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Link Sizing by Observation of Carried Traffic on the Internet

Hiroshi Toyoizumi
University of Aizu
E-mail： toyo@u-aizu.ac.jp

1. INTRODUCTION

The next killer application of the Internet would be streaming services such as internet radio, VoIP, live video-image broadcasting and so on. In general, streaming services requires high bandwidth and strict delay guarantee. On the other hand, many internet service providers are struggling to survive the severe competition by showing their quality is better than their competitors, so the concept of the guarantee of quality, like Service Level Agreement (SLA) is becoming more and more important.

To provide the service quality efficiently, we need to observe and model the current traffic on the network, and then design the network according to some objective. Many works has been done for observation of the traffic in the internet [1]. Also, many researches for designing the link speed has been done in the field of effective bandwidth (see for example [2,3]).

One of the traditional and basic design methods of network is queueing theory. In general, queuing theory requires determining the arrival process and the service time distribution of the queueing sytem. However, in the internet, it is not always possible to observe them directly. So, we should develop a design method using observable data only. Here in this paper, we propose a simple link-sizing method by observing traffic on the link.

2. OBSERVATION

Assume the n-th packet, whose size is L_n, arrives at the buffer of output link of a router at the time T_n. The packet waits to be transmitted at the buffer if other packets occupy the link. The router starts transmitting the packet to the link at the time S_n. Here we assume the FIFO-discipline at the output buffer for simplicity.

Generally, the arrival time T_n is not observable, since the arrival at the output link buffer cannot be observed outside the router. Of course, we can estimate the arrival time T_n by observing all the input link of router and gathering the packets to be transmitted to the output link. But this requires more tools with precise clock synchronization, so this assumption is not practical. Instead, we can observe the data $\{(S_n, L_n)\}_{n=1,2,\ldots}$ on the link connected to the router quite easily. $\{(S_n, L_n)\}_{n=1,2,\ldots}$ can be obtained by the conventional packet-capturing tools.

3. Queueing Inference

As we pointed out earlier, in the queueing theory, we need to specify the arrival process and service time distribution as well as the queueing discipline. However, we cannot build a model of the arrival process from the data $\{(S_n, L_n)\}_{n=1,2,\ldots}$ directly, because it does not have the information of the arrival points.

Moreover, the service time distribution might not be estimated by the packet size L_n, because the data can be segmented to multiple packets according to the maximum transfer unit (MTU) constraint.

Here in our method, we use the average busy period length $B_{average}$ and the average date rate Λ that can be easily estimated by $\{(S_n, L_n)\}_{n=1,2,\ldots}$. Then, we calculate the required bandwidth of the link satisfying the service level objective, with some assumptions of the arrival process and service time distribution.

There have been studies called Queueing Inference problem, which deals with estimation of performance of queueing systems with the limited observation of queues [4,5,6]. In [4], the authors deals with the similar problem to ours in the context of auto-teller machines, in which there is no data of arrival to the queue but only the start time of service. The difference is that they assume they know the service time sequence, but we assume the information we know is only the length of busy period.

4. MODELING THE SYSTEM

Assume a user demands to send her data of the size M_n at the time U_n, according to the Poisson process. Note the data might be segmented into the packets to be transmitting, so U_n is not always equal to L_n.

Hence the output link and its buffer can be modeled by an M/G/1 queue. The mean busy period length $B_{average}$ can be estimated by the following [7].

$$B_{average} = \frac{C/m}{1-\rho}, \qquad (1)$$

where C is the speed of the link, $\rho = \Lambda / C$ (the utilization of the link), and $m = E[M]$ (the mean data size to be transmitted).

So, given the average busy period, the mean data size can be estimated by

$$m = (1-\rho) B_{average} C. \qquad (2)$$

Moreover, we assume the data size to be exponentially distributed. (This assumption is quite artificial. Some study indicates the data size in the internet can have infinite variance, but to get a tractable solution, we assume it here.) Then, we have an M/M/1 system with the arrival rate λ and mean service time $1/\mu$ such as

$$\lambda = \Lambda / m = \rho / \{B_{average}(1-\rho)\}$$

$$1/\mu = m/C = (1-\rho) B_{average}. \qquad (3)$$

This M/M/1 queueing model has the same mean data rate and busy period length as the traffic observed.

5. SIZING THE LINK

Assume the input to the link (mean data rate, mean data size) to be (Λ, m). Let $W(C)$ be the sojourn time of the system (the delay in the queue plus the processing time in the link) given the link speed C. We need to know the new link speed C_{new} satisfying

$$P_y = P\{W(C_{new}) > y\}, \qquad (4)$$

for some predetermined threshold y and the objective probability P_y.

