The Monitoring of The Network Traffic Based on Queuing Theory

A Project Thesis

Submitted by

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Under the supervision of

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DEPARTMENT OF MATHEMATICS

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ROURKELA, ORISSA-769008

CERTIFICATE

This is to certify that the Project Thesis entitled “The Monitoring Of The Network Traffic Based On Queuing Theory" submitted by Palash Sahoo, Roll no: 409MA2073 for the partial fulfilment of the requirements of M.Sc. degree in Mathematics from National Institute of Technology, Rourkela, is a bonafide record of review work carried out by him under my supervision and guidance. The content of this dissertation, in full or in parts, has not been submitted to any other Institute or University for the award of any degree or diploma.

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DECLARATION

I declare that the topic `The Monitoring of the Network Traffic Based on Queuing Theory' for my M.Sc. degree has not been submitted in any other institution or university for the award of any other degree or diploma.

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Abstract

Network traffic monitoring is an important way for network performance analysis and monitor. The current project work explores how to build the basic model of network traffic analysis based on Queuing Theory. In the present work, two queuing models (M/M/1): ((C+1)/FCFS) and (M/M/2): ((C+1)/FCFS) have been applied to determine the forecast way for the stable congestion rate of the network traffic.

Using this we can obtain the network traffic forecasting ways and the stable congestion rate formula. Combining the general network traffic monitor parameters, we can realize the estimation and monitor process for the network traffic rationally.

Contents

Chapter -1

Introduction

Network traffic monitoring is an important way for network performance analysis and monitor. The research work seeks to explore how to build the basic model of network traffic analysis based on Queuing Theory [1]. Using this, we can obtain the network traffic forecasting ways and the stable congestion rate formula, combining the general network traffic monitor parameters. Consequently we can realize the estimation and monition process for the network traffic rationally.

Queuing Theory, also called random service theory, is a branch of Operation Research in the field of Applied Mathematics. It is a subject which analyze the random regulation of queuing phenomenon, and builds up the mathematical model by analyzing the date of the network. Through the prediction of the system, we can reveal the regulation about the queuing probability and choose the optimal method for the system.

Adopting Queuing Theory to estimate the network traffic, it becomes the important ways of network performance prediction, analysis and estimation and, through this way, we can imitate the true network, it is useful and reliable for organizing, monitoring and defending the network.

The mathematical model of the queuing theory

In network communication, from sending, transferring to receiving data and the proceeding of the data coding, decoding and sending to the higher layer, in all these process, we can find a simple queuing model. According to the Queuing Theory, this correspond procedure can be abstracted as Queuing theory model [2] , like figure-1. Considering this kind of simple data transmitting system satisfies the queue model [3].

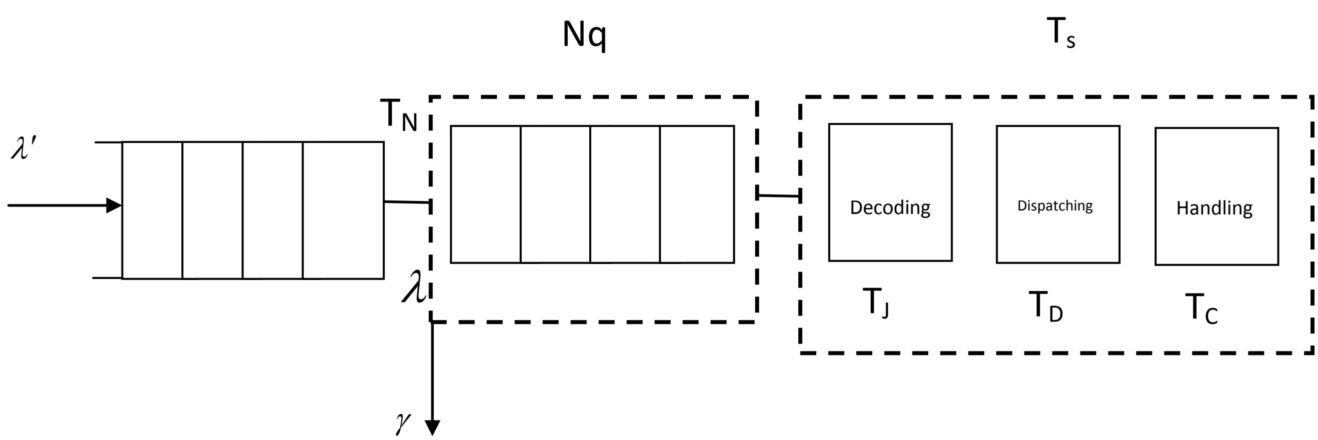

Figure -1:The abstract model of communication process

From the above figure-1,

λ' : Sending rate of the sender.

T_N: Transportation delay time.

λ : Arriving speed of the data packets

N_q : Quantity of data packets stored in the buffer (temporary storage).

