Comparative Analysis of Available Bandwidth Estimation Tools

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Abstract: - Available bandwidth tools or methods can be used by different application requirements. Some applications require not only measurement accuracy but also very short sampling time and high sampling frequency. So we analyze available bandwidth estimation tools which use SLoPS and PGM techniques. We made experimental simulations to analyze tools from four aspects which are measurement accuracy, total probe traffic generated, total estimation time and stability. From the experiments, we find the Pathload is the most accuracy but with high probe bandwidth and long estimation time. The results also indicate that which tool is the best in different applications.

Key-Words: - Available Bandwidth; Self-Loading Periodic Streams; Probe Gap Model

1 Introduction

In the process of Internet performance measurement, the available bandwidth (avail-bw) in a network path is of major importance in congestion control, streaming applications, QoS verification, server selection, and overlay networks. Measuring available bandwidth (Abw) is not only for knowing the network status, but also to provide information to network applications on how to control their outgoing traffic and fairly share the network bandwidth[1]. Some applications require very short sampling time and high sampling frequency, not only measurement accuracy. In this paper, we discuss what available bandwidth tools or methods can be used by different application requirements. The organization of this article is as follows. The section 2 introduces the techniques of bandwidth estimation and the end-to-end methodology for measuring avail-bw and four tools which measure avail-bw. The section 3 introduces the experiments of analyzing of available bandwidth estimation tools. The section 4 is the conclusion.

2 Analysis of Available Bandwidth Estimation Techniques

2.1 The Technique of SLoPS

The technique of SLoPS[2] is to measure the available bandwidth of an end –to-end link. The SLoPS assume: 1) FIFO queuing at all routers along the path; 2) cross traffic follows a fluid model (i.e., non-probe packets have an infinitely small packet size); 3) average rates of cross traffic change slowly and is constant for the duration of a single measurement.

Consider two network hosts PC1 and PC2. The path P is the sequence of store-and- forward links that transfer packets from PC1 to PC2. Suppose that PC1 transmits a periodic packet stream to PC2. The stream consists of K packets where K is the length of the stream. The size of each packet is L bits, while the packet transmission period is T seconds. The transmission rate of the stream is R =L/T bits per second.

When the stream rate R is larger than the avail-bw A, the stream creates a short-term overload in the tight link of the path. During that overload period, the tight link receives more traffic than what it can transmit, and so the queue of the tight link gradually builds up. So, the queuing delay of packet i at the tight link is expected to be larger than the corresponding queuing delay of packet j with j < i. Consequently, when R > A, the relative OWDs {D1, D2, …Dk} of the stream packets are expected to have an increasing trend. We refer to this effect as self-loading, if the stream will not cause an overload at the tight link, and thus the backlog of that link will not keep increasing with every new stream packet. So, when R<A, the relative OWDs {D1, D2, …, Dk} of the stream packets are expected to have a non-increasing trend. A more precise statement and proof of the previous properties, for a fluid model of the cross traffic in the path, is given in [1].

PC2 can infer whether the stream rate R is larger than the avail-bw A based on the self-loading effect of periodic stream, However, to actually estimate the avail-bw in the path, the two end-points have to cooperate so that the stream rate R converges iteratively to A, In the n'th step of this iterative procedure, PC2 checks whether the transmission rate R(n) of the n'th stream is larger than A, based on the presence of an increasing trend in the OWDs of stream n. If R(n) > A, PC1 sends an additional periodic stream with rate R(n+1) < R(n). If R(n) < A, the rate of the next periodic stream is R(n+1) > R(n). The method we examine the relation between R and A is the key idea in the measurement methodology.
The Pathload is a typical example tool that uses the SLoPS model. The basic idea of SLoPS is described using the tool of Pathload. Pathload consists of two components:_process A running at the sender and process B running at the receiver. The tool uses UDP for the periodic packet streams. Additionally, a TCP connection between the two end points serves as a 'control channel'. The control channel transfers messages regarding the characteristics of each stream, the abortion or end of the measurement process.

2.2 The Technique of PGM

The probe gap model (PGM) [3] exploits the information in the time gap between the arrivals of two successive probes at the receiver. A probe pair is sent with a time gap Δ_{in}, and reaches the receiver with a time gap Δ_{out}. Assuming a single bottleneck and that the queue does not become empty between the departure of the first probe in the pair and the arrival of the second probe, then Δ_{out} is the time taken by the bottleneck to transmit the second probe in the pair and the cross traffic that arrived during Δ_{in}, as shown in Fig.1.

