IJRSET January 2016 Volume 3, Issue 1 Pages: 23-28
ISSN 2394-739X
International Journal for Research in Science Engineering and Technology

OPTICAL TRANSMISSION TECHNIQUE: WAVELENGTH DIVISION MULTIPLEXING PROGRESS AND SHORTCOMINGS

[1] Anuradha bhasin, [2] Tanima Ghosh, [3] Neha Dhingra,[4] Anamika Jain,
[1, 2, 3, 4] Department of Electronics and Communication,
[1, 2, 3, 4] Bhagwan Purshuram Institute of Technology,
[1, 2, 3, 4] Sector-17, Rohini G.G.S.I.P. University, Delhi, India.

Abstrsct:-

The optical transmission techniques have been researched for quite some time. This field has matured enormously over this time. Optical wavelength division multiplexing technology has been deployed at a very rapid rate. In this paper we have given a technical review of the currently used optical transmission technique i.e. wavelength division multiplexing (WDM) along with the latest development trends on WDM optical networks. We have compared coarse wavelength division multiplexing with dense wavelength division multiplexing technique. Recent trends in WDM optical networks along with the challenges and limitations of the WDM architectures has been discussed.

1. INTRODUCTION

Fiber optic technology has potentially limitless capabilities: huge bandwidth (50terabits per second), low signal attenuation, low power requirement, low material usage, small space requirement [1,2]. The challenge is to turn the promise of fiber optics to reality to meet the information networking demands of the next decade. As more and more users start to use the data networks and their usage pattern evolve to include more and more bandwidth intensive networking applications such as data browsing on world wide web, java applications etc. there emerges a need for very high bandwidth transport network facilities, whose capabilities are much beyond those that of high speed ATM networks can provide. The only solution is Fiber optic technology. As a single mode fiber potential bandwidth is nearly 50Tb/s, which is nearly four orders of magnitude higher than electronic data rates of a few gigabits per second. The key in designing optical communication network s in order to exploit the fibers huge bandwidth is to introduce concurrency among multiple user transmissions into the network architectures and protocols. In an optical communication network this concurrency may be provided according to wavelength [wavelength division multiplexing]. Specifically, WDM is the current favorite transmission technology for long haul communications in optical communication networks. Wavelength Division multiplexing (WDM) can exploit the huge opto-electronic bandwidth mismatch by requiring that each end user equipment operate only at electronic rate, but multiple WDM channels from different end users may be multiplexed on the same fiber. Under WDM the optical spectrum is carved up into a number of non-overlapping wavelength bands with each wavelength supporting a single communication channel operating at whatever rate one desires.

Recently, a lot of research work has been carried out on the development of optical WDM networks [5-10]. A number of experimental prototypes have been and are currently being developed, deployed and tested. Current development activities indicate that WDM network will be deployed as a backbone network for large regions. WDM is turning out to be a more cost effective alternative compared to laying more fibers. A study [11] compared the relative cost of upgrading the transmission capacity of a point to point transmission link from OC-48(2.5 Gb/s) to OC-192(10Gb/s) via the following three possible solutions.

Installation of additional fibers and terminating equipment A four channel WDM solution, which includes a WDM multiplexer to combine four independent data streams each on unique wavelength, send them on a fiber and then demultiplexer at receiver.

OC-192, a higher electronic speed solution.

The analysis showed that for distances lower than 50 km the multifiber solution was the least expensive but for distances longer than 50 km WDM solution cost was the least.

In this paper we have provided a technical review on WDM transmission technique giving a detailed description of coarse wavelength division multiplexing (CWDM) technique and Dense wavelength division multiplexing (DWDM) technique. A comparison of CWDM and DWDM is also provided. Finally we have discussed the progress in WDM technologies and their limitations.

2. WAVELENGTH-DIVISION MULTIPLEXING (WDM)

In fiber-optic communications, wavelength-division multiplexing (WDM) is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e., colors) of laser light. This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity. The term wavelength-division multiplexing is commonly applied to an optical carrier typically described by its wavelength.

