A

Seminar report

On

Light Tree

Submitted in partial fulfillment of the requirement for the award of degree
of Bachelor of Technology in ECE

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Acknowledgement

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Preface

I have made this report file on the topic **Light Tree;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

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INTRODUCTION

Today, there is a general consensus that, in the near future, wide area networks (WAN)(such as, a nation wide backbone network) will be based on Wavelength Division Multiplexed (WDM) optical networks. One of the main advantages of a WDM WAN over other optical technologies, such as, Time Division Multiplexed (TDM) optical networks, is that it allows us to exploit the enormous bandwidth of an optical fiber (up to 50 terabits bits per second) with requiring electronic devices, which operate at extremely high speeds.

The concept of ***light tree*** is introduced in a wavelength routed optical network, which employs wavelength -division multiplexing (WDM). Depending on the underlying physical topology networks can be classified into three generations:

- **First Generation**: these networks do not employ fiber optic technology; instead they employ copper-based or microwave technology. E.g. Ethernet.
- **Second Generation**: these networks use optical fibers for data transmission but switching is performed in electronic domain. E.g. FDDI.
- **Third Generation**: in these networks both data transmission and switching is performed in optical domain. E.g. WDM.

WDM wide area networks employ tunable lasers and filters at access nodes and optical/electronic switches at routing nodes. An access node may transmit signals on different wavelengths, which are coupled into the fiber using wavelength multiplexers. An optical signal passing through an optical wavelength-routing switch (WRS) may be routed from an output fiber without undergoing opto-electronic conversion.

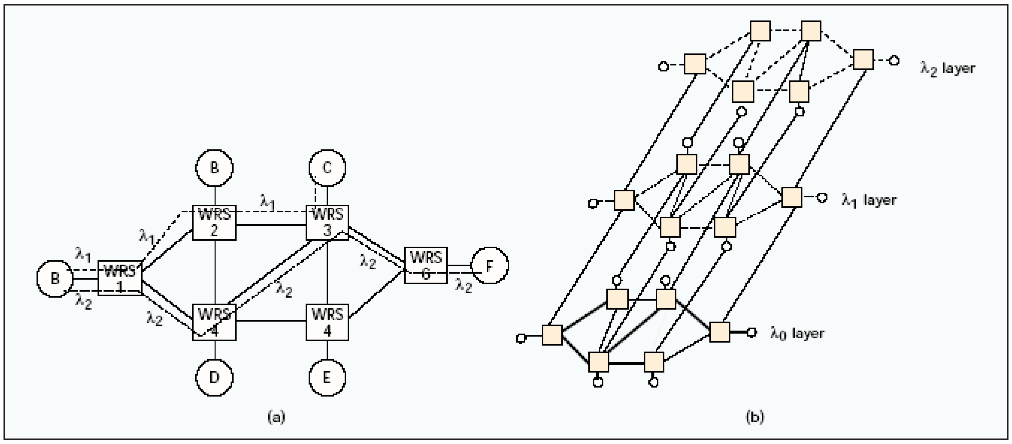
LIGHT PATH

A light path is an all-optical channel, which may be used to carry circuit switched traffic, and it may span multiple fiber links. Assigning a particular wavelength to it sets these up. In the absence of wavelength converters, a light path would occupy the same wavelength continuity constraint.

A light path can create logical (or virtual) neighbors out of nodes that may be geographically far apart from each other. A light path carries not only the direct traffic between the nodes it interconnects, but also the traffic from nodes upstream of the source to nodes upstream of the destination. A major objective of light path communication is to reduce the number of hops a packet has to traverse.

Under light path communication, the network employs an equal number of transmitters and receivers because each light path operates on a point-to-point basis. However this approach is not able to fully utilize all of the wavelengths on all of the fiber links in the network, also it is not able to fully exploit all the switching capability of each WRS.

LIGHT TREES



■ **Figure 2.** *Architecture of a wavelength-routed optical etwork and its layered-graph representation. a) Illustrated are: a lightpath on wavelength λ_1 from node A to node C, and a lightpath on wavelength λ_2 from node A to node F; b) layered-graph model with three wavelength layers.*

Thus, incorporating an optical multicasting capability extends the light path concept. Multicasting is the ability of an application at a node to send a single message to the communication network and have it delivered to multiple recipients at different locations. We refer light tree as a point to multi point extension of light path. Today, many multicasting applications exist, such as, teleconferencing, software/file distribution including file replication on mirrored sites, distributed games, Inter net news distribution-mail mailing lists, etc., but the implementation of these applications is not necessarily efficient because today's WANs were designed to support point-to-point (unicast) communication. In the future, as multicast applications become more popular and bandwidth intensive, there emerges a pressing need to provide multicasting support on WANs.

