A New Polling Architecture for Network with Non-exhaustive Multiple Token Mechanism

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Abstract

The multichannel network is one of the solutions to provide a huge network bandwidth, and the token passing is the scheme to guarantee the response in determinate interval and to provide the property of traffic collision-free. In this paper we study a multiple token system considered as a symmetric multiqueue, these queues are served in cyclic order by a number of identical tokens (servers). The discipline of service in this system is the non-exhaustive (Limited-1 service) type in which a token is permitted to serve at most one packet at a node (queue) per one token cycle. A node can simultaneously use more than one token at the same time. The study is concerned with the general case in which the walking time between nodes is not zero. By the renewal theory, we derive an approximate expression of the mean intervisit time in this system.

1. Introduction

The employment of data and computer communication has been getting more frequent and popular, and the messages communicated through network have converted from text mode to multimedia. The conventional network is difficult to meet the demand of transmission for these multimedia information and network application such as World Wide Web (WWW). People usually complain of their networks for the slow response, especially when they are interactively working with a network server. Therefore, it is worthy to study how a network provides people with a greater bandwidth, the multimedia capability and the real-time ability.

The multichannel network is one of the solutions to increase bandwidth, yet it will should keep the network compatibility. Multichannel network can be implemented by many channels attached to each station [1], and it can also be realized by a single physical medium using the Frequency Division Multiplexing (FDM), Time Division Multiplexing (TDM) or Wavelength Division Multiplexing (WDM) [2]. A network with the greater bandwidth can provide the better multimedia capability. Token passing is the scheme to guarantee the response in determinate interval. Base on the advantages of multichannel and token passing, we construct a multiple token system. The single token systems have been studied in the literature, furthermore they have the results included a non-exhaustive (limited-1 service) system [3][4][5][6].

This papaer is divide into five sections. In Section 2, we describe the system architecture. In Section 3, we describe the system model and introduce some definitions and assumptions. In Section 4, we translate the above model into superposition of renewal process. Use the renewal theory and observe the phenomenon to derive an approximate solution for mean intervisit time. Approximating the probability density functions in a manner simular to that in [10] can help the derivation of solution. Section 5 presents some concluding remarks and directions for future work.

2. System Architecture

The multiple token system can be implemented in bus or ring topology. Logically, the nodes are attached into many independent channels, and there is a single token circulating around its own channel. The bus topology is shown in Fig. 1, there are N nodes and m channels which a single token circulating around logically.

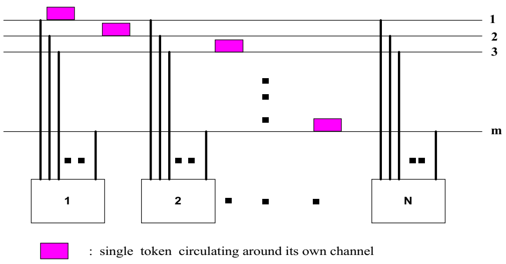

Fig. 1. The multiple token system topology

The architecture of multiple token system is shown in Fig. 2. It is divided into four layers called high layer, Logic Link Control (LLC), Medium Access Control (MAC) and physical layer. Every nodes has an independent Medium Access Control (MAC) layer for each ring to carry out the ring maintenance. Each node has m transmitters (TX_j) and m receivers (RX_j), which have the function to transmit packet or token frames to three layers. The main part of MAC layer called Access Control Unit (ACU) contains the process of token transmitted from RX_j and the discipline of service for the packets generated from LLC layer. The design of mechanism about ACU will be introduced in the next section.

