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Improving ZigBee AODV Mesh Routing Algorithm Topology and Simulation Analysis

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Abstract

ZigBee is one of the newest technologies developed by ZigBee Alliance and is an emerging standard for the low cost, low power and low rate wireless networks and the ZigBee technology is well suited to a wide range of energy management and efficiency applications in areas such as building automation, industrial, medical and home automation. ZigBee is a version of AODV routing protocol, where the routes are discovered RREQ through the network by the source broadcasting and sending RREP back the destination, so make ZigBee routing efficient. This paper used AODV mesh topology methods to send and receive data from source to destination and vice versa. In this paper we present an improved version of ZigBee-AODV mesh network, which utilizes and divide the topology of network into one or more logical clusters and restricts the flooding of route request outside the cluster. ZigBee-AODV mesh network uses nodes of the same cluster to share routing information, which significantly reduces the route path discovery and created cluster formation to decrease the routing path. The proposed protocol has higher reliability and lower overhead than AODV. We have done to figure out the various proposed modified algorithms based on the standard routing protocols, which have better network performance in terms of Average MAC control traffic sent/received, Average MAC data traffic sent/received, Average end to end delay, Packet loss (%), Network Lifetime, Throughput, Average Numbers of Hops, Average Packets Dropped, Normalized Routing Overhead, etc. As compare to standard routing algorithms used in ZigBee-AODV mesh network.

Keywords*: ZigBee, AODV, mesh topology, 802.15.4, routing protocol*

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1. Introduction

This paper simulates and explores the performance of ZigBee AODV mesh network under various conditions using OPNET modeler simulation tool.

The ZigBee NWK supports star, tree, and mesh topologies. In the star topology, the network is controlled by a single device called the ZigBee coordinator [1]. The ZigBee coordinator is responsible for initiating and maintaining the devices on the network. All other devices, known as end devices, directly communicate with the ZigBee coordinator. In mesh and tree topologies, the ZigBee coordinator is responsible for starting the network and for choosing certain key network parameters, but the network may be extended through the use of ZigBee routers. In ZigBee tree networks, routers move data and control messages through the network using a hierarchical routing strategy [2]. ZigBee enables devices to self-assemble into robust wireless mesh networks that automatically configure and heal themselves, and enable many individual devices to work for years on battery power alone [3].

Because ZigBee is a mesh network, every device is connected to all surrounding devices wirelessly. When data is transmitting ZigBee mesh network will find the best route for data traveling. If for any reason the preferred route becomes unavailable (e.g. device is not powdered, strong interference, etc). ZigBee mesh network will find a new route for the data by relaying it through other pathways [4]. Another benefit of ZigBee mesh network is that if a device loses its signal and can no longer transmit data through its current RF pathway, it will reroute its data to reach its destination through another RF pathway to reach its destination and each ZigBee Mesh network is capable of handling hundreds of nodes (devices) [5].

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A solar energy powered bicycle by a wireless sensor network (WSN) far-end network monitoring solar energy to transfer the electrical energy storage and the effectiveness analysis is proposed [8-9]. The primary goal of this paper is to improve the routing protocol of ZigBee wireless sensor network using AODV Mesh routing Algorithm and to better understanding of the use of OPNET simulation tool as well as to study the interest of ZigBee protocol and providing a brief overview of what ZigBee protocol is then simulating several simple examples of ZigBee AODV mesh networks using OPNET modeller simulation. The scope of this paper is to analyze a set of performance parameters on AODV and ZigBee routing protocols to enhanced ZigBee AODV mesh routing because of their simplicity and performances when implemented in ZigBee. The paper concentrates on the performance analysis of ZigBee AODV mesh routing for better understanding of protocol efficiency and flexibility [10].

