Inferring Delay Variations using Packet-pair probing techniques for Network measurement

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Abstract: IP networks are destined to become the ubiquitous global communication infrastructure. With the introduction of Service Level Agreements(SLAs), the importance of being able to accurately know and manipulate traffic behaviour in a network has increased. Inferring the delay distributions is of great importance for various network applications. In this paper, we adopt an active measurement technique which can infer delay variations by injecting back-to-back packet doubles or packet-pairs as probes instead of single packets across the end-to-end network. By this we exploit the 'dispersive' nature of packet-pairs to measure this performance metric. The modelling technique provides a commanding solution to address the problem of QoS estimation. Thus, the use of probe-packet stream ensures that the measurements derived are not pseudo-estimates of the original dimensions. Finally, we validate our scheme by performing network simulations.

1 Introduction

Evaluating the performance of packet (e.g. IP) networks is vital to the commercial success of broadband , wide area networks. Research in the recent past has been of focussed on the design of these large scale networks. Various traffic management schemes are adopted by IETF to provide scalable services differentiation on the Internet. And continuous efforts are being made to develop a number of new technologies for network measurements to enhance QoS capabilities. Most network operators and service providers have started relying on accurate measurement techniques to enhance the QoS capabilities. Substantial and accurate traffic measurements are necessary to access the capacity requirements and to design the network efficiently. A lot of effort has been put in the recent years to benefit from these packet-level monitoring techniques.

Fundamentally, network measurement techniques are of two types viz. Active and Passive measurement schemes. Both technologies have their own advantages and disadvantages. Some related work researched in this field are Service Assurance Agent[1] from Cisco, pathChirp[2], NetFlow[3] and other tools given in [4],[5]. Accuracy and bandwidth overhead[6], particularly in active measurement, should also be considered when it comes to implementing these techniques.

Passive measurements are employed to measure the traffic patterns and to infer parameters like throughput between the end-to-end nodes of the network. Due to the non-intrusive feature of the measurement, network operators have always found it safe with this method to monitor traffic. This method can either be single or multi-point. The idea involved in passive methods is to capture packets inorder to store and collect information from various fields within the packet header. The use of traffic meters substantially minimise the amount of stored data and work on the principle of comparing the data of the corresponding packets at each point.

Active measurements works by injecting probe packets whose measured end to end delays and evaluated packet loss probabilities are taken to be representative of all the traffic. For measurements of delay or loss to accurately reflect network performance these measurements must be valid over the periods when customers are active. If this were not so the probabilities could be averaged over virtually unloaded periods, and would not then reflect the real experience of customers.

Therefore in our work, we use the recommendations of Cisco Systems[1] , where it is stated that measurements should be carried out over a busy hour. In this paper we perform the injection of back-to-back probes along with the main-user stream to examine the actual network performance experienced by end-users. This paper is organised as follows. The basis of our measurement scheme is dealt briefly in Section 2. The model for analysis is presented in section 2 and simulation results are summarised in sections 4.

2. Problem Formulation

Initially, the concept of injecting back-to-back probes was derived from Network Tomography[9] and statistical sampling methods. Other authors[7],[8] have also proposed the combination of both the active and passive measurement techniques to monitor IP networks. Vinay *etal.* [2]proposed an algorithm called *pathChirp,* a way of per-flow delay measurement by means of rapidly increasing the probing rate with each exponential flight pattern of packets, also known as the 'Chirps'. This uses the packet inter-arrival times with respect to the user traffic and the probe traffic. This greatly decreases the need for Clock Synchronisation between the sender and the receiver. And in [10], an packet tailgating technique was presented to infer the theory of packet-pairs to measure bottleneck bandwidth. Instead we investigate the delay variations in a scenario similar to packet pair model in FIFO queuing systems of the same size from same source and destinations respectively.

