

EXPERIMENTAL ANALYSIS ON PASSIVE BANDWIDTH ESTIMATION TOOLS
FOR IPERF, NETPERF AND SPRUCE FOR MESH WIRELESS
LOCAL AREA NETWORK (WLAN)

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ABSTRACT

Available bandwidth estimation is useful for route selection in a network environment. While many tools has been created to estimate the available bandwidth, mainly by two techniques passive and active measurement. Passive measurement is performed by observing the traffic without intruding the network. Active measurement on the other hand, will probe the network by generating packet traffic into the network to perform the measurement with the availability of multiple available bandwidth estimation tools around, the question is which bandwidth estimation tool will be the best to perform the task in a given network situation? Which tools perform the best when fluctuation of bandwidth happens in a network? Accurate estimating available bandwidths in a network path are important for the right and efficient operation of many Internet applications and protocols as well as network management applications. End-to-end flow control, server selection for downloads and streaming media, peer-to-peer web host selection and content delivery, and multicast configuration protocols are just a few examples where accurate bandwidth estimations are valuable. This research will represent an experimental analysis of available bandwidth by using a few bandwidth estimation tools which are Iperf, Netperf, Spruce. The objective of the research is to measure available bandwidth with selected bandwidth estimation tools, compare the selected tools based on their estimation preference and to recommend the best bandwidth estimation tools in the three factors which are the failure pattern, accuracy and consistency of the tools.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

A wireless computer network (or wireless local area network, for wireless native space network, typically noted as a field, for native space, wireless network) is one within which a mobile user will connect with a local area network (LAN) through a wireless. The IEEE 802.11 cluster of standards specifies the technologies for wireless LANs. 802.11 standards use the LAN protocol related is CSMA/CA (carrier sense multiple access with collision avoidance) for both distribution and embrace an encoding technique, the Wired Equivalent Privacy formula. [1]

Commonly, a home and business WLAN employs one or two access points to broadcast a signal around a 100- to 200-foot radius. The wireless technology and hardware in this category subscribes to the 802.11a, b, or g standards (also known as Wi-Fi); some home and office WLANs now adhere to the new 802.11n standard.

The general used of wireless standard is 802.11g whereby will be used for this experimental project. 802.11g standard is the third generation of WLAN that use for home and business to give connectivity to the user to connect to the LAN. The first generation used is 802.11a continued by 802.11b although nowadays the 802.11n

have already released to be used by home and business user to connect to the LAN. This entire standard has pros and cons that stare at the table below. [2]

Accurately estimating available bandwidths in a network path is important for the right and efficient operation of many Internet applications and protocols as well as network management applications. End-to-end flow control, server selection for downloads and streaming media, peer-to-peer web host selection and content delivery, and multicast configuration protocols are just a few examples where accurate bandwidth estimations are valuable. Accurate bandwidth estimations are also valuable to network designers and administrators to aid in network troubleshooting, capacity provisioning, and traffic engineering.

Bandwidth capacity refers to the maximum data or throughput that can be transmitted on a link or a medium. It is important to understand and identify the maximum throughput of a link in network planning to cater the needs of the end user or end nodes. For example, for a normal user, it would be sufficient to have a link of Cat5 (Category 5) Ethernet cable of 100 Megabit per second (Mbit/s).

The bandwidth can be measured by tool to define the speed, accuracy, failure and consistency of the network. There are a lot of tools available in the internet, but not all can be used because due to upgrade of network technology nowadays. The tools can help network administrators to monitor the network, which will be recommended by researchers in this project.

There are two types of bandwidth estimation tools which are active measurement and the passive measurement. Active measurements inject probe packets into the network and observe their behavior. In contrast, passive measurements observe actual traffic without perturbing the network. In order to be able to measure or determine the available bandwidth actively, a bandwidth estimation tool needs to be used to perform the task. However, there are multiple bandwidth estimation tools that are available that could be used. Different type of estimation tools gives a different type of reading.

