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A comparison of DQDB and FDDI for the interconnection of LANs

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Abstract. This paper identifies the design issues that must be considered when interconnecting IEEE 802 LANs through either DQDB or FDDI backbone subnetworks using MAC bridges. A series of simulation results are presented that compare the performance of both subnetwork types for various types of LAN traffic, backbone subnetwork sizes (physical coverage and number of LANs) and other performance-critical parameters. The paper concludes with some guidelines to be followed to achieve an optimal performance to meet specific application requirements.

1. Introduction

The interconnection of LANs over a complete site, without any performance loss, is currently a major issue being addressed by network designers. The emerging IEEE DQDB [1] and ANSI FDDI [2] standards are the two candidate networks being considered to meet such requirements. Among the alternative interconnection methods, MAC bridges are popular since they are transparent to end stations and can provide a high throughput [3]. Moreover, they are now being standardized [4]. One of the preferred ways to interconnect LANs that are distributed over a site is by the connection of each LAN, via a bridge, to a high-speed backbone subnetwork [5]. The general scheme is shown in figure 1. Bridges are being proposed also for interconnecting high-speed LANs and backbones [6]. This paper is concerned with a detailed performance comparison of DQDB and FDDI when each is being used as a backbone subnetwork. In the next section, the essential features of both subnetwork types and bridges are presented and this is followed by a description of the issues relating to the interconnection of IEEE 802 LANs that must be addressed. This is followed by a set of performance results which have been obtained from a series of computer simulations. The paper concludes with some guidelines to be followed to achieve an optimum performance to meet specific application requirements.

Figure 1. A typical network comprising a high-speed backbone interconnecting several heterogeneous LANs.
2. FDDI

The architecture of a fibre distributed data interface (FDDI) subnetwork consists of two independent optical fibre rings. These are referred to as the primary ring and the secondary ring, each carrying data in opposite directions at a rate of 100 Mbps. The proposed standard specifies the maximum fibre path length to be 200 km with up to 500 physical connections. A typical FDDI network configuration is shown in figure 2. As can be seen, there are two types of station: a dual attachment station, which is connected to both rings, and a single attachment station, which is attached only to the primary ring. In practice, most stations are attached to the ring via a wiring concentrator. Further information on the FDDI standard can be found in [7, 8].

FDDI uses a timed token rotation protocol to control access to the medium. Each station measures the time that has elapsed since a token was last received. As part of the ring initialization process, all stations negotiate a target token rotation time (TTRT). The asynchronous service allows the use of a token only when the time since a token was last received has not exceeded the established TTRT. Each station on the ring measures the time since it last received the token. The time interval between two successive receptions of the token by a station is called the token rotation time (TRT). On receipt of the token, if a station has asynchronous (data) traffic to send, it computes the difference in the time between the TTRT and the actual token rotation time (TRT); that is (TTRT − TRT). The difference is known as the token holding time (THT). If THT is positive, the station can transmit for this interval prior to releasing the token. As can be deduced from this, the TTRT establishes a guaranteed maximum response time for the ring since, in the worst case, the time between the arrival of two successive tokens will never exceed twice the TTRT value.

Various performance studies of FDDI parameters have been reported in [9, 10], where the performance of FDDI has been shown to be dependent on the TTRT, the size of the network (length of cable), the total number of stations and the frame size. The TTRT, however, has been shown to be the key parameter that can be used to optimize the performance of network. As will be seen, unlike DQDB, FDDI provides fair access for all users for any network size and traffic load.

3. DQDB

The architecture of a distributed queue dual bus (DQDB) subnetwork consists of two unidirectional buses as shown in figure 3. Both buses, referred to as bus A and bus B, carry data in opposite directions allowing full duplex communication between any pair of stations connected to the network. As both buses are operational at all times, the total available bandwidth is up to twice the bandwidth of a single bus. The operation of the two buses in the transfer of data is independent. The head of each bus generates fixed-length slots which are used to carry data between stations on their respective buses. All data flow on both buses terminates at the end of the bus. As specified in the IEEE 802.6 standard, a station cannot remove data and can only alter it when permitted by the access protocol. The DQDB layer provides two modes of access control to the dual buses: prearbitrated (PA) and queued arbitrated (QA), which are used to provide isochronous and asynchronous services respectively. This paper quantifies the performance of a single DQDB subnetwork for the interconnection of LANs carrying connectionless data only. The following
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A performance study of the DQDB protocol reported in [11] shows that the basic access protocol has unfair bandwidth sharing for users when there are heavy traffic demands; especially at higher network speeds and larger station separations. The proposed IEEE 802.6 standard specifies a bandwidth balancing (BWB) mechanism to ensure fair sharing of bandwidth between stations operating at a single priority. The impact of the bandwidth balancing mechanism on network performance will be expanded upon later.

