Wavelength division multiplexing

Objective:

1- One of the most promising concepts for high capacity communication systems is wavelength division multiplexing (WDM).

2- Each communication channel is allocated to a different frequency and multiplexed onto a single fiber. At the destination wavelengths are spatially separated to different receiver locations.

Basic Information:

Wavelength-division multiplexing (WDM) is a method of combining multiple signals on laser beams at various infrared (IR) wavelengths for transmission along fiber optic media. Each laser is modulated by an independent set of signals. Wavelength-sensitive filters, the IR analog of visible-light color filters, are used at the receiving end.

WDM is similar to frequency-division multiplexing (FDM). But instead of taking place at radio frequencies (RF), WDM is done in the IR portion of the electromagnetic (EM) spectrum. Each IR channel carries several RF signals combined by means of FDM or time-division multiplexing (TDM). Each multiplexed IR channel is separated, or demultiplexed, into the original signals at the destination. Using FDM or TDM in each IR channel in combination with WDM of several IR channels, data in different formats and at different speeds can be transmitted simultaneously on a single fiber. In early WDM systems, there were two IR channels per fiber. At the destination, the IR channels were demultiplexed by a dichotic (two-wavelength) filter with a cutoff wavelength approximately midway between the wavelengths of the two channels. It soon became clear that more than two multiplexed IR channels could be demultiplexed using cascaded dichotic filters, giving rise to coarse wavelength-division multiplexing (CWDM) and dense wavelength-division multiplexing (DWDM). In CWDM, there are usually eight different IR channels, but there can be up to 18. In DWDM, there can be dozens. Because each IR channel carries its own set of multiplexed RF signals, it is theoretically possible to transmit combined data on a single fiber at a total effective speed of several hundred gigabits per second (Gbps).

The use of WDM can multiply the effective bandwidth of a fiber optic communications system by a large factor. But its cost must be weighed against the alternative of using multiple fibers bundled into a cable. A fiber optic repeater device called the erbium amplifier promises to make WDM a cost-effective long-term solution to the bandwidth exhaustion problem.

Frequency-division multiplexing (FDM) is a scheme in which numerous signals are combined for transmission on a single communications line or channel. Each signal is assigned a different frequency (sub channel) within the main channel.When FDM is used in a communications network, each input signal is sent and received at maximum speed at all times. This is its chief asset. However, if many signals must be sent along a single long-distance line, the necessary bandwidth is large, and careful engineering is required to ensure that the system will perform properly. In some systems, a different scheme, known as time-division multiplexing, is used instead.

Time-division multiplexing (TDM) is a method of putting multiple data streams in a single signal by separating the signal into many segments, each having a very short duration. Each individual data stream is reassembled at the receiving end based on the timing. The circuit that combines signals at the source (transmitting) end of a communications link is known as a multiplexer. It accepts the input from each individual end user, breaks each signal into segments, and assigns the segments to the composite signal in a rotating, repeating sequence. The composite signal thus contains data from multiple senders. At the other end of the long-distance cable, the individual signals are separated out by means of a circuit called a demultiplexer, and routed to the proper end users. A two-way communications circuit requires a multiplexer/demultiplexer at each end of the long-distance, high-bandwidth cable.

Course wavelength division multiplexing Originally, the term "coarse wavelength division multiplexing" was fairly generic, and meant a number of different things. In general, these things shared the fact that the choice of channel spacing's and frequency stability was such that erbium doped fiber amplifiers (EDFAs) could not be utilized. Prior to the relatively recent ITU standardization of the term, one common meaning for coarse WDM meant two (or possibly more) signals multiplexed onto a single fiber, where one signal was in the 1550 nm band, and the other in the 1310 nm band

Dense Wavelength Division Multiplexing (DWDM) is a fiber-optic transmission technique. It involves the process of multiplexing many different wavelength signals onto a single fiber. So each fiber have a set of parallel optical channels each using slightly different light wavelengths. It employs light wavelengths to transmit data parallel-by-bit or serial-by-character. DWDM is a very crucial component of optical networks that will allow the transmission of data: voice, video-IP, ATM and SONET/SDH respectively, over the optical layer.
Hence with the development of WDM technology, optical layer provides the only means for carriers to integrate the diverse technologies of their existing networks into one physical infrastructure. For example, though a carrier might be operating both ATM and SONET networks, with the use of DWDM it is not necessary for the ATM signal to be multiplexed up to the SONET rate to be carried on the DWDM network. Hence carriers can quickly introduce ATM or IP without having to deploy an overlay network for multiplexing.