1.1 Problem Statement

Knowing the capability of a network path should indeed be valuable in several situations, but the best methods for measuring bandwidth are essentially limited because of the nature of the network. The disadvantage associated with current measurement techniques is that they attempt to infer characteristics about a network that is not designed to expose any information in order to data that traverses it; this is especially true of the Internet. The network simply transports data to its destination as best it could, which is why the internet is considered a best effort network. There are no guarantees for data traveling over the Internet and there is no way to accurately predict how data is going to be handled. The only method to determine link capacities and utilization of the links is by examining how the network delivers a single packet or sequence of packets towards the destination or for specific hops over the path to the actual destination.

With the availability of multiple available bandwidth estimation tools around, the question is which bandwidth estimation tool will be the best to perform the task in a given network situation? Which tools perform the best when fluctuation of bandwidth happens in a network? Therefore, bandwidth estimation tools will be used to study and analyzing the bandwidth performance in the different type of wireless mesh network scenarios. A comparative analysis will be carried out for the following attributes:

- I. Accuracy: This will measure the accuracy of the tool to estimate the available bandwidth whether it will over estimate or underestimate the available bandwidth.
- II. Failure patterns: This attribute will monitor and measure the reliability of the tool's failure or error prone to estimate the bandwidth throughout the testing cycle.
- III. Consistency of measurement: This attribute will measure the consistency of the measurement of the tool as whether it will fluctuate of over estimating or underestimating the bandwidth.

1.2 Objective

This research was conducted to meet three objectives. The objectives of this research are:

- I. To measure available bandwidth with selected passive bandwidth estimation tools in multiple network environments.
- II. To compare the selected tool based on their estimation preference which is consistency, accuracy, and failure pattern in multiple network environments.
- III. To recommend the best bandwidth estimation tools for the given estimation tools in a multiple network environment and scenario of testing.

1.3 Scope

Due to the time and resources constraints and issues, this dissertation is limited in the following clauses:

- I. Four bandwidth estimation tools to be analyzed: - IPERF, NETPERF, SPRUCE.
- II. IEEE 802.11 as the wireless network standard
- III. Two metric readings have been collected, bandwidth estimated and time taken to estimate the bandwidth in seconds; convergence time.
- IV. Twenty readings will be taken for each tool to ensure consistency in reading and data for each experiment analysis.
- V. Wireless hardware: - Two laptops with built in wireless 802.11b/g and three D-link wireless router
- VI. Experiment environment was isolated from any other network to prevent any application from
- VII. automatically connected to the internet and mess up the measurement.
- VIII. Measurements are done generating any traffic on the link where the measurements are taken.

1.4. Thesis Organization

The research consists of five chapters:

- Chapter 1 Provide the overall overview of the thesis. Here, the problem statement will be introduced. Then based on the problem statement, the objective of the research is being defined. Lastly, chapter one also will explain about the research scope.
- Chapter 2 Introduces the hardware and software that will be used in this research project. It is mainly focuses on the performance of the bandwidth estimation tools. The literature review is organized in a way that readers can understand this.
- Chapter 3 Explains the methodology that will be used to carry out this research. The detail will be elaborated step by step process that is being used to complete the research.
- Chapters 4 Model will be developed in order to perform the test. It then followed with the continuously design on data analysis.
- Chapter 5 Concludes all the chapters and the recommendations for future researchers.

CHAPTER 2

LITERATURE REVIEW

2.0 IEEE Wireless 802.11 Network Technology

The IEEE 802.11 specification (ISO/IEC 8802-11) is an international standard describing the characteristics of a wireless local area network (WLAN). The wireless local area network is also known as Wireless Fidelity (Wi-Fi). The IEEE wireless 801.11 is a set of physical layer standard for implementing wireless local area network computer communication in the 2.4, 3.6, 5 and 60GHz frequency band. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802). [3]

According to the previous research, the development of IEEE 802.11, the physical layer (PHY) and medium access control (MAC) layer were mainly targeted by the IEEE 802 project. When the idea of wireless local area network (WLAN) was first conceived, it was just thought of another PHY of one of the available standards. The first applicant which was considered for this was IEEE's most prominent standard 802.3. [2]

