PERFORMANCE EVALUATION OF INTERCONNECTED HETEROGENEOUS LOCAL AREA NETWORKS

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ABSTRACT

A simulation model for the interconnected local area networks (LAN's) is presented in this report. The interconnected networks consist of token ring, fiber distributed data interface (FDDI) network and carrier sense multiple access with collision detection (CSMA/CD) network. In the interconnected networks, the local users on the token ring send intra- or inter-network packets. The inter-network packets are transmitted to CSMA/CD network via gateways and FDDI network. In the meantime, the local users on the CSMA/CD network generate intra-network packets. The model focuses on the end-to-end delay between two end users on token ring and CSMA/CD network.

1. INTRODUCTION

This report considers the interconnection of local area networks (LAN's), token ring and CSMA/CD network, each of which connects a large population of users. Both LAN's are connected to FDDI network. Since both LAN's and FDDI network have different protocols, gateways should be inserted between LAN's and FDDI network to convert packets from one protocol to another. Since the packet sizes in those networks are different, packet fragmentation and reassembly are sometimes necessary. These functions are performed by gateways.

Our token ring includes the priority operation and its protocols are based on prioritized token ring with reservation (R-PTR) [1] which is similar to IEEE standard 802.5 [2]. The differences between them are described in section 2. The protocols for FDDI and CSMA/CD networks are based on ANSI standard X3.139 [3] and IEEE standard 802.3 [4], respectively.

In this report, we propose a simulation model for evaluating the end-to-end delay on the interconnected heterogeneous LAN's. The report is organized as follows. In section 2, the interconnected networks under study are described. The description about each network is also given. The model is given in section 3 and the performance measures and analysis are given in section 4. Finally, conclusion is given in section 5 with suggestions for some future research topics.

2. INTERCONNECTED HETEROGENEOUS NETWORKS

Figure 1 shows the interconnection of heterogeneous LAN's. We assume that inter-network packets are only transmitted from token ring to CSMA/CD network.

2.1. Token Ring

In token ring, a token circulates around the ring when all stations are idle. A station wishing to transmit must wait until it detects a free token passing by. If it seizes a free token, it changes the free token to a busy token and transmits its packet which is appended to the end of the busy token. When the station completes the data transmission, it purges its transmitted packet and changes the busy token to a free token.

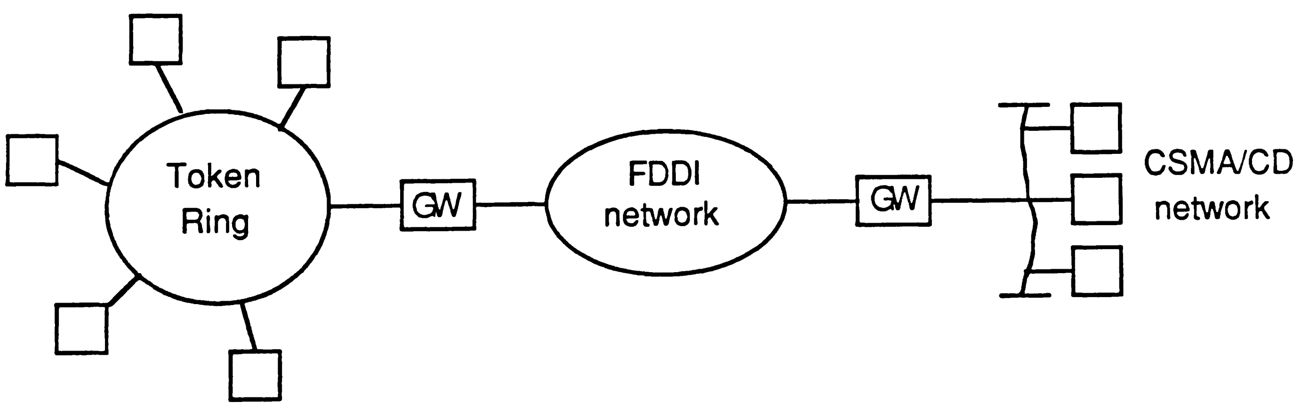

Figure 1. Interconnected Heterogeneous Networks

In the R-PTR, the priority operation is accomplished by assigning a priority to the free token. During one-round circulation, a busy token collects the information about the highest priority of all access waiting packets at all stations. When a new free token is generated, its priority is given by the highest level of priority.