A light tree is a point to point multipoint all optical channel, which may span multiple fiber links. Hence, a light tree enables single-hop communication between a source node and a set of destination nodes. Thus, a light tree based virtual topology can significantly reduce the hop distance, thereby increasing the network throughput.

Figure 1a shows a light tree, which connects node UT to nodes TX, NE and IL. Thus, an optical signal transmitted by node UT travels down the light tree till it reaches node

CO, where it is split by an optical splitter into two copies. One copy of the optical signal is routed to node TX, where it is terminated at a receiver. The other copy is routed towards node NE, where it is again split into two copies. At node NE, one copy of the optical signal is terminated at receiver, while the other copy is routed towards node IL. Finally, a copy of the optical signal reaches node IL, where it is terminated at a receiver. Thus the virtual topology induced by this light tree consists of three logical links.

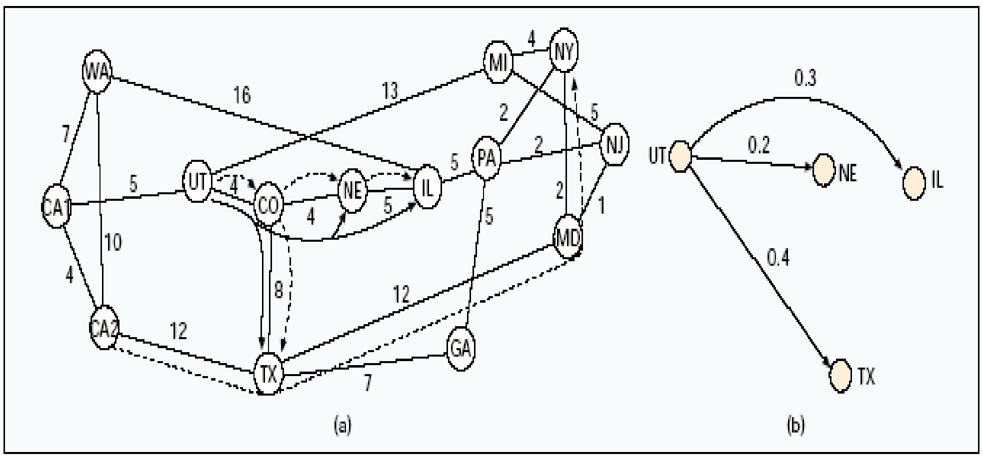
Let us assume that the bit rate of each light path is normalized to one unit, and node UT wants to send a certain amount of packet traffic to nodes TX, NE and IL. Let assume that we are allowed only one free wavelength on the links UT-CO, CO-NE, NE-IL and CO-TX. Then, a light path based solution would consist of the following four light paths:

- From UT to CO
- From CO to NE
- From CO to TX
- From NE to IL

Thus the light path based solution requires a switch at nodes CO and NE and a total of eight transceivers (one transmitter and one receiver per light path). On the other hand, a light tree based solution consists of a single light tree, which requires a total of four transceivers (one transmitter at UT and one receiver per node at TX, NE, and IL) and does not utilize the electronic switch at node CO or NE.

Requirements:

1. Multicast –capable wavelength routing switches (MWRS) at every node in the network.
2. More optical amplifiers in the network. This is because if we make n copies of an optical signal by using one or more optical splitters, the signal power of at least one copy will be less than or equal to 1/n times the original signal power; thus more amplifiers may be required to maintain the optical signal power above a certain threshold so that the signal can be detected at their receivers.



