Deviation of Mobile Nodes in Beacon Enable Zigbee Sensor Network

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ABSTRACT
This research work is based on IEEE 802.15.4/ Zigbee wireless sensor network. The main aim of this research is to analyze the performance of Zigbee network topologies in beacon enable mode by giving the random waypoint mobility model to its nodes. The scenarios have investigated the performance of network by varying speed and mobility of nodes. Results are evaluated using parameters throughput, data traffic sent and data traffic received and number of hops. The simulation is done by OPNET modeler 14.5. The results conclude that tree topology give good performance in case of data traffic sent and data traffic received, the throughput is also efficient. Hence tree topology constructs a robust network using mobile nodes.

Keywords
WSN, Zigbee, CSMA/CA, Mobility, Topologies.

1. INTRODUCTION
There are many numbers of small sensors spread everywhere in a wireless sensor network either inside or very close to the event to be sensed. Sensor nodes consist of sensing, data processing, and communicating components. Different wireless technologies like IEEE 802.11 WLANs, WPANs, and Bluetooth etc. can be used as Wireless sensor networks. Now these days the requirement of applications are low-power having a range of about 30 to 200 feet with data rates around 300 kbps. IEEE 802.15.4 is the approved low-rate standard for a simple, short range wireless communication with long battery life up to a single year. The low rate (LR) wireless personal access network (WPAN) (IEEE 802.15.4/LRWPAN) has to be implemented in industrial, residential, and medical applications with very low power , low cost, and low data rate and QoS. The low data rate to consume little power in the LR-WPAN [1]. ZigBee is a network and application layer specification developed by a multi-vendor consortium called the ZigBee Alliance. The IEEE 802.15.4 standard provides the physical (PHY) layer and medium access control (MAC) sublayer specifications for low data rate wireless connectivity [2]. The PHY layer performs functions like in-channel power energy detection, link quality indication, channel selection, Clear Channel Assessment (CCA), and also the transmission and reception of packet through the radio channel. The standard defines three bands: 868 - 868.6 MHz, 902 - 928 MHz, and 2400 - 2483.5 MHz, in which 26 separate channels are available with the bandwidth of 3 MHz. The MAC layer is responsible for channel assessment. Two different types of operating schemes are available in Mac layer for channel assessment. The first one is beacon mode based on CSMA/CA with time-slot allocation to schedules the network access. The second is non-beacon mode, which based on a pure CSMA/CA protocol. In non-beacon mode, each station wishing to transmit data after sensing the channel for desired time duration [3] In beacon-enabled mode a superframe structure constructed based on the Beacon Interval (BI) and define by the network coordinator, where BI defines the time between two consecutive beacon frames and on the Superframe Duration (SD), basically the active portion of the BI, and transmission of frames has been done by dividing BI into 16 equally-sized time. If BI > SD an inactive period is defined. During the inactive period all nodes save energy by moving in sleeping mode. There are many ZigBee applications for home-appliance networks, healthcare, medical monitoring, consumer electronics, and environmental sensors. Mobility is the necessary requirement of wireless networks in many applications that also impose QoS requirements. A mobile node has to listen to neighbor attachment points periodically so that it updates its neighbor list. IEEE 802.15.4/ZigBee nodes usually have less energy capacity, thus mobility management approach has to ensure low energy [4]. A network with highly mobile users raises challenging mobility issues, as the ZigBee specification defines a device discovery procedure activate by central server which is difficult to find out certain mobile end device. For this purpose, the central server simply over supplies the message in the whole network to find out the displaced end device. Due to the geographical structure of the network the mobility patterns of sensor nodes are inherently regular in many applications. To construct a proper routing topology the regularity should be developed which provides useful information for sensing data deliveries [5]. Doubtlessly mobility is a part of the ZigBee vision, and it is significant for the proper functioning of many visualized ZigBee applications. Since mobility is estimated and obligatory. A tolerable mobility support is necessary to make certain connections between mobile devices which are omnipresent [6]. In this paper, the behavior of Zigbee topologies has been investigated by giving mobility to nodes and also analyzed the performance of network, if it is totally mobile.

2. SYSTEM MODEL
The IEEE 802.15.4 can operate either in a Beacon enabled or a non-Beacon enabled mode. The coordinator sends periodic Beacons in a Beacon enabled network, which allows the network nodes to make synchronization with each other and nodes communicate with a superframe structure. The non Beacon enabled mode is often used for light traffic between the network nodes. The MAC control and Beacon frames uses a slotted CSMA/CA mechanism to access the channel. Data frame that follows the acknowledgment of a data request command but acknowledge frame doesn't follow the slotted CSMA/CA mechanism [7, 8]. An IEEE 802.15.4 WSN is consist of a parent PAN coordinator and a set of children and parent nodes. There are two types of devices used in this

