



## Performance Analysis of IEEE 802.15.4

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**Abstract**— *The continuous improvement of sensor skill and wireless communication is encouraging wireless sensor networking. IEEE 802.15.4 is a standard designed to meet the needs for simple, low-power and low-cost Wireless Personal Area Networks(WPANs) It operates primarily in the 2.4GHz ISM band, which makes the technology easily applicable and worldwide available. However, IEEE 802.15.4 is potentially vulnerable to interference by other wireless technologies working in this band such as IEEE 802.11. This paper gives a short overview of IEEE 802.15.4 and analyzes performance of IEEE 802.15.4 through measurements of end-to-end delay and packet dropped parameter with respect to AODV protocol using NS2. Further we present simulation results from the performance evaluation of IEEE 802.15.4. Finally we compare the results of delay and packet dropped parameter between IEEE 802.15.4 and IEEE 802.11*

**Keywords**—*Wireless sensor network, IEEE 802.15.4, WPAN, IEEE 802.11, AODV, NS2*

### I. INTRODUCTION

In the past years several wireless technologies have been developed to meet increasing demands for flexible connectivity [1]. Low Rate Wireless Personal Area Networks are designed to serve a wide range of applications including industrial controls, hospitals, hotels, home/office automation, environmental monitoring etc. IEEE 802.15.4 was developed to meet the needs for simple, low data rate, low-power and low-cost wireless communication. In the past couple of years it has become a popular technology for wireless sensor networks. It operates primarily in the 2.4GHz ISM band, which makes the technology easily applicable and worldwide available. However, IEEE 802.15.4 is potentially vulnerable to interference by other wireless technologies working in this band such as IEEE 802.11. The objective of our work is to analyze the performance of IEEE 802.15.4 based network by measuring delay and packet dropped parameter with respect to AODV protocol using Network Simulator 2 (NS2). Here we have analyzed the performance by taking 10 and 20 nodes in a network. Further we compare the results of delay and packet dropped parameter between IEEE 802.15.4 and IEEE 802.11, since both types of devices operate in the 2.4GHz ISM frequency band, it is of great importance to understand and evaluate the coexistence between two technologies.

### II. OVERVIEW OF 802.15.4

IEEE 802.15.4 is a standard which specifies the physical layer and media access control for Low-Rate Wireless Personal Area Networks (LR-WPANs)[2]. It is maintained by the IEEE 802.15 working group. IEEE standard 802.15.4 intends to offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices. The basic framework conceives a 10-meter communications range with a transfer rate of 250 kbit/s.

#### A] Protocol architecture:

The IEEE 802.15.4 protocol architecture consists of following layers [3].

##### i) The physical layer :

Physical layer is the initial layer in the OSI reference model used worldwide. The physical layer (PHY) ultimately provides the data transmission service, as well as the interface to the physical layer management entity, which offers access to every layer management function and maintains a database of information on related personal area networks. It operates on one of three possible unlicensed frequency bands:

- 868.0-868.6 MHz: Europe, allows one communication channel (2003), extended to three (2006)
- 902-928 MHz: North America, up to ten channels (2003), extended to thirty (2006)
- 2400-2483.5 MHz: worldwide use, up to sixteen channels (2003, 2006)

The original 2003 version of the standard specifies two physical layers based on *direct sequence spread spectrum* (DSSS) techniques: one working in the 868/915 MHz bands with transfer rates of 20 and 40 kbit/s, and one in the 2450 MHz band with a rate of 250 kbit/s.

##### i) The MAC layer :

The medium access control (MAC) enables the transmission of MAC frames through the use of the physical channel. Besides the data service, it offers a management interface and itself manages access to the physical channel and network beaconing. It also controls frame validation, guarantees time slots and handles node associations.

ii) Higher layers :

Other higher-level layers and interoperability sublayers are not defined in the standard. There exists specification like ZigBee. The IEEE 802.15.4 protocol stack is shown in Fig.1 below[3].

