Path-F3: Improving Accuracy and Network Load in Available Bandwidth Estimation based on SLoPS Methodology

Mazni Amil [1], Mohamad Yusoff Alias[2], Khairil Anuar[3] +

[1]Telekom Malaysia (TM) Research & Development and 2,3Multimedia University

Abstract. In this paper we presented the results of a series of available bandwidth experiments conducted in a control environment testbed by using WAN Emulator to represent the actual network. The approaches are classified according to the available bandwidth methodology of Self Loading periodic Streams (SLoPS). The comparative analysis of state-of-the-art available bandwidth will be focusing on a tool called Pathload that used SLoPS methodology, and compare it with our new technique called Path-F3. The results show that Path-F3 can give a near accurate estimation as compared to Pathload.

Keywords: Path-F3, Available Bandwidth and SLoPS

1. Introduction

With the increasing usage of Internet, there has been a great interest in bandwidth estimation development such as capacity, available bandwidth, bulk transfer capacity and achievable throughput.

The available bandwidth is defined as the maximum IP-layer throughput that a flow can get in the path from the sender, S to the receiver, Rx, without reducing the rate of the rest of the traffic in the path [1]. It was shown in [1], that the available bandwidth depends not only on the link capacity, but also on the traffic load, and is typically a time-varying metric.

The hop with the minimum available bandwidth is called the tight link of the end-to-end path [2]. The narrow and the tight link are both the bottleneck of a network. Self-Loading Periodic Streams (SLoPS) is one of the famous methodologies for available bandwidth measurement [2]. SLoPS requires access at both ends of path S and Rx. Sender sends series of packets to the receiver at the rate R of larger than the available bandwidth. Every packet gets a timestamp at the sender side. Comparison is then made to get the difference of successive packets timestamp and their arrival times in order to infer the available bandwidth. If the stream rate R is higher than the available bandwidth, the one-way delays of successive packets at the receiver will show an increasing trend as shown in Figure 1.

+ Corresponding author. Tel.: + (603 8883 933); fax: +(603 8883 9596).
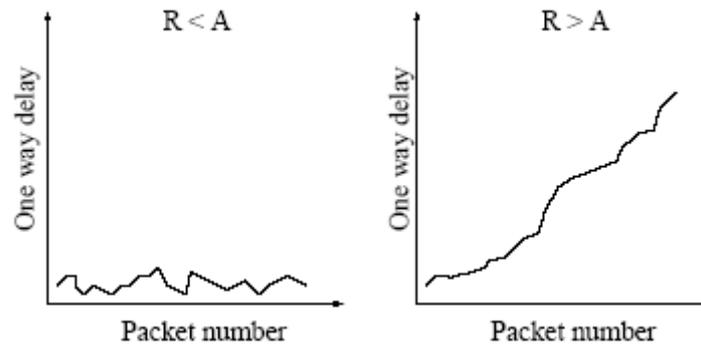 *E-mail address*: ([1]mazni@tmrnd.com.my, 2yusoff@mmu.edu.my, 3khairil@mmu.edu.myplease specify).

Fig. 1. One way delays increase when the stream rate R is larger than the available bandwidth A, but do not increase when R is lower than A [1].

In this paper, we propose a new technique based on SLoPS called Path-F3. This technique improves the accuracy and the network load problems that were faced by Pathload

2. Motivation

Internet Service Provider (ISP) such as Telekom Malaysia Berhad has implemented wireless, high speed and next generation networks. These networks are being constructed in-order to support the large growth in the Internet, as well as enabling higher bandwidth services to run over the network. There is an increasing demand to know if the performance obtained from these networks is what is expected from them [3-5]. Therefore, the ISP needs a tool to measure the bandwidth and troubleshoot the problem if bandwidth value is not expected. Besides the ISP, the customers also need to be guaranteed on their network subscription. Thus, there is always a demand for tools to enable customers to asses the performance without assistance. These tools need to be able to measure the end-to-end performance of the network quickly, easily and accurately.

For ISPs, tool to control rate or congestion control are crucial [6-7]. It should be noted that different network technologies may implement rate control at different levels [6]. For example in [8], the traffic in a network is the data flowing in an encoded form between pairs of points within it. These points may be simply the end points of a single transmissions link, a client/server pair in a local area network or two hosts joined by a wide area network or internet. Therefore, there is a need of a close inspection of figures resulting from a period of traffic measurement in a network that reveals an interesting inconsistency. Even if the root cause is easily identified, it would be more satisfying to followe the path to its end. A key feature in providing the right service is an awareness of what customers want in terms of the information they wish to send and receive. The slightest misunderstanding to the nature of the traffic a network carries can be very costly. The other motivation is the accuracy of bandwidth estimation. The estimation needs to be done quickly, easily, accurately and giving less congestion to the network.

There are several methodologies that researchers and industries have introduced to be implemented. However, each methodology exhibits its own disadvantages and advantages. Although, all bandwidth estimation methods give us an exact metric but it may not be accurate for different networks or situations. For an example, a technique to calculate the available bandwidth for a point-to-point in wireless 3G may not be the same as in wide area network using fiber optic or personal area network using Bluetooth.

