Performance Comparison of 802.11and 802.15.4 based Networks

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Abstract: The continuous improvement of sensor skill and wireless communication is encouraging wireless sensor networking. IEEE 802.15.4 was developed to meet the needs for simple, low-power and low-cost wireless communication. In the past couple of years it has become a popular technology for wireless sensor networks[1]. It is a standard which specifies the physical and MAC layer for Low Rate Wireless Personal Area Networks(LR-WPANs) and it operates primarily in the 2.4GHz ISM band. Wireless Sensor Networks are adopted in many ways, including industrial controls, hospitals, hotels, home/office automation, environmental monitoring etc. However, IEEE 802.15.4 is potentially vulnerable to interference by other wireless technologies working in this band such as IEEE 802.11 and Bluetooth. Here we have given a short overview of the IEEE 802.11 and IEEE 802.15.4 and carefully analyze the properties and compare the performance of IEEE 802.11 and IEEE 802.15.4 through simulation and measurement of jitter, End-to-End delay and packet dropped parameters, using NS2. Furthermore we present simulation results from the evaluation of the IEEE 802.11 and IEEE 802.15.4 We evaluate and compare the performance by taking 10,20 and 30 nodes for both 802.11 and 802.15.4 based networks.

Keywords: Wireless sensor networks, IEEE 802.11, IEEE 802.15.4, jitter, End-to-End delay, packet dropped, NS2

I. INTRODUCTION

As compared to wired networks wireless networks are blessed with the major advantage of cable replacement. In this modern era people are most concentrated on automation, either home or office. Low Rate Wireless Personal Area Networks(LR-WPANs), such as wireless light switches with lamps, electrical meters with in-home-displays, consumer electronics equipment via short-range radio needing low rates of data transfer and also low power consumption. ZigBee is a specification based on IEEE 802.15.4 standard for personal area network. It is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking. The name of the brand is originated with reference to the behavior of honey bees after their return to the beehive[2] It is intended to be simpler and less expensive than other WPANs, such as Bluetooth and Wi-Fi. Furthermore the standard is trying to solve some problems that were inadequately taken into account by Bluetooth technology. IEEE 802.15.4 distinguishes itself from other wireless standards such as IEEE 802.11/Wi-Fi and Bluetooth by some unique features given in section III. High power consumption of Wi-Fi makes battery life in mobile devices a concern. Mobile use of Wi-Fi over wider ranges is limited. Since both types of devices operate in the 2.4GHz ISM frequency band, it is of great importance to understand and evaluate the coexistence issues. In this paper we analyzed and compared the performance of IEEE 802.11 and IEEE 802.15.4 based network by measuring End-to-End delay, packet dropped and jitter parameters using Network Simulator 2 (NS2). Here we have analyzed the performance by taking 10, 20 and 30 nodes in a network.

II OVERVIEW OF THE IEEE 802.11

IEEE 802.11 is a set of standards for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6, 5 and 60 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802). These standards provide the basis for wireless network products using the Wi-Fi brand[3]. It has been deployed in airports, coffee shops, colleges, homes etc. Access points(APs) are used to which a mobile user could connect to. Users scan the wireless channel in order to find the AP which shows the highest signal strength and associate to it.

III OVERVIEW OF THE IEEE 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)[4][5]. 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 data rate, low power consumption and low-cost wireless networking[6]. 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 [7]. 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

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.

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[7].
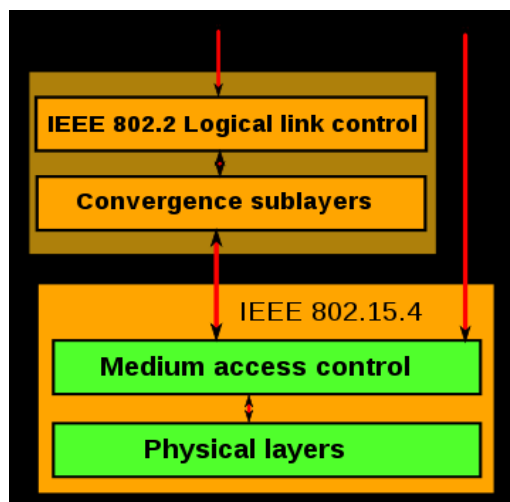

Fig. 1 IEEE 802.15.4 protocol stack

B] Network model [8]:
Node types:
The standard defines two types of network nodes: Full-Function Device (FFD) and Reduced Function Devices (RFD). FFD 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 RFD are meant to be extremely simple devices and they can only communicate with FFDs and can never act as coordinators.