network: Full Function Devices (FFD) called parent nodes are ZC, ZR (Zigbee coordinator and Zigbee router) and Reduced Function Devices (RFD) called children nodes are ZR, ZED (Zigbee router and Zigbee end devices). The PAN coordinator initiating the network set-up and control the whole network [9]. ZigBee supports three kinds of networks topologies, which are star, tree, and mesh networks. A star network has a coordinator with devices directly connecting to the coordinator. For tree and mesh networks is formed by one ZigBee coordinator and multiple ZigBee routers and devices can communicate with each other in a multihop fashion. Beacons and superframe structure are an important mechanism to save power of nodes. In a tree network beacons are announced by coordinator and routers. However, in a mesh network, regular beacons are not allowed [10]. Star networks can operate both in beacon-enabled and non beacon-enabled modes. In the star topology each device (FFD or RFD) joining the network and communicate with other devices through ZC, which helps the node to communicate with its destination node. The star topology communication is centralized and is not satisfactory for most WSN due to the lack of scalability. In the mesh topology decentralized communication is achieved by each node which directly communicates with any other node within its radio range. The mesh topology operates in an ad-hoc fashion which is helpful to enable the enhanced networking flexibility, but it allows multi-hop routing from any node to any other node and induces an additional complexity for providing end-to-end connectivity between all nodes in the network. The mesh topology may be more energy efficient than the star topology. In cluster-tree topology any FFD can act as a ZR and provide synchronization services to its child nodes ZEDs or ZRs. There is a unique ZC in the network and one ZR per cluster. Where there is a single routing path between any pair of nodes using distributed synchronization mechanism [11]. In ZigBee, a device is said to join a network successfully if it can obtain a network address from the coordinator or a router. The main parameters, which are helpful for network formation, are the maximum number of children of a router (Cm), the maximum number of child routers of a router (Rm), and the depth of the network (Lm). A router can support a router or an end device in the form of its children i.e. Cm ¸ Rm. Distributed address assignment mechanism used parameters Cm, Rm, and Lm to calculate nodes' network addresses and it is a default address mechanism in Zigbee. The basic idea of the assignment is that for the coordinator, the whole address space is logically partitioned into Rm+1 block. The first Rm blocks are to be assigned to the coordinator's child routers and the last block is reversed for child end devices. The Cskip value computes the size of first *Rm* address blocks by coordinator. In ZigBee, the maximum network address capacity is 2^{16} = 65536, because 16 bit is used by nodes to assign the network address [12].

3. EXPERIMENTAL SETUP

The OPNET 14.5 modeler has been used for the simulation of Zigbee network. The preliminary simulation result has been presented to illustrate the attributes of mesh, tree and star topologies. The performance of these three topologies have been compared under different network configuration as shown in Table 1 using slotted CSMA/CA mechanism and also analyze the performance of mobile coordinator in different network topologies.

Table 1: Simulation Parameters

Network Scale	45 m * 45 m
Mobility Model	Random Waypoint
Number of Nodes	50
Frequency	2.4 GHz
Simulation Duration	300 s

In first scenario, the number of mobile nodes in each routing scheme varying from 10 to 50 and speed of mobile nodes is 1 m/s. There are total 50 nodes used in the network, when all 50 nodes in the network are mobile then the coordinator used in network is also mobile. In second scenario the network is totally mobile and speed of mobile nodes varying from 5 to 15 m/s.

4. RESULTS AND DISCUSSION

On the basis of different network configuration the following results has been observed:

4.1 Throughput

It is the data quantity transmitted correctly starting from the source to the destination within a specified time (seconds). The importance of analyzing this QoS parameter is because the increased numbers of users of the wireless medium is the reason for increased possibility of interference. Throughput is quantified with varied factors including packet collisions, obstructions between nodes and the type of used topology. During the simulation throughput as a global statistics has been measured so any object could contribute to its value. It gives a general idea of the overall throughput of the system.

