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Impact of Coordinator Mobility in a Zigbee/IEEE 802.15.4 Based Wireless Personal Area Network

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ABSTRACT: A network which links a number of distributed low-power sensor nodes together, with every node devoted to a previously defined operation can be seen as a Wireless Sensor Network (WSN). The network must have the ability of collecting and transmitting the data created by end nodes effectively. The wide parts of Zigbee based LR-WPAN (Low Range-Wireless Personal Area Network) are- routers, coordinator and end devices. In this research paper the writers focussed on Zigbee based LR-WPAN and examined the impact of static and dynamic condition of Zigbee PAN Coordinator on the network performance. Here the evaluation is done on 3 topologies such as- mesh, star and tree with the support of Riverbed simulator. Writers advised that rather than building the dynamic end devices, the coordinator can move throughout the network region more easily, providing better performance of global network on static coordinator network with respect to end to end delay and throughput. For various configurations, different effects on network parameters are achieved. The primary objective of this work is to measure, by simulations, the impact of coordinator mobility in a ZigBee/IEEE 802.15.4 based wireless personal area network (PAN) and permit the people to form the network configuration as per the need and performance achieved here.

KEYWORDS: WSN, star, tree and mesh topologies, mobile coordinator, End to End delay, Throughput.

I. INTRODUCTION

The network performance is based on the configuration used which is for particular application. Here writers attempted to simulate by RIVERBED simulator the effect of several topologies on the global MAC statistics i.e. throughput, global application statistics i.e. end-to-end delay and global network statistics i.e. no. of nodes which shows average number of nodes propagated by application traffic in PAN. Mostly modern applications of Zigbee. Networks i.e. remote location event sensing deploy mobility of the nodes instead of stat structure.[9],[10] writers believe that the prime node (PAN coordinator) mobility highly affects the system performance. In section II, writers represented the Zigbee specification and its integration with IEEE 802.15.4, its protocol architecture and every layer parameters that we required and assembled in the study showed. ZigBee-compliant products work in unlicensed bands: 902 to 928 MHz (Americas), 2.4 GHz (global), and 868 MHz (Europe). The new data rates is 250 KB per sec at 2.4 GHz band (16 channels), 40 KB per sec at 915 MHz band (10 channels), and 20 KB per sec at 868 MHz band (1 channel). The transmission coverage range is from 10 to 75 m, based on the transmit power. As well, the higher output power of the radios is normally 0dbm (1 mW) [1]. However, ZigBee utilizes master-slave configuration, it can be made as mesh, star and cluster-tree configuration with minimum one coordinator available in the network. In the simple star configuration, ZigBee network can have maximum 254 end nodes around the coordinator. Many star configurations can be consisted in a clusters tree topology. Greater than 65000 nodes can be survived in a huge ZigBee network when the various clusters are managed by the upper coordinator. ZigBee coordinator can determine the beacon order and super frame order for the end nodes. For reducing the overlapping, beacon order should be much greater as compared to the super frame order. Hence, every device can communicate with the router or coordinator so that they are non-overlapping with respect to time. Particularly in the Peer-to-Peer (mesh) configuration, devices are permitted to sleep for power saving. In cluster-tree or star topology, end nodes can only communicate to the routers or coordinator in activate mode and can go to inactive mode mostly when there is no traffic load. IEEE 802.15.4 is a low-rate Wireless

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Personal Area Networks (WPAN) standard with high level of simplicity and stability. However, 2.4GHz band, is also used by the other wireless standards. The coexistence of the devices has become an important issue that they can operate without interference on each other. Especially with IEEE802.11 stations, IEEE 802.15.4 stations may be really important if the similar carrier frequencies are chosen. This scenario will cause to a Physical Layer (PHY) timeout. The effect of other systems (microwave ovens or Bluetooth) on IEEE802.15.4 results in an elaborated packet error rate, since, the level of below 10 % is not significant [2]. It indicates that the ZigBee interference has more impact on the IEEE 802.11g uplink as compared to the downlink. Moreover, the results show how IEEE 802.11g has greater impact by Bluetooth as compared to Zig Bee and how IEEE 802.11g affects the Zig Bee performance when the selected channels spectrum of operation co-inside [3].