■ **Figure 1.** *a) NSFNET backbone topology (link labels correspond to propagation delays.); b) virtual links induced by the light-tree consisting of source UT and destination nodes TX, NE, and IL.*

ARCHITECTURE OF WAVELENGTH-ROUTED OPTICAL NETWORK

A WDM control network may require efficient delivery of broadcast traffic. Consider a wavelength –routed optical network shown in figure2a, which may be modeled as a layered graph, in which each layer represents a wavelength, and each physical fiber has a corresponding link on each wavelength layer. Wavelength at 0 layer serves as the control network. For illustration, a broadcast tree is shown as the control network. Now, the switching state of each wavelength-routing switch (WRS) is managed by a controller. Controllers communicate with each other using a control network, either in-band, out-of-band or in-fiber, out-of-band. In in-fiber, out-of-band signaling (which is advocated for WDM WAN), a wavelength layer is dedicated for the control network. For example, in figure 2b the wavelength 0 may be used for the control network, and controllers may employ multiple light trees for fast information dissemination among themselves. Moreover, in the future, as multicast applications become more and more popular and bandwidth-intensive, there emerge a pressing need to provide multicast support on WANs. Some multicast applications may have a large destination set, which mat be spread over a wide geographical area; for example, a live telecast of a popular music concert is one such application. A light tree based broadcast layer may provide an efficient transport mechanism for such multicast applications.

MULTICAST SWITCH ARCHITECTURES

This section examines various switch architectures which have multicast capability.

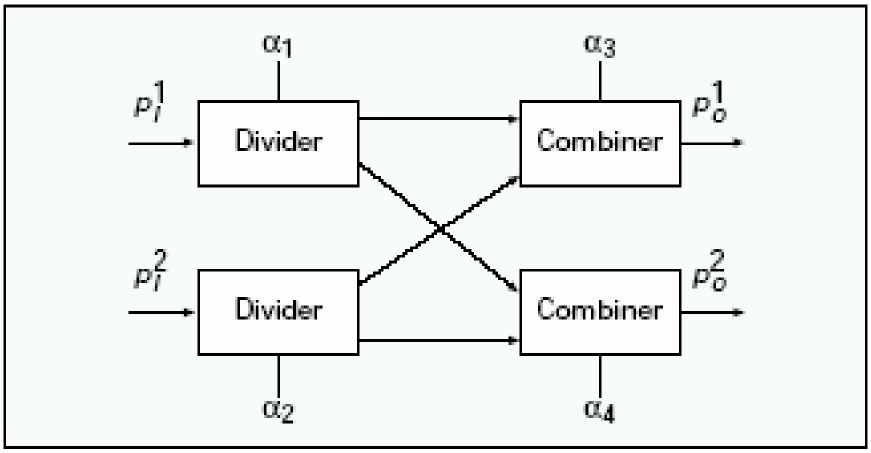


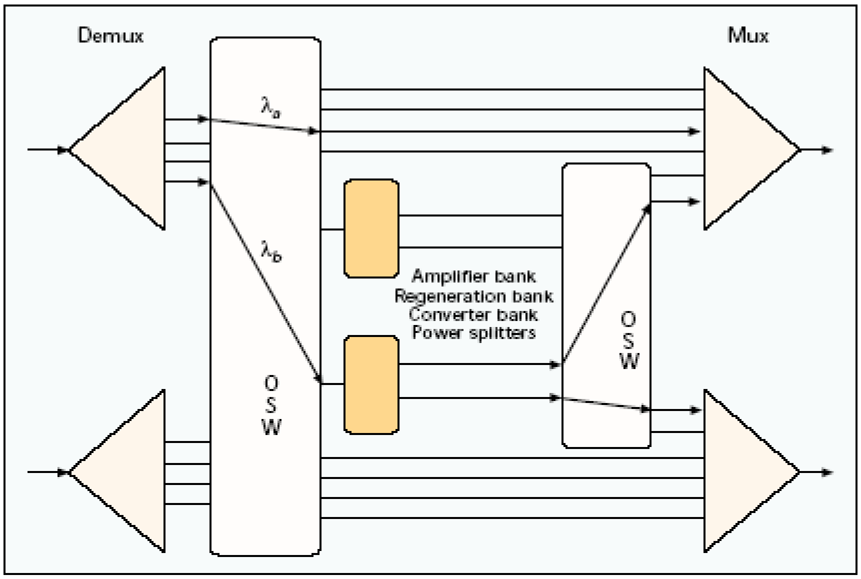
Figure 3. *Linear divider-combiner.*

Figure 3 shows a linear divider combiner with two input fibers (the Pis), two output fibers (the P0s), two dividers and four control signals (the αjs). A larger LDC will have more than two combiners and dividers. The LDC acts as a generalized optical switch with added functions of multicasting and multiplexing. The values of α1, α2, α3, α4 (each can be varied between 0&1) control the proportion of the input power that can be sent to the output links. Let Pi1 and Pi2 be the power on the input links, and let P01 and P02 be the output powers. Then,