The probes used are controlled/set by the parameters given below:

- *Probing packet size.* The experiments with very small probing packets are very sensitive to interference. Hence, the packet-pairs used must fairly have a large packet size in comparison with the size of the packet(of a single source). Otherwise the very objective of using them is nullified.
- *Number of probing packets.* The larger the number of probe packets, the higher is the precision of measurement. A short snapshot is not enough to cope up with the average load. However, sending too many packets will cause queue overflow, increase in load and will cause excessive congestion by intruding with the core traffic.
- *Initial probing gap.* This is also a measure of the probing rate. The rate at which the packet trains are sent must be controlled such that it does not cause ‘flooding’ in the network.

And here we exploit the property of packet doubles as probes to infer the levels of delay variations along with Queuing analysis. The initial formulation of the problem is the measure of delay variation given by the probing stream and the user-level traffic without the probing stream is briefly described as follows. The capacity of the link of the service rate is given by C_i. The size of the packet-pair stream generated by the probe source is given by P. These packet-pairs received by the receiver are dispersed by a quantity Δ. Assuming that there is a constant service rate, the value of the dispersion coefficient is given by P/C. And if the spacing between the packet pairs are random, it is also a measure of Cij, the service rate experienced by the ith probe stream with an interval j, where $t_n+1 = t_n + j$. Therefore the delay experienced by the probes are effectively equal to $\tau \equiv L/C_{ij}$, where L is the size of the packet-pair(also this gives a good estimate of Bandwidth estimation of the link, which is not crucial in our analysis. But this factor may be essential while estimating the overhead caused by probes).

Hence, we perform two sets of experiments for our measurement technique to inject these packet-pairs along with the user traffic to estimate the delay variations. We apply the results of queuing analysis to show how an active probing stream along with the foreground traffic could be modelled to improve the accuracy of active measurement techniques in general and the results are presented in section 4.

3. Network Model and Analysis.

Typical values of the parameters used in the simulation are given below in Table1:

	Source parameters	Probe parameters
Number	70	3600
Ton	0.69	-
Toff	1.69	-
Rate	167 packets/sec	1 probe/sec
Simulation time	1 hour	1 hour
Size	100 bytes each	64 bytes
Type	Multiplexed ON-OFF	Deterministic

Table 1: Model parameters

The delays are a determined by the capacity of the link, the size of the packet and the probe sizes. The queuing analysis helps us to infer the delay distribution of the user streams and the probe delay variations are inferred as described in section 2.

The probability for which the packets are delayed is calculated using the excess rate analysis[11], without probes are given by D obtained as follows:

$$D = \frac{No.B}{No - A + A.B} \quad (1) \quad \text{where} \quad B = \frac{\frac{A^{No}}{No}}{\sum_{r=0}^{No} A^r / r!} \quad (2)$$

The general formula for packet scale + burst scale queuing in a multiplexer serving bursty on-off (but Markovian and queue length of ‘k’ packets) traffic has been established to be [12]:

$$p(k) = (1 - P_{BS})(1 - \eta p^k)\eta p^k + P_{BS}(1 - \eta b^k)\eta b^k \quad (3)$$

p/ρ = the load on the buffer

$P_{BS}, \eta_{B,}$ = Probability expectation and the decay rate in the burst scale part of the queuing distribution;

η_P = decay rate in packet scale queuing part of the distribution ≈ ρ (see also [10] for more accurate expressions)

This expression in Eq.3 will also lead us to find the number of probe packets required and is given in[11]. But the probes used here are deterministic in nature with a rate of 1 probe/sec. However, this will be used in the future to model the probes in the network.

3.1 Model for Simulation Setup

With the parameters given above, the simulation model is setup is shown in Figure 1. The implementation was carried out in ns-2[13]. Due to clarity reasons, the probe source and sink are not represented explicitly.

