New Trends in High Speed Networking

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Abstract -- **Convergence of information and communication technology (ICT) has met the large demand of voice, data, video and internet. The necessity of high speed network between computer to computer, computer to business houses and industrial users is the current requirement. The high speed network in advanced countries has increased from 40 Gbps to 40 Tbps. Such signals can not be processed electronically due to low signal to noise ratio. Hence, new technology based on optical-optical multiplexing using lasers as transmitters and photo diode as receiver via optical fiber medium has been successfully developed now a days.**

The signal of 40 Gbps is multiplexed 250 times by wavelength division Mux to produce one stream of 10 Tbps and four such streams can transmit 40 Tbps upto a distance of 5000 km. Such technology is used in metro network, regional and national links. Wavelength division multiplexing (WDM) is frequently used so that there is no over lapping of wavelength channels.

The broadband optical fiber communication is used reliably for high speed networking throughout the world. This paper deals with new trends in broadband optical communication for high speed networking.

Keywords: Broadband, Fiber optics, High speed networking, Wavelength division Mux/demux, Optical amplifiers, Optical add drop mux, Optical cross connect.

I. INTRODUCTION

THE voice traffic is growing at a rate of 17% per annum, data is growing at 52% whereas internet demand is growing at a rate of 150% per annum. In view of such demand and growth of communication, convergence of information and communication technology (ICT) requires high speed networking with reliability and cyber security among computer to computer and computer to users (business houses, industry, govt. organizations, etc.).

In the year 1985, communication speed used was 45Mbps which has been enhanced to 10 Gbps by 1995. The speed is further increased to 30 Tbps by the year 2010 and still growing rapidly. In electronic devices, the noise is dominating as the signal speed & networking is increased above 10 Gbps. The nature has given a technology based on silica fibers which are highly secure, free from electromagnetic interference and reliable. These fibers alongwith optical transmitter and receiver have very long life. These new generation systems have become cheaper as compared to conventional electronic systems due to invention of optical amplifiers and dispersion compensators.

The photonics is extensively used for high speed networking & cyber security. The photon source is modulated and various channels of voice, computer data and video are multiplexed using wavelength division multiplexer. The signal is then amplified by optical amplifier (erbium doped and Raman optical amplifier) and passed through optical add-drop multiplexer (OADM) and optical cross connect (OCC) to various users. The high speed networking is done in local network at a speed less than 622 Mbps, in metro network at a speed of 2.5 Gbps, regional communication network at a speed of 10 Gbps, long haul link is done at a very high speed of 30 to 40 Tbps. In this way, 98% global communication is done using broadband optical high speed communication. 60% terrestrial high speed communication and networking is done in this way by using optical fibers.

In certain situations fiber may be used for short distance or long distance applications, due to important features:

i) Immunity to electromagnetic interference, including nuclear electromagnetic pulses (although fiber can be damaged by alpha and beta radiation).
ii) High electrical resistance, making it safe to use near high-voltage equipment or between areas with different earth potentials.
iii) Lighter weight-important, for example, in aircraft.
iv) No sparks-important in flammable or explosive gas environments.
v) Not electromagnetically radiating and difficult to tap without disrupting the signal-important in high-security environments.
vi) Much smaller cable size-important where pathway is limited, such as networking an existing building, where smaller channels can be drilled and space can be saved in existing cable ducts and trays.
vii) Resistance to corrosion due to non-metallic transmission medium.

II. TECHNOLOGY

Initially, laser transmitter is directly modulated by time division multiplexing (TDM) and the signal is coupled to fiber directly without any amplifier/regenerator or repeater. The distance and speed in such cases were limited. Later on, electronic regenerators are added to increase the distance but these have increased noise.

The electronic regenerator which converts optical signal to electrical signal, reshape it and then amplified electronically & again convert it into optical signal were used. This was a costly solution. Successful development of optical amplifier came in the early 90's and allowed longer distances as well as more bandwidth by adding a number of wavelength channels which could then be amplified simultaneously. 160 wavelengths at 10 Gbps each are used simultaneously which is giving an overall bandwidth of 1.6 Terabits per second. This has given significant increase in total transmission capacity.

