Performance Simulation of a Token Ring: Users' View

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Abstract

Most of performance studies for local area networks (LANs) have been based upon the average transmission time of a packet (or frame) as a performance criterion. Their models have been developed for the performance measure of the low-level physical and data link layers of LANs. They predict the relative efficiency of different network topologies, transmission media, and access protocols. However, they often fail to measure an end-user's message transmission time. A realistic performance measure for end-users should attempt to measure the average transmission time of the entire user message.

In this study, we concentrate on the performance of a token ring LAN system from a users' view. A simulator has been developed to quantitatively measure the elapsed time of an end-user's message.

Simulation results show that the performance of the network with the exhaustive service (ES) service strategy is much better than that of the network which works with the non-exhaustive service (NES) strategy. Also, the measure based on user messages are compared with the conventional performance measure based on packets and shows differences in performance measurement.

1. Introduction

Local Area Networks (LANs) are becoming an essential part of most office and factory environments. Therefore the evaluation of the capability of LANs that use different communication protocols and strategies to handle the desired message loads is becoming important for both network designers/installers and end-users.
message. Two fundamental service disciplines, the exhaustive service (ES) and the non-exhaustive service (NES), are examined in this research. One of the major objectives of this study is to measure the average transmission time for user messages, not for packets. The second objective is to compare the performance characteristics of an Exhaustive Service (ES) discipline and a Non-Exhaustive discipline of a token ring system in users' view.

2. Exhaustive Service discipline (ES) and Non-exhaustive Service Discipline (NES) in Token Ring LANs

Token ring is one of the oldest ring control techniques and is referred to as the Newhall loop [1]. It has become the most popular ring access technique and standardized by the ANSI/IEEE Standard Board [9]. A Token Ring network can be characterized as a sequence of point-to-point links between stations, closed on itself. All messages travel over a fixed route from the station around the ring, passing through network interfaces at each station. A station which holds a token (the one having access to the medium) transfers information to the ring. The addressed (destination) station copies the information as it passes. All other stations repeat each bit received [9,10].

Once a station has captured a free token and therefore has access to the ring, there are two types of operation strategies: Exhaustive Service (ES) and Non-exhaustive Service (NES).

In the ES discipline, the station retains use of the ring until it has transmitted all the packets stored in its transmit buffer. This means that all the packets that have been cumulated for transmission are transmitted once the station receives the free token.

In the NES discipline, a station is allowed to transmit only a specified number of bits at each time it captures the token.

The ANSI/IEEE 802.5 standard specifies a timer, token-holding time (THT), which controls the length of time for a station to occupy the medium before the station releases the token. The quality of service given to individual stations depends on the rule defining the time which a station is allowed to transmit per access opportunity. In this study we examine the performance characteristics of the two extreme cases of the token holding time. One is the case that the THT is so short that a station can transmit only one frame (packet) per token (non-exhaustive service discipline). The other is the case that the THT is so long that stations can empty their transmit buffer completely on each transmission opportunity (exhaustive service discipline).

3. Simulation Model

Analytic and queuing models applicable to token rings have been extensively studied, primarily in the context of polling systems [5,6]. Since analytic models of complete network systems that include the characteristics of actual hardware and software through low-to-high level protocols have not been developed, we developed a simulator to achieve our research goals.

The simulator was implemented in a hierarchical fashion. The first level consists of the control program, the next level provides the token ring emulation, and the third level provides the statistics collection. In the

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Figure 1. Simulation Program Structure.
simulator, each node has a linked list queue to emulate its transmit buffer. The first level of the simulator, the control program, receives various input parameters from an operator in an interactive menu driven fashion to initialize the simulator and generate the first message for each node. The second level, the token ring emulator, does packetizing and framing of the message and puts the packets into its corresponding queue. The emulated control token moves around the token ring and cumulates the individual packet transmission time and message transmission time. Once an empty queue is found, a new message is generated. The generated message is packetized and the packets are put into queue. The flowchart of the simulator is given in Figure 1.

The simulator was run twice, once for the conventional performance measure by packet by packet and again for the measure for user's view by message by message. In the first run, the simulator is initiated by the creation of a packet generator. Statistics are collected at the end of the run. In the second run, the simulator attempts to imitate the token ring operations as realistically as possible. In real application, messages are generated by the user in the station (i.e., transport or higher user layers), and are passed for subsequent transmission to the medium access control (MAC) layer. If the message is longer than the maximum-information field length of a frame, the message is segmented into packets as shown in Figure 2. The packets are queued for transmission into transmit buffer. Similarly, the simulator generates the messages for each station, segments them into packets, and puts them in queue.