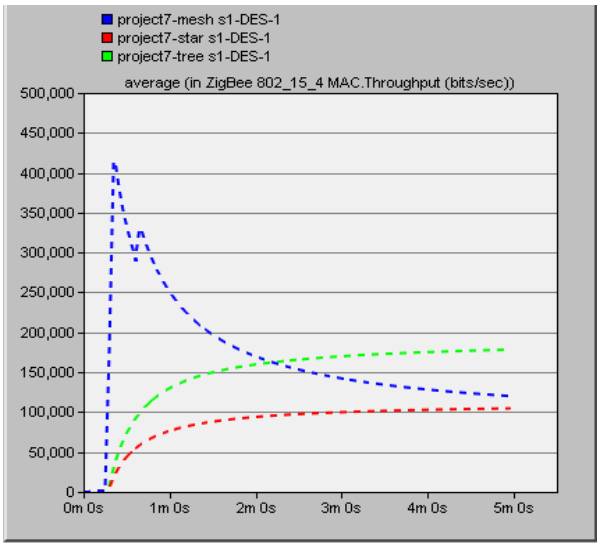

Fig 1: Throughput of Zigbee Network Topologies with Speed of Mobile Nodes 5m/s

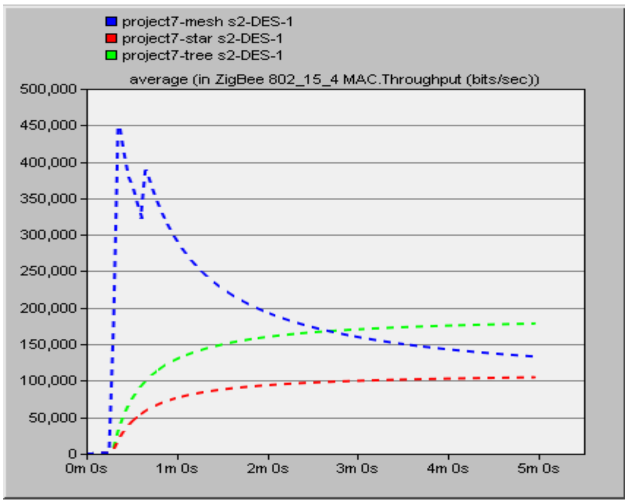

Fig 2: Throughput of Zigbee Network Topologies with Speed of Mobile Nodes 10m/s

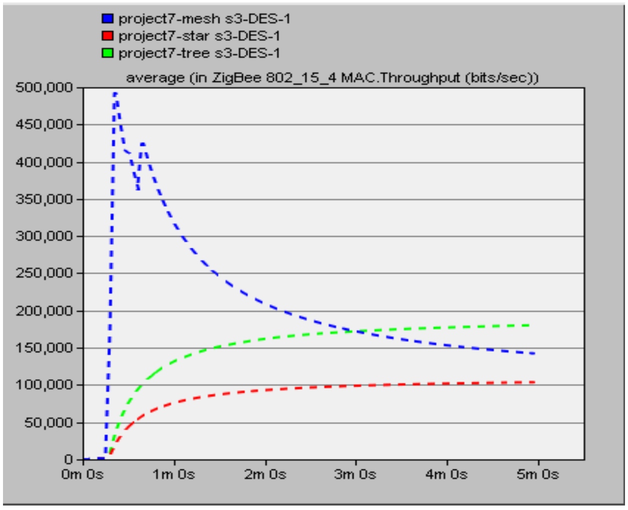

Fig 3: Throughput of Zigbee Network Topologies with Speed of Mobile Nodes 15m/s

The results shown in figure 1, 2, 3 the speed of mobile nodes vary from 5 to 15 m/s and in figure 4, 5 and 6 the mobile percentage of nodes vary from 10 to 50, where the maximum throughput achieved by mesh topology at starting of simulation time as speed and number of mobile nodes increase and goes down as simulation duration moves toward its end and the tree topology lagged by mesh topology with the increasing speed and number of mobile nodes but tree topology overcomes it at the end of simulation duration. The speed of mobile nodes doesn't affect the throughput of star topology it remains same in all case (referred to figure 1, 2, 3, 4, 5 and 6).