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 devices act as a 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 [9].

IV IMPLEMENTATION

Implementation is carried out using Window based Network Simulator2 (NS2). Several scripts have been written by taking 10,20 and 30 nodes for both 802.11 and 802.15.4 networks. NS2 is an open-source event-driven simulator designed specifically for research in computer communication networks[10]. 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 analyse network performance, we have to use scripting language to configure a network, and observe results generated by NS2. tcl file contains parameters and variables which help to change the network scenario and settings and control the simulation process. Settings includes channel type, propagation model, queue length, simulation time etc. The simulation time is a measure of the operating time of the network. An inappropriate selection of the simulation time may reflect as inaccurate results. However, given the simulation statistics, and the fact that the usual warm up period of the network (association phase of the network) would generally last a few tens of seconds after the start of the first node, the simulation time has been chosen as 200 to 300 seconds. The trace file .tr 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[11]. The network animator trace file .nam 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[11].

NS2 provides the network simulation environment for both wired and wireless networks. It also supports the number of routing protocols. A routing protocol is a protocol that specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network, the choice of the route being done by routing algorithms. For windows based Network Simulator we have to use 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.

Implementation steps:
Following are the steps for implementation.
 1: Write the tcl program for network.
 2: Create the CBR and Scenario file for the network.
 3: Start Cygwin
 4: Go to ns-2.29 directory.
 5: Export the following path:
 i.   PATH=$PATH:/usr/local/ns-allinone-
   2.29/bin:/usr/local/ns-allinone-
   2.29/tcl8.4.11/unix:/usr/local/ns-allinone-
   2.29/tk8.4.11/unix:/usr/local/iNSpect-release3.5/src
 ii.   LD_LIBRARY_PATH=/usr/local/ns-allinone-
   2.29/otcl-1.11:/usr/local/ns-allinone-
   2.29/lib:/usr/local/iNSpect-release3.5/gtkglext/lib
 iii.   TCL_LIBRARY=/usr/local/ns-allinone-
   2.29/tcl8.4.11/library
 iv.   export PATH
 v.   export LD_LIBRARY_PATH
 vi.   export TCL_LIBRARY
 6: Compile the tcl code for network. Files '.tr' and '.nam' will be generated.
 7: Start the NS2 command prompt.
 8: Start Network Animator.
 9: Load '.tr' file in trace-graph
10: Evaluate the performance of the network by considering various parameters obtained in the graph.

The network simulator window is shown below in Figure 2. The network animator tool is used to visualize the simulation of the networks in the form of actual communication patterns.
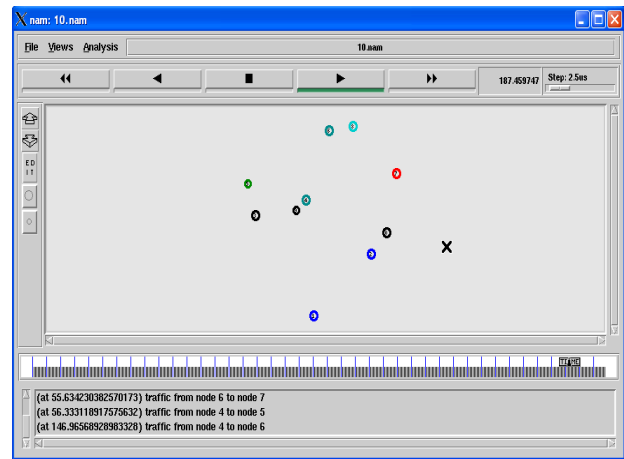

Fig. 2 NS2.29 window

Motivation for simulation:
1: Network simulator does not require costly equipments, therefore cheaper.
2: The complex scenario can be easily tested.
3: More ideas can be tested in a smaller timeframe
4: Controlled experimental conditions – Repeatability helps
   aid debugging
5: Disadvantages: Real systems too complex to model[12]

