DATA/VOICE/VIDEO INTEGRATION ON FIBER DISTRIBUTED DATA INTERFACE

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ABSTRACT

The Fiber Distributed Data Interface (FDDI) is a 100 megabit per second (Mbps) Local Area Network that uses Optical Fiber as the medium. It provides both the high bandwidth and low latency needed to match the capacity of future personal computers. Hence it is expected to become the preferred local area network systems of the 1990s. The FDDI protocol is based on a timed token ring access method. In this paper, we propose a media access control protocol for combined Data/Voice/Video services on FDDI. The most important service requirement for the packetized Voice and Video is the transport of this data with tolerable delays. The effect of multiple Voice and Video channels on the asynchronous data traffic and the capacity to handle these services on FDDI is investigated by means of simulation methods.

1. INTRODUCTION

Transmission of Voice/Data on local area network has attracted much interest in the recent years because of its simplicity and lower cost as a result of increased utilisation of the network resources. With the introduction of optical fiber as the medium and the new protocol standards, the present high speed LANs can be used for Video as well as Voice/Data transmission. Because of its extremely high bandwidth and guaranteed access delays tor synchronous data, FDDI is ideally suited for integrated Voice, Data and Picture transmission.

In this paper, we present a simulation model developed using C programming language to study the performance of FDDI with Video, Voice and Data. The Voice and Video are transmitted as synchronous data. Teleconferencing is taken as a typical Video transmission application. The average delay for Voice/Data and Video packet and the ring utilisation for various ring configurations are used to study the performance of the protocol.

2. FDDI OVERVIEW

FDDI standard is being developed by ANSI X3T9 committee to deal with three types of networks namely Backend Local Networks, used for interconnecting main frame and large data storage devices, high speed office networks for transfer of document images and Backbone networks for interconnecting lower capacity LANs[1].

The FDDI standard [2,3,4] addresses the physical and MAC layers and assumes the use of the IEEE 802 logical link control (LLC) standard operating above the MAC layer.

2.1 Access Protocol

FDDI media access control protocol is based on Timed-Token access mechanism. Two types of frames are defined: Synchronous and Asynchronous. Each station is allocated a certain length of time during which it can transmit synchronous frames. This time interval is called "Synchronous allocation". A target token rotation time (TTRT) which is large enough to accommodate synchronous transmissions from all the nodes plus the time taken by a frame of maximum size to travel around the ring is also defined for the network. A frame with a specific format called "token" is passed from one station to the next around the ring. On receipt of the token, a station is allowed to transmit as many frames as it has until a predefined time is reached. If a station has no frames to trasnsmit or when time for its transmission is over, the station sends the token to the next node. Each station on the network retransmits the frames that it receives and copies from the ring those that are addressed to it. The sending station is responsible for removing the frame from the ring. The status bits in the frame indicate whether errors have been detected. The error recovery and retransmission are left to higher layers. FDDI also supports "restricted-token" mode whereby two stations can communicate in dialog mode. The protocol also provides for several priority levels for asynchronous data transmission. Dykeman and Bux [5] discuss these in greater detail.

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2.2 Timed-Token Ring Protocol

To initiate transmission on the ring, each station sends a claim frame with an estimated TTRT value. If a station receives a claim frame with a TTRT value less than its own, then it transmits that claim frame. The station that receives frame with its own TTRT value begins its transmission first. Now the operating TTRT for the ring (T_opr) is the minimum TTRT. Each station has a timer called Token Rotation Timer (TRT). The TRT is initialised to T_opr on the network. It then starts counting down. When it reaches zero, it is reinitialised to T_opr and a variable Lt_count is incremented. Whenever the token is received at a station, token holding time (THT) is initialised to the current TRT value Lt_count is made zero. But if the token received is late, only Lt_count is set to zero and TRT is not tranferred to THT. The station then transmits synchronous frames for a time equal to its synchronous allocation and asynchronous frames for a time equal to THT. If Lt_count ≠ 0 when the token is received, the station is allowed to transmit only synchronous frames. If Lt_count ≠ 0 and a station's TRT expires, then the station initiates a claim process to reinitialise the ring. Hence a token can be received at a station as late as upto 2 * T_opr. This guarantees a delay less than 2 * T_opr for synchronous frames. The formal proof for this is given in [6].

