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Network Traffic Monitoring System in Non-Poisson Queues

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Abstract:
Network traffic monitoring is an important way for network performance analysis and monitor. This paper analyses the congestion control that involves both hosts and network elements such as routers. At the end hosts, the congestion control mechanism paces how fast sources are allowed to send packets. This is done in an effort to keep congestion from occurring in the first place, and it occurs to help eliminating the congestion. Each router must implement some queuing discipline that governs how packets are buffered while waiting to be transmitted. The queuing algorithm can be thought of as allocating both bandwidth (which packets get transmitted) and buffer space (which packets get discarded). It also directly affects the latency experienced by a packet, by determining how long a packet waits to be transmitted. By using the Queuing theory models, it is more 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.

1. Introduction

Queuing Theory, is also called random service theory, is a branch of Operation Research in the field of Applied Mathematics. This subject analyzes 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.. The research paper seeks to explore how to build the basic model of network traffic analysis based on Queuing Theory. 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. The network traffic is very common, The system will be in worse condition, when the traffic becomes under extreme situation, in which leads to the network congestion. 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 network and Network congestion rate is changing all the time. The instantaneous congestion rate and the stable congestion rate are often used to analyse the network traffic in network monitor.

2. Non-Poisson Queues

Queues, in which arrivals and/or departures may not follow the Poisson axioms, are called non-Poisson queues. The development of these queuing systems is more complicated, mainly because the Poisson axioms no longer hold good. Following are the techniques which are usually in studying the non-Poison queues:

a) Phase technique
b) The technique of Imbedded Markov Chain, and
c) The Supplementary variable technique.

The phase technique is used when an arrival demands phases of service, say k in number. The technique by which non-Markovian queues are reduced to Markovian is termed as Imbedded Markov Chain Technique. When one or more random variables are added to convert a non-Markovian process into a Markovian one, the technique involved in this conversion is called the Supplementary Variable technique. This technique has been applied in studying the queuing system. However, we shall introduce the queuing system $M/E_k/I$ and the steady-state results of M/G/I.

When a unit has to pass through k stages for its service, then these k stages of servicing are called k-phases. The distribution of servicing time in each of these phases will be an independent variable and distribution of time in all these phases. Since the exponential distribution involves only one parameter (the parameter μ), it is known as one parameter distribution. A two-parameter generation of the exponential distribution is called the Erlangian (Gamma) service time distribution. The p.d.f. of this Erlangian service time distribution is defined by

$g(t;\mu;k) = C_k t^{k-1} e^{-k\mu t}$, $\quad k = 1,2,\ldots$

where $0 \le t \le \infty$ and C_k are constants.

The value of constant C_k is given by

$$\int_0^\infty g(t;\ \mu;k)\,dt = 1 \text{ or } \int_0^\infty C_k t^{k-1} e^{-k\mu t}\,dt = 1$$

Or $\quad \frac{C_k}{(k-\mu)^k}\int_0^\infty y^{k-1}e^{-y}dy = 1$ for $k\mu t = y$

Thus $C_k = \frac{(k\mu)^k}{(k-1)!}$ and therefore $g(t;\mu;k) = \frac{(k\mu)^k t^{k-1} e^{-k\mu t}}{(k-1)!}$; $0 \le t \le \infty$.

Where μ = expected number of customers completing service per unit of time, and

k = a positive constant.

The expected value of the total service time and variance of Erlang distribution are $k(1/k\mu)$, i.e; $1/\mu$ and $k(1/k\mu)^2$, i.e; $1/k\mu^2$ respectively.

The mode of service time, t, for the kth Erlang is $(k-1)/k\mu$.

3. $(M/E_k/1)$: $(\infty/FCFS)$

This model consists of a single service channel queuing system in which there are n phases in the system (waiting or in service). It has been assumed that a new arrival creates k-phases of service and departure of one customer reduces k-phases of service. Let

n= number of customers in the system,

$\lambda_n = \lambda$, constant arrival rate per unit time,

$\mu_n = k\mu$, k phases of service per unit time.

When P_n denotes the steady-state probability of n phases in the system. The transition-rate diagram of the model under consideration is:

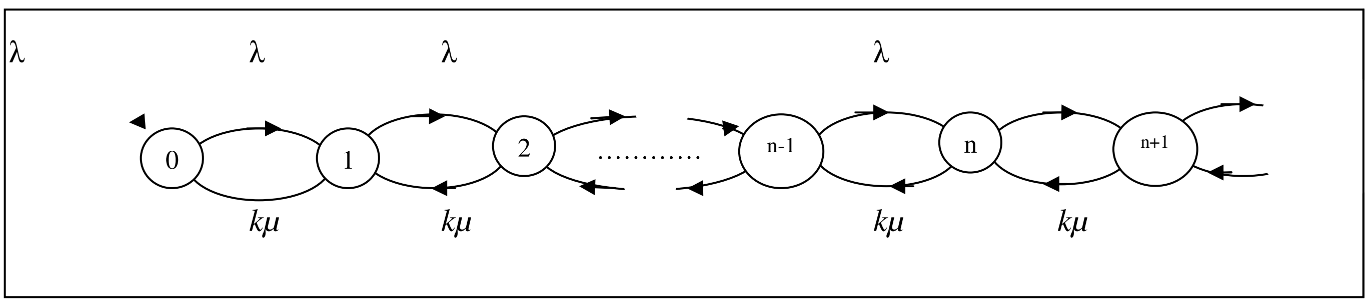

Figure 1: State transition rate diagram

The balance equations, therefore, are

$\lambda P_{n-k} + k\mu P_{n+1} = \lambda P_n + k\mu P_n$, $\quad n \ge 1$

and $\quad k\mu P_1 = \lambda P_0$, $\quad n = 0$

letting $(\lambda/ k\mu) = \rho$, these equations are

$(1+\rho) P_n = \rho P_{n-k} + P_{n+1}$, $\quad n \ge 1$

and $\quad P_1 = \rho P_0$, $\quad n = 0$.

4. Characteristics

(i) Average number of phases in the system $E(n_p)$ is obtained as follows:

Multiplying by n^2 on both sides and then taking summation, the difference equation gives

$$(1+\rho)\sum_{n=1}^{\infty} n^2 P_n = \rho\sum_{n=k}^{\infty} n^2 P_{n-k} + \sum_{n=1}^{\infty} n^2 P_{n+1}$$

$$= \rho\sum_{x=0}^{\infty}(x+k)^2 P_x + \sum_{y=2}^{\infty}(y-1)^2 P_y,$$

(where n-k = x and n+1 = y)

$$= \rho\sum_{x=0}^{\infty}(x^2+2xk+k^2)P_x + \sum_{y=1}^{\infty}(y-2y+1) P_y,$$

since $\sum_{y=2}^{\infty}(y-1)^2 P_y = \sum_{y=1}^{\infty}(y-1)^2 P_y$

$$= (1+\rho)\sum_{n=1}^{\infty} n^2 P_n + \rho\sum_{n=0}^{\infty}(2nk+k^2) P_n + \sum_{n=1}^{\infty}(-2n+1) P_n$$

or $\quad 0 = \rho\,[2k\sum_{n=0}^{\infty} n P_n + k^2\sum_{n=0}^{\infty} P_n] + \sum_{n=1}^{\infty} P_n - 2\sum_{n=1}^{\infty} nP_n$

or $\quad 2(1-k\rho)\sum_{n=0}^{\infty} nP_n = \rho k^2 - P_0 + 1,$

since $\quad \sum_{n=0}^{\infty} P = 1$ and $\sum_{n=1}^{\infty} nP_n = \sum_{n=0}^{\infty} nP_n$

.. $\quad E(n_p) = \frac{\rho k^2+1-1(1-k\rho)}{2(1-k\rho)} = \frac{k(k+1)\rho}{2(1-k\rho)}$

i.e., $\quad E(n_p) = \frac{k(k+1)}{2}\cdot\frac{\lambda/k\mu}{1-k\lambda/k\mu} = \frac{k+1}{2}\frac{\lambda}{\mu-\lambda}$

(ii) Average waiting time of the phases in the system is given by

$E(w_p) = \frac{E(n_p)}{\mu} = \frac{k+1}{2}\frac{\lambda}{\mu-\lambda}$

(iii) Average waiting time of an arrival is given by

$$E(w) = \frac{E(w_p)}{k} = \frac{k+1}{2k}\frac{\lambda}{\mu(\mu-\lambda)}$$

(iv) Average time an arrival spends in the system is given by

$$E(v) = E(w) + \frac{1}{\mu} = \frac{k+1}{2k}\frac{\lambda}{\mu(\mu-\lambda)} + \frac{1}{\mu}$$

(v) Average number of units in the system is given by

$$E(n) = \lambda\, E(v) = \frac{k+1}{2k}\frac{\lambda^2}{\mu(\mu-\lambda)} + \frac{\lambda}{\mu}$$

(vi) Average queue length is given by

$$E(m) = E(n) - \frac{\lambda}{\mu} = \frac{k+1}{2k}\frac{\lambda^2}{\mu(\mu-\lambda)}$$

5. Numerical Example

The interarrival time of packets at a network is exponential with mean 15 minutes. The network is operated by only one server, and it takes between 10 and 15 minutes, uniformly distributed to one response. Packets are served on a first-in, first-out (FIFO) basis. The objective of the simulation is to compute the following measures of performance:

1. The average utilization of the network.
2. The average number of waiting packets.
3. The average time a packet waits in queue.