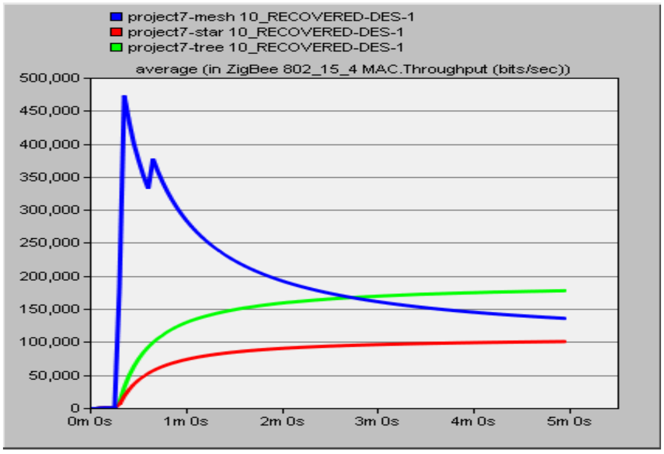

Fig 4: Throughput of Zigbee Network Topologies with 10 Numbers of Mobile Nodes

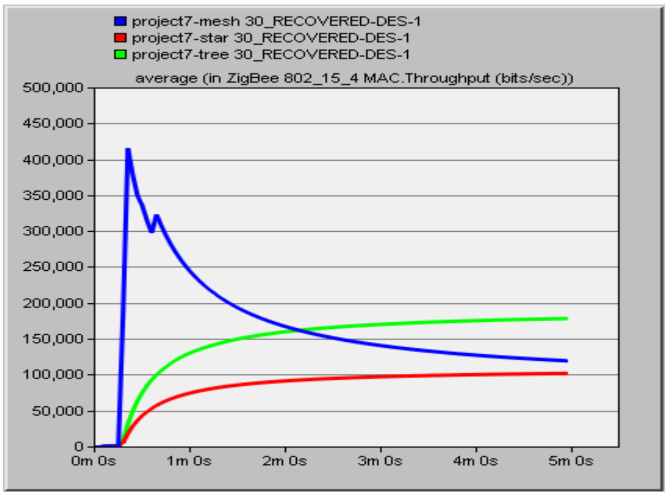

Fig 5: Throughput of Zigbee Network Topologies with 30 Numbers of Mobile Nodes

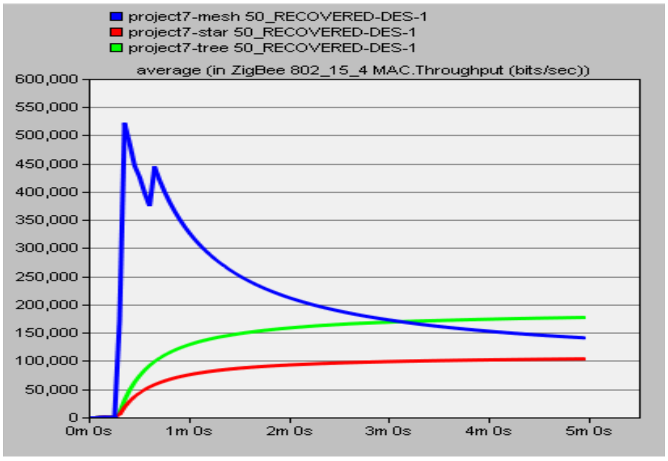

Fig 6: Throughput of Zigbee Network Topologies with 50 Numbers of Mobile Nodes

4.2 Number of hops

The number of hops is the number of times a packet travels from the source through the intermediate nodes to reach the destination [13]. There is no effect on mesh and star topology in case of number of hops it remain similar in both cases as speed and number of mobile nodes varies (referred to figures 7, 8, 9, 10, 11 and 12) but number of hops reduced in tree topology as speed and number of mobile nodes increases as shown in figure given below.

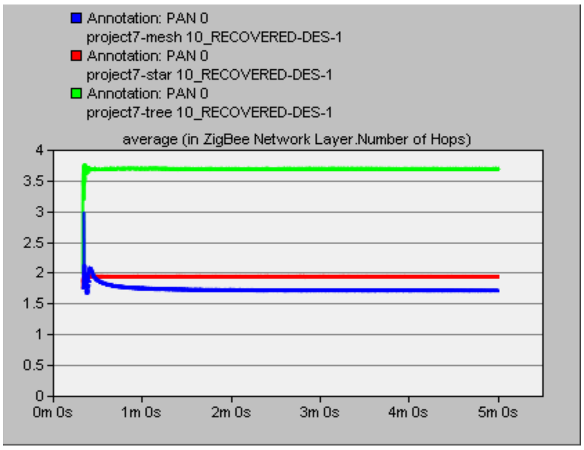

Fig 7: Number of Hops in Zigbee Network Topologies with 10 Numbers of Mobile Nodes

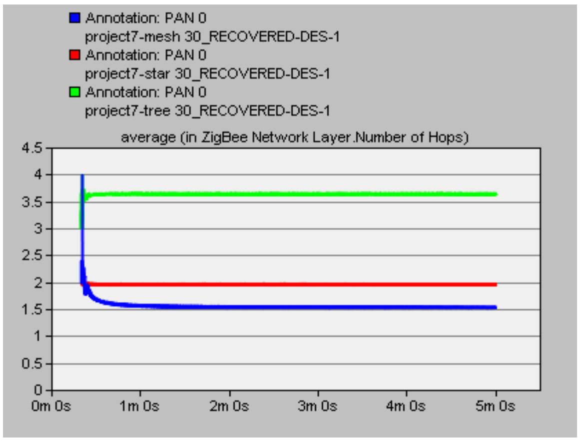

Fig 8: Number of Hops in Zigbee Network Topologies with 30 Numbers of Mobile Nodes

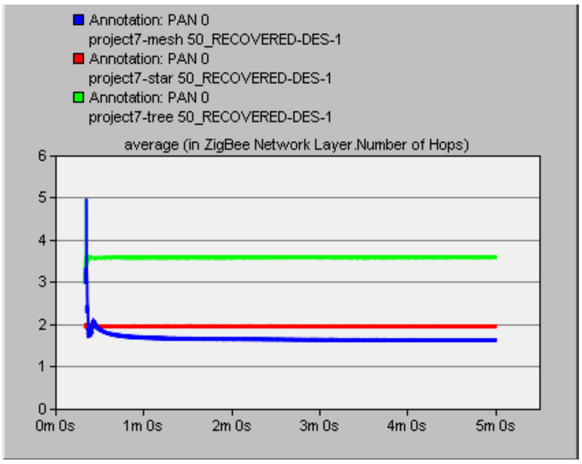

Fig 9: Number of Hops in Zigbee Network Topologies with 50 Numbers of Mobile Nodes

