DWDM: Oportunities and Challenges

Namita and Geetanjali Pandove

Abstract: The rapid growth of capacity demand on carrier's transport networks make high capacity transmission and new detection technology very important because of their potential to reduce cost per transmitted bit by sharing fiber and optical components over the more and more capacity. From 1990's, dense-wavelength-division- multiplexing (DWDM) and erbium-doped fiber amplifier (EDFA) technologies have been proposed for their potential to increase the capacity by using simple on/off keying (OOK) format and it also provides the direct detection up to 10 Gb/s per channel, and now we can talk even up to 100 Gb/s. This paper reviews the advantages as well as the requirements of the DWDM..

Keywords: **Bandwidth, CWDM, DWDM, TDM.**

I. INTRODUCTION

Highlight Dense wavelength division multiplexing (DWDM), have not only provided tremendous transmission capacity but it also created a paradigm shift for the network of next generation. This paper is organized as follows:
Section I explains the DWDM,
Section II compares the DWDM and TDM,
Section III compares DWDM with CWDM,
Section IV explains the advantages of DWDM,
Section V highlights the system requirements for the 100G network transport,
Section VI presents the constraints of this technology,
Section VII concludes the whole discussion.

II. WHAT IS DWDM?

Basically DWDM is an optical technology which allows transmitting across a fiber many wavelengths and by means of passive optical components they can be added and dropped as well. Because of the rapid growth of the Internet and e-business there is acceleration in the traffic loads, especially in the metro/access areas. For the accommodation of the large amount of traffic which is as expected, requires high-capacity terrestrial wavelength division multiplexing (WDM) transmission systems for the backbone networks. For increasing the WDM transmission capacity, presently following 3 approaches can be adopted:

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1) Expanding the usable wavelength band,
2) Increasing the bit rate, and
3) Narrowing the channel spacing.

In first approach the most important technical issue is broadband optical amplification. The Rare-earth-doped fiber amplifiers have been developed to cover the low-loss region of the optical fibers; some of the examples are
a) 1480-nm-band (*S*-band),
b) 1550-nm-band (*C*-band), and
c) 1580-nm-band (*L*-band).

With the help of many transmission experiments using several wavelength-bands have reported and the wideband transmission over 100 nm feasibility was confirmed. Raman amplifiers are also studied which cover bandwidth gaps produced between the different wavelength bands of rare-earth-doped fiber amplifiers.

With second approach, In WDM systems with the help of high-speed electronic circuits and optical time-division multiplexing (OTDM) technologies the bit rate per channel can be increased to 40 GB/s, and indeed 80 GB/s and even more. But for such higher and higher bit rates system the main technical issue of such higher bit-rate systems is to establish compensation techniques based on chromatic dispersion (CD) and polarization mode dispersion (PMD) for the improvement in the transmission performance.

For that in transmission experiments many compensation techniques are also have been proposed and assessed.

In third way, by using a relatively low bit rate per channel narrow channel spacing is now possible, when compared with second approach it reduces the effects of the CD and PMD. But a small WDM light sources must be developed with high-wavelength stability as we know that many wavelengths are required. Also there is requirement of Narrow-band multi/demultiplexers.

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III. DWDM VERSUS TDM

The SONET TDM takes both the synchronous and asynchronous signals and multiplexes them to a single higher bit rate for transmission at a single wavelength over the optical fiber. There is a requirement of source signals to be converted from electrical to optical or from optical to electrical and back to optical before the multiplexing.

Multiple optical signals are taken by WDM and then it maps them to individual wavelengths, and then multiplexes all the wavelengths over a single fiber. Moreover next fundamental difference between these two technologies is that without a common signal format WDM can carry multiple protocols but on the other hand SONET is not able to do this. Some other major differences between these are graphically illustrated in following figure.

