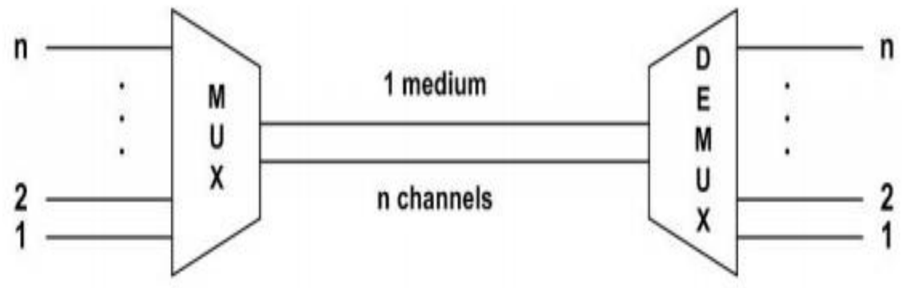
## Abstract

This paper includes the different multiplexing techniques and  some of the multiplexing issues in communication system design by examining overall system issues. Mutiplexing is designed to reduce the number of electrical connections or leads in the display matrix. Besides reducing the number of individually independent interconnections, multiplexing also simplifies the drive electronics, reduces the cost and provides direct interface with the microprocessors.

# 1.Introduction

In telecommunications and computer networks, **multiplexing** is a method by which multiple analog message signals or digital data streams are combined into one signal over a shared medium. The aim is to share an expensive resource. For example, in telecommunications, several telephone calls may be carried using one wire. The multiplexed signal is transmitted over a communication channel, which may be a physical transmission medium. The multiplexing divides the capacity of the high-level communication channel into several low-level logical channels, one for each message signal or data stream

It has been observed that most of the individual data-communicating devices typically require modest data rate. But, communication media usually have much higher bandwidth. As a consequence, two communicating stations do not utilize the full capacity of a data link. Moreover, when many nodes compete to access the network, some efficient techniques for utilizing the data link are very essential. When the bandwidth of a medium is greater than individual signals to be transmitted through the channel, a medium can be shared by more than one channel of signals. The process of making the most effective use of the available channel capacity is called Multiplexing. For efficiency, the channel capacity can be shared among a number of communicating stations just like a large water pipe can carry water to several separate houses at once. Most common use of multiplexing is in long-haul communication using coaxial cable, microwave and optical fibre.

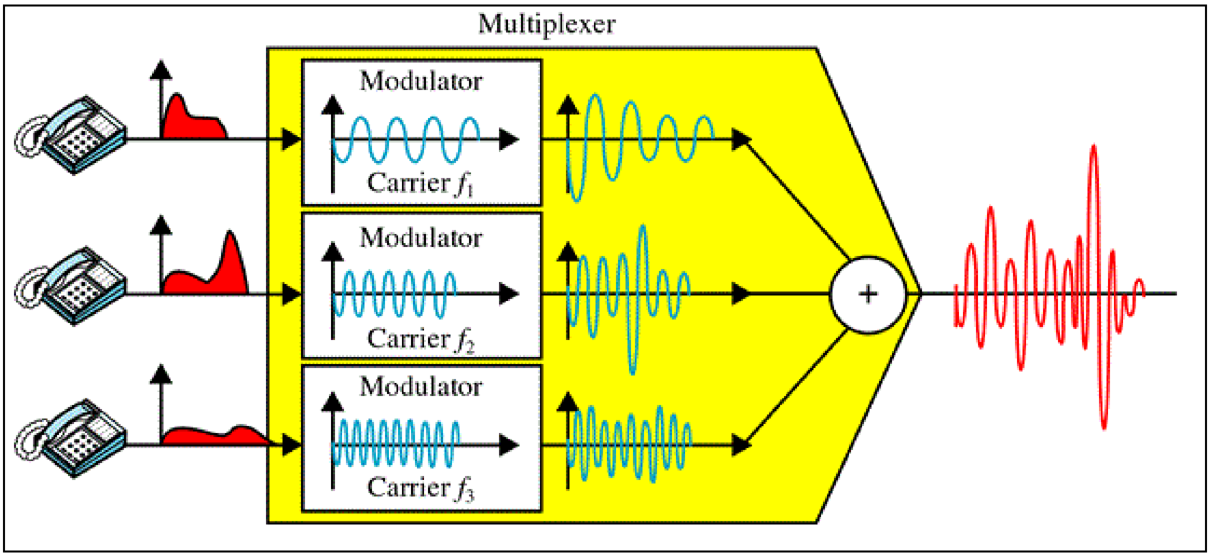



It depicts the functioning of multiplexing functions in general. The multiplexer is connected to the demultiplexer by a single data link. The multiplexer combines (multiplexes) data from these ‘n’ input lines and transmits them through the high capacity data link, which is being demultiplexed at the other end and is delivered to the appropriate output lines. Thus, Multiplexing can also be defined as a technique that