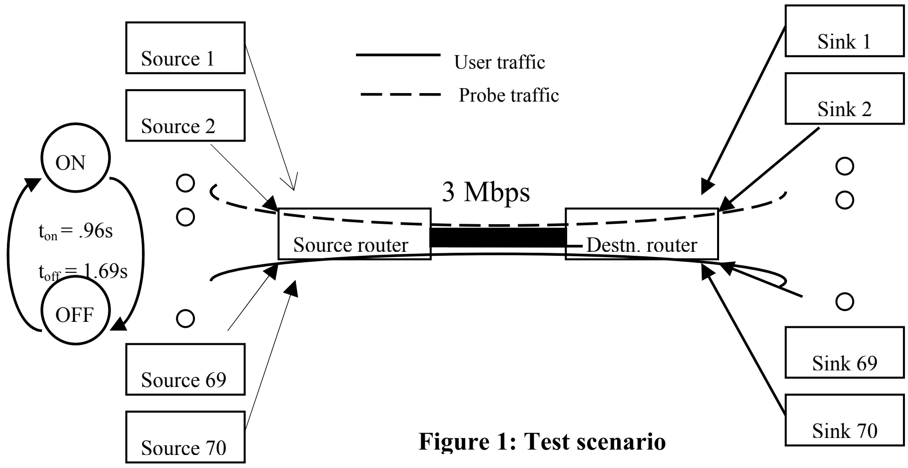

Figure 1: Test scenario

4.Experimental Results

We evaluate the scenario outlined above by simulations and the graphs are presented below. The delay distribution is presented in a log-linear scale interms of Delay(ms) and Probability. Firstly, the experiment performed is for the user traffic with the multiplexed sources without the injection of a probe stream. The actual results obtained from the traffic traces after performing the simulations are recorded. After calculations, delay variations were plotted for two different loads: 80% and 90% as presented in Appendix A1.

Next, a series of back-to-back packets(probes) are injected along with the user-traffic. Figs.2 and 3 shows the results for both loads. The measurement results say that for 80% load, there is a good estimate until certain period of packet delays. Since the number of probes is comparable to that of the user-traffic in the case of 80% load, it starts off well to give a good measure of the delay distribution.

When the load is increased to 90%, the extra-traffic among the users increases, and there is not enough probe packets to measure the delay distributions experienced along with the foreground traffic. Therefore, the estimate given in this less accurate case is than the previous one. And hence the 'flooring effect'. This gives a true measure of the burstiness of the traffic and is made possible from the service rate of the probes being serviced back-to-back.

