Improving Active Measurement Estimates Using One-Way Delays

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I. Introduction

Understanding network characteristics is essential to build accurate models necessary to improve the quality of multimedia real time applications. Some performance network parameters such as the round trip time (RTT) can be easily obtained in most cases. However, variables such as one-way delay (OWD) distributions and link capacities may be difficult to estimate without the use of special hardware, such as GPS equipment. Recently, several active measuring techniques have been proposed to cope with the problems that arise when one tries to measure such quantities based solely on probes sent between two end points and without the use of special hardware. In this work, we further extend previous techniques for measuring the one-way delay and bottleneck capacity, and present a few results to illustrate the proposed techniques.

II. One-Way Delays

The main difficulty for estimating one-way delays are the *skew* and the *offset* that arrise when clocks in the different computers are not perfectly syncronized. These issues have extensively been discussed, and solutions have been proposed [8], [9], [10], [13], [14]. However, other problems also existe such as clock updates in one of the machines used in the measure infraestructure, and temporary interruptions of the processes who deal with the received probes. As algorithms for calculating the skew are based on linear growth of estimated delay, an event of clock updates during the measurement may introduce errors on the results of skew removal algorithms [9], [14]. Temporary interruptions of the probe receiving process also introduces errors in the calculation of the probe delay. Those interruptions may be caused by the execution of a higher priority proccess in the operational system. Figure 1(A) illustrates such problems. In that figure is shown the OWD calculated from probes sent from a source to a destination machine before the skew and offset have been removed. One can observe the big spikes that are caused when one of the clocks is updated (that is, one of the machines synchronizes its clock with another machine using ntpdate) and when the processes involved in receiving the probes suffers from interruptions caused for instance by the machine scheduler.

We propose a new technique to overcome the problems mentioned above based on the algorithms of [8], [14], [12], [11]. The technique was implemented it in the Tangram-II modeling environment [6]. Figure 1(A) shows the delays calculated after applying our algorithm. Figure 1(B) shows the result after removing the skew. Finally, in Figure 1(C), the OWD for all the probes is obtained after the offset is removed.

To further illustrate the potential of the technique and the tool we implemented, we collected OWD measures between laboratories in Brazil and in the USA, using TANGRAM-II. These measures were used to obtain the distributions that best fit the collected measures. We use the method of moments to estimate the parameters of different distributions. In Figure 2, the estimated distributions are plot as well as the histogram obtained from the measured delays between a machine in UFRJ and another in UMass. In the figure the Mean Square Error is indicated for each distribution.

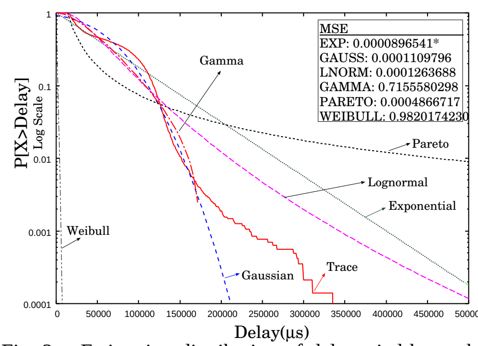

Fig. 2. Estimating distribution of delay tried by probes.

III. Link Capacity

In this section we are concerned with the estimation of the bottleneck link capacity. The packet pair technique has been proposed to estimate the bottleneck capacity [3], [5], [1]. However, recent results aimed at evaluating this technique have shown that the packet pair method is not accurate when the path used is highly loaded [2].

To improve the accuracy of the packet pair technique we developed a packet selection algorithm to be used with the basic packet pair method. Roughly, we employ OWD estimates to selected the packet pairs used in the calculations. In more detail a pair is selected for the packet pair estimation procedure when the estimated OWD of its first packet is within a given tolerance from the smallest OWD of the entire measurement samples.

