Analysis of ZigBee (IEEE 802.15.4 standard) for Star Topology with AODV Protocol

Priyanka Singh, Mukesh Kumar, A. K. Jaiswal, RohiniSaxena

Abstract: ZigBee is a new wireless technology based on the 802.15.4 standard which is extensively used in wireless communication. This isdesigned for applications like wirelessmonitoring andcontrol of lights, security alarms, motion sensors, thermostats and smoke detectors.ZigBee technology provides a low data rate, low power, and low costwireless networking on the device-level communication.IEEE 802.15.4 specifies physical and media access control layers. The MAC layer defines different network topologies, namely a star, tree and mesh topology. In this paper, we give a brief overview of ZigBee (IEEE 802.14.5 standard) which is the fundamental of low rate-wireless personal area network (LR-WPAN).Then we analysis the performance of ZigBee (IEEE 802.15.4) for star topology with different traffic scenarios namely CBR, FTP, and Poissonusing thesimulation tool NS-2.

Index Term: LR-WPANs, NS-2, ZigBee.

I. INTRODUCTION

ZigBee is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks standard [1].Thisstandard operates at three bands, 2.4GHz, 868 and 912 MHzby having data rate from 250kbps, 20kbps and 40kbps resp.ZigBee is mainly used in low rate and low power applications [2] because, the PHY and MAC layers adopt the standard of IEEE802.15.4, which makes the solutions independent of RF IC vendors due to the 2.4GHz standardized radio by IEEE 802.15.4 [3],[4]. Therefore, ZigBee is more cost-effective for designing short-range wireless communication applications [5].

Based on the PHY and MAC layers, the specifications of ZigBee introduce reliable and secure network topologies, including mesh, star and cluster-tree topology.In this paper we provide the results of our analysis of a star topology network based on the IEEE 802.15.4standard.Figure 1 shows a star topology networkcomprising a PAN coordinator and several sensors device as leafnodes.

In this paper, we are analyzing star topology with different amount ofbackground traffic such as Constant Bit Rate (CBR), FileTransfer Protocol (FTP) and Poisson with drop tail queue.

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Ms. Priyanka Singh,Electronics Communication & Engineering, SHIATS Allahabad, India.

Asst. Prof. Mukesh Kumar, Electronics Communication & Engineering, SHIATS Allahabada, India.

Prof. A.K.Jaiswal, HOD, Electronics Communication & Engineering, SHIATS Allahabad, India.

Asst. Prof. RohiniSaxena, Electronics Communication & Engineering, SHIATS Allahabad, India.

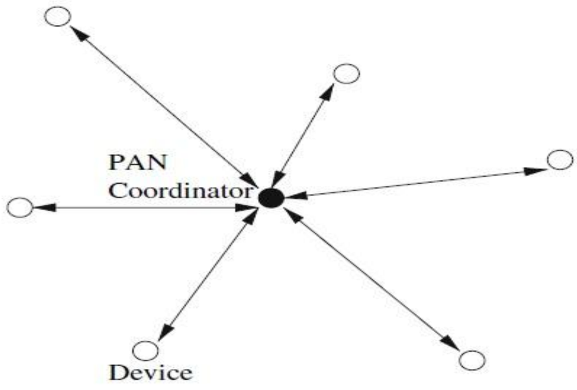

Fig. 1 A star topology

The rest of the paper is organized as follows. Section IIbriefly reviews ZigBee/IEEE 802.15.4 standard and zigbee devices.In Section III describes the performance evaluation. Results analysis is discussed in section IV.Section V is conclusion and future work.

II. ZIGBEE (IEEE 802.15.4 STANDARD)OVERVIEW

ZigBee mainly aims for low data rate applications and helps in energy conservation.The ZigBee protocol stack is built on top of the IEEE 802.15.4.

The IEEE 802.15.4standard [6] has evolved to realize the physical (PHY) andmultiple access control (MAC) layers of such LR-WPANS.The ZigBee alliance has developed the network and upperlayers [7].. Since we consider only a simple star topology of 40 nodes, withflow of different traffic from the leaf nodes to the PAN coordinator or PAN coordinator to leaf nodes, we needto consider only the PHY and MAC standards [4].

(A) Physical and MAC Layer Overview

Throughout we assume that we are working in the2.45 GHz band and hence the PHY data rate is 250 kbps,the symbol rate is 62.5 symbols/second; hence the symboltime is 16slot. In practice wireless transceivers are alwayshalf duplex. Hence the IEEE 802.15.4 devices require afinite amount of time to switch between transmission andreception. This time is denoted by aTurnaroundTime in thestandard and is equal to 12 symbol times.