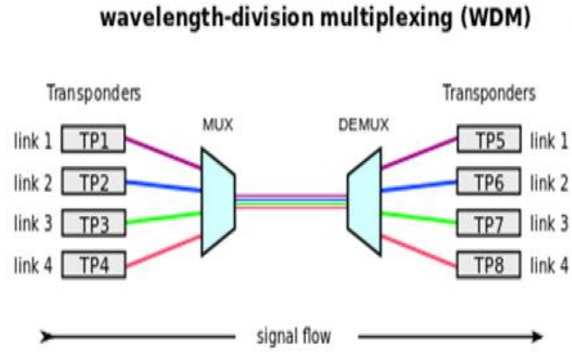

Figure: 1 A schematic diagram of WDM

Network. Capacity of a given link can be expanded simply by upgrading the multiplexers and demultiplexers at each end. Most WDM systems operate on single-mode fiber optical cables, which have a core diameter of 9 µm. Certain forms of WDM can also be used in multi-mode fiber cables (also known as premises cables) which have core diameters of 50 or 62.5 µm. Thus by allowing multiple WDM channels A WDM system (Fig1) uses **a** multiplexer at the transmitter to join the signals together, and a demultiplexer at the receiver to split them apart. The first WDM systems combined only two signals. Modern systems can handle up to 160 signals and can thus expand a basic 10 Gbit/s system over a single fiber pair to over 1.6 Tbit/s. The first WDM systems were two-channel systems that used 1310nm and 1550nm wavelengths. The multi-channel systems that used the 1550nm region – where the fiber attenuation is lowest. WDM systems are popular with telecommunications companies because they allow them to expand the capacity of the network without laying more fiber. By using WDM and optical amplifiers, they can accommodate several generations of technology development in their optical infrastructure without having to overhaul the backbone coexist on a single fiber one can tap into the huge fiber bandwidth, with the corresponding challenges being the design and development of network architectures, protocols and algorithms.

Coarse wavelength division multiplexing CWDM

Coarse wavelength division multiplexing (CWDM) typically has the capability to transport up to 16 channels (wavelengths) in the spectrum grid from 1270 nm to 1610 nm with a 20 nm channel spacing. Each channel can operate at either 2.5,4 or 10 Gbit/s. CDWM uses increased channel spacing to allow less sophisticated and thus cheaper transceiver designs. CWDM can not be amplified as most of the channels are outside the operating window of the Erbium Doped Fibre Amplifier (EDFA) .This results in a shorter overall system reach of approximately 100 kilometers. However, due to the broader channel spacing in CWDM, and use of cheaper un-cooled lasers, CWDM is the cost efficient transport in optical networks.

Dense wavelength division multiplexing (DWDM)

Dense wavelength division multiplexing (DWDM) refers to optical signals multiplexed within the 1550 nm band. DWDM has the capability to transport up to 80 channels (wavelengths) in the Conventional band or C band spectrum, with all 80 channels in the 1550 nm region. DWDM takes advantage of the operating window i.e. 1525–1565 nm (C band), or 1570–1610 nm (L band) of the Erbium Doped Fibre Amplifier (EDFA) to amplify the optical channels and extend the operating range of the system to over 1500 kilometers. This denser channel spacing requires tighter control of the wavelengths. Hence, cooled lasers i.e., temperature stabilized lasers are used to provide the needed channels count in DWDM. DWDM is economical for long-haul applications.

