Optical Networking Technology – An Introduction

Dr. Kumar N. Sivarajan
Chief Technology Officer, Tejas Networks

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Optical networks have been making "waves" recently, following the opening up of the national long distance market. We can expect a few Indian operators to install national optical networking backbones (surely, even just going by all the digging on the streets!). By and large, these backbones will be based on the newer dense wavelength-division multiplexing (DWDM) optical networking technology because DWDM provides enormous bandwidths at much lower (unit) cost. In this article, we attempt to clarify the basic concepts of optical networks, particularly DWDM networks.

Who needs more bandwidth?

Increased bandwidth demand will arise from a proliferation of applications such as data and call centers, as well as by the bootstrapping effect of increased consumption resulting from lower rates. For example, if the STD charges are reduced to one tenth of what they are today, I still do not expect to see my phone bill go down because my wife's phone calls will just become ten times longer. However, the network must now provide ten times more bandwidth. Similarly, when leased line costs are reduced by a tenth, businesses, which are using leased lines for their Internet connectivity, are likely to migrate to higher speed lines for the same cost, resulting in an increased bandwidth requirement from the network. As the bandwidth requirement increases, the carriers increase the capacities of their networks and the cost per unit capacity goes down further. This results in further increased consumption, and so on.

Optical Communication

Optical communication is the transfer of signals from one point to another using optical fiber as the communication medium. Simply put, optical fiber is an extremely thin, glass pipe that has an enormous communication capacity. The communication is effected by turning a light source, usually a laser, 'on' to indicate a '1' bit and 'off' to indicate a '0' bit. The rate at which the laser is turned on and off is the rate of communication. It is called the "bit rate" and measured in "bits per second." Optical fiber has a virtual monopoly as the communication medium whenever the distances exceed a few hundred meters, or the bit rate exceeds a few Mb/s. (1 Mb/s = 1 million bits per second. Telephone quality voice communication requires a bit rate of 64 kb/s, or 64,000 bits per second.) Optical fiber has been widely deployed today in the telecommunication backbone of many countries, and optical communication systems have been in use for well over a decade.

DWDM

As the communication needs (traffic) increased, the capacities of the fiber communication systems have had to keep pace. Initially this was accomplished by increasing the bit rate from 155 Mb/s to 622 Mb/s, then to 2,488 Mb/s, and finally to 10 Gb/s. (1 Gb/s = 1000 Mb/s.) These are the standard rates of the synchronous digital hierarchy, or SDH, networks, that are widely deployed globally, including in India. A higher rate SDH stream carries a number of lower rate SDH streams by interleaving them in time. This technique called time-division multiplexing or TDM. For example, a 10 Gb/s stream carries sixty-four “tributary” 155 Mb/s streams, by transmitting one byte (8 bits) from each tributary stream in turn. However, the communication capacity of many backbone networks needed to be at rates higher than 10 Gb/s, and lasers simply could not be turned on and off any faster. This led to the use of several signals at different frequencies, or equivalently different wavelengths, akin to the transmission of different radio or television signals at different frequencies. For example, we can transmit many different 10 Gb/s signals, each using a laser transmitting at a different wavelength, simultaneously over the same optical fiber. This technique is called dense wavelength-division multiplexing, or DWDM.

The first DWDM systems operated with 4–16 wavelengths. Today, DWDM systems supporting 160 wavelengths transmitting at 10 Gb/s each are commercially available. Such a system has a capacity of 1.6 terabits per second (1 terabit = 1 million, million bits). This is the equivalent of 25 million telephone calls, which means that the traffic resulting from all the phones in India can be carried on a single strand of fiber, even if all these phones were active simultaneously.

Optical Amplification

It is possible to send each signal over a different fiber rather than at a different wavelength over the same fiber, thus avoiding the use of DWDM. However, such a multifiber solution, which amounts to the use of multiple SDH networks in parallel, is inefficient, for the following reason. After traversing some distance, typically 60–80 km, the light signals become feeble. At this point, we can detect the feeble signals and use another set of lasers to retransmit the signals. This process is called regeneration. Multiple SDH networks require multiple regenerators, one for each fiber, thus increasing the cost. DWDM proves to be a cheaper alternative because all the signals are transmitted on a *single* fiber, and thus we can optically amplify all the light signals, when they become feeble, with a *single* optical amplifier. The use of optical amplification every 60–80 km made it possible to transmit DWDM signals without regeneration over distances of several hundred km. The availability of cost-effective optical amplification technology is the primary reason for the widespread use of DWDM technology today, and the consequent dramatic reduction in the costs of long distance communication.

New optical amplifier technologies such as Raman amplifiers (named after Sir C. V. Raman, the Indian Nobel Laureate) have made possible the realization of even longer optical DWDM links. Today, DWDM signals may be transmitted without being regenerated (detected and retransmitted) for thousands of kilometers: across the length and breadth of India, the continental United States, and most oceans of the world.

Intelligent Optical Networking

Optical communication uses optics merely for transmission and is only the first step in optical *networking.* A significant amount of research and development effort has been spent over the last decade to add more functionality at the optical level, which leads us to the next generation of optical networks, which are being put in place today. These networks make use of optical routing of signals, in addition to optical transmission, to realize even more significant cost savings. Today, these networks are commonly referred to as *intelligent optical networks*.

Consider an intelligent optical network consisting of Internet routers being linked by New Delhi–Mumbai and Mumbai–Bangalore fiber links. If we can arrange for the data being sent between Bangalore and New Delhi to remain on wavelengths separate from those carrying data to/from Mumbai, the former wavelengths can be optically switched at Mumbai, obviating the need for the data carried in them to be processed by the routers at Mumbai. This leads to significant savings in network equipment costs, since it is much cheaper to switch the wavelengths optically than to process all the data being carried on them, resulting in further decreases in bandwidth costs.

Combining SDH/TDM and DWDM

The traffic carried on an optical wavelength is frequently generated by some SDH equipment. Such equipment is the mainstay of conventional telecommunication networks, which carry mostly voice. Today, the TDM functionality provided by SDH—combining lower rate streams into a higher rate stream—is available directly within the DWDM equipment, obviating the need for separate SDH equipment. As a result, when the traffic is mainly data, say, from routers at speeds of 155 Mb/s, there is no need for separate SDH/TDM equipment between the routers and the DWDM equipment. This integration of TDM multiplexing functionality within the DWDM equipment contributes further to cost savings in the overall network.

Conclusion

The high cost of long distance communication has stifled the widespread use of Internet and WWW technologies in the country, and has curtailed even telephone usage. Compare the cost of US domestic long distance, which is about 5 cents per minute, or about Rs.2.50, coast-to-coast, with the STD rates in India, which for Bangalore–Delhi is Rs.33.60 per minute! The deployment of state-of-the-art DWDM optical networking backbones in the country, by competing long distance carriers, will see a marked decrease in bandwidth costs, enabling India to take active part in the global communications revolution.