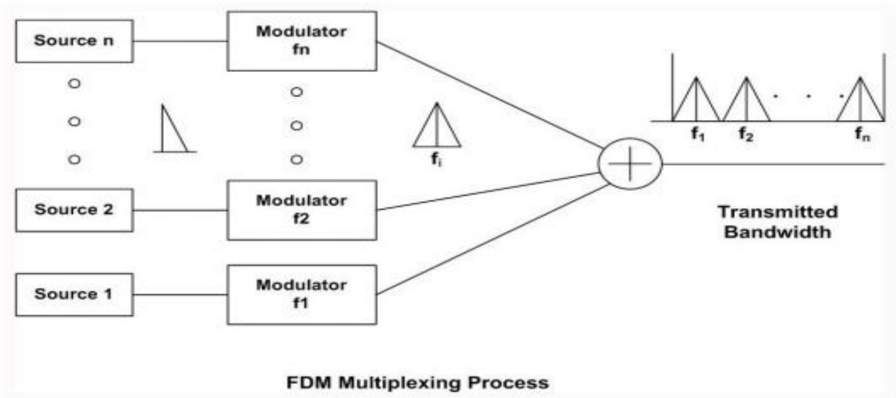
allows simultaneous transmission of multiple signals across a single data link.

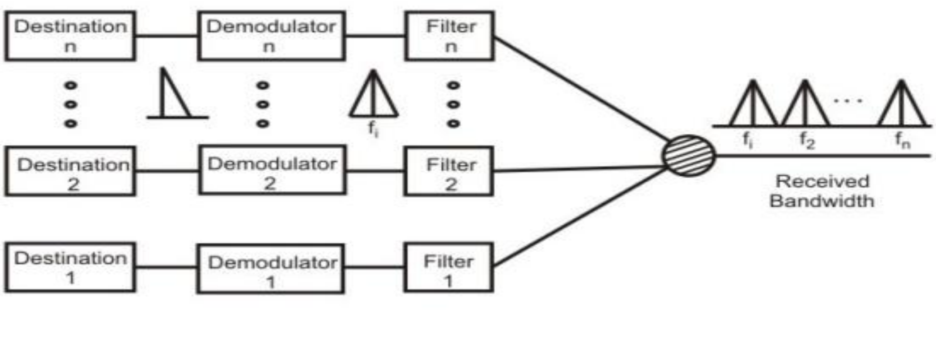
## 1.1.Multiplexing is of following three types:

**1.1.1.Frequency-division Multiplexing** (FDM) is an analog multiplexing technique that combines analog signals. FDM is applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted. In FDM, signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link. Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal. These bandwidth ranges are the channels through which the various signals travel. Channels can be separated by strips of unused bandwidth i.e **guard bands,** to prevent signals from overlapping. In addition, carrier frequencies must not interfere with the original data frequencies.




In frequency division multiplexing, the available bandwidth of a single physical medium is subdivided into several independent frequency channels. Independent message signals are translated into different frequency bands using modulation techniques, which are combined by a linear summing circuit in the multiplexer, to a composite signal. The resulting signal is then transmitted along the single channel by electromagnetic means as
shown in Fig. 2.7.2. Basic approach is to divide the available bandwidth of a single physical medium into a number of smaller, independent frequency channels. Using modulation, independent message signals are translated into different frequency bands. All the modulated signals are combined in a linear summing circuit to form a composite signal for transmission. The carriers used to modulate the individual message signals are
called sub-carriers, shown as f1, f2, …, fn in Fig.




FDM Demultiplexing Process

At the receiving end the signal is applied to a bank of band-pass filters, which separates individual frequency channels. The band pass filter outputs are then demodulated and distributed to different output channels.