Taking benefits of low loss fiber window between 1420 nm to 1670 nm, it was possible to transmit 30 Tbps signal per fiber to achieve high speed networking with information security.

In long distance network, amplifiers are placed from 200 to 600 km at a signal speed of 10 Gbps to 40 Gbps per wavelength giving overall transmission capacity of 30Tbps per fiber. The distance upto 5000 km is successfully networked. In regional ring networks, the amplifiers are located from 200 to 300 km at a speed per wavelength channel of 2.5 to 10 Gbps covering a distance of 600 km. In metro rings, the distances are 80 to 100 km & speed per wavelength channel is 622 Mbps to 10 Gbps. In metro access network, the distances are 40-50 km & the speed per channel is less than 622 Mbps whereas in residential premises, the distances are short and the speed is upto 10 Mbps. So, each of these segments needs a different type of system technology optimized for each application so that most economical performance is achieved.

Technologies which are extensively used are:

1. Optical Amplification by Erbium Doped Fiber Amplifier (EDFA) or Raman Amplifier (RA).
2. Course WDM or Dense WDM
3. Forward Error Correction
4. Optical Networking using OADM & OCC

Both the amplifiers (EDFA and RA) are used together to produce constant gain over a long distance as shown in figure 1. These hybrid amplifiers work over a wide range of wavelengths, thus allowing extensive use of WDM in high speed network.

Forward error correction is achieved by adding redundancy bits to compensate for bits loss over long distance transmission. This improves the system performance from 7% to 23% by error detection and correction of data electronically.

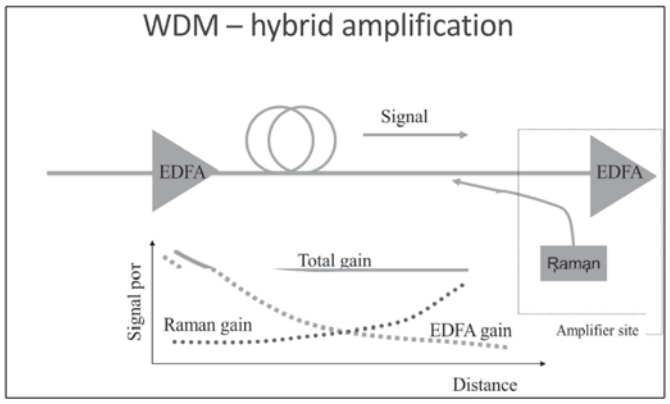

Figure 1. Broad Gain Hybrid Optical Amplifiers

In the high speed network, dispersion compensation is needed for single mode fiber due to propagation of several channels of wavelength together. Special dispersion compensated fiber are inserted into in line amplifier module which reduces the dispersion to zero level. Expensive electronic regenerators are replaced by optical amplifiers and dispersion compensated fibers. Significant cost savings has been achieved. Figure 2 shows use of dispersion compensated fibers.

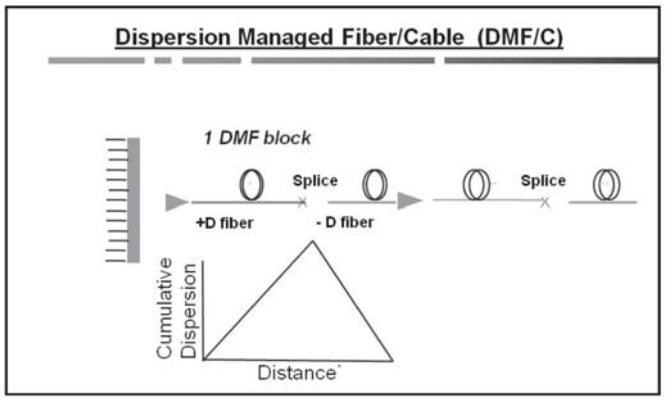

Figure 2. Use of Dispersion Compensated Fibers.

Network flexibility is achieved by inserting wavelength add drop multiplexer (OADM) alongwith optical amplifier. Optical cross connect (OCC) as a switch is also added to reroute the WDM signal to other areas/ couple with other networks without degrading the signal in high speed network. Optical network architecture is shown in Figure 3.

