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A Study on Design of Wavelength Converter and its Placement in WDM Network

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Abstract - This research aims to optimize the protocol performance of both the WDM Ring and the WDM Star, two networks that have previously only been studied separately. Furthermore, there is limited information on how ring and star networks compare in terms of performance. Numerous promising developments lie ahead for optical ring networks. The suggestion to combine two enhancements is an intriguing one. The goal is to build a high-performance network (HPN) that functions optimally across a small subset of the wavelengths in a larger ring. As an added bonus, the hybrid ring-star network offers a variety of load-balancing and routing options for each source-destination pair. One-chain RPR networks can benefit from a guideline for WDM upgrades by studying the effects of advanced routing methods on the efficiency of hybrid ring-star networks (resilient packet ring). This optical fiber type, as the name suggests, is limited to transmitting a single mode of light. As a result, it can only transmit a single wavelength of light along its length. Typically, this is a 1310nm or 1550nm wavelength. That prevents it from transferring more data, we assume, restricts its potential. However, single-mode optical fibers are preferable over multimode ones due to their higher bandwidth and lower loss. In other words, no other method comes close to matching the pace. It's interesting to note that single-mode fibers appeared later than multimode fibers. They came later than multimode cables did. Because their cores are so small, these cables can physically support just a single mode of transmission. That is to say, the core's diameter is about comparable to the wavelength of light traveling through it. The only kind of illumination that is employed is lasers. It's important to note that the wavelengths of light employed in single-mode fibers are not in the visible range. Since the light doesn't bend or refract, it can be used in systems where connections across greater distances are necessary. The difficulty in coupling single-mode fibers is a major drawback.

Keywords - Wavelength Converter, WDM Network, WDM Ring, high-performance network, RPR networks

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INTRODUCTION

Due to its high dielectric strength and large bandwidth (BW), fiber optic communication has found primary application in the design and construction of automated distribution systems. This paper presents a comprehensive analysis of optical fiber, dissecting its fundamentals, applications, and root causes in the development and deployment of fiber optic cabling. The necessity of and comparison to optical fiber technologies are discussed in this paper [1]. Wireless communication and broadcasting technologies have enabled the continuous global expansion of multinational corporations. In terms of technological advancement, fiber-optic communication stands out as the most recent and cutting-edge option available. Since then, the growing population has steadily increased the demand for BW in communications. In order to motivate scientists working in communication to seek out new options, ever large BWs were required. Researchers in the field of communication were scouring the globe for a medium of data transmission that was both wireless and minimal in loss, hoping to recover as much information as quickly as possible at the expense of quality. This unceasing exploration of potential transmission mediums ultimately resulted in the advent of optical fiber. A cursory review of past interactions [2] is in order. Signals from different cables do not interfere with one another, and there is no amplification of background noise. Electrical interference does not affect fibers. Due to the electric nature of unarmored fiber cables, they can effectively shield high-voltage communication devices, such as those found in power plants or in areas where metal communications are vulnerable to lightning. It can also be employed in environments where there is a risk of explosive gases without the need for any kind of ignition source. The tap-resistance of these concentrated dual-core fibers is similar to that of electrical connections, although it involves a more involved process (in this case, fiber tapping). Fibers are commonly used for short-distance connections between devices. Since most modern HDTVs provide an optical digital audio input. Using the TOSLINK protocol, it is possible to send audio signals through optical fibers [3]. Networks that transmit data via lightwaves using wavelength division multiplexing (WDM) are referred to as WDM networks. They use the same optical cable to convey information at many optical wavelengths at the same time. However, since several connections can be exchanged simultaneously on the same cable, the enormous bandwidth capacity of optical fibers is better exploited. It allows for parallel electronic processing, with up to 40 Gb/s, but with multiple users. In addition, each link established between the terminal nodes on a WDM channel might have its own data rate and data format. Transparency in wavelength division multiplexing describes this feature. Networks sharing a fiber infrastructure must assign distinct wavelengths to each of their users. It is also known as another type of wavelength restriction.

