Performance Analysis of IEEE 802.11b, 802.15.1 and 802.16a Standards

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Abstract

The ever-expanding and explosive growth of the Internet over the last decade has led to an increasing demand for high-speed, ubiquitous Internet access. Broadband Wireless technologies are increasingly gaining popularity by the successful global deployment of the Wireless Personal Area Networks (Bluetooth-IEEE 802.15.1), Wireless Local Area Networks (WiFi- IEEE 802.11b), and Wireless Metropolitan Area Networks (WiMAX-IEEE 802.16a). In this paper we have used the QualNet Simulator to analyze the performance of IEEE 802.11b, 802.15.1, and 802.16a Standards by varying mobility of the nodes. The performance metrics measured in this study includes end-to-end delay, packet-loss ratio, and throughput. The results show how mobility affects the performance of IEEE 802.11b, 802.15.1 and 802.16a.

Keywords

IEEE 802.11b, 802.15.1, 802.16a, Wi-Fi, Bluetooth, WiMAX, MANET, QualNet.

I. Introduction

A sudden increase in use of mobile devices within the organization, and increase in mobility, has fuelled the demand for Wireless networks. Initially, the technology was slow, expensive and reserved for mobile situations or hostile environments, where cabling was impractical or not feasible to install. With the maturity of industry standards and the deployment of lightweight Wireless devices alter the need of hardware software co-design to overcome the problems of present Wireless scenario. Wireless technology has come of age, which enables two or more computers to communicate using standard network protocols. Wireless networking does not require any fixed infrastructure and cabling [1]. This technology has propelled the emergence of cross-vendor industry standards such as IEEE 802.11b, IEEE 802.15.1, and IEEE 802.16a. This technology has produced a number of affordable Wireless solutions that are growing in popularity within the organizations for sophisticated applications, where more mobility is required.

Performance analysis of any system quantifies the service it delivers which help to justify the feasibility of its operation intended for some purpose. In this paper, the analysis of IEEE 802.11b, IEEE 802.15.1 and IEEE 802.16a have been done using QualNet Simulator [10]. We have investigated the effect of node movement. The rest of the paper is organized as follows. Section II, is an overview about the IEEE 802.11b, 802.15.1 and 802.16a. Section III, includes the simulations as well as the results obtained. Finally, Section IV, has the general conclusion of the work.

II. Overview

A. IEEE 802.11b

In 1997, the Institute of Electrical and Electronic Engineers (IEEE) created the first WLAN standard. They called it 802.11 after the name of the group formed to oversee its development. WLAN required different management and physical features which was addressed in the OSI (Open System Interconnect) through changes in Data Link layers and PHY (Physical) layer. The upper networking layers are common for all the IEEE 802.x protocols, but the DLL(Data Link Layer) and PHY layers are different. Medium Access Control (MAC) sub layer of DLL determine how to access the channel or medium and who gets to transmit the data next. PHY handles data transmission and reception among stations [2].

In this paper we concentrate on 802.11b. The 802.11b standard is currently the most widely used one released in September 1999. It offers a throughput or maximum raw data rate of 11 Mbps (6 Mbps in practice) without line-of-sight requirements and a reach of up to 300 meters in an open environment. It uses the 2.4 GHz frequency range, with 3 radio channels available. The 802.11b use HRDSSS (High Rate-Direct Sequence Spread Spectrum) technique. An 802.11 LAN is subdivided into cells, with each cell referred to as a Basic Service Set (BSS). Each BSS is controlled by a base station which is referred to as an Access point (AP). Several APs can be connected to as a common backbone. When this occurs, the backbone is referred to as Distribution System (DS). The upper layers of the OSI Reference Model are referred to as an Extended Service Set (ESS) [11]. IEEE802.11b uses the Carrier Sense Multiple Access and Collision Avoidance (CSMA/CA) for contention,Request-To-Send (RTS/CTS) mechanism to accommodate the hidden terminal problem, and an optional mechanism called point coordination function (PCF) to support real time applications [3].