III. COMPARISON OF TDM AND WDM

The size of optical fibers in the communication link on one hand is increasing upto 12,000 km and is decreasing to micrometer on photonics devices on the other hand. We are limiting the scope of this paper to high speed network and cyber security. Both TDM and WDM technology are used in high speed network. TDM is used where numbers of wavelengths are less and distance is small whereas WDM

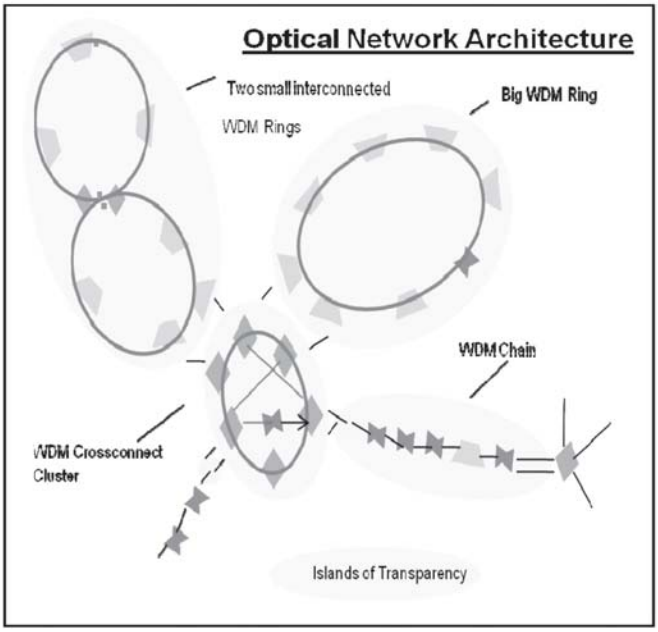

Figure 3. Interconnection of Optical Fiber Rings.

technique is used where dense and ultra dense wavelength multiplexing is used over long distances. So high speed networking and data rate transmitted over a fiber is achieved by WDM where more than 250 wavelength channels without any overlapping from 40 Gbps to 400 Gbps per channel are used successfully. TDM is done only upto 10 Gbps electronically and 4 wavelengths together can produce 40 Gbps in TDM whereas WDM technology can be used for transmission of 100 Tbps over a single fiber. We may use course WDM or dense WDM. In CWDM, the channel (ë) spacing is 20 nm whereas in DWDM, it is 1.6 nm to 0.2 nm. In WDM, the optical signal is amplified by in line amplifiers.

The concept and working of optical amplifier with WDM, Mux-Demux is shown in Figure 4.

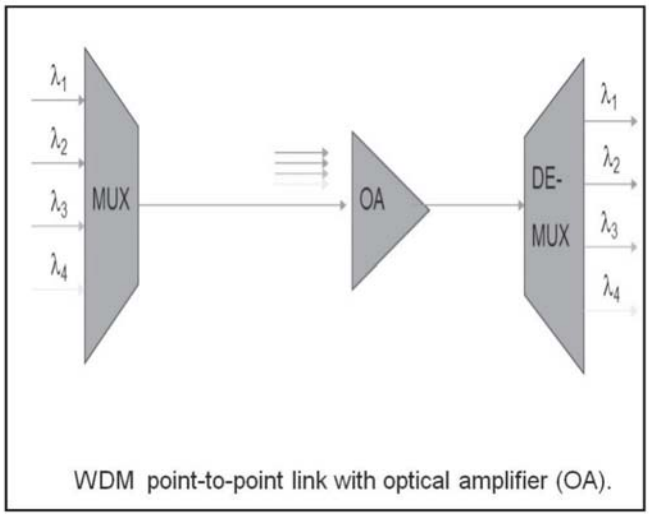

Figure 4. WDM-Optical Amplifier.

So, WDM is widely used after development of optical amplifiers. Two types of amplifiers are used:

i) Erbium doped fiber amplifier (EDFA)
ii) Raman optical amplifier (ROA)

In order the get constant optical gain over long distance, hybrid optical amplifier using EDFA & ROA is used.The working of WDM-Raman optical amplifier is shown in Figure 5.