V SIMULATION RESULTS

Simulation is carried out for evaluating and comparing the performance of 802.11 and 802.15.4/ZigBee network with respect to jitter, End-to-End delay and packet dropped parameters. For simulation purpose we used tracegraph 2.02 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/20.tr/30.tr for 10,20,30 nodes respectively.)
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. In graph window we have to choose option 2D Graphs, from where we can select various options like end-to-end delay, packets dropped, jitter etc. to get the resulting graphs. As an illustration, Network Simulation Information of 802.11 and 802.15.4/ZigBee network with 10 nodes is shown below in Fig. 3 and Fig. 4 Respectively.
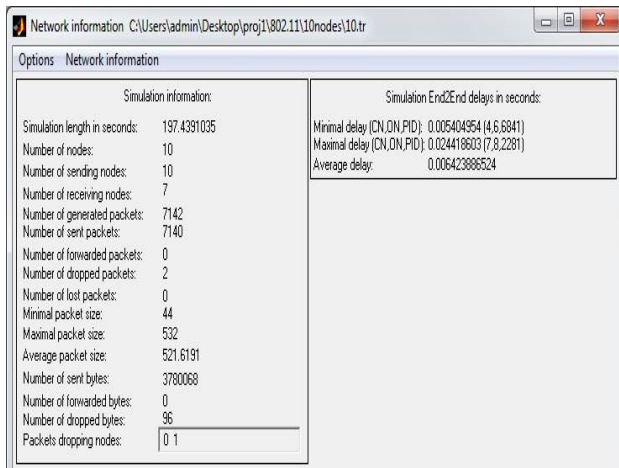
.

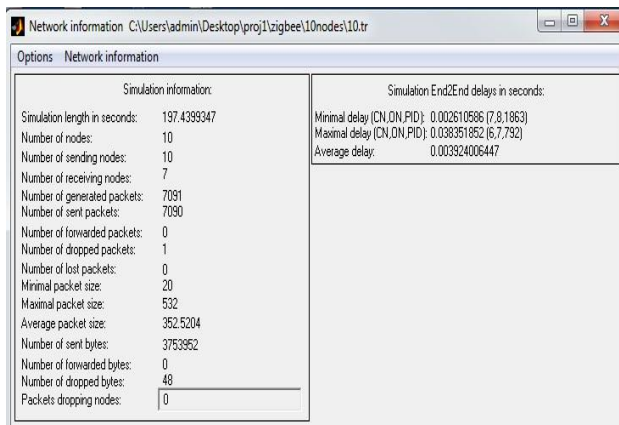Fig. 3 Network Simulation Information of 802.11 Network with 10 Nodes

Fig. 4 Network Simulation Information of 802.15.4/ZigBee Network with 10 Nodes

In order to get simulation results for 20 and 30 nodes we have to follow the above mentioned path only with the difference that we need to select path as: Tracegraph-bin-win32-trgraph2.02-file-open a trace file (e.g. 20.tr) for 20 nodes and Tracegraph-bin-win32-trgraph2.02-file-open a trace file (e.g. 30.tr) for 30 nodes respectively. Whatever results obtained from the 2-D graph window and whatever values we got for the parameters like jitter, end-to-end delay and packet droppe are taken for the performance comparison, which is shown in Table 1 and 2 respectively. By taking values from these comparison table we can draw bar charts.

Table 1 Performance comparison table for jitter and End-to-End Delay

Parameters	Jitter(s)			End-to End Delay(s)		
No. of Nodes	10	20	30	10	20	30
802.11 Network	1.8	0.35	0.36	0.0064	0.015	0.030
802.15.4/ ZigBee Network	5.2	0.35	0.33	0.0039	0.013	0.024

Table 2 Performance comparison table for packet dropped

Parameters	Packet Dropped		
No. of Nodes	10	20	30
802.11 Network	2	140	5390
802.15.4/ ZigBee Network	1	125	5089