We now turn to the MAC specifications. The IEEE802.15.4 can operate either in a beacon enabled or a non-beaconenabled mode. In the beacon enabled mode, thePAN coordinator works with time slots defined through asuperframe structure (see Fig. 2). This permits a synchronousoperation of the network so that nodes can go to sleepand wake up at designated times.

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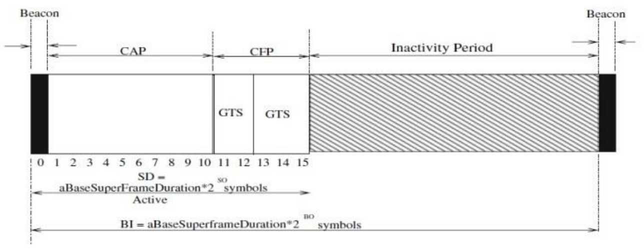

Fig. 2 The IEEE 802.15.4 superframe structure

Formerly all the Pan-coordinators were generating beacon with a same intervalas as shown below, also to be noted that BO is set to 3 by default for every full-function device added in the network, but it can be changed manually ifrequired.

BI(beacon interval) = abasesuperframeduration *2^{BO}

Abasesuperframeduration = abaseslotduration X anumsuperframeslots
Abaseslotduration = 60 symbols
Anumsuperframeslots = 16

= 60 X 16

= 960

As here, BO = 3 therefore,
BI = 960 x 2^3 symbols
BI = 7680 symbols
BI|250K = 7680/250000
BI = 30.72msec
Above calculation explains that all the pan-coordinators in a network aregenerating beacons after every 30.72 msec.
ZigBee devices are designed for low cost and low data rates [2], it is expected their use in home and building automation with significantly small costs.

(B) Zigbee Device Types

ZigBee network primarily uses three device types: Network Coordinator, Full Function Device and Reduced Function Device. These devices will be discussed as follows:

(i) Network Coordinator

It is a device which is authorized to provide synchronization services in an establishednetwork. There can be two different kinds of coordinators based on their operation scope. Firstis the PAN-Coordinator, which acts as a coordinator for the entire PAN. Whereas an ordinarycoordinator can only function within the scope of a cluster.There are 14 PHY and 35 MAC Primitives defined by the IEEE 802.15.4 standard.

(ii) Full Function Device

It is a device which supports all the 49 primitives supported by the technology.It is a fully functional device which is capable of assuming the role of either a PAN Coordinator, a Coordinator, or just as an end node (device). Also an FFD can function as a routing device incertain network topologies where data transfer among FFD is allowed.

(iii) Reduced Function Device

It is a device with reduced functionality which can only function as an enddevice or node. It cannot communicate with any other device other than the coordinator. Giventheir extremely low functionality, these devices are normally intended for simple applications likea light switch, etc. They merely send information to the coordinator at regular intervals aboutthe status of the device it is monitoring. It can only support a maximum of 38 primitives.

III. PERFORMANCE EVALUATION

We consider a Zigbee usingoperating frequency of 2.4GHz with maximum data rate250kbps. It uses omnidirectional antenna for communication.A two-ray ground propagation model is used. The queuingmodel used is drop tail queue. Simulation results haveincorporated into trace files. The routing is based on Ad-hocOn Demand Distance Vector Protocol (AODV) [8] [9].Simulation parameters are given in Table I.

(A) Performance Metrics

We have selected the Packet Delivery Ratio, End-to-endDelay, and Load Factor as a metrics during the simulationwith AODV Protocol.

a) Packet Delivery Ratio(PDR): This is the number ofpackets sent from the source to the number of packets receivedat the destination.

PDR = Number of packets received / Number of packets sent

b) End-to-End Delay(EED): This is the average timedelay for data packets from the source node to the destinationnode.EED is measured as from PAN coordinator to RFD.

EED = Received Packet Time - Sent Packet Time

c) Load Factor: It is calculated as Packet rate by channelcapacity. Load factor decides the performance of the networkby utilizing channel capacity of network.

Load Factor = Packet Rate / Channel Capacity

Channel capacity = Data Rate / Each Channel size

Packet Rate = Total packet sent + Total packet received / Simulation Time
Each channel is 16 kbps with data rate 250 kbps and eachpacket is 20bytes. Channel capacity has kept constantthroughout the simulation. With a constant Channel Capacity,we have considered different Packet Rate such that the LoadFactor conforms from 0.1 to 0.9 in steps of 0.1.

TABLE I: SIMULATION PARAMETERS

Routing Protocol	AODV
Network topology	Star
MAC Protocol	IEEE 802.15.4
Simulation Time	500 Seconds
Number of Node	40
Terrain Size	200 X 200 m^2
Traffic Type	Constant Bit Rate, File Transfer Protocol, Poisson Traffic
Packet Size	20 bytes
Queue type	Drop Tail
Beacon Order & Super Frame Order	3

The performance of star topology networkscenarios has been identified by having different types oftraffic; such as FTP traffic having tcp packets, CBR traffic withcbr packet and Poisson traffic with exponential packet.