3. Related work

Pathload is one of the tools for estimating the available bandwidth of an end-to-end path from a host sender to a host receiver. Pathload is designed as an open source and the source code is easily downloadable [9]. In short, Pathload is based on the key idea that when a process at sender sends a periodic stream of UDP packet at a rate higher than the available bandwidth in the path, the relative one-way packet delays show an increasing trend. However, when the stream rate is lower than the available bandwidth, the relative one-way packet delays show no consistent trend. From that point Pathload estimates the available bandwidth when the one-way packet delays start to show an inconsistentcy trend. For this research we will focus on Pathload and compare it to our proposed technique, Path-F3.

4. Path-F3 Key Idea

Path-F3 is an enhanced version of Pathload in order to improve the network performance and accuracy of the existing Pathload. The improvement is done by looking at the total number of fleets and packet size that are streamed per train. Existing Pathload sends multiple train of 1200 same sized packet with a total size of 240,000 bytes per stream.

On the other hand, *Path-F3* is designed by sending the multiple trains with 180 same sized packets with total bytes of 36,000 bytes per stream. The calculation for the total number of bytes is given by:

$$Total\ Bytes = Number\ of\ Fleets\ x\ Total\ Packets\ x\ Bytes\ per\ Packet \qquad (1)$$

During our measurement, *Path-F3* generates report in range format rather than single estimation. The range estimates the variation of available bandwidth while the average of available bandwidth shows from the centre of the range.

5. Path-F3 work flow

Path-F3 is based on the idea of SLoPS Methodology [1,4]. The name Path-F3 was chosen based on fleet 3 sending from sender to receiver. Path-F3 consists of two programs namely sender and receiver. The sender is installed on source host, while the receiver is installed on destination host. Path-F3 technique requires access to both ends of the path, but does not require super user privileges because it only sends UDP packets.

Before the sender sends the packet to the receiver, the sender will open a connection to receiver. The connection will be established between the sender and the receiver in order to make sure the sender could send the packet and the receiver could calculate the packet stream.

When a process at the sender sends a periodic stream of UDP packet at a rate higher than the available bandwidth in the path, the relative one-way packet delays show an increasing trend. When the stream rate is lower than the available bandwidth, the relative one-way packet delays show no consistent trend. During an estimation process, the sender transmits trains of probe packets at different rates, while the receiver collects the one-way transmission delays (OWDs) of the packet trains and processes the OWDs with statistic algorithm to infer available bandwidth.

From that point, Path-F3 will estimate the available bandwidth when the one-way packet delays start to show an inconsistent trend.

6. Experimental setup

For the experimental setup, we decided to run the experiment at Multimedia lab in Telekom Malaysia (TM) Research and Development. We also formulate a few situations, scenarios and runs with the different time to get better results. The comparative analysis of available bandwidth will be focusing on tools that use SLoPS methodology, in our case Pathload. The experimental setups and scenario for the Available Bandwidth Estimation testing are explained in the following sections.

6.1. Experiment 1: End-to-End without traffic
Our first set-up is for the end-to-end network without any traffic. In this environment, two desktops running Linux Ubuntu 7.0.3 operating systems are connected through the wide area network (WAN) Emulator as shown in Figure 2. We set the bandwidth at WAN Emulator as scenario below and we send the packet from sender to receiver to get the result for available bandwidth at that time. Environment test is a control environment by simulating the network using the WAN Emulator and by assuming that there is no traffic between the two hosts. To get better results, we tested each tools for 50 times with the same bandwidth setting. The bandwidths that we have set at WAN Emulator for the testing purpose were 512kbps, 1Mbps, 2Mbps and 4Mbps.

6.2. Experiment 2: End-to-End with Wireshark
The second experiment will capture the result for the range of bandwidth estimation while opening the Wireshark. Wireshark is a tool for Monitoring Network Performance. For this environment, we also used two desktops running Linux Ubuntu 7.0.3 operating system connected through the WAN Emulator as shown

in Figure 2. The bandwidth was set at WAN Emulator. We tested it by sending the packet from sender to receiver to get the result for available bandwidth at that time. Environment test is local and it is a controlled environment. To get better results, we tested each tools for 50 times with the same bandwidth setting. Just as in Experiment 1, the bandwidths that we have set at WAN Emulator for the testing purpose are 512kbps, 1Mbps, 2Mbps and 4Mbps.

Fig. 2. Experiment setup for the wired environment without traffic and with Wireshark.

7. Results and Discussion

Table 1 shows the results for Experiment 1. From Table 1, it can be seen that Path-F3 is more consistence and more accurate in estimating the available bandwidth as compared to Pathload. For the 4 Mbps bandwidth, Path-F3 result shows a range of 3.68 – 3.73 Mbps available bandwidth measured from this technique. If we look closely at the 2 Mbps bandwidth, Path-F3 proves that the available bandwidth measurement is nearer to the bandwidth offered. When we compare the result for Pathload, the result range is 0.00 – 1.98 Mbps and it means the available bandwidth measured for 2 Mbps is 0, which could not be accepted because the experiment was in a control network without any traffic interruption. For the 512 kbps bandwidth, it is proven that Path-F3 could handle for measurement less than 1 Mbps as compared to Pathload that cater only the bandwidth that is greater than 1 Mbps. From the results captured, we could summarized that Path-F3 has successfully given a close approximate measurement of the available bandwidth as per propose in this research.