$Po1=(1-\alpha 1)(1-\alpha 3)\ Pi1+(1-\alpha 2)\ \alpha 3Pi2$ and

$Po2=\alpha 1\ (1-\alpha 4)\ Pi1+\alpha 1\alpha 4Pi2$

AN MWRS BASED ON A SPLITTER BANK



■ **Figure 4.** *A multicast-capable wavelength-routing switch.*

An optical splitter splits the input signal into multiple identical output signals. Since an optical splitter is a passive device, the power from at least one output signal of an n-way optical splitter is less than or equal to 1/n times the input power. To be detected, the optical signal power needs to be more than a threshold, and hence an optical switch may require a large number of optical amplifiers.

Figure 4 shows a 2*2 multicast-capable wavelength-routing switch (MWRS), which can support four wavelengths on each fiber link. The information on each incoming link is first demultiplexed into separate wavelengths, each carrying a different signal. Then the separate signals, each on separate wavelengths, are switched by the optical switch (OSW). Signals that do not need duplication are sent directly to ports corresponding to their output links, while those signals that need to be duplicated are sent to a port connected to a splitter bank.

The splitter bank may be enhanced to provide optical signal amplification, wavelength conversion and signal regeneration for multicast as well as unicast signals. For example, in figure 4 wavelengths is a unicast signal and is a multicast signal. The output of the splitter is connected to a smaller optical switch, which routes the different copies of a signal to their respective output links.

MWRS BASED ON A “DROP AND CONTINUE” SWITCH

In a “drop and continue” switch, a light path can be terminated at a node and simultaneously an identical copy of the light path can be allowed to continue to another node in the network. By employing a “drop and continue” switch, we can construct a chain of nodes, which are connected by a “drop and continue” light path. Thus, all nodes on the chain will receive transmissions on a drop and continue light path where light is “dropped”. Note that, a “drop and continue” light path is a special case of a light tree.

THE OPTICAL LAYER

In general, the topology of a wavelength routing network may be an arbitrary mesh. It consists of wavelength cross connect (WXS) nodes interconnected by fiber links. The network provides light paths between pairs of network nodes. A light path is simply a high bandwidth pipe, carrying data up to several gigabytes per second. It is realized by allocating a wavelength on each link in the path between two nodes. Clearly we cannot assign the same wavelength to two light paths on any given link.

Each link can support a certain number of wavelengths. The number of wavelengths that can be supported depends on the component and transmission imposed limitations.

The optical layer provides light paths to the higher layers. In addition to the pass through capability provided by the optical layer, several other features, which include are:

Transparency: Transparency refers to the fact that light paths can carry data at a variety of bit rates, protocols, and so forth, and can, in effect, be made protocol insensitive. This enables the optical layer to support a variety of higher layers concurrently.

Wavelength reuse: Although the number of wavelengths available may be limited, the network can still provide enormous capacities, since wavelengths can be spatially reused in the network.

Reliability: the network can be configured such that in the event of failures, lightpaths can be rerouted over alternative paths automatically. This provides a high degree of reliability in the network.

Virtual topology: the virtual topology is the graph consisting of the network nodes, with an edge between two nodes if there is a light path between them. The virtual topology thus refers to the topology seen by the higher layers using the optical layer. To an ATM network residing above the optical layer, the lightpaths look like links between TM switches. The set of lightpaths can be tailored to meet the traffic requirements of the layers.

Circuit switching: The lightpaths provided by the optical layer can be set up and taken down circuits in circuit switched networks, except that the rate at which the set up and take down actions occur is likely to be much slower than, say, the rate for telephone networks with voice circuits. No packet switching is provided within the optical layer.

UNICAST, BROADCAST, AND MULTICAST TRAFFIC

Understanding the differences between unicast, broadcast, and multicast network traffic is central to understanding the benefits of IP/TV. Each of these types of transmission uses a different type of destination IP address to accomplish its task, and can have a very different level of impact on network bandwidth consumption.

UNICAST TRAFFIC

IP/TV On Demand use unicast traffic. Each user can request the program at a different time, with the number of simultaneous users limited by the available bandwidth from the video streams.

Unicast traffic is sent from a single source to a single destination IP address. The address belongs to one (and only one) machine in the network. FIGURE 5-1: shows a simple example of unicast traffic, with one data stream being transmitted from a single source to a single destination.