γ : Packets rate which have mistake in sending from receiver i.e. lost rate of the receiver.

T_s: Service time of data packets in the server

where $T_s=T_J+T_D+T_C$,

$T_{J:}$ Decoding time

T_D: Dispatching time

T_C: Calculating time or, evaluating time or handling time.

Chapter-2

Model-1:

The Queuing model with one server (M/M/1):((C+1):FCFS)

In model M/M/1, the two M represent the sending process of the sender and the receiving process of the receiver separately. They both follow the Markov Process [4], also keep to Poisson Distribution, while the number 1 stands for the channel.

Let N(t)=n be the length of the queue at the moment of t. So the probability of the queue whose length is n be

$$P_n(t) = \text{prob [N(t)= n]}$$

In this model,

λ_n = Rate of arrival into the state n

μ_n =Rate of departure from the state n.

We have the transition rate diagram,

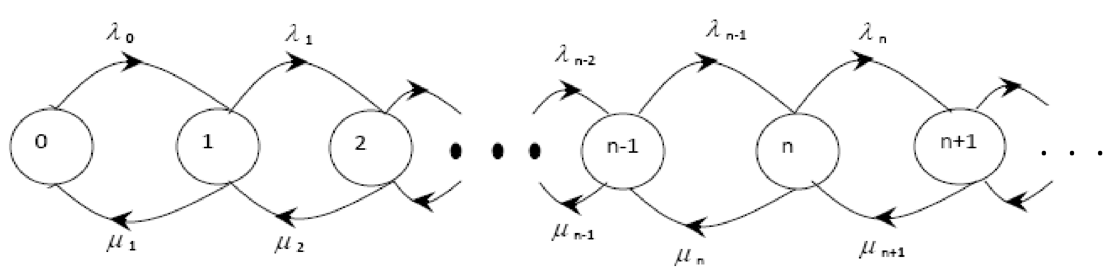

Figure-2: State transition diagram

The system of differential difference equation is.

$$\frac{d}{dt}\{P_n(t)\} = -\lambda_n P_n(t) - \mu_n P_n(t) + \lambda_{n-1} P_{n-1}(t) + \mu_{n+1} P_{n+1}(t) \quad \text{, for } n \geq 1 \qquad (1)$$

And $\frac{d}{dt}\{P_0(t)\} = -\lambda_0 P_0(t) + \mu_1 P_1(t);$ *for n=0* *(2)*

In model M/M/1, we let

$\lambda_n = \lambda$ And $\mu_n = \mu$

Where λ and μ are constants.

Then (1) and (2) reduces to

$$\frac{d}{dt}\{P_n(t)\} = \lambda P_{n-1}(t) + \mu P_{n+1}(t) - (\lambda + \mu) P_n(t); \quad \text{for } n \geq 1 \qquad (2)$$

And $\frac{d}{dt}\{P_0(t)\} = -\lambda P_0(t) + \mu P_1(t);$ for n=0 (3)

Here, λ is considered as the arrival rate while μ as the service rate.

In the steady state condition

$$\underset{t \to \infty}{Lt} P_n(t) = P_n$$

And $\underset{t \to \infty}{Lt} \frac{d}{dt}\{P_n(t)\} = 0$

Hence from (2) and (3) when $t \to \infty$ we get

$$0 = \lambda P_{n-1} + \mu P_{n+1} - (\lambda + \mu) P_n \qquad (4)$$

And $0 = -\lambda P_0 + \mu P_1$

0r, $P_1 = (\frac{\lambda}{\mu}) P_0$

From (4) when n=1, we get

$$(\lambda+\mu)P_1 = \lambda P_0 + \mu P_2$$

or $P_2 = (\frac{\lambda}{\mu})^2 P_0$

In general $P_n = (\frac{\lambda}{\mu})^n P_0$

or, $P_n = \rho^n P_0$ where $\rho = \frac{\lambda}{\mu}$

and ρ is called server utilization factor or traffic intensity.

We know, $\sum_{n=0}^{\infty} P_n = 1$

Also $P_n = \rho^n P_0$

This implies that

$$\sum_{n=0}^{\infty} P_n = \sum_{n=0}^{\infty} \rho^n P_0$$

or, $1 = P_0 \sum_{n=0}^{\infty} \rho^n$

or, $P_0 = 1-\rho$, where $\rho < 1$

Hence $P_n = \rho^n (1-\rho)$, n=0, 1, 2,… (5)

Suppose, L stands for the length of the queue under the steady state condition. It includes the average volume of all the data packets which enter the processing module and store in the buffer.

$$L = \sum_{n=0}^{\infty} nP_n = \sum_{n=1}^{\infty} n\rho^n (1-\rho)$$

$$= (1-\rho)\sum_{n=1}^{\infty} n\rho^n$$

Hence $$L = \frac{\rho}{1-\rho} \quad (6)$$

Also $$L = \frac{\lambda}{\mu-\lambda} \quad \text{(since, } \rho = \lambda/\mu\text{)} \quad (7)$$

If N_q shows the average volume of the buffers data packets.

$$N_q = L - \rho = \frac{\rho^2}{1-\rho} \quad (8)$$

Also $$N_q = \frac{\lambda^2}{\mu(\mu-\lambda)}$$

If the processing module is regarded as a closed region, the parameter is brought into the formula (8).

