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

Priyanka Singh, Mukesh Kumar, A. K. Jaiswal, Rohini Saxena

Abstract: ZigBee is a new wireless technology based on the 802.15.4 standard which is extensively used in wireless communication. This is designed for applications like wireless monitoring and control of lights, security alarms, motion sensors, thermostats and smoke detectors. ZigBee technology provides a low data rate, low power, and low cost wireless 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 analyze the performance of ZigBee (IEEE 802.15.4) for star topology with different traffic scenarios namely CBR, FTP, and Poisson using the simulation 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]. This standard operates at three bands, 2.4GHz, 868 and 912 MHz by having data rate from 250kbps, 20kbps and 40kbps respectively. ZigBee is mainly used in low rate and low power applications [2] because, the PHY and MAC layers adopt the standard of IEEE 802.15.4, 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 802.15.4 standard. Figure 1 shows a star topology network comprising a PAN coordinator and several sensors device as leaf nodes.

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

The rest of the paper is organized as follows. Section II briefly 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 802.15.4 standard [6] has evolved to realize the physical (PHY) and multiple access control (MAC) layers of such LR-WPANS. The ZigBee alliance has developed the network and upper layers [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 need to consider only the PHY and MAC standards [4].

(A) Physical and MAC Layer Overview

Throughout we assume that we are working in the 2.45 GHz band and hence the PHY data rate is 250 kbps, the symbol rate is 62.5 symbols/second; hence the symbol time is 16s/lot. In practice wireless transceivers are always half duplex. Hence the IEEE 802.15.4 devices require atinite amount of time to switch between transmission and reception. This time is denoted by A Turnaround Time in the standard 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 beacon enabled mode. In the beacon enabled mode, the PAN coordinator works with time slots defined through asuperframe structure (see Fig. 2). This permits a synchronous operation of the network so that nodes can go to sleep and wake up at designated times.

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Formerly all the Pan-coordinators were generating beacon with a same intervals 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 if required.

\[
BI(\text{beacon interval}) = \text{abasesuperframeduration} \times 2^\text{BO}
\]

\[
\text{abasesuperframeduration} = \text{abaseslotduration} \times \text{anumsuperframeslots}
\]

\[
\text{abaseslotduration} = 60 \text{ symbols}
\]

\[
\text{anumsuperframeslots} = 16
\]

\[
= 60 \times 16
\]

\[
= 960
\]

As here, \(BO = 3\) therefore,

\[
BI = 960 \times 2^3 \text{ symbols}
\]

\[
BI = 7680 \text{ symbols}
\]

\[
BI_{250K} = 7680/250000
\]

\[
BI = 30.72 \text{msec}
\]

Above calculation explains that all the pan-coordinators in a network are generating 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 established network. There can be two different kinds of coordinators based on their operation scope. First is the PAN-Coordinator, which acts as a coordinator for the entire PAN, whereas an ordinary coordinator 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 in certain 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 end device or node. It cannot communicate with any other device other than the coordinator. Given their extremely low functionality, these devices are normally intended for simple applications like a light switch, etc. They merely send information to the coordinator at regular intervals about the status of the device it is monitoring. It can only support a maximum of 38 primitives.

### III. PERFORMANCE EVALUATION

We consider a Zigbee using operating frequency of 2.4GHz with maximum data rate 250kbps. It uses omnidirectional antenna for communication. A two-ray ground propagation model is used. The queuing model used is drop tail queue. Simulation results have incorporated into trace files. The routing is based on Ad-hoc On 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-End Delay, and Load Factor as a metrics during the simulation with AODV Protocol.

- **a) Packet Delivery Ratio (PDR):** This is the number of packets sent from the source to the number of packets received at the destination.

  \[
  \text{PDR} = \frac{\text{Number of packets received}}{\text{Number of packets sent}}
  \]

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

  \[
  \text{EED} = \text{Received Packet Time} - \text{Sent Packet Time}
  \]

- **c) Load Factor:** It is calculated as Packet Rate by channel capacity. Load factor decides the performance of the network by utilizing channel capacity of network.

  \[
  \text{Load Factor} = \frac{\text{Packet Rate}}{\text{Channel Capacity}}
  \]

<table>
<thead>
<tr>
<th>Packet Rate</th>
<th>Total packet sent + Total packet received / Simulation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Size</td>
<td>Each Channel size</td>
</tr>
</tbody>
</table>

- Each channel is 16 kbps with data rate 250 kbps and each packet is 20 bytes. Channel capacity has kept constant throughout the simulation. With a constant Channel Capacity, we have considered different Packet Rate such that the Load Factor conforms from 0.1 to 0.9 in steps of 0.1.

### TABLE I: SIMULATION PARAMETERS

<table>
<thead>
<tr>
<th>Routing Protocol</th>
<th>AODV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network topology</td>
<td>Star</td>
</tr>
<tr>
<td>MAC Protocol</td>
<td>IEEE 802.15.4</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>500 Seconds</td>
</tr>
<tr>
<td>Number of Node</td>
<td>40</td>
</tr>
<tr>
<td>Terrain Size</td>
<td>200 X 200 m²</td>
</tr>
<tr>
<td>Traffic Type</td>
<td>Constant Bit Rate, File Transfer Protocol, Poisson Traffic</td>
</tr>
<tr>
<td>Packet Size</td>
<td>20 bytes</td>
</tr>
<tr>
<td>Queue type</td>
<td>Drop Tail</td>
</tr>
<tr>
<td>Beacon Order &amp; Super Frame</td>
<td>3</td>
</tr>
</tbody>
</table>

The performance of star topology network scenarios has been identified by having different types of traffic; such as FTP traffic having tcp packets, CBR traffic with cbr packet and Poisson traffic with exponential packet.
IV. RESULT ANALYSIS

This section describes result which has been inferred according to the table1. Graphs have been plotted from trace file after simulation as shown below. Trace file contains traffic packets, 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, figure 4 and figure 5.

(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.

REFERENCES

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