A Modified Optical Network for Interactive Video-on-Demand Services

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Abstract--**In typical proposals for Video-on-demand (VOD) networks, customers are serviced individually by allocating and dedicating a transmission channel and a set of service sources to each customer. In this paper an interactive VOD optical network is proposed that can offer video, TV, banking and shopping services (among others) to a large number of users. Several network parameters are studied using computer simulation taking into account effects like fiber dispersion, node distance and network usage. The studied parameters include maximum over-all fiber transmission rate, average user waiting time, and fiber percentage usage time.**

I. Introduction

VOD optical networks have been under development since the early 1980s. For example, a two-year trial by Fibervision in 1982 involved a small network serving 18 customers in Milton Keynes [1]. The technology for the Fibervision trial was basic; one channel in square-wave FM form was carried over each multimode fiber. Improved trials were conducted later. One of these trials is BIDS (broad-band integrated distributed-star), which integrated the concepts of a switched cable TV network and a remote telecommunications multiplexer, providing a full range of services to the end user [2].

In this paper we suggest an interactive VOD optical network that offers customers many services, such as video, TV, banking and shopping. Effects of optical fiber dispersion, node distances and network usage are studied.

An optical pulse transmitted through an optical fiber undergoes attenuation, delay and distortion, in addition to many other effects. A constant delay of the signal due to transmission can normally be tolerated, as long as the length of the delay is within reasonable limits. Through appropriate synchronization the transmitted information can be received correctly, in spite of delay. Attenuation sets an upper limit on the distance between the transmitter and the receiver or between repeaters [3]. Distortion in the form of pulse broadening, commonly referred to as dispersion, can result in intersymbol interference (ISI). ISI can cause pulses representing different information symbols to overlap. As a result of ISI, symbols may become inseparable at the receiver, leading to reception errors. Attenuation and dispersion set the prime limits on the information transmission performance of optical fiber communication systems. Thus, they are taken into consideration in the simulation.

The relation between dispersion and the maximum over-all fiber transmission rate will be shown for different node distances. Also average user waiting time and optical fiber percentage usage time relations with dispersion will be illustrated. Simulation is performed assuming long node distance (100 km), medium distance (60 km), and short distance (20 km), in order to view the effect of node distance on the network performance. User numbers and request rate were varied to study the behavior of the network when it is lightly, moderately, or highly crowded.

This paper is organized as follows. The structure of the proposed network is discussed in details in section II. Computer simulation results are discussed in section III. In section IV main conclusions of this work are presented.

II. System Model

As shown in Figure 1 the proposed interactive VOD optical network is mainly constructed from three major units: the main station (MS), substations (SS), and user units (nodes). Every node is connected to its own SS via two fibers. One fiber is directed from the node to the SS and carries a signal that holds the user request. The other fiber carries data from the SS to the node.

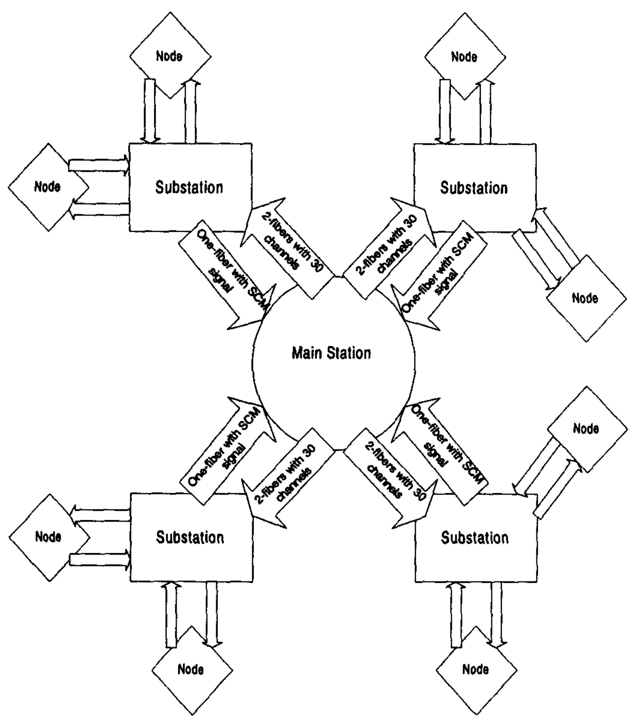

Figure 1. The proposed VOD optical network model

Each SS is connected to the MS through three long fiber cables. One fiber is directed from the SS to the MS, carrying all the requests of the users connected to this SS using subcarrier multiplexing (SCM) with multiple optical carriers as

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shown in Figure 2. Using SCM in the VOD network makes it much more efficient, compared to other networks that transmit each node request on a separate fiber. In some other networks, a single fiber is used to sequentially transmit all the requests. In the proposed scheme, based on the use of SCM, only one signal is transmitted. This signal carries all currently available requests. Thus, all requests made by users arrive simultaneously and hence, are all serviced at the same time by the MS.