A wireless computer network is one within which a mobile user will connect with a local area network (LAN) through a wireless. The IEEE 802.11 cluster of standards specifies the technologies for wireless LANs. 802.11 standards use the LAN protocol related is CSMA/CA (carrier sense multiple access with collision avoidance) for path distribution and embrace an encoding technique, the Wired Equivalent Privacy formula.[1]

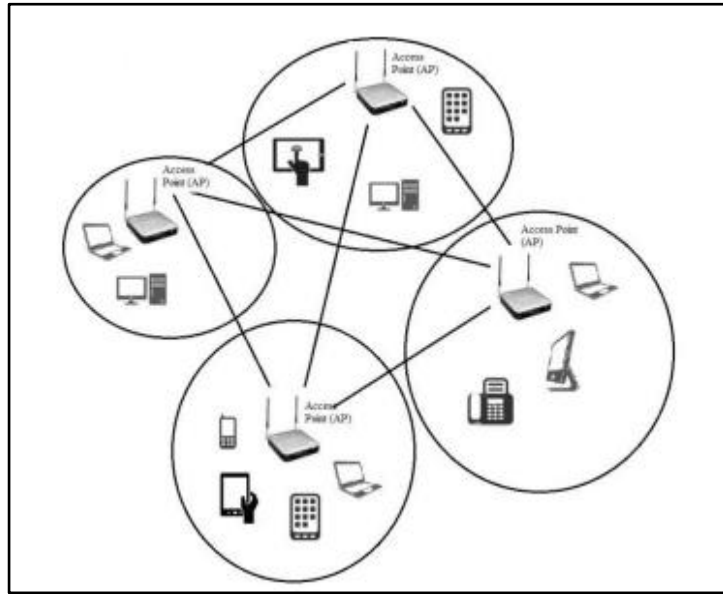


Figure 1: Mesh wireless local area network

2.1 Available Bandwidth

Available bandwidth is a term used to define the maximum throughput that flow between two hosts can achieve in the presence of cross-traffic. It is useful for the route selection in overlapping networks, traffic engineering and Quality of service (QoS) verification. The available bandwidth (ABW) at a link is its unused capacity. Based on PAESSLER there were two problems when measuring the available bandwidth. The two problems are:

1. The only way to measure available bandwidth is to create as much as uploads as it can handle while measuring the data rate.
2. For an exact measurement, two personal computers (PC) that are placed directly on both ends of the data line.

There are mainly two techniques to estimate the available bandwidth – passive and active measurement. Passive measurement is performed by observing the traffic without

interfering the network. Active measurement on the other hand, will probe the network by generating packet traffic into the network to perform the measurement. And in order to be able to measure or determine the available bandwidth actively, a bandwidth estimation tool needs to be used to perform the task. However, there are multiple bandwidth estimation tools that are available that could be used. But the question will be which bandwidth estimation tool will be the best to perform the task. [4]

2.2 Impact for Different Environment

According of the website computer networking, we have two environments which use one access point (AP) and two access point (AP). In Wi-Fi networking, we have “bridging mode” which is it allows two or more wireless access points (APs) communicate with each other for the purpose of joining multiple local area network (LANs). Although operating in bridging mode, wireless APs utilize a substantial amount of bandwidth. Wireless clients on bridged Wi-Fi networks generally share the same bandwidth as the bridge devices. Consequently, clients tend to perform slower in bridging mode than otherwise. For environments that use one AP, it generally shares the same bandwidth for each device. [5]

2.3 Acceptable range reading of bandwidth in WLAN

In the previous research, since packet transmission with a contention based MAC such as 802.11 involves significance per-packet overhead, the researcher quantify the impact of packet size on the maximum achievable throughput by using the tool to blast stream of back-to-back packets of various sizes. In that research, the card rate the researcher set to 6Mbps and 54Mbps. Based on previous article, the researcher study in two cases which is the cumulative throughput of the pair increase significance with the packet size but does not depend strongly on the number of communicating pair. The range within 6Mbps – 54Mbps

are the benchmark to get a result of accurate in the reading of bandwidth. Result from the researcher experiment said that the main source of throughput reduction in MAC-layer overhead and not OS overhead at the individual sender or receivers.[6]