By taking the data obtained from the simulation graphs for the jitter, End-to-End delay and packet dropped parameters following bar charts are drawn in Fig. 5, 6 and 7 respectively.
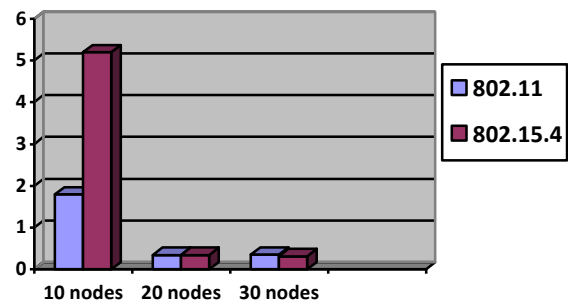

Fig. 5 Bar-chart comparison of jitter

Fig. 5 shows as number of nodes increases jitter decreases for both 802.11 as well as 802.15.4/ZigBee network, when considered individually. For 10 nodes jitter for 802.15.4/ZigBee network is more as compared to the 802.11, but later for 20 and 30 nodes it is almost constant for both networks.
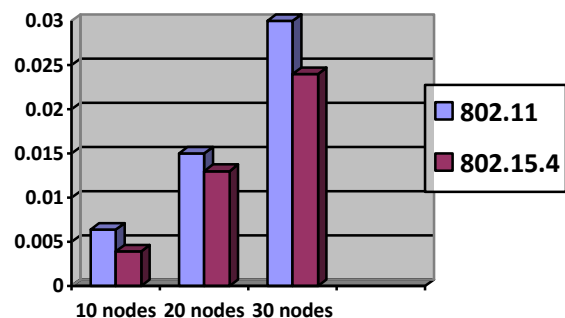

Fig. 6 Bar-chart comparison of End-to-End delay

Fig. 6 shows as number of nodes increases End-to-End delay also increases for both 802.11 as well as 802.15.4/ZigBee network, when considered individually. But if we compared these two networks 802.15.4/ZigBee has lower End-to-End delay as compared to 802.11 network.
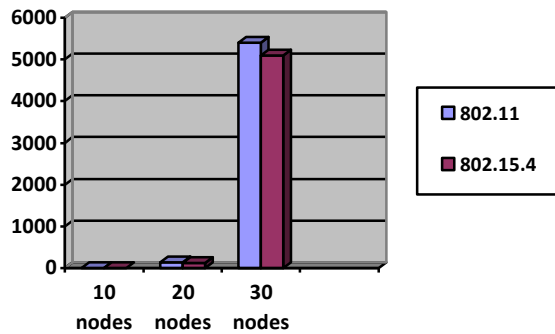
[9]   http://www.stg.com/wireless/ZigBee_netw.html
[10]   Introduction to Network Simulator-2 :Teerawat Issariyakul Ekram Hossain by Springer
[11]http://www.ifn.et.tudresden.de/~marandin/ZigBee/ZigBeeSimulatio nEnvironment.html
[12]   www.cse.iitb.ac.in/../ns-tutorial.pdf NS2 Tutorial Kameswari Chebrolu Dept. of Computer Science andEngineering, IIT Bombay

Fig. 7 Bar-chart comparison of packet dropped

Fig. 7 shows as number of nodes increases number of dropped packets also increases for both 802.11 as well as 802.15.4/ZigBee network, when considered individually. But if we compared these two networks 802.15.4/ZigBee has lower dropped packets as compared to 802.11 network.

VI CONCLUSION

Now a days there are many wireless sensor, monitoring and control applications which covers wide range for industrial and home markets. Such applications require lower data rates, longer battery life, low power consumption 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 adresses the above needs. In this regard, 802.15.4/zigbee has become the global sensor, monitoring and control network standard. Here we evaluate the performance of both 802.15.4/zigbee and 802.11 based networks with respect to jitter, End-to-End Delay and Packet Dropped parameters. From the measurements we observed that performance of 802.15.4/ZigBee with respect to the delay and packet dropped parameter is good as compared to 802.11, whereas with increased number of nodes jitter remains almost constant, for both 802.11 and 802.15.4/ZigBee networks. We can further evaluate the performance by taking other parameters like throughput, energy consumption etc.

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