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Wavelength Division Multiplexing: An Overview & Recent Developments

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ABSTRACT
As speed & bandwidth has always been a cause of concern in communication network, WDM emerges as a vital solution to these problems. The problem arises when the demand for bandwidth in a fiber optic network exceeds the current capacity, WDM helps in expanding the capacity of a fiber optic network without requiring additional fiber. The decision problem is to find the most cost-effective combination of WDM equipment and fiber that increases the capacity of the network to a point where all the expected demand can be handled. This paper presents an overview about WDM technology and recent developments in this field and how the overall capacity of the communication network can be incremented using this technology.
Keywords **–** bandwidth, multiplexing, optical network unit, OCDM, passive optical network.

I. INTRODUCTION

The main drawbacks of our communication networks are capacity, speed, signal losses, distortion & power limitation. Fiber optic technology emerges as a pertinent solution to counter these problems. It has several advantages like high capacity, huge bandwidth, low signal losses & small space requirement [1]. Wavelength division multiplexing (WDM) involves the transmission of number of signals having different wavelengths in parallel on a single optical fiber. This technology is finding a tremendous attention as users are multiplying day by day to use data networks. The user usage requires huge bandwidth for various applications like data browsing over internet, video conferencing, voice over internet and several other java applications. [2]

This paper starts with an overview about WDM technology followed by review of recent developments in this field. It is also presented that how utilization of this technology helps in incrementing the overall capacity of the communication network.

II. WDM

Apart from increasing the transmission capacity, Wavelength Division Multiplexing (WDM) also adds flexibility to complex communication systems. In particular, different data channels can be injected at different locations in a system, and other channels can be extracted. For such operations, add–drop multiplexers can be used, that allows one to add or drop data channels based on their wavelengths. 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. WDM systems are popular with telecommunication companies because they allow them to expand the capacity of the network without laying more fiber. 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 [3].

In WDM technology, huge opto-electronic bandwidth mismatch is being exploited by requiring that equipment of each user operate only at electronic rate, but several WDM channels of different end users may be multiplexed on same fiber. Under WDM, the optical transmission spectrum is carved up into a number of non overlapping wavelength (or frequency) bands, with each wavelength supporting a single communication channel operating at whatever rate one desires, e.g., peak electronic speed. Thus, by allowing multiple WDM channels to coexist on a single fiber, one can tap into the huge fiber bandwidth, with the corresponding challenges being the design and development of appropriate network architectures, protocols, and algorithm. In fiber optic communication system, WDM is a technology which enables bidirectional communications over one strand of fiber, as well as multiplication of capacity. A WDM system uses a multiplexer at the transmitter to join the signals together and a demultiplexer at the receiver to split them apart. With the right type of fiber it is possible to have a device that does both simultaneously, and can function as an optical add-drop multiplexer [4].

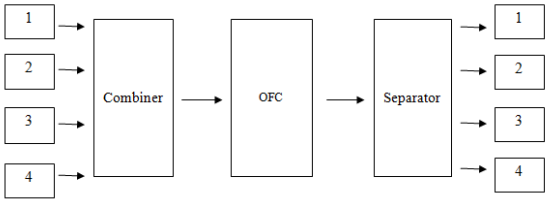

FIGURE 1: BASIC BLOCK OF WDM

Wavelength division multiplexing (WDM) is an emerging technology that enables carriers to significantly increase transport capacity while leveraging existing fiber-optic equipment. Unlike conventional TDM transport alternatives, WDM gives carriers the flexibility and scalability they need to deploy capacity when and where it is needed. Early deployments of WDM are based on wideband technology. Figure 2 shows how wideband WDM doubles the capacity of fiber plant by optically coupling the outputs of two terminals in a fiber-optic transmission system (FOTS); one terminal operates in the 1310 nm range and the other in the 1550 nm range. Although this is a cost-effective solution for applications with restricted reach, wideband WDM systems, which tend to consist of little more than an optical coupler and splitter, suffer from the absence of maintenance capabilities.