B. IEEE 802.15.1

The IEEE 802.15.1 standard is the basis for the Bluetooth wireless communication technology. It is designed as a short range, low cost, low power connectivity solution for small peripherals, portable, and electronic devices like mobile phones, PDAs, printers, keyboards etc [4]. Bluetooth is a wireless telecommunications technology designed to eliminate cables in connections among electronic devices. The most general characteristics of Bluetooth are: short range (less than 100 meters), operates in star topology and transfer rate up to 3 Mbps in version 2.0 + EDR (Enhanced Data Rate), ratified in November 2004. Bluetooth uses the unlicensed Industrial, Scientific, and Medical (ISM) band around the 2.4 GHz frequency range. With a transmitting power of 1 mW can reach a distance of range up to 10 meters and with 100 mW up to 100 meters.

Bluetooth allows instantaneous connection among devices found in the same operation area. Bluetooth protocols establish a session in a transparent way to the user. The devices found in this operation area form a network known as piconet. In a Bluetooth network the basic unit used is known as piconet [5]. A Bluetooth piconet consists of 1 master and 7 (at most) active slave device (all nodes must be within a range of 10 meters) but more than 7 devices can be congigured for a piconet. Two piconets can be connected through a common Bluetooth devices (a gateway or bridge) to form a scatternet. These interconnected piconets within the scatternet form a backbone for the Mobile Area Network (MANET), and can enable devices which are not directly communicating with each other, or which are out of range of another device, to exchange data through several hops in the

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scatternet. The biggest Scatternet can link up to 10 piconets. Within a piconet, the communication between master and slaves nodes is achieved using a TDD (Time Division Duplex) protocol. The master node (MN) is the administrator of overall network, beside MN assigns the time slots. If the Piconet's MN is turned off, the slave nodes negotiate who will be the new master node. Also this process is transparent to the users [6].

C. IEEE 802.16a

802.16a, also known as WiMAX, is a wireless networking standard that offers greater range and bandwidth than the Wi-Fi family of standards, which includes 802.11a, 802.11b and 802.11g. While Wi-Fi is intended to provide coverage over relatively small areas, such as in offices or hot spots, WiMAX can transfer around 70Mbit/sec (and more in favorable conditions) over a distance of 30 miles (48 kilometers) to thousands of users from a single base station. Approved in January, 2003, 802.16a provides wireless, last-mile broadband access over the frequency bands below 11 GHz (2-11 GHz) to connect homes, organizations and Wireless LANs. 802.16a greatly improves non-line-of-sight (NLOS) performance, and it is the most appropriate technology available when obstacles such as trees and buildings are present. Stations can be mounted on homes or buildings rather than towers on mountains. With throughput up to 75M bit/sec, the wireless standard gives companies another way to get business-quality broadband service [7]. 802.16a provides flexibility not possible with wired services, such as high-speed backhaul for events such as trade shows, with hundreds or even thousands of 802.11 hot-spot users. On-demand connectivity also could benefit businesses such as construction companies that have sporadic or nomadic connectivity needs. The 802.16e extension to 802.16a introduces nomadic capabilities that let users connect while roaming outside their home service areas. The technology also offers privacy and Triple-DES encryption features to support secure transmissions and authentication. In a typical enterprise deployment, laptop and desktop computers are connected via wired Ethernet or 802.11b (Wi-Fi) access points located throughout the campus. An 802.16a directional antenna provides the connection from the business to a service provider's cell tower. Even if there is no line of sight between the antenna and the tower, signal can still be received after it reflects off buildings or other obstructions and reaches the tower indirectly [8]. At the base station, 802.16a technology correctly interprets the information even though reflections distort the radio frequency signal. Backhaul to the Internet is then provided via wireless 802.16a point-to-point links or by traditional wired backhaul such as DS3 and OCX. 802.16a technology also provides low latency for delay-sensitive services such as circuit-switched voice traffic or voice over IP, optimized transport for video, and prioritization of data traffic. This is especially important for businesses that want voice in addition to data services from their broadband service provider.