A. DWDM system components:

1. A DWDM **terminal multiplexer**. The terminal multiplexer contains a wavelength-converting transponder for each data signal, an optical multiplexer and where necessary an optical amplifier (EDFA). Each wavelength-converting transponder receives an optical data signal from the client-layer, such as Synchronous optical networking [SONET /SDH] or another type of data signal, converts this signal into the electrical domain and re-transmits the signal at a specific wavelength using a 1,550 nm band laser. These data signals are then combined together into a multi-wavelength optical signal using an optical multiplexer, for transmission over a single fiber (e.g., SMF-28 fiber). The terminal multiplexer may or may not also include a local transmit EDFA for power amplification of the multi-wavelength optical signal. In the mid-1990s DWDM systems contained 4 or 8 wavelength-converting transponders; by 2000 or so, commercial systems capable of carrying 128 signals were available.
2. An **intermediate line repeater** is placed approximately every 80–100 km to compensate for the loss of optical power as the signal travels along the fiber. The 'multi-wavelength optical signal' is amplified by an EDFA, which usually consists of several amplifier stages.
3. An **optical add-drop multiplexer**. This is a remote amplification site that amplifies the multi-wavelength signal that may have traversed up to 140 km or more before reaching the remote site. Optical diagnostics and telemetry are often extracted or inserted at such a site, to allow for localization of any fiber breaks or signal impairments. In more sophisticated systems (which are no longer point-to-point), several signals out of the multi-wavelength optical signal may be removed and dropped locally.
4. A DWDM **terminal demultiplexer**. At the remote site, the terminal de-multiplexer consisting of an optical de-multiplexer and one or more wavelength-converting

transponders separates the multi-wavelength optical signal back into individual data signals and outputs them on separate fibers for client-layer systems (such as SONET / SDH). Originally, this de-multiplexing was performed entirely passively, except for some telemetry, as most SONET systems can receive 1,550 nm signals. However, in order to allow for transmission to remote client-layer systems (and to allow for digital domain signal integrity determination) such de-multiplexed signals are usually sent to O/E/O output transponders prior to being relayed to their client-layer systems. Often, the functionality of output transponder has been integrated into that of input transponder, so that most commercial systems have transponders that support bi-directional interfaces on both their 1,550 nm (i.e., internal) side, and external (i.e., client-facing) side.

Recent innovations in DWDM transport systems include pluggable and software-tunable transceiver modules capable of operating on 40 or 80 channels. This dramatically reduces the need for discrete spare pluggable modules, when a handful of pluggable devices can handle the full range of wavelengths.

Comparison of DWDM and CWDM

DWDM systems have to maintain more stable wavelength or frequency than those needed for CWDM because of the closer spacing of the wavelengths. Precision temperature control of laser transmitter is required in DWDM systems to prevent "drift" off a very narrow frequency window of the order of a few GHz. In addition, since DWDM provides greater maximum capacity it tends to be used at a higher level in the communications hierarchy than CWDM, for example on the Internet backbone and is therefore associated with higher modulation rates, thus creating a smaller market for DWDM devices with very high performance. These factors of smaller volume and higher performance result in DWDM systems typically being more expensive than CWDM. Because of the high costs involved, DWDM is only economical for long-haul applications. Thus, Dense Wavelength Division Multiplexing (DWDM) is the technology of choice for transporting extremely large amounts of data traffic over long distances in telecom networks. Optical networking and especially the use of DWDM technology has proven to be the optimal way of combining advanced functionality, which can cope with the bandwidth explosion from the access network. Whereas, Coarse Wavelength Division Multiplexing (CWDM) is the technology of choice for cost efficiently transporting large amounts of data traffic in telecoms or enterprise networks over short distances. Optical networking and especially the use of CWDM technology has proven to be the most cost efficient transmission for shorter distances.

3. RECENT DEVELOPMENTS IN WDM NETWORKS

Newer approaches and technologies are constantly under development to potentially increase the effectiveness of WDM networks. In this paper two new approaches are briefly reviewed.

All wave fiber: Recent developments in fiber optics have expanded the usable fiber bandwidth. A new type of fiber called all wave fiber has been designed. This fiber does not have the 1385nm water peak window which the conventional fiber has. The conventional fiber has the maximum attenuation at 1385nm and the usable optical spectrum extends from 1440nm to 1625nm. The all wave fiber has low attenuation region extending from 1335nm to 1625nm, thereby supporting 300 channels via WDM in CDWM having the spectrum grid from 1270 nm to 1610 nm.