The main differences between the R-PTR studied in this report and the IEEE-PTR are as follows.

First, in the IEEE-PTR, the priority of a new free token is given by the maximum of the current token priority and the highest priority of access waiting packets known to the busy token during its one-round circulation. In the R-PTR, the priority is given by the highest priority of the access waiting packets.

Second, in the IEEE-PTR, two types of stacks, S_r and S_x, are used to store old and new values of token priority, respectively. On the contrary, such stacks are not used in the R-PTR.

Since each station maintains its own copy of those stacks in IEEE-PTR, the space for the stacks becomes large in the situation of very large number of stations. In addition, the manipulation of the stacks makes the IEEE-PTR rather complex. Shen, Masuyama, Muro and Hasegawa [1] prove that the performance of the R-PTR is not inferior to that of the IEEE-PTR under almost all traffic load environments.

Because of the above reasons, we use the R-PTR as our token ring model and the model is described in section 3.

2.2. FDDI network

The FDDI provides a high-bandwidth (100 Mbits/sec), general-purpose interconnection among computers and peripheral equipment using fiber optics as the transmission medium in a ring configuration. As with IEEE 802.5, the FDDI medium access control (MAC) protocol is a token ring. The basic operation of token ring is very similar for both 802.5 and FDDI.

Two main differences between 802.5 and FDDI can be observed. First, in FDDI, a station seizes a token by absorbing while in 802.5, a station seizes a token by flipping a bit. Second, in FDDI, a station generates a new token as soon as it completes packet transmission while in 802.5, a station releases a new token when it completes transmission of its packet and begins to receive its packet. Because of the high bandwidth, these techniques are needed.

The priority operation used in 802.5 does not work in FDDI because a new token is created before the transmitted packet returns to its originating station.

FDDI supports two classes of service: synchronous and asynchronous. The synchronous class of service is used for those applications whose bandwidth and response time limits are predictable in advance. The asynchronous class of service is used for those applications whose bandwidth requirements are less predictable or whose response time requirements are less critical.

A target token rotation time (TTRT) is negotiated during ring initialization and each station stores the same value for TTRT. Each station has a known allocation of synchronous bandwidth. The allocation must be set such that:

$$\sum SA_i + D\_Max + F\_Max + Token\_Time \leq TTRT$$

where

SA_i	allocation for station i
D_Max	maximum ring latency
F_Max	time required to transmit a maximum length frame
$Token\_Time$	time required to transmit a token.

Asynchronous bandwidth is controlled by two classes of tokens : nonrestricted and restricted token. In the case of nonrestricted token, asynchronous bandwidth is time-sliced among all requesters, while in the case of restricted token it is dedicated to a single extended dialog between specific requesters. Figure 2 depicts the complete capacity allocation scheme.

The network begins operation in nonrestricted token mode. A station captures a nonrestricted token, transmits the first frame of the dialog to the destination station, and then issues a restricted token. Only the station that received the last frame may transmit asynchronous frames using the restricted token. Restricted token mode is terminated when the terminating station captures a restricted token, transmits its final dialog frame(s), then issues a nonrestricted token.

