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Performance Investigation of IEEE 802.15.4 ZigBee Routing Incorporating High Quality of Services

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Abstract— ***The wireless automation infrastructure started to connect sensors and actuators of commercial products a few years ago. ZigBee is one of the leading technologies that provide the functionalities expected for a Wireless Sensor and Actuator Network (WSAN). The routing capabilities are the main feature of ZigBee, thus, can also be used to build mesh networks. In this research paper we compared the performance of tree based routing and mesh routing in a ZigBee network on the basis of QoS parameters end to end delay, number of hops, throughput and overall network load. Simulations were done using network simulator OPNET Modeler 14.5.***

Keywords- IEEE 802.15.4, ZigBee, Zigbee Tree Routing, Zigbee Mesh Routing, QoS.

I. INTRODUCTION

ZigBee is a wireless technology based on IEEE 802.15.4 standard for Personal Area Networks (PANs). The IEEE 802.15.4 the ZigBee standard finds various applications like commercial & home applications, security, medical & agricultural applications etc. It defines the network and application layers on the top of physical and data link layers normalized in IEEE 802.15.4.ZigBee stack offers a wireless communication solution coupled with low cost, low energy consumption characteristics. Figure 1 shows the protocol stack for ZigBee. In ZigBee 868MHz, 915MHz or 2.4 GHz industrial scientific and medical (ISM)frequency bands are used for communication. The 2.4 GHz frequency band is very famous as it is an open band &mostly used in many countries worldwide. The 868 MHz band is specified for European use whereas the 915 MHz band can only be used in the United States, Canada and a few other countries and territories that accept the FCC regulations. The raw data rates is 250 Kbit/s at 2.4 GHz band (16 channels), 40 Kbit/s at 915 MHz band (10 channels), and 20 Kbit/s at 868 MHz band (1 channel). The transmission range is from 10 to 75 meters, depending on the transmit power. Besides, the maximum output power of the radios is generally 1 mW. The ZigBee specification categorizes three kinds of devices that integrate ZigBee radios: A coordinator, which arranges the network and maintains routing table. Routers, which can maintain routes as well as communicate with all kind of devices. End devices, which can communicate with routers and the coordinator, but not to each other. ZigBee devices can be either full functional devices (FFD) or reduced functional device (RFD)[6,7]. For example, coordinators and routers are FFD and end devices are RFD.

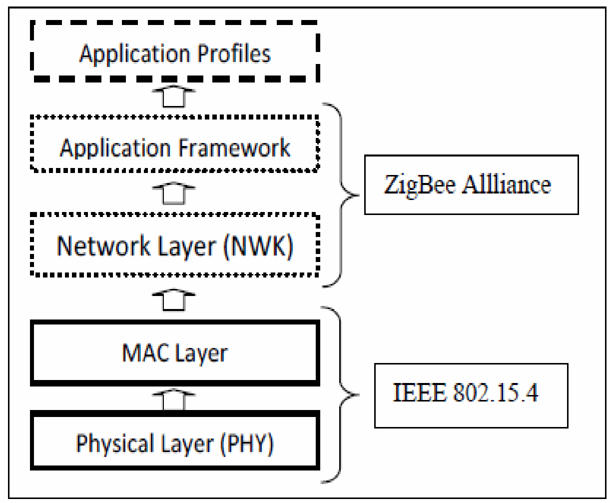

Fig1. ZigBee Protocol Stack

This paper presents the performance study of ZigBee routing. It consists in analyzing both ZigBee Tree routing and Mesh routing and comparing their performance in terms of end to end delay, number of hops, throughput and overall network load. The goal for this research is to obtain the most suitable routing technique for ZigBee networks.

II. ROUTING IN ZIGBEE

Routing is moving of information across an internetwork from a source to a destination. Along the way, at least one intermediate node typically is encountered [2].The goal of using routing is to establish an efficient route between a pair of nodes, so that messages can be delivered in a timely manner. Two routing schemes are available in ZigBee networks; mesh routing and tree routing.

In ZigBee mesh routing, route requests (RREQ) are broadcasted on-demand when data is to be transmitted to a destination of an unknown path. Routes are constructed based on the route replies (RRPL from intermediate nodes and destination node), and a route error (RERR) message is transmitted to the user when a path can't be found. The route repair mechanism repairs invalid routes when a previous route cannot be found. Since only coordinators/routers (FFDs) can actively participate in mesh Routing in a ZigBee enabled network is very similar to the one in a Mobile Adhoc network (MANET) [2].