2.4 Passive Bandwidth Estimation Tools

Measurements in network testbeds can be dividing into two categories: active and passive. Active measurements are based on sending and receiving specifically crafted packet probes through the infrastructure. These probes enable a variety of characteristics to be measured such as end-to-end delay, loss and jitter. While active probe-based measurements are important and widely used in testbeds and operational networks, they may lack detail or precision or be entirely unable to capture aspects of behavior that are critical for experiments.

Passive measurements are founded on using particular counting or capture mechanisms that are built into software and systems deployed in network testbeds. One of the most compelling types of passive measurement is the ability to capture packet information from transmissions on links in a testbed. Information from packet traces can be critical to experiments with new network applications, protocols and security techniques, as well as for day-to-day management and troubleshooting of the testbed infrastructure itself.

In the previous paper, the researcher found that the myriad of challenges to enabling packet capture capability within a network testbed. Packet capture almost always requires dedicated systems since measurements on high-bandwidth links can result in overheads that are beyond the capability of standard hardware. That means the sufficiently capable systems must be acquired, configured, deployed and securely managed alongside the experimental systems. Further, if packet capture is meant to be available to concurrently running experiments, the measurement systems must be able to log data such that multiple tenants have exclusive access to their own data. Finally, packet capture always has security

and privacy implications since packets can contain personally identifiable and private information. Depending on the size and diversity of the testbed, these challenges can become quite significant.[7]

2.4.1 Iperf

Iperf is a commonly used network testing tool that can create TCP and UDP data streams and measure the throughput of a network. Iperf allows the user to set various parameters that can be used for testing a network, or alternatively for optimizing or tuning a network. Iperf has a client and server functionality, and can measure the throughput between the two ends, either unidirectional or bi-directionally. Iperf is a client server program.

Iperf was originally developed by NLANR/DAST as a modern alternative for measuring TCP and UDP bandwidth performance. Iperf is a tool to measure maximum TCP bandwidth, allowing the tuning of various parameters and UDP characteristics. Iperf reports bandwidth, delay jitter, datagram loss. Iperf consists of TCP which is to measure bandwidth and report MSS/MTU size and observed read sizes. Besides, it supports for the TCP window size via socket buffers and it is multi-threaded if pthreads or Win32 threads are available. Client and server can have multiple simultaneous connections.

There is also UDP in Iperf where clients can create UDP streams of specified bandwidth and measure packet loss. On the other hand, it measures delay, jitter and it is multicast capable. It is also multi-threaded if pthreads are available. Client and server can have multiple simultaneous connections. Where appropriate, options can be specified with K (kilo-) and M (mega-) suffices. Therefore, it is 128K instead of 131072 bytes. Iperf also can run for a specified time, rather than a set amount of data to transfer. It will pick the best units for the size of data being reported. The server handles multiple connections, rather than quitting after a single test. Next, it prints periodic, intermediate bandwidth, jitter, and loss reports at specified intervals. Iperf runs the server as a daemon and it runs the server as a Windows NT Service. Lastly, it uses representative streams to test out how link layer compression affects your achievable bandwidth.[8]