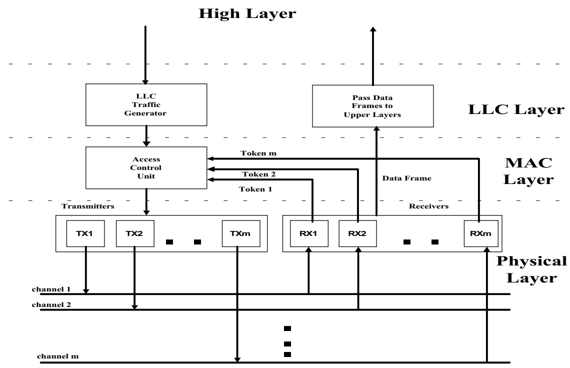

Fig. 2. The multiple token system architecture

3. The Model

In order to analyze the operation of a node in detail, an analytical model of this network is proposed as show in Fig. 3. Here are the assumptions and notations used in our analysis. The system we consider consists of N symmetric nodes (queues) each of which has an infinite buffer, served cyclically by m identical tokens (servers). There are m channels in the system, and each channel has its own independent token. All channels posses the same characteristics and every node uses the same operation model shown in Fig. 3. The broad arrows in the figure correspond to the flow of data packet and the narrow ones represent the flow of token. Packets generated from LLC layer enter the queue (infinite buffer) then through the high speed $1 \times m$ packet switch to the one packet size $buffer_j$ that attached to the transmitters (TX_j), where j=1,2,…,m. Because the packet can be transferred to each buffer from the $1 \times m$ packet switch as soon as possible, the buffer always has packet in it except the LLC layer queue is empty. Additionally each buffer at most store one packet, so the buffer size is the maximum size of a data packet frame. The discipline of token service is Limited-1, that is at most one packet will be served by the token in a token cycle. A node can simultaneously use more than one token at the same time.

The token walking time from node i to node i+1 mod N, i =0,1,…,N-1, is assume to be a random variable u. Its mean value is $\bar{u}$.

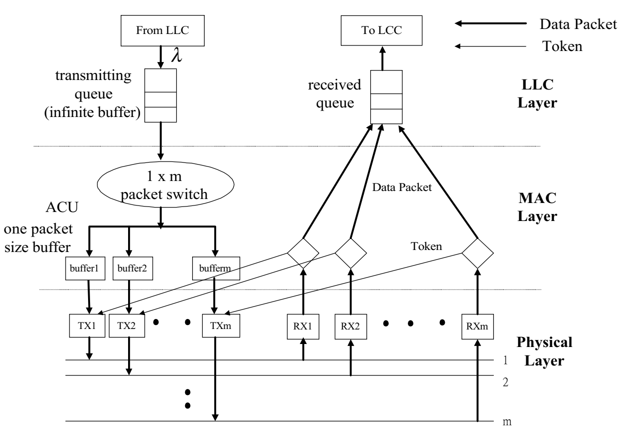

Fig. 3. The analytical model of the multiple token system(operating in a node)

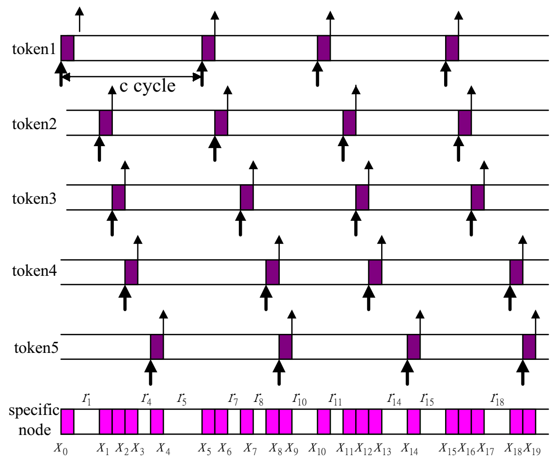

Fig. 4. Relation token cycle time c and specific node intervisit time r

In what follows we take the viewpoint of a specific node, *i*. Thus, we define two type of cycles [7]:

(1) c , the cycle from the point of view of token *i* which is defined to be the time lapse between the token's departure from node *i* to its return to the same node.

(2) r , the cycle from the point of view of specific node *i*. This is defined as the time between the departure of a token from node *i* to the arrival of next token to this node. *r* is the node intervisit time.