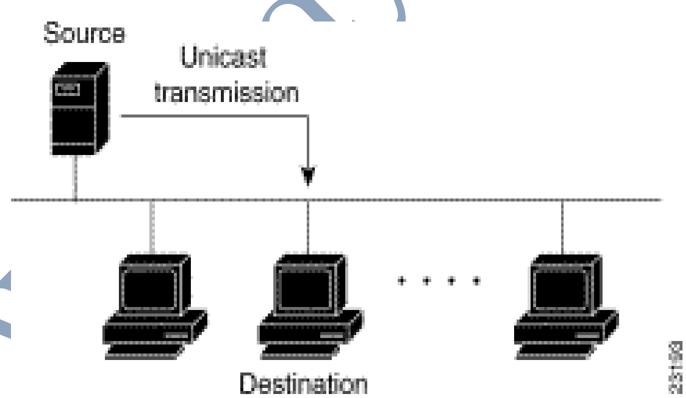


Figure 5-1: Example of Single Unicast Traffic

Unicast traffic is appropriate for many client/server applications, such as database applications, in which all the data resides on the server and the client runs an application to retrieve, modifies, add, or delete data. For each transaction, there can be many bursts of unicast traffic traveling back and forth between the client and the server.

However, in the case of an application such as multimedia presentations, there might be a single source and several destinations. When a source machine wants to send the same data to two destination addresses using the unicast address scheme, it must send two separate data streams, thus doubling the amount of network bandwidth that is used.

Figure 5-2: shows an example of multiple-stream unicast traffic, with a single source sending separate data streams to multiple destinations. Because the source must replicate the entire data stream for each intended destination, this can be a very inefficient use of network bandwidth

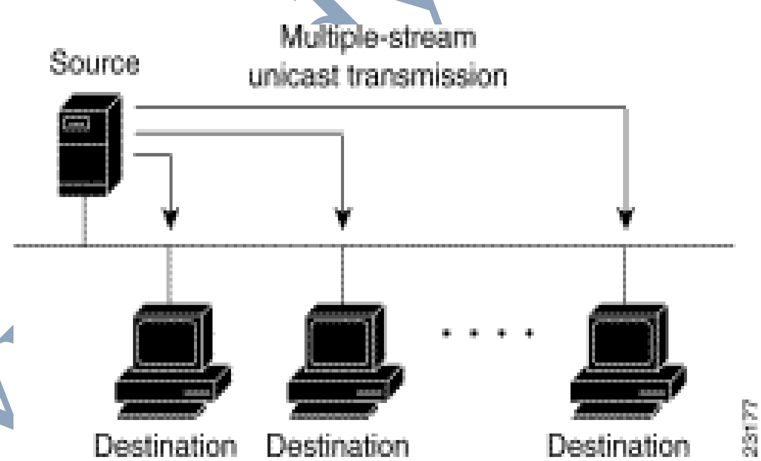


Figure5-2: Example of Multiple-Stream Unicast Traffic

BROADCAST TRAFFIC

Broadcast traffic uses a special IP address to send a single stream of data to all of the machines on the local network. A broadcast address typically ends in 255 (for example, 192.0.2.255) or has 255 in all four fields (255.255.255.255). Note, however, that every machine receives the data stream, whether the user wants it or not. For this reason, broadcast transmissions are usually limited to network level services such as address resolution. Because the destination machine has no choice about whether to receive the data, it is not practical to use broadcast transmissions for applications such as streaming video.

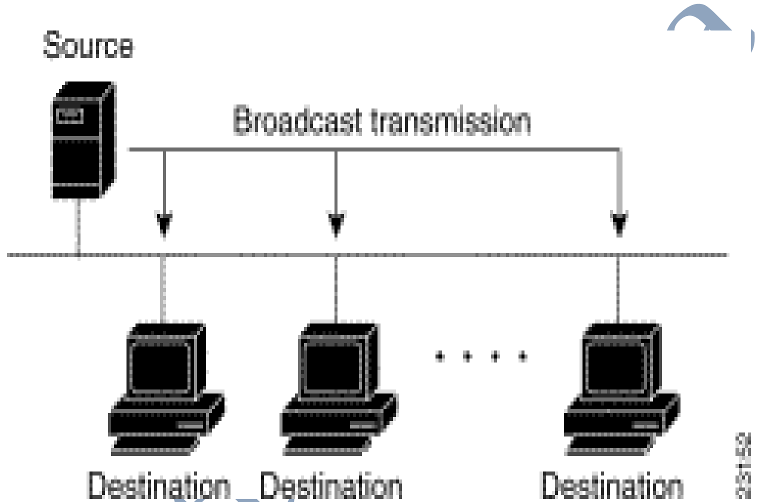


Figure 5-3: Example of Broadcast Traffic

MULTICAST TRAFFIC

IP/TV scheduled programs use multicast transmissions which can reach unlimited numbers of viewers simultaneously without overloading the network.