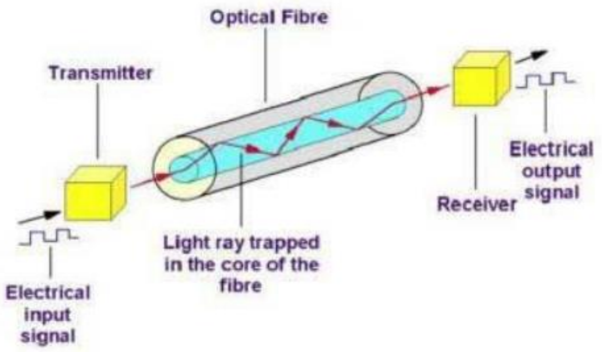

Figure 1: Fiber-Optic communication

In most cases, optical fibers (OFs) have a core surrounded by a cladding made of a transparent material with a reduced index of refraction. Complete internal reflection makes the fiber act like a waveguide, stabilizing the center of the beam of light. [5] Single-mode fiber (SMF) supports that use more than one transmission mode or transverse mode are called multi-mode fibers. Compared to single-mode fibers, multi-mode fibers (MMF) have a larger core diameter [6] and are used for high-power transmission in networking and short-distance communication applications. [7] Single-mode fibers are typically utilized for connections longer than a kilometer (3,300 ft). Fibers, the precise arrangement of fibers, and connection of these aligned cores must all be precisely cleared before the process can begin, making it more involved than simply connecting the electrical wire or cable. Fusion splices are commonly used when a permanent connection is required. Fiber ends are fused using an electric arc in this process. Another frequent approach is mechanical splitting, in which the fibers' ends are kept in touch using mechanical force. There are temporary and semi-permanent connections that can be made with OF connectors. [3] In wavelength division multiplexing (WDM), many signals are combined onto a single laser beam, which is then sent through a fiber optic cable at various wavelengths. Each laser receives its own unique set of modulating signals. WDM is similar to FDM, the infrared analog of color filters for visible light, at the receiving end. Instead of employing RF frequencies, however, wavelength division multiplexing (WDM) operates in the infrared (IR) region of the electromagnetic spectrum. Each infrared channel provides a mix of frequency division multiplexing (FDM) and time division multiplexing (TDM) signals. To go to their intended destinations, all IR multiplex channels are either separated or de-multiplexed. Infrared (IR) channels can be used in conjunction with wavelength division multiplexing (WDM) or multiple IR channels to allow for the simultaneous transport of data in a variety of formats and at varying data rates [4]. About halfway to its final destination, the signal was DE multiplexed between the wavelengths of two channels using a dichroic (2 wavelength) filter with a cutoff wavelength. It soon became clear that more than 2 IR multiplex channels may be de-multiplied by cascading dichroic filters, which ushered in the era of coarse WDM (CWDM) and Dense WDM (DWDM). In CWDM, eight independent IR channels are standard, with a maximum of eighteen channels possible. In DWDM, there could be hundreds. With multiplexed RF signals for each infrared (IR) channel, a single fiber can theoretically carry data at a rate of several hundred gigabits per second (Gbps) [5].

OVERVIEW OF FIBER OPTIC CABLE

Optical fiber is a cylinder-shaped, glass- or plastic-based material divided into a core, a cladding, and a jacket. The diameter is extremely small, and it is a highly flexible medium that can be used to direct optical rays. The core is the central section of a fiber and is made up of one or more very thin fibers, typically between 8 and 50 m in diameter, of glass or plastic. The center is covered by a glass or plastic casing with a thickness of up to 125 m. The optical characteristics of the core and cladding are distinct. The light signal traveling through the core is reflected off of the interface between the cladding and the core. The jacket, which may be composed of plastic or other materials, encases the core and cladding in one or more bundles of fibers. A jacket's protective layer shields its wearer from the elements. Multi-mode, single-mode, and graded index cross-sectional views are shown in Figures 2, 3, and 4, respectively.

