ANALYSIS AND PERFORMANCE EVALUATIONOF HIGH SPEED NETWORK WITH DISCRETIONARY PRIORITY JUMPS.

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ABSTRACT

In the present study the main emphasis is on performance measures of computer network giving prime importance to average packet delay and packet loss occurring in delivering a packet from source to destination in high speed traffic, the prominent factors in data communication. The study focuses on developing models employing queuing theory as a tool for the integrated digital networks, which are used to integrate multiple input channels (like voice, data, images, video etc.) into single transmission line and make the Network as high- speed data network. The queuing theory is applied as a primary tool for analyzing the network delay. The use of queuing models for delay analysis provides a basis for adequate delay approximations, as well as valuable qualitative results worthwhile insights for the performance evaluation of high speed data networks

Keywords : ATM, BISDN, Queuing Model, Cell Loss Ratio, Weighted Fair Queuing.

INTRODUCTION

The research activity in the area of broadband integrated networking (B-ISDN) has been expanding at a rapid pace. There will be no surprise knowing that the future B-ISDN/ATM networks promise to provide the means to transport diverse traffic streams with variable traffic characteristics and Performance requirements. In future broadband high-speed networks, asynchronous transfer mode (ATM) packet switches should be able to support diverse applications such as voice, data, image, video and even unknown services, which have different traffic characteristics and shall require quality of service quality of service (QoS)) .

The representative Quality of service (QoS) of ATM connections are end-to-end delay and loss probability of packets. To support multiple classes of traffic in multimedia networks, priority mechanisms can be used. Multiple priority levels are provided, and different priority levels are given to different class of traffic. Thus, it is necessary to distinguish packets and assign priorities to them based on their delay and loss constrains in networks.

In order of find a solution for this problem, several dynamic priority schemes have been proposed in the literature. A class of dynamic priority schemes is the queue-length threshold scheduling discipline (QLT). In these discipline, the priority queues are served depending on their queue length [Chip 89, Choi 01, Choi 98, Frat 90, Knes 02, Lee 98]. Another class of dynamic priority schemes is the head-of-line with priority jumps (HOL-PJ) disciplines.

MATHEMATICAL MODEL

In this, we investigate a discrete-time queuing system with one server and two queues whereby the capacity of the queue is infinite. Time is assumed to be slotted and the transmission time of packet is one slot. There are two types of traffic arriving in the system, namely packets of class 1 and packets of class 2, which arrive in the first and second queue respectively. The number of arrivals of class j during slot k is denoted by $a_{j,k}$ (j = 1, 2) and the $a_{j,k}$'s are independent and identically distributed (i. i. d.) from slot –to-slot. However, in one slot, the number of arrivals of one class can be correlated with the number of arrivals of the other class. This dependence is characterized by their joint probability mass function (pmf) a(m, n):

$$a(m, n) \cong \text{Prob}[a_{1,k} = m, a_{2,k} = n],$$

and by the joint probability generating function (pgf) A (z_1, z_2):

$$A(z_1,z_2) \cong E[z^{a1,k}\, z_2^{\ a2,k}]$$

The total number of arriving packets during slot k is denoted by

$$A_{T,k} \cong a_{1,k} + a_{2,k} \text{ and its pgf is defined as } A_T(z) \cong E[z^{aT,k}] = A(z, z).$$

The total arrival Rate is the sum of the arrival rates of both classes:

$$\lambda_T = A'_T(1) = \lambda_1 + \lambda_{2.}$$

I_{int} (z_2) is a distribution for interrupted packets of class 2 whose mean is $\lambda_{int.}$

The system has one server that provides the transmission of packets, at a rate of one packet per slot. Newly arriving packets can enter service at the beginning of the slot following their arrival slot at the earliest. Cells in queue 1 have a higher priority than those in queue 2.