As mentioned earlier, optical networks use Dense Wavelength Multiplexing as the underlying carrier. The most important components of any DWDM system are transmitters, receivers, Erbium-doped fiber Amplifiers, DWDM multiplexors and DWDM demultiplexors. Fig 1 gives the structure of a typical DWDM system.
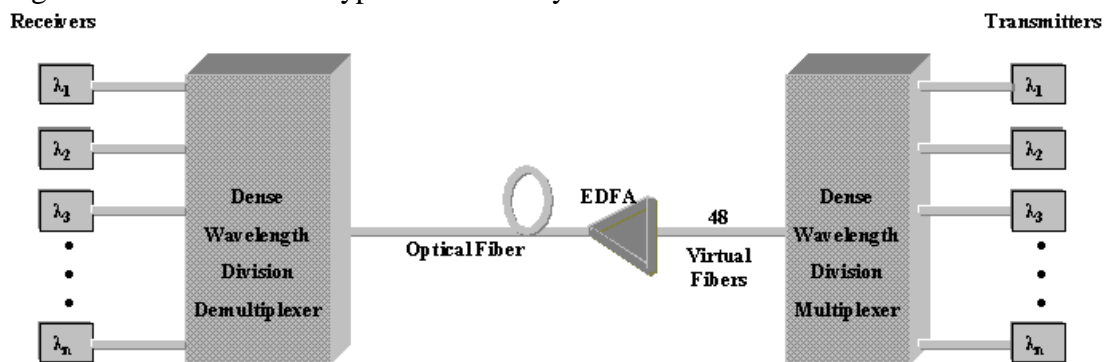

Fig.1 Block Diagram of a DWDM System

The concepts of optical fiber transmission, amplifiers, loss control, all optical header replacement, network topology, synchronization and physical layer security play a major role in deciding the throughput of the network. These factors have been discussed briefly in this sections that follow

WAVELENGTH DIVISION MULTIPLEXING (WDM) Systems:
- A basic point-point communication configuration is illustrated below:
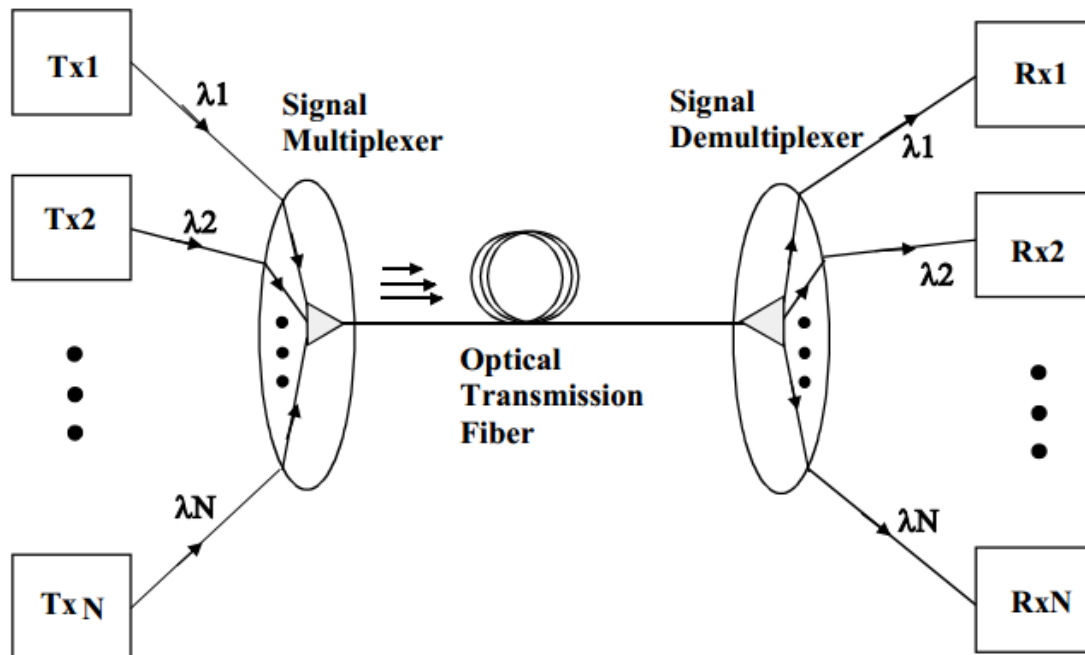
- For single frequency point-point links the bit rate is limited ~100 Gb/s due to dispersion. This is well below the capability of the optical carrier frequency
- WDM can increase the total bit rate of point-to-point systems.
- For N channels with bit rates B1, B2… BN transmitted simultaneously over a fiber of length L, the bit rate-length product becomes.

$$B - L = \left(B_1 + B_2 + \ldots + B_N \right) \cdot L$$

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