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QPSX and FDDI-II Performance Study of High Speed LAN's

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Abstract

Currently different proposals for the standardization of high speed local area networks (HSLAN's) like QPSX or FDDI-II are in discussion. For a proper performance evaluation of these two HSLAN's extensive studies are necessary. Based on detailed traffic models which were derived from the system descriptions, simulation programs were developed. Using these tools performance results in terms of mean transfer time, throughput, and blocking probabilities are obtained for all interesting parameters including different CS load distributions.

1 Introduction

A new class of local area networks (LAN's) currently gains upon the well-known LAN proposals to satisfy the growing requirements of integration and interconnection of LAN's. Offering an access scheme to maintain packet switched (PS) as well as circuit switched (CS) connections in a flexible fashion the requirements of several diverse environments can be met. Using fiber optic loops and transmission rates of 100 Mbps or more the integration of different services and the interconnection of different LAN's will also be supported by these new high speed local area networks [1]. Currently different concepts are in discussion to propose new standards: Queued Packet and Synchronous Switch (QPSX) [2], the hybrid Fiber Distributed Data Interface (FDDI-II) [12] and the multiple slot and token protocol(MST). The performance study presented in this paper only includes QPSX and FDDI-II.

2 QPSX

The architecture of the QPSX [2]–[5] Metropolitan Area Network (MAN) is based on a pair of contrary flowing unidirectional buses. For the integration of CS and PS traffic, on each bus a pulse frame of constant length is used which is subdivided into equal-sized slots. The buses originate and terminate at the central controller, but there are no through connections at the controller and hence the buses do not form rings. The central controller generates the pulse frame and is responsible for the CS connection management. Nodes are connected to both of the buses via a write connection and a read tap ahead of the write connection. All these components of the QPSX MAN are depicted in Fig. 1

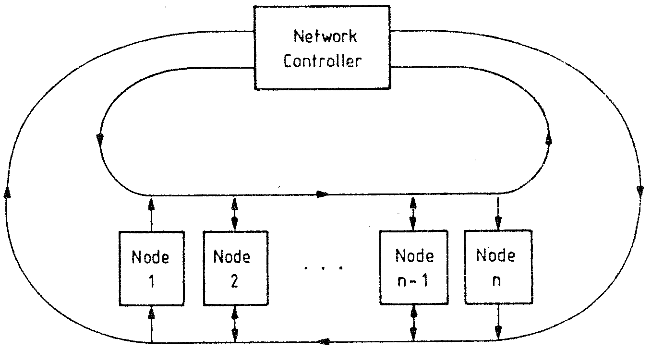

Figure 1: Topology of the QPSX MAN

Every node is able to communicate with each other node sending information on one bus and receiving on the opposite bus. The selection of the bus used to send messages depends on the location of the destination node and as described below, the buses are not connected through the central controller under normal operation. In the case of a physical break or a failure in the bus the choosen bus topology is well suited to reconfigure the network. The buses will be

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connected through the central controller to generate a "new" pair of buses. The access to the bandwidth available for PS traffic is performed by the *Distributed Queuing Protocol* [3].

The duration of a frame generated by the central controller is 125 μs (Fig.2) which is subdivided into fixed length slots of 35 bytes. There are three different kinds of slots assigned for the purposes of the hybrid switching concept: *Isochronous Slots (ISC)* for CS traffic,*First Non-isochronous Slots (FST)* and *Following Non-isochronous Slots (FLW)* respectively for PS traffic. Isochronous slots are allocated by the central controller by setting the Busy-Bit in the Access Control Field (ACF). The remaining 34 bytes are used for 34 isochronous 64 kbps channels [4]. To establish a full-duplex connection, two channels are allocated at a time (one channel on each bus).

The Non-isochronous slots contain an ACF too, but the remaining 34 bytes are available for PS data. A *Segmentation and Reassembly (SAR)* entity provides the segmentation of higher level data units into 34 byte packets or reassembles the received 34 byte packets to a higher level data unit. The first 34 byte packet transmitted is marked as a FST in the ACF type subfield. The following 34 byte packets of the same data unit are marked as FLW's. The four Request-Bits of the ACF are used by the Distributed Queuing Protocol providing four classes of priorities.