2.3 Fault Management

Fault management on the network is distributed in nature. Each station monitors the network and initiates the claim process if there is an extended period of inactivity on the ring. The FDDI protocol provides for dual (with two physical layers) and multiple attachment (multiple physical layers) stations [7] which enhance its fault tolerance.

When a serious failure, such as a break in the ring, occurs a "beacon process" is initiated. If a station which is sending claim frames recognizes that a defined time period has elapsed without the claim token process being resolved, it initiates the beacon process by continuously transmitting a stream of beacon frames. If a station receives a beacon frame from another station, it stops sending its beacon frames and retransmits the received beacon frame. Eventually, beacon frames from the station immediately following the break will be propagated through the network allowing the ring to be reconfigured.

3. TRAFFIC TYPES and INTEGRATION STRATEGIES

Traffic on an integrated LAN can be of two types: Real-time and Non-Real-time. Packetized Voice and Video can be thought of as real-time data while facsimile, graphics etc are non-real-time. A packet switching scheme is used for integration of these non-real-time and real-time data. The Video and Voice are treated as synchronous data. The Voice packets are sent first and the Video packets are transmitted in the remaining synchronous bandwidth.

The synchronous bandwidth allocation at each node is made based on the amount of Voice and Video Data it has, subject to the maximum TTRT value of 165 ms as specified in the MAC standard [3]. The Data is sent during the asynchronous bandwidth.

4. SIMULATION MODEL

4.1 Model for Data

The arrival of data packets at a node is assumed to follow a poisson distribution with the packet lengths exponentially distributed [8]. The Data is sent as asynchronous frames.

4.2 Model for Voice

The arrival of calls at a node follows a poisson process with an interarrival time of 20 minutes [9]. The average duration of a call is 3 minutes and it follows an exponential distribution [10]. The Voice is modelled as a continuous stream of PCM bits. The packetization duration is taken as 16 milliseconds (128 bytes). The call consists of alternate talk-spurt and silence periods. The talk-spurt and silence are assumed to follow an exponential distribution with the mean values of 352 milliseconds and 625 milliseconds respectively[11]. We also make an assumption that a call starts with talk-spurt and ends with a silence period.

4.3 Model for Video

Video conferencing requires 33 frames of picture to be transmitted per second [9]. The picture signal consists of two parts namely the luminance part, having a resolution of 352 x 288 and a colour part with a resolution of 176 x 144 [9]. Using Transform Coding Techniques [12], the average bits per pixel in case of video conferencing can be reduced to a value between 0.1 to 0.5, thereby resulting in an enormous savings in bandwidth [13, 14]. The image is also coded as a continuous stream of bits and is transmitted as synchronous data in the left over synchronous bandwidth after transmitting voice.

5. SIMULATION RESULTS

The performance statistics include delay for data,voice,and image and ring utilisation. The ring configuration used for simulation is as follows.

Mean asynchronous packet size : 2kbytes
Asynchronous arrival rate : exponential distribution
Mean duration of video conference : 15 minutes
Mean number of stations with video conference : 50

The average delays for data, voice and image are plotted against the number of active stations in figures 1 and 2, with asynchronous mean interarrival time of 75ms with 85ms respectively. The asynchronous delay increases enormously when the number of active stations is more than 200. When the number of active stations exceeds 200, the time between successive arrivals of the token increases above the time interval between two asynchronous packet arrivals, resulting in the building up of the queue.

Voice delay increases with the number of active stations, due to increased number of calls. This in effect, increases image delay since image data is transmitted either in the absence of, or after voice data, in the synchronous bandwidth. When the number of active stations is less, the voice arrivals are less frequent and the number of packets transmitted are also correspondingly low. Consequently a few voice packets may have to wait for a long time before they are transmitted which increases the average voice delay. In contrast, the number of image packets transmitted are high (33 frames/sec) even for less number of active stations. The waiting time for many of these packets is less. Therefore the image delays are lower when the number of active stations are less. But when the number of active stations crosses 400, the number of calls are more and hence voice delays tend to be lower than the image delay.