We know that the distribution of the sojourn time for the M/M/1 queue [7], i.e.

$$P\{W > y\} = e^{-\mu(1-\rho)y} = e^{-y(C-\Lambda)/m}. \qquad (5)$$

Hence the required speed C_{new} satisfying (4) can be obtained by

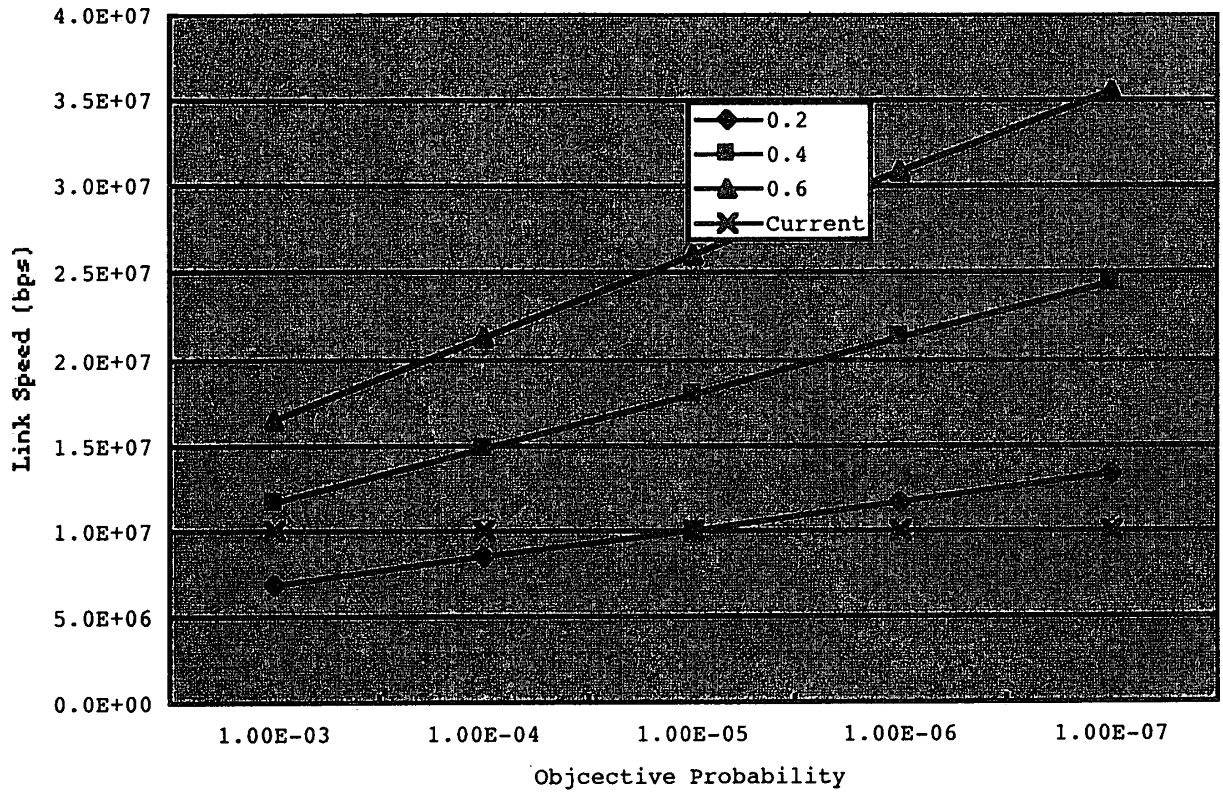

Figure 1. Required Link Speed

$$\begin{aligned} C_{new} &= \Lambda + m \log P_y / y \\ &= \Lambda - (C_{old} - \Lambda) B_{average} \log P_y / y \end{aligned}, \quad (6)$$

where C_{old} is the current link speed.

6. NUMERICAL EXAMPLES

Figure 1 shows numerical examples of our method. Here we assume y (the predetermined sojourn time threshold) = 1 sec, the current link speed is 10 Mbs. Moreover, we assume that the observed mean data rate is 2 Mbps. Each line corresponds to the different observed mean busy period length ($B_{average}$= 0.2, 0.4, 0.6 sec) with various objective probability P_y. The figure shows the longer mean busy period requires the more bandwidth since the longer busy period means the corresponding data size might be larger, even if the mean data rate is same.

Also, we can see that the difference among the required speed for each $B_{average}$ increase as the objective probability increases. This means that we should pay much more attention on the traffic when busy periods become longer.

REFERENCES

[1] CAIDA, www.caida.org
[2] F.P. Kelly, "Effective bandwidth at multi-class queues," Queueing Systems, 9, pp.5-16,

1991
[3] F.P. Kelly, "Tariffs and effective bandwidth in multiservice networks," ITC 14, pp.401-410, 1991
[4] R.C. Larson, "The queue inference engine: deducing queue statistics form transactional data, " Management Science, Vol. 36, No. 5, pp 586-601, 1990
[5] D. Daley and L.Servi, "Exploiting Markov chain to infer queue length from transactional data, J. Appl. Prob., Vol.29, pp. 713-832, 1992
[6] H. Toyoizumi, "A simple method of estimating mean delay by counting arrivals and departures, IEEE INFOCOM '93, pp. 823-834, 1993
[7]L. Kleinrock, Queueing Systems Vol. 1, John Wiley & Sons, 1975.