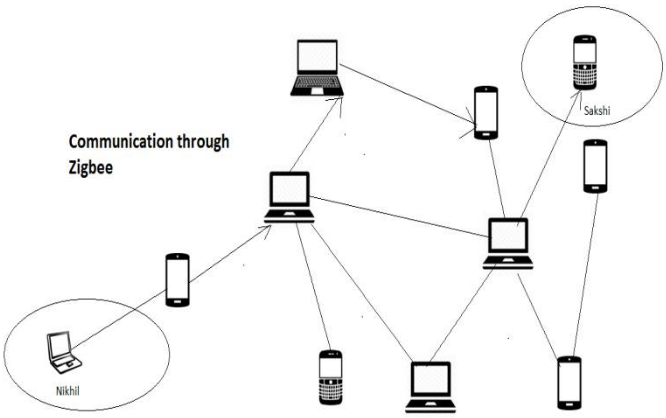

Figure 1: Zigbee Communication

IEEE802.11 standard utilizes Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) medium access method which provides support to the three configurations. The media access is depending on contention; since, employing the optional super frame structure, time slots can be assigned by the coordinator to devices with time based data. ZigBee coordinator can offer link to the other networks. [4].

In ZigBee networks, one of the most general transmission scenarios is that all devices forward packets to a sink. The overhead may have to be the serious challenge on performance analysis. Collision and interference could clearly reduce the throughput and packet delivery ratio of the global network. On this matter, tree topology is always employed to decrease end-to-end delay and drop the repeated packets which could be created in the same environment. Rather than the packets transmission directly to the sink, packets may be transmitted to the router first and then the router combines the obtained packets and forwards to the sink. Hence, the total packet delivery ratio can be enhanced with low overhead at the sink. The sink should be able to deal with huge amounts of data in comparison of the general end nodes. Relating to the simulation part, NS-2 [6] and QUALNET [5] are the most important tools for protocols simulation. Because of the fact that NS-2 was really formulated for IP networks and then explored for IEEE 802.11 wireless networks, QUALNET can analyze the ZigBee protocol more accurately without unessential overheads. Simulation should be carried out to examine how configuration, access mechanism, the amount of end nodes, traffic size and transmit power affect the ZigBee network performance. Same as ZigBee, Bluetooth offers short range links and works on 2.4 GHz band. Opposite to ZigBee, Bluetooth operates with maximum data rate up to 1Mbps which is much greater as compared to 250Kbps in ZigBee. Since, Bluetooth can only have maximum 8 nodes in a subnet cluster while ZigBee provides support to a large no. of end nodes and can have maximum up to 255 nodes in star configuration. Bluetooth could utilize scatter nets to explore the network with various piconets. Bluetooth has several different states and modes based on the needs of power and latency, i.e. park, sniff, active, hold etc [7]. Only sleep or active modes are utilized by ZigBee. When the end node is made shut down, ZigBee can activate from sleep mode in 15 msec or less while it consumes three seconds for Bluetooth devices to be active. The sleep mode substantially decreases the average power consumption and increases the battery life. Each device should have life of battery minimum two years to pass ZigBee certification [8]. Bluetooth utilizes three-slot technique and it‘s more effective for larger packet size. While slotted CSMA/CA technique is optional for ZigBee and it‘s more effective for transmissions of small packet size. Zigbee builds usage of less data rate and utilize lesser power consumption. Bluetooth, on the other side, works with greater

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power. Zigbee is normally utilized for control and monitoring while Bluetooth is all about link between laptops, PDA's, and other such devices. [9].

II. ZIGBEE-802.15.4- OVERVIEW

The development in wireless technology has lead to a growth of many standards particularly in the ISM radio band with frequencies**:** 868 MHz, 915 MHz and 2.4 GHz. The 868 MHz frequency band is employed primarily in Europe, the 915 MHz primarily in North America while the 2.4 GHz is employed throughout the world. There was often a requirement for a standard communication between sensors with low power consumption and low data rate. As a solution to this difficulty, several companies formed an alliance to produce a standard which could be accepted throughout the world. It was the Zigbee Alliance which produced Zigbee. [11] ZigBee is a specification depending on IEEE 802.15-2006 standard employed for high level communication protocols, building a personal area networks from small and low-powered digital radio system. ZigBee"s are able of propagating data over long distances by travelling data through intermediary devices, arriving more distant ones, hence building a network. The main elements of a Zigbee network are- routers, PAN coordinator, and end devices. All these components can be assembled to work with various applications as large as 124 at the same time. ZigBee"s are used in applications which need a longer battery life, lower data rate and protected networking. It has a defined 250kb/s data rate. The technologies explained in the ZigBee specification are planned to be simpler and less costly as compared to other (WPANs) technology.[6] ZigBee comprises of four layers. The top two (Application and Network & security) layers specifications are offered by the ZigBee Alliance to offer manufacturing standards. The bottom two (PHY and MAC) layers specifications are offered by the IEEE 802.15.4-2006 standard to assure availability without interference with other wireless protocols i.e. Wi-Fi. [12]

