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Performance Comparison between Expressnet and FDDI for Integrated Voice and Data Traffic

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음성과 데이타의 통합트래픽에 대한 Expressnet과 FDDI의 성능비교

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In this study, we compare performance of priority schemes of FDDI and Expressnet for integrated voice and data traffic through simulation. The voice capacity of FDDI is higher than that of Expressnet for all cases considered. When compared to Expressnet, FDDI achieves a higher data throughput for file transfer traffic, but it incurs a longer delay for interactive data traffic.

이 연구에서는 음성과 데이타가 통합된 트래픽에 대하여 Expressnet과 FDDI의 성능을 비교하였다. 모든 시뮬레이션 결과에서 FDDI가 더 많은 음성 스테이션을 지원하는 것으로 나타났다. Expressnet에 비하여, FDDI가 파일전송형 데이타 트래픽에 대하여 높은 throughput을 보였으나 대화형 트래픽에 대해서는 긴 지연 시간을 보였다.

Key words : Integrated traffic, Medium Access Control, LAN

I. Introduction

Network traffic sources that impose different bandwidth requirements and delay constraints on a high speed LAN are broadly classified into two types: isosynchronous and asynchronous sources. Isosynchronous sources generate a fixed length of data at known, periodic time intervals. Isosynchronous traffic requires that the delay must be kept within a maximum allowable bound, but it can tolerate some error or loss during transmission. For example, for voice conversations between two stations over a local area network, the voice packets should be delivered to the destination within 100-200 ms, while a loss up to 1-2 percent is acceptable to the listener.[1)]

Asynchronous sources generate information at random times (the message may also be of random length). In general, asynchronous traffic can tolerate a relatively long delay, but normally the information must be delivered without loss or error. Typical examples of asynchronous traffic are data traffic generated by computer communication applications such as file transfer, e-mail, and remote login.

In order to meet the conflicting requirements of integrated traffic, many packet switching LANs proposed in the past have incorporated priority functions.[2),3),4),5)] Among them, FDDI and Expressnet are the most prominents examples of such protocols. In this study, we evaluate and compare the performance of the priorty schemes of FDDI and Expressnet for integrated voice and data traffic via simulation.

II. Description of Priority Schemes

1. Expressnet

In the priority scheme of Expressnet,[2)] two types of trains, the voice train and the data train are defined to allocate the bandwidth dynamically between voice and two types, and stations are required to transmit their packets only on the train of the corresponding type. To satisfy the delay constraint for the synchronous traffic, the data train is restricted to a fixed maximum length. The length of the voice train, however, is determined only by the number of voice stations and the voice packet length. In order to keep track of the alternating cycles of the two types of trains, each station maintains a flag which is complemented every time the *EOT* is sensed on the inbound channel.

A fare sharing of the bandwidth assigned to the data type stations is achieved as follows. In a cycle for the data train, each data type station is either in the *Active* state, if it has not transmitted in the current cycle, or in the *Dormant* state if it has. A station in the *Dormant* state switches to the *Active* state when the length of a subsequent data train does not reach
the predefined maximum limit. A station in the *Dormant* state is not allowed to contend for the bus. Tobagi et al.[2)] have evaluated the maximum number of voice type stations capable of being supported by the priority scheme described above.

2. FDDI

The priority scheme of FDDI defines two classes of service:[6)] synchronous service where a packet is transmitted whenever a station captures the token, and asynchronous service where access to the medium is controlled by the timed token rotation (TTR) protocol. Under the TTR protocol of FDDI, each station, during an initialization procedure, bids a target token rotation time (*TTRT*) that is equal to one-half the maximum acceptable delay of its synchronous packets, and the minimum such time is selected to become the *TTRT* of the system.

Under the TTR protocol, each station maintains two clocks: one measures the token rotation time *TRT*, the elapsed time since the receipt of the last token), and the other measures the token holding time (*THT*) that limits the transmission time of asynchronous packets. When a station captures a free token, it calculates the token holding time as $THT = TTRT - TRT$ and if the value is positive, the station can transmit multiple packets until the *THT* timer expires.