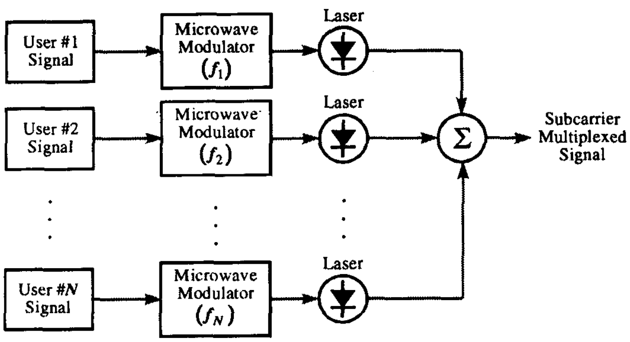

Figure 2. Subcarrier multiplexing with multiple optical carriers

The other two fibers are directed from the MS to the SS. They carry data requested by the SS, into fifteen wavelength division-multiplexing (WDM) channels on each fiber in order to achieve a high transmission bandwidth.

The node is controllable by the end user in such a way through which the user can send information or data, and request any service available on the network. The user is known to all the other users on the network. Nodes can exchange data according to the permission policies assigned to them.

The SS is responsible for adding, deleting and configuring nodes connected to it. It receives requests from nodes and sends them to the MS, depending on the status of the fiber connection with the MS and the response data availability. The SS has a storage unit that contains the user requests. Every node is assigned a dedicated storage location in the storage unit. This location contains the response data of the request the node made. The SS receives the responses from the MS and stores them in the proper storage location for every node that made a request. The SS sends the response directly to the node

location. This is done in order to reduce the user waiting time.

To account for interactivity to the VOD nature of the network, the user can completely control the node. Among the control features available to the user are: rewinding, pausing, and forwarding according to the availability of the data. Assigning these control functions to the user eliminates many problems that exist in other networks that have to deal with the signal in the optical fiber to perform pause, forward, and rewind functions. Dealing with the signal in the fiber implies using delays and sometimes holding the fiber in use for a longer time by the same user.

old data. The SS checks if any of the requests has its response

s response

without sending the request to the MS. This reduces the user waiting time and the fiber usage time. It also eliminates the need for retransmitting data that already has been transmitted. This is very useful when many users request the same data.

In fact, some VOD networks use what is called multicast communication [4] to reduce the required bandwidth. With multicast, users can share a single movie stream (or network service), resulting in reduced system cost per user and improved system scalability. However, a drawback of multicast is that, sharing of system resources contradicts, to a certain extent, the need for individualized service in an interactive VOD system. As it turns out, providing interactive functions in a multicast VOD system typically involves either added complexity in the set-top box, or a redefinition of the interactive functions. It may also be required to sacrifice some of the on-demand nature of the system. Systems in which some interactivity and part of the on-demand nature are sacrificed to achieve cost-effectiveness or other objectives are usually called near-VOD systems.

The MS is connected to all TV channels and other data sources responsible for the network services. It contains multiple processors, each one servicing one

connected to the MS. The requests from each SS are stored in a queue (first-in-first-out). The MS serves the requests from the queue and sends the response to the SS through its fiber. The fiber has a finite capacity through which the MS can send a simultaneous number of responses. If the fiber channels are busy, the responses should wait in the queue till one of the channels becomes available. The number of users on one of the substations and the number of substations connected to the MS are variable, but within finite upper limits. The service performance of a substation depends on the number of fiber channels and channel bandwidth, which may differ from one substation to another.

III. Simulation Results

In this section computer simulation results are presented and discussed. Several factors that affect the network performance are taken into consideration in the simulation. Distance between the nodes and the main station is an important factor. The effects of the request rate (low, normal and high) were included in order to view the performance of the network under different demand conditions. Fiber dispersion was considered as an example of the network dependence on the channel characteristics.

Figure 3 shows the relation between the dispersion factor in Gbit.km/sec with the overall maximum optical fiber transmission rate, for various distances. As expected, for all distances the transmission rate, which is one of the most important factors in any network is inversely proportional to the dispersion [5]. It can be seen that the dispersion effect cannot be neglected. Obviously, dispersion tends to degrade the network performance. For example, as shown in Figure 1 the transmission rate is approximately halved when the dispersion is increased from 10 to 50 Gbit.km/sec. The distance, like dispersion, has a significant effect on the transmission rate. For example, a 20-km fiber with 30 Gbit.km/sec dispersion has almost twice the transmission rate of a 60-km fiber with the same dispersion. When the dispersion factor is large enough it is clearly seen that the transmission rates becomes almost independent of node distances.