2.1 Zigbee Stack Protocol

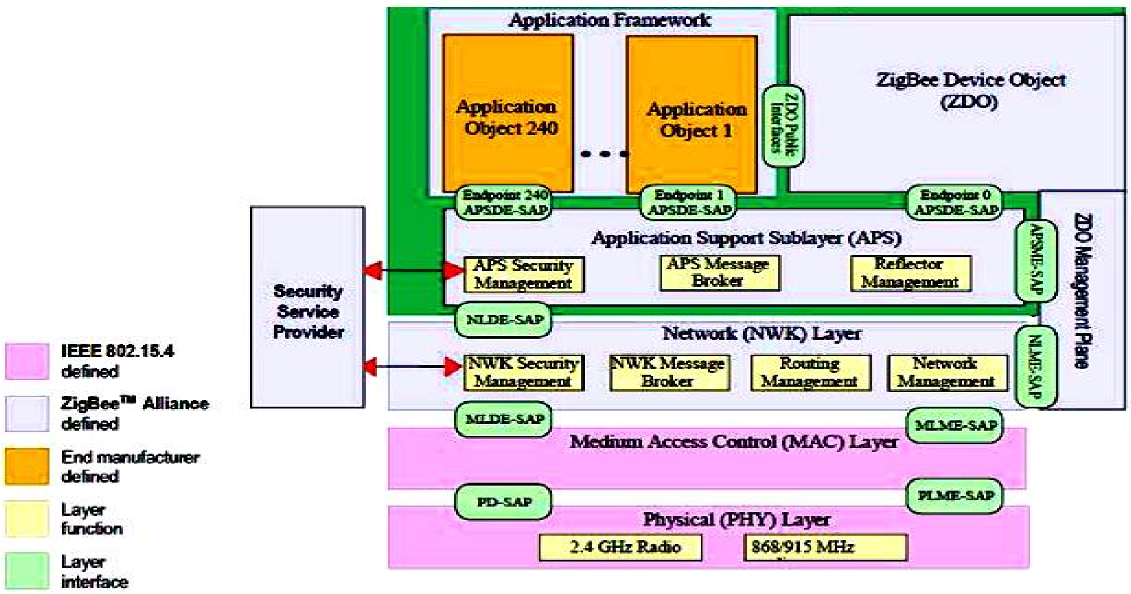

Figure 2: Zigbee Stack Protocol Layers [1]

2.1.1 Physical Layer

Zigbee employs three frequency bands for data transmission- 868 MHz band with a single channel having 20kb/s data rate. The 915MHz band with 10 channels and every channel having a central frequency distinguished from the nest band by 2 MHz and 40 kb /s data rate. BPSK modulation mechanism is employed in which symbols transmission is done at 1 bit per symbol. The 2.4 GHz ISM band having 16 channels, 5 MHz wide provides 250 kb/s data rate. It employs O-QPSK modulation with 4 bits/symbol transmitted utilizing DSSS with 32 Bit chips. [12]

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2.1.2 MAC layer-
The transmission Channel is obtained mainly by Carrier Sense Multiple Access- Collision Avoidance (CSMA-CA) protocol. The MAC layer can manage transmitting data. The MAC layer selects whether to employ unslotted or slotted CSMA-CA. It also manages the scanning of channel, starting PANs, discovering and resolving PAN ID issues, doing device discovery etc [12].In our scenarios we held channel sensing duration as 0.1 seconds for optimizing the consumption of power with acknowledgements enabled.

2.1.3 Network and Security layer-
The network layer manages device configuration, network startup, topology specific routing, and offering security. On every node, the network layer is the part of the stack that performs the route computations, neighboring node discovery and reception control. [12] In our work the route discovery time-out is held as 20 seconds, enough for network region of 100 meters coverage.