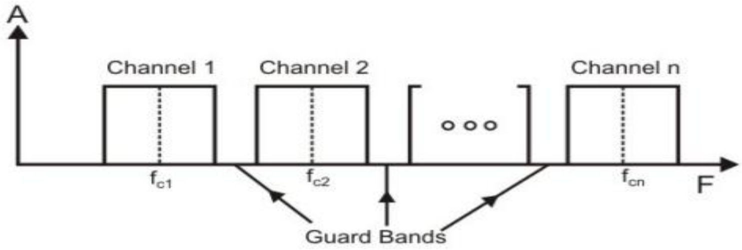
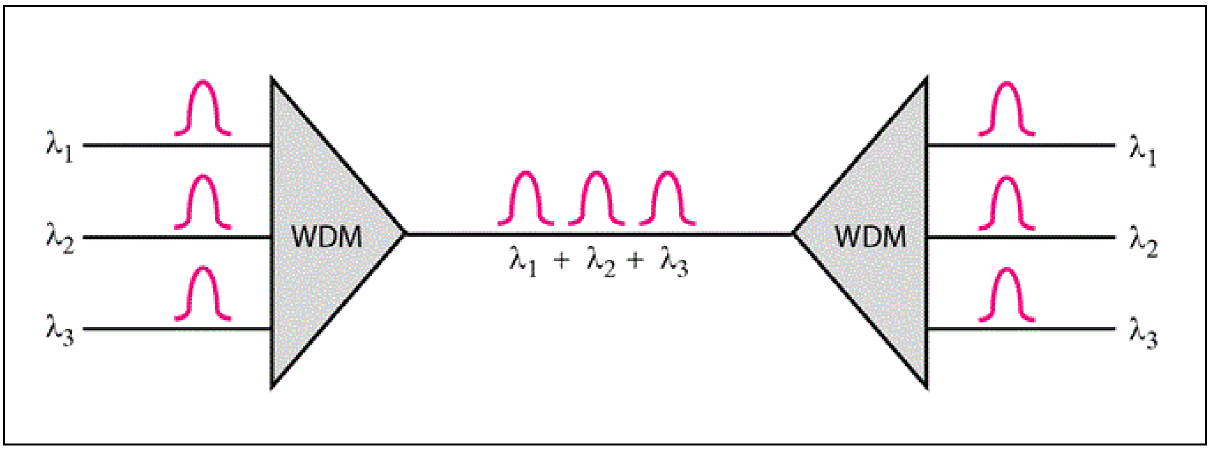



**Figure 2.7.4** Use of guard bands in FDM

If the channels are very close to one other, it leads to inter-channel cross talk. Channels must be separated by strips of unused bandwidth to prevent inter-channel cross talk. These unused channels between each successive channel are known as guard bands as shown in Fig. 2.7.4.

FDM are commonly used in radio broadcasts and TV networks. Since, the frequency band used for voice transmission in a telephone network is 4000 Hz, for a particular cable of 48 KHz bandwidth, in the 70 to 108 KHz range, twelve separate 4 KHz sub channels could be used for transmitting twelve different messages simultaneously. Each radio and TV station, in a certain broadcast area, is allotted a specific broadcast frequency, so that independent channels can be sent simultaneously in different broadcast area. For example, the AM radio uses 540 to 1600 KHz frequency bands while the FM radio uses 88 to 108 MHz frequency bands.

**1.1.2.Wavelength-division multiplexing** (WDM) is an analog multiplexing technique to combine optical signals.WDM is designed to use the high data rate capability of fiber-optic cable. The optical fiber data rate is higher than the data rate of metallic transmission cable. Using a fiber-optic cable for one single line wastes the available bandwidth. Multiplexing allows us to combine several lines into one.
WDM is conceptually the same as FDM, except that the multiplexing and demultiplexing involve optical signals transmitted through fiber-optic channels. The idea is the same: We are combining different signals of different frequencies. The difference is that the frequencies are very high.




Wavelength-division multiplexing (WDM) is conceptually same as the FDM, except that the multiplexing and demultiplexing involves light signals transmitted through fibre-optic channels. The idea is the same: we are combining different frequency signals. However, the difference is that the frequencies are very high. It is designed to utilize the high data rate capability of fibre-optic cable. Very narrow band of light signal from different source are combined to make a wider band of light. At the receiver the signals are separated with the help of a demultiplexer as shown in Fig. 2.7.5.