Using the Little's law, we have $\frac{1}{\mu}$ = average service time of the server = T_s

$$\Rightarrow \quad \rho = \lambda T_s \quad \text{and here } \lambda = \lambda' \quad (9)$$

Using (9), (8) reduces to

$$N_q = \frac{\rho^2}{1-\rho}$$

or, $(1-\lambda T_s)N_q = (\lambda T_s)^2$

or, $(\lambda' T_s)^2 + \lambda T_s N_q - N_q = 0$, (since, $\lambda = \lambda'$) (10)

From the above equation (10) we conclude that , among three variables viz.

T_s ≡ service time

λ' ≡ Sending rate

N_q ≡ Quantity of data packets stored in the buffer.

If we know any two variables it is easy to obtain the numerical value of the third one.

So, these three variables are key parameters for measuring the performance of the transmission system.

Chapter-3

Queuing theory and the network traffic monitor

Forecasting the network traffic using Queuing Theory

The network traffic is very common [5], The system will be in worse condition, when the traffic becomes under extreme situation, in which leads to the network congestion [6]. There are a great deal of research about monitoring the congestion at present ,besides, the documents which make use of Queuing Theory to research the traffic rate appear more and more. For forecasting the traffic rate, we often test the data disposal function of the router used in the network.

Considering a router's arrival rate of data flow in groups is λ, and the average time which the routers use to dispose each group is $\frac{1}{\mu}$, the buffer of the routers is C, if a certain group arrives, the waiting length of the queue in groups has already reached, so the group has to be lost. When the arriving time of group timeouts, the group has to resend. Suppose, the group's average waiting time is $\frac{1}{\mu}$. We identify $P_i(t)$ to be the arrival probability of the queue length for the routers group at the moment of t, supposing the queue length is i:

$P(t) = (P_0(t), P_1(t), . . . , P_i(t)), i = 0,1, . . . ,C+1$.

Then the queuing system of the router's date groups satisfies simple Markov Process [7], according to Markov Process, we can find the diversion strength of matrix of model 1 as follow:

$$
Q=\begin{pmatrix}
-\lambda & \lambda & 0 & 0 & \cdots & 0 & 0 \\
\mu & -(\lambda+\mu+v) & \lambda+v & 0 & \cdots & 0 & 0 \\
0 & \mu & -(\lambda+\mu+2v) & \lambda+2v & \cdots & 0 & 0 \\
0 & 0 & \mu & -(\lambda+\mu+3v) & \cdots & 0 & 0 \\
0 & 0 & 0 & \mu & \cdots & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\
0 & 0 & 0 & 0 & \cdots & -(\lambda+\mu+Cv) & \lambda+Cv \\
0 & 0 & 0 & 0 & \cdots & \mu & -\mu
\end{pmatrix}
$$

Network Congestion Rate

Network congestion rate is changing all the time [8]. The instantaneous congestion rate and the stable congestion rate are often used to analysis the network traffic in network monitor. The instantaneous rate A_c (t) is the congestion rate at the moment of t. The A_c (t) can be obtained by solving the system length of the queue's probability distributing, which is calledP_{c+1}(t).

Let P_k (t)(K=0,1,. . .,C+1) to be the arrival probability of the queue length for the routers group at the moment of t by considering the queue length is k .

Then the queuing system of the router's date groups satisfies simple Markov Process. According to Markov Process, P_k(t) satisfies the following system of differential difference equations.

Let,

$$P_k(t) = \text{prob}\ \{\ k\ \text{no. of data packets present in the system in time t}\ \}$$

and $P_k(t+\Delta t)$ = prob { k no. of data packets present in the system in time $(t + \Delta t)$ }

Case 1:

For $k \geq 1$

$P_k(t+\Delta t)$ = Prob { k no. of data packets present in the system at time t } $\times$prob { no data packets arrival in time (Δt) } $\times$ prob {no data packet departure in time Δt }

+ Prob { (k -1) no. of data packets present in the system at time t } $\times$ prob { 1 data packet arrival in time (Δt) } $\times$ prob { no data packet departure in time Δt }

+ prob { (k +1) no. of data packets present in the system at time t } $\times$ prob { no data packets arrival in time (Δt) } $\times$ prob { 1 data packet departure in time Δt }+. . .