2. ZigBee AODV Mesh Routing Algorithm Topology

According to the topology model, our objective is to improve an efficient routing algorithm for by using AODV Mesh routing Algorithm to improve ZigBee wireless network routing protocol as shown in figures below:

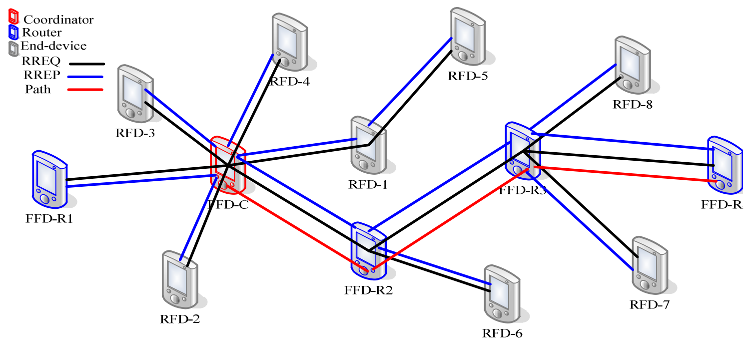

Figure 1. The Example of ZigBee AODV Algorithm

In order to describe the algorithm and he model; see the example in Figure 1. The coordinator FFD-C is a source node and FFD-R4 is a destination nodes set to illustrate the principle approximation algorithm. This algorithm implementation process as follows:

Step 1: Our network was just formed and there are no entries in the routing table. An application needs to send a frame from the FFD-C to the FFD-R4 router on the far right, and the FFD-C source node must discover the route to theFFD-R4 destination node by broadcasts RREQ Packet contains information such as source id, source address, destination address, destination id and so on.

Step 2: As can be seen form Figure 1 and Table 1, the FFD-C node broadcasts RREQ command frame payload its RREQ id and destination address to the neighbor nodes FFD-R1, FFD-R2, RFD-1, RFD-2, RFD-3, and RFD-4.

Step 3: Each nodes receives RREQs command frame from the sender node creates RREP command frame and sends it back as a unicast frame to node that originated the route request.

Step 4: In the same way, the broadcast continues to propagate through the network, each node receives route request command frame will create an entry table for it, so RFD-1 node broadcasts RREQ command frame to RFD-5 and FFD-R2 router node broadcast RREQ command frame to nodes FFD-R3 and RFD-6, and this time the sender changed to reflect the address the request was received from.

Step 5: New entries are again created; the route request continues to propagate until the route request reaches its destination, so the sender now is the node FFD-R3 broadcast RREQs to FFD-R4, RFD-7, and RFD-8.

Step 6: FFD-R4, RFD-7, and RFD-8 are directly connected from FFD-R3 and the route request reaches its destination, so finally it reaches its destination, and now all nodes contain a route discovery entry for the route request. The destination nodes (FFD-R4) create a route reply (RREP) and send it back as a unicast frame. The next hop is specified by the sender address in its routs discovery entry, and works the same steps from step 1~step 6 payload the RREP command frame from the (FFD-R4) destination node to (FFD-C) source node and from destination node to the source node route reply paths are fulfilled: FFD-R4 →FFD-R3→FFD-R2→FFD-C as shown in Figure1 and Table 2.

Step 7: the complete route is not contained on any (RFD) end devices. Each device just knows the next hop in the path in the way to the destination node, and from source node to the destination node route paths are fulfilled: FFD-C →FFD-R2→ FFD-R3→ FFD-R4.

Table 1. Route Request (RREQs) Entry Table

Process name	Source id	Source address	Node sender	Nodes neighbors
1	FFD-C id	FFD-C address	FFD-C	FFD-R1, FFD-R2, RFD-1, RFD-2, RFD-3, RFD-4.
2	FFD-C id	FFD-C address	FFD-R2,RFD-1	FFD-R3,RFD-6,RFD-5
3	FFD-C id	FFD-C address	FFD-R3	FFD-R4, RFD-7, RFD-8

Table 2. Route Reply (RREPs) Entry Table

Process name	destination id	Source address	Node sender	Nodes neighbors
1	FFD-R4 id	FFD-C address	FFD-R4	FFD-R3.
2	FFD-R4 id	FFD-C address	FFD-R3	FFD-R2
3	FFD-R4 id	FFD-C address	FFD-R2	FFD-C

3. Simulations Model and Processing Implementation Using OPNET

Network simulators such as OPNET, NetSim and NS2 can be used to simulate IEEE 802.15.4 ZigBee networks. These simulators come with open source C or C++ libraries for users to modify.