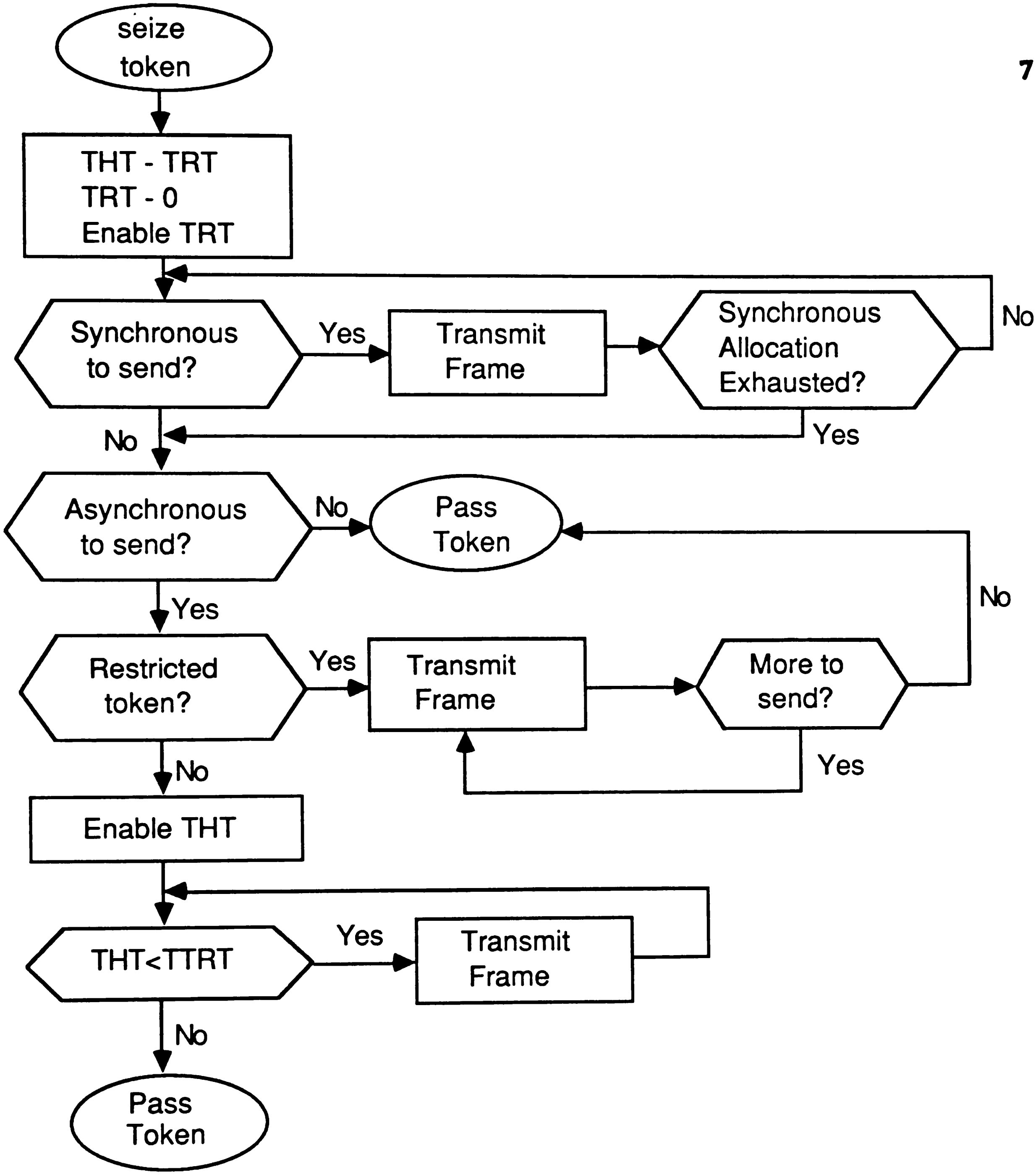

Figure 2. FDDI Capacity Allocation Scheme

2.3. CSMA/CD network

In CSMA/CD network, a station wishing to transmit must listen to the network in order to find out whether any transmission is in progress. If the station detects any transmission, it defers its transmission until the end of the current transmission. If a collision is detected during transmission, the station ceases transmitting the packet and transmits a brief jamming signal to assure that all stations know there has been a collision. After transmitting the jamming signal, the station remains silent for a random amount of time (backoff) before attempting to transmit again. When the number of attempts becomes 16, the station gives up the transmission and reports an error.

The backoff delay is determined by a controlled randomization process called "truncated binary exponential backoff". The delay is an integer multiple of slot time. The number of slot times to delay before the n-th retransmission attempt is chosen as a uniformly distributed random integer r in the range

$$0 \le r < 2^k \qquad \text{where} \quad k = min(n, 10)$$

3. MODEL DESCRIPTIONS

Our model is shown in Figure 3 and can be characterized by the following assumptions:

(1) A stream of packets arrives at each station on token ring and CSMA/CD network according to Poisson process with mean values λ_1 and λ_2, respectively. In addition, the arrivals on both networks are independent.

(2) Packet length is independently exponentially distributed.

(3) Each station has only one buffer whose size is infinite.

(4) In token ring, the priority level of a packet is a uniformly distributed random integer between 0 and 7. "Round-robin" packet transmission strategy is considered.

(5) Gateway is considered as an infinitely buffered queue.