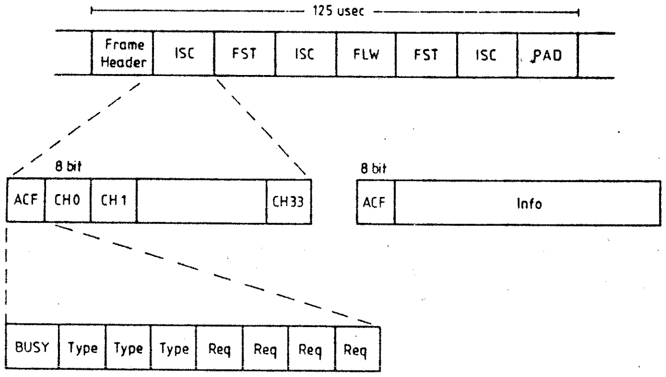

Figure 2: QPSX Frame Structure

The access to the bandwidth of the buses available for PS data is controlled by the Distributed Queuing Protocol. A functionally Distributed Queue is installed for each class of priority. In each node a Countdown Counter and a Request-Bit Counter per bus and per priority are used. The value of the Request-Bit Counter determines the place of the node in the according Distributed Queue. The Request-Bit Counter is incremented for each Request-Bit received on the opposite bus. This indicates that an additional packet is queued for transmission in a node downwards of the considered node. The Request-Bit Counter is decremented for each empty slot passing the node on the bus.

If a node has a packet for transmission and the Request-Bit Counter is not zero the value of the Request-Bit counter is transferred to the Countdown Counter and the Request-Bit Counter is cleared. Now the Countdown Counter is decremented by each empty slot passing on the bus to satisfy the nodes downwards which are still waiting for access. In this state Request-Bits on the opposite bus increment only the Request-Bit Counter. When the value of the Countdown Counter is zero the considered node is allowed to access the next empty slot for packet transmission. Further packet transmissions are handled in the same manner.

3 FDDI

FDDI is a protocol employed for a 100 Mbps token passing physical ring using a fiber optic medium. The FDDI standard has been developed by the American National Standards Institute X3T9 committee. In the year 1986 draft proposals of the Physical [7],[8] and MAC layer [6],[9] of the FDDI protocol were published which describe only a non-isochronous operation mode. At the moment a hybrid mode, so-called FDDI-II, is defined [10]. This hybrid mode is a superset of the FDDI standard and supports isochronous traffic as well as non-isochronous traffic [10],[12]. Thus this paper is focused on the FDDI-II protocol where four traffic classes are distinguished.

An isochronous traffic class carries the circuit switched services. All other classes handle the packet switched traffic which are defined in the FDDI draft proposals. The non-isochronous classes are subdivided in a synchronous traffic class which allows data transmission by a pre-allocated bandwidth scheme and an asynchronous traffic class. The data transmission in the asynchronous traffic class is controlled by a timed token protocol using a so-called non-restricted token. In this non-restricted token mode up to eight priority levels can be recognized. A special restricted token mode in the asynchronous traffic class allows dialogue oriented connections between some selected stations.

To handle both, circuit switched and packet switched capabilities, a hybrid switching scheme for FDDI-II is used. This switching scheme is based on a cycle structure which is generated from a cycle master station periodically every 125 μs (Fig. 3).