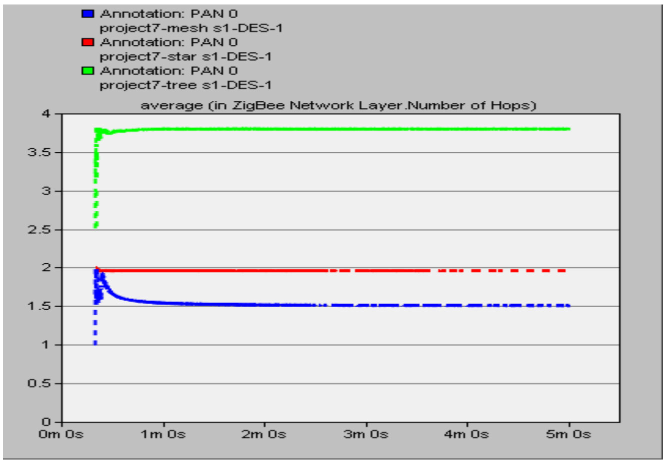

Fig 10: Number of Hops in Zigbee Network Topologies with Speed of Mobile Nodes 5m/s

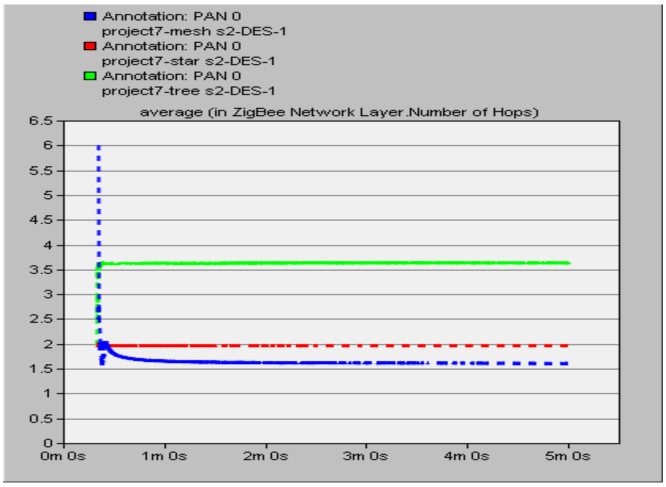

Fig 11: Number of Hops in Zigbee Network Topologies with Speed of Mobile Nodes 10m/s

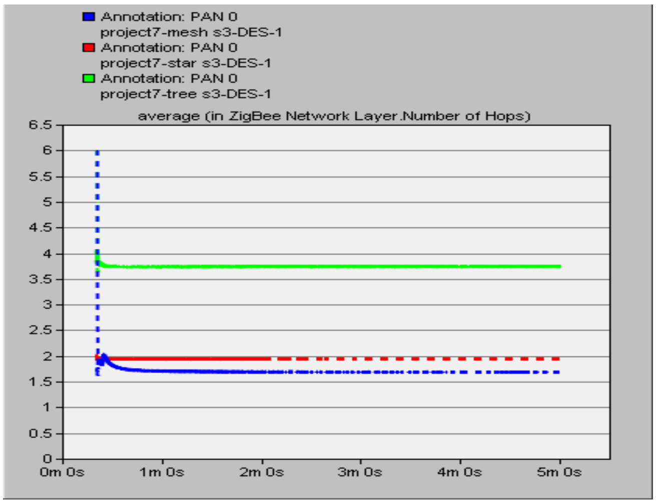

Fig 12: Number of Hops in Zigbee Network Topologies with Speed of Mobile Nodes 15m/s

4.3 Data Traffic Received (DTR)

These statistics record successfully received data traffic on this network interface from the physical layer. When these statistics are reported in units of bits/second, the physical and the MAC header sizes are included in the computation of the total amount of traffic received. These statistics record all the data received on the network interface regardless of the destination address. As referred to figure 13, 14, 15, 16, 17 the maximum data traffic received by tree topology in both scenarios and mesh topology receive minimum DTR. Star topology received average DTR between the values of mesh and tree topology but not affected by number or speed of mobile nodes as shown in figures given below.