$$\Rightarrow P_k(t+\Delta t) = P_k(t) \times \{1 - \lambda_k \Delta t + o(\Delta t)\} \times \{1 - \mu_k \Delta t + o(\Delta t)\}$$

$$+ P_{k-1}(t)\{\lambda_{k-1}\Delta t + o(\Delta t)\} \times \{1 - \mu_{k-1}\Delta t + o(\Delta t)\}$$

$$+ P_{k+1}(t) \times \{1 - \lambda_{k+1}\Delta t + o(\Delta t)\} \times \{\mu_{k+1}\Delta t + o(\Delta t)\} + o(\Delta t)$$

$$\Rightarrow P_k(t+\Delta t) - P_k(t) = -(\lambda_k + \mu_k)P_k(t) \times \Delta t + P_{k-1}(t)\lambda_{k-1} \times \Delta t + P_{k+1}(t)\mu_{k+1} \times \Delta t + o(\Delta t)$$

Dividing both sides by Δt and taking limit as $\Delta t \to 0$

$$\Rightarrow \frac{d}{dt}\{P_k(t)\} = -(\lambda_k + \mu_k)P_k(t) + \lambda_{k-1}P_{k-1}(t) + \mu_{k+1}P_{k+1}(t) \qquad (11)$$

Since, $\lim_{t\to\infty}\frac{o(\Delta t)}{\Delta t}=0$

Here in state k data packet arrival is $(\lambda + k\gamma)$

i.e., $\lambda_k = \lambda + k\gamma$

Also in state k data packet departure is μ

i.e., $\mu_k = \mu$

Hence (11) reduces to

$$\frac{d}{dt}\{P_k(t)\} = -(\lambda + k\gamma + \mu)P_k(t) + \{\lambda + (k-1)\gamma\}P_{k-1}(t) + \mu P_{k+1}(t)$$, where k =1,2,…,C (12)

Case 2:

For k =0, we have

P_0 (t+Δt) = prob {no data packet present in the system in time (t+Δt) }

= prob {no data packet present in time t }× prob { no data packet arrival in time Δt }

+ prob {one data packet present in time t} × prob {no data packet arrival In time Δt } × prob { one data packet departure in time Δt } .

$$= P_0(t)\times\{1-\lambda_0\Delta t + o(\Delta t)\} + P_1(t)\times\{1-\lambda_1\Delta t + o(\Delta t)\}\times\{\mu_1\Delta t + o(\Delta t)\}$$

$$\Rightarrow P_0(t+\Delta t) - P_0(t) = -\lambda_0 P_0(t) + P_1(t)\mu_1 + o(\Delta t)$$

Dividing both sides by Δt and taking limit as $\Delta t \to 0$, we get

$$\Rightarrow \frac{d}{dt}\{P_0(t)\} = -\lambda P_0(t) + \mu P_1(t) \qquad \text{, for k=0} \qquad (13)$$

(since, $\lambda_k = \lambda + k\gamma$ And $\mu_k = \mu$)

Case 3:

For k =C+1, we have

P_{C+1}(t+Δt) = prob { (C+1) no. of data packet present in the system in time (t+Δt)}

= prob {C no. of data packet present in time t } × prob {1 data packet arrival in time Δt } × prob { no data packet departure in time Δt }

+ Prob { (C+1) no of data packets present in time t } × prob { no data packet departure in time Δt }

$$= P_C(t) \times \{\lambda_C \Delta t + o(\Delta t)\} \times \{1 - \mu_C \Delta t + o(\Delta t)\} + P_{C+1}(t) \times \{1 - \mu_{C+1}\Delta t + o(\Delta t)\}$$

$$\Rightarrow P_{C+1}(t+\Delta t) - P_{C+1}(t) = P_C(t)\lambda_C + o(\Delta t) - \mu_{C+1} P_{C+1}(t)$$

Dividing both sides by Δt and taking limit as $\Delta t \to 0$ we get

$$\frac{d}{dt}\{P_{C+1}(t)\} = P_C(t)\lambda_C - \mu_{C+1} P_{C+1}(t)$$

$$\Rightarrow \frac{d}{dt}\{P_{C+1}(t)\} = (\lambda + C\gamma)P_C(t) - \mu P_{C+1}(t) \qquad \text{(Since, } \lambda_C = \lambda + C\gamma \text{)} \qquad (14)$$

By solving this differential equation system, we can get the instantaneous congestion rate $A_0(t)$ as

$$A_0(t) = P_1(t) = \frac{\lambda}{\mu + \lambda}(1 - e^{-(\mu+\lambda)t})$$

The instantaneous congestion rate can not be used to measure the stable operating condition of the system, so we must obtain the stable congestion rate of the system. The so-called stable congestion rate means it will not change with the time changing, when the system works in a stable operating condition. The definition of the stable congestion rate is

$$A_C = \lim_{t\to\infty} A_C(t)$$

Considering, $P = \lim_{t\to\infty} P(t)$ as the distributing of the stable length of the queue and C as the buffer of the router, the stable congestion rate can be obtained in two ways: firstly, we obtain the instantaneous congestion rate ,then make its limit out . According to its definition, it can be obtained with the distributing of the length of the queue. Secondly, according to the Markov Process, we know that the distributing of the stable length of queue can be get through system of steady state equations.