2.1.4 Application Support Sub Layer
It interfaces the application layer and network layer offering a basic set of facilities by two entities, APS Management Entity and the APS Data Entity. These offered facilities like group filtering, creating application level PDU, and maintaining Object database. [12]

III. ZIGBEE NETWORK TOPOLOGIES-OVERVIEW

3.1 Zigbee Network Devices:
3.1.1 Zigbee Coordinator (ZC): It is very capable device which makes the root of the network tree and bridge to other networks. It gathers and collect the network information. A coordinator has the following features: It • permits end devices and routers to integrate the network • guides in data routing• cannot sleep- always on device.
3.1.2 Zigbee Router (ZR): A Zigbee Router can perform as an intermediary device, propagating on data from other devices and also running an application function.
3.1.3 Zigbee End devices (ZED): Its task is to intercommunicate with the parent node (either the router or Coordinator).It cannot pass data from other devices. This relationship permits the node to be sleep a essential amount of the time hence providing long battery life. A ZED needs the minimum amount of memory, and so it is less costly in comparison of ZR or ZC.

3.2 Zigbee Network Topologies:
3.2.1 Star Topology: In star topology, a coordinator is the parent node and all other nodes are directly linked to it. Each data interchange between 2 end devices must travel first through the coordinator. This configuration is very much prone to collapses since the complete network goes down if the parent node fails. Using routers is a waste of energy here as their work is never actually utilized. [13]
3.2.2 Tree Topology: In tree topology, the parent node would be the network root node with hierarchical body. There is a point to point link between any 2 nodes such as a single route is available for arriving a node. Because of the self maintained ability of dynamic routing used, in situation of collapses the backup would be made from the vicinity at that instant (if exists).[13]
3.2.3 Mesh Topology: In mesh topology, data packets can be directly passed between the routers and then to nodes. They have no requirement to pass through the parent node. This network has various routes for arriving a node and therefore a backup can be prepared easily in failure circumstances for example- if a router stops working then any nearest router will accept the traffic of that router in a very limited time without striking the performance much.[13]

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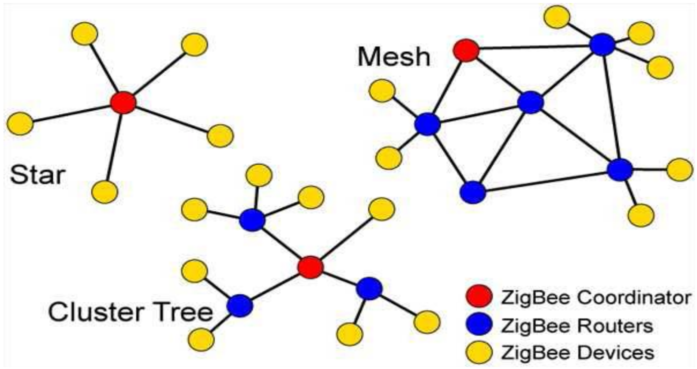

Fig 3: Star, mesh and tree topologies

IV. SIMULATION TOOLS

4.1Wireshark: Wireshark [11], previously called Ethereal, is a free and open-source and free packet analyser tool utilized for network troubleshooting and examine for Windows and Unix systems. It has been also utilized as a packet sniffing application and utilizes the pcap library to catch packets. It draws network data utilizing a libpcap file format supported by WinPcap and libpcap, so it can exchange caught network traces with other applications that utilize the similar format, involving tcpdump. Wireshark is a tool that realizes the structure of several networking protocols and thus can analyze the fields, along with their meaning as defined by several networking protocols. Apart from catching live traffic, it can also read several different capture file formats. This tool was very important for us in examining the raw network data such as tcpdump file and realizing the network data, which also permits several filtering options for network data visualization.

4.2 WEKA: WEKA [13] is a tool which composed of no. of machine learning algorithms for data mining tasks i.e. classification, data preprocessing, regression, clustering, association rule mining along with data visualization services. It is freely existed for downloading and can be utilized for academic aim. We have utilized this for computing 'Gain Ratio' and 'Information Gain'.

4.3 MATLAB: Matlab [14] is a tool utilized for numerical calculation, programming and visualization. It offers an easy platform to code and examine data along with in-built functions to conduct clustering, classification and visualization tasks. It can be also utilized with other programming languages i.e. java, C/C++ and Python. It has a rich set of toolkits which are easy to utilize and helps to decrease the time and enhance the work efficiency. We have utilized MATLAB for the aim of our main processing which involves performing clustering and classifying the general patterns utilizing one-class SVM.