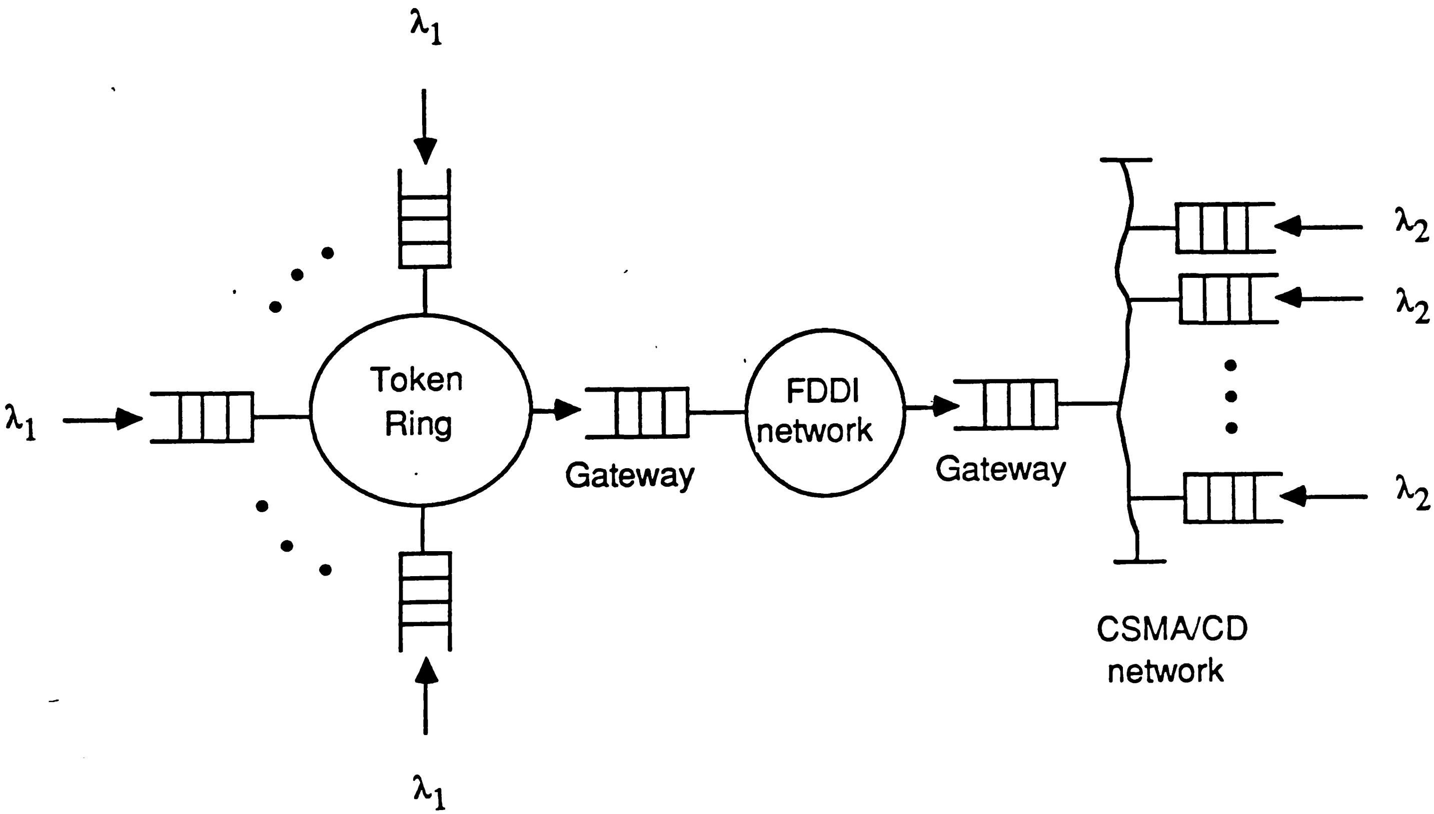

Figure 3. Model for Interconnected Heterogeneous Networks

Most parameters for simulation are given interactively during execution. Each station on token ring generates intra- or inter-network packets. The ratio of both packets is also determined interactively.

If we assume that in token ring a token holding time is 10 msec and a bandwidth is 4 Mbits/sec, then maximum frame size is 5000 bytes. Maximum frame sizes for FDDI and CSMA/CD networks are 4500 bytes and 1518 bytes, respectively. Since each network has a different maximum frame size, packet fragmentation and reassembly are sometimes necessary. Both functions are performed by gateway. The basic packet conversion, fragmentation and reassembly functions on gateway are resolved by adding time interactively to service time of gateway queue.

