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Performance Evaluation of ZigBee Protocol with OPNET

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Abstract— ***This paper scrutinizes the performance of ZigBee with OPNET. The ZigBee protocol stack is based on IEEE 802.15.4 which offers a sensible, worthwhile solution for low-cost and low power consuming WPANs. These characteristics make ZigBee network an ideal aspirant for Wireless Sensor Networks in many applications such as natural calamity prediction, data gathering for agricultural fields, commercial building and home automation, medical equipment monitoring, industrial control and etc. OPNET 14.5 is network simulation tool that evaluates the effectiveness of ZigBee with fixed nodes in the network, the determining factors will be delay with respect to network time, throughput, number of hops and etc.***

Keywords— OPNET, PAN, WSN, WPAN, ZigBee.

I. INTRODUCTION

The need of monitoring over the large areas or fields and automating the services are soaring at the fast pace. During the last decade there has been a detonation of devices using sensor technologies for control and monitoring purposes. Wired Sensors are now projected to be replaced with wireless technologies. The corporate have been envisioning of a digital home where every device is connected, and remotely controlled and monitored. Even though a perfect digital home is yet a mirage, we are now able to apply several technologies to suite our home and industrial networking needs. However, this concept of a digitally connected home has received a luke warm response due to lack of feasible solutions. Over the years, several possible nominees have been identified. But none match the robustness and reliability required for the automation applications. Sturdiness when it comes to critical application scenarios as applicable to industrial needs and reliability when it comes to power usage and prompt response [1]. ZigBee is a specification for a set of high level communication protocols used to create personal area networks built from tiny, low-power digital radios and the computer connected. ZigBee is based on an IEEE 802.15 standard. Though low-powered, ZigBee devices can transmit data over long distances by passing data through median devices to reach the distant ones, creating a mesh network i.e. a network with no centralized control or high-power transmitter/receiver able to reach all of the networked devices. The decentralized nature of such wireless ad-hoc networks make worthy applications where a central node can't be pivoted [2].

ZigBee is used in applications that require only a low data rate, long battery life, and secure networking. ZigBee has a defined rate of 250 kbit/s, best suited for periodic or discontinuous data or a single signal transmission from a sensor or input device. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range wireless transfer of data at relatively low rates. ZigBee networks are secured by 128 bit symmetric encryption keys. In home mechanization applications, transmission distances range from 10 to 100 meters line-of-sight, depending on power output and environmental characteristics. ZigBee was conceived in 1998, standardized in 2003 and was revised in 2006. The name refers to the jiggling of honey bees after their return to the beehive. The ZigBee protocol can support over 64,000 nodes and can operate in three network topologies: Star, Tree and Mesh. The large amount of supported nodes is another appealing characteristic, specifically in industrial applications [3].

A. ZigBee Hardware

ZigBee networks are comprised of three main components. Each device is responsible for specific roles within the network.

1) ZigBee Coordinator

For every ZigBee network there must be one and only one coordinator. The coordinators responsibilities include initializing the network, selecting the transmission channel and permitting other ZigBee nodes to connect to its network. A ZigBee coordinator can also route traffic within a network.

2) ZigBee Router

A ZigBee router is liable for message routing within a network. Not all networks require a router because traffic can travel directly from an end device to a coordinator or even from end device to another end device by using routing features of a coordinator.

3) ZigBee End Device

ZigBee end devices connect to routers or coordinators in a network but cannot have other devices connect to the ZigBee network by sharing the accomplishments of its connection [2].End devices are the end points of a ZigBee network and contain limited functionality to talk to parent nodes (coordinator or a router). Since they do not have routing responsibilities and can enter low-power sleep modes during periods of inactivity, ZigBee end devices have plethora of battery lives. Due to its limited functionality, end devices impose limited memory footprints and can therefore be less expensive to manufacture than a router or a coordinator.

B. ZigBee Layers

The ZigBee Alliance provides the specifications for the Application and Network layers whereas the IEEE 802.15.4 standard provides specifications for the bottom two layers: Medium Access Control (MAC) and Physical. MAC and Physical layer specifications are provided by the IEEE 802.15.4 standard to assure coexistence with other wireless protocols such as Bluetooth and Wi-Fi [2].