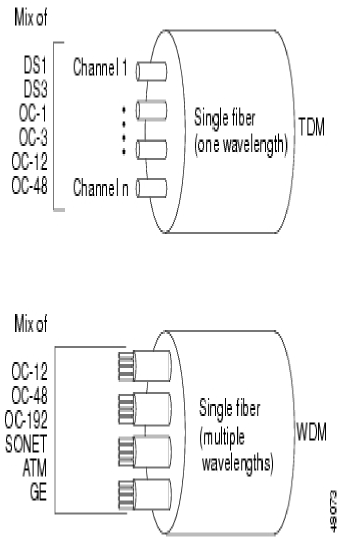

Figure 1: TDM and WDM Interfaces

IV. DWDM VERSUS CWDM

As it is known that the physical fiber optic cabling is expensive to implement for each and every service separately so its capacity expansion using a Wavelength Division Multiplexing (WDM) is a necessity to make it economical. Concept of WDM describes the combination of several streams of data or storage or video or voice on the same physical fiber-optic cable by using various frequencies (wavelengths) of light with each frequency carrying different information or data.

Two types of WDM architecture are available:

a) Coarse Wavelength Division Multiplexing (CWDM) and
b) Dense Wavelength Division Multiplexing (DWDM).

Typically CWDM systems provide 8 wavelengths which are separated by 20nm, from 1470nm to 1610nm. For increasing the number of wavelengths, we can also use 1310 nm window so that the CWDM channels can be increased to 16. Some of the DWDM systems can provide up to 96 wavelengths, typically with maximum spacing of 0.4nm, rough estimate is over the C-band range of the wavelengths.

Main advantage of the CWDM is its optic cost is hardly 1/3rd of the cost of the equivalent DWDM optic. This huge difference in economic scale make it really very popular for the limited budget that is faced by many customers, and the typical initial requirements not exceeding 8 wavelengths, which means that for many customers CWDM can be proved a more popular entry point. With the PacketLight's WDM equipment a customer can start with 8 CWDM wavelengths but then the growth is possible by introducing DWDM wavelengths into the mix that is by utilizing the existing fiber and leading to maximization of return on the investment. Therefore for the better results we can implement CWDM and DWDM or the mixture of both and with this mixing the carriers and enterprises are able to transport services from 2Mbps to the 100Gbps of the data.

The Best of Both Worlds is:

Basically CWDM solutions can provide up to 8 wavelengths capability hence it enables the transport of the 8 client interfaces over the single fiber. However because of the relatively large separation between the CWDM wavelengths expansion of the CWDM network is possible with an additional 44 wavelengths with 100GHz spacing hence utilizing DWDM technology, so the expansion of the existing infrastructure capability is possible and now the same equipment can be utilized as part of the solutions based on integration.

Moreover, the typical data rates supported by CWDM spectrum for the data transport rates is up to 4.25Gbps, but on the other hand DWDM utilize more for the large capacity data transport need up to the 100Gbps. With the mapping of DWDM channels within the CWDM wavelength spectrum much higher data transport capacity can be achieved on the same fiber optic cable and moreover there is no need of changing the infrastructures of the existing fiber in between the existing network sites.

Most important thing is this expansion can be achieved without any service interruption to the rest of the network services or to the data, and there is no need for the change or replacement of not even single of the CWDM infrastructures.

Hence PacketLight's CWDM and DWDM equipment is one of a serious contender for today's requirements of the optical transport. Its advantages are as follows:

a) Low-cost initial setup with targeted future growth path
b) Low incremental cost: "Pay as you grow" Architecture
c) Easy conversion and upgrade capabilities up to 44+ wavelengths
d) Easy upgrade to support 10Gbps/40Gbps and 100Gbps services
e) Seamless, non traffic effective network upgrades
f) Provides reliable, secure, and standards based architecture
g) Is simple to install and maintain
h) Provides full performance monitoring

With the help of Packet Light's compact CWDM solutions, we can receive all above mentioned benefits and even much more, for example remote monitoring and setup, integrated amplifiers, protection capabilities, and integration with 3^{rd} party networking devices, etc and all this will be very cost effective as it allow us to expand as we grow, and provides maximum utilization of our physical as well as financial resources.

V. WHY DWDM (ADVANTAGES)

As we have seen that from both economical and technical perspectives, its most obvious advantage is its potential to provide limitless transmission capacity. Not only the current investment in fiber plant can be preserved, but we can optimize it by at least a factor of 32. As the demands will be increasing, so more capacity can be easily added, either by up gradation of the simple equipments or number of lambda can be increased on the fiber, without performing any expensive upgrade. High capacity can be obtained from the equipment and existing fiber plant investment is also retained.

