Performance evaluation and comparative study of Star and Cluster-Tree topology in ZigBee Network

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Abstract: In the new era, the ZigBee devices are rapidly used in the various fields, such as Internet of Things, Wireless Sensor Networks & in many more, because of their attractive advantages like simplicity, smaller size, lower data transfer rate, secure networking, powerful antenna coverage, Open Global Standard for wireless techniques, built for low power i.e. economical to deploy & digital-radio signals for PAN. It runs on IEEE 802.15.4 Standard i.e. applied in the number of applications such as automatic climate control in homes, industries & medical services. In this paper, we evaluate the performance results of star & cluster-tree topology, using the metrics of throughput, delay & ratio of packets transmitted with packets collided. By comparing both topologies, we explore that the cluster-tree topology has higher throughput & higher number of packets transmitted in advantage from star topology, but the star topology has lesser number of packets collided & short delay in advantage from cluster-tree topology. The problems that have occurred during the path are also evaluated using the ratio of Packets Transmitted with Packets Collided, thus the distraction in the path will be calculated.

1.INTRODUCTION

ZigBee mechanism is featured as simple, economic, lesser data rate & low power consumptionMoridi et al.(2018). Its most defining advantage is the secure transmission between the originator and receiver. This was attained by the company with 128-bit cryptographic keys. This method is used as a basis of symmetric keys, i.e. both the users of the same transaction are required to share the same keyMu and Han (2016). PAN is specially interpreted as LR-WPAN i.e.

invented for use in different types of applications such as WSNs. ZigBee established on IEEE 802.15.4 standard. This standard is designed to visualize the physical and MAC layers for LR-WPAN Medagliani et al. (2011). The root of the network is established by PAN Co-ordinator. It performs the following functions:-

a) Network creation

b) Waiting for the nodes, i.e. joining the connections automatically.

c) Authorize all nodes for the transmission within the network and storage of data.

Fig.1. Network architecture of ZigBee Star and Cluster-Tree topology

The intermediate nodes are used as co-ordinator(FFD) for communication between the PAN coordinator and end devices, because of limited communication range. The end devices are working as RFD's, such as they can only sense and transmit the data, but the intermediate co-ordinator can sense, transmit as well as receive data from other nodes.The end devices and intermediate co-ordinators are usually battery-powered, along with the PAN co-ordinator generally run on AC Power. In sleep mode, the end devices save a lot of energy, thus in the Star and Cluster-Tree topology, they are valuable.This analysis aims to measure the efficiency of the ZigBee network by comparing the relative study of the Star and Cluster-Tree scenarios using NetSim V 9.0. In this scenario, the end devices, PAN co-ordinator and intermediate nodes are randomly assumed. The mesh topology is less energy-efficient than others. Our centre of attention on the Star and Cluster-Tree topologies to evaluate the performance metrics of Throughput, Delay, Number of Packets Transmitted and Packets Collided based on the simulations.

2. Working Criteria

Number of research solutions are developed by explaining the single topologyAhmed et al. (2017), Wadhwa et al. (2015), Kim et al. (2009) and by comparing the 2 and 3 topologiesMoridi et al. (2018), Khalaf and Mokadem (2016). These solutions have a valuable effect on the improvement of results. The simulation process is merely used to analyse and optimize different topologies. This simulation is evaluated for the clarity of the performance and efficiency by comparing the Cluster-Tree and Star topology, using stationary nodes.

An analysis of QoS metrics i.e. Throughput, Delay, Packets Transmitted and Packets Collided are required by performance and efficient networks of ZigBee topologies.

Fig.2. Methodology of the proposed work

3. ZigBee Network Performance Metrics

The Star and Cluster-Tree topologies, which are used for high energy efficiency areas, are evaluated. The efficiency and reliability of a topology mainly consist of Throughput, Delay, Packets Transmitted and Packets Collided.

Any topology has a higher throughput, number of packets transmitted, less no. of packets collided, the lower delay between the transmission of packets is more advantageous.

In this paper, the following metrics are defined:

Throughput

It is the capability of a network, to send a specific amount of data successfully from source to destination in a particular unit of time. In this simulation, the Throughput (Mbps) is generated.

Delay

It deals with the time it takes to send a specific amount of data within the network from one end to another. It is mainly calculated in fractions of seconds. In this simulation, the delay is evaluated in Microseconds. Delays can vary slightly according to the placement of a particular set of communication endpoints.

