IEEE 802.11b Wireless Class Room Network Performance Evaluation

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Abstract

The advent of mobile computers and wireless networks enables the deployment of wireless servers and clients in short-lived ad hoc network environments, such as classroom area networks. This paper outlines wireless network infrastructure establishment in a classroom environment and provides experimental methodology and test site for an ad hoc IEEE 802.11b wireless LAN, using a wireless-enabled server, a set of wireless clients and a wireless network analyzer. The experimental focus is on the wireless network performance and throughput achievable in the wireless classroom area network environment.

Key Words

Wireless network performance, delay, throughput, bandwidth, error rate, network protocol, network measurement

1. Introduction

Wireless LANs (Local Area Networks) are typically installed, configured and maintained by the individuals lacking detailed knowledge of wireless network performance and network coverage area of such networks. This is due to the fact that wireless networks can often experience an unexpected RF (radio frequency) environment when they are used indoors.

This reason has motivated to a methodology to conclude optimum model out of a set of models and to evaluate throughput based on indoor RF propagation. The models can be used to evaluate the throughput by any user at any location in the coverage area of a wireless LAN access point. This paper also attempts to analyze actual measurement campaign results of wireless LANs by other researchers and the methods used to calculate the parameters of the empirical throughput.

2. Network Performance Statistics

The literature on wireless LAN network performance present measurements using various different statistics. The different network statistics used are studied and the additional statistics of importance are suggested for consideration in evaluating network performance.

Delay: Latency and Round Trip Time

One of the key statistics used in evaluating the performance of a network connection is the delay experienced by data which travels from one host to another. The term latency is used to describe this concept. However, care must be taken in the use of the term because it is not always clear whether latency refers to the time to travel from one host to another, or the time required in transmitting a packet and receiving an acknowledgment, or some other delay. A related term to latency is the round trip time (RTT) of a network connection. Latency and round trip times are typically measured in milliseconds for IP-based networks.

Throughput

Throughput is a measurement of the average rates that data (in bits) can be sent between a one user and another and is typically reported in kbps or mbps. The throughput of the same network connection can vary greatly depending on the protocol used for transmission (e.g., UDP, TCP, etc.), the type of data traffic being sent (e.g., HTTP, FTP, VoIP or other traffic) as well as the quality and data bandwidth of a network connection. Throughput is measured at the highest protocol level possible to reflect as accurately as possible the performance.

Data Bandwidth

The data bandwidth or channel data rate is the maximum available, raw rate at which data can be transmitted over a network connection. The data bandwidth of a connection is similar to the throughput of a connection except that the data bandwidth is the theoretical maximum rate at which data can be transmitted if all of the overhead and checksums of the protocols used is included and the multiple access protocol is completely efficient. Like throughput, data bandwidth is measured in units of bits per second or bps. However, the data bandwidth of a network connection is always larger than the measured throughput of the connection. For example, wireless LAN connections with 11 Mbps data bandwidths have been measured to have throughputs of 2 Mbps.

Error Rates

The error rate of a data connection, until recently, has not been a common metric of the network performance of a connection. Packets can be lost by routers over long trips across backbone networks due to collisions, but over short, LAN connections, typical wired or fiber optic transmission mediums have raw bit error rates on the order of 10^{6} to as low as 10^{14}. With the addition of error checking in many packet transmission protocols, bit errors in wired and fiber-based data transmissions are insignificant and, therefore, not often measured for local area networks. The error rate of a network connection is of importance. This has resulted in increased interest in bit error rates and packet error rates. The Bit Error Rate (BER) is the percentage of bits that are received in error or not received of those that are sent. The Packet Error Rate (PER) is the percentage of packets that are dropped or received incorrectly of those that are sent.

Delay Variation or Jitter

Delay variation or jitter is an important metric for quantifying data network performance, especially for VoIP and video streaming applications in which the protocol relies on regular arrival rates of data packets. The delay variation or jitter of a packet is defined to be of the average variation in the arrival time of a packet and is reported in milliseconds or other appropriate time scale **[1]**.

3. Network Protocols

The overwhelming majority of network measurements are carried out using either Transmission Control Protocol (TCP) or User Datagram Protocol (UDP) packets. This is not surprising since most of the traffic on the Internet consists of mainly these two protocols. UDP does not guarantee whether or not packets will arrive, or if they do arrive they are not guaranteed to arrive in the order they were sent. In either case the sender will not receive an acknowledgment of the transmission. These characteristics makes UDP ideal for video or voice streaming applications in which retransmissions and acknowledgments are a waste of bandwidth and the transmissions can make use of the low overhead associated with UDP. TCP guarantees that packets arrive and arrive in the order transmitted. TCP also attempts to avoid network congestion by sometimes delaying the transmission of packets.