The layer stack of ZigBee protocol is shown in Fig.2

- Application Layer
- Network Layer
- Medium Access Control Layer
- Physical Layer

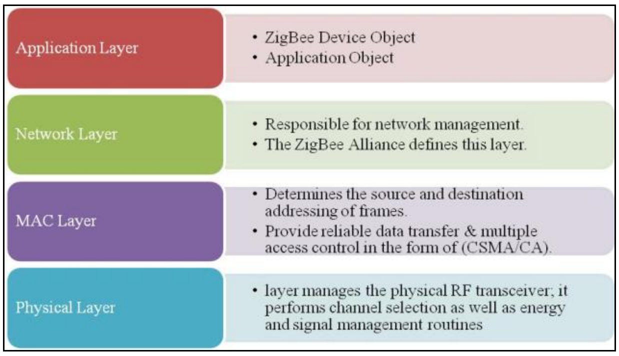

Fig.1 ZigBee Layers

C. Simulator OPNET

Riverbed OPNET Modeler® Suite embraces a suite of protocols and technologies with a chic development environment. By modeling all network types and technologies (including VoIP, TCP, OSPFv3, MPLS, IPv6, and more), OPNET Modeler analyzes networks to compare the impact of different technology designs on end-to-end behavior. OPNET Modeler Suite lets you test and exhibit technology designs before production; increase network R&D productivity; develop proprietary wireless protocols and technologies; and evaluate enhancements to standards-based protocols [6].

Further this paper has been organized into four sections, Section II Network Architecture, III Simulated Results and IV Conclusion.

II. NETWORK ARCHITECTURE

This paper will evaluate the performance of the ZigBee network with or without router to check the end to end delay of traffic in seconds, throughput of the network, total delay and load in the network. The simulations are done in OPNET 14.5 educational version. Here the logical subnet is taken under consideration. Two scenarios are made with equal number of nodes i.e. 42 nodes with coordinator and router. Here the attributes can be edited and it can be set for the desired node in this paper we take the destination at ZigBee coordinator as displayed in the Fig.2 where the attributes are being edited. These changes will be applied on all the nodes bearing same characteristics.

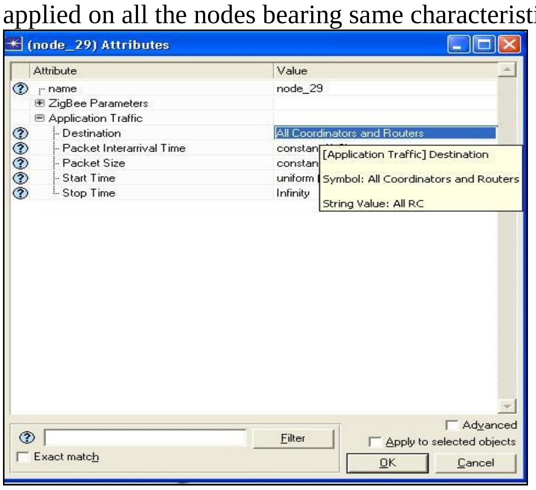

Fig.2 Editing Attributes

A. Scenario Architecture

Personal Area Network (PAN) 0 contains the static nodes here forty end devices and a router and coordinator are used as shown in Fig.4. The notations that will be used as:

- ZED: ZigBee End Device.
- ZCR: ZigBee Coordinator.
- ZR: ZigBee Router.
- ZigBee works with three types of topologies: star, tree & mesh.

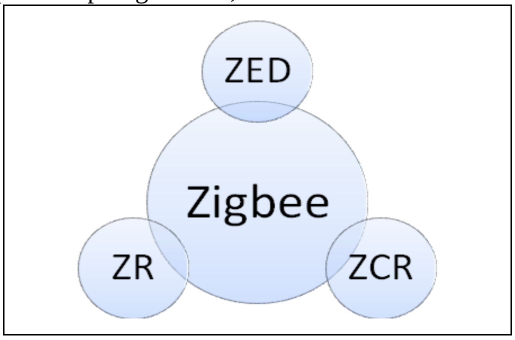

Fig.3 ZigBee Devices.