4.4 jNetPcap: jNetPcap [16] is an open-source java library which consists java wrapper for closely all libpcap library native calls. jNetPcap utilizes a mixture of java and native implementation for optimal packet decoding performance. It supports to decode caught packets in real-time and offers a huge library of network protocols. It offers a framework for the subscribers to easily add their own protocol definitions utilizing java SDK. We have employed this library for the TCP headers information extraction.

4.5 LIBSVM: LIBSVM [12] is a library for Support Vector Machines. It provides support to regression (epsilon-SVR, nu-SVR), vector classification (C-SVC, nu-SVC) and distribution estimation (one-class SVM). It also provides multi-class categorization. LIBSVM offers a simple interface which subscribers can easily utilize to connect it with their own programs. We have utilized this tool for the aim of utilizing one-class SVM in Matlab. The primary characteristics of LIBSVM are:

- Deals with several SVM formulations
- permits effective multi-class classification
- Can perform cross validation for model selection
- permits probability estimation
- Easy usage of several kernels (involving pre calculated kernel matrix)
- permits to use weighted SVM for unbalanced data
- offers both Java and C++ sources

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- offers a simple GUI establishing SVM regression and classification
- offers extension to tools like R, Python, Perl, MATLAB, Weka, Ruby.

V. SIMULATION SCENARIOS FOR CAMPUS ENVIRONMENT

Riverbed is robust tool employed to simulate and model sensor networks. The latest version provides support to heterogeneous networks simulation which can be employed in many communications protocols. Riverbed provides support to network simulation at packet-level to examine static, mobile and satellite networks. The Riverbed modeled environment favors the Zigbee based sensor networks simulation by offering three elements. We have considered a campus having dimensions of 100m x 100m. The simulation results are then modeled. This practical environment can be employed to connect various Departments i.e. in Schools, Hospitals and College etc. Take a College consisting six departments and every department is linked to central coordinator. These departments are connected with 3 different network configurations namely mesh, star and tree topology. Efficiency of every network is measured. We have taken mobile Zigbee coordinators in the second scenario. These mobile coordinators are very important for an industry run application process or may be in field to keep track of enemies. We are taking two scenarios in account. First, writers are doing the comparison of the three possible topologies (Star, Mesh and Tree topology) to each other utilizing *six* ZigBee routers (ZR), only *one* ZigBee Coordinator (ZC), and *six* ZigBee End devices (ZED) in every configuration. This comparison involves global throughput and end-to-end delay. For the second scenario, we are considering the same three configurations and similar Zigbee devices but ZC as mobile that shown in figure 3, 4 and 5.

Table 4: Simulation Parameters

Examined Protocols Cases	DSR
Number of Nodes	100
Types of Nodes	Mobile
Simulation Area	60*60 km
Simulation Time	3600 seconds
Mobility	Uniform(10-100) m/s
Pause Time	200 seconds
Performance Parameters	Throughput, Delay
Trajectory	VECTOR
Long Retry Limit	4
Max Receive Lifetime	0.5 seconds
Buffer Size(bits)	25600
Mobility model used	Random waypoint
Data Type	Constant Bit Rate (CBR)
Packet Size	512 bytes
Traffic type	FTP, Http
Active Route Timeout	4 sec.
Hello interval(sec)	1,2
Hello Loss	3
Timeout Buffer	2
Physical Characteristics	IEEE 802.11g (OFDM)
Data Rates(bps)	54 Mbps
Transmit Power	0.005
RTS Threshold	1024
Packet-Reception Threshold	-95

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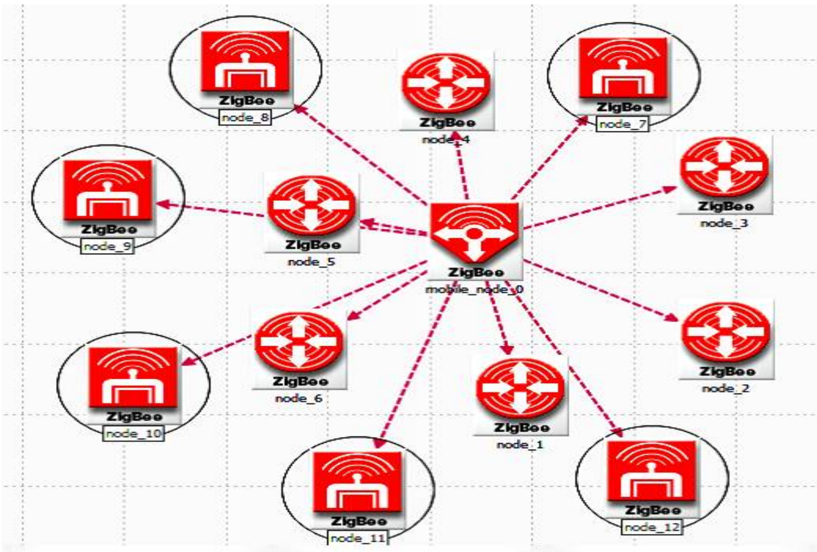