CONTENTS OF THE SYSTEM

We have derived the steady- state joint pgf of the system contents of both queues in this section. We assume that the packet in service (if any) is part of the queue that is serviced in the slot. We denote the system contents of queue j at the beginning of slot k by $u_{j,k}$ and the total system contents at the beginning of slot k by $u_{T,k.}$

The joint pgf of $u_{1,k}$ and $u_{2,k}$ is denoted by U_k (z_1, z_2):

$$U_k(z_1, z_2) \cong E[z_1^{u1,k}\, z_2^{u2,k}]$$

System contents of both queues evolve in time according to the following system equations:

If , $U_{1,k} = 0$:

$$U_{1,k+1} = \begin{cases} [u_{2,k} - 1]^{+} + A_k + a_{2,k} & \text{with Probability } \beta \\ A_{1,K} & \text{with Probability } 1-\beta \end{cases} \quad \ldots\ldots\ldots(1)$$

$$0 \qquad {}_{k+1} = \begin{cases} 0 & \text{with probability } \beta \\ 1 & \text{with probability} 1-\beta \end{cases} \quad \ldots\ldots\ldots(2)$$

$$_{,k+1} = \begin{cases} [u_{1,k} - 1]^{+} + u_{2,k} + a_{1,k} + a_{2,k} + I_{int}(z) & \text{with probability} \beta \\ [u_{1,k} - 1]^{+} + a_{1,k} & \text{with probability } 1-\beta \end{cases} \quad \ldots\ldots\ldots\ldots(.3)$$

$$U_{1,k+1} = \begin{cases} [u_{2,k} - 1]^{+} + A_k + a_{2,k} & \text{with probability } \beta \\ u_{2,k} + a_{2,k} & \text{with probability } 1-\beta \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

System equation (1) and (2) can be explained as follows:

If high priority class queue is empty at the beginning of slot k, a packet of low priority class is served during slot k, the remaining packets of low priority queue and the arriving packets of the low priority queue jump with a probability of β to high priority queue. On the other hand, if there is at least one packet present in high priority queue and low priority packet is in service, then the service of low priority queue is interrupted and the high priority packet jumps at the service station with β probability [system equation (3) and (4)].

Calculation of the joint pgf of the system contents of both queues at the binning of slot k +1 yields:

$U_{k+1}(z_1z_2) \cong E[z_1^{u1,k+1}z_2^{u2,k+1}] = E[z_1^{u1,k+1}z_2^{u2,k+1}\{u_{1,k}=0\}] + E[z_1^{u1,k+1}z_2^{u2,k+1}\{u_{1,k}>$
$=\beta E[z_1^{u1,k+1}z_2^{u2,k+1}\{u_{1,k}=0\}] + (1-\beta)E[z_1^{u1,k+1} z_2^{u2,k+1}\{u_{1,k}=0\}] + \beta E[z_1^{u1,k+1}z_2^{u2,k+1}\{u_{1,k}>0\}] +$
$(1-\beta)E[z_1^{u1,k+1}z_2^{u2,k+1}\{u_{1,k}>0\}]$

$= \beta E[z_1^{a1,k+a2,k+u2,k-1}\{u_{1,k}=0\}] + \beta E[z_1^{u1,k+u2,k+a1,k+a2,k-1+I(z1)}\{u_{1,k}>0\}] + (1-\beta) E[z_1^{a1,k} z_2^{u\,2,k-1+a2,k}\{u_{1,k}=0\}] + (1-\beta)E[z_1^{u\,1,k-1+a1,k} z_2^{u2,a2,k}\{u_{1,k}>0\}]$
$= \beta z_1^{-1}E[z_1^{a1,k+a2,k}]E[z_1^{u2,k}\{u_{1,k}=0\}] + \beta z_1^{-1}E[z_1^{a1,k+a2,k}] I_{int}(z_2) E[z_1^{u1,k+u2,k}\{u_{1,k}>0\}]$
$+ (1-\beta) z_2^{-1}E[z_1^{a1,k} z_2^{a2,k}] E[z_2^{u2,k}\; u_{1,k}=0\}] + (1-\beta) z_1^{-1}E[z_1^{a1,k} z_2^{a2,k}]$ ……………(5)

$E[z_1^{u1,k} z_2^{u2,k}\{u_{1,k}>0\}]$

Using the system equations, we from the following relation between $U_{k+1}(z_1, z_2)$ and $U_k(z_1, z_2)$:

To define the steady-state distribution of the system contents, $U(z_1, z_2)$ as:

$$U(z_1, z_2) \cong \lim_{k\to\infty} U_k(z_1, z_2)$$

Applying this limit in equation and to determine equation for $U(z_1, z_2)$ as:

$$U(z_1, z_2)= \frac{\dfrac{[z_2(z_1-1)U(0,0)+ z_2(1-\lambda_{int}) U(0, z_2)+ z_2\lambda_{int} U(z_1, z_2)]}{[z_2(z_1-1)U(0,0)+ z_2(1-\lambda_{int}) U(z1,z2)]}\qquad \beta A(z_1, z_2)\, z_2(z_1-(1-\beta) A(z_1, z_2)}{1-\qquad z_2(z_1-(1-\beta) A(z_1, z_2)} \quad \text{……………………(7)}$$

In the right hand side of equation (5.3.7), there are three quantities yet to be determined, namely the factions $U(0, z_2)$ and $U(z_1, z_1)$ and the constant $U(0,0)$. First we compute the function $U(z_1, z_1)$ by substituting the value of z_2 by z_1 in equation (5.3.7)

$$U(z_{1,z2}) \quad \frac{A(z_1, z_1)(z_1-1)U(0,0)}{z_1-A(z_1,z_1)} \quad \text{………(8)}$$

$U(z, z) = U_T(z) = E[z^{uT,k}]$, is the pgf of the totalsystem contents.

This expression is identical to the generating function of the system contents of a queue with a FCFS- discipline and with one class (with arrivals determined by $A_T(z)$). This is expected, because for the total system contents, it does not matter in which order the packets are being served. Next, we can determine the constant U(0,0) from equation (5.3.8) by substituting z_1 by 1, by applying the normalization condition U(1,1) = 1 and by using L' Hospital's rule. The result is the probability of having an empty system is $U(0,0) = 1 - \lambda_T$,

Finally, we derive an expression for the function u (0, z_2). The equation $z_1 = (1 - \beta)A(z_1, z_2)$ has one solution in the unit circle for z_1, which is denoted by $\gamma(\beta, z_2)$ in the remainder, and which is implicitly defined by $\gamma(\beta\ z) = (1 - \beta) A(\gamma(\beta, z), z)$. Since $\gamma(\beta, z_2)$ is a zero of the denominator of the right hand side of equation (5.3.8) and since a generation function remains finite in the unit circle, $\gamma(\beta, z_2)$ must also be a zero of the numerator.

$$U(0,Z2)= \frac{\beta A_T(\gamma(\beta, z_2))[z_2(\gamma(\beta, z_2)-1)U(0,0)+z_2\lambda_{int}U_T(\gamma(\beta,z_2))]}{\gamma(\beta, z_2)[z2-\gamma(\beta, z_2)+\beta A_T(\gamma(\beta, z_2),z_2)(\lambda_{int}-1)]} \quad \text{.......... (9)}$$

$$+ \frac{\gamma(\beta, z_2)(z_2-1)U(0,0)}{[(z2-\gamma(\beta, z_2))+\beta A_T(\gamma(\beta, z_2))\, z_2\,(\lambda_{int}-1)]}$$

After substituting the values of $U(0,z_2)$ and $U(z_1,z_1)$ in equation (5.3.7)

$$\mathbf{U(Z_1,Z_2)=} \left\{ \frac{[\beta A(z_1, z_2)),z2(z_1-1)+(1-\beta)A(z_1,z_2)'z_1(z_2-1)U(0,0)]}{z_2[z1-(1-\beta)A_T(z_1, z_2))} \right\}$$

$$+\frac{[\beta A(z_1, z_2)),z2(z_1-1)+(1-\beta)A(z_1,z_2)'z_1(z_21)U(0,0)]}{z_2[z1-(1-\beta)A_T(z_1, z_2))}$$

$$+\frac{[\beta A(z_1, z_2)),z2(1-\lambda_{int})+(1-\beta)A(z_1,z_2)'(z_1-z_2)]}{z_2[z_1-(1-\beta)A(z_1, z_2))} \quad \text{................ 10)}$$

$$\left\{ \frac{x\beta A_T(\gamma(\beta, z_2)) \ [z_2(\gamma(\beta, z_2)-1)U(0,0)+z_2\lambda_{int}U_T(\gamma(\beta, z_2))]}{\gamma(\beta, z_2)-[(z2-\gamma(\beta,z_2))+\beta A_T(\gamma(\beta,z_2))z_2(\lambda_{int-1})]} \right\} \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

$$+ \frac{\gamma(\beta, z_2)-(z_2-1)U(0,0)}{[(z_2-\gamma(\beta, z_2))+\beta A_T(\gamma(\beta, z_2))z_2(\lambda_{int-1})]}$$

from this joint pgf we can calculate the marginal pgf's $U_j(z)(j=1,2)$ of the system contents of class j:

$U_j(z = \lim E(z^{u1,k}) = U(z,1)$, $U(z,1)=\beta A_T(z)(z-1)\beta A_T(z)\lambda_{int} A_{T(}(z)(z-1)U(0,0)$

$U_{2j}(z) = \lim E(z^{u2,k}) = U(1,z)$

$$U(1,z)= \frac{(1-\beta)A(1,z)(z-1)U(0,0)-[\beta z(1-\lambda_{int})+(1-\beta)}{A(1,z)(1-z)] \quad z\beta A(1,z)}$$

$$\left\{ \frac{{}_x\,\beta A_T(\gamma(\beta,,z)) \quad [z(\gamma(\beta,z)-1)U(0,0)+z\lambda_{int}U_T(\gamma(\beta,z))]}{\gamma(\beta,z)[(z-\gamma(\beta,z))+\beta A_T(\gamma(\beta,z)z(\lambda_{in}-1)]a} \right\}$$

$$\boldsymbol{+(\gamma(\beta,z_2)(z-1)U(0,0)[(z-\gamma(\beta,z))+\beta,A_T(\gamma(\beta,z))z(\lambda_{int}-1))]} \quad ,\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\mathbf{(12)}$$

PACKET DELAY

The packet delay is defined as the total amount of time that a packet spends in the system, i.e., the number of the slots between the end of the packets arrival slot and the end of its departure slot. We have derived expressions for the pgf's of the packets delay of both classes.

Since a jump of the contents of queue 2 to queue 1 takes place at the end of the slot, the newly arriving packets of class 1 are queued in front of packets that jump in the same slot. As a consequence, the packet delay of a tagged class 1 packet only depends on the system contents of queue 1 at the beginning of its arrival slot. This also mean that the packet delay of a tagged class 1 packet is the same as in a corresponding single class system with only packets of class 1 arriving. The amount of time a tagged class 1 packet spends in the system is as given below:

$$d_1 = [u_{1,k} -1]^{+} \quad +f_{1,k} +1 \qquad (4.1)$$

Where, slot k is assumed to be the arrival slot of the tagged packet, $u_{1,k}$ is the system contents of queue 1 at the beginning of the slot and $f_{1,k}$ is defined as the total number of class 1 packet that arrive during slot k and which have to be served before the tagged packet. Indeed, the tagged class 1 packet has to wait in queue 1 until all packets that work already in this queue at the moment of its arrival are effectively served. The number of these packets is determined by all packets in queue 1, at the beginning of its arrival slot (potentially including class 2 packets which jumped to queue 1 before the tagged packet arrive) and all class 1 packets that arrived before the tagged packet in its arrival slot. The delay, then, equals this waiting time arguments with the service time of the packet, which equals 1. This leads to expression (5.4.1). The p.g.f is defined as:

$$d_1(z) = E[z^{d1}] = F_1(z)\,[\,U_1(z)+(z-1)U_1(0)] \qquad (4.2)$$

We have taken care of the fact that u1,k and f1,k are uncorrelated (because the number of arrivals are i.i.d from slot- to- slot).

The pgf $f_1(z) \cong E[z^{f1,k}]$ can be calculated by assuming that an arbitrary packet is more likely to arrive in large bulk (Burn 93).

$$F_1(z)= \frac{A_1(z)-1}{\lambda_1(z-1)} \qquad (4.3)$$

Using equation (11) and (5.4.3) in (5.4.2) and solving we get:

$$2(1-\lambda_{int})[\,A_1(z)(1-A_T(z))]\,\beta A_T(\gamma(\beta,z))[\,(\gamma(\beta,z)-1)(1-\lambda_T)+ -\lambda int U_T(\gamma(\beta,z))]+$$

$$5 \quad \lambda_T(1-A_1(Z))\gamma(\beta,z)[(1-\gamma(\beta,z))+ \quad \beta A_T(\gamma(\beta,z)) \quad (\lambda_{int}-1)] \quad + \quad 1-\beta)A_1^{m} \quad (Z) \quad \beta A_T[(\gamma(\beta,z)-1)U(0,0)+\lambda_{int}U_T(\gamma(\beta,z))]$$

$$5\beta\lambda_1(1-A_1(z))[(1-\gamma(\beta,z))+ \beta A_T(\gamma(\beta,z))(\lambda_{int}-1)]$$