The ZigBee tree routing is widely used in many resource-limited places and applications it doesn't require any routing table and route discovery overhead to send a packet to the destination .In TR protocol, an FFD device which is a router device called coordinator, is responsible to initiate the network by choosing certain key of network parameters. Other nodes can join the network by becoming the children of the existing node [3].

III. Literature Survey

A comprehensive review of the research work in the field of IEEE 802.15.4 ZigBee Ad-hoc Networks and its routing algorithms is reported by various researchers is presented below: In paper [4] authors evaluated the performance AODV and DSR for IEEE 802.15.4/ZigBee using matrices packet loss, packet delivery ratio, network throughput, average delay and energy consumption using NS2.Authors in [5] proposed the temporally planned Routing Algorithm for Geo-cast routing, in which Location based routing uses the routing method based on flooding and without flooding network & concluded that in flooding location based routing; by using two methods the network maintain a multicast tree. In [1] authors have evaluated the effect of topologies variation i.e. Tree, Star and Mesh on load, delay and throughput in different bands using ZigBee wireless sensors by means of OPNET modeler & observed that star, tree and mesh topologies have less delay and maximum throughput in 2450MHz band.

IV. Simulation Stepup

The basic network model is consisted of a coordinator, 8 end devices & 5 routers. Two identical networks were made for tree routing & mesh routing. Figure 2 & 3 shows the tree routing & mesh routing ZigBee network models respectively. The majority of the nodes have been configured with Random traffic; however Router 1 has been explicitly configured to send traffic to Router 3. The PAN in the Tree Routing scenario has been configured as a Default Tree Network. Application traffic will be routed to the destination along the parent-child links of the network tree. The PAN in the Mesh Routing scenario has been configured as a Default Mesh Network.

After mesh routes establishment (a few seconds after network formation), application traffic will be routed by the shortest possible route using any router or coordinator in the simulation as a relay. End devices do not participate in mesh routing, therefore they must still route traffic through their parent node. Figure 4 shows mesh network after routing.