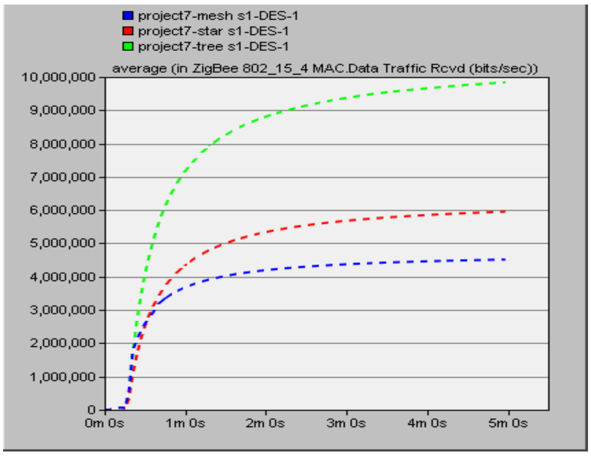

Fig 13: DTR in Zigbee Network Topologies with Speed of Mobile Nodes 5m/s

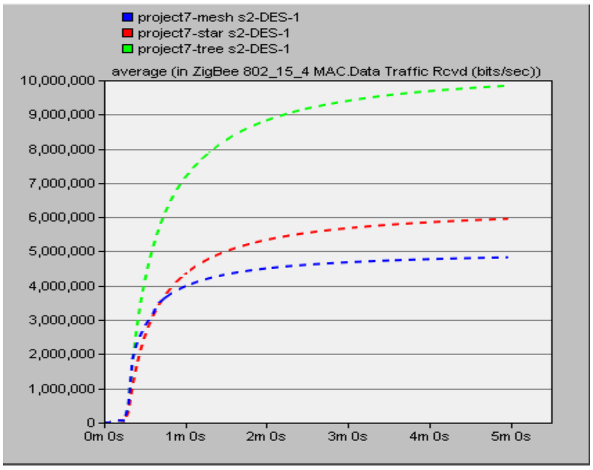

Fig 14: DTR in Zigbee Network Topologies with Speed of Mobile Nodes 10m/s

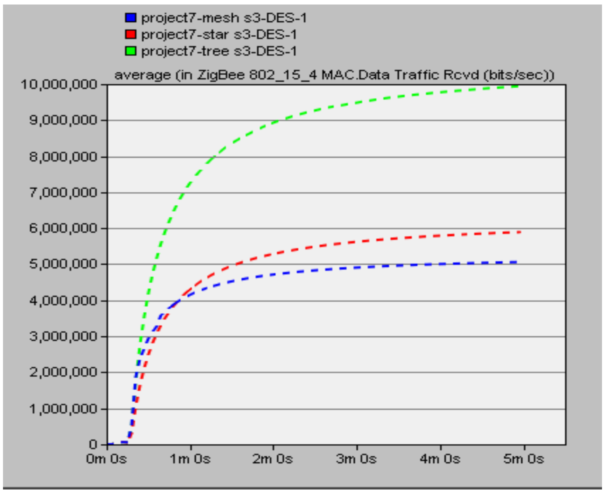

Fig 15: DTR in Zigbee Network Topologies with Speed of Mobile Nodes 15m/s

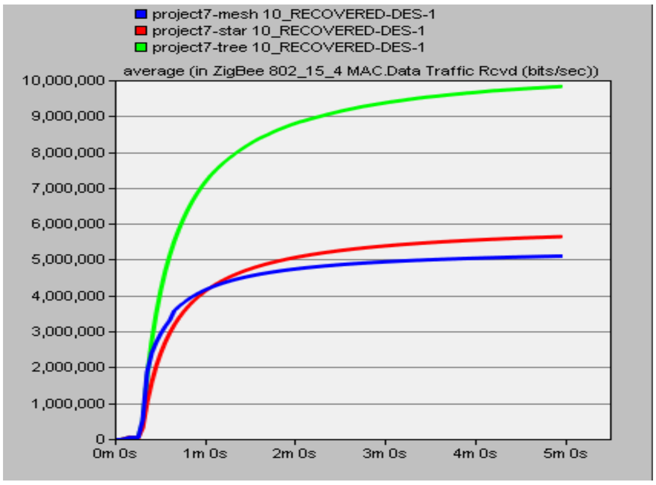

Fig 16: DTR in Zigbee Network Topologies with 10 Numbers of Mobile Nodes

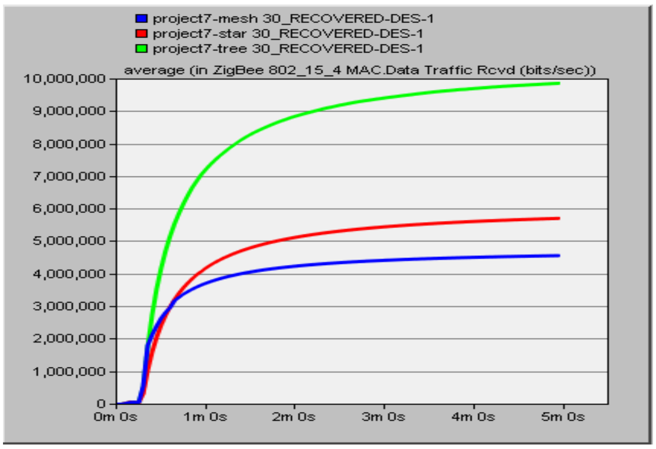

Fig 17: DTR in Zigbee Network Topologies with 30 Numbers of Mobile Nodes

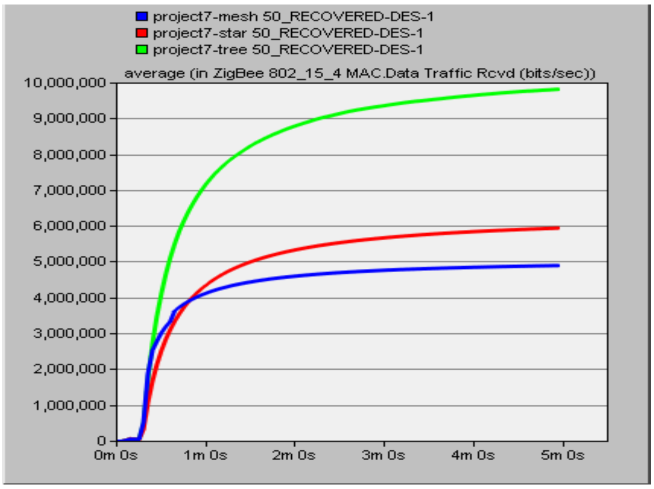

Fig 18: DTR in Zigbee Network Topologies with 50 Numbers of Mobile Nodes

4.4 Data Traffic Sent (DTS)

These statistics record the amount of data transmitted by the network interface onto the physical layer. When these statistics are reported in units of bits/second, the physical and the MAC header sizes are included in the computation of the total amount of traffic sent [14]. The maximum data traffic sent by tree topology in both scenarios and mesh topology sent minimum DTS as shown in figure 19, 20, 21, 22, 23, and 24 given below. Data traffic sent by star topology is between the values of mesh and tree topology but doesnot affected by number or speed of mobile nodes as shown in the following figures.

