A Method for estimating non-responsive traffic at a router *

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ABSTRACT

In this paper, we propose a scheme for estimating the proportion of the incoming traffic that is not responding to congestion at a router. The idea of the proposed scheme is that if the observed queue length and packet drop probability do not match with the predicted results from the TCP model, then the error must come from the non-responsive traffic; it can then be used for estimating non-responsive traffic. The proposed scheme utilizes queue length history, packet drop history, expected TCP and queue dynamics to estimate the proportion. We show that the proposed scheme is effective over a wide range of traffic scenarios through simulations.

Keywords

Estimation, non-responsive traffic, traffic modeling, control theory

1. INTRODUCTION

Several multimedia applications rely on UDP to transport packets. Researchers are developing protocols that respond to congestion differently from TCP to provide smoother bandwidths to end applications. These trends portend increased diversity of network protocols and changes in the distribution of bandwidth among protocols in the future. Some of these new applications may not respond to network congestion. It is possible to stage denial-of-service (DOS) attacks on end hosts and the network by pumping large amounts of non-responsive traffic into the network. Some of the recent DOS attacks have used such "UDP floods". If the network could regulate the utilization of such traffic to a fraction of the link capacity, the impact of such attacks could be mitigated. The diversity of these protocols makes it difficult to employ simple byte counters for each protocol to determine the amount of non-responsive traffic at a router. Applications may respond to congestion even when they employ UDP. We consider scenarios with a large number of "web mice" [6], where while each flow employs TCP, the traffic may appear non-responsive on an aggregate level.

In this paper, we present a technique for estimating the fraction of the arriving traffic at a router that is non-responsive to congestion. Such estimations may lead to a better control of traffic through appropriate adaptive control algorithms and can help one choose appropriate parameters for the active queue management. The presented scheme utilizes queue length history and packet drop history at the router which are easily measured at a router and the expected TCP response to packet drops. The effectiveness of the estimation algorithm, (a normalized gradient algorithm of the linearized, extended model of traffic) is shown through ns-2 simulations.

2. MODELING AND ESTIMATION

Without any loss of generality, we use TCP flows as responsive flows and Constant Bit Rate(CBR) flows as non-responsive flows to describe our model of traffic mix. Models of TCP dynamics have been proposed and studied in [5, 4, 1]. Following the fluid-based models of TCP flows and queue dynamics in [5], we introduce a similar model for both TCP and non-responsive flows over a single bottleneck link by adding differential equation for the evolution of the window size of non-responsive traffic and accounting for the non-responsive traffic in the total incoming traffic at the router. For the purpose of developing an estimation algorithm, we will express the model in terms of the total responsive load $z(t)$ and the total non-responsive load D. The terms $z(t)$ and D are given by the following relationships: $z(t) := N_s W_s(t), D := N_u W_u$. W_u is the window size of a representative non-responsive flow; $W_s(t)$ is the window size of a TCP flow; N_s is the number of incoming TCP flows; N_u is the number of incoming non-responsive flows. The terms $z(t)$ and D are scaled loads, scaled relative to $R(t)$, where $R(t)$ is the Round Trip Delay. The quantity of D will be estimated in the algorithm[7].

In terms of $z(t)$ and D, the dynamics of traffic mix is given by:

$$\dot{z}(t) = \frac{N_s}{R(t)} - \frac{z(t)z\big(t-R(t)\big)}{2N_s R(t)} p\big(t-R(t)\big) \tag{1}$$

$$\dot{q}(t) = \frac{z(t)+D}{R(t)} - C \tag{2}$$

$$R(t) = \frac{q(t)}{C} + T_p \tag{3}$$

Observable quantities of packet drop probability, queue length and total number of incoming packets are sampled in each *sampling interval* to estimate the desired fraction of non-responsive load $\psi = 1 - \frac{z(t)}{D+z(t)}$. We develop an estimation algorithm based on the mixed traffic model developed here.

In the congestion avoidance phase of TCP, $z(t)$ changes very slowly with time. So we are able to rewrite the combination of eqn. 2 and eqn. 1 according to the regression model [2] as follows,

$$\begin{aligned} & R(t)\ddot{q}(t) + (\frac{\dot{q}(t)}{C} + 1)\dot{q}(t) \\ = & \begin{bmatrix} \frac{1}{R(t)} & -\frac{p\left(t-R(t)\right)}{2R(t)} \end{bmatrix} \begin{bmatrix} N_s \\ \frac{z(t)z\left(t-R(t)\right)}{N_s} \end{bmatrix} \end{aligned} \tag{4}$$

We base the estimation algorithm on "small signal" behavior and we have: $q(t) \approx q_0; R(t) \approx R_0 = \frac{q_0}{C} + T_p; z(t) \approx z_0 \approx z(t -$

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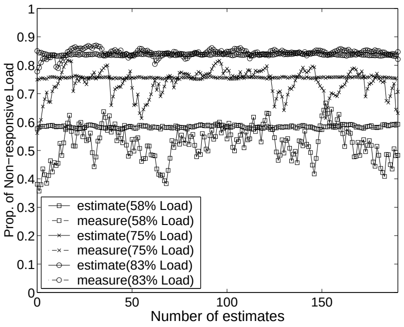

Figure 1: High Non-responsive Load

R_0).