The logic of the simulation model can be described in terms of the actions associated with the arrival and departure events of the model.

5.1. Arrival Event

1. Generate and store chronologically the occurrence time of the next arrival event (= current simulation time + interarrival time).
2. If the facility (server) is idle
   a. Start service and declare the facility busy. Update the facility utilization statistics.
   b. Generate and store chronologically the time of the departure event for the packet (=current simulation time + service time).
3. If the facility is busy, place the customer in the queue, and update the queue statistics.

5.2. Departure Event

1. If the queue is empty, declare the facility idle. Update the facility utilization statistics.
2. If the queue is empty
   a. Select a customer from the queue, and place it in the facility. Update the facility utilization and queue statistics.
   b. Generate and store chronologically the occurrence time of the departure event for the packet (= current simulation time + service time).

From the data of the problem, the interarrival time is exponential with mean 15 minutes, and the service time is uniform between 10 and 15 minutes. Letting p and q represent random samples of interarrival and service times, then, we get

$$p = -15 \ln(R) \text{ minutes}, 0 \le R \le 1$$

$$q = 10 + 5R \text{ minutes}, 0 \le R \le 1$$

We also use the symbol T to represent the simulation clock time. We further assume that the first packet arrives at T=0 and that the facility starts empty.

Because the simulation computations are typically voluminous, the simulation is limited to the first 5 arrivals only. The example is designed to cover all possible situations that could arise in the course of the simulation.

5.3. Arrival of packet 1 at T=0.

Generate the arrival of packet 2 at

$$T = 0 + p_1 = 0 + [-15\ln(0.0589)] = 42.48 \text{ ms}$$

Because the facility is idle at T = 0, packet 1 starts service immediately. The departure time is thus computed as

$$T = 0 + q_1 = 0 + (10 + 5 \times 0.6733) = 13.37 \text{ ms}$$

The chronological list of future events thus becomes

Time, T	Event
13.37	Departure of packet 1
42.48	Arrival of packet 2

Table 1

- Departure of packet 1 at T=13.37.

Because the queue is empty, the facility is declared idle. At the same time, we record that the facility has been busy between T = 0 and T = 13.37 ms. The updated list of future events becomes

Time, T	Event
42.48	Arrival of packet 2

Table 2

- Arrival of packet 2 at T = 42.48. Packet will arrive at

$T = 42.48 + [-15\ln(0.4790)] = 53.49$ ms

Because the facility is idle, packet 2 starts service, and the facility is declared busy.

The departure time is

$T = 42.48 + (10 + 5 \times 0.9486) = 57.22$ ms

The list of future event is updated as

Time, T	Event
53.49	Arrival of packet 3
57.22	Departure of packet 2

Table 3

- Arrival of packet 3 at T = 53.49.

Packet 4 will arrive at

$T = 53.49 + [-15\ln(0.6139)] = 60.81$ ms

Because the facility is currently busy (until T = 57.22), packet 3 is placed in queue at T = 53.49. The updated list of future events is

Time, T	Event
57.22	Departure of packet 2
60.81	Arrival of packet 4

Table 4

- Departure of packet 2 at T = 57.22.

Packet 3 is taken out of the queue to start service. The waiting time is

$W_3 = 57.22 – 53.49 = 3.73$ ms

The departure time is

$T = 57.22 + (10 + 5 \times 0.5933) = 70.19$ ms

The updated list of future event is

Time, T	Event
60.81	Arrival of packet 4
70.19	Departure of packet 2

Table 5

- Arrival of packet 4 at T = 60.81.

Packet 5 will arrive at

$T = 60.81 + [-15\ln(0.9341)] = 61.83$ ms

Because the facility is busy until T = 70.19, packet 4 is placed in the queue. The updated list of future event is

Time, T	Event
61.83	Arrival of packet 5
70.19	Departure of packet 3

Table 6

- Arrival of customer 5 at T = 61.83.

The simulation is limited to 5 arrivals, hence packet 6 arrival is not generated. The facility is still busy, hence the packet is placed in queue at T = 61.83. The updated list of events is

Time, T	Event
70.19	Departure of packet 3

Table 7

- Departure of packet 3 at T = 70.19.

Packet 4 is taken out of the queue to start service. The waiting time is
$W_4 = 70.19 - 60.81 = 9.38$ ms
The departure time is
$T = 70.19 + [10 + 5 \times 0.1782] = 81.08$ ms
The updated list of future event is

Time, T	Event
81.08	Departure of packet 4

Table 8

- Departure of packet 4 at T = 81.08.