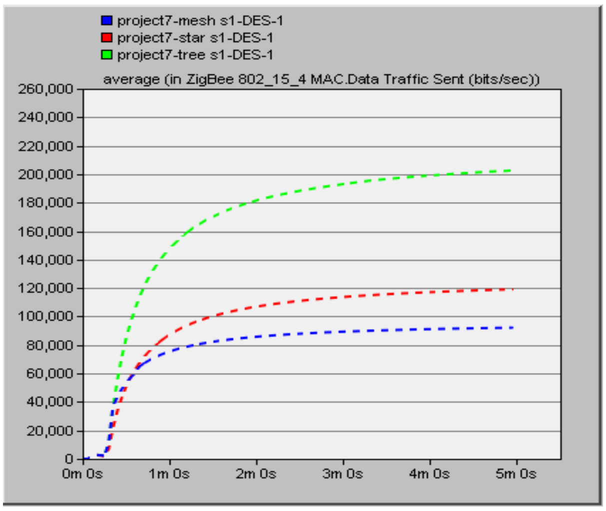

Fig 19: DTS in Zigbee Network Topologies with Speed of Mobile Nodes 5m/s

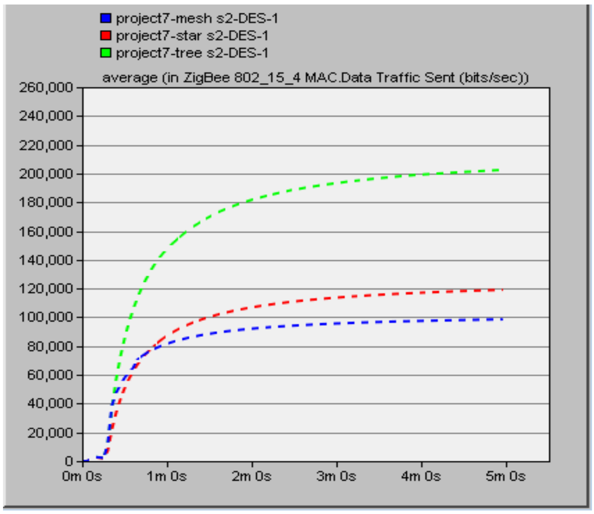

Fig 20: DTS in Zigbee Network Topologies with Speed of Mobile Nodes 10m/s

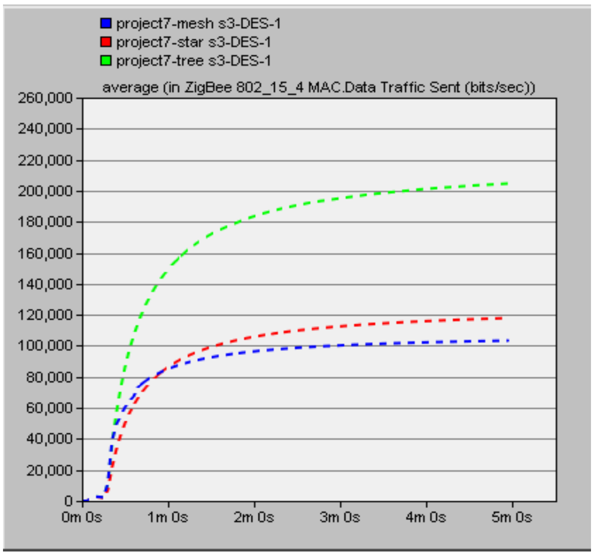

Fig 21: DTS in Zigbee Network Topologies with Speed of Mobile Nodes 15m/s

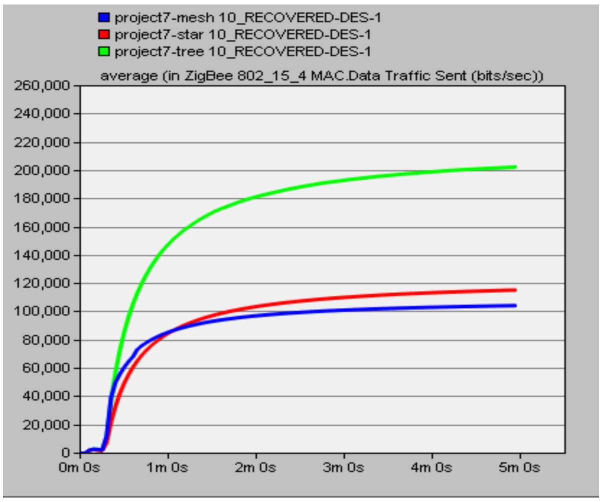

Fig 22: DTS in Zigbee Network Topologies with 10 Numbers of Mobile Nodes

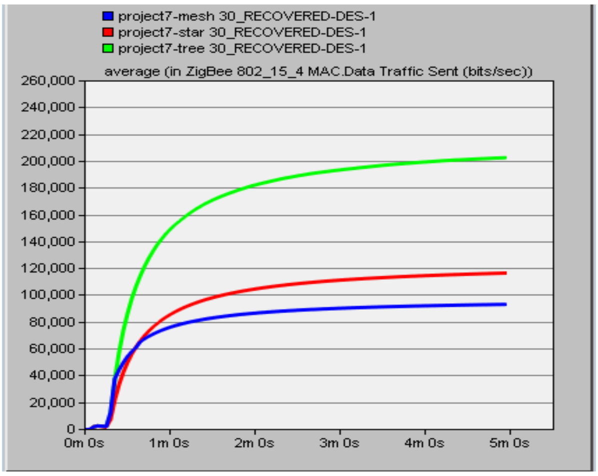

Fig 23: DTS in Zigbee Network Topologies with 30 Numbers of Mobile Nodes

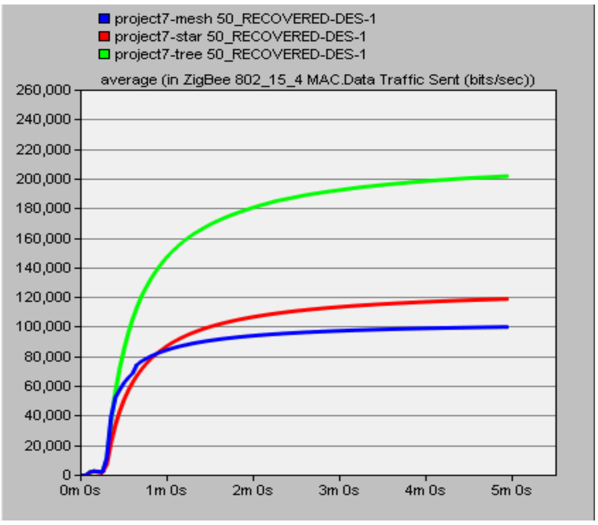

Fig 24: DTS in Zigbee Network Topologies with 50 Numbers of Mobile Nodes

5. CONCLUSION

From the simulation results it is observed that the throughput in tree topology is highest at the end of simulation duration but almost the mesh topology get maximum throughput as number and speed of mobile nodes increases. Throughput of star topology is similar in all cases. The number of hops remains same in star and mesh topologies but in case of tree topology it goes on decreasing as number and speed of mobile nodes increases. Mesh topology receive minimum DTR and DTS. The maximum data traffic sent and received by tree topology in both scenarios but in case of star topology the DTS and DTR is similar in all cases, whose value is in between the range of mesh and tree values. Here the mobility doesn't affect the star topology. The overall performance shows that the performance of tree topology is better than star and mesh topologies.

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