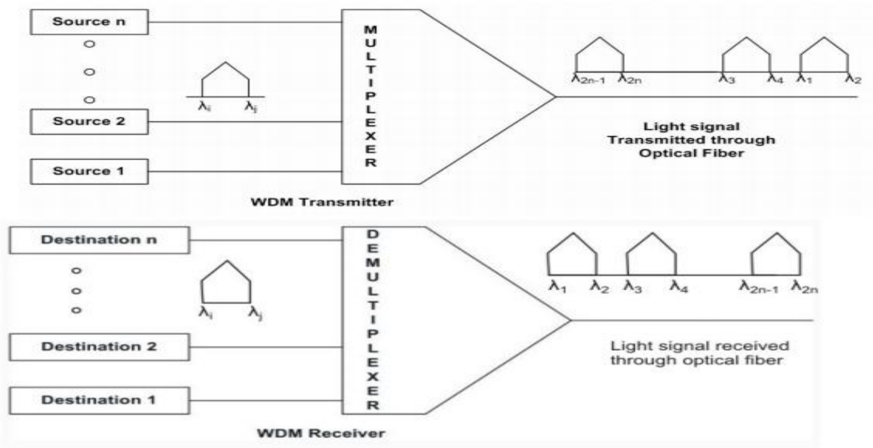
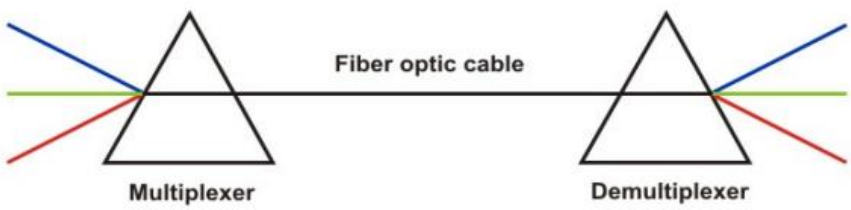


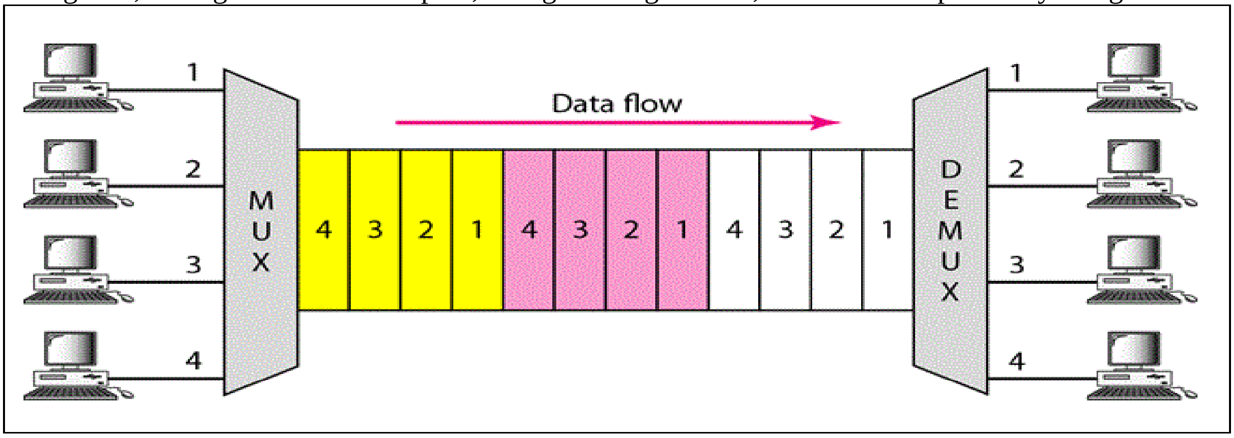

Figure Basic WDM multiplexing and demultiplexing

Multiplexing and demultiplexing of light signals can be done with the help of a prism as shown in Fig. 2.7.6. From the basic knowledge of physics we know that light signal is bent by different amount based on the angle of incidence and wavelength of light as shown by different colours in the figure. One prism performs the role of a multiplexer by combining lights having different frequencies from different sources. The composite signal can be transmitted through an optical fibre cable over long distances, if required. At the other end of the optical fibre cable the composite signal is applied to another prism to do the reverse operation, the function of a demultiplexer.

