International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.5, Sep-Oct. 2012 pp-3807-3809 ISSN: 2249-6645

An Efficient Approach for Packet Loss Measurement

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ABSTRACT: *Various tools are available in market to measure packet loss in the end-to-end networks. But all the existing tools are not able to calculate packet loss in the network accurately. So measuring packet loss efficiently is still an open problem in the networks due to relatively occurrence and short duration of packet loss. The aim of our research is to understand how to efficiently calculate packet loss in the network. In this paper we presented an algorithm for measuring packet loss in the network. To evaluate the performance of the proposed algorithm, we simulate the algorithm in the NS2 simulator. Our experimental results shows the trade-offs between impact on the network and measurement accuracy. We show that measuring packet loss is more efficient in our proposed algorithm than traditional loss measurement tools.*

Keywords: *packet loss, NS2, Bernoulli loss model, BADABING*

I. INTRODUCTION

Users can monitor network nodes for packet loss on routers using SNMP. Various tools are available in market to measure packet loss in the end-to-end networks. But all the existing tools are not able to calculate packet loss in the network accurately. PING is the most commonly used tool for measuring packet loss in the end-to-end paths. PING tool send ICMP echo packets to the destination at fixed intervals.

Sender assumes an occurrence of packet loss, if the acknowledgement from the destination is not received within a specified time period [1], [2]. Synchronization between sender and receiver is very important for measuring packet loss in the network. Strict synchronization of two entities connected by a varying delay link, can prove to be impossible without access to an external universal time reference as provided by a GPS (Global Positioning System) time reference. Even if GPS acquisition cards are now more frequently used enabling feasible delays with a resolution around 1 µsec, It worths to try to extract as much as information from the loss process which much more simple to measure. A measurement approach is problematic because of the discrete sampling nature of the probe process. Thus, the accuracy of the resulting measurements depends both on the characteristics and interpretation of the sampling process as well as the characteristics of the underlying loss process.

Joel Sommers [3] proposed an approach in the network, tells us that Poisson modulated probes will provide unbiased time average measurements of a router queue's state. But this method needs higher moments of measurement to determine valid results. A closely related issue is the fact that loss is typically a rare event in the Internet [4]. This reality implies either that measurements must be taken over a long time period, or that average rates of Poisson-modulated probes may have to be quite high in order to report accurate estimates in a timely fashion.

However, increasing the mean probe rate may lead to the situation that the probes themselves skew the results.

Thus, there are trade-offs in packet loss measurements between probe rate, assurement accuracy, impact on the path and timeliness of results [5], [6]. Measuring and analyzing network traffic dynamics between end hosts has provided the foundation for the development of many different network protocols and systems. Of particular importance is under-standing packet loss behavior since loss can have a significant impact on the performance of both TCP- and UDP-based applications. Despite efforts of network engineers and operators to limit loss, it will probably never be eliminated due to the intrinsic dynamics and scaling properties of traffic in packet switched network.

Network operators have the ability to passively monitor nodes within their network for packet loss on routers using SNMP. End-to-end active measurements using probes provide an equally valuable perspective since they indicate the conditions that application traffic is experiencing on those paths [1], [2].

The rest of the paper is organized as section 2: discuss about the related work, section 3: presents the proposed model, section 4: discuss about the experimental setup, section 5: concludes the paper.

II. RELATED WORK

J. Bolot [9] and V. Paxson [10] have proposed algorithms to measure packet loss in the end-to-end networks. Yajnik [8] has evaluated packet loss correlations on longer time scales and developed Markov models for temporal dependence structures. Zhang [11] has characterized the packet loss in to several aspects based on their behavior. Papagiannaki [12] used a sophisticated passive monitoring infrastructure inside Sprint's IP backbone to gather packet traces and analyze characteristics of delay and congestion. Later, Sommers and Barford have discussed some of the drawbacks in standard end-to-end Poisson probing tools by comparing the loss rates measured by such tools to loss rates measured by passive means in a fully instrumented wide area infrastructure. The foundation for the notion that Poisson Arrivals See Time Averages (PASTA) was developed by Brumelle [13], and later formalized by Wolff [7]. Adaptation of those queuing theory ideas into a network probe context to measure loss and delay characteristic began with Bolot's study [9] and was extended by Paxson [7]. Baccelli [14] has analyzed the usefulness of PASTA in the networking. Several studies include the use of loss measurements to estimate network properties such as bottleneck buffer size and cross traffic intensity [15], [16].

