P. Introduction to industrial control networks. IEEE Communication Survey. Tutor. 2013, 15, 860–880.
4. Waleed Noori Hussein etal.2017, A Simulation of Wireless Sensor Network Using ZigBee Computer Engineering and Intelligent Systems www.iiste.org ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online) Vol.8, No.3, 2017.
5. Waleed Noori Hussein etal.2017, A Simulation of Wireless Sensor Network Using ZigBee Computer Engineering and Intelligent Systems www.iiste.org ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online) Vol.8, No.3, 2017
6. AshrafF.Khalil etal. 2015, Stability and Time Delay Tolerance Analysis Approach for Networked Control Systems, Hindawi Publishing Corporation Mathematical Problems in Engineering Volume 2015.

7. Gang Zhao, (2011). Wireless Sensor Networks for Industrial Process Monitoring and Control: A survey, Macro Think Institute Network Protocols and Algorithms, VOL. 3, ISSN: [1943-3581].
8. Iftekharul Hoque. 2013, modeling and performance study of large scale of zigbee based greenhouse monitoring and control network, at Massey University, Albany,NewZwaland.
9. WirelessHART is a wireless sensor networking technology based on the Highway Addressable Remote Transducer Protocol (HART).
10. A MAC PDU is a bit string that is byte aligned (i.e., multiple of 8 bits) in length. Similarly, MAC SDUs are bit strings that are byte aligned (i.e., multiple of 8 bits) in length.
11. Md. Abbas Ali Khan et al (2016), DAFFODIL INTERNATIONAL UNIVERSITY JOURNAL OF SCIENCE AND TECHNOLOGY, VOLUME 11, ISSUE 1, JANUARY 2016.
12. Kuldeep Vats et al. (2012), ZigBee –based WSN Topology Simulation Investigation and Performance Analysis using OPNET, NTERNATIONAL JOURNAL OF ADVANCED SCIENTIFIC RESEARCH AND TECHNOLOGY ISSUE 2, VOLUME 3 (JUNE-2012)
13. Arrian Prince-Pike, Power Characterisation of a Zigbee Wireless Network in a Real Time Monitoring Application, AUT univerrsty,April 2009,p20-21.
14. IEEE Computer Society. "802.15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)". 2006.
15. Dominik Bunyai,2012 ZigBee Network Layer Simulation on top of IEEE 802.15.4, Technische Universität Wien.
16. Arrian Prince-Pike, Power Characterisation of a Zigbee Wireless Network in a Real Time Monitoring Application, AUT univerrsty,April 2009,p26.
17. Arrian Prince-Pike, Power Characterisation of a Zigbee Wireless Network in a Real Time Monitoring Application, AUT univerrsty,April 2009,p28.
18. Gilberto Flores Lucio et al.2014, OPNET Modeler and Ns-2: comparing the accuracy of network simulators forpacket-level analysis using a network testbed, https://www.researchgate.net/publication/228560494.
19. Hadeel S. Obaid.2020, Wireless Network Behaviour during Jamming Attacks: Simulation using OPNET, Journal of Physics: Conference Series1530 (2020) 012009 doi:10.1088/1742-6596/1530/1/012009.
20. Mohammed Abdullah Al-Rudaini.2009, Wireless Network Simulation Using OPNET IT Guru Academic Edition, Technical Report · February 2009