4. Network Performance Measurement Techniques

There are many techniques and software tools available to measure the network performance of any data network which supports Internet Protocol (IP) transmissions, such as IEEE 802.11 wireless LANs. However, a relatively small number of methods have been applied to the actual measurement of wireless networks. This section outlines some of the popular techniques for wireless LAN measurement and the prior research that has gone into measuring the performance of wireless LAN connections. Additional information about how each of these techniques has been used in the literature is shown in following Table

Measurement Technique or Software	Prediction Technique	Reference
A variant of ttcp, a UNIX, command line based program	None	[2]
Test file transfer using FTP	None	[3]
Test file transfer using FTP	None	[4]
Chariot 3.1 Test packet based software	Test packet based software	[5]
Harris WLAN Evaluation software, test packet based software	Predicted minimum adjacent channel interference power ratio for different channel settings	[6]

Table 1: Network Performance Measurement Techniques Used in Wireless LAN Research

Due to the diverse array of techniques available for the measurement of network performance statistics, an overview of the popular techniques is presented here. The following network performance measurement techniques and software products are intended to quantify the network performance of the network connection between two hosts. In general, the measurement solutions will send some sort of test data from one host to another using a certain protocol and a certain test pattern. Measurements are repeatedly made of the test data and then averaged for better accuracy.

Test Packet measurement under UNIX environment

There are several command line utilities that run under UNIX operating systems. These command line utilities are simple and intuitive to use (for individuals familiar with IP networks), and are often used to quickly test and diagnose problems with networks on a daily basis. Some examples of these programs include ping, and TTCP, but there are great deals of others. Ping is a simple program that allows the user to send packets to a specific Internet host which acknowledges the packet. Ping has the advantage of not requiring a second software program to answer the test packets sent by the originating host since this is done by the operating system software. Alternatively, TTCP sends packets from one host to another and provides users with significantly more control of the way packets are sent between two hosts. TTCP allows the user to transmit data using the TCP or the UDP protocol and measures the latency and throughput of a network connection.

Test Packet measurement under Windows environment

Chariot is a popular network measurement software tool. The from NetIQ Corporation, is representative of a class of network measurement software packages that precisely control the characteristics of test packets sent over a connection to measure a range of net- work performance statistics. Chariot is capable of emulating a wide range of traffic types, such as Web traffic or Voice over IP traffic, and a wide range of network protocols such as TCP, UDP and IPX [7]. For any of these protocols or traffic types, Chariot can measure the throughput, latency, jitter, and packet error rates [7].

File Transfers Using FTP in UNIX/Windows environment

A simple and inexpensive method for measuring the throughput of a connection is available using FTP software. In this technique, test files of a known size are transferred from one host to another host. The time required to transfer the file is then used to calculate the throughput. This technique, however, does not give any information about the latency of the connection. Thus, the measured throughput using this technique tends to be optimistic because many network applications have vastly different network traffic characteristics, including packet size variations and fewer unidirectional transfers of data.

5. Network Performance Measurements Research Survey

This part presents the survey of some of the research on wireless LAN network performance measurement, prediction and modeling. Simple means for predicting the throughput or desired network performance statistic are yet to be established. However, the diverse array of research does show how measurements of the network performance of wireless data networks have been performed.

BER and Throughput Correlation to Delay Spread

Maeda, Takaya and Kuwabara published a measurement of wireless LAN performance and the validity of a ray-tracing technique to predict the performance of a wireless LAN [8]. The measurements were tracked in a small, highly-controlled radio frequency (RF) environment and indicated that the wireless LAN throughput and BER were correlated to the delay spread of the wireless channel. The researchers have not, however, presented any way to actually predict the Bit Error Rate (BER) or throughput from the predicted delay spread profile output by a ray-tracing technique.

Early Wireless LAN Network Performance Measurements

Xylomenos and Polyzos explored the performance of UDP and TCP packets sent over several fixed IEEE 802.11 wireless LAN network connections in [9] and [2]. The research focused on throughput limitations caused by software implementation issues and operating system shortcomings. All measurements were taken between three fixed locations and focused on varying the wireless LAN card types and the end-user computer hardware. The researchers make recommendations for changes in the implementation of network protocols and Linux operating system enhancements.The measurements did not consider the effects of different physical locations, signal strength, or the effect of variations in the wireless communications channel on the network throughput.