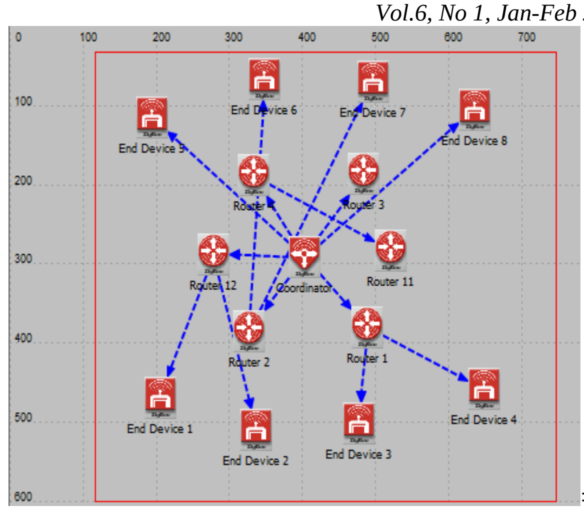

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Fig2. ZigBee Tree network

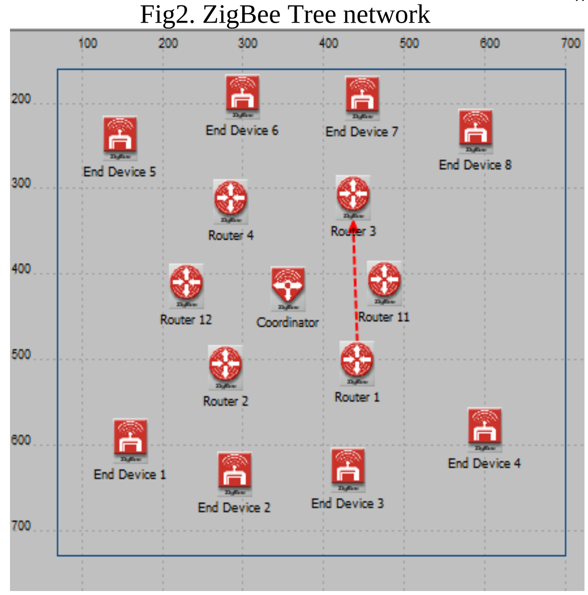

Fig3. ZigBee Mesh network

V. Results &- Discussuions

The average of end-to-end delay includes all possible delays caused by propagation, buffering during route discovery process, and retransmission by the failure of link [1]. End-to End delay is minimum in case of tree topology, about 17 msec., because it doesn't require any routing table and route discovery overhead to send a packet to the destination. Figure 5 shows comparative graph for end to end delay w.r.t simulation time in both mesh & tree network. Mesh routing has maximum end to end delay. The total load (in bits/sec) submitted to 802.15.4 MAC is represented by all higher layers in all WPAN nodes of the network [1]. Figure 6 shows the comparative graph for overall load w.r.t simulation time in both routing schemes. It has been observed from graph that the traffic received was maximum in tree topology because the end to end delay delivered by network using tree routing is minimum as compared to mesh routing. Tree topology has lower packet loss which leads to the maximum data traffic due to the lesser collisions. It is the average number of bits or packets successfully received or transmitted by the receiver or transmitter channel per second [1].

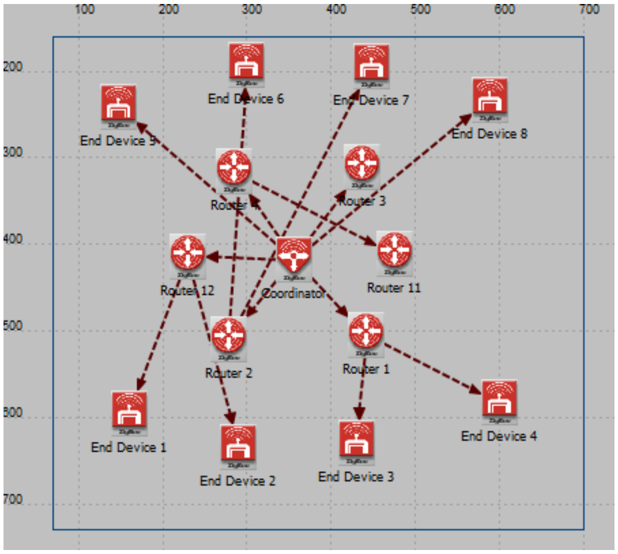

Fig4. ZigBee Mesh network after Routing

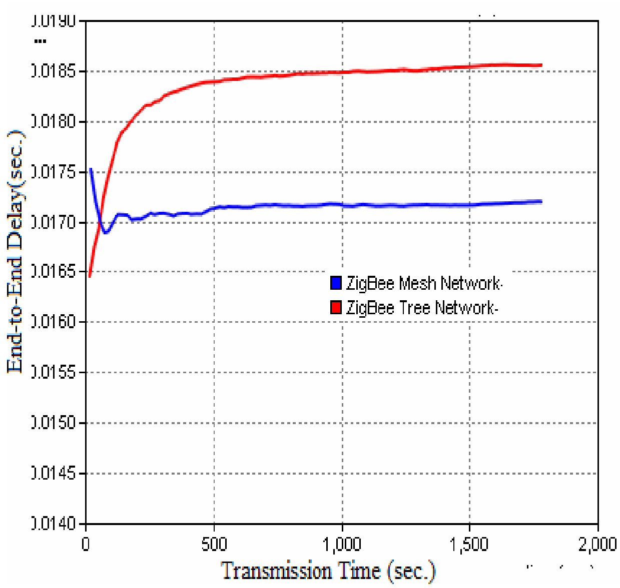

Fig 5: End-to-End w.r.t Simulation Time

Figure 7 shows the comparative graph for throughput with respect to simulation time for both mesh & tree routing. It has been observed from the graph that the ZigBee network using tree routing scheme delivered maximum throughput than the network using mesh routing scheme. It was observed that throughput was maximum in case of tree topology because, In tree topology the overall load of the network was divided among the routers and the coordinator due to which lesser collisions and lesser packet drops takes place which results maximum throughput in case of tree topology. In mesh Topology all nodes communicate with each other, therefore the communication between ZigBee end devices were not efficient than communication between end devices to coordinator or routers. Hence in mesh topology the throughput was less than tree-topology.