III. Simulation and Result Analysis

The purpose of our simulations is to analyze the performance of IEEE 802.11b, 802.15.1 and 802.16a. The simulations have been performed using the QualNet Simulator ver 5.0. This simulator models the OSI seven layer network architecture and includes models of IP routing. QualNet provides a scalable simulation environment and is a comprehensible suite of tools for modeling large wireless and wired communication networks [9]. QualNet uses a parallel discrete-event simulation capability provided by SNT. It . It can also be used as a parallel programming language. QualNet simulates networks with up to thousand nodes linked by a heterogeneous communications capability that includes multicast, asymmetric communications using direct satellite broadcasts, multi-hop wireless communications using Ad-Hoc networking, and traditional Internet protocols. It uses simulation and emulation to predict the behavior and performance of networks to improve their design, operation, management, scenarios and analyzing their performance [10].

A. Simulation scenarios

This section describes the scenario with all the network parameter which is used for simulation. The various parameters used in simulation to compare and analyze the performance of the concerned wireless standards have been shown below in Table. 1.

Table 1: Various Parameters Used

Parameters	IEEE 802.11.b	IEEE 802.15.1	IEEE 802.16.a
Simulation time	10M	10M	10M
Terrain Dimensions	1500, 1500	1500, 1500	1500, 1500
Number of Nodes	20	20	20
Traffic Model	CBR	CBR	CBR
Node Placement	Uniform	Uniform	Uniform
Mobility	0-30 (m/s)	0-30 (m/s)	0-30 (m/s)
MAC-Protocol	802.11b	802.15.1	802.16a
Routing Protocol	DSR	DSR	DSR
Tx-Power	15	4	43
Bandwidth	6000000	2000000	12000000
Radio Frequency	2.4 e9	2.4 e9	2.5 e9

B. Result

In this section, we will analyze the performance of IEEE 802.11b, 802.15.1 and 802.16a standards by changing the parameter node mobility. Then we will analyze the affect of changing mobility on the performance of these technologies.
The three metrics that are used in the evaluation of this are the average end-to-end delay, throughput, and packet-loss ratio.

1. Average End-to-End Delay (Unit: Seconds)

The end-to-end delay of a path is the sum of the node delay at each node plus the node-link delay at each link on the path. The average end-to-end delay is the total latency experienced by a packet to traverse the network from the source to the destination. At the network layer, the end-to-end packet latency is the sum of processing delay, packetization time, transmission delay, queuing delay, and propagation delay. In a wireless link, the propagation delays are very small and almost equal for each hop on the path. The queuing delay and MAC delay are considered as two main factors that accumulated in the node's delay.

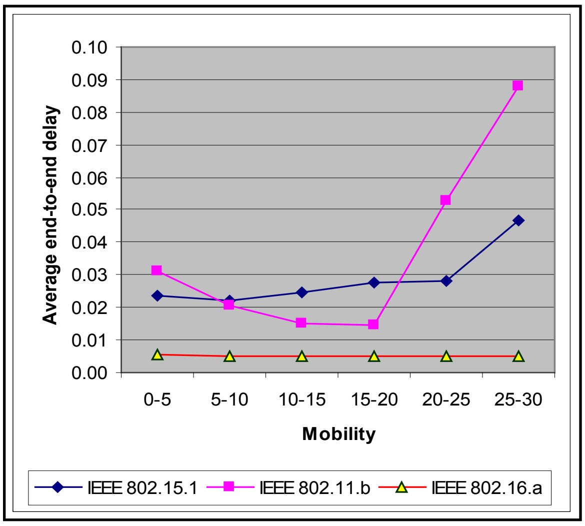

Fig. 1: Average End-to-End Delay

The end-to-end delay increases as the node speed is increased. Higher mobility causes more links to be broken and frequent re-routing and thus causing larger end-to-end delay. The end-to-end delay in IEEE 802.11b and IEEE 802.15.1 is more than end-to-end delay observed in IEEE 802.16a.