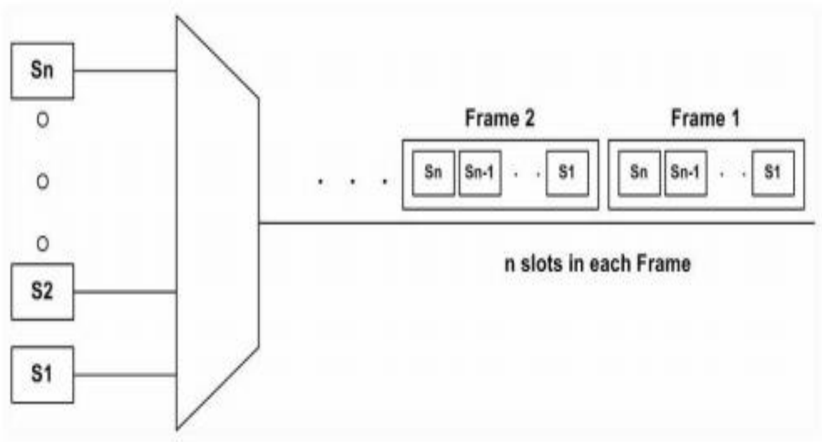



Multiplexing and demultiplexing of light signals with help of prisms

**1.1.3.Time-division Multiplexing (TDM)** is a digital mutiplexing technique for combining several low rate channels into one high-rate one.TDM is a digital process that allows several connections to share the high bandwidth of a link Instead of sharing a portion of the bandwidth as in FDM, time is shared. Each connection occupies a portion of time in the link.Digital data from different sources are combined into one timeshared link. However, this does not mean that the sources cannot produce analog data; analog data can be sampled, changed to digital data, and then multiplexed by using TDM.



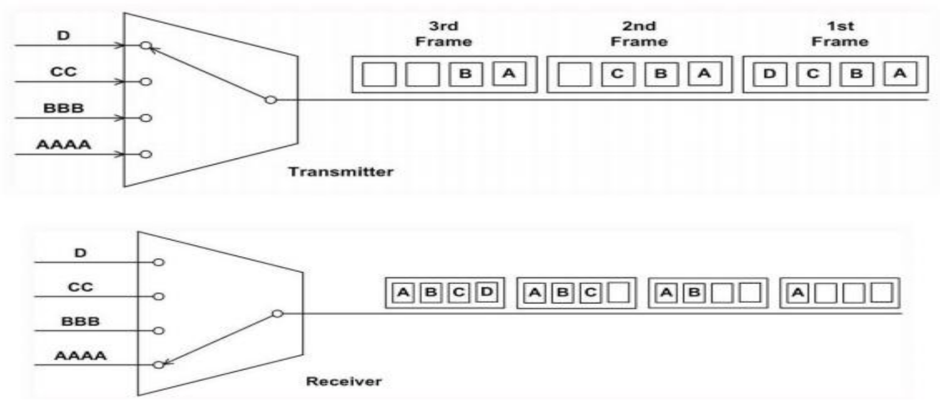

In frequency division multiplexing, all signals operate at the same time with different frequencies, but in Time-division multiplexing all signals operate with same frequency at different times. This is a base band transmission system, where an electronic commutator sequentially samples all data source and combines them to form a composite base band signal, which travels through the media and is being demultiplexed into appropriate
independent message signals by the corresponding commutator at the receiving end. The incoming data from each source are briefly buffered. Each buffer is typically one bit or one character in length. The buffers are scanned sequentially to form a composite data stream. The scan operation is sufficiently rapid so that each buffer is emptied before more data can arrive. Composite data rate must be at least equal to the sum of the individual data rates. The composite signal can be transmitted directly or through a modem. The multiplexing operation is shown in Fig.




Time division multiplexing operation

As shown in the Figure, the composite signal has some dead space between the successive sampled pulses, which is essential to prevent interchannel cross talks. Along with the sampled pulses, one synchronizing pulse is sent in each cycle. These data pulses along with the control information form a frame. Each of these frames contain a cycle of time slots and in each frame, one or more slots are dedicated to each data source. The maximum bandwidth (data rate) of a TDM system should be at least equal to the same data rate of the sources.

Synchronous TDM is called synchronous mainly because each time slot is preassigned to a fixed source. The time slots are transmitted irrespective of whether the sources have any data to send or not. Hence, for the sake of simplicity of implementation, channel capacity is wasted. Although fixed assignment is used TDM, devices can handle sources of different data rates. This is done by assigning fewer slots per cycle to the slower input devices than the faster devices. Both multiplexing and demultiplexing operation for synchronous TDM are shown in Fig.