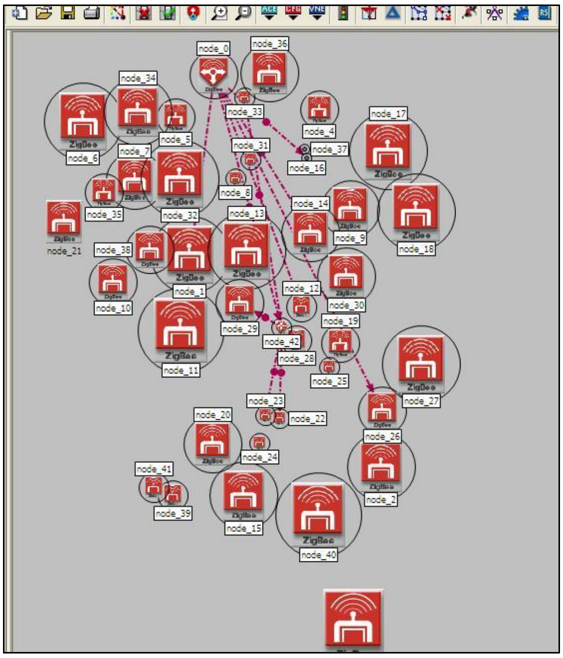

Fig.4 Nodes in Scenario

The scenario1 works with active router and the Fig.5 will display the tree routes in the scenario1. Here the network is initialized at the coordinator, nothing will happen in the network if the coordinator is failed.

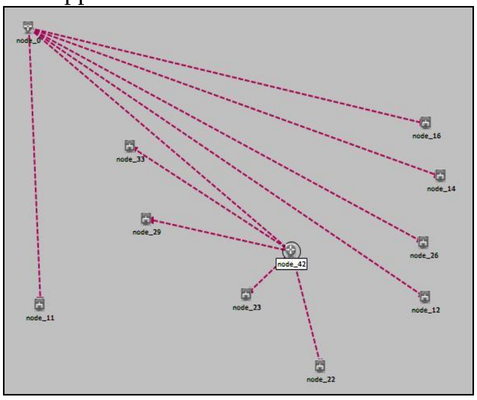

Fig.5 tree route in scenario with active router

The Fig. 6 will display the tree route when the router is failed, in ZigBee the coordinator and router both work as the root nodes, so when both are included in the network then the tree will be having the depth level of two; but without router node tree will be having the depth at level one

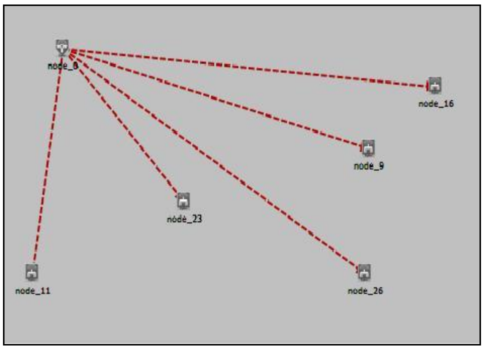

Fig.6 Tree route without router

III. SIMULATED RESULTS

A. Comparative Results after Simulation

The simulation is done for 200seconds and the parameters are chosen 'Delay', 'Throughput' and 'Number of hops', for each of the scenario; which will be shown on running the simulation. The results are depicted in the form of graphs.

- For Delay X-axis is in seconds and Y-axis is in seconds.
- For Throughput X-axis is in Bits and Y-axis is in Sec and the measurement will be done in terms of bits/sec.
- For No. of Hops the X-axis is in hops and Y-axis is in sec and measurement is done in terms of hops/sec.

The results are generated by the DES (Discrete Event Simulation).