2. Throughput (Unit: Mbps)

The amount of information or data transferred from one place to another or processed in a specified amount or interval of time. Throughputs are measured in Kbps, Mbps and Gbps. This data may be delivered over a physical or logical link, or pass through a certain network node. It is clear from the figure that the maximum throughput has been observed in 802.16a (WiMAX). Throughput performance with respect to the mobility is plotted in fig. 2. From the fig. 2, it is clear that as mobility is increased, the throughput decreases in case of IEEE 802.11b, due to less support of mobility the curve is going downward.

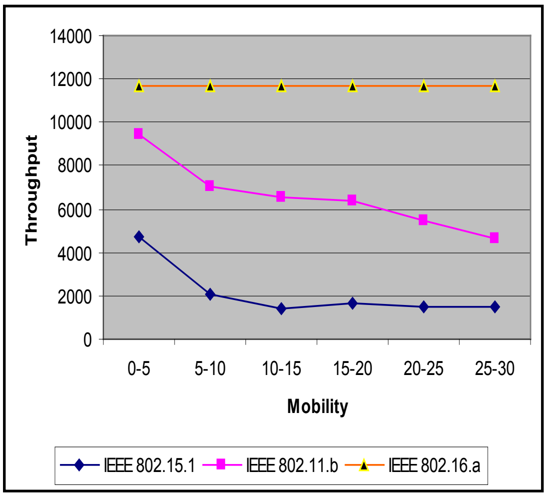

Fig. 2: Throughput

The throughput of IEEE 802.15.1 decreases with respect to mobility, this is because of the broken links sue to higher mobility and lower data rate of Wi-Fi and Bluetooth as compared to WiMAX. The throughput of IEEE 802.16a is constant because it easily support mobility rate up to 50 km/ hour.

3. Packet-Loss Ratio (Unit: %)

The Packet-loss ratio has been defined as the ratio between the packets that are lost and all the sending packets.

The fig. 3, shows the effect of increasing node mobility on packet loss of IEEE 802.11b, 802.15.1 and 802.16a. It can be seen that increase in node speed results in increase in the packet loss in both the IEEE 802.15.1 and IEEE 802.1b due to more link breaks. The increase in packet loss for IEEE 802.15.1 and IEEE 802.11b is more than that in IEEE 802.16a. The 802.16a show no loss because it can deliver more than 75Mbps.

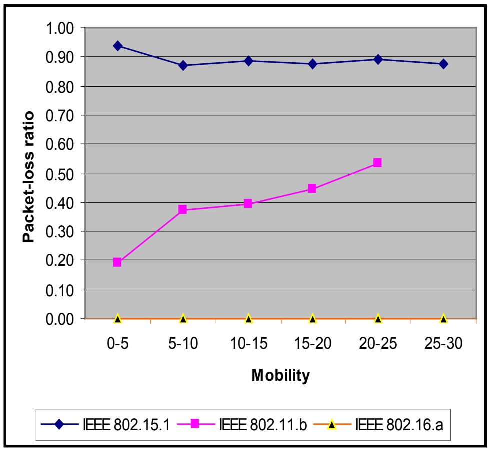

Fig. 3: Packet-Loss Ratio

IV. Conclusion

The use of a particular Wireless Network depends upon factors like size of the network, load, mobility requirements etc. This paper has presented a performance analysis of the IEEE 802.11b, IEEE 802.15.1 and IEEE 802.16a standards by using QualNet Simulator by varying the mobility of the nodes. In summary, it can be said that for robust scenario where mobility is high, nodes are dense, area is large, the amount of traffic is more and network is for longer period, IEEE 802.16a performs better among all the studied wireless network. For the normal situations where a network is of general nature with moderate traffic and moderate mobility IEEE 802.11b would be the right choice as it delivers more packets at the destination with lowest routing overheads. For low mobility and less number of nodes, IEEE 802.15.1 is preferable. Results indicate that the performance of IEEE 802.16a is the best among all compared wireless standards.

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