The simulation model implements IEEE 802.15.4 physical and medium access control layers and ZigBee application and network layers.

This scenario is a general and simple case to observe the behavior of ZigBee network in OPNET, the OPNET Modeler 14.5 simulation supports many topology where the communication is established between devices, called inside the (RFD) model End Devices, and (FFD) a single central controller, called PAN Coordinator. Each device operates in the network must have a unique address.

The wireless module extends the functionality of the OPNET Modeller with accurate modelling, simulation and analysis of wireless networks leading discrete-event network modelling and simulation environment.

3.1. Simulation Models

In the ZigBee AODV mesh topology, RFDs are Full Function Devices which can communicate with each other, but in the star topology, the RFDs only have one hop to the FFD coordinator. The mesh topology uses AODV routing protocol which is suitable for large scale networks. ZigBee AODV mesh topologies in the following are deployed in the office scale 10m X 5m square area with 5,12,30,50 nodes, the simulation time of one run is equal to 20 minutes with the development kernel type, network formation threshold (5.0), and simulation balance interval (100000), in OPNET as shown in the Table 3.

Table 3. ZigBee Network Model Scenario

ZigBee Dialog Name	Value
Initial Topology	Select the default value: Create empty scenario.
Choose Network Scale	Select Office. Select the use metric units.
Specify Size	Select the default size: 10 m x 5 m
Select Technologies	Include the ZigBee model family.
Review	Check values, and then click Finish.
Duration	20 minutes
Seed	128
Values per statistic	100
Update interval	500000 events
Simulation kernel	Development
Packet Reception Power Threshold	-85
Transmission Power	0.05
Transmission Bands	Worldwide 2450 MHz Band
Initial Topology	Select the default value: Create empty scenario.
Choose Network Scale	Select Office. Select the use metric units.

3.2. ZigBee Simulation Processing Implementation

The figures of this part explains the management and control traffic transmitted by the end devices to perform route discovery. It shows that FFD coordinator or router receives traffic from all neighboring devices initially and it can be seen that stationary router picks up the end device traffic and continues to route the traffic payload the data to the destination and performs route discovery to find th next optimal path to its destination as shown in Figure 4, 5 below:

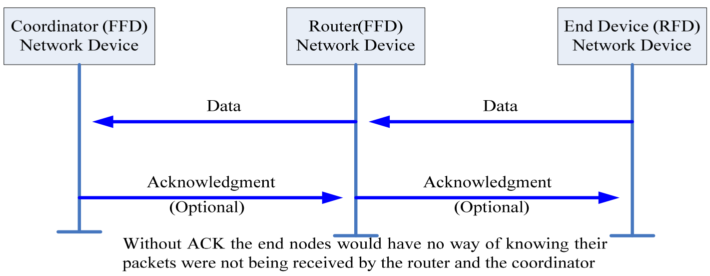

Figure 4. Nodes Processing of Data and Acknowledgement

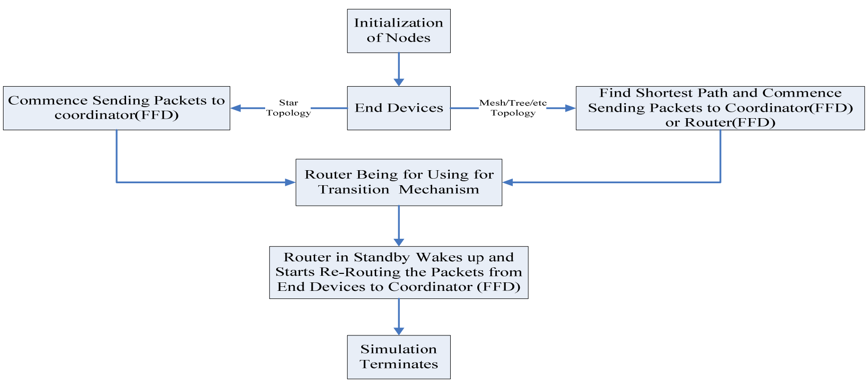

Figure 5. Processing of ZigBee Implementation

3.3. Simulation Results

The simulation results concern the Total Events, Average Speed, MAC data traffic and MAC control traffic in sending and receiving data in different numbers of nodes, the Throughput, End to End Delay, Number of Hops, across the full ZigBee stack, under different topology-deployment strategies with different number on nodes, are analyzed.

The ZigBee simulation modules, which we use in this paper is operated at 2.4GHz with a maximum throughput of 250kbps. The throughput is calculated as the total of packet size (128 bytes) divided by the total of transmission time.

The simulation in this paper presents the average of overlaid statistics in the MAC layer, Application layer and Networks layer.

Table 4. Total Events and Average Speed with the Elapsed Time of ZigBee Simulation Nodes

Nodes	Total Events	Average Speed events/sec	elapsed time
50	74,066,896	951,221	60.17 sec
50	74,066,896	951,221	60.17 sec
50	74,066,896	951,221	60.17 sec
50	74,066,896	951,221	60.17 sec

Table 4 shows the total events of nodes as a function of the maximum number of retransmissions (events/sec). For each node, the events of nodes is calculated as the time progress/sec by all sources frames to the number of received frames by the sink and the event is significantly increased when the ZigBee nodes increasing and Table 1 presents the results concerning network average speed for different nodes obtained through simulation, for different nodes ((ZigBee nodes= 5 devices), (ZigBee nodes= 12 devices), (ZigBee nodes= 30 devices), and (ZigBee nodes= 50 devices)). As expected, when the device node increases the average speed will also increases.

3.3.1. ZigBee MAC Layer Simulation Result Analysis

In order to evaluate the simulation performance of ZigBee AODV mesh wireless sensor networks FFD-C source mobility FFD-R4 sink mobility, we have used the OPNET modeler 14.5 simulations for the mesh topologies in which we did the analysis of the seven parameters (MAC control traffic/data traffic with received/sent, end-to-end delay and throughput, number of hop, packet dropped) of the nodes in the different layers (MAC layer, Application layer and Network layer). In MAC layer, the simulation results for a static sink are given in which first of all the results for average sent and receive data for network nodes in different control traffic and data traffic in (Figure 8, 9), (Figure 10, 11) and (Figure 12, 13) are shown then results of MAC delay and MAC throughput.

Figure 8, 9 shows the average presentation in overlaid statistics in ZigBee 802.15.4 MAC data traffic and control traffic in sent and receive data in different number on nodes. Mesh network shows good performance when router/node ratio is high. As we see in in Figure 12 as the delay time between sequential transmissions decreases, we have used the asynchronous transmission with varying delay times to measure the impact of transmission delay. We delayed the transmission from 0m, 5m, 10m, 15m, and 20m simultaneously to analysis the delay between the different nodes.

So as shown in the Figure 5 the delay in ZigBee AODV mesh model with the 5 nodes is stable, and when the devices more and more the delay time between sequential transmissions decrease.

The above result shows that the delay time decreases when the nodes devices are in 12, 30 and 50 as compare to 5 nodes device.

In this section, we change the mount number of nodes and find out the effect of the mount number of nodes for both throughput and delay.

Throughput is the data quantity transmitted correctly starting from the source device to the destination device within a specified time (20m).

Figure 12 shows the average throughput varying the number of nodes, so the delay time between sequential transmissions decreases and the throughput of the network increases linearly as shown in Figure 16. This makes sense because as the delay time decreases, more data are sent over the network in any arbitrary block of time. The above result shows the maximum throughput achieves when the nodes device are 30 and 50 as compare to nodes devices are 5 and 12.