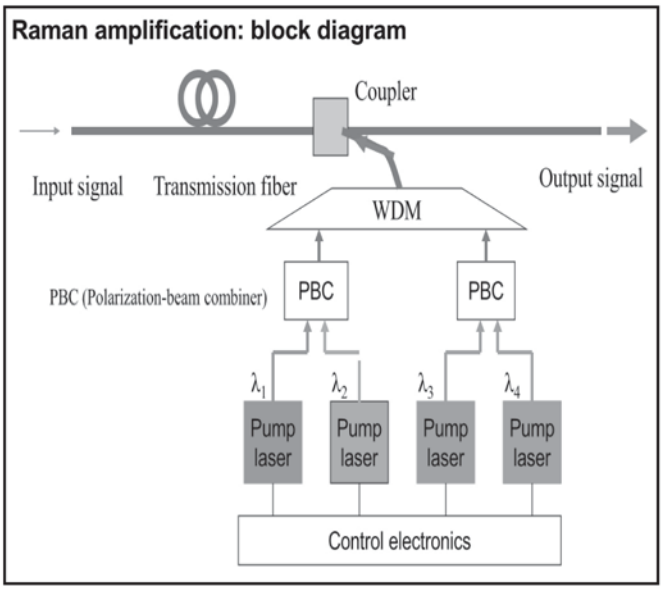

Figure 5. WDM-Raman optical amplifier.

WDM spectrum is shown in Figure 6.

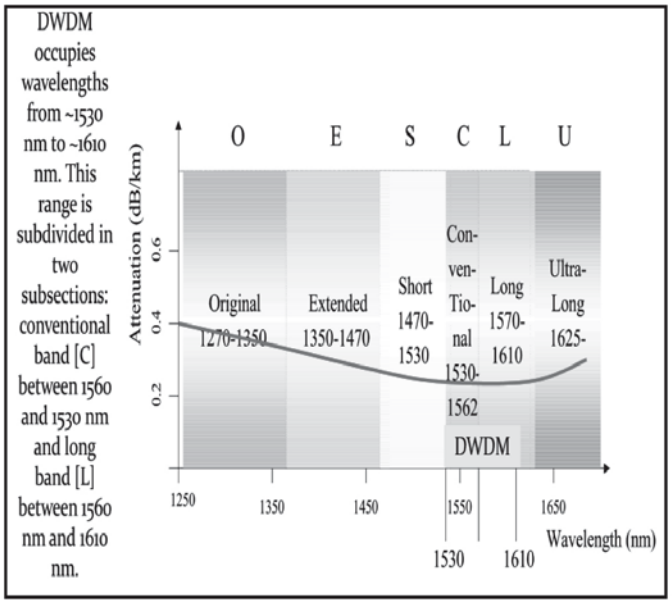

Figure 6. WDM-Spectrum.

DWDM is extensively used among frequency grid of 196.1 THz (1528.77 nm) with the frequency channel spacing of 12 GHz (0.1 nm) to 100 GHz (0.8 nm) and even upto 200 GHz.

Inter connectively of various networks is shown in Figure 7.

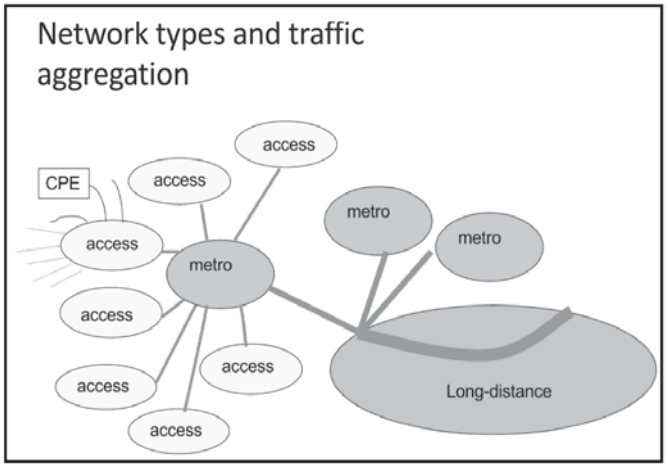

Figure 7. Three types of networks: Traffic Aggregation.

