Analysis of Time Delay of Packet on Multi-Service System in Loop LAN

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Abstract

In this paper, a new queuing model G (General arriving) /G (General Service) /1 (One Server) /S (Number of limited buffers) / FCFS (First Come, First Served) is proposed for integrated service with limited buffers in loop LAN. The model is build through reconstructed probability space in discrete time. According to the imbedded Markov chain theory and the generating function, a mathematical analysis and computer simulation have been developed in this paper. The delay time of packet of the system are explicitly obtained. The results of computer simulation show their concordance with the theoretical analysis.

1. Introduction

Loop LAN is a multi-queues cycle service system. Research of the system has obtained very big progress in recent years [1-6]. Base on the current results, this paper attempts to establish a queue model with principles: General arriving / General service /1 server / S(Limited buffers) / FCFS (First Come, First Served), which approaches the actual loop LAN, BISDN(Broadband Integrated Services Digital Network) more. The characteristics of the queue model are:

1. The packets are random when they arrive at the input buffers in one unit time. It is resulted in the service’s variety (data, voice, figure and image etc.).
2. The length of service time is different, because the length of the packets is variable in different type of service.
3. There is a server in the system. The reference time is slotted with a slot size equal to a unit.
4. For each queue, the service intermittent time distributions are random, during which the server starts (to offer service for another packet) to serve another packet at the terminal after serving a packet. As a result, the service period includes service time and intermittent time. Therefore intermittent should be generally distribution.
5. The size of buffers in which packets are preserved and waiting for served, is limited.
6. Service rule: first come, first served (FCFS). The reference time is slotted with a slot size that equal to a unit.

2. Modeling Analysis

2.1 Assume Analysis Parameters

1. The studied system is in statistical equilibrium.
2. In unit time, the packets which arrives the buffer are random and independent, and same distribution. It’s the probability generating function and mean value are: \( A(z) \), \( \lambda = A'(1) \) respectively.
3. It is the random and independent on service time distribution, during which the server serves a packet in the input buffers. The probability generating function and the mean values of service time are \( B(z) \), \( \beta = B'(1) \) respectively.
4. After sent a packet, the probability generating function and mean of intermittent random distribution are \( R(z) \), \( \gamma = R'(1) \) respectively.
5. The service intermittent time distribution, during which the time delayed if there are not any packets at the terminal, is also random and independent. It’s the state probability generating function, the mean value are \( R_1(z) \), \( \gamma_1 = R_1'(1) \) respectively.

2.2 The input buffer is limitless

At time \( t_n \), the server starts serving for them if there are any packets in the input buffer. If the buffer is empty, the clock will back off a random intermittent time \( \gamma_1 = R_1'(z) \). Its probability generating function is \( R_1(z) \), and waiting for the next packet arrival. At the time \( t_n \), suppose there are \( \xi(t_n) = \alpha \)
packets in the buffer with the probability \( P(\xi(t_n) = a) \), one of packets has served successfully by the server of system at the time \( t_{n+1} \), and then delay time \( R(z) \). During this time, \( p_{a,n}(\xi(t_n) = j) \) is the probability of that there are \( j \) packets arriving system. At the moment, the state of system presented by \( \xi(t_n) + \xi(t_n) - 1 \), and probability is \( P(\xi(t_n+1) = n) \). At the time \( t_{n+1} \), probability generating function of system’s state is given by[5]

\[
G_{t_{n+1}}(z) = B(A(z))R(A(z))\frac{1}{z}[G_{t_n}(z) - G_{t_n}(0) + G_{t_n}(0)R_1(A(z))]
\]

Where:

\[
p_n(t_n) = G_{t_n}(0) = \frac{1 - \lambda(\beta + \gamma)}{1 - \lambda(\beta + \gamma - \gamma_1)}
\]

2.3 The input buffer is limited

2.3.1 Probability generating function:

With the limited of buffer capability, considering the services have the ability of burst out. Therefore, the packet loss mechanism is required.