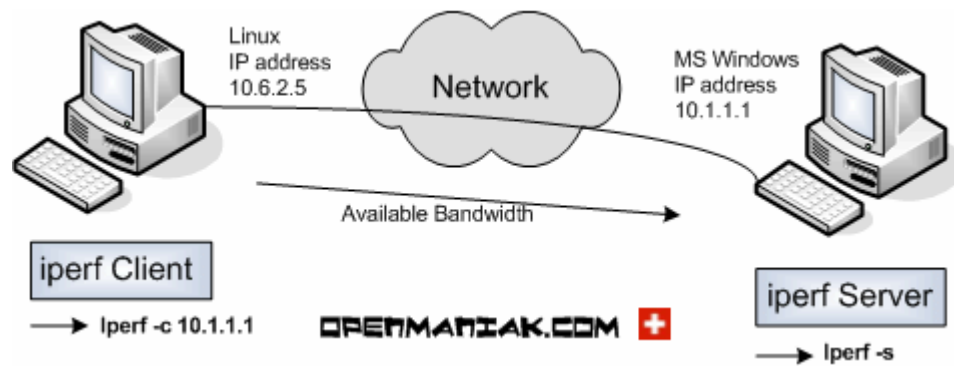


Figure 2: Iperf

2.4.2 Netperf

Netperf is a benchmark that can be used to measure various aspects of networking performance. The primary attentions are bulk data transfer and request performance using either TCP or UDP and the Berkeley Sockets interface. As of this writing, the tests available either unconditionally or conditionally include:

- I. TCP and UDP unidirectional transfer and response over IPv4 using the Sockets interface.
- II. TCP and UDP unidirectional transfer and response over IPv4 using the XTI interface.
- III. Link-level unidirectional transfer and response using the DLPI interface.
- IV. Unix domain sockets
- V. SCTP unidirectional transfer and response over IPv4 using the sockets interface.

Netperf is supposed around an elementary client-server model. There are two executable - netperf and netserver. Generally it will only execute the netperf program, with the netserver program being controlled by the remote systems or having been previously started as its own standalone daemon.

The tool netperf it will establish a “control connection” to the remote system. The connection will be used to pass test configuration information and results to and from the remote system. Regardless of the type of test to be run, the control connection will be a TCP connection using BSD sockets.

Once the control connection is up and the configuration information has been passed, a separate “data” connection will be opened for the measurement itself using the APIs and protocols appropriate for the specified test. When the test is completed, the data connection will be torn-down and results from the netserver will be passed-back via the control connection and combined with netperf’s result for display to the user.[9]

```

Netperf Example - TCP_STREAM

$ /usr/etc/net_perf/netperf
TCP STREAM TEST ← the test type
Recv  Send  Send
Socket Socket Message Elapsed
Size  Size  Size  Time   Throughput
bytes bytes bytes secs.  KBytes/sec
4096  4096  4096  10.00  2847.18 ← the performance
  ↑      ↑
  send size on the local system
  receive size on the remote system

$ /usr/etc/net_perf/netperf -S 4096 -s 2048 -m 64 -H hainfd9
TCP STREAM TEST
Recv  Send  Send
Socket Socket Message Elapsed
Size  Size  Size  Time   Throughput
bytes bytes bytes secs.  KBytes/sec
4096  2048  64   10.00  18.05
  ↑      ↑      ↙
  changed by -s changed by -m
  changed by -S

$ /usr/etc/net_perf/netperf -P 0 ← don't display test header
4096  4096  4096  10.00  2797.33

$ /usr/etc/net_perf/netperf -P 0 ~ 0 ← just display the result
2828.19

$ █

```

Figure 3: Netperf

2.4.3 Spruce

In the existing research, Spruce was a simple and light weight tool for measuring available bandwidth. The researcher show that Spruce is more accurate than the existing tools like Pathload and IGI. Spruce is a tool for end host to measure available bandwidth. It sample the arrival rate at the bottleneck by sending pairs of packets spaced that he second probe packet arrives at a bottleneck queue before the first packet depart the queue. Spruce then calculate the number of bytes that arrived at the queue between the two probes from the inter-probe spacing at the receiver. Spruce computes the available bandwidth as the difference between the path capacity and the arrival rate at the bottleneck.

Spruce was designed around the probe gap model, which assumes a single bottleneck. However, the researcher experiment shows that spruce works well in realistic environment and is robust against deviation assumption. Spruce consists of separate user-level sender and receiver program. The sender takes as arguments the DNS name of the receiver, and the know capacity of the path. Based on the existing article, Spruce has tested on Linux 2.4.19 and FreeBSD 4.7 systems.