With approximations mentioned above, we define the following regression equation:

$$\begin{aligned}
\chi(t) &= R(t)\ddot{q}(t) + (\frac{\dot{q}(t)}{C} + 1)\dot{q}(t) && (5)\\
&= \boldsymbol{W^T}(t)\beta^* && (6)\\
\chi_e(t) &= \begin{bmatrix} \frac{1}{R(t)} & -\frac{p\left(t-R(t)\right)}{2R(t)} \end{bmatrix} \begin{bmatrix} N_s \\ \frac{z(t)z\left(t-R(t)\right)}{N_s} \end{bmatrix} \\
&\approx \begin{bmatrix} \frac{1}{R_0} & -\frac{p\left(t-R_0\right)}{2R_0} \end{bmatrix} \begin{bmatrix} N_s \\ \frac{z_0^2}{N_s} \end{bmatrix} \\
&= \boldsymbol{W^T}(t)\beta && (7)
\end{aligned}$$

In the real-time parameter estimation, $\beta(t)$ is the "best estimate" of β^* at time t. $\chi_e(t)$ is the predicted value of $\chi(t)$. The error $e(t)$ between $\chi(t)$ and $\chi_e(t)$ can be used to update β recursively. The error $e(t)$ is given by: $e(t) = \chi(t) - \chi_e(t)$

We apply modified Kaczmarz's projection algorithm in the following manner:

$$\beta(t+1) = \beta(t) + e(t)\frac{\gamma \boldsymbol{W}(t)}{\alpha + \boldsymbol{W^T}(t)\boldsymbol{W}(t)} \qquad (8)$$

Once we get β_0 and β_1 from eqn. 8, we can calculate estimation values as follows: $N_s = \beta_0, z_0 = \sqrt{\beta_0\beta_1}$. After initialization, the algorithm collects history information of $p(t)$ and $q(t)$. Then the algorithm utilizes history information of several data points before current one to compute the estimation with simple matrix operations, according to equations shown above. The current data point becomes history information of later computation. So the computation complexity is O(1).

3. IMPLEMENTATION AND RESULTS

We implemented our estimation algorithm in RED module of ns-2 Simulator. Our algorithm computes an estimate every sampling interval. Several of these estimates are averaged to produce an estimate over a larger time interval called *estimate interval*. We use Mean Square Error(MSE) and Relative Error(RE) to describe the accuracy of the estimation compared to the measurement value.

High Non-responsive Load: In this experiment, we set up 35 responsive flows and 19, 22 and 25 non-responsive CBR flows respectively. Each CBR flow pumps packets at the rate of 1Mbps. The estimation and measurement values are shown in Figure 1. We observe from the results that the estimation algorithm works well at high non-responsive loads.

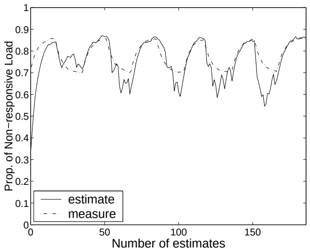

Figure 2: Dynamic Response

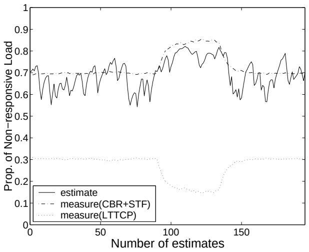

Figure 3: Mixed Traffic

Dynamic Response to Traffic Change: To test the dynamic response of our algorithm to variations in the traffic, we conducted the following experiments. We initiate the simulator with a number of responsive and non-responsive flows. Of the 26 non-responsive flows, 6 of them are of ON/OFF type flows. They are ON for 20 seconds and OFF for the next 20 seconds. The results from these experiments are shown in Figure 2.

Mixed Traffic: To simulate more realistic traffic environments, we simulated a mixed traffic load consisting of short-term TCP flows, long-term TCP flows and a number of non-responsive flows. Initially, the traffic consists of only long-term TCP flows and non-responsive flows. At 100s, we start 300 short-term TCP flows. In the Figure 3, we show the results of our estimation algorithm when short-term TCP flows send 20pkts during each ON period. Notice that the estimation algorithm counts the proportion of short-term TCP load as part of non-responsive load. These flows do not persist in the network long enough to observe significant number of packet drops and hence appear to be non-responsive. Similar observations about short-term flows have been made in a number of recent studies [6, 3].

4. CONCLUSION

In this paper, we have provided a model for mixed traffic at a router. A linearization of the mixed traffic model developed here was used to derive an algorithm for estimating the fraction of the incoming traffic that is non-responsive to congestion. We have shown that the proposed algorithm works acceptably in a wide range of traffic scenarios through ns-2 based simulations. We observed that persistence of excitation plays a significant role in the accuracy of the proposed estimation algorithm. We are in the process of making our algorithm more robust based on these observations.

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