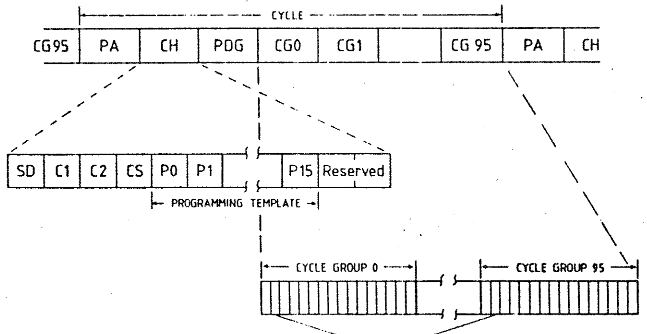

Figure 3: FDDI-II Cycle

Each cycle contains a *cycle header*, a *dedicated packet data group* and 96 *cycle groups*. The packet data group provides a guaranteed minimum bandwidth of 768 kbps for packet switched services. The bandwidth used by the cycle groups is partitioned into 16 so-called *Wide Band Channels (WBC's)*, each with a bandwidth of 6.144 Mbps. Each of these WBC's is individually assigned to either packet or circuit switched mode according to the programming template of each cycle header. The WBC's are arranged byte-interleaved across the 96 cycle groups.

The network management can allocate channels with different bandwidth within the isochronous WBC's marked by the programming template. The packet switched channel is built up by concatenating all WBC's which are associated to the PS mode and the packet data group. The channel access to that allocated packet bandwidth is controlled by a timed token protocol.

Each station contains a so-called *Token Rotation Timer (TRT)*. This timer measures the token interarrival time between the last token arrival and the actual token arrival. During the ring initialization phase a *Target Token Rotation Time (TTRT)* is negotiated. If the measured TRT is less then the negotiated TTRT the station gets an usable token and is able to transmit several packets; otherwise, the station must release the token at once.

Besides the token rotation timer stations have a *Token Hold Timer (THT)*, respectively. The token hold timer contains the remaining time between the TRT and the TTRT. Exceeding this token hold time the station must release the token after the current frame transmission is complete. Within the asynchronous non-restricted token class 8 priority levels are implemented by using different timer thresholds. If the transmission of all pending packets of a higher priority level is finished within the token hold time, lower priorities are able to transmit data packets if their threshold is greater than the remaining token hold time.

4 System Modelling

In this performance study the main interest is focused on the packet media access part of both HSLAN's. Thus detailed models of the P-MAC's are derived under the assumption of fixed CS streams. This assumption is justified as the transmission of the packet switched traffic is changed in μs whereas the circuit switched connections are established for a few minutes.

As described above, the distributed queuing MAC of QPSX allows the assignment of four priority levels to the non-isochronous data. In the queuing model of the P-MAC of a QPSX station (Fig. 4) each priority level is represented by a pair of queues.

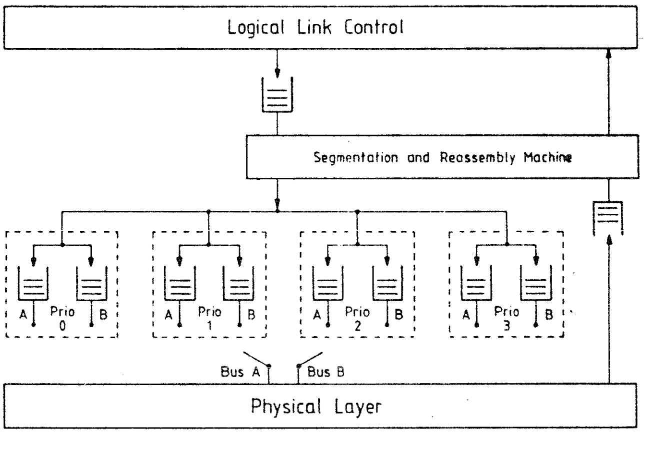

Figure 4: P-MAC Model of a QPSX Station

Packets arriving from the LLC layer enter the Segmentation and Reassembly machine to arrange fixed length data units according to the given slot format.

Then these fixed length packets enter the queue corresponding to their priority level and their destination address. The access of the queues to the two buses is controlled by the distributed queuing protocol as briefly characterized above.

The packet mode (non-isochronous mode) of FDDI-II distinguishes three traffic classes: a synchronous traffic class, an asynchronous traffic class using the restricted token mode and an asynchronous traffic class using the non-restricted token mode. The derived queuing model of the P-MAC of a FDDI-II station is depicted in Fig. 5.