4. Transparent bridges

Bridges operate at the medium access control (MAC) sublayer and are transparent to end stations. A description of the detailed operation of transparent bridges is given in [3]. A bridge receives and buffers all frames in their entirety before performing the relaying (interconnection) function. During normal operation, the MAC address of each end station is learnt by the bridge and retained in a routing table known as the forwarding database. After the learning phase, when a frame is received at a bridge port, the forwarding database is searched to determine whether the destination address is present for this port. If so, the frame is discarded, otherwise it is relayed to the appropriate port for forwarding. The bridges do not inspect or change the data carried by the MAC frame and end stations perceive the bridged network as a single, extended LAN.

5. LAN interconnection issues

The various IEEE 802 LAN standards differ at the physical layer and medium access control (MAC) sublayer, but are compatible at the logical link control (LLC) sublayer [12]. The relationship between FDDI, IEEE 802.6 and the different 802 LANs within the three lower layers of the ISO reference model is shown in figure 5. Both FDDI and IEEE 802.6 provide a connectionless MAC service to the LLC sublayer in a manner consistent with other 802 LANs.

<table>
<thead>
<tr>
<th>Network Layer</th>
<th>802.2</th>
<th>LLC</th>
<th>MAC</th>
<th>Data Link layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.3</td>
<td>802.4</td>
<td>802.5</td>
<td>802.6</td>
<td>FDDI</td>
</tr>
</tbody>
</table>

Figure 5. Position of IEEE 802 LANs, FDDI and IEEE 802.6 in ISO reference model. LLC, logical link control; MAC, medium access control.
This makes both network types suitable for use as backbones for LAN interconnection using MAC bridges. The maximum frame size specified in FDDI is 4500 bytes and in 802.6, 9188 bytes, both of which are greater than the maximum frame size range of 802.3 (CSMA/CD) LANs (1518 bytes). Although there is no specified frame size limit in 802.5 (token ring) when interconnected via MAC bridges the frame size with these LANs must not exceed the allowable limits of the backbones. Moreover, FDDI, IEEE 802.6 and each of the 802 LANs use and can recognise only unique frame formats specific to their MAC protocol. Hence, in the same way that frames between dissimilar 802 LANs cannot be relayed, LAN frames cannot be transmitted directly onto either an FDDI or DQDB backbone. The bridge, therefore, must encapsulate a LAN frame within a FDDI or DQDB MAC frame before forwarding it onto the backbone. Then, prior to forwarding the frame onto the destination LAN subnetwork, the MAC frame must be decapsulated and retransmitted in the correct format.

In order to encapsulate a LAN frame within a FDDI MAC frame, 27 bytes are added. For DQDB, at least 28 bytes are added to form an initial MAC protocol data unit (IMPDU). In FDDI, MAC frames are transmitted on the medium without segmentation. In the case of DQDB, each IMPDU is segmented into fixed length (44-byte) units. Control and message identifier fields are then added to each segment prior to transmission in a 53-byte DQDB slot. These are used by the destination stations to reassemble segments into the original IMPDU. To avoid the unnecessary use of both buses, the source bridge must know which of the two buses to use for transmitting each frame. One suggestion given in the 802.6 standard is the generation of a bus selection table for every end station on the entire bridged network. With this scheme, however, table maintenance can become unacceptably large as the size of the bridged network increases. In general, therefore, this is not used and each frame is transmitted on both buses. All bridges then reassemble all segments received back into their initial MAC PDU and, from their stored forwarding database, relay appropriate frames onto their required LAN subnetwork. As can be concluded from the foregoing, DQDB requires additional segmentation/reassembly overheads compared with FDDI. Moreover, if both rings in FDDI are used, this yields a more efficient utilization of transmission bandwidth.

To enhance the performance of the DQDB, a scheme known as destination release has been proposed [13]. A special bit, called previous slot received (PSR), is defined in the slot header which indicates whether or not the previous slot has been read. Some special access nodes, called eraser nodes, 'erase' all the slots that have been marked as 'read' so that they can be reused downstream by other users. In practice, however, because of the similar reasons mentioned before, bridges cannot set PSR bits. Hence, with bridges, the total available bandwidth of a DQDB backbone remains equal to the transmission rate of a single bus.

6. Simulation environment

The results presented in the following section have all been derived using a commercial simulation package—NETWORK II.5 [14]. For comparison purposes, both FDDI and DQDB have been modelled for similar network configurations and similar LAN traffic. Both run at the
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Figure 7. Impact of bandwidth balancing mechanism on the fairness of DQDB.