In order to get the packet loss rate \( P_{loss} \) at first we need reconstruction probability space (the buffer size: \( S = 0, 1, 2, 3, \ldots \)).

\[
\sum_{i=0}^{\infty} p_i = 1
\]

Assume:

\[
1 - \sum_{i=0}^{\infty} p_i = \sum_{i=0}^{s} p_i = c_s
\]

Assume: \( p_s = p_i/c_s \) \( \sum_{i=0}^{s} p_i = 1 \)

Through reconstruction probability space, we can get the probability generating function with the limited buffer at the time \( t_{n+1} \).

\[
\bar{G}_{t_{n+1}}(z) = B(A(z))R(A(z))\frac{1}{z}[\bar{G}_{t_n}(z) - \bar{G}_{t_n}(0) + \bar{G}_{t_n}(0)R_1(A(z))]
\]

Where:

\[
\bar{p}_0(t_n) = \bar{G}_{t_n}(0) = \frac{1 - \lambda(\beta + \gamma)}{c_s(1 - \lambda(\beta + \gamma - \gamma_1))}
\]

2.3.2 The probability of packet loss \( P_{loss} \):

Limited buffer system (S is most number of packet in the buffer), The probability of packet loss is defined as a ratio of the lost packets division the total number of the packets input, this rate is the probability to fill buffer \( S \). It was proved and published in textbook [7]. So utilize formula (4)-(7) and the characteristic of probability generating function, we get:

\[
P_{loss} = \bar{\tilde{p}}_s(t_{n+1}) = \frac{1}{s!} \bar{\tilde{G}}_{t_{n+1}}^{(s)}(0)
\]

Where \( \bar{\tilde{G}}_{t_{n+1}}^{(s)}(0) \) is the value of \( s \)-order differential \( \bar{\tilde{G}}_{t_{n+1}}(z) \) to \( z \) (Assume \( z > 0 \))

2.3.3 The mean queue length of packet in buffer: \( \bar{q}_s \)

The mean queue length of packet in the Limited buffer system (S is most number of packet in the buffer) is defined as a mean length of the packets waiting in the buffer at one moment.

\[
\bar{q}_s = \bar{G}'(z)|_{z=1} = \sum_{i=1}^{s} \bar{\tilde{p}}_i
\]

2.3.4 The mean time delay of packet \( \bar{w}_s \)

The system mean time delay of packet is defined as the period from the packet into the buffer until be served and sent off. The time is the sum of services and waiting time that a packet in the buffer. The system mean time delay presented as \( \bar{w}_s \).

Assume \( 1 - P_0 = c \), and reconstruct probability space, at time \( t_a \) after served for the NO. \( i \) packet. The mean time delay of packet can be presented as[5]:

\[
\bar{w}_s = \frac{\sum_{i=1}^{s} \bar{\tilde{p}}_i}{\lambda(1 - P_0)} - \frac{1}{\lambda} + \beta
\]

3. Numerical calculation and computer simulation

In order to test the validity of the theories, the \( M_x \) Poisson distribution come)/D(fixed time service)/1(one server)/D (fixed time delay) /S (The number of buffer) /FCFS[first come, first service ] model can be simulated. Theories and computer simulation will use the same parameters.

Load is define as \( p = \lambda(\gamma + \beta) \). Example: (1) load \( p = \lambda(\gamma + \beta) = 0.2 \) (The parameters: arrival signal rate \( \lambda = 0.02 \), intermittent time \( \gamma = 4 \) slots, service time \( \beta = 6 \) slots, \( \gamma_1 = 1 \) slot ) ; (2) \( p = 0.6 \) (The parameters: \( \lambda = 0.06 \), \( \gamma = 5 \) slots, \( \gamma_1 = 1 \) slot ) ; (3) \( p = 0.9 \) (The parameters: \( \lambda = 0.09 \), \( \gamma = 5 \) slots, \( \gamma_1 = 1 \) slot ) . The relationship of packet time delay and buffer S can be
obtained. The simulation value and theoretical value is present in table 1, table 2 and table 3.

Moreover, from the above forms, we can obtained the relationship between mean time delay $\tilde{w}_s$ and buffer limited $S$ (Figure 1). The relationship between mean time delay $\tilde{w}_s$ and load $\rho$ (Figure 2). The theoretical value and simulation value are too close to give their differences in figure 1 and Figure 2, so the value of theory and simulation are sharing the same curve together.

![Image](attachment:image.png)

Figure 1 The Relationship between mean time delay $\tilde{w}_s$ and buffer limited $S$

4. Conclusion:

Through reconstructed probability space, A new queuing model $G/G/1(G)/S/FCFS$ is proposed for integrated service with limited buffers in loop LAN. This paper also analysis the system performance such as the mean queue length of the packet and the mean time delay, improved system performance base on the literature [5,8-10]. The parameters of model are very well. In the simulation experimentation, select 30 samples, confidence level is 95 percent. The results of computer simulation show their concordance with the theoretical analysis.