Multicast transmissions use a special class of destination IP addresses (the addresses in the range 224.0.0.0 through 239.255.255.255). Multicast addresses are Class D addresses. Unlike unicast addresses, these multicast addresses are not assigned to individual machines on the network. Instead, when a data stream is sent to one of these addresses, potential recipients of the data can decide whether or not to receive the data. If the user wants the data, the user's machine receives the data stream; if not, the user's machine ignores it.

For an application such as IP/TV, this means that a source server can transmit a single data stream that is received by many destinations without overloading the Network by replicating the data stream for each destination. Unlike the broadcast case, the user can choose whether to receive the data.

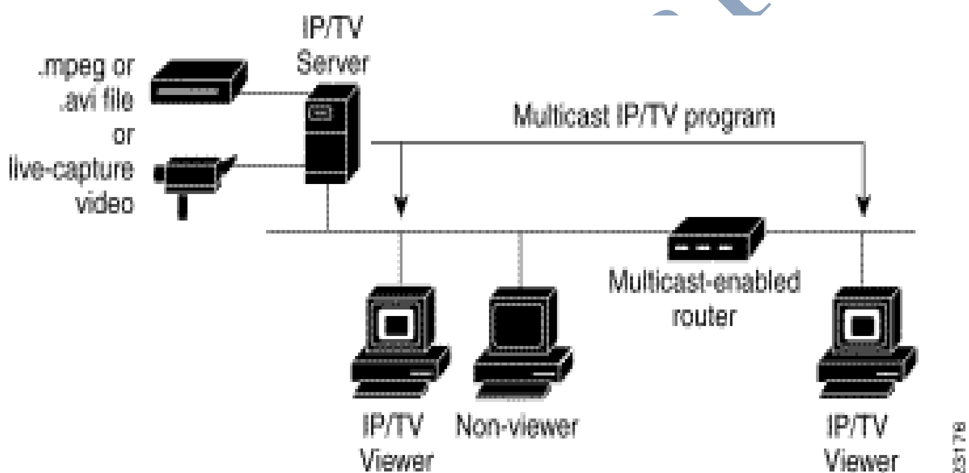


Figure5-4: Example of Multicast Traffic

IP/TV uses multicast addressing to deliver multimedia content to the user without overburdening the network with unnecessary data streams. Note, however, that multicast transmissions require the routers in the network to be multicast-enabled.

Combining Unicast and Multicast Traffic

If the routers in a network are not capable of handling multicast traffic, IP/TV can use unicast transmissions to send the multimedia content across the nonmulticast-enabled router. A server on the other side of the router can then use multicast transmission to deliver the content to its local users.

Figure 5-5: shows an example in which both multicast and unicast transmissions are used to deliver IP/TV multimedia content.

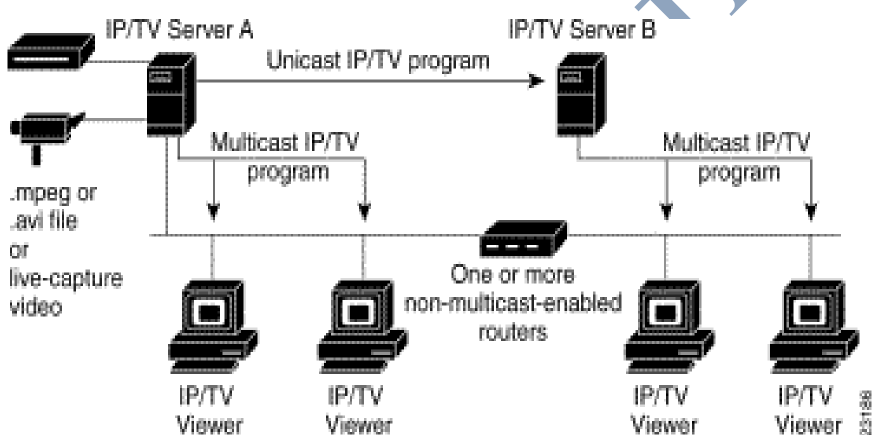


Figure5-5: Example of Combined Multicast and Unicast Traffic

Note, however, that each time a data stream is replicated, it adds to network traffic loads. Assume that a single data stream requires 1.15 Mbps per second of network bandwidth (which is typical for MPEG video), and the server sends one multicast data stream and seven unicast data streams (the maximum number permitted by IP/TV). In this case, the total network bandwidth consumed would be 9.2 Mbps, which is enough to severely overload the average 10BaseT Ethernet network.

