Test and Performance Comparison of End-to-End Available Bandwidth Measurement Tools

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Abstract — **The bandwidth measurement is essential for resource management, provisioning of network. There are many measurements techniques and tools, but the accuracy and intrusiveness of these tools are not much shown concurrently in a paper. Thus, we survey bandwidth measurement tools and evaluate performance of some well-known tools. In this paper, we present measurement results in accuracy and intrusiveness perspectives with IGI-PTR, pathChirp. Also, we present traffic volume of probing packets and measurement time using probing packet inspection with tcpdump. The test results give us information about what we should consider when we measure bandwidth.**

Keywords — **Available Bandwidth Measurement, Bandwidth Estimation, Network Monitoring**

1. Introduction

According to [1], several applications can benefit from knowing bandwidth characteristics of their network path. For example, based on available bandwidth, peer-to-peer applications can decide their dynamic user-level networks. Overlay networks can also configure location of their server or a routing table. Available bandwidth can be applied to Service-Level-Agreements (SLAs) between providers and customers to define their services. Other applications, such as end-to-end admission control and video/audio streaming, use bandwidth as key concept. In order to measure bandwidth, many tools are used depending on the metrics. These metrics are capacity in a link or a path and available bandwidth in a link or a path. Capacity means maximum transfer rate in a rink and end-to-end capacity means maximum transfer rate in a path. In addition, available bandwidth is unused capacity in a link and end-to-end available bandwidth is unused capacity in a path. To measure these metrics, various tools and methods are used. The results are little bit different depending on the measurement tools.

Most of bandwidth tools are based on active measurement. It means that measurement tools generate probing packets and these probing packets can affect a network. Sometimes, these may cause network congestion. Thus, intrusiveness of tools is one of important issues in active measurement. In this reason, these days many tools developer mentioned that their tools are non-intrusive tools. Usually, they compare their tool with Iperf and if probing packets of their tool is smaller than that of Iperf, they mention that their tool is a non-intrusive tool. However, the intrusiveness is ambiguous. No one defines the intrusiveness and classifies the tools into intrusive or non-intrusive tools.

Bandwidth measurement tools are classified as single hop capacity, end-to-end capacity, and end-to-end available measurement tools. Depending on the measurement metrics, tools use different methods. Most popular methods are the packet pair or packet train based methods for capacity measurement. The sender sends packet pairs or packet trains to the receiver. When the receiver receives these packet pairs or packet trains, the tool estimates the bandwidth with a dispersion of packet pairs or packet trains. Also, these methods are utilized in available bandwidth measurement tools. The other methods for available bandwidth measurement tools are self induced congestion methods. These methods cause the congestion during testing. They change various parameters such as a packet rate and a byte rate. The accuracy of each tool is different but there is no reference about which tool is accurate.

In these reason, we need to compare and analyze those tools and know which tools is less intrusive and accurately estimates bandwidth. In this paper, we just focus on available bandwidth measurement tools because we infer the end-to-end quality of service level with these tools. The organization of this paper is as follows; section 2 presents some related works about measurement techniques used in tools. In section 3, we show our examination results and analyzing those results. Finally, we conclude our paper in section 4.

2. Related Works

In this section, we describe measurement techniques used by well-known tools which are compared and analyzed in this paper. Basically, widely used methods are packet dispersion technique, self-load induced technique, and achievable throughput test for measuring available bandwidth.

A. Packet Dispersion Techniques

Packet dispersion techniques[3] utilizes packet pairs which uses two or more packet or a packet train which arranges lots of packet in a regular interval. A sender transmits packet with a same size of interval between neighbor packets and a receiver observes an interval of transmitted packets. In a router queue or a node queue, packets have delay because of a capacity of a router or other traffic, so the received interval can differ from a sent interval. The dispersion which occurs in this case is used. The size of packets in packet pairs or packet train is same. Packet pair probing can estimate end-to-end available bandwidth with the value of packet size and the value of estimated transmission delay which is obtained through dispersion of a packet interval of sender and that of receiver.