In the developed model, we can get performance of the system model, just need the follow parameters: the mean arriving rate of the packets; the mean serving time and the mean time delay. Furthermore, $\lambda$ and $\beta$ are variable in the model, so that it can support the speed-based control services (Through dynamic control or feedback loop to regulate the packet sent speed or transmission speed). This model also supports any buffer queuing asymmetrical service by regulating parameter $\gamma$, intermittent time.

![Image](attachment:image.png)

Figure 2 The Relationship between mean time delay $\tilde{w}_s$ and load $\rho$

Reference


Table 1: The Relationship between Mean Time Delay $\bar{w}_s$ and Buffer Limited S with same Load of Packet Switched (Load $\rho=\lambda(\gamma+\beta)=0.2$)

<table>
<thead>
<tr>
<th>S</th>
<th>$\bar{q}_s$ (Theory)</th>
<th>$\bar{q}_s$ (Imitate)</th>
<th>$\bar{w}_s$ (Theory)</th>
<th>$\bar{w}_s$ (Imitate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.24494×10^{-2}</td>
<td>(2.25618±0.00323)×10^{-2}</td>
<td>6.11989</td>
<td>7.00217±0.02761</td>
</tr>
<tr>
<td>3</td>
<td>2.5240×10^{-2}</td>
<td>(2.5240±0.00198)×10^{-2}</td>
<td>7.74169</td>
<td>7.74207±0.00515</td>
</tr>
<tr>
<td>5</td>
<td>2.4380×10^{-2}</td>
<td>(2.4381±0.00267)×10^{-2}</td>
<td>7.74996</td>
<td>7.74159±0.00562</td>
</tr>
<tr>
<td>$\infty$</td>
<td>2.24390×10^{-2}</td>
<td>(2.2350±0.00199)×10^{-2}</td>
<td>7.75000</td>
<td>7.74290±0.00838</td>
</tr>
</tbody>
</table>

Table 2: The Relationship between Mean Time Delay $\bar{w}_s$ and Buffer Limited S with same Load of Packet Switched (Load $\rho=\lambda(\gamma+\beta)=0.6$)

<table>
<thead>
<tr>
<th>S</th>
<th>$\bar{q}_s$ (Theory)</th>
<th>$\bar{q}_s$ (Imitate)</th>
<th>$\bar{w}_s$ (Theory)</th>
<th>$\bar{w}_s$ (Imitate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.59324×10^{-2}</td>
<td>(9.5759±0.012076)×10^{-2}</td>
<td>6.62731</td>
<td>7.05655±0.01816</td>
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<tr>
<td>4</td>
<td>0.18072</td>
<td>(1.80923±0.002590)×10^{-1}</td>
<td>12.05881</td>
<td>11.78985±0.02293</td>
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<tr>
<td>8</td>
<td>0.192561</td>
<td>(1.92724±0.001391)×10^{-1}</td>
<td>12.94541</td>
<td>12.96474±0.04060</td>
</tr>
<tr>
<td>14</td>
<td>0.193041</td>
<td>(1.93421±0.000929)×10^{-1}</td>
<td>12.99982</td>
<td>13.01465±0.04133</td>
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<tr>
<td>$\infty$</td>
<td>0.193043</td>
<td>(1.93143±0.000891)×10^{-1}</td>
<td>13.00000</td>
<td>13.01561±0.05650</td>
</tr>
</tbody>
</table>

Table 3: The Relationship between Mean Time Delay $\bar{w}_s$ and Buffer Limited S with same Load of Packet Switched (Load $\rho=\lambda(\gamma+\beta)=0.9$)

<table>
<thead>
<tr>
<th>S</th>
<th>$\bar{q}_s$ (Theory)</th>
<th>$\bar{q}_s$ (Imitate)</th>
<th>$\bar{w}_s$ (Theory)</th>
<th>$\bar{w}_s$ (Imitate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.34892</td>
<td>0.34926±0.00170</td>
<td>9.874242</td>
<td>10.02953±0.00362</td>
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<tr>
<td>6</td>
<td>1.09186</td>
<td>1.09142±0.00295</td>
<td>25.27020</td>
<td>24.43051±0.12512</td>
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<td>10</td>
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<td>30</td>
<td>2.32976</td>
<td>2.41957±0.03671</td>
<td>48.75566</td>
<td>49.03597±0.50388</td>
</tr>
<tr>
<td>$\infty$</td>
<td>2.40907</td>
<td>2.40907±0.03214</td>
<td>50.50000</td>
<td>50.03254±0.49085</td>
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