The percentage ring utilisation is plotted against the number of active stations in figure 3. The percentage ring utilisation is low when there are fewer active stations, since the amount of data transmitted is less and the token rotation overhead is predominant. The utilisation drops when the number of active stations are more since the packet overheads become predominant at higher data transmissions. The ring utilisation reaches a peak value of 77.4% for an asynchronous interarrival time is 75ms.

6. CONCLUDING REMARKS

We have proposed and investigated the performance of Fiber Distributed Data Interface (FDDI) with voice, video and data. The voice and video are given priority over data. Among voice and video, voice is transmitted first. The average delays for voice, video and data packets and the average ring utilization for various values of data arrival rates are used to study the system performance. FDDI is found to support around 200 stations with image and voice. The ring utilisation reaches a peak value for 300 stations. The voice and image delays are found to be within tolerable limits for even 400 stations, but data delays are enormous. Thus the protocol supports voice/video and data integration when the number of stations on the ring is around 200.

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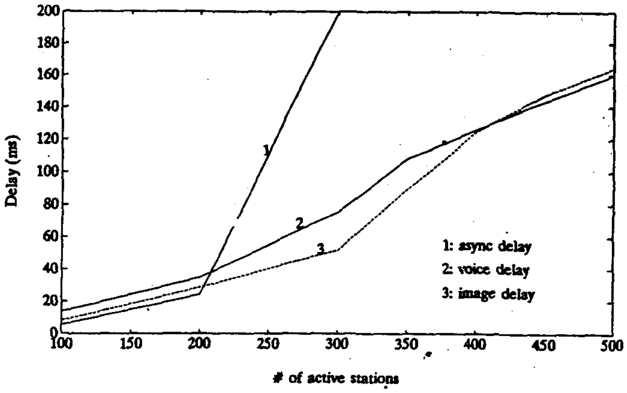

Figure 1. Delay characteristics (Data arrival = 75ms)

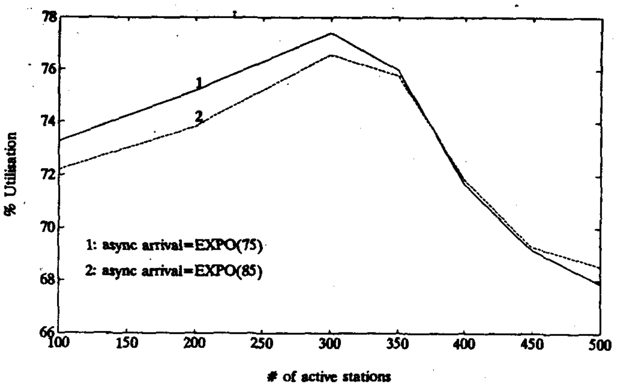

Figure 3. Utilisation characteristics

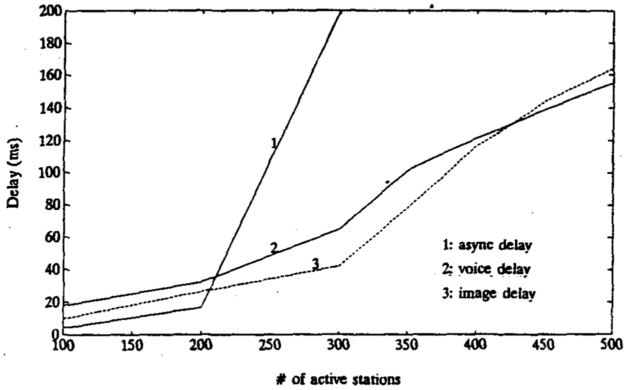

Figure 2. Delay characteristics (Data arrival = 85ms)

The models for the standard and exhaustive transmission strategies are shown in Fig.8 and 9. There are 'M' stations each provided with a buffer of infinite capacity. Each station in these models are individually analysed using the M/G/1 and M/D/1 Queueing models. The interarrival rate of the packets follow a Poisson Distribution while the packet lengths are of a General Distribution. There is a single server the passive bus. The discipline used for the Queue is First-in-First-out (FIFO). The performance metrics for the Token Passing Bus can be derived in closed loop form which are tractable with the realistic situation. The input quantities used in the modelling are: Number of stations on the network, channel capacity, packet size, overheads involved, token length, cable length, buffer size and arrival pattern. The behaviour of the various parameters were studied through a Pascal program to calculate the values for the parameters of interest using the mathematical model. The mathematical model for the bus utilization for standard and exhaustive strategies are:

$$U = 1 - (1 - \bar{T})^M \qquad (7)$$

$$U = 1 - (1 - T)^M \qquad (8)$$

Where U, T and M are the logical ring utilization, token rotation time, arrival rate and number of active stations in the ring. Fig.10 and 11 represent the characteristics of utilization with respect to arrival rate for both cases. The utilization increases with increase in arrival rate. A comparison of both the standard and exhaustive transmission strategies of operation at different arrival rates are made. It has been found that exhaustive transmission strategey performs much better than standard transmission strategy.

V. FIBER-OPTIC APPLICATIONS

The application of the Fiber-Optic transmission medium to the bus type LAN is considered. The various issues and problems encountered in Fiber-Optic buses are studied. A comparison of the bus systems are made to evolve the best configurations which is representative of the Fiber-Optic bus topology.

The primary issue involved in bus type Fiber-Optic Lan (FOLAN) is the implementation of a tap. An ideal tap would be as shown in Fig.12. The signal comming from A is almost transmitted to B with small percent being tapped for station C. Similarly a signal coming from B gets through to A with minimum loss. On the other hand the signal transmitted by C must enter the bus without significant reflections and should almost equally split towards A and B. In electrical terms, the station C should have very high input impedance and very low output impedance. While this is possible in electrical momain, it is a serious problem to implement using optical fibers. The basic coupling mechanism from one fiber to another centre around a (2x2) coupler as shown in Fig.13. At any one time either port 2 or port 4 may be activated. The couplers do allow the injected power to be split in the output ports. The couplers are symmetrical.

The ports 2 & 4 must have required value of input impedance to tap-off the power from the bus. The output impedance must be designed to be such that a larger fraction of the power launched by a station gets coupled onto the bus. The Uni-directional property of light propagation in optical fiber requires that power launched into port 2 of the coupler must travel in the direction of the port 3. This property demands to use more than one coupler or a dual bus while implementing the bus topology using optical fibers. Based on the above issues, it is possible to configure various implementations for the fiber optic bus networks. For the network to be reliable the bus should preferably be configured by using passive components at an expense of power losses. The different configurations of the bus network using fiber optics are: Active Linear Bus, Passive Linear Bus, Star Coupler Bus, and Linear Buses with Assymetric couplers.

Active Linear Bus:

Fig.14 shows the active linear fiber optic bus. The system uses active taps. The taps involve optical to electrical converters and electrical to optical converters. Each tap consists of two pairs of transceivers. Each pair of transceiver include a PIN diode and a LED. The reliability of an active star is a major issue in this system. Since the continuity of a common channel depends on each of the active tap being in operation. This configuration can accomodate a maximum of 100 stations on the network.

Passive Linear Bus:

Fig.15 shows the configuration of the FOLAN using a passive linear bus. It involves a bus coupler and a station coupler to ensure bidirectional transmission. This configuration has a disadvantage that the Number of stations which can be accomodated is limited. A much improved configuration of passive linear bus is shown in Fig.16. This is implemented using dual fiber bus. In actual practice a dual fiber cable can be taken and spliced at one end. The signal propogates only in one direction in the fiber. Using this dual fiber bus, the number of station can be increased. Fig.17 shows the configuration for a passive FOLAN using 2 buses, the R-L and the L-R bus. Each station is attached to the buses via two power couplers. This configuration can support a maximum of 30 stations.

Star Coupler Bus:

Fig.18 shows the configuration of a FOLAN bus topology which is implemented using a passive star coupler. This network is the most popular implementation of an optical fiber bus topology. The transmitters of each station are connected to one side of a star coupler where as the other side of the star coupler is connected to the receivers. As in any bus network, in this case, whenever any station transmits, all other stations listen and if two stations transmit simultaneously, a Collission occurs. Passive star couplers are available as 8 x 8, 16 x 16, 32 x 32 or 64 x 64. Using this coupler, a fiber optic bus network can be satisfactorily designed to accomodate 64 stations.