The Internet Performance Measurement and Analysis efforts [17], [18] resulted in a series of RFCs that specify how packet loss measurements should be conducted.

However, those RFCs are devoid of details on how to tune probe processes and how to interpret the resulting measurements. ZING tool [19] is used for measuring end-to-end packet loss in one direction between two participating end hosts. It sends UDP packets at Poisson-modulated intervals with fixed mean rate. Savage [20] has presented STING tool to measure loss rates in both forward and reverse directions from a single host. This tool uses a clever scheme for manipulating a TCP stream to measure loss. Allman [21] has presented a method to estimate TCP loss rates from passive packet traces of TCP transfers taken close to the sender. Finally, M. Coates and N. Duffield [22, 23] have presented network tomography based on using both multicast and unicast probes for inferring loss rates on internal links on end-to-end paths.

III. PROPOSED MODEL

In our proposed model, we consider a tree-structured network consisting of single source and multiple receivers which is described in figure 1. From the source a distinct path is associated for every receiver. Each path consists of one or more links between nodes. If subpaths consisting of two or more links with no branches exist in the network, then those subpaths either removed or replaced by a single composite link. For packet transmissions, we assume a simple Bernoulli loss model for each link. The unconditional success probability of link i is defined as

$$\alpha_i \equiv \text{Pr(packet successfully transmitted from } \rho(i) \text{ to } i),$$

where p(i) denotes the index of the parent node of node. A packet is successfully sent from p(i) to i with probability α_i and may be dropped with probability $1-\alpha_i$. The loss processes of links are mutually independent of each other. Although spatial dependence may be observed in networks due to common traffic, such dependence is highly circumstantial and cannot be readily incorporated in a model that is intended to be generally applicable to a variety of networks.

Bolot [10] proposed a Markovian model of packet loss based on traffic in the internet. V. Paxson [7] has discussed that Markovian model do not fully account for the extended loss bursts. In our proposed model, we adopt a similar method for modeling the packet loss processes on each link. If two, back-to-back packets are sent from node p(i) to node i, then the conditional success probability is defined as

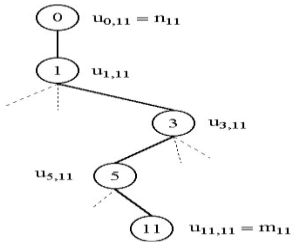

Figure 1: Tree structured network model

$$\beta_i \equiv \text{Pr(2nd packet } \rho(i) \to i \mid \text{1st packet } \rho(i) \to i\text{)}, \quad (1)$$

Where p(i) → i denotes the successful transmission of a packet from p(i) to i .That is, given that the first packet of the pair is received, then the second packet is received with probability β_i and dropped with probability $1-\beta_i$ .We anticipate that $\beta_i > \alpha_i$ for each i since knowledge that the first packet was successfully received suggests that the queue for link i is not full.

Each link in the tree has unconditional and conditional success probabilities, α_i and β_i respectively. These probabilities will effect the measurement of packet loss in the end-to-end network . The packet loss can be measured in various ways such as UDP can be used for active probing or TCP connections may be passively monitored, in which back-to-back events are selected from the TCP traffic flows.

Single Packet Measurement: Suppose that n_i packets are sent to receiver i in that m_i packets are actually received and n_i-m_i are dropped. The likelihood of m_i given n_i is binomial and is given by

$$l(m_i \mid n_i, p_i) = \binom{n_i}{m_i} p_i^{m_i} (1-p_i)^{n_i-m_i} \quad (2)$$

Back-to-Back Packet Pair Measurement: Suppose that the source sends a large number of back-to-back packet pairs in which the first packet is destined for receiver i and the second for receiver j. We assume that the timing between pairs of packets is considerably larger than the timing between two packets in each pair. Let $n_{i,j}$ denote the number of pairs for which the first packet is successfully received at node i, and let $m_{i,j}$ denote the number of pairs for which both the first and second packets are received at their destinations. Furthermore, let $k_{i,j}$ denote the node at which the paths p(0,i) and p(0,j) diverge, so that $p(0,k_{i,j})$ is their common subpath. The $m_{i,j}$ likelihood of given $n_{i,j}$ is binomial and is given by

$$l(m_{i,j} \mid n_{i,j}, p_{i,j}) = \binom{n_{i,j}}{m_{i,j}} p_{i,j}^{m_{i,j}} (1-p_{i,j})^{n_{i,j}-m_{i,j}}$$