From (12),(13),(14), we have the system of differential difference equations as follows

$$\frac{d}{dt}\{P_k(t)\} = -(\lambda + k\gamma + \mu)P_k(t) + \{\lambda + (k-1)\gamma\}P_{k-1}(t) + \mu P_{k+1}(t) \quad \text{for k=1,2,3,..,C} \tag{15}$$

$$\frac{d}{dt}\{P_0(t)\} = -\lambda P_0(t) + \mu P_1(t) \quad \text{for k =0} \tag{16}$$

$$\frac{d}{dt}\{P_{C+1}(t)\} = (\lambda + C\gamma)P_C(t) - \mu P_{C+1}(t) \quad \text{for k=C+1} \tag{17}$$

According to some properties of Markov process, we know that

$P_i(t)$ (i=0,1,2,…,C+1) satisfies the above differential equation .

Here $P(t) = [P_0(t), P_1(t),..., P_{C+1}(t)]$

$P(0) = [P_0(0), P_1(0),..., P_{C+1}(0)]$

$P_0(0) = 1, P_1(0) = 0, P_2(0) = 0,..., P_{C+1}(0) = 0$

For steady state condition $\lim_{t\to\infty} \frac{d}{dt} P_k(t) = 0$ and $\lim_{t\to\infty} P_k(t) = P_k$

Under steady state condition,(15),(16),(17) transform to following balance equations.

0= $(\lambda + k\gamma + \mu)P_k + \{\lambda + (k-1)\gamma\}P_{k-1} + \mu P_{k+1}$ for k =1,2,3,… ,C (18)

$0 = -\lambda P_0 + \mu P_1$, for k =0 (19)

$0 = (\lambda + C\gamma)P_C - \mu P_{C+1}$ for k =C+1 (20)

The above system of steady state equations can be written in matrix from as

$$PQ = 0$$

$$\sum_{i=0}^{C+1} P_i = 1$$

Where $P = (P_0, P_1,..., P_{C+1})$

and

$$Q = \begin{pmatrix} -\lambda & \lambda & 0 & 0 & \cdots & 0 & 0 \\ \mu & -(\lambda+\mu+v) & \lambda+v & 0 & \cdots & 0 & 0 \\ 0 & \mu & -(\lambda+\mu+2v) & \lambda+2v & \cdots & 0 & 0 \\ 0 & 0 & \mu & -(\lambda+\mu+3v) & \cdots & 0 & 0 \\ 0 & 0 & 0 & \mu & \cdots & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ 0 & 0 & 0 & 0 & \cdots & -(\lambda+\mu+Cv) & \lambda+Cv \\ 0 & 0 & 0 & 0 & \cdots & \mu & -\mu \end{pmatrix}$$

For C= 0 ,

From (19) we get

$$\lambda P_0 = \mu P_1 \tag{21}$$

Also, $P_0 + P_1 = 1$ (22)

Solving (21) and (22) we get

$$P_1 = \frac{\lambda}{\lambda + \mu}$$

Hence

$$A_0 = P_1 = \frac{\lambda}{\lambda + \mu} \tag{23}$$

For C=1,

$$0 = -\lambda P_0 + \mu P_1 \tag{24}$$

$$0 = -(\lambda + \mu + \gamma) P_1 + \lambda P_0 + \mu P_2 \tag{25}$$

$$0 = (\lambda + \gamma) P_1 - \mu P_2 \tag{26}$$

Also, $P_0 + P_1 + P_2 = 1$

From (23) we get

$$\frac{P_0}{\mu} = \frac{P_1}{\lambda} = k$$

$$\Rightarrow P_0 = k\mu, P_1 = \lambda k$$

From (25) we get

$$P_2 = (\frac{\lambda+\gamma}{\mu})\lambda k \qquad \text{(since, } P_1 = \lambda k\text{)} \tag{27}$$

Using equation (26) we get

$$k[\mu+\lambda+\frac{\lambda+\gamma}{\mu}\lambda]=1 \qquad \Rightarrow k = \frac{\mu}{\lambda(\lambda+\gamma)+\mu(\lambda+\mu)}$$

From (27) we get

$$P_2 = (\frac{\lambda+\gamma}{\mu}).\lambda.\frac{\mu}{\lambda(\lambda+\gamma)+\mu(\lambda+\mu)}$$

Hence,

$$A_1 = P_2 = \frac{\lambda(\lambda+\gamma)}{\lambda(\lambda+\gamma)+\mu(\lambda+\mu)}$$