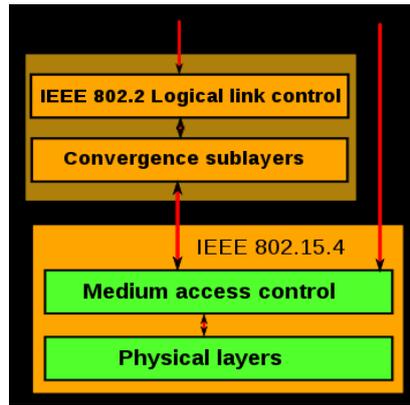


Fig. 1 IEEE 802.15.4 protocol stack

B) IEEE 802.15.4 Features:

- Data rates of 250 kbps, 40 kbps, and 20 kbps.
- Two addressing modes; 16-bit short and 64-bit IEEE addressing.
- CSMA-CA channel access.
- Automatic network establishment by the coordinator.
- Fully handshaked protocol for transfer reliability.
- Power management to ensure low power consumption.
- 16 channels in the 2.4GHz ISM band, 10 channels in the 915MHz I and one channel in the 868MHz band[4].

IEEE 802.15.4 is the basis for the ZigBee specification[3]. Zigbee builds upon the IEEE 802.15.4 standard and defines the network layer specifications and provides a framework for application programming in the application layer[5]. ZigBee builds upon the physical layer and medium access control defined in IEEE standard 802.15.4 (2003 version) for low-rate WPANs. The specification goes on to complete the standard by adding four main components: network layer, application layer, *ZigBee device objects* (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration. The Network layer supports multiple network topologies including star, mesh and cluster tree. Besides adding two high-level network layers to the underlying structure, the most significant improvement is the introduction of ZDOs. These are responsible for a number of tasks, which include keeping of device roles, management of requests to join a network, device discovery and security. Because ZigBee nodes can sleep most of the time, average power consumption can be low, resulting in long battery life. The name ZigBee refers to the waggledance of honey bees after their return to the beehive[6].

The ZigBee protocol stack is shown in Fig. 2[6].

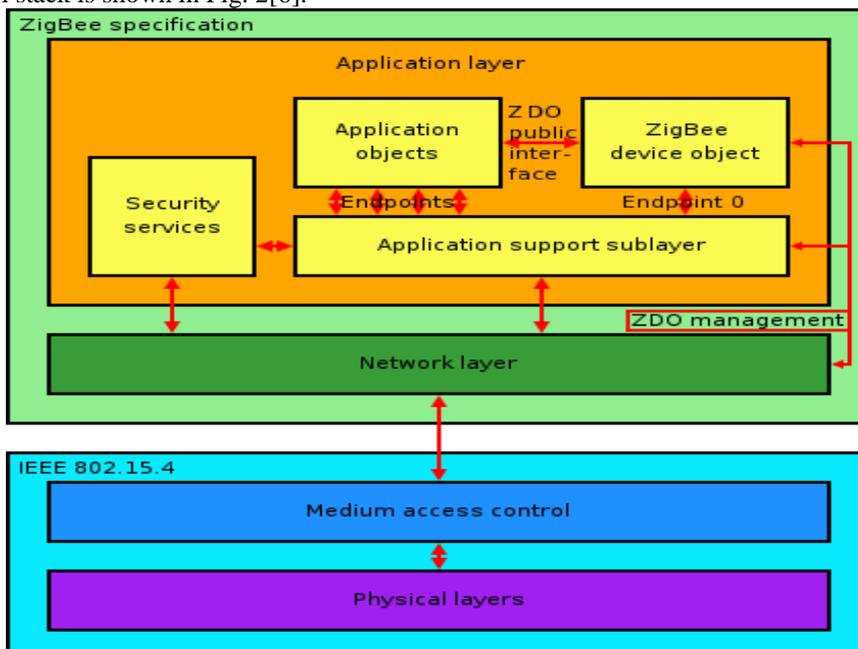


Fig. 2 ZigBee protocol stack

### **C] Network model [1]:**

#### **i) Node types:**

The standard defines two types of network node:

**Full-Function Device (FFD):** It can serve as the coordinator of a personal area network just as it may function as a common node. It implements a general model of communication which allows it to talk to any other device.

On the other hand there are **Reduced Function Devices (RFD)**. These are meant to be extremely simple devices with very modest resource and communication requirements; due to this, they can only communicate with FFDs and can never act as coordinators.