4. PERFORMANCE MEASUREMENTS

In our simulation model, the end-to-end delay between two end users on token ring and CSMA/CD network is obtained for several cases. When different values are assigned to a certain parameter, the other parameters have the following values.

Token ring :

Number of stations : 30

Transmission rate : 4 Mbits/sec

Station delay : 10 micro-seconds

Ring length : 4 Km

Token holding time : 10 milli-seconds

Mean packet length : 3000 bytes

Mean packet inter-arrival time : 0.3 seconds

FDDI network :

Number of stations : 2

Transmission rate : 100 Mbits/sec

Ring length : 20 Km

Targer token rotation time : 5 milli-seconds

CSMA/CD network :

Number of stations : 50

Transmission rate : 10 Mbits/sec

Slot time : 51.2 micro-seconds

Mean packet length : 1000 bytes

Mean packet inter-arrival time : 0.2 seconds

The simulation results for different parameters of token ring are shown in Figures 4, 5 and 6. Consequently, the end-to-end delay increases as the number of stations on token ring increases or mean packet length increases. The delay decreases as mean time between arrivals increases.

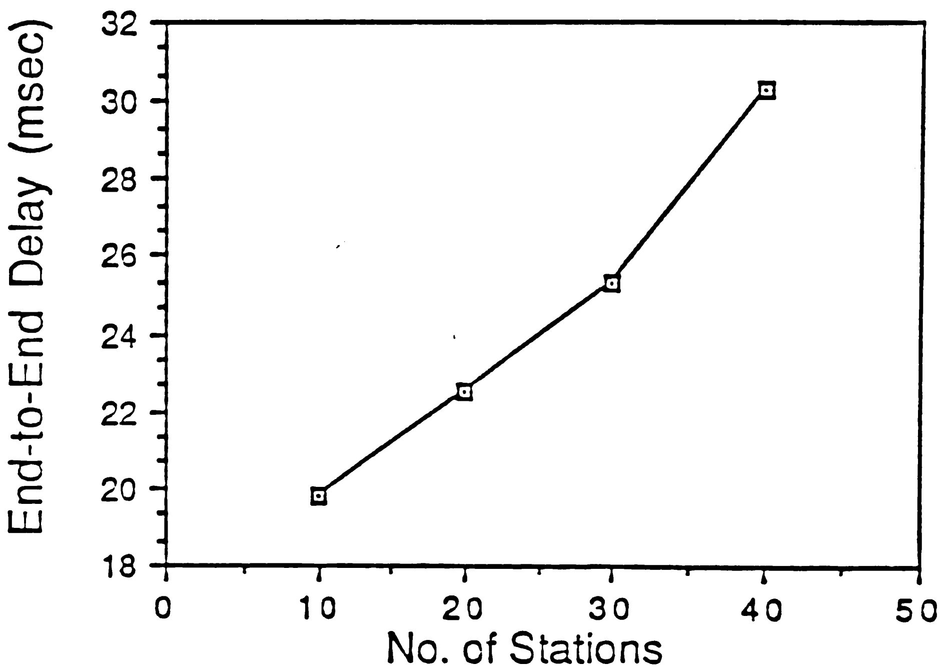

Figure 4. End-to-End Delay vs. No. of Stations

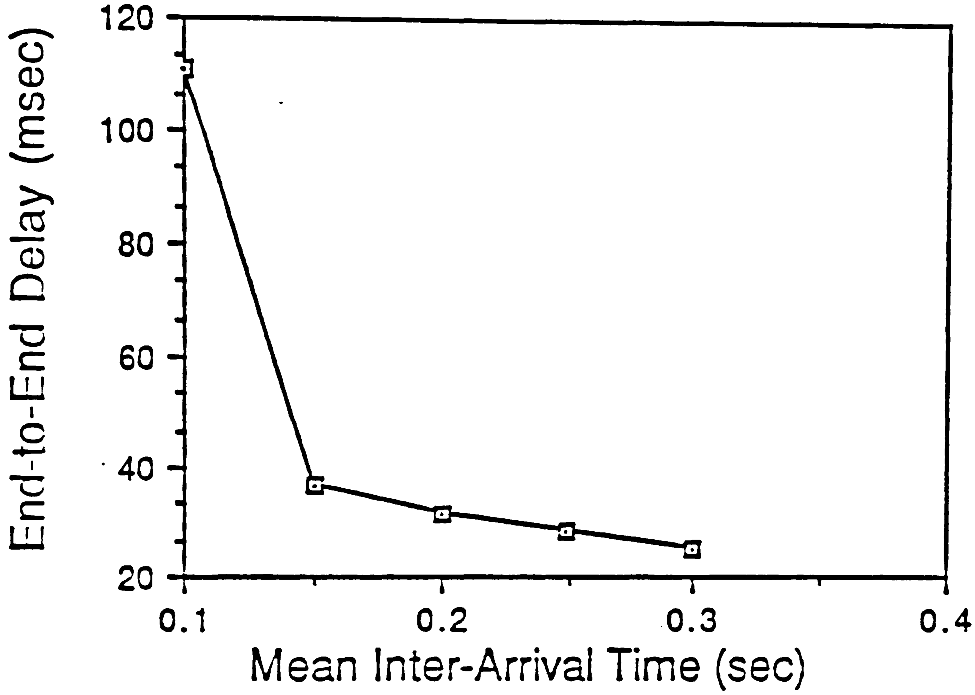

Figure 5. End-to-End Delay vs. Mean Inter-arrival Time

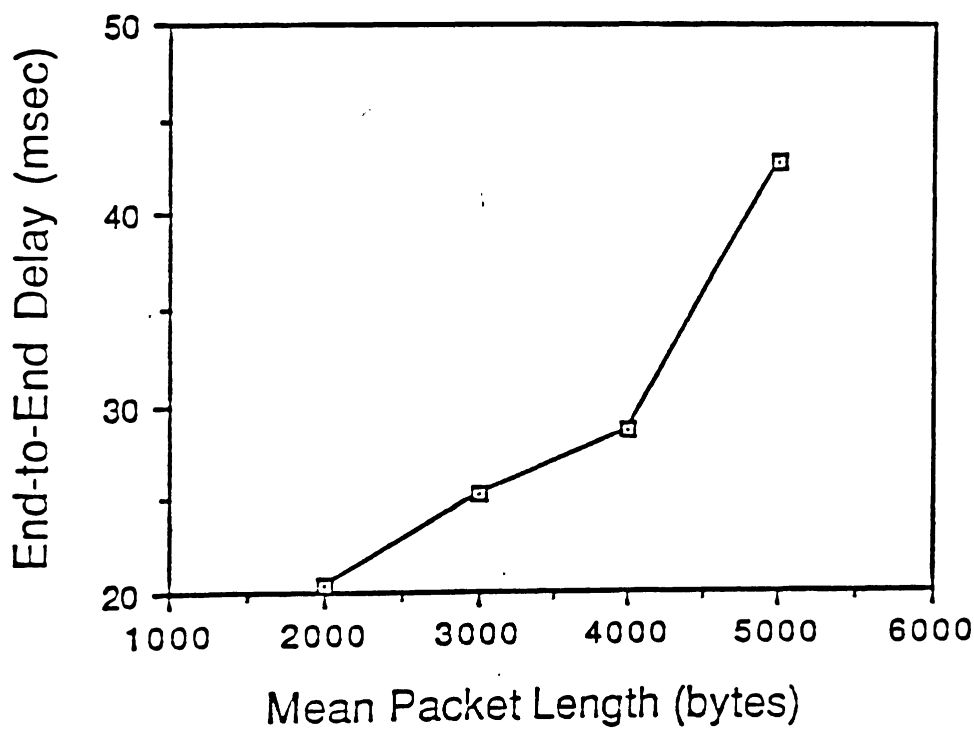

Figure 6. End-to-End Delay vs. Mean Packet Length

Figures 7,8 and 9 graphically show the simulation results for different parameters of

CSMA/CD network.