TDM is restricted due to bit rate (upto 10 Gbps). There is security and confidentiality concerns / issues. WDM is not restricted to bit rate and security issues are addressed as it is optical multiplexing. N Wavelengths can be used and multiplexed together with clarity and security as shown in Figure 8.

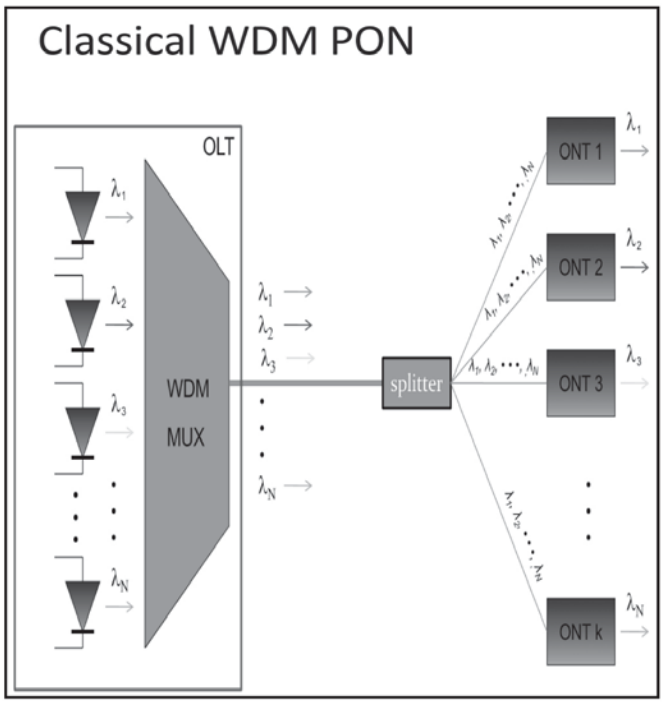

Figure 8. Multiwavelength WDM Network.

IV. KEY COMPONENTS FOR OPTICAL FIBER COMMUNICATIONS

Optical fiber communication systems rely on a number of key components:

- Optical transmitters, based mostly on semiconductor lasers (often VCSELs), fiber laser and optical modulators.
- Optical receivers mostly based on photodiodes (often avalanche photodiodes) .
- Optical fibers with optimized properties concerning losers, guiding properties, dispersion and nonlinearities.
- Dispersion-compensating modules.
- Semiconductor and fiber amplifiers (mostly erbium-doped fiber amplifiers, sometimes Raman amplifiers) for maintaining sufficient signal powers over long lengths of fibers or as preamplifiers before signal detection.
- Optical filters (e.g. based on fiber Bragg gratings) and couplers.
- Optical switches and multiplexers (e.g. based on arrayed waveguide gratings), for example, optical add/drop multiplexers (OADMs) allow wavelength channels to be added or dropped in a WDM system.
- Electrically controlled optical switches.
- Devices for signal regeneration (electronic or optical regenerators), clock recovery and the like.
- Various kinds of electronics e.g. for signal processing and monitoring.
- Computers and software to control the system operation.

V. RESULTS & DISCUSSION

The use of wavelength division multiplexing (WDM), optical amplifiers (OA), optical add drop mux (OADM), and optical switches & cross connect alongwith reliable laser source have ensured integration and convergence of information & communication technologies (ICT) for long distance high speed network with dedicated security & reliability. The technology is now a days used in access network, metro and regional networks, long distance network, upto a high speed of 40 Terabits per second. 98% global and 60% terrestrial communication is done using high speed fiber optical network. The fast growth in internet, data and voice services are accommodated successfully & the future demands can be taken care efficiently.

VI. CONCLUSION

Optical routers working at 160 Tbps are operational. The potential future target of router is 3000 Tbps so that high speed network upto 1000 Tbps can be used in USA, Europe, Korea and Japan by the year 2015which can be expanded upto 3000 Tbps and deployed into global high speed network by the year 2020 to meet the world data growth demand.

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Prof. (Dr.) S.C. Gupta is a reputed professional in the field of Electronics and Communication. He was awarded Ph.D. from Delhi University and completed Post Doctoral Research from University of HULL, England. He was leader of PPC team deputed by Hindustan Aeronautics Ltd. at Ferrant Ltd, UK in 1980 and 1982.

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