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Chapter III

Management and Control of Intelligent Optical Networks

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INTRODUCTION TO OPTICAL NETWORKING

Recent years have witnessed rapid improvements in optical technologies, resulting in dramatic increases in both transmission and switching rates. Progress in optical networking components, such as lasers, amplifiers, filters and fibers, has enabled the development of systems capable of transmitting hundreds of channels, each at speeds up to 10 Gbps, on a single fiber.

At the same time, the proliferation of the Internet and the introduction of new applications such as sharing of audio and video files have led to substantial changes in traffic profiles. IP traffic is growing at such an explosive rate that it is dominating all other types of traffic, including voice traffic. Doubling times for IP traffic are now measured in months, not years. Future applications, such as video on demand and web agents, are likely to continue or even accelerate these traffic growth rates. As traffic is increasing and traffic patterns are changing, new networking paradigms are required.

Despite the fast pace of progress in packet processing equipment, such as IP routers and ATM switches, it is becoming increasingly harder for such network elements to keep up with the increases in traffic. At the same time, it is recognized that the complexity of full packet processing is not required in every node of future communication networks. New technologies, such as MPLS (Rosen, Viswanathan & Callon, 2001) attempt to utilize circuit-switching concepts for use in datagram networks. Fortunately, the widespread commercialization of optical technology and the rapid improvements in optical networking components have led to the emergence of high bandwidth transmission and switching equipment, operating at the

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optical layer (Stern & Bala, 1999). These new classes of equipment offer distinct advantages in designing multiservice networks; at the same time, however, they pose new challenges in the management and control of heterogeneous networks.

In this chapter we first present a brief overview of the technologies that have enabled the spectacular growth in optical networking. Next, we discuss various emerging architectures for heterogeneous optical networks. The remainder of this chapter presents details on the management and control of optical networks.

Overview of Enabling Technologies

Optical fibers were first deployed in commercial telecommunications networks in the late 1970s. The advantage of fiberoptic communication is based on the principle that light in a glass medium can carry more information over longer distances than electrical signals can carry in a copper or coaxial medium.

The operation of an optical fiber is based on the principle of total internal reflection. Light reflects (bounces back) or refracts (alters its direction while penetrating a different medium), depending on the angle at which it strikes a surface. An optical fiber consists of two different types of highly pure, solid glass, composed to form the core and cladding. The core and cladding have carefully chosen indices of refraction to ensure that the lightwaves are guided to the other end of the fiber by being reflected within the core. Most of the transmitted light bounces off the cladding glass and stays within the core; thus, the fiber core acts as a waveguide for the transmitted light (Corning, 2000).

Advances in fiber optic transmission systems are targeting two main areas: increases in the distance that light signals can travel without any need for amplification and increases in the total amount of bandwidth that can be transmitted in a single fiber. The former reduces operating expenses by reducing the number of installations required to regenerate signals while the later provides the obvious benefit of higher capacity to cope with the ever-increasing traffic demands. The continuous advances in process technology, electronics and lasers have enabled today's glass fibers to transmit digitized light signals in long distances (hundreds of kilometers) without any need for amplification. A significant step in this path took place in the early 1990s with the discovery of the erbium-doped optical amplifier. By doping a small strand of fiber with ions of the rare earth element erbium, optical signals could be amplified without converting the signal back to an electrical state. The amplifier provided enormous cost savings over electrical regenerators, especially in long-haul networks. In particular, these amplifiers could boost the power of many wavelengths simultaneously.

The advances in optical amplifiers, filters and laser technologies enabled the development of a technology that allows multiple wavelengths to be transmitted on the same fiber. Termed "Dense Wavelength Division Multiplexing" (DWDM), this technology has provided tremendous increases in optical fiber bandwidth. DWDM combines multiple optical signals so that they can be amplified as a group and transported over a single fiber. Each signal can be carried at a different rate and in

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