For C=2,

$$0 = -\lambda P_0 + \mu P_1 \tag{28}$$

$$0 = -(\lambda+\mu+\gamma)P_1 + \lambda P_0 + \mu P_2 \tag{29}$$

$$0 = (\lambda+\gamma)P_1 - (\lambda+\mu+2\lambda)P_2 + \mu P_3 \tag{30}$$

$$0 = (\lambda+2\gamma)P_2 - \mu P_3 \tag{31}$$

Also $P_0 + P_1 + P_2 + P_3 = 1$ (32)

From (28) we get

$$P_0 = k\mu \quad \text{and} \quad P_1 = \lambda k$$

From (29) we get

$$P_2 = \frac{\lambda(\lambda+\gamma)}{\mu} k$$

From (31) we get

$$P_3 = \frac{(\lambda+2\gamma)}{\mu} P_2$$

$$= \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)}{\mu^2} k$$

From (32) we get

$$k = \frac{\mu^2}{(\lambda+\mu)\mu^2 + \mu\lambda(\lambda+\gamma) + \lambda(\lambda+\gamma)(\lambda+2\gamma)}$$

Hence, $A_2 = P_3 = \dfrac{\lambda(\lambda+\gamma)(\lambda+2\gamma)}{\mu^2(\lambda+\mu) + \mu\lambda(\lambda+\gamma) + \lambda(\lambda+\gamma)(\lambda+2\gamma)}$

For C=3,

we have

$$0 = -(\lambda+\gamma+\mu)P_1 + \lambda P_0 + \mu P_2 \qquad (33)$$

$$0 = -(\lambda+2\gamma+\mu)P_2 + (\lambda+\gamma)P_1 + \mu P_3 \qquad (34)$$

$$0 = -(\lambda+3\gamma+\mu)P_3 + (\lambda+2\gamma)P_2 + \mu P_4 \qquad (35)$$

$$0 = -\lambda P_0 + \mu P_1 \qquad (36)$$

$$0 = (\lambda + 3\gamma)P_3 - \mu P_4 \qquad (37)$$

From (36) we get

$P_0 = k\mu$ And $P_1 = k\lambda$

From (33) we get

$$P_2 = \frac{\lambda(\lambda+\gamma)}{\mu}k$$

From (34) we get

$$P_3 = \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)k}{\mu^2}$$

From (37) we get

$$P_4 = \frac{(\lambda+3\gamma)}{\mu}P_3$$

$$= \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)k}{\mu^3}$$

Also, $P_0 + P_1 + P_2 + P_3 + P_4 = 1$

$$\Rightarrow k = \frac{\mu^3}{\mu^3(\lambda+\mu) + \lambda(\lambda+\gamma)\mu^2 + \lambda(\lambda+\gamma)(\lambda+2\gamma)\mu + \lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}$$

Hence,

$$A_3 = P_4 = \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}{\mu^3(\lambda+\mu)+\lambda(\lambda+\gamma)\mu^2+\lambda(\lambda+\gamma)(\lambda+2\gamma)\mu+\lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}$$

On the analogy of this , we conclude that ,the stable congestion rate is

$$A_C = P_{C+1} = 1 - \frac{\mu}{(\lambda+\mu+C\gamma)A_{C-1} - \{\lambda+(C-1)\gamma\}(1-A_{C-1})A_{C-2}+\mu}$$, for $C \geq 2$

Chapter-4

Model 2:

The Queuing Model with additional one server (M/M/2) : ((C+1)/FCFS)

In this model, number of servers or channels are two and these are arrange in parallel.

Here, arrival distribution is poission distribution with mean rate λ per unit time. The service time is exponentional with mean rate μ per unit time. Each server are identical i.e. each server gives identically service with mean rate μ per unit time .The overall service rate can be obtained in two situations .

If there are n numbers of data packets are present in the system.

Case-1

For n < 2

There will be no queue. Therefore (2-n) server will remain idle and the combined service rate will be

$$\mu_n = n\mu \ , 1 \leq n < 2$$

Case-2

For $n \geq 2$

Then all the servers will busy. So, maximum (n-2)(≤C+1) number of data packets present in the queue. The combined service rate will be

$$\mu_n = 2\mu, n \geq 2$$

Hence combining case-1 and case-2 we get

$$\lambda_n = \lambda. \text{ , for all } n \geq 0$$

$$\mu_n = n\mu, 1 \leq n < 2$$

$$\mu_n = 2\mu, n \geq 2$$

$$\mu_0 = 0, n = 0$$

$$\mu_1 = \mu, n = 1$$

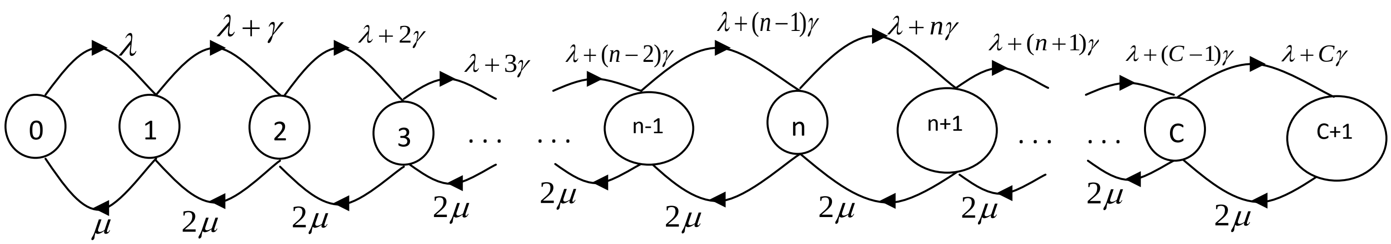

Figure 3: State transition rate diagram

The steady state equations are,

$\lambda P_0 = \mu P_1$, for n=0 (38)