Figure 8. Performance comparison of DQDB and FDDI subnetworks (frame size = 64 bytes, network size = 100 km).

transmission rate of 100 Mbps. In DQDB, each frame is transmitted on both buses and, to keep the same bandwidth, a single FDDI ring is used. The physical size of the backbone is varied from 1 km to 200 km. The TTRT values used for FDDI are 4 and 8 milliseconds. The bandwidth balancing modulus (BWB – M) values for DQDB vary from 4–8. Each backbone contains 10 bridges and each bridge connects two similar LANs to the backbone. The performance of each backbone type was measured for three frame sizes: 64 bytes and 1218 bytes.
CSMA/CD frames) and 4000 bytes (to represent token ring.) The arrival of frames at bridges from each of the LANs is exponentially distributed and the total traffic over the backbones is uniformly distributed between the bridges.

The performance measures are the mean response time of the backbone with varying offered load and the maximum effective throughput for various backbone sizes and varying traffic. The mean backbone response time is
defined as the delay between the frame arriving at the source bridge and the corresponding destination bridge receiving the entire frame. For the comparison of the two backbone subnetworks, the bridge processing overheads are assumed to be negligible. The presented simulation results are after the steady state network conditions have been reached.

7. Simulation results

As indicated earlier, a feature of a DQDB subnetwork is that, under heavy load conditions, the access delay of stations varies depending on their position on the bus. This is shown in figure 6. Station numbers indicate their relative position on the bus; station 1 is close to the head of bus A and station 10 is close to the head of bus B. To simulate heavy load conditions, all stations always have a segment ready to transmit on bus A. As seen from the graphs the stations located in the middle experience longer access delays. Also the extent of unfairness increases with increasing network size. Stations located next to the bus heads always show a better performance. Such unfairness is unacceptable for backbone networks and it is for this reason that the bandwidth balancing (BWB) mechanism has been introduced.

To implement the BWB mechanism, each station has a BWB counter which is incremented after every transmission. Then, whenever the BWB counter reaches a limit known as the BWB-modulus, $M$, the RQ counter is incremented by one thereby forcing the station to let a free slot pass. The impact of using a BWB $- M = 4$ and 8 for a 200 km network is shown in figure 7. The network still shows a level of unfairness with a BWB $- M = 8$ and completely fair with a BWB $- M = 4$. From other simulation results it was found that a BWB $- M = 6$ for 100 km and 8 for smaller network sizes is suitable. Hence in the rest of the simulation results presented, these BWB $- M$ values have been used for corresponding network sizes.

The performance comparison of FDDI and DQDB backbones for various frame sizes is presented in figures 8–10. The backbone size is 100 km and the total offered load varies from 1 to 100 Mbps. A frame size of 64 bytes has been used for the results in figure 8. The effective throughput of a FDDI backbone is 60.5 Mbps with a TTTRT = 4 and 65.5 Mbps with a TTTRT = 8. The DQDB backbone gives a throughput of only 39.6 Mbps with this frame size. The MAC frame encapsulation overheads are responsible for the low throughputs in both types of backbone. The segmentation overheads in DQDB further reduce the effective throughput. After encapsulation, the 64 byte MAC frame size is increased to 92 bytes to form an IMPDU with DQDB which, in turn, requires 3 slots. For larger frames, the impact of encapsulation overheads is relatively small as shown in figures 9 and 10. These are for 1518 byte and 4000 byte frame sizes respectively. Similar results have also been reported in [15] for a different traffic model. For both FDDI and DQDB, the backbone response times are

![Graph showing maximum throughput of DQDB and FDDI subnetworks at various frame and network sizes.](image-url)
relatively low. The DQDB has relatively lower delays within its effective bandwidth range compared to FDDI. Using a TTRT = 8, the FDDI throughput is further increased compared with a TTRT = 4.

The maximum throughput obtained for different frame sizes with varying backbone lengths is shown in figure 11. As can be seen, for a 1 km FDDI backbone (TTRT = 4), 99 Mbps throughput can be obtained with a 4000 byte frame size. Also, the throughput of FDDI decreases with longer distances whilst there is almost no change in the throughput with DQDB.

8. Conclusions

This paper has presented simulation results relating to the use of FDDI and DQDB networks for the interconnection of LANs. Both networks have been used as backbone subnetworks and the effect on their performance of varying operational parameters investigated. In the case of DQDB, the unfair access delay of stations in relation to their position on the bus has been identified and the effect of the use of a bandwidth balancing mechanism demonstrated. It may be concluded from the throughput delay graphs that both networks give a low access delay up to their throughput limits. However the FDDI backbone gives a higher maximum throughput for all frame sizes providing the network size is less than 140 km. This is particularly the case with the lowest frame size because of the larger segmentation overheads with DQDB. For distances greater than 140 km, then DQDB gives a better throughput for the larger frame sizes which demonstrates its appeal for metropolitan area networks.

References