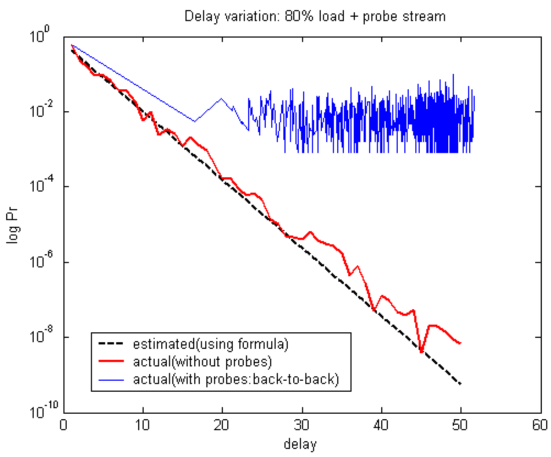

Figure 2: Delay distribution for ρ = 0.8

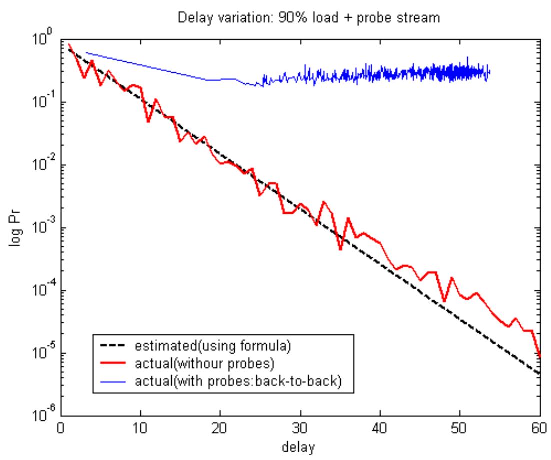

Figure 3: Delay distribution for ρ = 0.9

As the percentage of bandwidth occupied by the probes with in comparison with the user traffic decreases, the probes go unnoticed. This is because the user-traffic dominates the traffic inside the network. Hence, we argue that they do not give ‘pseudo-estimates’ like the conventional passive measurement schemes as the delay variations are directly notified by the amount of dispersion levels of packet-pairs and also the strength of our scheme.

5. Conclusions

In this paper, we have proposed a modelling technique using our active measurement scheme. As seen in the results, the delay variations are plotted with two different loads along with the introduction of back-to-back packet-pairs. The user-level control of the probing parameters adds more flexibility to our technique giving the actual measure of the traffic itself. Further, this research leads us to solve the problem of when and where to use the probes to measure the network parameters efficiently. An application where the probe intensities would decrease on demand and scalability issues for a mix of traffic sources is currently being studied. We presented our preliminary work researched in this area. As this research is ongoing, addressing this scheme to make the probe streams independent of whatever the traffic type be and monitoring other QoS parameters is reserved for future work. This paves way to combine both active and passive technologies and design novel applications to measure performance metrics effectively. This will give an accurate measure to evaluate the network’s capability to support value added services(QoS, IP telephony , etc.) as well.

References.

[1] Service-Level Management: Defining and Monitoring Service Levels in the Enterprise http://www.cisco.com/en/US/products/sw/cscowork/ps2428/products_white_paper09186a0080091ba5.shtml , Cisco White Paper, 2003

[2] Riberio V, Reidi RH, Baraniuk R.G, Navaratil J, Cotrell L: “pathChirp: Efficient Available Bandwidth Estimation for Network Paths”, Proc. of Passive and Active Measurements Workshop PAM2003.

[3] White Paper - NetFlow Services and Applications: http:// www.cisco.com/warp/public/cc/pd/iosw/ioft/neflct/tech/napps_wp.htm.

[4] IPMA: Internet performance measurement and analysis. http://www.merit.edu/ipma/.

[5] CAIDA cooperative association for Internet data analysis. http://www.caida.org/tools/.

[6] Schormans J.A.: “Bandwidth overhead of packet probing”. Queen Mary Internal report. Available from john.schormans@elec.qmul.ac.uk

[7] T. Lindh. A.: “New approach to performance monitoring in IP networks - combining active and passive methods”. Proc. of Passive and Active Measurements Workshop, PAM 2002.

[8] Paxson V., Adams A.K., Mathis M.: “Experiences with NIMI”, Proceedings of Passive and Active Measurements (PAM) 2000, Hamilton, New Zealand, 2000.

[9] T. Bu, N. Duffield, F. Lo Presti, D. Towsley.: “Network tomography on general topologies”, Proceedings ACM Sigmetrics 2002, Marina Del Rey, CA, June 15-19, 2002.

[10] Kevin Lai and Mary Baker, "Measuring Link Bandwidths Using a Deterministic Model of Packet Delay", *Proceedings of ACM SIGCOMM 2000*, August 2000

[11] Pitts, J.M. and Schormans, J.A.: “Introduction to IP and ATM Design and Performance”, Wiley, Dec 2000.

[12] Timotijevic, T. and Schormans, J.A.: “Bandwidth overhead of probe technology guaranteeing QoS in packet networks”. IEE Electronics Letters, 15th May, 2003, Vol. 39, No. 10, pp 816-818.

[13] Ns2. http://www.isi.edu/nsnam/ns.

Appendices.

Appendix A.1: Measure of delay variations: Plotted for two vales of loads(ρ = 0.8, ρ = 0.9)