#### **ii) Topologies:**

Networks can be built as either peer-to-peer, star or cluster tree networks. However, every network needs at least one FFD to work as the coordinator of the network. Networks are thus formed by groups of devices separated by suitable distances.

**Peer-to-peer (or point-to-point):** Peer-to-peer networks can form arbitrary patterns of connections, and their extension is only limited by the distance between each pair of nodes. They are meant to serve as the basis for ad hoc networks capable of performing self-management and organization.

**Star:** In a star network, one of the FFD-type devices assumes the role of network coordinator and is responsible for initiating and maintaining the devices on the network. All other devices, known as end devices, directly communicate with the coordinator.

**A cluster tree:** A cluster tree network consists of a number of star networks connected whose central nodes are also in direct communications with the single PAN Coordinator [7].

## **III SOFTWARE DEVELOPMENT**

### **i) Network Simulator2 (NS2):**

NS2 is an open-source event-driven simulator designed specifically for research in computer communication networks[8]. NS2 provides the simulation and research supports for the wired networks, wireless networks by using TCP, and UDP, IP, and CBR patterns of the communications. To investigate network performance, researchers can simply use scripting language to configure a network, and observe results generated by NS2. OTcl language is suitable for the programs and configurations which are demanding for the fast and frequent network changes. tcl file contains parameters and variables which help change the network scenario and settings and control the simulation process. Settings like, channel type, propagation model, queue length, node starting time, start and stop time of the simulation, file containing the current seed value, antenna height, and several other parameters specific to WPAN simulations are referred as TCL commands. NS2 is made of two parts basically such as NS means network simulator and other one is NAM means network animator. There are also some other features of the NS2 which increases our interests of using the NS2 simulator for the simulation of our network applications such as:

- NS2 provides the network simulation environment for both wired and wireless networks.
- Provides the modules for the wireless channel such as 802.11, 802.15.4, 802.16 etc.
- Provides the number of routing protocols for choice in which the routing is done along multiple paths.
- Simulations of the cellular networks possible as the mobile hosts are simulated as well.

NS2 was initially developed for the UNIX systems but later by using the environment of the Cygwin under the Windows XP.

### **ii) Cygwin:**

Cygwin is a Unix-like environment and command-line interface for Microsoft Windows. Cygwin provides native integration of Windows-based applications, data, and other system resources with applications, software tools, and data of the Unix-like environment. It is free and open source software, released under the GNU General Public License version 3.

### **iii) Trace graph:**

Trace graph is a free network trace files analyzer developed for NS2 trace processing. Trace graph can support any trace format if converted to its own or NS2 trace format. Trace graph runs under Windows, Linux, UNIX and MAC OS systems. Some of the features of tracegraph are :

- supports 2D and 3D graphs
- any graph saved in text file with 2 or 3 columns can be plotted
- script files processing to do the analysis automatically.
- supports delays, jitter, processing times, round trip times, throughput graphs and statistics
- whole network, link and node graphs and statistics
- all the results can be saved to text files, graphs can also be saved as jpeg

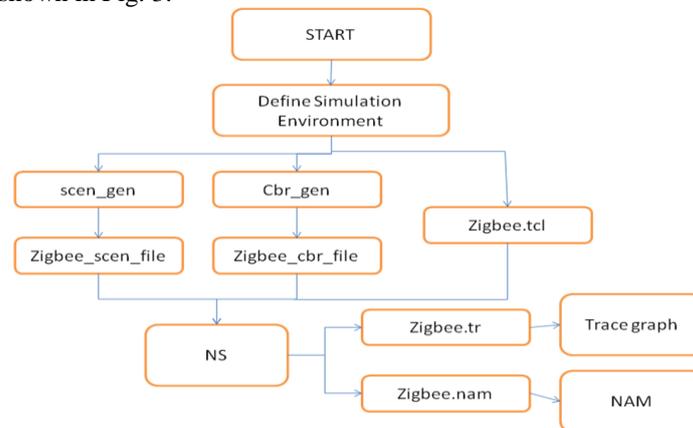
## **IV IMPLEMENTATION**

### **A] Motivation for simulation:**

- Network simulator does not require costly equipments, therefore cheaper.
- The complex scenario can be easily tested.
- more ideas can be tested in a smaller timeframe

- Controlled experimental conditions – Repeatability helps aid debugging[9]

Implementation is carried out using Window based Network Simulator2 (NS2). Several scripts have been written by taking variable nodes for both 802.11 and ZigBee/802.15.4 network. Various parameters and variables are defined while writing tcl scripts. The details of implementation are given below with the help of process structure flow-chart for 802.15.4/ZigBee Network shown in Fig. 3.