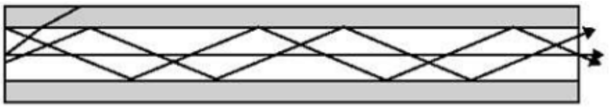

Figure 2- Multi-mode propagation

Figure 3- Single mode propagation

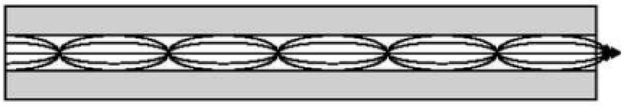

Figure 4- Graded Index Multi-mode propagation

There was a period when the price of fiber was exorbitant, but now it's reasonable for various uses like Long-haul trunks, Metropolitan trunks, rural exchange trunks, Subscriber loops, and Local Area Networks (LANs). Fiber cables, in particular, are widely used for long-distance transmission due to their unique properties.

- Higher data rate in the range of Gigabits/second (Gbps) even over long distances
- Attractiveness in smart places
- Signal attenuation is very low
- It is completely isolated by Electromagnetic fields, and hence it is not susceptible to interference, impulse noise, or crosstalk, and it does not radiate any electromagnetic energy and hence no disturbances by fiber cable.
- Data security in the transmission line is high since no one can tap the signal without affecting the physical fiber cable
- Since the effect of attenuation is very less the need for the number of repeaters is reduced

As a result of the optical fiber's higher index of refraction compared to its surrounding medium, any type of communication can be encoded into a light beam and carried to the other end of the cable via total internal reflection. For wavelengths between about 1014 and 1015 Hertz, which include the infrared and visible spectrums, the optical fiber serves as a conduit for the light.

OVERVIEW OF WAVELENGTH DIVISION MULTIPLEXING

Increasing the capacity of communication is necessary because of the high volume of users. All types of high-throughput and backbone applications can be serviced by an optical network. With wavelength division multiplexing (WDM), optical signals of various wavelengths can be mixed, transported across great distances, and then separated once they reach their destination. A 20-channel local and metropolitan WDM testbed was deployed in the Boston region for characterisation and experimental applications, as described in the work by Kaminow et al. (1996). The association on Wideband in all-Optical Networks, funded by ARPA, has produced a number of important contributions to our knowledge of optical WDM networks, including designs, technology components, and applications that make them more scalable, widerband, and more readily apparent to users. The widespread adoption of WDM systems in the telecom industry is attributable to the fact that increasing network capacity is achieved through the application of this technology rather than the deployment of more fiber. Through the use of WDM technology, the capacity of a particular link can be increased by merely upgrading the multiplexers and de-multiplexers on both ends of the connection.

Routing and Wavelength Assignment in Group Communication

In all optical WDM networks, the Routing and Wavelength Assignment (RWA) is seen as the central component of the proposed work. Without the use of Optical Cross Connects (OXCs), multicast traffic is routed from a single source to several destinations using effective wavelength assignment along each possible link. The challenge of RWA is in deciding which of multiple possible links between two points uses the fewest wavelengths while yet connecting them.

In routing, the goal is to determine the best route between two points. Since there are so many variables at play, finding the shortest path is an ongoing area of study. The shortest route is determined by the starting point and ending point, and this is the method used in the direct approach. The number of paths in a big network grows in a non-polynomial fashion as its size grows. In modern implementations of the shortest path algorithm, distance is just one of many considerations. The impact of every intermediate station's delay is calculated as well. Transmission delay, propagation delay, and various queuing delays are some of the most common types of delay characteristics. The transmission delay can be easily calculated as a function of the data length and the medium's bandwidth. The time taken for a signal to get from its source to its destination is called "propagation delay," and it varies with distance. The queuing delay, on the other hand, is not fixed but rather relies on a number of different variables, making it impossible to calculate with anything except a probabilistic method. The path from the source to the destination is determined by the path cost in the case of unicast transmission. However, it is not easy to calculate the multicast cost because it requires locating a path from the source to several destinations. The process of calculating the shortest path is complex as well.