Figure 1 represents packet dispersion by a node. It shows how an interval of packets becomes different after passing through a node or a router.

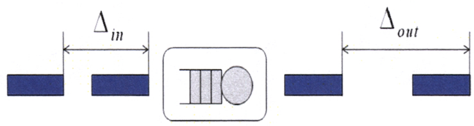

Fig. 1. Packet Dispersion with a router or a node

B. Self-load Induced Techniques

Self-load induced techniques, called SLoPS[4], are active probing methodologies which induce congestion in the network from a estimation tool. It uses packet pair to estimate available bandwidth of a present network state, and using that result, it decides a transmission rate. The size of packets is same. This methodology uses a variation of one way delay. If a transmission rate is larger than current available bandwidth, then one-way delay increase; because, the probing packets queue in a router or a node. On the other hand, it has a negligible minimum one-way delay. The tool measures a one-way delay until a transmission rate is the maximum, and it transmits packet pairs gradually decreasing a transmission rate until there is no change of delay. SLoPS estimates the available bandwidth when the transmission delay is the minimum.

C. Achievable Throughput

It uses large TCP transfers to measure the achievable throughput in an end-to-end path[1]. It gives lots of TCP transfers to the network until TCP transfers fill the available bandwidth. Therefore, it occupies lots of part of a path and produces more overhead relatively. This methodology can control the socket buffer size and the maximum window size for an accurate result. Like this, because various elements influence results, this methodology is difficult to define for measuring. Therefore, although the available bandwidth is same, the results which are measured with various versions of TCP can be different. Especially, Iperf supports multiple parallel transfers.

3. Results

We build testbed with 2 routers, 2 switches, and 1 linux based router. And then, we setup available bandwidth measurement tools such as IGI-PTR, Iperf, pathChirp, and Pathload. The testbed are shown in Fig.3. Basically, routers, switches, and network interface cards support 1 Gbps link. In addition, we use AX/4000 for generating cross traffic to verify the effect of cross traffic. This traffic generator can generate and analysis traffic up to 1Gbps. We generate cross traffic through the path. The end systems are linux based system. The kernel versions are 2.6.25 and 2.6.18 and the default TCP windows size are 85.5 and 16.0 Kbytes depending on the kernel versions. We choose some available bandwidth measurement tools such as pathload, pathChirp, IGI-PTR, and Iperf, and basic information is shown in table 1.

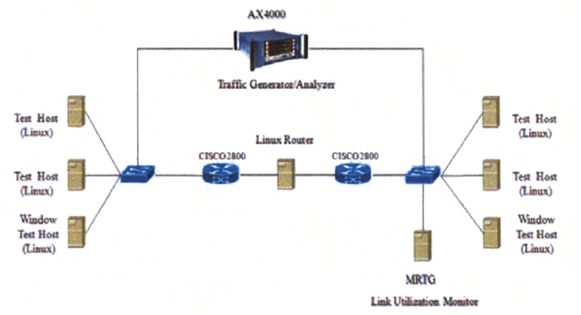

Fig. 2. Simulation Network Organization

Table 1 shows basic information of bandwidth measurement.

Table 1. Summary of Bandwidth Measurement Tools

Tool	Authors	Version	Protocol	Methods
pathload	Jain	1.3.2	UDP	SLoPS
pathChirp	Ribeiro	2.4.1	UDP	chirp train
IGI-PTR	Hu	2.1	UDP	SLoPS
Iperf	TCP	2.0.4	TCP/UDP	Bulk

First, we run these tools in the testbed without any other cross traffic. When we measure the bandwidth with AX/4000, the minimum, maximum, and average bandwidth are 360, 450, and 392Mbps respectively. Thus, we compare the estimated bandwidth with average bandwidth of AX/4000.