Fig. 4 shows an example of a five-token system. The viewpoint of the specific node is used. Each node vacation time r_k, is follow by a virtual service time x_k where the subscript *k* refers to the time sequence of cycles and node service times [8]. The virtual service time will be an actual service time if the node's queue is not empty. Otherwise, it is zero. The broad arrows in the figure correspond to the token arrivals at the specific node while the narrow ones represent token departures. Because we adopt the Limit-1 service discipline, the reasons for token departures has two: (1) the buffer is empty (2) has served one packet. Due to the specific node can use more than one token at the same time, the node service time may be formed by many token service time x_k, correspond to the intervisit time r_k is zero.

The arrival of packets at node *i*, where *i* =0,1,…,*N*-1, is assume to form Poisson process with a mean arrival rate of λ.

We define α as the probability that average number of packet served during a cycle (*r* cycle). In steady-state (under equilibrium), this probability is given by

$$\alpha = \lambda(\bar{r} + \bar{x}) < 1$$

where $\bar{r}$ is average node cycle time (mean intervisit time) and $\bar{x}$ is the average virtual service time at a node. Besides we let the actual service time at any node, *i,* be a random variable, h , with mean $\bar{h}$, for *i* = 0,1,…,*N*-1. Under equilibrium the virtual service time *x* is related to the service distribution of *h*, by

x = *h* with probability α

0 with probability 1-α

Besides the Laplace-Stieltjes Transform (LST) of *x* is given by

$$\phi_s(s) = \alpha\phi_h(s) + 1 - \alpha$$

where $\phi_h(s)$ is the LST of $F_h(t)$. Thus the first moment of *x* is given by $\bar{x} = \alpha\bar{h}$ and α can be expressed as

$$\alpha = \lambda(\bar{r} + \bar{x}) = \lambda(\bar{r} + \alpha\bar{h}) = \frac{\lambda\bar{r}}{1 - \lambda\bar{h}} \qquad (1)$$

4. Model Analysis

The multiple token operation in a station is presented in last section. It can be realized that the phenomena of token operation will be considered as renewal process. Thus it is similar to the behavior of renewal process when we analyze the model. About renewal process has developed into general results in probability theory given by renewal theory [9]. By study of renewal theory we derive the formula skillfully. We translate Fig. 4 into the superposition of five renewal processes shown in Fig.5.

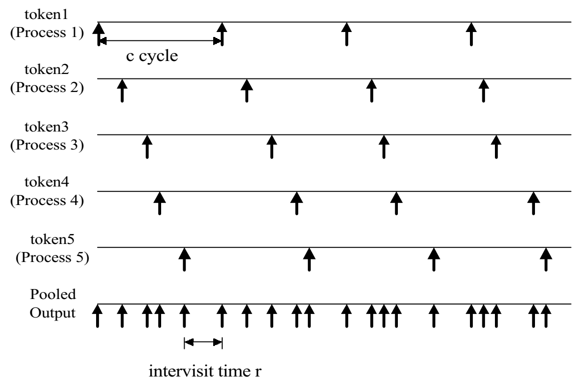

Fig. 5. Superposition of five renewal processes

We can take five independent tokens for five independent ordinary renewal processes in operation simultaneously, all with the same *p.d.f.* of token cycle time *c*. On the other hand, a process (Pooled Output) formed by superposing several ordinary renewal processes and can be used to discuss node intervisit time *r*.

We assume that m processes (tokens) are in use simultaneously. If the individual processes are Poisson process of rate σ, the pooled process is a Poisson process of rate $m\sigma$. The mean intervisit time between renewals is easily seen to be μ/m, where μ is mean token cycle time , i.e. $\mu = \bar{c}$. In general, it is true for Poisson renewal process. However, without loss of generality we consider token cycle time *c* to be such a renewal process.

According to the analysis of above, first we should derive the mean cycle time $\bar{c}$. Fig. 6 shows the multiqueue and multiple token system. Using the dependence assumption between token's cycles, the Laplace transform of the *p.d.f. c* is given by [10].