The use of combined multicast and unicast transmissions to deliver IP/TV content is called Small Casting.

LIGHT TREES: PROBLEM FORMULATIONS

The problem of embedding a desired virtual topology on a given physical topology (fiber network) is formally stated below. Here, we state the problem of unicast traffic. We are given the following inputs to the problem:

- A physical topology Gp=(V, Ep) consisting of a weighted undirected graph, where V is the set of network nodes, and Ep is the set of links connecting nodes. Undirected means that each link in the physical topology is bi-directional. Nodes correspond to network nodes (packet switches), and links correspond to the fibers between nodes; since links are undirected, each link may consist of two channels or fibers multiplexed (using any suitable mechanism) on the same buffer. Links are assigned weights, which may correspond to physical distances between nodes. A network node i is assumed to be equipped with a Dp (i) x Dp (i) WRS, where Dp (i), the physical degree of node i, equals the number physical fiber links emanating out of node i.

- The number of wavelength channels carried by each fiber =W.

- An NxN traffic matrix, where N is the number of network nodes and the (i, j) th element is the average rate of traffic flow from node i to node j.

- The number of wavelength tunable lasers (Ti) and wavelength tunable filters (Ri) at each node.

Our goal is to determine the following.

A virtual topology Gp=(V, Ep) as another graph the out-degree of a node is the number of transmitters at the node the nodes of the virtual topology. In the virtual topology correspond to the nodes in the virtual topology, a link between nodes i, and j corresponds to a light tree rooted at node i with node j as one of the leaves on the light Tree.

Unicast traffic:

Formulation of the optimization problem

The problem of finding an optimum light path based virtual topology is formulated as an optimization problem, using principles of multi commodity flow for routing of light trees on the physical topology and for routing of packets on the virtual topology.

Optimization criterion – minimize one of the two objective functions:

- Average packet hop distance
- Total number of transceivers required in the network

Constraints -we divide the problems constraints into three categories as follows:

- ✓ Constraints arising from limited number of transceivers per node.
- ✓ Constraints arising from limited number of wavelengths.
- ✓ Constraints arising from the limited bandwidth of light tree.

Lightpath solution	Transceivers	Wavelengths		
		4	6	8
	4	1.59	1.58	1.58
	5	1.48	1.38	1.38
	6	1.42	1.32	1.30
Light-tree solution	Transceivers	Wavelengths		
		4	6	8
	4	1.23	1.13	1.08
	5	1.21	1.12	1.07
	6	1.19	1.09	1.07

Table 1. *Average packet hop distance for lightpath-based and light-tree-based virtual topologies.*

Traffic matrix	Virtual topology	
	Lightpath	Light-tree
Random	104	102
Broadcast to neighbors	70	54

Table 2. *The number of transceivers required by lightpath-based and light-tree-based virtual topologies for different traffic matrices.*

CONCLUSION

Recently, there has been a lot of interest in WDM based fiber optic networks. In fact, there is a general consensus that, in the near future, WANs will be based on WDM optical networks. So far, all architectures that have been proposed for WDM WANs have only considered the problem of providing unicast services. In addition to unicast services future WDM WANs need to provide multicast and broadcast services. A novel WDM WAN architecture based on light trees that is capable of supporting broadcasting and multicasting over a wide-area network by employing a minimum number of opto-electronic devices was discussed. Such WDMWAN can provide a very high bandwidth optical layer, which efficiently routes unicast, broadcast and multicast packet-switch traffic.

Each node in the WDM WAN consists of a multicast-capable wavelength routing switch (WRS), an "off –the-shelf" electronic packet switch, and a set of opto electronic converters. The problem of finding an optimum set of light-trees was formulated as a mixed integer linear problem. Preliminary results show that if we employ a set of light trees, then significant savings can be achieved in terms of the number of opto electronic devices that are required in the network.

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