Fig-3 Dynamic Zigbee Coordinator-Star Topology

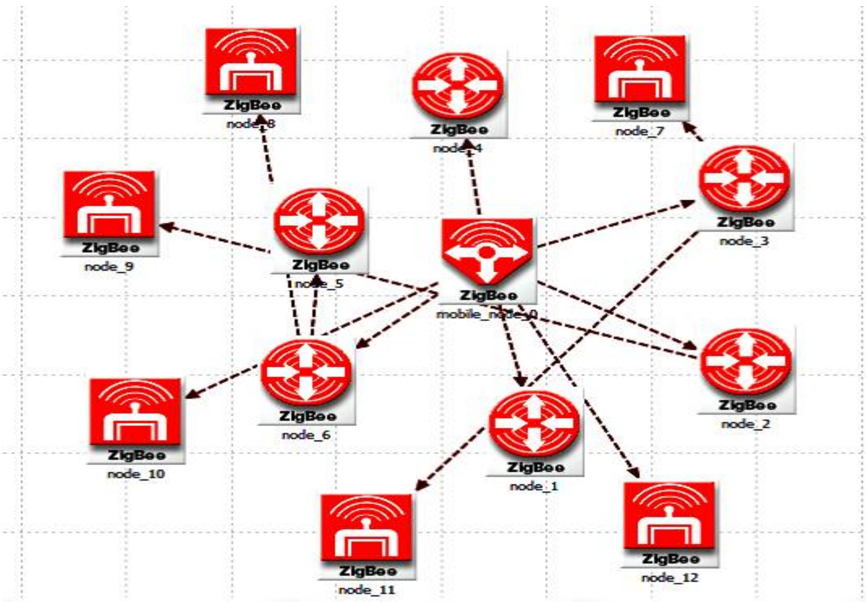

Figure 4: Dynamic Zigbee Coordinator-Mesh Topology

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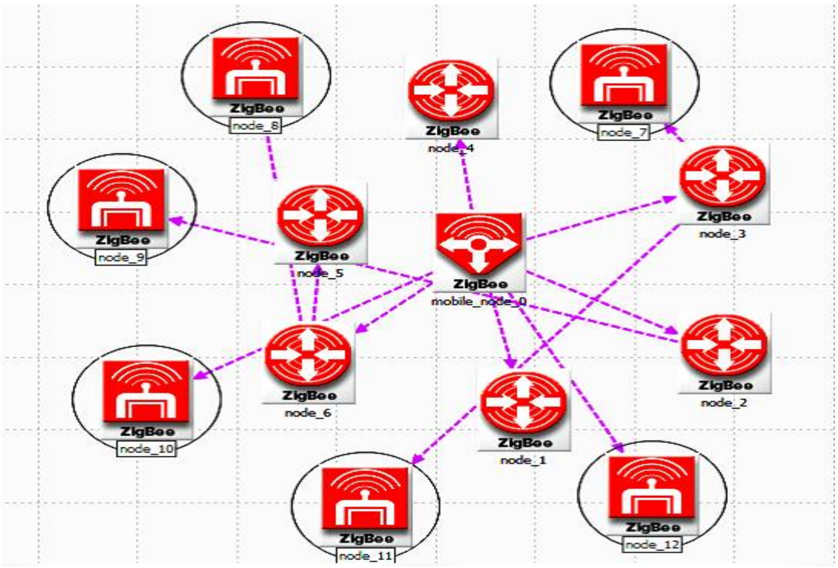

Figure 5: Dynamic Zigbee Coordinator-Tree Topology

VI. SIMULATION RESULTS

We have taken end to end delay and Throughput as the primary parameters for efficiency comparison between Mesh, Star and Tree topologies.