Quality of Service in WDM Networks

Both quantitative and qualitative metrics can be used to assess QoS. Quantitative metrics are evaluated objectively, whereas qualitative metrics, such as speed of response, customer happiness, and data integrity, are evaluated subjectively. In order to plan for capacity for any kind of needs, however, quantitative methods are the only ones that can be used to analyze network performance. Link velocity, bandwidth usage, and path failure are the parameters influencing these indicators. Therefore, these considerations should be made, and optimistic models and algorithms for the proper allocation of wavelengths and routes should be devised. Network capacity determines the maximum link speeds and bandwidth available. Unfortunately, external factors like natural disasters, human error, and so on are beyond the control of network architects and administrators, leading to path failure.

Choosing Alternate Path for Enhancing Reliable Service

Fiber optic communication is more secure, although it might be disrupted by noise or other environmental factors. Therefore, an alternative communication path to the supplied light path is preferred. So, in the proposed work, we use numerous light routes for all of our exchanges.

EFFECTIVE UTILIZATION OF WAVELENGTH FOR MULTICAST WDM MESH NETWORK

However, no work is described in the literature for the multicast traffic that is common in many real-time applications, even though it is considered by most of the existing Routing and Wavelength Assignment (RWA) algorithms. Optical network technology is currently state-of-the-art because of the increasing demand for high-bandwidth networks brought on by the popularity of bandwidth-intensive services like video-on-demand and multimedia conferences. The assignment of wavelengths for multicast traffic is a fundamental issue in wavelength-division multiplexing (WDM) mesh networks. Work is proposed to maximize network capacity by wavelength-division multiplexing using just optical signals. To begin, we look at the challenge posed by RWA algorithms in WDM mesh networks that have to deal with time limitations that vary depending on the type of data being transmitted. We're all heading in the direction of a society where anyone, at any time and from any location, can get the answers they need instantly. In the past twenty years, Internet traffic has skyrocketed. Meanwhile, there is an increase due to the ever-increasing need for bandwidth on the internet. The exponential expansion of the Internet and the World Wide Web, in terms of both the number of users and the quantity of bandwidth consumed by each, is the primary driver of this rising demand. High bandwidth is essential for the new generation of multimedia applications like video-on-demand. The current electronic network infrastructure is not likely to be able to keep up with this rising demand any time soon. Due of the extreme bandwidth requirements, brand-new technology is required. Delays, such as those caused by queuing and processing, accumulate quickly in traditional store and forward networks. Consequently, the lighpath is required to get data from the source to the destination, or from the source to numerous destinations in the case of multicast applications like video conferencing, without having to go through the hops in the network. WDM segments an optical fiber's massive bandwidth into numerous, mutually exclusive channels (wavelengths), allowing it to meet the needs of the next-generation networks' high-bandwidth applications. Due to the need for more than one least cost feasible route, as mandated by Wang et al. (2003) for bigger sized WDM networks, the fundamental problem in WDM all-optical networks, routing and wavelength assignment problem, is always considered a Non-Polynomial (NP) hard problem in general. Maximizing network throughput while minimizing wavelength costs and/or the rate at which calls are blocked are typical RWA challenge objectives.