Figure 3 shows the measurement result using Iperf. The default TCP windows sizes are 16K and 85.3K bytes. Even though the client and server are reported that the transferred data is same size in the client and server, the bandwidths are little different between the client and server. Also, the results are different in the same testbed without cross traffic.

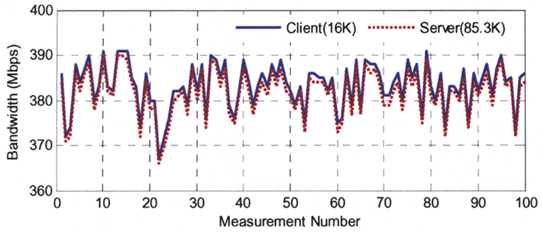

Fig. 3. Ipef test results without cross traffic

Figure 4 shows results by each tool without cross traffic. These tools are run in same environment. As we described in figure, the results are varied within specific range. The result of Iperf is close to the 400Mbps which is measured by AX/4000. Other results have more difference. The results of pathload has just two values.

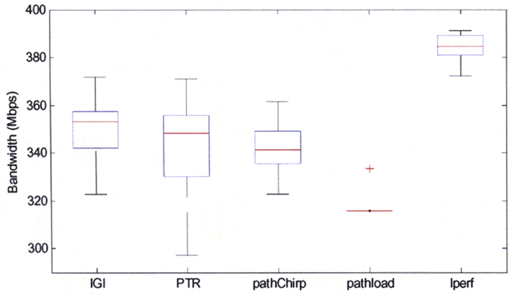

Fig. 4. Test results with cross traffic

Figure 5 shows results by each tool with cross traffic. In here, we increase cross traffic gradually up to 350Mbps. In this figure, we can see that most of results decrease as increasing cross traffic. However, the result of pathload has just one or two values.

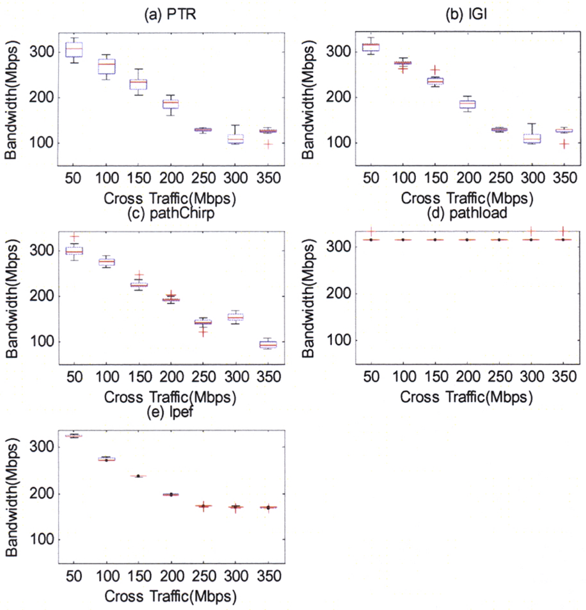

Fig. 6. Test results with cross traffic

Table 2 shows the traffic information. We capture the probing packets using tcpdump without cross traffic. This table shows that Iperf has large traffic compared to other tools. pathChirp has the longest time to measure bandwidth. Pathload has short measurement time and light traffic volume.

Table 2. Summary of Probing Traffic

Tool	Time (sec)	Packets	Volume (byte)	B/W (Mbyte)
pathload	1	946	564,512	315
pathChirp	120	39,618	40,489,332	348
IGI	1	540	3,983,120	344.5
PTR				351.4
Iperf	10	510,518	60,963,944	408

4. Conclusion

In this paper, we performed test and performance comparison of some bandwidth measurement tools. In accuracy view point, Iperf is the best tool, but Iperf generate lots of probing packets. These probing packets can cause traffic congestion. Also it uses TCP so we need to optimize many TCP variables because test results of Iperf are varied depending on these variables. IGI-PTR and pathChirp shows similar estimation results, but pathChirp has a less variation in results.

5. Acknowledgments

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