FDDI supports multiple priority levels for asynchronous service packets by assigning different time thresholds for each priority level. Using the above scheme, FDDI provides a guaranteed bandwidth and a bounded response time for synchronous service. Sevcik and Johnson[7)] have shown that the average *TRT* is bounded above by the *TTRT* and that the maximum *TRT* does not exceed the value of $2 \cdot TTRT$.

III. Simulations

In this section, the priority schemes Expressnet and FDDI are simulated for integrated voice and data traffic under various conditions

1. Voice Station Protocol

We use the following voice packetization protocol. The analog voice signal is encoded at a constant rate V bits/s. The voice sample is required to be transmitted within the maximum bound D_{max}. If it is not transmitted within D_{max}, the speech sample is discarded. The station accumulates the speech samples in a buffer of size B_{max} bits as they are generated. When the size of the accumulated speech samples in the buffer reaches B_{min} bits, the station forms a packet for transmission. The packet continues to grow until the station completes the transmission of the preamble. Since the speech sample is discarded when its waiting time in the buffer exceeds D_{max}, the maximum size of the voice sample in bits in the buffer is

$$B_{max} = D_{max}V. \qquad (1)$$

If the buffer becomes full prior to being able to transmit the speech packet, the station discards the oldest voice sample when a new sample generated. Therefore, the voice packet is of a variable length within minimum and maximum bounds. The minimum size of a speech sample packet in bits is given by

$$V_{\min} = B_{\min} + \frac{t_p}{C} \qquad (2)$$

where t_p is the preamble transmission time and C is the data rate in bits/s. The second term in (2) represents the speech samples generated while the preamble is being transmitted. Clearly, the maximum size in bits of the speech samples in a packet is $V_{max}=B_{max}$.

2. Data Station Protocol

An interactive data station generates packets based on the linear feedback model. The interarrival time of the packets is exponentially distributed with the mean chosen to provide the desired data traffic load. The length of an interactive data packet is fixed to 1000 bits (not including the preamble). A station performing a file transfer operation generates a new packet immediately after it completes transmission of a packet. The size of the file transfer packet is fixed to 5000 bits.

In this simulation, the *normalized offered load* a station i, denoted as G_i, is defined as the ratio of the transmission time T of a data packet to the mean interarrival time θ_i to the station. That is, $G_i = T/\theta_i$. By definition, the normalized offered load of a station performing a file transfer is unity. The total normalized offered load G of N stations is given by $\sum_{i=1}^{N} G_i$. The delay of a data packet is defined as the time measured from its arrival until the successful completion of transmission.

3. Network Parameters

The network parameters used in the simulations are listed in Table I.

Table I. Simulation Parameters

Parameters	Values
Network span	10 km
Bandwidth	100 Mb/s
End-to-end propagation delay	100 μs
Preamble transmission time	64 bit times
Packet overhead transmission time	80 bits times
Carrier detection time	20 bit times
Maxmum bound, D_{max}	1, 10, 100 ms
Data packet transmission time	1000, 5000 bit times
Voice encoding rate	64 kbps
Token size of FDDI	46 bit times
LOCOMOTIVE transmission time	46 bit times

In order to isolate the effect of topology, stations are assumed to be placed along a straight line with equal distance for all systems.[4] This configuration of stations is unfavorable to FDDI because, in general, the propagation delay of a ring is smaller than the two-way propagation delay of a bus when the two topologies are used to connect a set of stations. In the case of FDDI, the token size is 46 bits,[4] and the station delay is assumed to be the same as the carrier detection time of the proposed system and Expressnet. Since the *TI* and *TOI* are control packets like the token in FDDI, their size are assumed to be the same as the token size. The *LOCOMOTIVE* of Expressnet is also assumed to be 46 bits long, although it has been pointed out that a relatively long *LOCOMOTIVE* is required in a network with large physical length.[8]