Table1. The average result from Experiment 1

Bandwidth (Mbps) for Experiment 1	Tools for Available Bandwidth Estimation	
	Path-F3	Pathload
	Mean Range of Available Bandwidth (Mbps)	
4.0	3.68 - 3.73	2.98 - 3.97
2.0	1.83 - 1.83	0.00 - 1.98
1.0	0.91 - 0.93	0.00 - 0.99
0.512	0.15 - 0.51	0.00 - 0.00

Table 2 show that Bandwidth measurement accuracy for Path-F3 was not affected even though Wireshark application was open during testing. For 1 Mbps bandwidth, average ranges of available bandwidth are 0.88 – 0.94 and it's mean near to actual bandwidth offered. But if we look at Pathlaod result for 1 Mbps, the result shows range between 0.00 – 0.99 and if we conclude that 0 available bandwidth was measured for 1 Mbps. This result is not accurate because we are in control network with no other traffic interrupt this network

From 2 Mbps results show the average packet size 1489 send from sender to receiver using Path-F3, compare to Pathload 2427. This results shows that Path-F3 sends less packet than Pathload. Even less packet send by Path-F3 the result for available bandwidth measurement is nearer to the bandwidth offered compare to Pathload.

For bandwidth setting at 4 Mbps, result show that Average Bytes/ seconds are 11572.05 for Path-F3 and 21206.87 Average Bytes/ seconds for Pathload. From the results shows at Table 2 we could summarized that Path-F3 techniques help to reduce the network load in the network environment.

Table 2: The average results from Experiment 2.

Bandwidth (Mbps) for Experiment 2	Tools for Available Bandwidth Estimation							
	Path-F3				Pathload			
	Mean Range of Available Bandwidth (Mbps)	Mean Packet size	Mean from average bytes/sec	Mean Total Bytes	Mean Range of Available Bandwidth (Mbps)	Mean Packet size	Mean average bytes/sec	Mean Total Bytes
4.0	3.68 - 3.72	1471	11572.05	388386	2.88 - 3.96	4843	21206.87	1182786
2.0	1.83 - 1.84	1489	9686.25	392621	0.00 - 1.98	2427	11026.58	621802
1.0	0.88 - 0.94	1817	8782.88	626846	0.00 - 0.99	2045	8897.48	704297
0.512	0.15 - 0.51	732	3664.49	221086	0.00 - 0.00	1050	5117.46	301908

8. Conclusion and Future Plan

We have presented the experimental results and find out that Path-F3 has successfully measured end-to-end available bandwidth in Linux Platform as compared to Pathload. At bandwidth setting of 512 kbps, we found that Pathlaod is ineffective and cannot be trusted whereas the Path-F3 measurement is more reliable and consistent. In the future, we plan to test in Windows operating system platform to improve that Path-F3 could give the accurate, reliable and consistent results as compared to Pathload.

9. References

[1] Prasad. R., Dovrolis, C., Murray, M., and Claffy, K., "Bandwidth Estimation: Metrics, Measurement Techniques, and Tools", IEEE Network, vol. 17, Issue 6, pp. 27-35, Nov.-Dec. 2003.

[2] C. Dovrolis and M. Jain, End-to-End Available Bandwidth: Measurement Methodology, Dynamics, and Relation with TCP Throughput," IEEE/ACM Transactions in Networking, August 2003.

[3] Feng Wu, Shipeng Li, Rong Yan, Xiaoyan Sun and Ya-Qin Zhang, Efficient And Universal Scalable Video Coding, Volume 11, p.p. 37– 40, IEEE ICIP 2002.

[4] Guillaume Boisson, Edouard François and Christine Guillemot, Efficient Scalable Motion Coding For Wide-Range Scalable Video Compression, Proceedings of XII European Signal Processing Conference, p.p. 1979-1982, Vienna, September 2004.

[5] James Curtis and Tony McGregor, Review of Bandwidth Estimation Techniques, Department of Computer Science, University of Waikato, Hamilton, New Zealand

[6] John G. Apostolopoulos, Wai-Tian Tan and Susie J. Wee, Video Streaming: Concepts, Algorithms, And Systems, Technical Report, Mobile And Media Systems Laboratory, Hewlett-Packard 2002

[7] Lai. K. and Baker M., Measuring bandwidth, Proceedings of 18th Annual Joint Conference of the IEEE Computer and Communications Societies. Volume 1, p.p. 235 – 245, 21-25 Mar 1999.

[8] Vic Grout, Measuring Network Traffic: The Hidden Distribution, Mathematics Today: Bulletin of the Institute of Mathematics and its Applications, Volume 37, Number 6, p.p.179-183, December 2001

[9] C. Dovrolis and M. Jain "a measurement tool for end-to-end available bandwidth" This work was supported by the SciDAC program of the US Department of Energy (award # DE-FC02- 01ER25467).