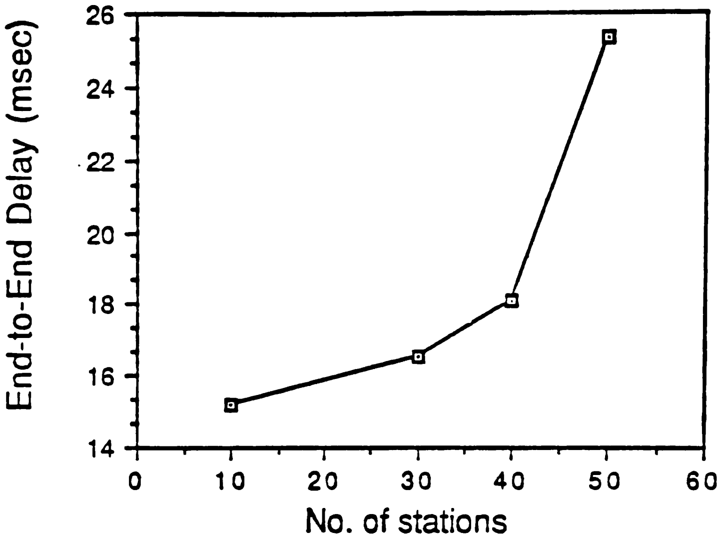

Figure 7. End-to-End Delay vs. No. of Stations

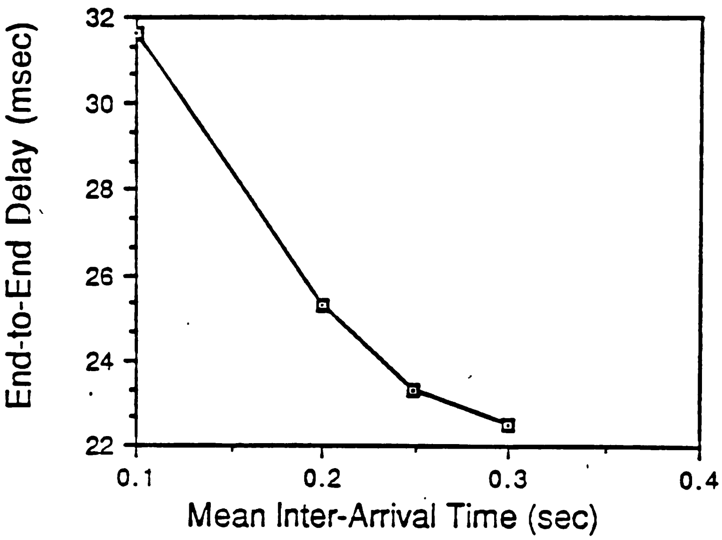

Figure 8. End-to-End Delay vs. Mean Inter-arrival Time

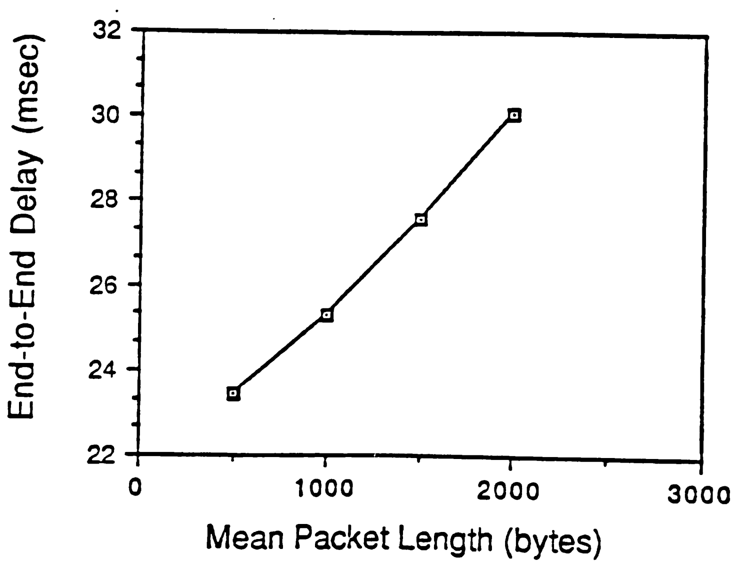

Figure 9. End-to-End Delay vs. Mean Packet Length

5. CONCLUSIONS AND FUTURE RESEARCH WORKS

We have proposed a simulation model for evaluating the end-to-end delay on the interconnected heterogeneous LAN's. We have tested our simulation model for several cases and obtained resonable measurements.

This work calls for further research. Efforts should be made to develop an analytic model for each network. And then those models are combined to find an analytic model for the interconnected heterogeneous networks. After obtaining some measurements from the analytic model, we compare them to the measurements for simulation model to validate the analytic model.

The interconnected heterogeneous networks can be extended by attaching another network to FDDI network via gateway. The above procedures could be applied to evaluate performances of the extended networks.

REFERENCES

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