**Fig. 3 A process structure**

**B] Process Structure:**

The above flow chart describes the simulation structure, to generate the final statistics. Several scripts and programs have been designed by taking various nodes for 802.11 and ZigBee/802.15.4 network, to generate the results. The Fig. 3 explains the inter dependency of the scripts and programs of the simulation environment by taking into consideration ZigBee/802.15.4 network. Same procedure is repeated for 802.11 network.

**i) scen\_gen:**

Parameters: It accepts the following command line parameters

-scen gen [number-of-nodes] [X-Pos-of-coord] [Y-Pos-of-coord] [Personal-Operating-Space] number-of-nodes: Number of nodes to be placed around the coordinator.

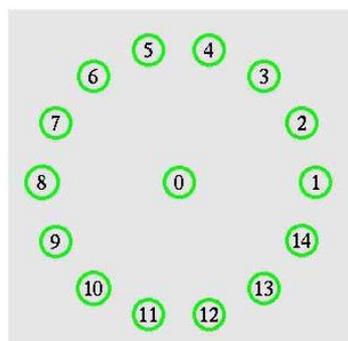
X-Pos-of-coord: X position of the coordinator, with respect to the area of the network dimensions.

Y-Pos-of-coord: Y position of the coordinator, with respect to the area of operation of the network.

Personal-Operating-Space: The operating space or the reachability of the coordinator.

Example: scen gen 11 25 25 10

The resultant position file for the node placement by scen\_gen is shown below in Fig. 4[10]:



**Fig. 4 Node placement by scen\_gen**

**ii) cbr\_gen:**

Parameters: ns cbrgen star.tcl [-type cbr—tcp] [-nn nodes] [-seed input-seed] [-mc max connections] [-rate datarate] [-starttime st][[-timegap tg]

type: Traffic type (cbr/tcp)

nn: Number of nodes in the scenario

seed: Seed to the RNG to generate a random traffic pattern

mc: Maximum Number of traffic flows

rate: Traffic rate in kbps

starttime: The time at which the first traffic flow would start

timegap: The time gap with which other traffic flows would start with respect to the first traffic flow.

**iii) ZigBee.tcl**

The ZigBee.tcl (\*.tcl ) file contains parameters and variables which help change the network scenario and settings and control the simulation process. Settings like, channel type, propagation model, queue length, node starting time, start and stop time of the simulation, file containing the current seed value, antenna height, and several other parameters specific to WPAN simulations are referred as TCL commands.

**iv) Trace File (\*.tr) :**

The trace file contains information about the various events that occurred during the simulation duration. It contains every detail of node behaviour, packet transmissions and receptions, packet type, layer responsible for communication, drops and reasons for drops, energy consumption, etc, to the utmost possible precision [10].

**v) NAM Trace file (\*.nam):**

The network animator trace file contains information about topology, e.g; nodes, links, as well as packet traces. It can be said as a mirror of the trace file, with the exception that it uses a different syntax to work with the visualization [10].

**C] Simulation Parameters:**

Simulation is a flexible means for assessment of the performance of parameters. However, identifying the correct simulation parameters is key for a successful and nearly realistic analysis of any study. Here we have considered end-to-end delay and packet dropped parameters for the simulation purpose. Scripts are written by taking 10 and 20 nodes using AODV protocol for both 802.11 and ZigBee/802.15.4 network. For simulation purpose we used tracegraph2.02 software.

**End-to-end delay:**

It refers to the time taken for a packet to be transmitted across a network from source to destination [11].

**Packet Dropped:**

If one of the packets fails to get from source to destination it is called packet loss but deliberate loss of a packet due to some reason like if the router is overloaded or if the router believes the packet is part of a DOS attack, then it is called packet dropped.