The speech sample is assumed to be generated using a fixed rate 64 kb/s PCM coding. Silence detection is not considered in this analysis, but might well be used in practice. B_{max}, the maximum size of the voice samples in the voice station's buffer, is determined by Eq. (1). When D_{max} is 100 ms, for example, B_{max} is 6400 bits. There is no explicit constraint on B_{min}. If, however, B_{min} is close to B_{max}, speech samples can be occasionally discarded even when the number of voice stations is small. Suppose that a voice station receives the token when the size of the sample speech in the buffer is just under B_{min}. The station then passes the token on without transmission. By the next time the station receives the token, it will have to discard some speech samples because the delay exceeds B_{min}.

In,[9] the authors empirically found that value of B_{min} on the order of $B_{max}/10$ or less minimize voice loss. Following their suggestion, we chose B_{min} to be 64 and 640 bits for D_{max}=10 and 100 ms, respectively. For D_{max}=1 ms, we chose B_{max} to be 8 bits. The delay of a speech packet is defined as the time from the generation of the oldest sample until the completion of transmission of the entire packet. Under heavy loading, due to the congestion, the voice samples whose waiting time in the buffer exceed B_{max} are discarded. We let β be the percentage of discarded speech samples out of total speech samples generated by voice stations.

4. Simulation Results

We compare the performance of Expressnet, and FDDI for two different values of D_{max} and two different conditions of the *background* data traffic.

a. Case 1

We first consider, D_{max}=10 ms. Data traffic is assumed to be generated by a large number of interactive stations (500 stations). Each data station generates a 1000 bit packet with mean interarrival time of 10 ms. Thus, total normalized offered load G_d by all the data stations is 0.5. The maximum data packet transmission time L_{dmax} of Expressnet are set to 5420 μs. The value of *TTRT* of FDDI is set to 5000 μs.

Figure 1 (a) shows voice delay D_v as a function of n_v. When n_v is less than 1100, Expressnet has a longer delay than FDDI. The longer delay of Expressnet results from its latency between the voice and the data cycles. For Expressnet, D_v increases approximately linearly with n_v and reaches D_{max} when n_v approaches the maximum value N_v (740 stations in this case). The voice delay of FDDI shows a slow increase up to $n_v \approx 800$ because the token rotation time exceeds TTRT (5 ms) and data stations do not transmit at all. Consequently, FDDI shows the higher voice capacity (1097 stations) than Expressnet.

Voice loss β is plotted in Figure 1 (b) as a function of n_d. The shapes of curves are similar for the two protocols. The point at which voice loss begins is well defined for the Expressnet. In the case of FDDI, voice loss begins before voice delay exceeds D_{max}.

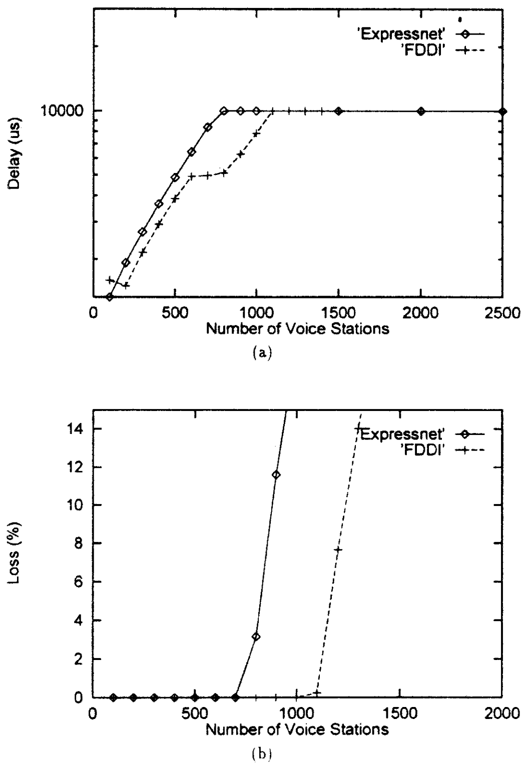


Figure 1. The variation of voice delay D_v (a) and voice loss β (b) with n_v under the two protocols. Expressnet (L_{dmax}=5.42 ms), FDDI (TTRT=5 ms). D_{max}= 10 ms, interactive data traffic withG_d=0.5.