Linear Bus with Assymetrical Couplers:

The development of the assymetric couplers has enabled a FOLAN which does not employ a star coupler but which has the capability to accomodate more stations than possible using star coupler fiber optic bus network. The system configuration is similar to Fig.18, but each of the symmetrical couplers are replaced by an asymmetric coupler such a configuration is practically found to be identical to the electrical bus network in its implementation.

A comparison of the power margin characteristics for these configurations of the fiber optic bus topology have been made. The dual fiber bus system using asymmetrical couplers has been estimated to show the best performance considering all the restrictions imposed by the fiber optic medium.

VI. CONCLUSION

In this work, "Performance Analysis of LAN with Fiber-Optic Applications", a detailed modelling of the Media Access Protocols used in LAN's have been performed. The Protocols modelled are the IEEE 802.3 and the IEEE 802.4 systems. Modelling of the CSMA/CD Protocol has been performed using both Analytical techniques and Simulation techniques. The analytical modelling was performed to obtain the performance metrics. For the IEEE 802.3, CSMA/CD protocol, the modelling has been performed using both Queueing analysis and Markov Chain analysis. The simulation modelling for the CSMA/CD system has been performed. It was possible to obtain for most of the performance metrics defined in the analysis. It has been found that metrics like throughput, average packet delay, state of the channel estimated follow the analytical model. In addition, simulation was performed for the Prioritized CSMA/CD system for which no definite analytical model was possible. The estimated performance for this system has been found to be superior when compared to the Non-Prioritized CSMA/CD systems. The analysis of the Token Passing Protocol has proved that in the range of operation of the network, for which the CSMA/CD system fails in performing properly, the Token Passing system has proved its merit in high performance. It has been found from the results that the CSMA/CD protocols can be applied favourably to the network in the regions of low and medium loading. For high loading the results obtained for the CSMA/CD system are not agreeable. But the Token Passing Bus system has proved to perform well at high to very high loading though its performance at low loading is poor.

The considerations in the application of the IEEE 802.3 protocol to the Fiber-Optic Bus Topology have been considered. The different configurations of the Fiber-Optic Bus Topology have been analysed. These includes, the single Fiber Bus, the Folded Bus, the Dual Fiber Bus system using symmetrical couplers and the system using Asymmetrical couplers, the Active Bus and the Star Coupler Bus systems. A comparison of the power margin characteristics for these systems have been made. The Dual Fiber Bus system using Asymmetrical couplers has been estimated to show the best performance considering all the restrictions imposed by the Fiber Optic Medium.

The performance evaluation has shown that a system incorporating the feature of both CSMA/CD system and Token passing Bus system, as applied to loading, could be applied to the Fiber Optic Medium so as to obtain uniform characteristics for the entire range of loading. Such a system could be investigated using the modelling techniques.

ACKNOWLEDGEMENT

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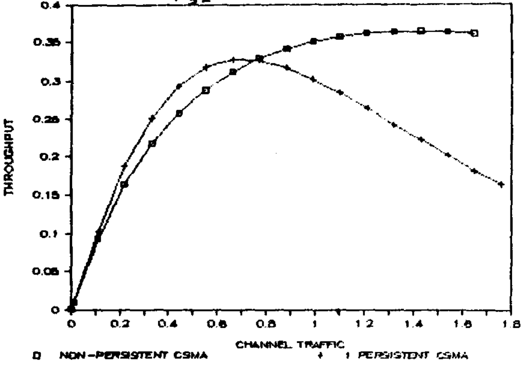
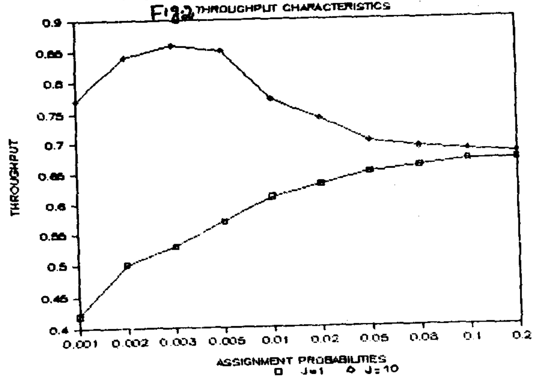
ANALYTICAL MODELLING OF CSMA/CD