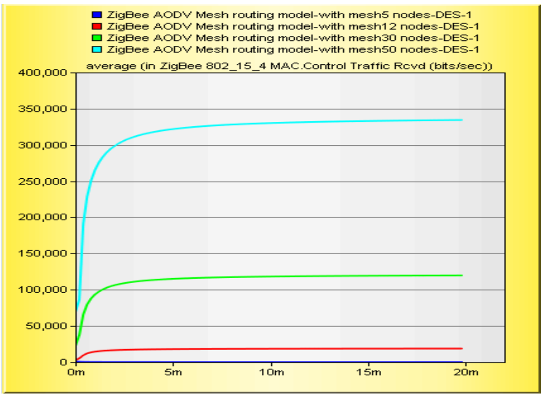

Figure 8. Average MAC Control Traffic Received

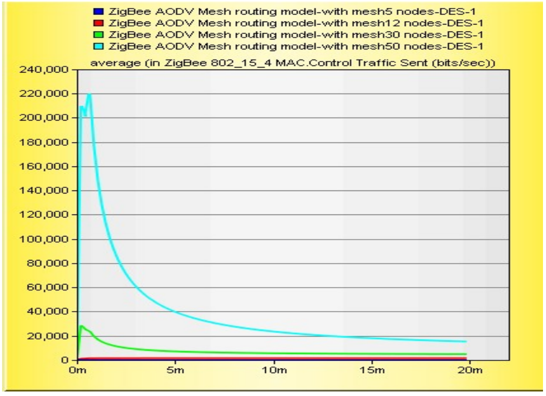

Figure 9. Average MAC Control Traffic Sent

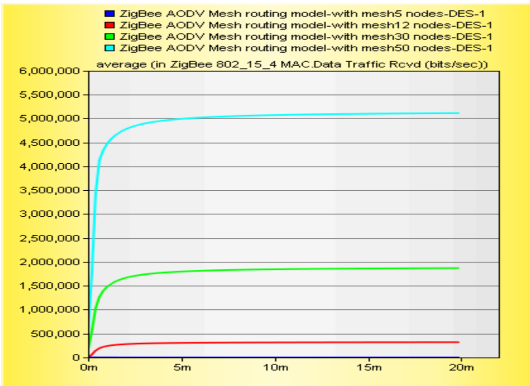

Figure 10. Average MAC Data Traffic Received

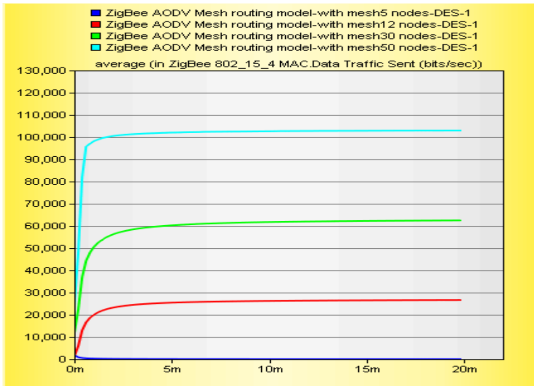

Figure 11. Average MAC Data Traffic Sent

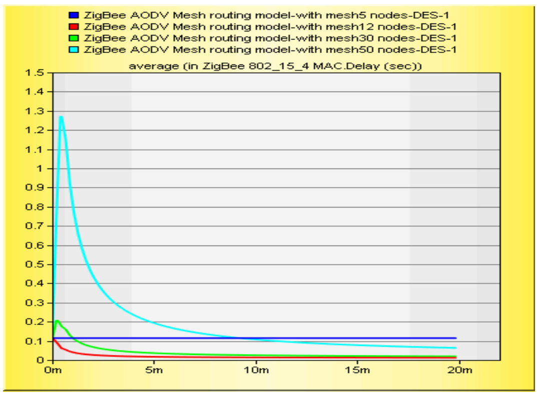

Figure 12. Delay vs Total Transmission Time

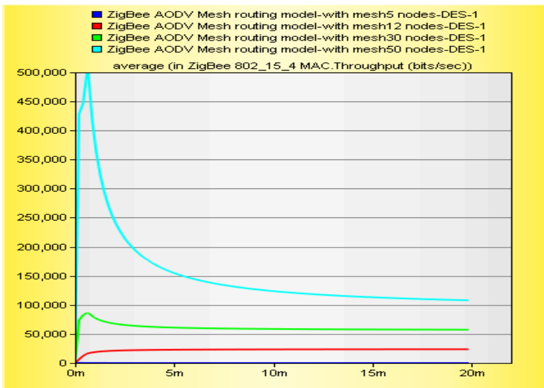

Figure 13. Throughput vs Total Transmission Time

3.3.2. ZigBee Network Layer Simulation Result Analysis

In last results for average number of hope, packets dropped, sent by the coordinator FFD-C and received by the router FFD-R4 are shown in (Figure 14 to Figure 15).

It is the average number of hops travelled by application traffic in the PAN. In this Figure. all the different nodes simulation analysis have single number of hop.

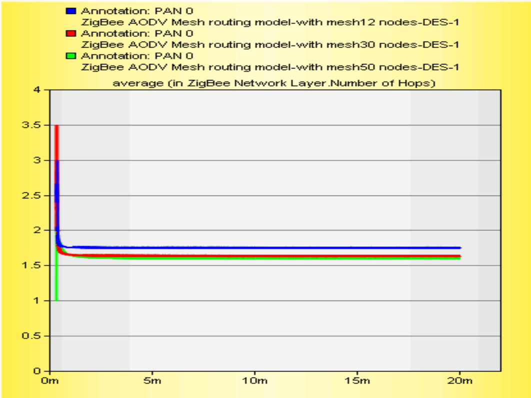

Figure 14. Average Numbers of Hops

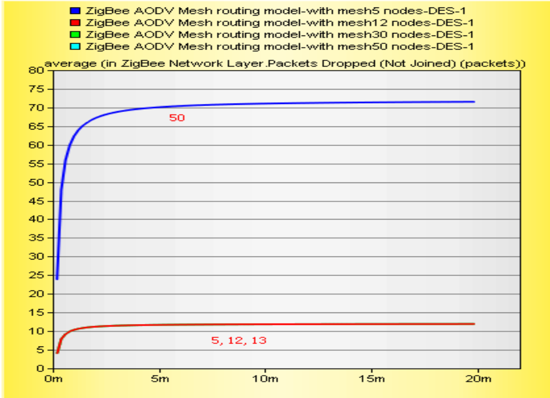

Figure 15. Average Packets Dropped

4. Conclusion

Wireless Sensor Networks have become a viable and cheap solution for a variety of applications, including critical infrastructure monitoring (military applications, telecommunications systems, power grids, agriculture, traffic networks, disaster recovery situations, etc.). In simulation results, mesh topology performs better than the other topology with more end devices and more suitable for battery capacity, bandwidth and computing power's limitations of wireless sensor network.

In this work, we have compared the different number of nodes with different parameters using mesh topologies using OPNET Modeler v14 simulation tool to obtain the results in order to study the performance of the system in terms of tree routing, mesh routing in direct transmission between source and sink are collected using through-put, delay and packet delivery ratio. The results shows that mesh was more suitable for WSN and mobility of end device was better in AODV mesh routing.

We have designed and implemented simplified networking simulation model to explore and evaluate the network performance by using ZigBee AODV mesh network in the OPNET Modeler 14.5 that supports multiple interfaces/channels in the sense that other factors are also taken into account in our thesis, such as routing protocols , QoS ,cost-effectiveness sensitive to customers, etc.

Improve the ZigBee routing protocol using AODV mesh topology. Because ZigBee is a version of AODV routing protocol, where the routes are discovered RREQ through the network by the source broadcasting and sending RREP back the destination, so to make ZigBee routing efficient, we used AODV mesh topology methods to send and receive data from source to destination and vice versa.

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