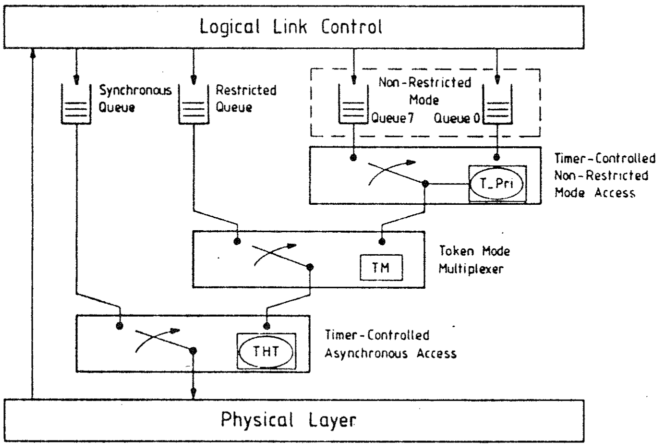

Figure 5: P-MAC Model of a FDDI-II Station

The synchronous traffic will be transmitted by a pre-allocated bandwidth scheme thus the throughput of this queue is guaranteed and is independent of the token status. If the kept token is usable, i.e. the token hold timer can be loaded with a positive value, the actual token mode decides if the restricted or non-restricted mode is selected for packet transmission. The non- restricted token mode contains 8 queues, one for each priority class. The access of one of these eight queues is controlled by the timed token protocol described in section 3.

Based on the models for a QPSX and a FDDI-II station simulation programs have been developed and some of the results are presented in the next section.

5 Results

To get realistic results a configuration with 25 stations interconnected by a fiber optic path of 100 km is assumed. The arrival process of the data packets is modelled by a Poisson process with a constant packet length of 64 byte. The non- isochronous traffic is equally distributed amoung all stations assuming a frozen isochronous data traffic. A MAC framing overhead of 104 bit is taken into account. The station latency using the FDDI-II protocol is supposed to be 80 bit and the chosen target token rotation time is 10 ms.

The Segmentation and Reassembly unit (SAR) of the QPSX stations is simulated without consuming any time. The influence of the service time by the SAR can be taken into account easily by increasing the depicted results with a fixed threshold. For both protocols the mean transfer time versus the normalized offered PS traffic is given in Fig. 6. The normalized offered PS traffic means the residual PS bandwidth which is given by different CS/PS ratios. The width of the 95% confidence intervals for all given diagrams is limited by 1%.

For slight traffic the mean transfer time of the FDDI-II protocol is higher than the mean transfer time of the QPSX protocol due to the timed token protocol. Token protocols imply basically a larger waiting time than slot/packet oriented access schemes, i.e. the QPSX protocol (see [11]).

Each FDDI-II station has the same transfer time behavior due to the fairness of the timed token protocol. The transfer time behavior using the QPSX protocol depends strongly on the location of the station within the dual bus. In the area of modest traffic and with the assumption of symmetric load conditions the station which is connected in the middle of both buses (station 13) obtains the most empty slots. Thus the mean transfer time is shorter than the transfer times of all other stations. The worst situation occurs at the station which is directly connected to the central controller (station 1 and station 25). These stations can transmit data packets to all other stations only on one of both buses. The Distributed Queuing Protocol implies that these stations may use only those empty slots, which have not been previously allocated by other stations during the last bus access (see Request-Bit Counter). Thus these stations get the highest waiting time for bus access. In the high load area this dependency of the station location disappears due to the growing request allocation of all stations.

Reaching the high load area the transfer time of the QPSX MAN increases dramatically. First a station must wait to transmit its Request-Bit, then the