Fig 1 THROUGHPUT VS TRAFFIC a = 0.01



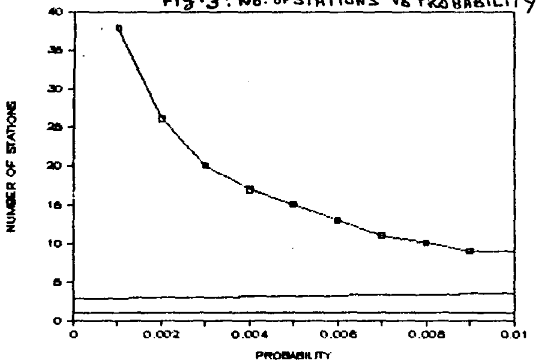
NON-PERSISTENT CSMA/CD

Fig 2 THROUGHPUT CHARACTERISTICS



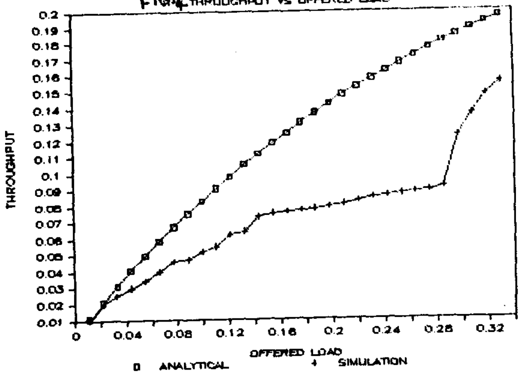
MODELLING OF NON-PERSISTENT CSMA/CD

Fig-3 : No. OF STATIONS VS PROBABILITY



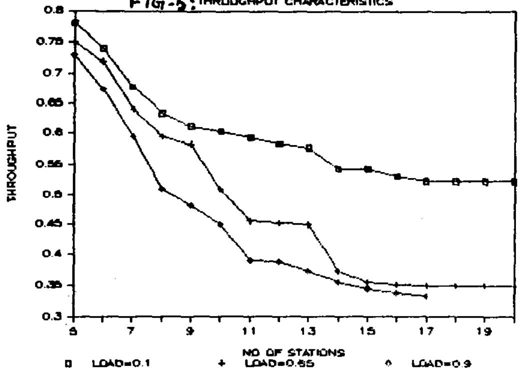
SIMULATION OF NONPERSISTENT CSMA/CD

FIG-4 THROUGHPUT VS OFFERED LOAD



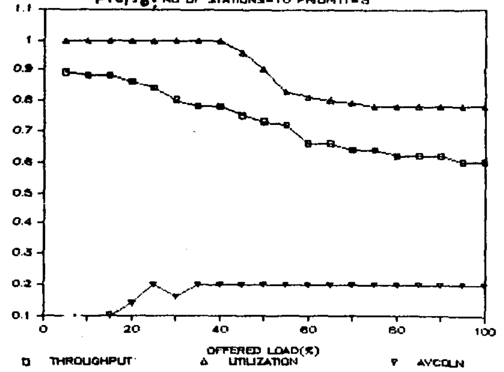
SIMULATION OF CSMA/CD

FIG-5: THROUGHPUT CHARACTERISTICS



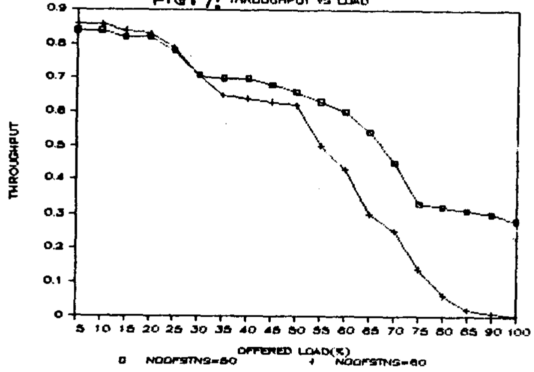
SIMULATION OF PRIORITY CSMA/CD

FIG-6: NO OF STATIONS=10 PRIORITY=5



PRIORITY CSMA/CD

FIG-7: THROUGHPUT VS LOAD



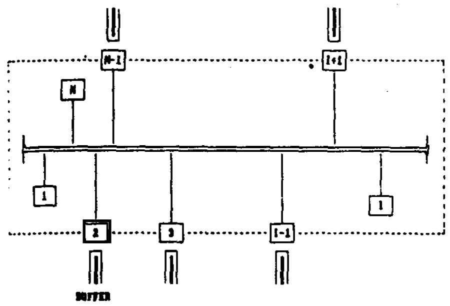


FIG-8: SYSTEM MODEL FOR STANDARD TRANSMISSION STRATEGY

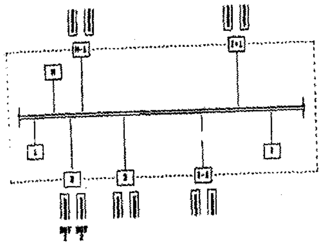
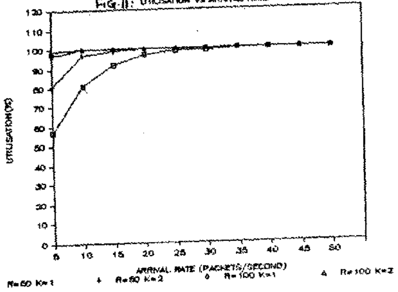