IEEE 802.11 Throughput Measurements in a Hallway

Duchamp and Reynolds presented packet throughput measurement results for varying distances for IEEE 802.11 wireless LANs [10]. These measurements were performed in a single hallway. Thus, these measurements, too, suffer from failing to measure a representative environment. This work have not considered multiple users and had a focus on estimating the potential range of the wireless LAN in a nearly free space environment.

Idealized Wireless LAN Performance Measurements

Bing presented measured results of the performance of an IEEE 802.11 Wireless LAN. In [11], Bing presents delay and throughput measurements as well as theoretically based throughput and delay estimations for various wireless LAN configurations. The results presented are an upper bound on best possible results and are yet to extend into a site-specific wireless LAN performance prediction technique.

Causes of Throughput Variation in IEEE 802.11 Networks

Demir, Komar, and Ersoy compared the effects of different system configuration factors on IEEE 802.11, 2-Mbps DSSS wireless LAN performance as measured by throughput [4]. The authors measured the throughput of an FTP-based file transfer and the signal strength percentage reported by the wireless LAN card hardware for 1, 2 and 3 simultaneous users. The authors considered the SNR, the number of simultaneous users, and the file size used in the data transfer. The authors concluded that the number of simultaneous users has the greatest effect on the throughput experienced by a single user.

Wireless LAN Performance Issues

The authors have reviewed many of the important factors in wireless LAN deployment, including a basic review of the IEEE 802.11 standard, standard indoor propagation models and interference and coexistence concerns with wireless LANs [12]. The authors also present some measurement results, although without any information about how the results were produced, in which an IEEE 802.11b wireless LAN user 's throughput is compared to the received signal strength. The results show that the user achieves a consistent throughput of about 4.8 Mbps until the received signal strength reaches about -85 dBm. From this point, the throughput in Mbps falls in an almost linear fashion relative to the dBm value of the received signal strength until it reaches zero at approximately -97 dBm. [13].

6. Proposed Experimental Setup

Network traffic measurement experiments are conducted on an IEEE 802.11b wireless LAN in a classroom at the Saurashtra University Rajkot Gujarat. The configuration, shown in **Figure 1**, consists of about 8 mobile clients and one server. In addition, we use a wireless network analyzer to monitor the wireless channel. The server machine is a desktop running Window2003 with 800 MHz Pentium III. Most of the client machines are similarly configured but running the Windows 2000 operating system. Two Compaq machine running clients with windows XP were also used.

Each wireless device (server and clients) has a D-link wireless card DWL +520 Series Adapter for access to the IEEE 802.11b wireless LAN. The wireless cards are configured to operate in ad hoc mode. For simplicity, the node mobility, multihop, or ad hoc routing issues are not considered in these experiments. The analogous physical model has been setup at the Saurashtra University Department of Computer Science Rajkot to measure the performance statistics.

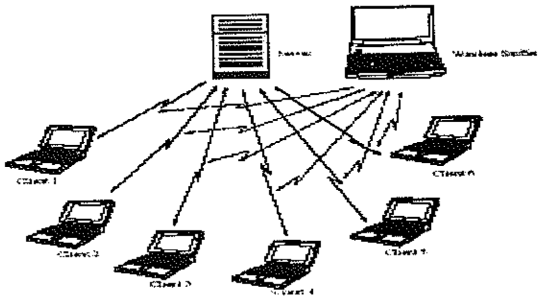

Figure 1: Experimental Setup for Wireless Classroom Network Traffic Measurements

Network traffic measurements are collected using a wireless network analyzer. Decoding of the captured traces enables protocol analysis at the MAC, IP, TCP, and HTTP layers. These traces are used to assess wireless channel contention, TCP protocol behaviors, and HTTP transaction performance.

7. Measurement Model

The data collection will be based on proposed experimental setup network. The data collection will be done at four locations inside the Department of Compute Science, Saurashtra University Rajkot.

Data Collection

The data will be collected when test data transmission is going on the wireless network. The data collection will be the average of 10 times for better reliability. The following data will be collected for fixed user with various locations based on distance.

1. End-user Wireless link SNR and Coverage
2. Network Delays using :TCP protocol and UDP protocol
3. Single User Uplink throughput: TCP protocol and UDP protocol
4. Single User Downlink throughput: TCP protocol and UDP protocol
5. Two User TCP response time
6. Two User UDP response time

The collected data are to be analyzed for the network performance with possible comparisons leading to meaningful conclusions.

8. Conclusion

The measurement under the proposed measurement model on suggested experimental setup is in process and the analysis is expected to predict the throughput of a wireless LAN in different locations. This is expected to measure realistic, non-optimistic, site-specific throughput and shape throughput prediction models for wireless LAN design.

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