$(\lambda + \gamma + \mu)P_1 = \lambda P_0 + 2\mu P_2$, for n=1 (39)

$\{\lambda + (n-1)\gamma\}P_{n-1} + 2\mu P_{n+1} = (\lambda + n\gamma)P_n + 2\mu P_n$, for $2 \leq n \leq C$ (40)

$(\lambda + C\gamma)P_C = 2\mu P_{C+1}$, for n=C+1 (41)

The above system of steady state balance equations can be written in matrix form as

$$PQ = 0$$

and $$\sum_{i=0}^{C+1} P_i = 1$$

Where $P = (P_0, P_1, ..., P_{C+1})$

and

$$Q = \begin{pmatrix} -\lambda & \lambda & 0 & 0 & \cdots & 0 & 0 \\ \mu & -(\lambda+\mu+v) & \lambda+v & 0 & \cdots & 0 & 0 \\ 0 & 2\mu & -(\lambda+2\mu+2v) & \lambda+2v & \cdots & 0 & 0 \\ 0 & 0 & 2\mu & -(\lambda+2\mu+3v) & \cdots & 0 & 0 \\ 0 & 0 & 0 & 2\mu & \cdots & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ 0 & 0 & 0 & 0 & \cdots & -(\lambda+2\mu+Cv) & \lambda+Cv \\ 0 & 0 & 0 & 0 & \cdots & 2\mu & -2\mu \end{pmatrix}$$

For C=0 we have

$$\lambda P_0 = \mu P_1 \qquad (42)$$

Also, $P_0 + P_1 = 1$ (43)

From (43) we get $P_0 = 1 - P_1$

Then (42) becomes

$$\lambda(1 - P_1) = \mu P_1$$

$$\Rightarrow P_1 = \frac{\lambda}{\lambda + \mu}$$

Hence $A_0 = P_1 = \dfrac{\lambda}{\lambda + \mu}$

For C=1

$$\lambda P_0 = \mu P_1 \qquad (44)$$

$$(\lambda+\gamma+\mu)P_1=\lambda P_0+2\mu P_2 \tag{45}$$

$$(\lambda+\gamma)P_1=2\mu P_2 \tag{46}$$

Also, $P_0+P_1+P_2=1$ (47)

From (44) we get

$$\frac{P_0}{\mu}=\frac{P_1}{\lambda}=k \text{ (say)}$$

and $P_0=\mu k$ $P_1=\lambda k$

From (46) we get

$$P_2=\frac{(\lambda+\gamma)\lambda k}{2\mu}$$

Since $P_0+P_1+P_2=1$

$$\Rightarrow k[\mu+\lambda+(\frac{\lambda+\gamma}{2\mu})\lambda]=1$$

$$\Rightarrow k=\frac{2\mu}{2\mu^2+2\lambda\mu+\lambda(\lambda+\gamma)}$$

Therefore,

$$P_0=\frac{2\mu^2}{2\mu^2+2\lambda\mu+\lambda(\lambda+\gamma)}$$

And $P_1 = \frac{2\lambda\mu}{2\mu^2 + 2\lambda\mu + \lambda(\lambda+\gamma)}$

Hence $A_1 = P_2 = \frac{\lambda(\lambda+\gamma)}{\lambda(\lambda+\gamma) + 2\mu(\lambda+\mu)}$

For C=2

$$\lambda P_0 = \mu P_1 \tag{48}$$

$$(\lambda+\gamma+\mu)P_1 = \lambda P_0 + 2\mu P_2 \tag{49}$$

$$(\lambda+2\gamma+2\mu)P_2 = (\lambda+\gamma)P_1 + 2\mu P_3 \tag{50}$$

$$(\lambda+2\gamma)P_2 = 2\mu P_3 \tag{51}$$

Also,

$$P_0 + P_1 + P_2 + P_3 = 1 \tag{52}$$

From (48), we get $P_0 = \mu k$ and $P_1 = \lambda k$

From (49) we get

$P_2 = \frac{(\lambda+\gamma)}{2\mu}\lambda k$ [since, $P_0 = \mu k, P_1 = \lambda k]$