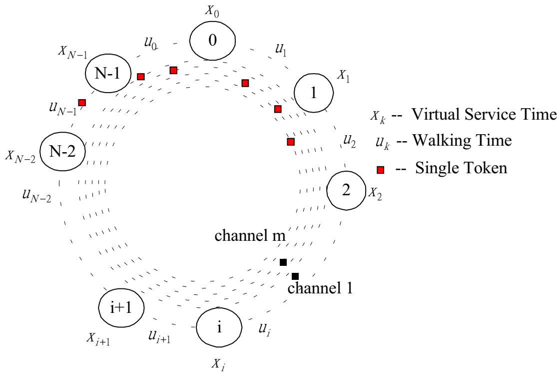

Fig. 6. multiqueue and multiple token system

$$\phi_c(s) = \left(\prod_{l=0}^{N-1}\phi_u(s)\right)\cdot\left(\prod_{\substack{l=0\\ l\neq i}}^{N-1}\phi_x(s)\right) = \left(\prod_{l=0}^{N-1}\phi_u\right)\cdot\left(\prod_{\substack{l=0\\ l\neq i}}^{N-1}[\alpha\phi_h(s)+1-\alpha]\right) \quad (2)$$

Using equation (2)

$$\bar{c} = N\cdot\bar{u} + (N-1)\cdot\alpha\cdot\bar{h} \quad (3)$$

By the study of renewal process the mean intervisit time $\bar{r}$ is approximate given by

$$\bar{r} \approx \frac{\bar{c}}{m} = \frac{N\cdot\bar{u}+(N-1)\cdot\alpha\cdot\bar{h}}{m} \quad (4)$$

Using equation (1)

$$\bar{r} \approx \frac{N\cdot\bar{u}+(N-1)\cdot\frac{\lambda\bar{r}}{1-\lambda\bar{h}}\cdot\bar{h}}{m}$$

$$\approx \frac{N\cdot\bar{u}}{m} + \frac{(N-1)\lambda\bar{r}}{m(1-\lambda\bar{h})}\cdot\bar{h}$$

$$\bar{r}\left(1-\frac{(N-1)\cdot\lambda\cdot\bar{h}}{m(1-\lambda\bar{h})}\right) \approx \frac{N\cdot\bar{u}}{m}$$

$$\therefore \bar{r} \approx \frac{N\cdot\bar{u}}{m}.\left(1-\frac{(N-1)\lambda\bar{h}}{m(1-\lambda\bar{h})}\right)^{-1} \quad (5)$$

We set *N*=20, *m*=10,15,20, $\bar{h}=0.18$ (*sec*) and $\bar{u}=0.00125$ (*sec*). The results and the calculated values from equation (5) are shown in Fig. 7. In this figure, it is apparent that $\bar{r}$ can be reduced by increasing m. Besides we can predict the fact if m approach to infinite large the $\bar{r}$ is approach to zero. That is to say when a large number of tokens in this system, we can neglect the random variable *r*, which is complicated in discussing M/G/m system [11]. Thus we can simplify the M/G/m as M/M/m system [11].

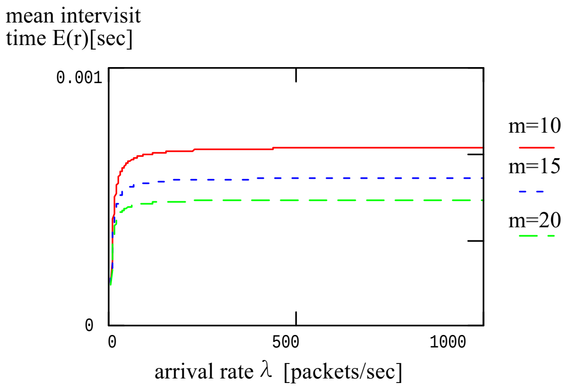

Fig. 7. arrival rate v.s mean intervisit time

5. Conclusions

In this paper, a multiple token system in which a node can use more than one token at the same time, adopting non-exhaustive (Limit-1 service) discipline is investigated. In order to derive approximate solution, it is found the system (model) we construct can appropriately translate the superposition of renewal process. From analysis we can obtain some results under the condition a large number of tokens. It is obviously seen that an approximate mean waiting time to M/G/m is difficult to achieve. Hence, the future work we devote to solve such problem using renewal theory, point processes [12], and other stochastic processes [13][14].

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