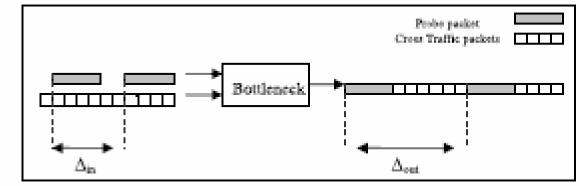

Fig.1 the Probe Gap Model (PGM) for Estimating Available Bandwidth.

Thus, the time to transmit the cross traffic is $\Delta_{out}-\Delta_{in}$, and the rate of the cross-traffic is $\left(\Delta_{out}-\Delta_{in}/\Delta_{in}\right)\times c$, where C is the capacity of the bottleneck. The available bandwidth is:

$$A = C \times \left(1 - \Delta_{out} - \Delta_{in}/\Delta_{in}\right) \quad (1)$$

Spruce [4], IGI [5], and Pathchirp [6] are example tools that use the gap model.. Both the PGM also assume: 1) FIFO queuing at all routers along the path; 2) cross traffic follows a fluid model (i.e., non-probe packets have an infinitely small packet size); 3) average rates of cross traffic change slowly and is constant for the duration of a single measurement.

Further, the probe gap model assumes a single bottleneck which is both the narrow and tight link for that path. These assumptions are necessary for the model analysis but the tools might still work even when some of the assumptions do not hold [5].

3 Experiments and Analysis

Available bandwidth tools or methods can be used by different application requirements. Some applications require very short sampling time and high sampling frequency, not only measurement accuracy. So we evaluate tools rather than techniques, focusing on design and implementation details that affect measurement accuracy, total probe traffic generated, total estimation time and stability. We put the focus on analyzing experimental results for iterative tests performance.

3.1 Measurement method

In order to show the accuracy of our evaluation, we use real environment to do our experiment. In the experiment, we choose the tools which are Pathload, Pathchar, Spruce, IGI. The Illustration of experiment is as Fig 2.

In the Fig 2, there are three links from PC1 to PC2. The link1 is from PC1 to Router1.The link2 is from Router1 to Router2. The link3 is from Router2 to PC2. We use automated traffic generation tools such as Iperf to make traffic in sender as in Fig 2. In the experiment, Sender sends packets to PC2 using Iperf. Two hosts are required to run the tools such as Pathload, Pathchirp, IGI and Spurce. Repeated procedures have led to the development of tests automation such as results processing and recording scripts in two hosts.

The machines which are used in the experiment all have 100M Ethernet network cards. PC1 and PC2 are only running the tools. First, Sender sends on packets, the bandwidth is 100M and the available bandwidth is nearly same as the bandwidth on the three links. We use tools to measurement the available bandwidth on the links. We call the real available bandwidth standard available bandwidth and we call the available bandwidth which is measured by the tools measurement available bandwidth. Second, Sender sends packets to PC2 using Iperf at the rate of 10Mbps. Then the available bandwidth on the link3 should be 90M. So the standard available bandwidth is 90M and the values of measurement available bandwidth which are measured by the tools are various. We have made 10 experiments with the values of standard available bandwidth which are varied from 0M to 100M increased by 10M every time.

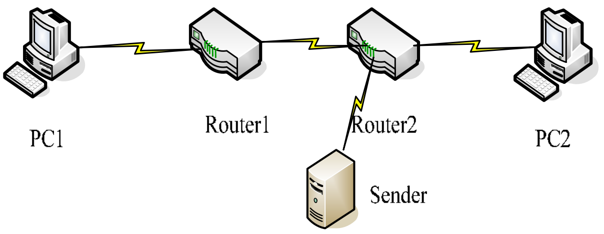

Fig.2 the Illustration of Experiment

3.1.1 Three experiments

Experiment one: the relation between the standard available bandwidth and measurement available bandwidth.

Experiment two: the relation between the standard available bandwidth and total estimation time.

Experiment three: the relation between the standard available bandwidth and probe bandwidth.

Each experiment was performed 8 times and the averages are given.