6.1 Throughput: The Network throughput is the rate of successful message delivery throughout a communication channel. This data may be arrived over a logical or physical connection, or pass through a particular network node. It is often evaluated in bits per second, bit/s or bps.

6.1.1 Throughput: Static Zigbee Coordinator: For ZC as Static, throughput is high in the case of Tree Topology with mean value of 35000bits/s that shown in figure 6. In the case of Star and Mesh Topology with mean value of 30000bits/s, 28000 bits/sec that shown in figure 6.

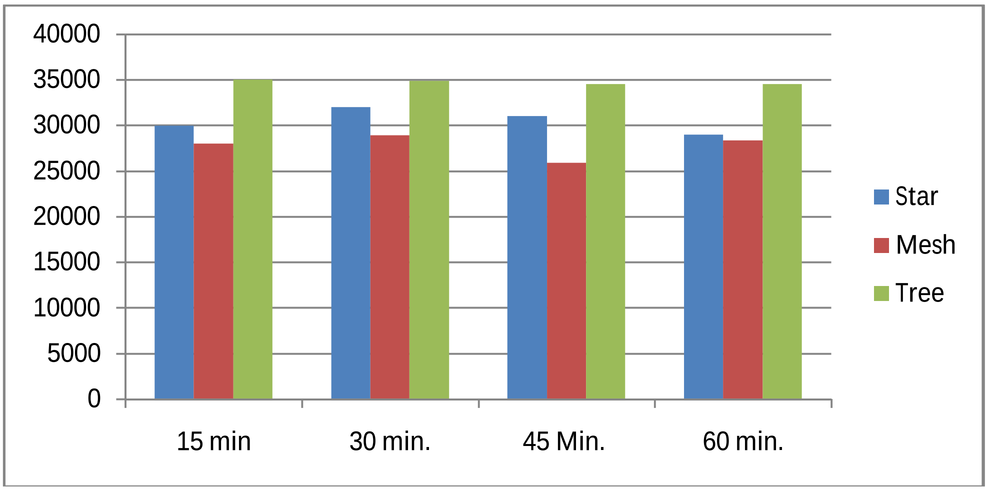

Figure 6: Throughput of Static Zigbee Coordinator

6.1.2 Throughput: Dynamic Zigbee Coordinator

For ZC as Dynamic, the performance of Tree topology is better in comparison of Static ZC with throughput little greater than the earlier by 35000 bits/s and the case of Star and Mesh Topology with mean value of 30000bits/s, 25000 bits/sec that shown in figure 7.

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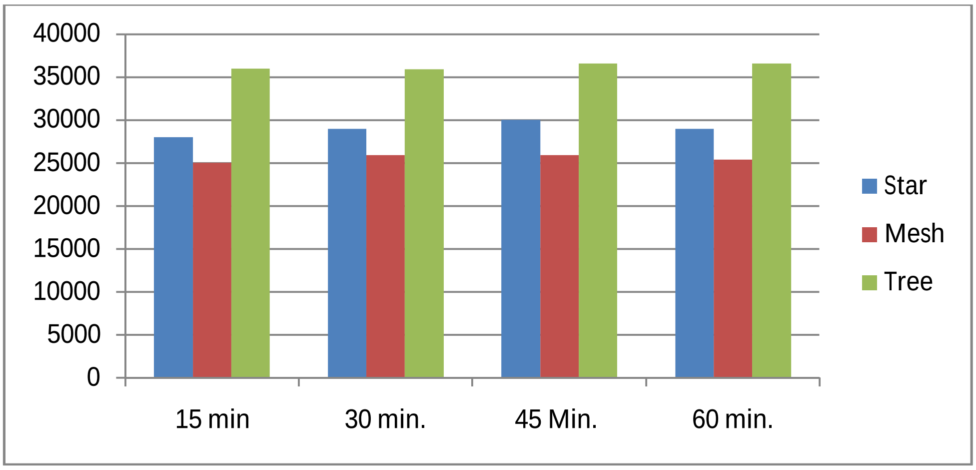

Figure 7: Throughput of Dynamic Zigbee Coordinator

6.2 End To End Delay:

End-to-end delay means the time taken for a packet to arrive from source node to destination node in a network.

6.2.1 Static Zigbee Coordinator end to end delay: ZC as Static Mesh topology is having minimum End to End delay of 0.0132s that shown in figure 8. In the case of Star and Mesh Topology with mean value of 0.015 seconds, 0.0181 seconds that shown in figure 8.