For the analysis of the packet delay of a class 2 packet we consider logically equivalent to queuing system where all high-priority packet of queue 1 are stored in front of the packets of queue2, and let us tag an arbitrary class2 packets that arrives in the system. The time spend in the system equals:

$d_2(z)$ = packets in service + arrival of ,low priority packets that jump in queue1 with probability β + interrupted packets in queue 2 + time spend in service of an ordinary Data

$$d_2 = \quad [u_{2.k} -1]+\beta f_{1,k}+A_{int}(z_1)+ f_{2,k}+1$$

NUMERICAL EXAMPLE

The results obtained in the former sections are applied to an out-put queuing switch having N inlets and N outlets. We assumed two types of traffic: traffic of class 1 is delay sensitive (for instance, voice) and traffic of class 2 is assumed to be delay insensitive (for instance, text data). The packet arrivals on the inlets are generated by identical and independent processes with arrival rate λ_T, an arriving packet is assumed to be a class j with probability λ_j / λ_T (($\lambda_1 + \lambda_2 = \lambda_T$). The incoming packets are then routed to the output queue corresponding to their destination. The fig. 5.1 shows the mean packet delay of both classes (when $\beta = 0.05$) as a function of the total load for $\alpha = 0.25$, where $\alpha = \lambda_1 / \lambda_T$.

From the Fig 5.1 we conclude that the priority scheduling for, low priority packets does what it is designed for i.e. giving lower delay for high- priority packets d_1 as compared to the delay for the low- priority packets d_2**.** The parameter β can be chosen depending on the delay guarantees for both types of traffic. A low will highly favor the high- priority packets.

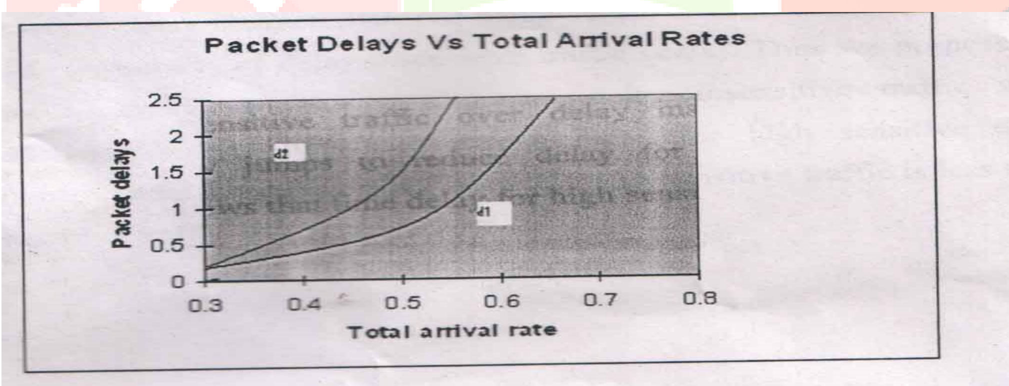

Fig. 5.1 : Total Arrival Rate Vs Packet Delays (HOL-DPJ)

CONCLUSION

In this chapter, we have analyzed a queuing system with HOL-DPJ priority schemes. A generating function approach is adopted, which led to expressions of performance measure, such as mean of the system contents in the both queues and mean of packet delay of both types of packets. In real time system, delay characteristics of delay-insensitive traffic (voice) are more stringent than those of delay insensitive traffic (data). Thus we proposed a priority to delay sensitive traffic over delay insensitive traffic with discretionary priority jumps to reduce delay for high sensitive data. Developed model shows that time delay for high sensitive traffic is less than non-sensitive traffic.

SCOPE AND SUGGESTIONS FOR FUTURE INVESTIGATION

As the performance evaluation of high-speed data networks has several dimensions, it was not possible to take care of all the aspects. In the present work some issues need further attention. In this we derived the expressions for mean packet delays of two types of traffic arrivals. Taking more traffic arrivals with interruption server mode can further extend of this model. Since in the present communication scenario multiply system (Integrated Digital Networks) is excessively used for real-time systems, therefore, the extension of the model can create a framework for future research.

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