Overview of Fiber Optic Communications Systems

Jeffrey Livas
Ciena Corporation

The telecommunications industry has experienced tremendous growth over the past decade, fueled by the explosive demand of the Internet. Technology that was once deployed only in the specialized application of undersea communications has become widely deployed for terrestrial use, and new technology has been developed especially for very high capacity communications. The net result has been a large drop in the cost of transmitting data from place to place in the core of optical networks, enabling new, more efficient network designs and applications. More recently, as the rate of growth in the telecommunications industry has slowed, the focus has shifted from applying technology to enhance the capacity-distance product to reducing costs, including operating costs. As costs continue to drop, optical communications becomes economically viable out toward the edge of the network and closer to the final end-user.

This talk will describe some of the technology behind high capacity long distance optical communications over fiber, with an emphasis on the transport of information from point to point in the core of the network.

The different applications spaces for optical transport will be outlined and placed into context within the architecture of a typical network. A typical state of the art optical communications system will be defined, with an emphasis on Wavelength Division Multiplexing (WDM) technology. The fundamentals of optical signal transmission over fiber will be described, including some of the metrics used to measure performance and the challenges associated with predicting performance margin for the extremely demanding specifications of modern communications systems. The fundamentals will be used to explain the difference between undersea and terrestrial communications and to resolve the large apparent difference in performance between the two types of systems. State of the art performance will be compared against one of the known fundamental limits from communications theory. Actual performance falls somewhat short of what is possible in principle, and one reason is that there are many practical limitations and challenges, including non-linearities and the effects associated with transmitting many channels. The strategies for dealing with these limitations will be described, and some of the outstanding technical challenges for the field will be presented. Finally, current trends will be extrapolated for a look at what future communications systems may be like.

Keywords

Bit Error Rate (BER): Defined as the ratio of errors counted in a fixed time divided by the number of bits sent in that same time. This is equivalent to the error rate (in errors per second) divided by the data rate (in bits per second).

Wavelength Division Multiplexing (WDM): A technique for combining many separate communications channels onto a single, composite channel (usually a fiber) by modulating the signals onto separate wavelengths and then combining those wavelengths. This concept is to be

compared with Time Division Multiplexing (TDM), where signals are assigned to different blocks of time and combined into a single stream, or Frequency Division Multiplexing (FDM), where signals are assigned to different frequencies and combined. In practice, FDM and WDM are very similar over small bandwidths.

Dense Wavelength Division Multiplexing (DWDM): Avariant of WDM where the signals are spaced very closely together in frequency or wavelength. "Very closely" typically means a spacing of the order of the bandwidth of the modulated signal. For example, for a 10 Gbps signal, the channel spacing would be of the order of 25-50 GHz.

Optical Signal to Noise Ratio (OSNR): This is the ratio of the signal power to the noise power is a fixed (by convention) noise bandwidth of 0.1 nm. The concept is analogous to the more commonly used electrical signal to noise ratio (SNR), and is a measure of signal quality.

Amplified spontaneous emission (ASE): Fundamental noise generated by an optical amplifier when it provides gain.