TERMINOLOGIES ASSOCIATED WITH THE NETWORK CAPACITY

In spite of the fact that wireless networking is currently cutting edge, optical network technology is the driving force behind the next generation of networks because it offers low bit error rate and high capacity for most backbone networks. The Wavelength Division Multiplexing (WDM) method is used to get the most out of the bandwidth provided by optical fibers. WDM network integration will be aided by the further development of novel designs like CHEETAH presented by Veeraraghavan et al (2003), which can provide high-speed, end-to-end circuit connectivity on a call-by-call basis in a packet-switched Internet. In wavelength division multiplexing (WDM), the optical bandwidth is split up into many channels, each operating at its maximum speed for its own wavelength. As a rule, optical networks can provide either 100% service reliability (even in the face of a single problem) or 0% service reliability (with no protection at all). More and more, modern networks are being built to serve not only traditional voice and data services, but also cutting-edge multimedia programs. Multicast is a type of point-to-multipoint communication in which a single set of messages is sent to numerous recipients over a network, with copies being made only when the paths to those recipients diverge. WDM optical networks, which construct a light path on fiber lines by reserving one wavelength at each hop, are a hotbed of current research. It is possible for a single data channel, or light route, to span numerous fiber links and connect two different network nodes while maintaining the same wavelength across the whole channel. All fiber lines along a given light path would use the same wavelength if wavelength converters weren't used. Ed (2004) argued that WDM networks could benefit from automation and simplification of service providing due to the emergence of new network control and management solutions. By automating the service provisioning process, optical service providers can rapidly and efficiently incorporate new service types into the underlying optical infrastructure to better serve their customers. Offering a variety of services allows businesses to meet the needs of a wide range of customers and, in turn, boosts both revenue and profit.

To put it simply, the RWA issue is crucial in an optical WDM network. RWA is a well-studied issue with regards to unicast connections. Multicast Routing and Wavelength Assignment (MRWA) is a natural generalization of the unicast RWA problem. Given a finite number of wavelengths and a collection of multicast calls, the problem of finding an optimal selection of links and wavelengths to connect the source and destinations is stated. To reduce the rate at which calls are blocked, MRWA aims to increase the proportion of multicast calls that are accepted. If each connection request uses a distinct wavelength, then a single optical link can serve both of them. Routing and wavelength assignment in RWA is a coupled or decoupled challenge. According to Ramamurthy and Mukherjee (1996), service requests in a dynamically running WDM network can be categorized based on the number of wavelengths on demand and the statistics of the service period. Network traffic management requirements for various applications vary. While application to application, traffic generation rates vary, one constant is the need for a network that can handle that traffic. For the sake of effective network management and prospective service provisioning, it is crucial for the optical service provider to classify the call-level (subscription-level) performance of their offered services. With these considerations in mind, this research presents an analytical performance evaluation of dynamic routing and wavelength assignment strategies for WDM networks.

CONCLUSION

WDM-based work receives increased attention from researchers because of the high demand for high-speed backbone links and improved usage of the wavelengths. WDM cost reduction with QoS is dictated by multicasting over fiber tunneling over a preset group. By constructing several spanning trees, as recommended by the planned Multicast Routing and Wavelength Assignment (MRWA), performance is enhanced with minimal blocking, and network capacity is maximized. Using MESH - 6 and 8 nodes, NSFNET-14, the proposed Weighted Multicast Routing and Wavelength Assignment algorithm exhibits encouraging results, with the approach achieving least cost coverage ratio and delay. Finally, the suggested algorithm seeks global minima, whereas the Static Cost Greedy (SCG) and Dynamic Cost Greedy (DCG) techniques only found and used local minima. Additionally, the fault tolerance is studied by randomly increasing the number of connection failures and switching the wavelengths given to each node. Improving the blocking rate from link failures is shown as proof that the suggested Routing and Wavelength Assignment with Fault Tolerance (RWFT) method of building multiple spanning trees with wavelength assignment to reach all of the destinations for multicast applications works. In order to guarantee dependability and improved QoS, this research presented a random wavelength assignment in multicast networks. Due to the enormous number of spanning trees in a network of that size, the total number of possible routes from the origin to each of the nodes grows exponentially. As a result, unconventional methods, such as soft computing, must be used to assign wavelengths for the comprehensive expansion of optical lines.

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