Besides of bandwidth, some of the most compelling technical advantages of DWDM are following:

a) Transparency—as DWDM is a physical layer architecture hence it can transparently supports both TDM and data formats such as Gigabit Ethernet, ESCON, ATM, and Fiber Channel over a common physical layer with the open interfaces.

b) Scalability—in many metropolitan area and enterprise networks DWDM can leverage the abundance of dark fiber for quick meet to the demand for capacity on point-to-point links and also on the spans of existing SONET or SDH rings.

c) Dynamic provisioning—the Fast, simple, and dynamic provisioning of network connections give providers ability to give high-bandwidth services in few days instead of months.

VI. SYSTEM REQUIREMENTS FOR 100G DWDM NETWORK TRANSPORT

A Compatibility of the equipment with the existing infrastructure is must which supports the deployment of 10G DWDM. It means that the equipment must be able to tolerate the current PMD and the nonlinearities; also it must meet the already existing engineering rules which are established for the 10G.

Also the equipment must be able to support the channel spacing of 50 GHz. As grids of the most of the providers are deployed on 50 GHz spacing and hence it would be spectrally inefficient to deploy any system on anything different from 50 GHz.

Dispersion tolerance of the system must be large and also it should be easily deployed as well as managed. Equipments are not allowed to demand for tweaking and addition of lambdas can not be difficult.

All the products must be cost effective. It is very clear that to attract the providers there should be price points so that providers will move faster to consolidate their previous networks to this 100G network.

Firstly these 100G DWDM will be deployed in long-haul and the core networks, where distance requirements are from 600 km to 2,000 km and ther will be requirement of the optical filtering support for fewer than five or six ROADMs. Such networks are very less cost sensitive than regional or metro networks because in that cases distance is less challenging and there is significant increase in the number ROADMs.

VII. CONSTRAINTS OR CHALLENGES

As we all know that DWDM technology offers tremendous transmission capacity in the communication through optical fiber. But we cannot ignore that here switching and routing capacity lags behind the transmission capacity. As today most packet switches and routers are implemented using slower electronic components therefore it s effect can be ignored but with the improvement of the electronic components this can degrade the performance of the DWDM technology.

Another limit of the ultra dense WDM (DWDM) systems is coherent crosstalk between adjacent WDM channels which is a main source of its degradation: On detection adjacent channels interfere with one another and the resulting beating leads to signal distortions but it must be considered that the beat frequencies lie within the bandwidth of the detection electronics. Coherent WDM cross talks are basically random in nature because the interfering adjacent WDM channels carry different randomly aligned bit patterns, also the generation of different WDM channels is done with the help of laser sources which are mutually incoherent, and hence, they all have an optical phase relationship which varies randomly.

With addition to above mentioned mechanisms different clock frequencies and differences in the group velocities, which leads to the alteration in the bit alignment of the signal the WDM channels may walk off from each other and interference occurs over time.

Network design challenge- it includes that it is really challenging to design such a perfect network to remove above mentioned interferences.

In any DWDM system, the spectral efficiency limit simply defined as the capacity per channel divided by channel spacing. However, the spectral efficiency limit is in the linear regime is independent of chromatic dispersion, because the full compensation of dispersion at the receiver is possible.

Another important factor is the Spectral Efficiency Limits with Coherent Detection as fiber nonlinearities leads to limitation on the transmission distance and also affects the capacity of the DWDM systems. The most important reason for the nonlinearities in the fiber is the Kerr effect, stimulated Raman scattering and the stimulated Brillouin scattering. When the intensity of the aggregate optical signal perturbs the fiber refractive index and hence leads to the modulation of the phase of the signals is known as Kerr effect. In the DWDM systems, the reason for the arising of SPM is when phase of a channel is modulated by its own intensity and XPM is by the intensity of other channels. When the two channels beat with each other causing the intensity modulation at difference frequencies, resulting in phase-modulation of all the channels and generate new frequency component which is the main reason for the arising of the FWM. It is noted practically and experimentally that among the above mentioned various nonlinearities, the greatest effect on the channel capacity is because of the Kerr effect.

VIII. CONCLUSION

From the above discussion it is very clear that DWDM is clearly have capability to be the next generation optical communication technology because without altering the existing fiber network we can increase the capability of the system or high data rates and large data can be transported but some issues like coherent adjacent channel interference and overlapping and network design constraints issues must be solved so that the full utilization of this wonderful technology can be implemented with high efficiency.

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