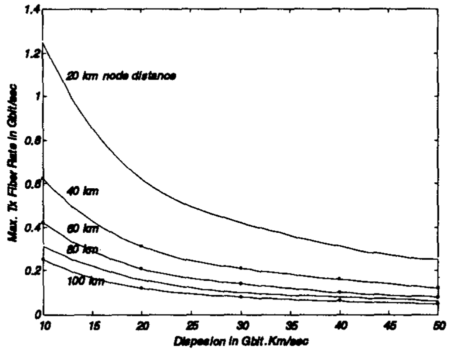

Figure 3. Transmission rate versus dispersion

In Figure 4 the relation between dispersion and average user waiting time is shown for three node distances: long distance (100 km), medium distance (60 km), and short distance (20 km). The request rate is assumed to be moderate. As can be seen, the waiting time is directly proportional to dispersion. This should be obvious; since increasing dispersion increases signal time delay, thus increasing the user waiting time. It can be easily justified that the average user waiting time is increased for a higher number of users, or higher request rates. This is due to the serving time needed by the main station in order to prepare the requests. The serving time is substantially increased in the case of highly crowded network; since not only the main station serving time is increased, but also some requests have to wait in the main station queue when all the fiber channels are in use.

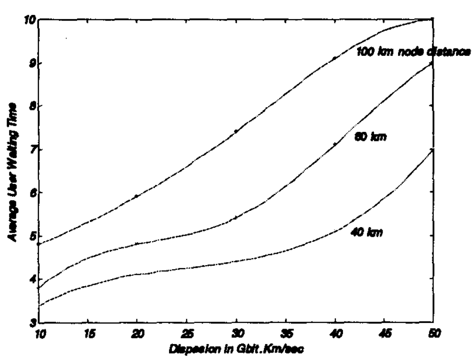

Figure 4. Average user waiting time versus dispersion

In Figure 5 the relation between dispersion and the percentage fiber usage time is shown. As in the previous case, a moderate request rate is assumed. The resulting curve is very similar to that of the average waiting time. The similarity is expected; since increasing dispersion decreases the transmission rate and thus, increases the waiting time. Hence, data stays longer in the fiber, thus, increasing the percentage fiber usage time. Again, the percentage fiber usage time is increased for higher number of users or higher request rates. This is due to the increased amount of data needed to be transmitted to the users in the substations.

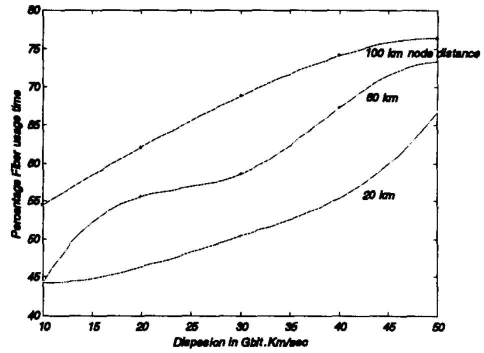

Figure 5. Percentage fiber usage time versus dispersion

IV. Conclusions

A modified interactive VOD network has been proposed. The suggested network model overcomes several inefficiencies found in existing networks. Several measures to evaluate the proposed network behavior under a wide range of operating conditions have been calculated using computer simulation.

V. Glossary

VOD .... Video on Demand.
ISI............... Intersymbol Interference.
MS .... Main Station.
SS .... Substation.
SCM .... Subcarrier Multiplexing.
WDM........... Wavelength Division Multiplexing.

VI. References

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VII. Biographies

Mohammad M. Banat - Was born in Irbid, Jordan, in 1963. He received the B.Sc. and M.Sc. degrees both in electrical engineering, from Yarmouk University, Jordan, in 1984 and 1986, respectively, and the Ph.D. degree in electrical engineering from the University of Ottawa, Canada, in 1995. During the academic year of 1986/1987, he taught electrical engineering courses at the Hijjawi College of Technology, Yarmouk University, Jordan, and worked as a teaching assistant at the Department of Electrical Engineering, Jordan University of Science and Technology. Between 1987 and 1989 he served as a communications engineer at the Jordanian Civil Defense Communications Department. In 1989 he joined as a lecturer the Department of Electrical Engineering at the University of Petroleum and Minerals, Saudi Arabia, where he was engaged in research on echo cancellation on voice-band data transmission networks. In Sep. 1991 he joined the University of Ottawa, Canada, to work towards the Ph.D. degree in Electrical Engineering. Since Feb. 1995 he has been with the Department of Electrical Engineering at the Jordan University of Science and Technology. His current research interests are in coherent optical fiber communication systems and networks, with focus on WDM/SCM lightwave networks.

Thaier S. Hayajneh - was born in Amman, Jordan in 1974. He received the B.Sc. degree and the M.Sc. degree in electrical engineering, majoring in communications and electronics, in 1997 and 1999, respectively, from the Jordan University of Science and Technology. His current research interests are in optical fiber communication systems and VOD optical networks.