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IV. RESULT ANALYSIS

This section describes result which has been infered according the table1.Graphs have been plotted from trace file after simulation as shown below.Trace file contains trafficpackets, source, and destination, sent time, etc. We have analyzed different types of traffic such as CBR, FTP and Poisson in star topology.

(A) End to End Delay

EED is near about zero with all traffic as shown below in figure 3, figure4 and figure.

(B) Packet Delivery Ratio (PDR)

PDR has been increased in CBR traffic compared with other traffic. In CBR traffic PDR is 100% as shown in figure 3. Packet delivery 74% constant in FTP traffic as shown in figure 5.It is increase with interval from 80% to 98% in poisson traffic as shown in figure 4.

(C) Load Factor

Load factor is high in CBR traffic compared with other traffic. It has decreased with intervals as shown in figure 3, figure 4 and figure 5.

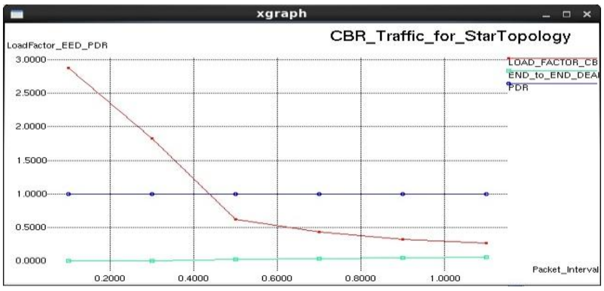

Fig.3 Star Topology using CBR Traffic

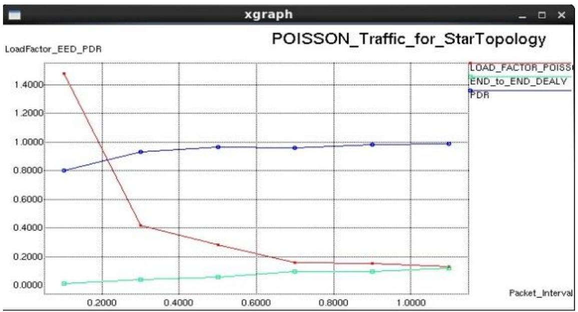

Fig.4 Star Topology using Poisson Traffic

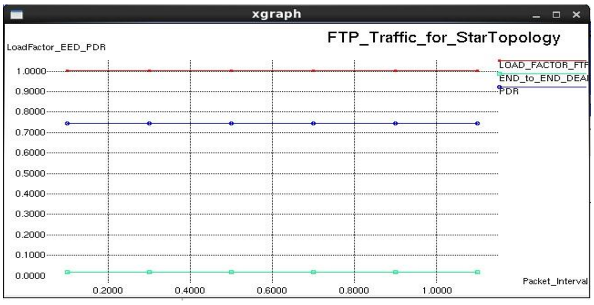

Fig.5 Star Topology using FTP Traffic

V. CONCLUSION & FUTURE WORK

We have observed that packet delivery ratio is 100% which is better in star topology with CBR traffic compared with other traffics because there is no acknowledgement generated by CBR traffic for controlling. The dropped packets are fewer in CBR as it provides constant bit rate throughout the simulation. Overall load factor is high in CBR traffic and decreased with intervals.

To improve the performance of star topology for simulate application scenarios like sensors reporting to a central node, controlling and monitoring systems in future work.

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AUTHORS PROFILE

Priyanka Singh, is PG Student in the Department of Electronics & Communication Engineering in SHIATS, Allahabad. She is pursuing M.Tech in Signal Processing in SHIATS, Allahabad. Her research is focused on Wireless Sensor Network and Computer Networks.

Mukesh Kumar, is working as a Asst. Prof. in the Department of Electronics & Communication Engineering in SHIATS, Allahabad. He received his M.Tech. Degree in Advanced Communication System Engineering from SHIATS, Allahabad in 2010. His research is focused on Wireless Sensor Network and Computer Networks Microwave Engineering, as well as Optical fiber communication.

A. K. Jaiswal, is working as professor and HOD in the department of ECE atSam Higginbottom Institute Of Agriculture Technology And Sciences, Allahabad. He worked for thepromotional activities in optical fiber communication systemsponsored by Government of India, in association with IITKharagpur and Madras. His research interests areOptical system, sensors and networks.

RohiniSaxena, is working as a Asst. Prof. in the Department of Electronics & Communication Engineering in SHIATS, Allahabad. She received her M.Tech. Degree in Advanced Communication System Engineering from SHIATS, Allahabad in 2009. Her research is focused on Microwave Engineering, Wireless Sensor Network and Computer Networks and Mobile communication.

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