Packet 5 is taken out of the queue to start service. The waiting time is
$W_5 = 81.08 - 61.83 = 19.25$ ms
The departure time is
$T = 81.08 + (10 + 5 \times 0.3473) = 92.82$ ms

The updated list of future event is

Time, T	Event
92.82	Departure of packet 5

Table 9

- Departure of packet 5 at T = 92.82.

There are no more packets in the system (queue and facility) and the simulation ends.
Figure summarizes the changes in the length of the queue and the utilization of the facility as a function of the simulation time.

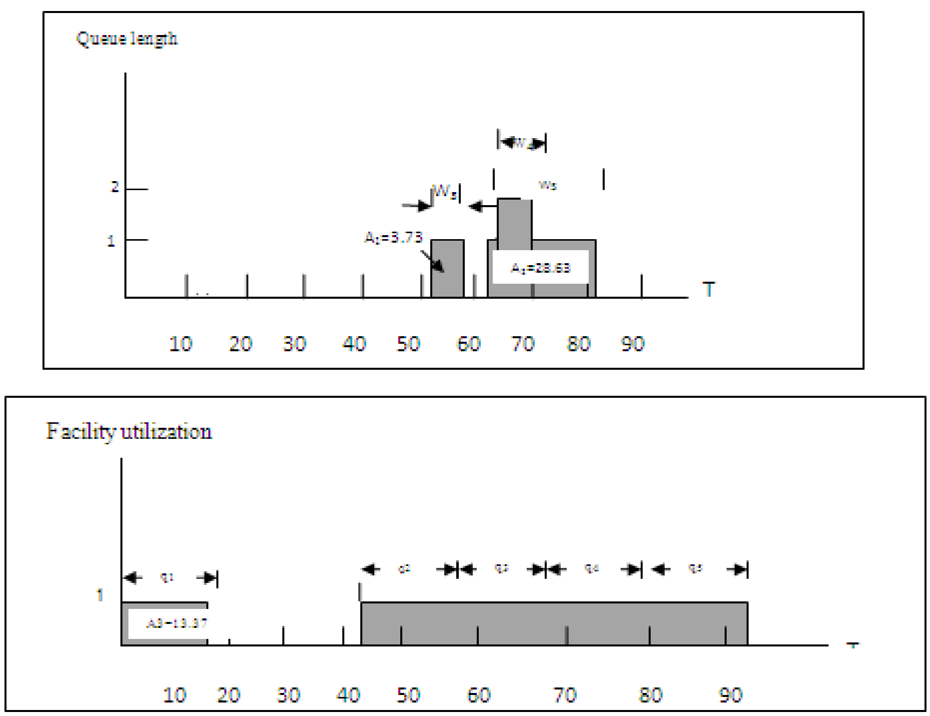

Figure 2: Changes in queue length and facility utilization as a function of simulation time, T

The queue length and the facility utilization are known as time-based variables because their variation is a function of time. As result, their average values are computed as

$$\begin{pmatrix}\text{average value of a} \\ \text{time} - \text{based variable}\end{pmatrix} = \frac{\text{Area under curve}}{\text{simulated period}}$$

Implementing this formula for the data in figure, we get

$$\begin{pmatrix}\text{average queue}\\ \text{length}\end{pmatrix} = \frac{A_1+A_2}{92.82} = \frac{32.36}{92.82} = 0.349 \text{ packets}$$

$$\begin{pmatrix}\text{Average facility}\\ \text{utilization}\end{pmatrix} = \frac{A_3+A_4}{92.82} = \frac{63.71}{92.82} = 0.686 \text{ server}$$

The average waiting time in the queue is an observation-based variable whose value is computed as

$$\begin{pmatrix}Average\ value\ of\ an\\ observation-based\ variable\end{pmatrix} = \frac{\text{Sum of observations}}{\text{number of observations}}$$

Examination of figure reveals that the area under the queue-length curve actually equals the sum of the waiting time for the three packets who joined the queue; namely,

$$W_1 + W_2 + W_3 + W_4 + W_5 = 0 + 0 + 3.73 + 9.38 + 19.25 = 32.36 \text{ ms}$$

The average waiting time in the queue for all packets is thus computed as

$$W_q = \frac{32.36}{5} = 6.47\text{ms}$$

6. Conclusion

In this paper, I describe 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 this paper, Non-Poisson queuing model with random selection have been analyzed. Most congestion control mechanisms are targeted at the best effort service model of today's Internet, where the primary responsibility for congestion control falls on the nodes of the network. Independently, what the end nodes are doing exactly is, the routers implement a queuing discipline that governs which packet gets dropped. Sometimes, this queuing algorithm is sophisticated enough to segregate traffic, and in other cases, the router attempts to monitor it's queue length and then signals the source host when congestion is about to occur. By using the Queuing theory models, it is more 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, I can say that network traffic rate can have an important role in the network communication system.

7. References

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