Where

$$p_{i,j} = \prod_{q\in\mathcal{P}(0,k_{i,j})} \beta_q \prod_{r\in\mathcal{P}(k_{i,j},j)} \alpha_r \quad (3)$$

IV. EXPERIMENTAL SETUP

Let us now consider the simple two-receiver network shown in Figure 2. Assume that we have made measurements of single packet and back-to-back packet

$$\mathcal{M} = \{m_i\}_{i=2,3} \cup \{m_{i,j}\}_{i,j=2,3}$$
$$\mathcal{N} = \{n_i\}_{i=2,3} \cup \{n_{i,j}\}_{i,j=2,3}.$$

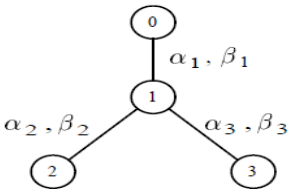

Figure 2: small network with two receivers

Maximum likelihood estimates of α_1, α_2, α_3 are given by

$$(\widehat{\alpha}_1, \widehat{\alpha}_2, \widehat{\alpha}_3) = \arg\max_{\alpha_1,\alpha_2,\alpha_3} \left[\max_{\beta_1,\beta_2,\beta_3} l(\mathcal{M} \mid \mathcal{N}, \alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3) \right]$$

Note that direct optimization requires the joint maximization of the six dimensional likelihood function; a daunting task even in this simple case. Using the Expectation-Maximization (EM) Algorithm [15] we can easily determine maximum likelihood in 0(k) time. where k is the number of iterations of the algorithm. For example

$$(\alpha_1, \alpha_2, \alpha_3) = (0.80, 0.90, 0.70)$$
$$(\beta_1, \beta_2, \beta_3) = (0.99, 0.99, 0.99)$$
$$\mathcal{N} = \{n_i = 10000\}_{i=2,3} \cup \{n_{i,j} = 10000\}_{i,j=2,3}$$

To evaluate the performance of proposed algorithm, we have implemented our proposed algorithm in NS2, which has been highly validated by the networking research community. The simulation parameters where listed in table 1.

Table 1: NS2 parameters

Parameters	Value
MAC Layer	IEEE 802.11
Number of nodes	20
Data rate	11Mbps
Packet Size	512 B
Simulation Duration	200 sec
Traffic Flow	TCP

Figure 3 and 4 shows results for the constant bit rate traffic with loss episodes of uniform duration.

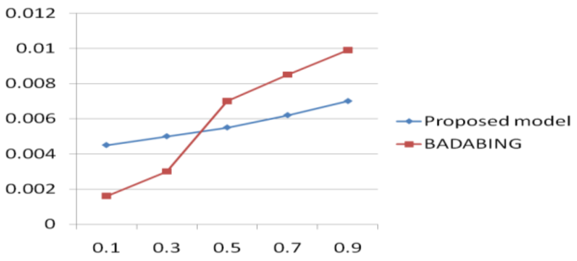

Fig 3: Packet loss frequency

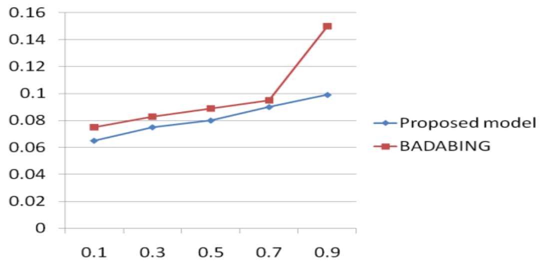

Fig 4: packet loss duration

V. CONCLUSION

Estimation of end-to-end packet loss in the network is very useful in various safety and non safety applications. Various tools are available in market to measure packet loss in the end-to-end networks. But all the existing tools are not able to calculate packet loss in the network accurately. In this paper we presented an algorithm for measuring end-to-end packet loss in the network. To evaluate the performance of the proposed algorithm, we simulate the algorithm in the NS2 simulator. The experimental results reveal that our proposed algorithm is very efficient in estimation of packet loss frequency and duration when compared BADABING tool.

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