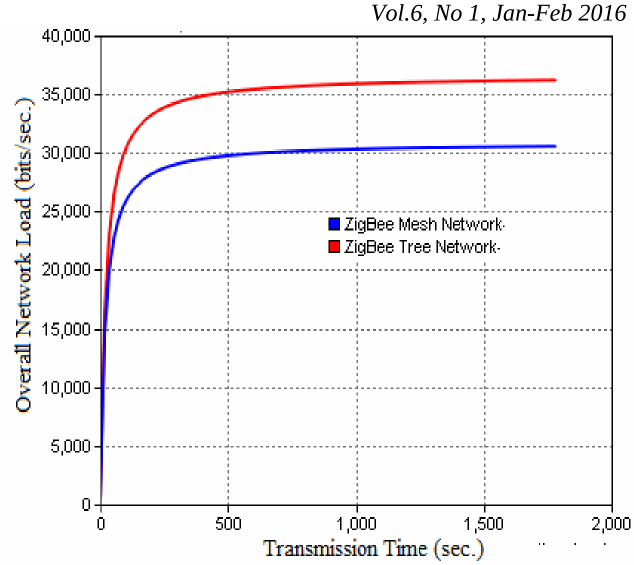

Fig 6. Overall Network Load w.r.t Simulation Time

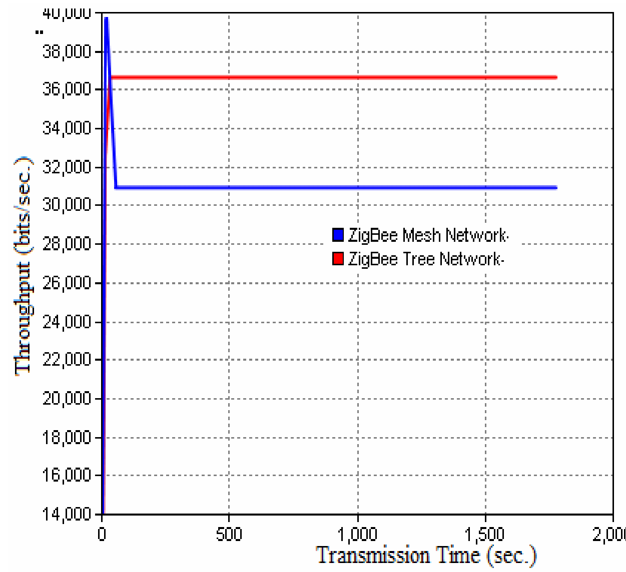

Fig7. Overall Throughput w.r.t Simulation Time

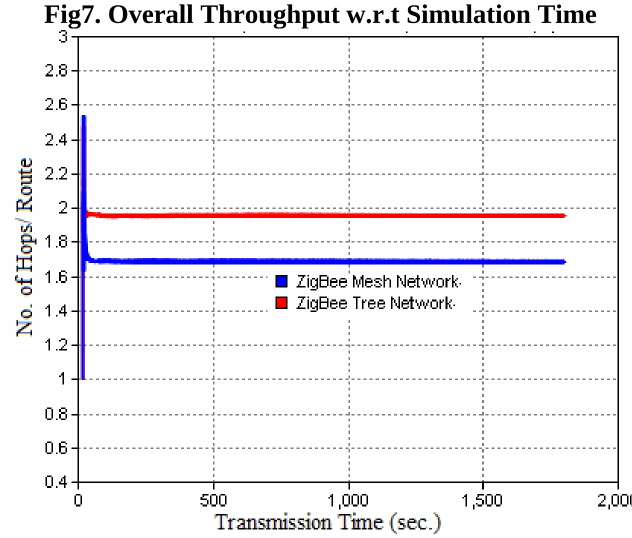

Fig. 8: No. of Hops/Route w.r.t Simulation Time

Figure 8 indicates the comparative graph for number of hops w.r.t to simulation time. Graph shows that the number of hops in tree routing scheme is maximum than mesh routing .Number of hops in tree routing scheme is about 1.6 while in mesh routing it is about 1.9. Results in Tabular form are discussed in table -1 as below.

Table 3: End-to-End Delay and Network Load using Different Nodes

Network Size	**Tree Network**	**Mesh Network**
End-to-End Delay (msec.)	17.13713	18.34227
No. of hops/route	1.68328	1.953681
Throughput (bits/sec.)	31020.17	36566.91
Overall Network load (bits/sec.)	29226.91	34553.55

VI. CONCLUSION

In this paper we analyze the performance of different ZigBee routing schemes. Two routing schemes: ZigBee Tree routing and Mesh routing are compared in terms of end to end delay, number of hops, throughput and overall network load. The results show that tree topology has minimum delay, maximum load, maximum throughput & maximum number of hops/routes than the mesh routing. It has been concluded that tree topology is more efficient and best suited for the ZigBee wireless sensors networks.

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