Packets Transmitted

The number of data packets that can be successfully sent from source to destination in a particular unit of time is called packets transmitted.

Packets Collided

Whenever more than one node tries to send data over the network equivalently, then a packet collision occurs. If a packet collision occurs, the packets are either rejected or transferred back to the sender nodes and then retransmitted after a specific time period to avoid further collision. It results in a lack of packet integrity or also degrades the performance of a network.

Table 1: Definition of Parameters used.

Parameters	Details
Area	100*100 Meters
Node Placement	Random
Network Size (Nodes)	6 (Star), 10 (Cluster-Tree)
Network Topology	Star & Cluster-Tree
Physical & MAC Models	802.15.4 Radio
Antenna Model	Omni – directional
Location of PAN Coordinator	Centre
Traffic	ZigBee Application
Simulation Time	100 Seconds
Routing Protocol	DSR

4. Results & Examination

The resultant values are evaluated in the star and cluster-tree topologies through several performance metrics by random placement of nodes in the 100*100 meters area. 6 nodes are used in the star topology and 10 nodes in the cluster-tree topology to obtain results by simulating both scenarios for 100 seconds using DSR protocol. This examination is based upon the metrics of Throughput (Mbps), Delay (Microseconds), packets transmitted and packets collided (As mentioned above in section 3).

Fig. 3. Node scenario of the Star Topology

Fig.4. 10 node scenario of the Cluster-Tree Topology

4.1. Throughput

The throughput between both topologies is defined in Fig. 4. The maximum throughput between both topologies is 0.005729Mbps in the cluster tree topology, which is significantly reduced to 0.005723Mbps in the star topology. It is determined that the star topology produces a lower throughput related to the cluster tree topology because of fewer packets transmitted.

Fig. 4.Throughput Comparison of topologies in network-size of 1000*1000m^2

4.2. Delay

The delay is decreased in the star topology compared to the cluster tree as defined in the Fig.5. We have concluded that the delay will depend upon the number of nodes i.e. if the number of nodes increases and decreases then the delay will increase and decrease as well. The star topology produces a delay of 2423382.177843 microseconds, which is lower compared to 2433320.136505 microseconds of the cluster tree topology due to the lower number of nodes in the star topology related to the cluster tree topology.

Fig. 5. Delay Comparison of topologies in network-size of 1000 *1000 m^2

4.3 Packets Transmitted

The number of packets transmitted comparing both topologies is defined in Fig. 6. The maximum number of packets transmitted is 2123 in the cluster tree topology, which is significantly reduced to 2086 in the star topology. This is because the cluster tree topology scenario has a higher number of nodes related to the star topology scenario.

Fig. 6. Comparison of Packets Transmitted between topologies in network-size of 1000 * 1000 m^2

4.4. Packets Collided

In the star topology, the number of packets that collide is less compared to the cluster tree as defined in the Fig.7. This is because, in the star topology, the end devices are directly connected to the PAN coordinator. However, in the cluster tree topology, the devices may be connected directly or not to the PAN coordinator. Therefore only 3 packets collide in the star topology, which is very low from 31 packets collide in the cluster tree topology.

Fig. 7.Comparison of Packets Collided between topologies in network-size of 1000 * 1000 m^2

5. CONCLUSION

This is very imperative to determine a suitable ZigBee topology for the specific workstations.

In this paper, the ZigBee-based topologies are evaluated according to energy efficiency. The most essential network metrics are examined in the scenarios of the ZigBee star and cluster-tree topologies. In these scenarios Throughput (Mbps), Delay (Microseconds), Packets Transmitted and Packets that collide are assessed through simulations with differing nodes numbers.

Table 2. Comparison of the simulation results of Star and Cluster-Tree Topology.

Metric	Star	Cluster-Tree
Throughput	F	T
Delay	T	F
Packets Transmitted	F	T
Packets Collided	T	F

T is a better choice compared with F

In various areas, energy efficiency is a very essential issue, as well as achieving performance and efficiency.

In terms of performance, cluster tree topology having benefits of higher Throughput and higher packets transmitted, but in terms of efficiency, star topology has advantages of lower delay and lower packets collided. Therefore, it is assumed that both Topologies have their advantages, so the user can choose any topology, according to their specifications.

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