FIG. 9: SYSTEM MODEL FOR EXHAUSTIVE TRANSMISSION STRATEGY

EXHAUSTIVE TRANSMISSION STRATEGY

FIG. 11: UTILISATION VS ARRIVAL RATE



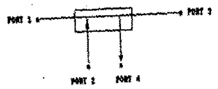


FIG. 13 A 2x2 FIBRE OPTIC COUPLER

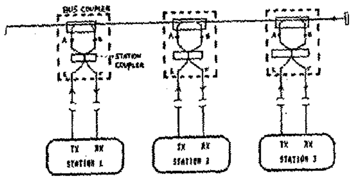


FIG. 15. SINGLE FIBRE BUS CONFIGURATION

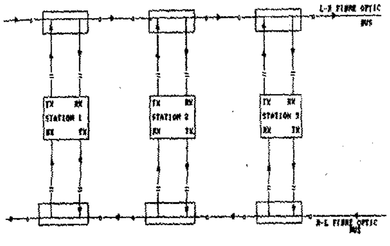
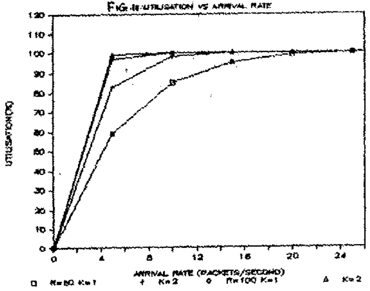


FIG. 17: DUAL FIBRE BUS NETWORK

STANDARD TRANSMISSION STRATEGY

FIG. 10: UTILISATION VS ARRIVAL RATE



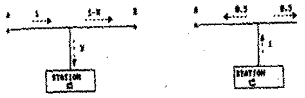


FIG. 12: AN IDEAL TAP ON A BUS

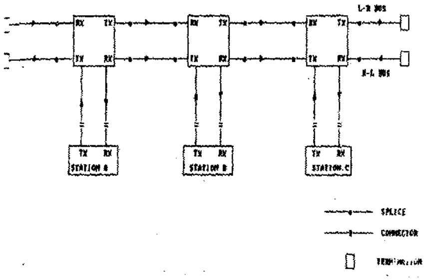


FIG. 14. FIBRE OPTIC IMPLEMENTATION OF AN ACTIVE LINEAR BUS

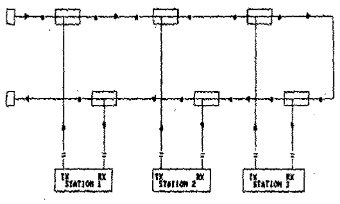


FIG. 16: FIBRE OPTIC IMPLEMENTATION OF A FOLDED BUS

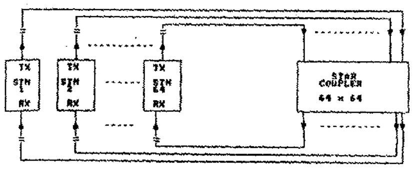


FIG. 18: FIBRE OPTIC BUS NETWORK USING STAR COUPLER