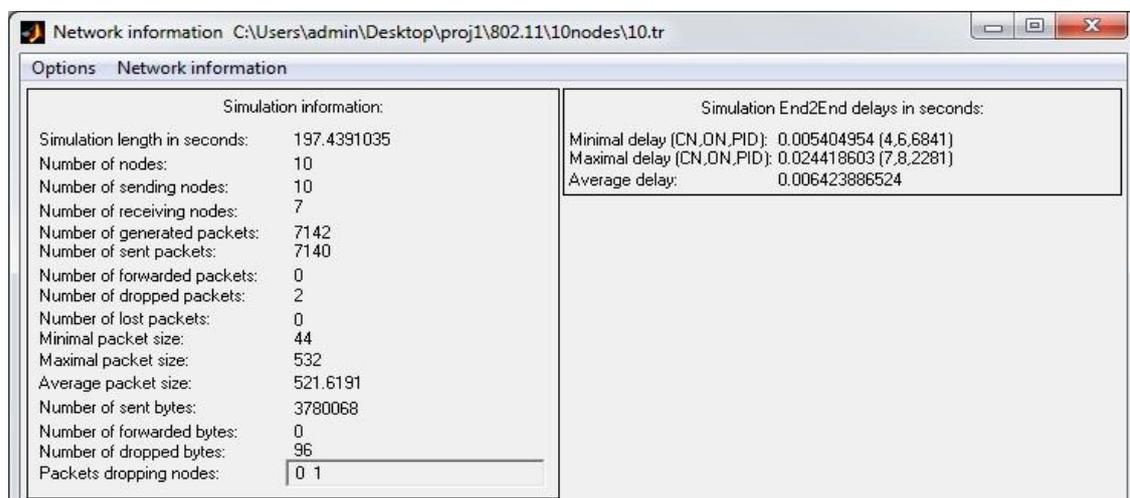
**AODV protocol:**

**Ad hoc On-Demand Distance Vector (AODV) Routing** is a routing protocol for mobile ad hoc networks (MANETs) and other wireless ad-hoc networks. It is a reactive routing protocol, meaning that it establishes a route to a destination only on demand. In contrast, the most common routing protocols of the Internet are proactive, meaning they find routing paths independently of the usage of the paths. AODV is, as the name indicates, a distance-vector routing protocol. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates, a technique pioneered by DSDV. AODV is capable of both unicast and multicast routing [12]. AODV builds routes using a route request / route reply query cycle [13].

**V. EXPERIMENTAL RESULTS**

For simulation purpose we used tracegraph2.02 software. In order to get simulation results for various parameters we have to select the following path:

1. Tracegraph-bin-win32-trgraph2.02-file-open a trace file (e.g. 10.tr)
2. Then we will get **network information** and **graph window**. In network information window after selecting network information option we will get simulation information as shown below. As an illustration, Network Simulation Information of 802.11 and 802.15.4/ZigBee with 10 nodes is shown in Fig.5 and 6 respectively.



