Chapter IV
Wavelength Division
Multiplexing Technologies and
their Applications

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ABSTRACT

This chapter is an introduction of the Wavelength-division multiplexing (WDM) technologies (such as Dense WDM and coarse WDM) and their recent applications in optical networks. WDM is used to multiplex multiple optical carrier signals on a single optical fibre by using different wavelengths of laser light to carry different signals. This allows for a multiplication in available bandwidth and, in addition, makes possible to perform bidirectional communications over one strand of fibre. We present the optical components used in WDM and review some of the most important applications of the technology.

Introduction to Multiplexing Technologies

The explosion in demand for network bandwidth today, forces long-haul service providers to move away from Time Division Multiplexing (TDM) based systems, which were optimized for voice but now, prove to be costly and inefficient. In addition, the explosive growth of data traffic (due mainly to the rapid growth of Internet applications based on the Internet Protocol IP) is followed at the same time with higher complexity of the nature of the traffic itself. Traffic carried on a backbone can originate as circuit based (TDM voice and fax), packet based (IP), or cell based (Asynchronous Transfer Mode ATM and Frame Relay) and at the same time delay sensitive data, such as voice over IP and streaming video are also becoming increasingly important.

In order to handle the dramatically increasing capacity while constraining costs, carriers have two options:

a. Install new fibre
b. Increase the effective bandwidth of existing fibre.
Laying new fibre to expand existing networks is a rather costly solution (most of the cost is the cost of permits and construction rather than the fibre itself). Increasing the effective capacity of existing fibre can be accomplished either by increasing the bit rate of existing systems or by increasing the number of wavelengths of light transmitted in a fibre.

Increase the Bit Rate in a TDM system

Time Division Multiplexing (TDM) was invented as a way of maximizing the amount of voice traffic that could be carried over a medium. In the old telephone network each telephone call required its own physical link which makes the network to be expensive and unscalable. With the invention of multiplexing, it is possible to have more than one telephone on a single physical link. TDM increases the capacity of the transmission link by slicing time into smaller intervals (slots) so that the data from multiple telecommunicating entities can be carried on the same link, with each entity making use of one time slot (Figure 1).

Each entity is serviced in a cyclical way, thus making this method fair but inefficient, since each time slot is reserved even when there is no data to send. This problem is mitigated by the use of statistical multiplexing used in Asynchronous Transfer Mode (ATM), although there are practical limits to the speed that can be achieved, due to the fast electronics required for segmentation and reassembly of ATM cells.

Using TDM, data can be transmitted at 2.5 Gbps (OC-48), at 10 Gbps (OC-192) and more recently at speeds of 40 Gbps (OC-768). However, technical issues such as increase of chromatic dispersion in higher speed, the effect of nonlinear phenomena due to the greater transmission power required at the higher bit rates and polarization mode dispersion restrict the applicability of this approach.

Optical transmission of TDM data is covered by standards adopted by the telecommunications industry such as the Synchronous Optical Network (SONET) or Synchronous Digital Hierarchy (SDH), where SONET is used in North America and SDH elsewhere. SONET/SDH standards specify the parameters in order to take a number of n bit streams of a bit rate equal to b, to multiplex them, to optically modulate the signal and to send it into the fibre using a light emitting device with a final bit rate equal to b × n. For example traffic arriving from four places at 2.5 Gbps rate will go into the fibre as a single stream at 10 Gbps.

Increase the Number of Optical Carriers (Light Wavelengths)

In this approach, a number of wavelengths are combined onto a single fibre. This multiplexing method is called Wavelength Division Multiplexing (WDM). In this method it is possible to combine even 128 or 160 wavelengths on a single fibre, thus increasing the effective capacity of existing fibre plant by the same factor without having to lay new fibre (Figure 2).

Figure 1. TDM with three input links. The output link is divided in three time slots and data from each input link make successive use of first, second and third time slot.
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