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Review of Designing and Operation of WDM Transport Networks

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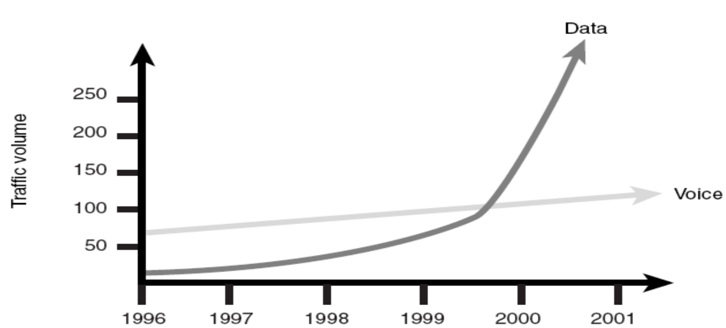
ABSTRACT

In this work, the architecture, design, and operation of Wavelength Division Multiplexing (WDM) are briefly reviewed. Commercial networks have employed the WDM transmission method to transmit messages across long distances. With its ability to transmit more bits per second over greater distances, efficient network flexibility, and performance monitoring feature, WDM is the most advantageous technique for minimizing transport cost per bit and operating cost. This paper not only gives an overview of WDM networks but also illustrates the challenges experienced in the development of WDM technology.

Keywords: WDM networks, optical networks, photodetectors, Avalnche Photodiode, Arrayed waveguide grating (AWG).

INTRODUCTION

The bandwidth demands for recent Optical Fiber communication and telecommunication networks are rapidly increasing worldwide. Reasons are increasing number of users in communication networks and development of new service with higher bandwidth requirements leading to an exploding growth especially of data traffic. A photonic network[2] represents a promising way to cope with demands. Many networks use optical point-to-point connections now, but it is already increasingly clearer that actual optical networks exist. Internet usage is increasing by 300% annually although traditional phone traffic is just increasing at a 13% cumulative annual rate.



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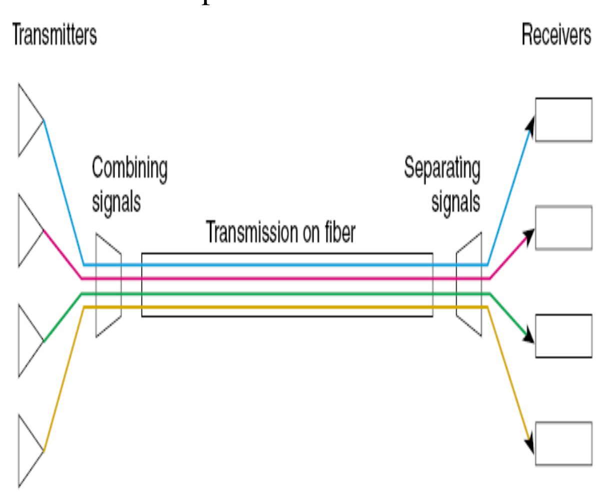
Wave Length Division Multiplexing (WDM) is an answer to all these problems. Each wavelength is discharged into the fibre in a WDM system, and the signal is demultiplexed at another end. Each input signal is transmitted by WDM independently from the others. This signifies that rather than being separated up and brought in time slots as in TDM, each channel will have its own specialized bandwidth and all signals arrive instantaneously. By minimizing the distance between wavelengths, Wavelength Division Multiplexing (WDM) can also be used more effectively, enhancing its capacity by a factor of several. This process is known as Dense Wavelength Division Multiplexing (DWDM). [1]

The advancement of fibre optics was closely related to the employment of specific optical radio spectrum of narrow bandwidth loss. These regions are referred to as windows. It operated in the first window, or around 850 nm, in its initial periods. At 1310 nm, the second window was developed. At 1550 nm, the third C band window, and 1625 nm, the fourth L band window. Wideband WDM, generally referred as the initial phases of WDM, employed two widely separated wavelengths in the 1310 nm and 1550 nm areas. The channels in the second generation of WDM, narrowband WDM, which used two to eight channels, are all now spaced at a spacing of roughly 400 GHz in the 1550 nm window. The advancement of WDM technology ultimately resulted in DWDM technology, which has 16 to 40 channels separated between 100 GHz and 200 GHz. With the capacity to facilitate 64 to 160 channels, densely compacted at 50 GHz to 25 GHz periods, DWDM later phases evolved. WDM opens up possibilities for expanding link capacities. WDM facilitates the transfer of multiple wavelength channels over a single fibre, practically without any interference. Nowadays, optical communication via fibres using a single wavelength channel functioning at a specified bit rate is used for the majority of long distance transmission links in telecommunication networks. WDM networks offers great improvement in bandwidth demands. [3]