A. Results for delay in the network

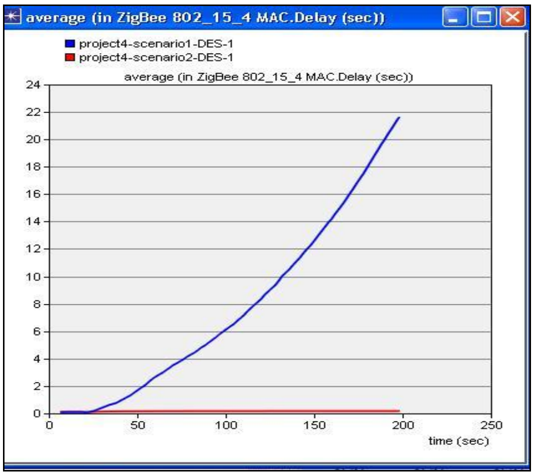

Fig.6 Scenario1 and 2 delay comparison in sec.

Let R_A denotes the router with active status and R_F denotes the faulted out router.
From Fig.6 by, Comparing the value DR_A (Delay with active router) & DR_F (Delay with faulted router) at various points, it can be depicted easily that

$$DR_A > DR_F \text{ from TABLE I} \quad \text{--- (1)}$$

B. Results for throughput

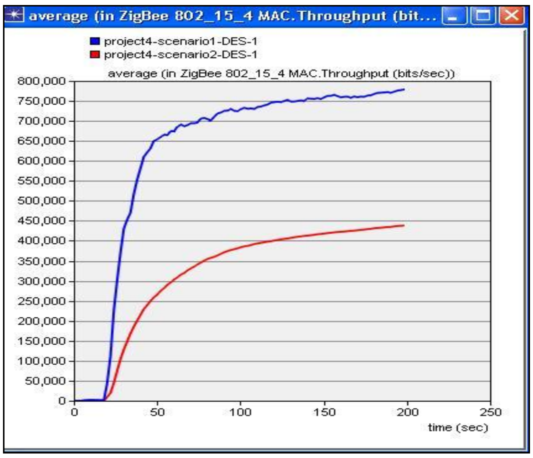

Fig. 7 Throughput comparisons

Fig.7 depicts the throughput in both the cases, TR_A (Throughput with active router) & TR_F (Throughput with faulted router)

$TR_A > TR_F$ from TABLEI --- (2)

C. Results for number of hops

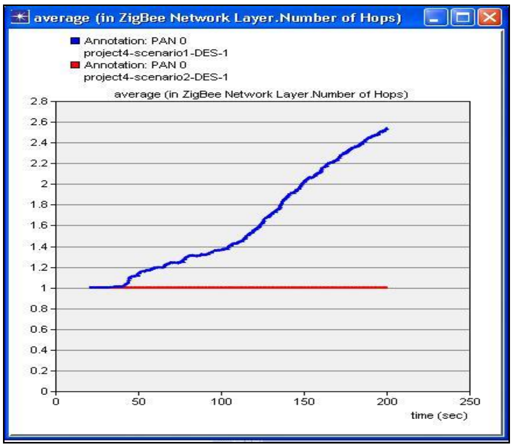

Fig. 8 No. of hops

Fig.8 displays the number of hops in the network, NR_A (No. of hops with active router) & NR_F (No. of hops with faulted nodes).

$NR_A > NR_F$ from TABLE I --- (3)

By comparing the equations (1), (2) and (3), the values of delay, throughput and no. of hops is greater in case of active router. As the router is active then it changes the tree depth level to 2 that increases the parameters

TABLE I FOR SIMULATED RESULTS

Simulated Results(Total Simulation time 200 seconds)		
Parameters	*Router Active R_A (at 120 sec)*	*Router Failed R_F (at 120 sec)*
Delay(Sec)	8	0
Throughput(bit/sec)	750,000	375,000
No. of Hops(hops/sec)	1.5	1

IV. CONCLUSION

This paper has been putting emphasis on the effectiveness of the ZigBee network in two cases one is when the router node is active and the other is when it is faulted out. The active router increases the network capacity and hence enhances the network effectiveness. These WSN technologies enlarge the space for next generation communication applications, monitoring, observation and etc.

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