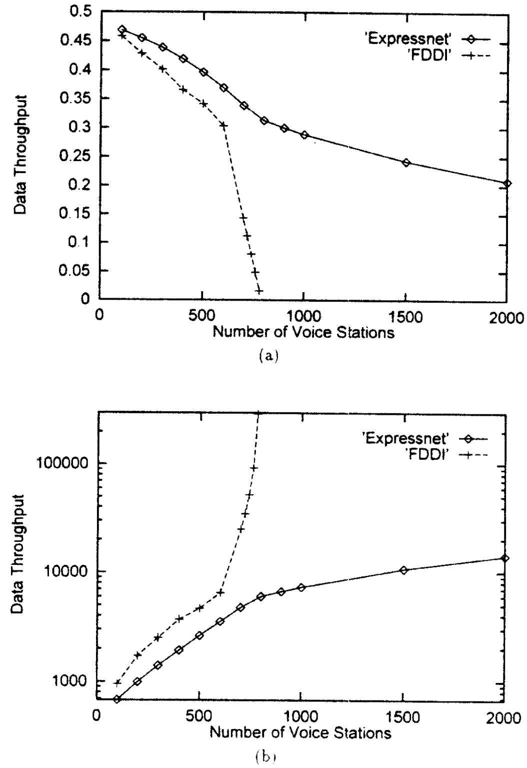


Figure 2. The variation of data throughput (a) and data delay (b) with n_v under the two protocols. Expressnet (L_{dmax}=5.42 ms), FDDI (TTRT=1 ms). D_{max}=10 ms, interactive data traffic with G_d=0.5.

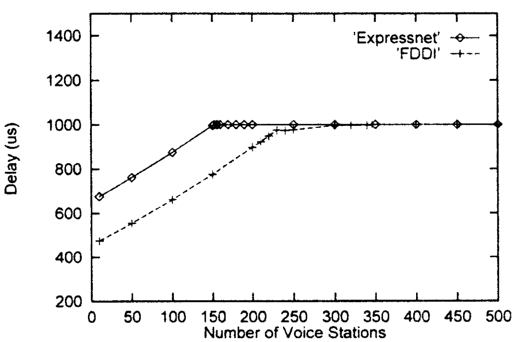
In Figure 2, the total throughput and the average delay of data stations are plotted as a function of n_v. The figure shows that the total data throughput for a given n_v is larger in the case of Expressnet compared to FDDI. In the case of FDDI, data throughput rapidly drops to zero when the token rotation time approaches TTRT. This results from the fact that the token holding time of data stations decreases as the token rotation time increases. If the token rotation time exceeds TTRT, no data stations transmit their packets.

b. Case 2

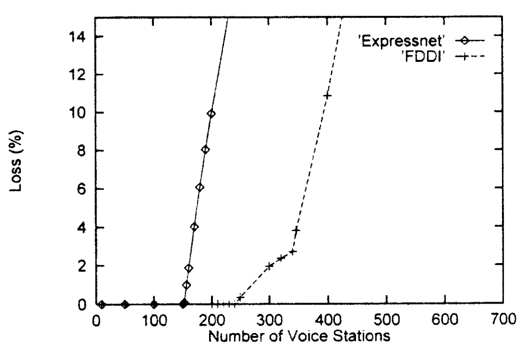
We also ran a simulation for the the following condition: D_{max} is 1 ms, data traffic is generated by 50 interactive stations with mean interarrival time of 1 ms (G_d=0.5), and L_{dmax} is 542 μs. The TTRT of FDDI is set to 1~ms for this case. Simulation result shows that, for this value of D_{max}, voice loss occurs well before the voice delay reaches D_{max} for all systems. There is a relatively big difference in the voice capacities of FDDI and Expressnet (240 vs.~64 stations) when compare to Figure 1 (b) (1012 vs.~740 stations). This is due to the fact that the latency between the voice and the data cycles in Expressnet becomes a significant portion (20\% in this case) of D_{max} as the value of D_{max} becomes smaller. Data delay is smaller in the case of Expressnet than FDDI. In the case of FDDI, data throughput drops rapidly to zero and delay increases to infinity when n_v is greater than 300.