Multiplexing and demultiplexing in synchronous TDM

**a.) Synchronous TDM**

One drawback of the TDM approach, as discussed earlier, is that many of the frame are wasted. It is because, if a particular terminal has no data to transmit at particular instant of time, an empty time slot will be transmitted. An efficient alternative to this synchronous TDM is statistical TDM, also known as asynchronous TDM or

Intelligent TDM. It dynamically allocates the time slots on demand to separate input channels, thus saving the channel capacity. As with Synchronous TDM, statistical multiplexers also have many I/O lines with a buffer associated to each of them. During the input, the multiplexer scans the input buffers, collecting data until the frame is filled and send the frame. At the receiving end, the demultiplexer receives the frame and distributes the data to the appropriate buffers. The difference between synchronous TDM and asynchronous TDM is illustrated with the help of Fig. 2.7.9. It may be noted that many slots remain unutilised in case synchronous TDM, but the slots are fully utilized leading to smaller time for transmission and better utilization of bandwidth of the medium. In case of statistical TDM, the data in each slot must have an address part, which identifies the source of data. Since data arrive from and are distributed to I/O lines unpredictably, address information is required to assure proper delivery as shown in Fig. 2.7.10.. This leads to more overhead per slot. Relative addressing can be used to reduce overhead.

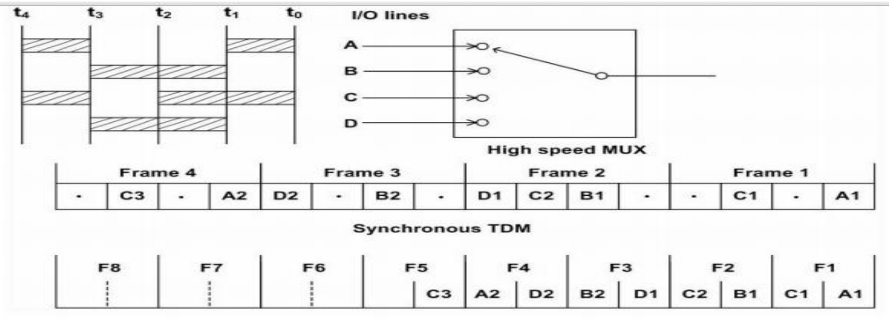
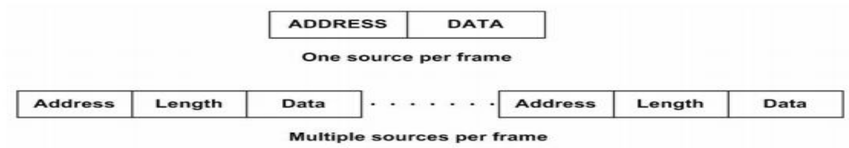



**Figure 2.7.9** Synchronous versus asynchronous TDM




Address overhead in asynchronous TDM

# 2. Literature Survey

## 2.1.Multiplexing issues in communication system design

ACM SIGCOMM Computer Communication Review

**Volume 20 Issue 4, Sep. 1990**

**Pages 209-219**

This paper considers some of the multiplexing issues in communication system design by examining overall system issues. In particular, we distinguish physical multiplexing of resources from logical multiplexing of streams. Both physical-resource multiplexing and logical multiplexing determine the service that can be provided by a communication system. We also discuss two issues affected by logical multiplexing - flow control and the relationship between control and data streams of a connection. We conclude that the granularity of physical resource sharing must be fine enough to meet the jitter and latency constraints of demanding applications. Also, high speed communication systems should restrict their logical multiplexing to layer 3.

## 2.2.Issues of Quality and Multiplexing When Smoothing Rate Adaptive Video

**N. G. Duffield,**
**Member, IEEE,**
**K. K. Ramakrishnan,**
**Member, IEEE**
**and Amy R. Reibman,**
**Member, IEEE**
**IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 1, NO. 4, DECEMBER 1999**

They have proposed a smoothing and rate adaptation algorithm—SAVE (Smoothed Adaptive Video over Explicit rate networks)—for transport of compressed video over rate controlled networks. SAVE attempts to preserve quality as much as possible, and exercises control over the source rate only when essential to prevent unacceptable delay. In order to understand the impact on quality of rate adaptation, we have evolved the quality metrics typically used to evaluate the efficacy of mechanisms to transport video. In this paper, we investigate the dynamic nature of rate reduction: any prolonged impairment is likely to be noticeable. We study the sensitivity of SAVE to its parameters and network characteristics. Finally, the utility of the proposed scheme is measured by its ability to multiplex a large number of streams effectively. Our evaluations are based on experiments with 20 traces of entertainment videos using different compression algorithms.