WDM NETWORK ARCHITECTURE

WDM Network comprises of various components-



Transmitter: At transmitter end for generating the signal semiconductor and optical lasers are used. The semiconductor lasers, monolithic Distributed feedback (DFB) and Fabry-Pérot lasers. Due to its nearly homogenous light emission, fast speed, superior signal to noise ratio, and better linearity, the

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DFB laser is well adapted for DWDM applications [4].
Receiver: At the receiving end the signals of different wavelength are to be recovered by the photodetectors. Due to the broadband nature of photodetectors, optical signals should first be demultiplexed prior reaching the detector. Positive intrinsic negative (PIN) and Avalanche Photodiode detectors are indeed the two most used varieties (APD). APD have superior reception sensitivity and precision and provide gain through an amplification mechanism in which one photon acting on the device discharges several electrons. One photon colliding on the device produces several electrons, resulting in gain through an amplification process, and the device has enhanced reception sensitivity. [15]

Multiplexer and Demultiplexer: A prism can be used for multiplexing and demultiplexing. In this approach, a beam of light impacts a prism's surface and each wavelength is consequently diffracted in a unique way. It's called the "Rainbow effect" Each wavelength is then brought into sharp focus by a lens so that it can enter the fibre. It is also important to incorporate an alternative method depending on the diffraction and optical interference principles. When a source of light strikes a diffraction grating using this approach, it is diffracted at various angles. This concept-based arrayed waveguide grating (AWG) can be employed for the abovementioned objective. Another strategy requires utilising interference filters built into the device, commonly referred to as thin film filters or multilayer interference filters.

Filters: Filters are similar to multiplexers. They allow isolating a single wavelength. For tunable filter, tuning speed and tuning range are important parameters,

Amplifiers: Attenuation limits the range of optical signals. As a result, optical amplifiers are used to deal with the attenuation issue. Without converting from optical to electrical or electrical to optical, an optical amplifier amplifies every wavelength at once. Erbium doped fiber amplifier (EDFA) have the ability to provide significant amplification in all transmission window. Erbium when exited emits lights around 1.54 micrometers.[6]

Wavelength converters and Switches: In WDM network operation converter are required for wavelength interchanging. For large, fast, and scalable optical switches, there are also still many technological problems such as high signal attenuation. This holds also for switching, but rather small switches are required for protection switching.[14]

DESIGN AND PLANNING ASPECTS:

In beginning of planning process, various decision have to be made for reducing the problem complexity. Examples for decision in this phase are what type of network should planned, the decision for certain network architecture and technology or planning with consideration of existing infrastructure.

The aim of planning process is to find an optimum solution according to certain criteria. Photonic networks add an additional layer to the existing networks thus multilayer planning problems arises which leads to further increase in complexity. As a result, optimization methods are necessary for designing optical networks. [10] [11]

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In WDM networks, wavelength conversion leads to higher network flexibility by providing wavelength interchange functionality in switching nodes. Isolated consideration of wavelength converter elements is done on component level by focusing on realization techniques. On the node level, node architecture and performance is investigated while at the network level the focusing is on the networking point of view.[12]

Optical networks carry high traffic streams on the optical layer so the network operators have to guarantee a high survivability of optical networks. Various schemes of protection of optical networks are in existence but basically protection and restoration schemes can be distinguished-

1) Protection schemes are constructed on pre planned spare capacities which are assigned to a certain network in advance.

2) Restoration schemes restores the affected traffic failure by rerouting. These schemes are usually more efficient but slower than protection schemes.

   Survivabity schemes influence the planning and designing process because in addition to working capacities also spare capacities have to be provided.[5]

OPERATIONAL ASPECTS OF WDM NETWORKS

WDM point to point link are associated with many physical layer problems such as dispersion compensation, power management, monitoring of physical parameters, or fault recognisation and restoration. Due to parameter variations which occur during network operations, the physical layer problems become more challenging when shifting between point-to-point links and networks. For example the attenuation or dispersion of an optical path strongly depends on the path length and the network elements in the path. These factors can not be known in advance as these factors depends on the routing path. One way to solve these physical layer problem is to define the worst case limits but this leads to network limitations.[7]

Fault recognisation is more complex in networks as compared to point to point links. Internetworking also becomes typical in such networks.[8] Another big problem is the fault management in the multilayer networks for example a fiber break may disturb several wavelength channels. Thus, responding to a fibre breakage is highly advised. The main problem is the link to network management. Basic administration tasks like configuration, performance, fault, security, and accounting management must be completed for optical networks. [9] [13]

CONCLUSIONS

This paper gives an overview on photonic network based on WDM as a key technology to efficiently use of huge bandwidth available on fiber. Various aspects concerning the design and planning for photonic networks are described showing that many problems still have to be solved to achieve efficient network solutions. Further progress is needed to provide the way for a successful introduction of photonic networks. Due to large transport capacities, these networks are an essential part of the telecommunication infrastructure required for the future information systems.

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