3.2 Experiment results and analysis

1. Measurement accuracy

In the first experiment, we measure the influence of the changes of standard available bandwidth on the measurement available bandwidth. We can find that the values given by the use of the tool of Pathload are the most close to values of the standard available bandwidth, then the tool of spruce. With the increase of the standard available bandwidth, the values of measurement available bandwidth given by the use of the tool of Pathchirp deviate more and more from it.

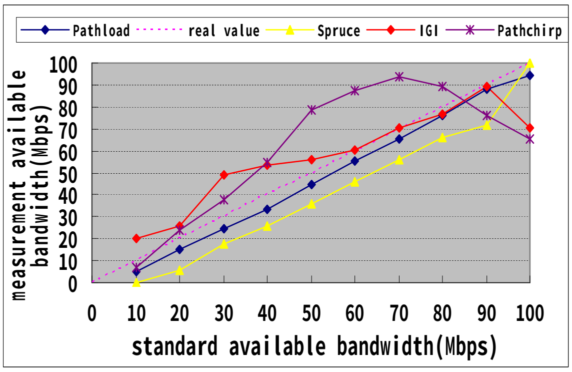

Fig.3 the Relation between the Standard Available Bandwidth and Measurement Available Bandwidth

2. Total estimation time

In the second experiment, we measure the total estimation time for different standard available bandwidth. Because estimation time of Pathchip is continual with short intervals, so we do not measure the estimation time of the tool, hence no illusion about it in Fig 4. From Fig 4, We find that the estimation time is changes litter except Pahtload, we can also find that the estimation time when the standard available bandwidth is 10M is nearly four times the estimation time when the standard available bandwidth is 100M. But in the middle of the curve, it changes a litter.

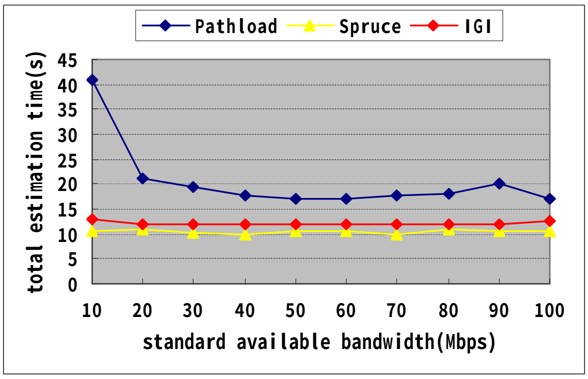

Fig.4 the Relation between the Standard Available Bandwidth and Total Estimation Time

3. Total probe traffic generated

In the third experiment, we measure the probe bandwidth of four tools. We find the values of Pathlaod are increasing quickly from 10M to 100M. The probe traffic which is generated by the other three tools has changed a litter and far less than 1Mbps. There are shown in Fig 5.

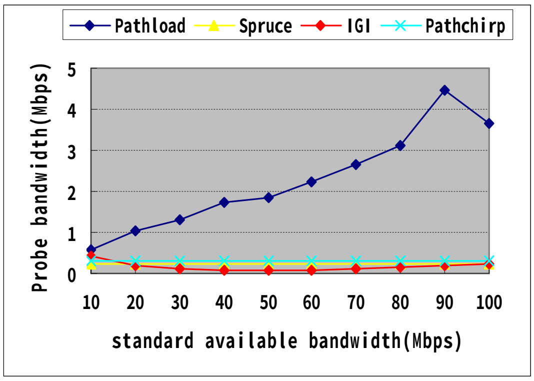

Fig.5 the Relation between the Standard Available Bandwidth and Probe Bandwidth

4. Stabilization

From the above three experiments, we can find the values of Pathload is the most close to the standard available bandwidth and stable on accuracy. On the contrary, the values of estimation time and probe bandwidth given by the tools of IGI and Pathchip change little with lower accuracy. The values of standard available bandwidth given by the tool of Spruce are second in accuracy with a litter bandwidth and takes short estimation time.

4 Conclusion

We have presented the measurement method to comparative analysis of available bandwidth tools. In the paper, we evaluate these tools rather than techniques, focusing on design and implementation details that affect measurement accuracy, total probe traffic generated, total estimation time and stability. We made experimental simulations to analyze tools. From the experiments, we find Pathload is the most accuracy but with the high probe bandwidth and long estimation time. So if accuracy is focused on in network applications, you can choose the tool of Pathload. Otherwise, considering all aspects, you might have other choice.

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