In the Exhaustive Service case, once a station gets a free token, it starts transmitting all the packets in its transmit buffer until it is emptied. Then it passes a free token to the next station in the ring. The elapsed time, from the user message's arrival at the sending station to the arrival at destination for the last packet of the user message, is collected for statistics.

In the non-exhaustive service a station is allowed to transmit only one packet once it receives a free token. Then it releases a free token. Again the elapsed time for the user message is collected for network performance measure.

4. Assumptions in Simulation Model

The following assumptions are included in the simulation model:

1. A single destination for each user message,
2. User messages (not packets) arrive at each node according to the Poisson distribution,
3. User message length is exponentially distributed and if the message is longer than the size of one packet, it is partitioned into several packets,
4. Propagation delay around the ring is 30 microseconds,
5. Channel data rate may be 1 Mbps, 4 Mbps or 16 Mbps, and
6. The packet format is the same as the IEEE 802.5 token ring packet format [9]. This means 13 bytes MAC header overhead plus 4 bytes LLC header overhead.

There are a number of parameters that affect the performance of the system and are therefore accepted by the simulator program as input:

1. The mean message length,
2. The maximum frame (packet) size allowed in a token ring,
3. The choice of exhaustive or non-exhaustive discipline,
4. The station latency (2 bit by default),
5. The number of nodes in the ring (100 nodes default, maximum 512), and
6. The ring propagation delay (30 micro-seconds default).

5. Simulation Results and Discussion

In order to get an accurate performance
prediction for the end-user, the message transmission time includes all the possible time delays in a real system. Then the simulator run a number of times to collect desired statistics.

5.1 An Example Simulation Model Description

An example configuration of a 100-node network was simulated with the assumptions of 2 bit time durations for station latencies, which is the same as the existing token ring VLSI chip set [11], and 30 μsec ring propagation delay. The simulator runs with the channel speed with choice of 1 M bps, 4 M bps, and 16 M bps, which are the channel speeds currently supported by vendors [12].

Table 1. Input Parameters in An Example Simulation.

<table>
<thead>
<tr>
<th>Mean Message Length</th>
<th>1K, 5K, 10K, 20K, 30K Byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Frame Size</td>
<td>1,024 LLC Data Frame</td>
</tr>
<tr>
<td>Working Mode</td>
<td>Exhaustive, Non-Exhaustive</td>
</tr>
<tr>
<td>Station Latency</td>
<td>2-bit Time</td>
</tr>
<tr>
<td>The Number of Node</td>
<td>100 node</td>
</tr>
<tr>
<td>Channel Speed</td>
<td>1M, 4M, 16M bit/second</td>
</tr>
</tbody>
</table>

5.2 Simulation Results and Discussion

The simulation quantities of primary interest were the average message transmission time and the normalized average transmission time (the average message transmission time/(average message length/channel speed)) for the comparison study with a conventional performance measures. The average message transmission time includes the local queuing time prior to transmission and real transmission time.

Several simulation results are plotted in Figures 3 through 7. Figure 3 shows the performance characteristic based on a conventional measure (a packet
by packet measure) with a small message size. In a light traffic, there is no big difference between the average transmission times in the exhaustive service and non-exhaustive service disciplines. With a high traffic, the transmission characteristic of the exhaustive service discipline is slightly getting better than that of non-exhaustive service discipline case. This means that the conventional performance measure on a packet-by-packet basis fail to exhibit the sharp difference between the performance of the exhaustive and the non-exhaustive disciplines.

Typical performance comparisons in users' view, for the several different cases, are given in Figures 4 through 7 for average message sizes of 5 Kbyte, 10 Kbyte, 20 Kbyte, and 30 Kbyte, respectively. It is observed that the performance differences between the two service disciplines is getting wider as user message size gets large. The token ring's performance working with exhaustive service discipline supports the remarkably better performance characteristics to the end users even the very low traffic case, and the differences between those two service discipline is more visible than in a conventional packet by packet measure. In fact, this is expected because the elapsed time (transmission time) for user messages have to be cumulated until the last packet has to be transmitted. In another words, since packets are transmitted one at a time, the elapsed time accumulates delay until the last packet of the user message is transmitted.

6. Conclusion

A token ring simulation model was developed to measure an actual performance in users' view. It was designed to characterize some of the factors captured from the higher level protocols. Simulation results show that, based on the average message transmission time with message by message measure, the performance of the exhaustive service discipline is remarkably better than that of the performance of the non-exhaustive discipline even in very low traffic, while the measured average transmission time on a packet-by-packet basis (a conventional performance measure), the difference in performance is even visible.

References