From (51) we get

$$P_3 = \frac{(\lambda + 2\gamma)}{2\mu} P_2$$

$$\Rightarrow P_3 = \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)}{4\mu^2} k \qquad \text{[Using the value of } P_2 \text{]}$$

Since $P_0 + P_1 + P_2 + P_3 = 1$

or, $k[\lambda + \mu + \frac{(\lambda+\gamma)}{2\mu}\lambda + \frac{(\lambda+2\gamma)(\lambda+\gamma)}{4\mu^2}\lambda] = 1$

$$\Rightarrow k = \frac{4\mu^2}{4\mu^2(\lambda+\mu) + (\lambda+\gamma)2\lambda\mu + \lambda(\lambda+\gamma)(\lambda+2\gamma)}$$

Hence $A_2 = P_3 = \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)}{4\mu^2(\lambda+\mu) + (\lambda+\gamma)2\lambda\mu + \lambda(\lambda+\gamma)(\lambda+2\gamma)\}}$

For C = 3

$$\lambda P_0 = \mu P_1 \tag{53}$$

$$(\lambda + \gamma + \mu)P_1 = \lambda P_0 + 2\mu P_2 \tag{54}$$

$$(\lambda + 2\gamma + 2\mu)P_2 = (\lambda+\gamma)P_1 + 2\mu P_3 \tag{55}$$

$$(\lambda + 3\gamma + 2\mu)P_3 = (\lambda + 2\gamma)P_2 + 2\mu P_4 \tag{56}$$

$$(\lambda + 3\gamma)P_3 = 2\mu P_4 \qquad (57)$$

From (53) we get

$P_0 = \mu k$ And $P_1 = \lambda k$

From (54) we get

$$2\mu P_2 = (\lambda + \gamma + \mu)P_1 - \lambda P_0$$

$$\Rightarrow P_2 = \frac{(\lambda + \gamma + \mu)}{2\mu}\lambda k - \frac{\lambda\mu k}{2\mu}$$

$$= \frac{(\lambda + \gamma)}{2\mu}\lambda k$$

From (55) we get

$$2\mu P_3 = (\lambda + 2\gamma + 2\mu)P_2 - (\lambda + \gamma)P_1$$

$$\Rightarrow 2\mu P_3 = \frac{(\lambda + 2\gamma + 2\mu)(\lambda + \gamma)\lambda k}{2\mu} - (\lambda + \gamma)\lambda k$$

$$= (\lambda + \gamma)\lambda k[\frac{(\lambda + 2\gamma + 2\mu)}{2\mu} - 1]$$

$$= \frac{\lambda k(\lambda + \gamma)(\lambda + 2\gamma)}{2\mu}$$

$$\Rightarrow P_3 = \frac{\lambda k(\lambda + \gamma)(\lambda + 2\gamma)}{4\mu^2}$$

From (57) we get

$$P_4 = \frac{(\lambda + 3\gamma)}{2\mu}P_3$$

$$= \frac{\lambda k(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}{8\mu^3}$$

Also,

$$P_0 + P_1 + P_2 + P_3 + P_4 = 1$$

$$\Rightarrow k[(\lambda+\mu) + \frac{\lambda(\lambda+\gamma)}{2\mu} + \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)}{4\mu^2} + \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}{8\mu^3}] = 1$$

$$\Rightarrow k = \frac{8\mu^3}{8\mu^3(\lambda+\gamma) + 4\lambda\mu^2(\lambda+\gamma) + 2\lambda\mu(\lambda+\gamma)(\lambda+2\gamma) + \lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}$$

Hence

$$A_3 = P_4 = \frac{\lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}{8\mu^3(\lambda+\mu) + 4\lambda\mu^2(\lambda+\gamma) + 2\lambda\mu(\lambda+\gamma)(\lambda+2\gamma) + \lambda(\lambda+\gamma)(\lambda+2\gamma)(\lambda+3\gamma)}$$

On the analogy of this, we conclude that, the stable congestion rate is

$$A_C = P_{C+1} = 1 - \frac{2\mu}{(\lambda+2\mu+C\gamma)A_{C-1} - \{\lambda+(C-1)\gamma\}(1-A_{C-1})A_{C-2} + 2\mu} \quad \text{for } C \geq 2$$

Chapter -5

Conclusion

This research program cites the analysis of the network traffic model through Queuing Theory. In the present analysis, we describe that how we can make a queuing model on the basis of queuing theory and subsequently we derive the estimation after analyzing the network traffic through queuing theory models. In the present work two queuing models (M/M/1): ((C+1)/FCFS) and (M/M/2):((C+1)/FCFS) have been applied. These two models are used to determine the forecast way for the stable congestion rate of the network traffic. Using the Queuing Theory models, it is convenient and simple way for calculating and monitoring the network traffic properly in the network communication system. We can monitor the network efficiently, in the view of the normal, optimal and or even for the high overhead network management, by monitoring and analyzing the network traffic rate.

Finally, we can say that network traffic rate can have an important role in the network communication system.

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