**Fig. 5 Network Simulation Information of 802.11 Network with 10 nodes**

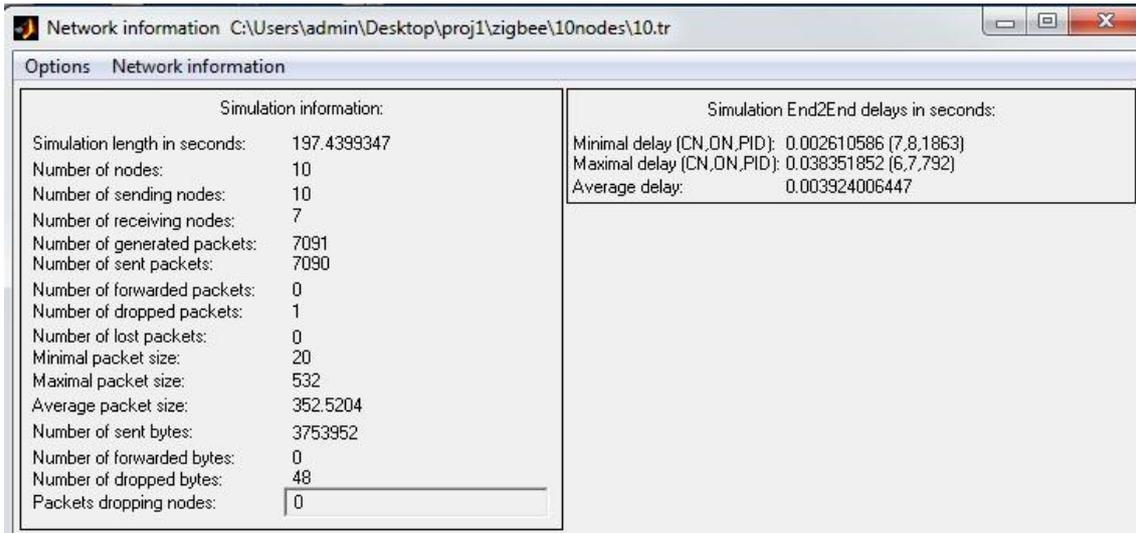


Fig. 6 Network Simulation Information of 802.15.4/ZigBee Network with 10 Nodes:

In graph window we have to choose option 2D Graphs, from where we can select various parameter options. Here we have to choose end-to-end delay and packets dropped option for getting resulting graphs.

**Performance Comparison:** Performance comparison for 802.11 and 802.15.4/ZigBee with respect to End-to-End delay and packet dropped parameter is shown in the Table 1 below. Parameter information shown in comparison table is obtained by using tracegraph software .

Table 1 Comparison table for AODV protocol

Parameters	End-to-End delay		Packet Dropped	
	10	20	10	20
<b>802.11 (MANET Network)</b>	<b>0.0064</b>	<b>0.015</b>	<b>2</b>	<b>140</b>
<b>802.15.4 (ZigBee Network)</b>	<b>0.0039</b>	<b>0.013</b>	<b>1</b>	<b>125</b>

**Performance Comparison Graph:**

Performance comparison between 802.11 and 802.15.4/ZigBee with respect to End-to-End delay and packet dropped parameter is shown below in Fig. 7 & 8 with the help of Bar-Chart.

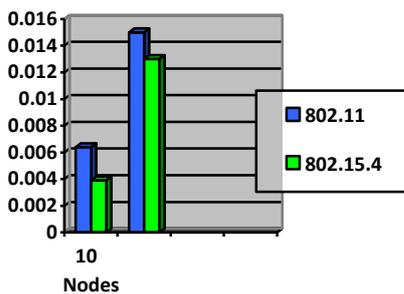


Fig. 7 Bar chart comparison graph for End-to-End Delay Dropped

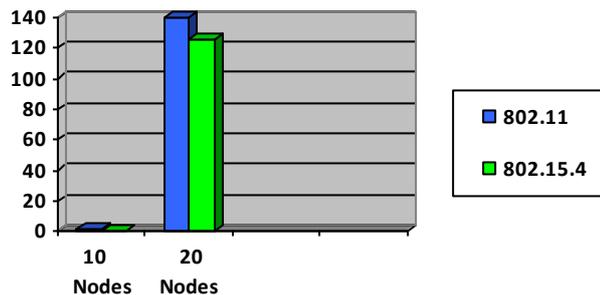


Fig. 8 Bar chart comparison graph for Packet Dropped

From the above graph we can say as number of nodes increases we get increased End-to-End Delay and packet dropped when 802.11 and 802.15.4/ ZigBee networks are considered individually whereas if we compare these two networks we get reduced amount of End-to-End Delay and packet dropped.

**VI CONCLUSION**

There are many wireless monitoring and control applications for industrial and home markets which require longer battery life, lower data rates and less complexity than available from existing wireless standards like Wi-Fi and Bluetooth.

So, there was a need for a standard based, interoperable wireless technology that addresses the unique needs of low data rate wireless control and sensor based networks. In this regard, 802.15.4/zigbee has become the global monitoring and control network standard. We evaluate the performance of 802.15.4/zigbee and 802.11 with respect to End-to-End Delay and Packet Dropped parameters. We got good performance with respect to these parameters for 802.15.4/zigbee as compared to 802.11

#### **VI FUTURE SCOPE**

We can evaluate the performance by taking other parameters like throughput, jitter, energy consumption etc.

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