Spruce characteristic:

- Spruce uses a Poisson process of packet pairs rather than packet trains (or chirps). This form of sampling allows Spruce to be both non-intrusive and robust.
- Spruce ensures that the bottleneck queue does not empty between the two probes in a pair, which is a requirement for the correctness of the gap model.
- Spruce separates capacity measurement from available bandwidth measurement. It assumes that capacity can be measured easily with one of the capacity measurement tools and that capacity stays stable when measuring available bandwidth. For the environments for which Spruce is designed, selecting paths in overlay networks, this assumption holds.
- Spruce doesn't overwhelm the narrow link on a path, because its probe rate is no more than the minimum of 240 Kb/s and 5% of the capacity of the narrow link.[10]

2.5 Comparison of other research

2.5.1 Measuring end-to-end bandwidth with Iperf using Web100

End-to-end bandwidth opinion equipment similar to Iperf though pretty appropriate is usually uncomfortable. Within this cardstock, most of us identify how with the instrumented TCP heap (Web100), we are able to calculate the actual end-to-end bandwidth accurate, though having even less circle bandwidth and moment. Most of us improved Iperf make use of Web100 for you to detect the finish regarding slow-start and calculate the actual end-to conclude bandwidth by means of testing how much info dispatched with regard to a short period (1 second) following your slow-start, once the TCP throughput is usually reasonably stable. Most of us purchased bandwidth rates differing by means of a lot less than 10% when compared to operating Iperf with regard to 20 seconds, and financial savings within bandwidth opinion moment up to 94% and financial savings within circle visitors up to 92%.[11]

2.5.2 A Measurement Study of Available Bandwidth Estimation Tools

Available bandwidth estimates the useful for route selection in overlay networks, Qos verification and traffic engineering. A few tools have been recommended and evaluated in simulation and over a limited number of internet path, but there is still great doubt in the performance of these tools over the internet at large. Based on previous research Spruce, was a simple, light-weight tool for measuring available bandwidth and compares it with existing tools which is IGI and Pathload. The experiment of the tools was determined on accuracy, failure pattern, and probe overhead and implementation issues. The researcher verified that the measure available bandwidth by comparing it to Multi-Router Traffic Grapher (MRTG) data and by measuring how each tool responds to encouraged changes in available bandwidth. The experiment showed that Spruce is more accurate that pathload and IGI. [10]

2.5.3 Bandwidth Estimation in Broadband Access Networks.

There has been much work on developing techniques for estimating the capacity and the available bandwidth of network path based on endpoint measurement. The focus has primarily been on setting where the constrained link can be modeled as a point-to-point link with a well-defined bandwidth, serving packet in FIFO. Based on this paper, the researchers point out that broadband access network, such as cable modem and 802.11 based wireless network, break this model in various ways. In this paper, the author constrained link could employ mechanisms such as token bucket rate regulation, schedule packets in a non FIFO manner and support multiple distinct rates. The researchers study how these characteristic impacts the operation of the various existing methods and tools for capacity and available bandwidth estimation. Based on this research, they evaluation is based on experiment with actual 802.11a and cable modem links.[6]

2.5.4 Bandwidth estimation: Metrics, measurement techniques and tools.

Through this paper, in a packet network, the terms “bandwidth” often characterize the amount of the data that the network can transfer per unit of time. Bandwidth estimation is of interest to users wishing to optimize end to end transport performance; overlay network routing and peer-to-peer file distribution. In this paper, the technique for accurate bandwidth estimation was also important for traffic engineering and capacity planning support. In this article, the researcher focuses on estimation of bandwidth metrics in this latter data network context. Existing bandwidth estimation tools measure one or more of three related metrics: capacity, available bandwidth, and bulk transfer capacity (BTC). In this paper, the researcher studied recent bandwidth estimation literature focusing on underlying and methodologies as well as open source bandwidth measurement tools. [12]