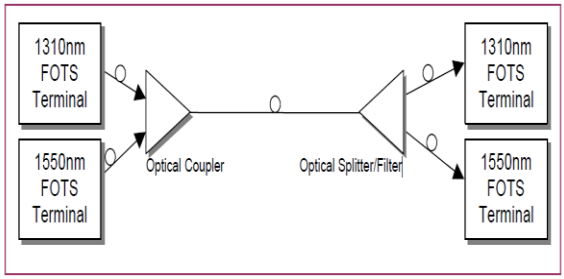

FIGURE 2: WIDEBAND WDM

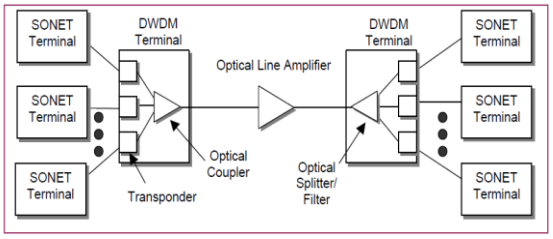

FIGURE 3: NARROW BAND WDM

III. RECENT ADVANCEMENTS IN WDM

Being one of the most promising technology to enhance the overall capacity of the communication networks, various WDM based communication networks [5-6] have been presented and still research is going on to optimized these network models. In this regard authors [7] proposed and implemented WDM passive optical system as a triple play service. In this amplified spontaneous emission injected Fabry-Perot laser diode scheme was employed having 32 channels of 125 Mbps. Schenutzow et al. [8] presented packet switched unidirectional & bi-directional ring WDM network which provide increased capacity due to spatial wavelength reuse. The maximum average transmitter, receiver & multicast throughput were achieved. Later authors proposed WDM local area network that offers efficient data delivery & fast fault recovery by establishing four non overlapping light paths [9]. A novel light wave centralized hybrid bidirectional access network by integrating WDM-OFDM-PON with radio over fiber system using multi-wavelength generation and carrier reuse technique was proposed [10]. It was demonstrated experimentally that this can reduce Rayleigh back scattering because of the use of different frequencies for down link & up link. Yeh et al. [11] presented a ring based WDM-PON that has the promising feature of limiting the Rayleigh back scattering. A novel optical network unit was architected to generate two propagating directions for downstream & upstream traffic. Later WDM-PON was proposed providing both unicast & broadcast services using an OFF set polarization multiplexing techniques [12]. In this, transmission of 10 Gbps downstream unicast & broadcast of differential phase shift keying as well as 2.5 Gbps upstream ON-OFF signal over 20 km standard single mode fiber was successfully demonstrated experimentally. A novel wavelength division multiplexing – radio over fiber passive optical network based on polarization multiplexing & carrier suppressed return to zero Quadrature differential phase shift keying (CSRZ-QDPSK) was proposed [13] that can provide wire line & wireless access synchronously. Improvement in the bandwidth utilization was achieved. The design has the source free optical network unit (ONU) including wireless access and upstream communication. By utilizing semiconductor optical amplifier & the reuse of downstream light source, ONU omit laser source & makes WDM-PON colorless. It has large coverage area and network implemented wireline and wireless access without any RF source in ONU. Aladeloba et al. [14] presented a WDM access network by incorporating high speed free space optical (FSO) communication for the distribution link. The overall system cost was reduced by combining FSO communication with optical fiber. It provides the high bandwidth access in regions where optical fiber installation is problematic. The proposed system can provide human safe & high capacity access network. A novel chaos based WDM-PON scheme was proposed [15] which effectively increase the security of physical layer. In this the upstream & downstream data was encrypted & decrypted using chaotic carrier. It was demonstrated that sufficient wavelength spacing, high quality chaos synchronization between twin lasers at optical line terminal & optical network unit can be maintained which allowed simultaneous upstream & downstream WDM chaotic communication. Minato et al. [16] presented a novel metropolitan & access network for providing services to long reach depopulated households through geographical difficulty with energy saving system. The network was realized using hybrid WDM & optical code division multiplexing (OCDM). The

WDM & OCDM cross talk impact was reduced by apodizing the filter device. Authors proposed a HPON by combining WDM & TDM technology [17]. In this HPON architecture different degree of resilience was offered depending upon the user profile i.e. partial & full protection for residential or business access. They provide cost efficient protection upgrade.

IV. FUTURE WORK

As WDM technology is emerging as one of the most promising technology that can help in countering various problems related to communication network, still much of the work is needed in order to provide the cost effective solutions using this technology. Optimization of the existing networks as well as new networks can also be developed so as to tackle the problems related to the communication networks.

V. CONCLUSION

An overview about the WDM technology is being presented & it is being shown how this technology helps in increasing the capacity of the communication network. A review about the recent developments in this technology is also presented.

VI. ACKNOWLEDGEMENTS

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