## 2.3.Architectural Considerations in the design of WDM-based Optical Access Networks

**Eytan Modiano and Richard Barry**
**Computer Networks and ISDN Systems, February, 1999.**

They describe a WDM-based optical access network architecture for providing broadband Internet services. The architecture uses a passive collection and distribution network and a configurable Feeder network. Unlike earlier papers that concentrate on the physical layer design of the network, we focus on higher layer architectural considerations. In particular we discuss the joint design of the electronic and optical layers including: WDM Medium Access Control protocols; the choice of

electronic multiplexing and switching between the IP and WDM layers; joint optical and electronic protection mechanisms; network reconfiguration algorithms that alter the logical topology of the network in response to changes in traffic; and traffic grooming algorithms to minimize the cost of electronic multiplexing. Finally we also
discuss the impact of the optical topology on higher layer protocols such as IP routing, TCP flow control and multi-layer switching.

## 2.4.Multiplexing Endpoints of HCA for Scaling MPI Applications: Design and Performance Evaluation with uDAPL , Sept 2010.

With an ever increasing demand for computing power, number of nodes to be deployed in a cluster based supercomputer is increasing. Limited hardware resources such as Endpoints (equivalent to Queue Pairs) on a Host Channel Adapter (HCA) of a high speed interconnect limit the scalability of a parallel application based on MPI that sets up reliable connections between every process pair using endpoints, prior to communication. In this paper, we propose a novel approach of multiplexing hardware endpoints (hweps) to extend scalability. (a) We discuss critical design issues with the multiplexing technique that differentiates a hwep from its software counterpart (swep) and enables sharing of hwep by multiple sweps. (b) We introduce the concept of Virtual Identifier (VID) which ensures that the connection between hardware endpoints is strictly one-to-one. (c) We also present static mapping scheme that offsets the overheads incurred due to multiplexing. User Direct Access Programming Library (uDAPL) defines a single set of APIs for all RDMA capable transports. We have incorporated the proposed multiplexing technique as a part of uDAPL implementation. Using this approach, we are able to scale MPI applications beyond the limit imposed by HCA and with no visible performance degradation.

# 3.Methodologies used:

### 3.1.Issues and Objectives of Multiplexing:

Multiplexing is designed to reduce the number of electrical connections or leads in the display matrix. Besides reducing the number of individually independent interconnections, multiplexing also simplifies the drive electronics, reduces the cost and provides direct interface with the microprocessors. . There are limitations in multiplexing due to complex electro-optical response of the liquid crystal cell. However, fairly reasonable level of multiplexing can be achieved by properly choosing the multiplexing scheme, liquid crystal mixture and cell designing. By introducing voice stream multiplexing , bandwidth efficiency can be improved by reducing header overhead. The Congestion in IP Network can be avoided due to telephony traffic by reducing number of voice packets.

**Bandwidth Utilization**: Bandwidth utilization is the wise use of available bandwidth to achieve specific goals. Efficiency can be achieved by multiplexing; i.e., sharing of the bandwidth between multiple users.

# 4.Gaps in Study

Multiplexing is a technique used to improve the bandwidth efficiency and reducing the number of electrical connections. There are limitations in multiplexing due to complex electro-optical response of the liquid crystal cell.

# 5.Summary

In telecommunications and computer networks, **multiplexing** is a method by which multiple analog message signals or digital data streams are combined into one signal over a shared medium. The aim is to share an expensive resource.It has been observed that most of the individual data-communicating devices typically require modest data rate. But, communication media usually have much higher bandwidth. As a consequence, two communicating stations do not utilize the full capacity of a data link. Moreover, when many nodes compete to access the network, some efficient techniques for utilizing the data link are very essential. When the bandwidth of a medium is greater than individual signals to be transmitted through the channel, a medium can be shared by more than one channel of signals. The process of making the most effective use of the available channel capacity is called Multiplexing.

## 6. Future Scope

Multiplexing is a technique used to improve the bandwidth efficiency and reducing the number of electrical connections. There are limitations in multiplexing due to complex electro-optical response of the liquid crystal cell. However, fairly reasonable level of multiplexing can be achieved by properly choosing the multiplexing scheme, liquid crystal mixture and cell designing.

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