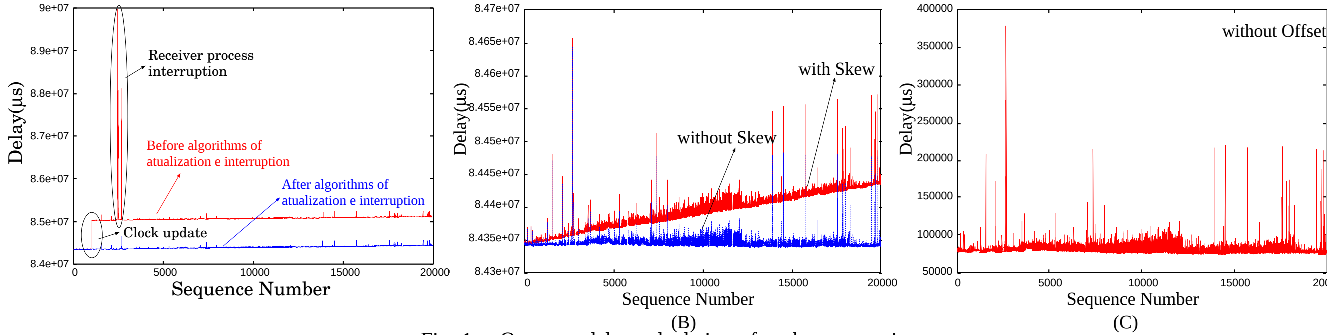

Fig. 1. One-way delay calculation of probes generation.

We have evaluated the efficacy of the proposed approach via simulation and using high loaded network paths. The technique has also been implemented in Tangram-II Traffic tool and several experiments were performed using the tool. Figure 3 illustrates the results when the basic packet pair procedure is used and when the pair selection approach is employed. A similar approach has independently been proposed in [4] for estimating the bottleneck link capacity. However, the filter used by the method is based on the round trip time. Furthermore, the technique of [4] uses a single packet pair experiment to estimate capacity.

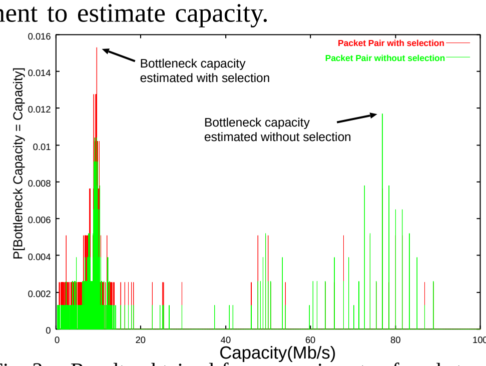

Fig. 3. Results obtained from experiments of packet pairs.

IV. Estimating Buffer Sizes

Methods to estimate the buffer size of the bottleneck router and drop rate variables have been proposed in [7]. In that work, the loss pair technique was used to estimate performance parameters of the bottleneck link in a path. The assumptions used are: (i) the bottleneck is the router with the lowest bandwidth capacity in the path; (ii) most losses occur at the bottleneck router; (iii) there is only one bottleneck in the considered round trip path between the two computers involved in the measures. In the technique all parameters are estimated based on round trip time values, due to the difficulties in calculating one-way delays. However, the estimated measures of interest can be considerably inacurate when more than one bottleneck exists in the round trip path. Intuitively, the probability of having more than one bottleneck considering the round trip is higher than that using one-way. Therefore, applying the method using one-way reduces the chances of more than one bottleneck in the path. Since we have an accurate tool for estimating one-way delays (Tangram-II), the buffer size and loss rate of the bottleneck link can be accurately estimated based on the OWD.

V. Summary

In this work we developed a technique to overcome difficulties to estimate the one-way delay between to non-synchronized machines. We illustrate the applicability of the technique to characterize one-way distributions. Subsequently we showed that the OWD can be employed to improve the accuracy of the packet pair technique in order to estimate the capacity of the bottleneck link. We indicate that the OWD can be also used to improve the accuracy when the packet loss pair technique is used to estimate the buffer size of the bottleneck router. We are currently evaluating the increase in accuracy that can be obtained. We have implemented the techniques as part of the *Tangram-II* modeling environment. Further experiments are under way to illustrate the advantages of using the OWD metric as part of active measurement approaches.

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