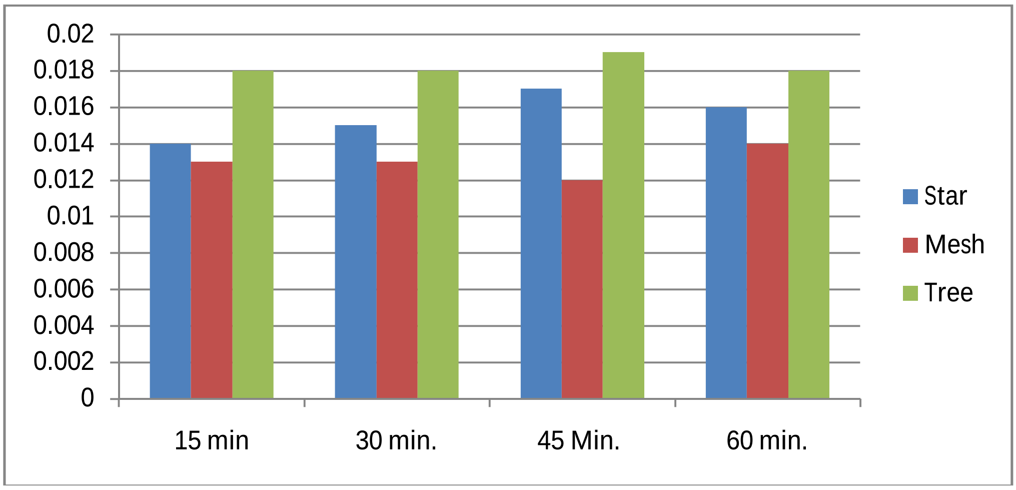

Figure 8: Delay of Static Zigbee Coordinator

6.2.2 Dynamic Zigbee Coordinator End to End delay: ZC as Dynamic, Mesh topology is having minimum End to End delay and has good performance in comparison of Static ZC.

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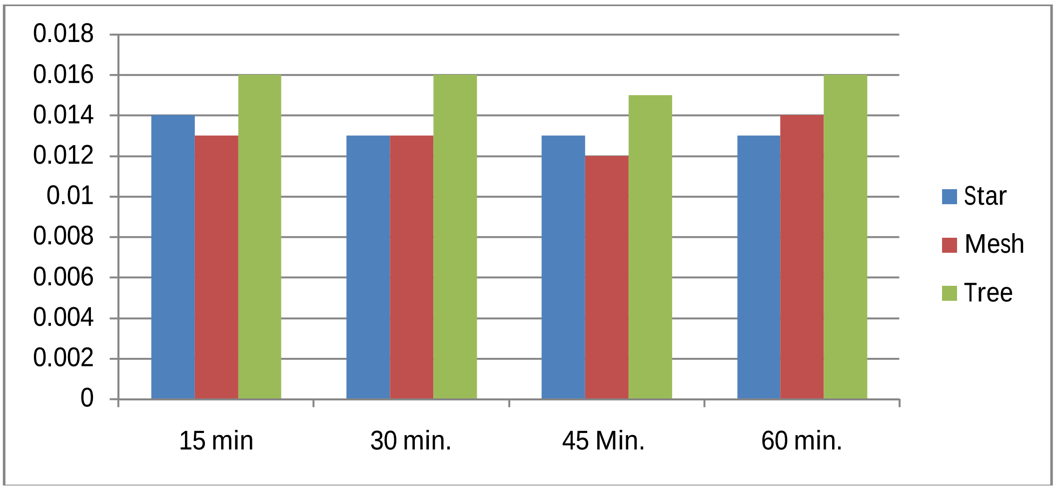

Figure 9: Delay of Dynamic Zigbee Coordinator

VI. CONCLUSION

In this research paper we have studied various analysis for obtaining optimal throughput and end to end delay for smart campus for Zigbee. By creating the coordinator as dynamic in Zigbee based LR-WPAN, throughput of tree topology enhances substantially in comparison of star and mesh topologies. Our Riverbed simulator results show that by utilizing dynamic coordinator least end-to-end delay is obtained. In dynamic, coordinator end to end delay decreases in comparison of static, therefore when end to end delay decreases automatically energy consumption also decreases. We can say that our analysis obtained good performance with respect to end to end delay and throughput for dynamic tree topology in comparison of any other. This work can be continued further for large scale WSNs.

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