Another new technology is a new type of amplifier device which use erbium doped fiber amplifier (EDFA) as a building block. The normal EDFA has a gain spectrum of

30-40 nm typically in the 1530-1560 nm range. The fibers employ EDFAs for long haul communication via DWDM which takes advantage of the Erbium Doped Fibre Amplifier (EDFA) gain spectrum to amplify the optical channels. The amplifier circuit of ultra-wide band EDFA fully exploits the expanded low attenuation region of all wave fiber.

4. CHALLENGES

Research on optical network architectures has shown that a sound knowledge of device capabilities and limitations is required to produce realizable and useful technology. WDM optical technology has many desirable characteristics, but it also possesses some not-so- desirable properties. The issues that need to be taken care off are:

1. Physical Layer issues: A signal degrades in quality due physical layer impairments as it proceeds through switches by picking up crosstalk/noise and EDFAs that further amplifies the noise due to which the bit error rate (BER) at the receiving end become unacceptably high. It is required to develop network layer solutions to combat the physical layer impairments like laser shift and dispersion in fiber.

2. Signal regeneration in WDM networks: An optical WDM channel should support end to end communication of data independent of bit rates and signal formats, which is difficult to achieve for long haul transport networks. Moreover the quality of an optical signal degrades as it travels long distances through various optical components. So, long distance communication may require signal regeneration at strategic locations in a WDM network. Further, in a digital network optical signals are amplified by first converting the information stream into an electronic data signal and then retransmitting the signal optically. For this re-clocking of the signal is the challenge faced.

3. IP over WDM: In an IP over WDM network , network nodes employ wavelength routing switches and IP routers. Any two IP routers in this network can be connected together by all optical WDM channel i.e. a light-path and the set of light-paths form a virtual interconnection pattern. Thus, in such an optical WDM network architecture, the failure of a network component such as a fiber can lead to the failure of all the light paths that traverse the failed fiber and this can lead to a significant loss of bandwidth and revenue. Hence, two methods of providing protection have been proposed. 1) provide protection at the WDM layer by setting up backup light path for every primary light-path. 2) provide restoration at the IP layer i.e. overprovision the network so that after a fiber cut the network should be able to carry the same amount of traffic. The significant research work in designing IP over WDM networks is underway.

4. Traffic Grooming in WDM networks: In a WDM network each wavelength can carry several lower rate traffic streams in TDM fashion. Due to heavy traffic demand, which is the integral multiple of timeslot capacity, virtual connections are needed to be added and dropped at the two end nodes of the connection. Hence instead of having an add/drop multiplexor (ADM) on every wavelength at every node, it may be possible to have some nodes on some wavelength where no add/drop is needed on any timeslot. Hence the network cost can be reduced. Moreover savings can be maximized by carefully packing the virtual connections into wavelengths.

CONCLUSION

The major scarce resource in telecommunication is bandwidth – users want to transmit at high rate and service providers want to offer more services, hence, the need for a faster and more reliable high speed system. For this the only solution is optical fiber communication as data rates possible in optical transmission are usually in Gbps on each wavelength. The wavelength division multiplexing (WDM) allows combination of different wavelengths in a single fiber which means more throughput in one single communication system. Moreover, each wavelength, λ, can carry multiple signals in TDM fashion.This further reduces the cost of hardware. Optical communication has low attenuation compared to other transport system, less propagation delay and more services offered. Moreover, Fiber optic technology can be the future transmission technology by achieving all-optical networks that will reduce optical-to-electrical conversion overhead as optical/electrical/optical conversions introduce unnecessary time delays and power loss. The growth of the internet requires fiber optic transmission to achieve greater throughput. Optical multiplexing finds application in image processing and scanning application.

REFERENCES

1. Optical communication book by Senior.
2. Optical communication book by keiser.
3. Fiber-to-the-Home Services Based on
4. Fiber-to-the-Home Services Based on Wavelength-Division-Multiplexing Passive Optical Network Soo-Jin Park, Chang-Hee Lee, Ki-Tae Jeong, Hyung-Jin Park, Jeong-Gyun Ahn, and Kil-Ho Song.