c. Case 3

Now, we consider a case where D_{max}=1 ms and data trafficis generated by 5 stations performing file transfers (G_d=5), which is shown in Figure 3 and Figure 4. L_{dmax} is 500 μs, and the TTRT is 1 ms. Figure 3 shows that the voice capacity of each system is slightly decreased when compared to Figure 1 where interactive data traffic was considered. For this type of data traffic, FDDI higher data throughput than Expressnet (Figure 4).



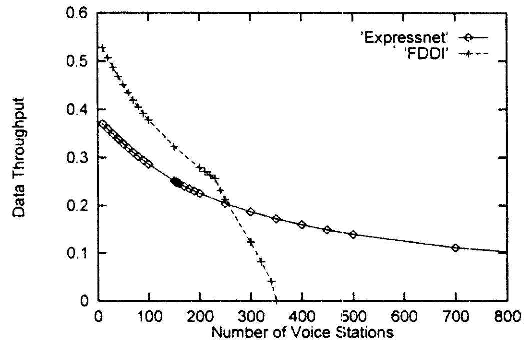
(a)



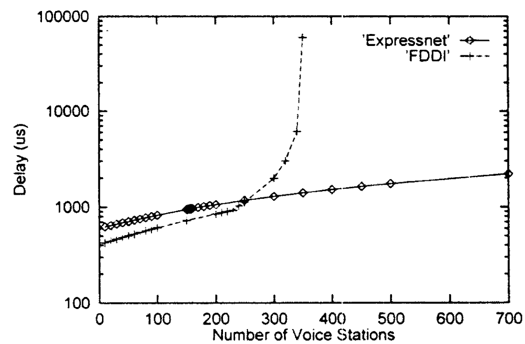
(b)

Figure 3. The variation of voice delay (a) and voice loss (b) with n_v. L_{dmax}=542 μs, TTRT=1 ms. D_{max}=1 ms, file transfer data traffic with G_d=5.

When n_v is small, the difference in data throughput is significant. The reason for this situation is explained as follows. Under both protocols, the number of data packets transmitted in each cycle is the same. However, the interval between two consecutive cycles is smaller in the case of FDDI, and hence data throughput of FDDI is higher than for the Expressnet. As before, however, data throughput in the case of FDDI drops to zero when n_v exceeds the maximum value.



(a)



(b)

Figure 4. The variation of data throughput (a) and data delay (b) with n_v. L_{dmax}=542 μs, TTRT=1 ms. D_{max}=1 ms, file transfer data traffic with G_d=5.

IV. Conclusions

In this study, the priority schemes of Expressnet, and FDDI were simulated for several delay constraints on the voice traffic and two patterns of data traffic. The voice capacity of FDDI is higher thanthat of Expressnet for all cases considered. The difference in the voice capacities of FDDI and Expressnet is most pronounced when D_{max} is small. When the TTRT $\leq D_{\max}$, FDDI shows the higher voice capacity at the expense of degraded data throughput.

When compared to Expressnet, FDDI achieves a higher data throughput for file transfer traffic, but it incurs a longer delay for interactive data traffic. The priority scheme of Expressnet considered to be more flexible than FDDI in allocating bandwidth to data stations in that it can provide data stations a guaranteed bandwidth. In the case of FDDI, data throughput falls to zero when n_v approaches N_v.

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