PROBABILITY OF QUEUE OVERFLOW IN A QUEUING NETWORK

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Abstract—**This paper addresses the issue of packet loss guarantees used in a Quality of Service (QoS) network on today's IP backbones. QoS is defined by parameters namely jitter, packet loss and delay. The paradigm of choice for this research is based on Diffserv, where aggregated traffic is treated as of a group of flows on a per class basis. Since loss is an important parameter to consider we will show how the queues behave on an individual and aggregate basis. Diffserv leaves the exact parameters to configure routers to the Service Provider since Diffserv is a descriptive collection of recommendations. TCP throughput is a function of both packet loss and delay. Since delay can be measured easily it is important to obtain analytically how loss occurs in the system.**

***Key Words*—Traffic modelling, Queuing systems, Packet loss probabilities, Random Early Detection**

I. INTRODUCTION

The internet has become an infrastructure that supports high speed traffic over tandem networks. These networks are characterized by queues that are used for various network traffic sent between end-to-end hosts.

To this extend Telkom uses industry accepted best practice calculations from Cisco. The inputs to such calculations are typically the size of links, average traffic offered and the delay budgets. Hence through a cascading of router calculations Telkom is able to offer and end-to-end delay guarantee. However for certain applications/traffic classes loss is a more relevant network performance metric than delay. In truth TCP throughput is a function of both packet loss and delay. Currently an industry accepted calculation methodology which either focuses on packet loss, or incorporates a loss bound does not exist.

This is understandable given the difficulties in statistically characterizing traffic and the fact that loss has several causes i.e. the traffic policies, the WRED congestion avoidance algorithm as well as packet time-outs.

II. QUEUES OVERVIEW

A. Terminology

For the purpose to analyze network queues we first need a solid definition base to understand the effects of changing parameters. The following definitions are used in the analysis of queues which were obtained from [5]:

Interarrival PDF: $A_n(t) = P[t_n \le t]$

Service time PDF: $B_n(x) = P[x_n \le x]$

The definitions above are for single instances for a queue. To generalize our definitions more we have expressions for the time duration of the queue which are presented by the following equations.

Number of arrivals: $\alpha(t) \rightarrow$ Arrivals in (0, t)

Number of departures: $\delta(t) \rightarrow$ Departures in (0, t)

Number of customers: $N(t) = \alpha(t) - \delta(t)$ in (0, t)

Total time all customers spent in queues: $\gamma(t) = \int_0^t N(t)dt$

Average arrival rate: $\lambda_t = \frac{\alpha(t)}{t}$

B. Theory of Large Deviations

Large deviations theory [2] is well known to be the theory of rate events. The reason for this study is to obtain an analytical way of establishing the probability that data will exceed the queue size.

We can say that a queue has a Bernoulli distribution. This is an important fact since the samples are distributed around the average of the distribution. With some mathematical analysis it gives rise to the fact that $P[M_n < x] = e^{-nI(x)}$ and $P[M_n > x] = e^{-nI(x)}$ for the sample size.

For a very large sample size we have that $\lambda(t) = \log(E[e^{tX_1}])$ for identical and independent samples.

C. Queuing theory

Large deviation theory is used to obtain practical approximations to queuing systems. It is a well known fact that $Q = \max_t\{At - st\}$ which is used for E.B.B calculations.

If $P[\frac{At}{t} > x] \approx e^{-tI(x)}$, we then have $P[Q > q] \approx e^{-q\delta}$ for large values of *q*, with $\delta = \max\{\theta : \lambda(\theta) \le s\theta\}$, $s = \frac{\lambda(\delta)}{\delta}$ and $\lambda(\theta) = \lim_{t \to \infty} \frac{1}{t} \log E[e^{\theta A t}]$. This leads to the conclusion that the probability of queue overflow is $P[Q > q] \approx ke^{\frac{-rq}{MTU}}$.

III. OVERVIEW OF EXISTING MODEL

A. *Class Differentiation*

Application traffic are marked and classified in four different service classes [1]. Each class is handled differently according to the service specified per class. This way priority can be given to certain traffic supporting the customer's business goal. Four traffic classes are used supporting the following aggregations of data:

- Real Time Data
- Interactive business Data
- Business Data, and
- Best Effort Data

Customers specify the amount of bandwidth, delay and loss they want for their specific service. Because of the statistical nature of Internet traffic, service providers have to allocate more bandwidth for customer that is needed, to guarantee acceptable levels of QoS.

B. *Queues*

The area of research is how the queues behave between end nodes. Figure 1 illustrates why this study is important.

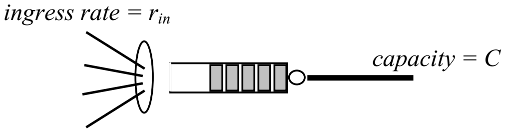

Figure 1. Queuing in networks

As traffic traverses the network, queues fill and loss occur. The focus point for the research is on the queues and how the random early packet dropping influences the traffic.

IV. OBJECTIVES OF CURRENT RESEARCH

The current packet loss guarantee calculation algorithm does not calculate the amount of packet loss accurate which leaves a gap to optimize the method used to calculate this loss. Since there is a great demand for bandwidth in the information era, the research mainly focuses on high levels of service not to exceed a set amount of loss.

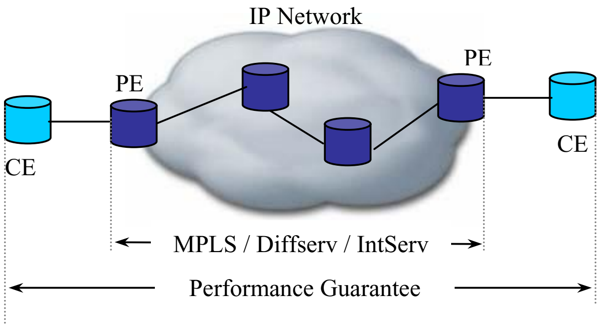

Figure 2. Logical construction of IP network

Telkom has a network structure shown in Figure 2. This figure illustrates that a Customer Edge (CE) router links the customer to a Provider Edge (PE) router that aggregates several CE links into Telkom's public IP network. The research to be done will be between two CE routers since guarantees are measured at those points.

The goal of the research is thus to calculate packet loss more accurately while keeping the same QoS in each class. When significant improvement has been reached, further research will be done develop recommendations to apply the refined packet loss guarantee approach and a tool to automate the application of these recommendations.

V. RESEARCH APPROACH

An iterative optimization approach is being followed. The system measurements will be done with different techniques to find the best technique [4]. Real application traffic will be measured and analyzed statistically in each distinctive traffic class. These statistical analyses will be used to characterize the traffic. Modelling will be done from these traffic characteristics and compared to existing traffic models [3].

It has been found that the traditional statistical models are not very good approximations of internet-traffic arrival distributions. Several variations of self-similar models show much closer approximations [3].

VI. CONCLUSION

Statistical analyses, modelling and fitting of real traffic distributions along with existing self-similar traffic models will be the major concern in the refinement of packet loss distributions.

Although the field of statistics and traffic engineering seems quite matured, and research in these fields will only lead to minor changes in packet loss models, it will result in major financial benefits. Better packet loss guarantees means better revenue. It has the potential to increase customer's satisfaction, reduce the total cost of IP VPN solutions, and increase competitiveness of the product in the market.

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