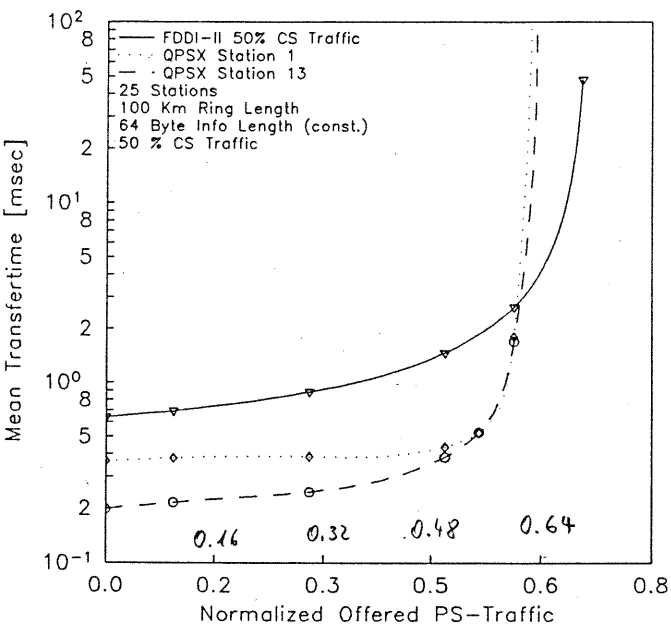

Figure 6: Mean Transfer Time of QPSX and FDDI-II

station must wait to obtain the allocated slot.

Fig. 7 depicts the mean transfer time with respect to different CS/PS ratios. Using the FDDI-II protocol an insignificant increasing of the mean transfer time with increasing isochronous traffic can be achieved. The major reason is the frame structure of FDDI-II. The WBC's which are allocated for PS traffic are byte-interleaved within the 96 cycle groups. Thus the waiting time to transmit two successive data bytes is limited by the duration of one cycle group ($\leq 1.28\ \mu s$). Increasing the CS data stream the mean transfer time of the QPSX protocol increases due to the increasing number of used Request-Bits. Thus the waiting time to obtain a free slot is enlarged.

The given simulation results assume a symmetrically distributed isochronous slot arrangement for both protocols, i.e. for 50% CS traffic the slots are allocated for CS and PS traffic alternatively. Other slot arrangements like the partitioned frame principle one part for CS traffic and the other part for PS traffic, will also increase the mean transfer time of the QPSX protocol due to a higher waiting time to catch the first free slot.

The isochronous channel arrangement within the FDDI-II protocol is defined by the 16 WBC's. Each WBC can be allocated for CS or PS traffic. As a result of the byte-interleaved arrangement of the WBC's within the cycle group, the mean transfer time is nearly independent of the isochronous channel arrangement.

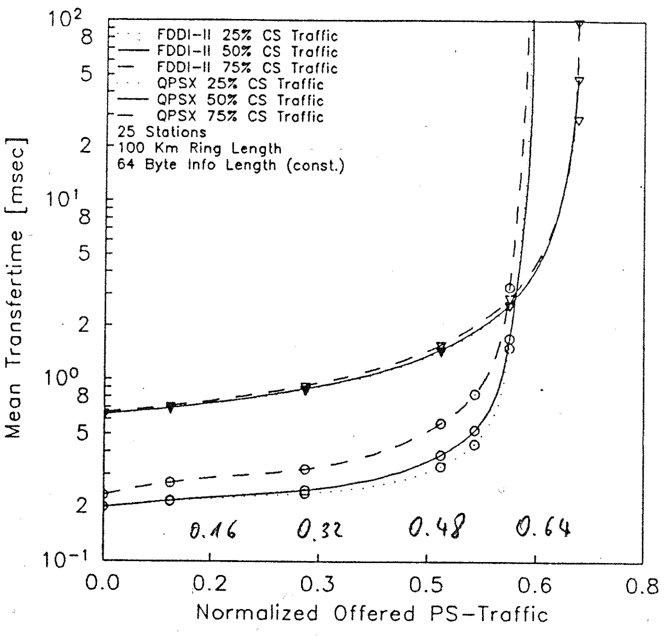

Figure 7: Mean Transfer Time using different CS/PS Ratios

6 Conclusion

A performance comparison of two highly discussed metropolitan area networks has been presented. Based on detailed MAC models simulation programs are derived for the FDDI-II protocol and QPSX protocol. Both protocols are compared in terms of mean transfer times which depict the influence of the location of stations and different CS traffic load as well as miscellaneous cycle arrangements for both protocols.

Acknowledgement

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