PERFORMANCE ANALYSIS OF DWDM

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ABSTRACT

Dense Wavelength Division Multiplexing (DWDM) is a key component of the world's communications infrastructure. The tremendous growth in telecommunications services is possible today in part through optical networks, where DWDM systems allow much greater bandwidth over existing optical systems. Telecommunication companies have sought out such technologies to help respond to a growing array of customer demands, including streaming video, which require large amounts of bandwidth to create transmissions in real time. Some leading service providers have reported the doubling of bandwidths about every six to nine months. DWDM allows such transmissions by virtually splitting the fibers' capabilities into more than two carriers. From both technical and economic perspectives, the ability to provide potentially unlimited transmission capacity is the most obvious advantage of DWDM technology. The current investment in fiber plant can not only be preserved, but optimized by a factor of at least 32. As demands change, more capacity can be added, either by simple equipment upgrades or by increasing the number of lambdas on the fiber, without expensive upgrades. Capacity can be obtained for the cost of the equipment, and existing fiber plant investment is retained.

1. INTRODUCTION

Dense wavelength division multiplexing (DWDM) is a fiber-optic transmission technique that employs light wavelengths to transmit data parallel-by-bit or serial-by-character.

DWDM puts together multiple signals and sends them at the same time along a fiber, with transmissions taking place at different wavelengths. This turns a single fiber into the virtual equivalent of a handful of fibers. The most modern of these systems allows for much more than a handful of fibers.

Systems with up to 160 wavelengths are not entirely uncommon. Because of this cutting-edge technology, existing fibers have been able to transmit at speeds of up to 400 gigabits a second. DWDM is extremely adaptable and versatile as well, in that it can vary the kind of data as well as the wavelength at which that data travels.

DWDM's most compelling technical advantages can be summarized as follows:

- Transparency—Because DWDM is a physical layer architecture, it can transparently support both TDM and data formats such as ATM, Gigabit Ethernet, ESCON, and Fibre Channel with open interfaces over a common physical layer.
- Scalability—DWDM can leverage the abundance of dark fiber in many metropolitan area and enterprise networks to quickly meet demand for capacity on point-to-point links and on spans of existing SONET/SDH rings.
- Dynamic provisioning—Fast, simple, and dynamic provisioning of network connections give providers the ability to provide high-bandwidth services in days rather than months.

2. EXPANSION AND FLEXIBILITY: DWDM

The third choice for service providers is dense wavelength division multiplexing (DWDM), which increases the capacity of embedded fiber by first assigning incoming optical signals to specific frequencies (wavelength, lambda) within a designated frequency band and then multiplexing the resulting signals out onto one fiber. Because incoming signals are never terminated in the optical layer, the interface can be bit-rate and format independent, allowing the service provider to integrate DWDM technology easily with existing equipment in the network while gaining access to the untapped capacity in the embedded fiber.

DWDM combines multiple optical signals so that they can be amplified as a group and transported over a single fiber to increase capacity . Each signal carried can be at a different rate (OC–3/12/24, etc.) and in a different format (SONET, ATM, data, etc.) For example, a DWDM network with a mix of SONET signals operating at OC–48 (2.5 Gbps) and OC–192 (10 Gbps) over a DWDM infrastructure can achieve capacities of over 40 Gbps. A system with DWDM can achieve all this gracefully while maintaining the same degree of system performance, reliability, and robustness as current transport systems—or even surpassing it. Future DWDM terminals will carry up to 80 wavelengths of OC–48, a total of 200 Gbps, or up to 40 wavelengths of OC–192, a total of 400 Gbps—which is enough capacity to transmit 90,000 volumes of an encyclopedia in one second.

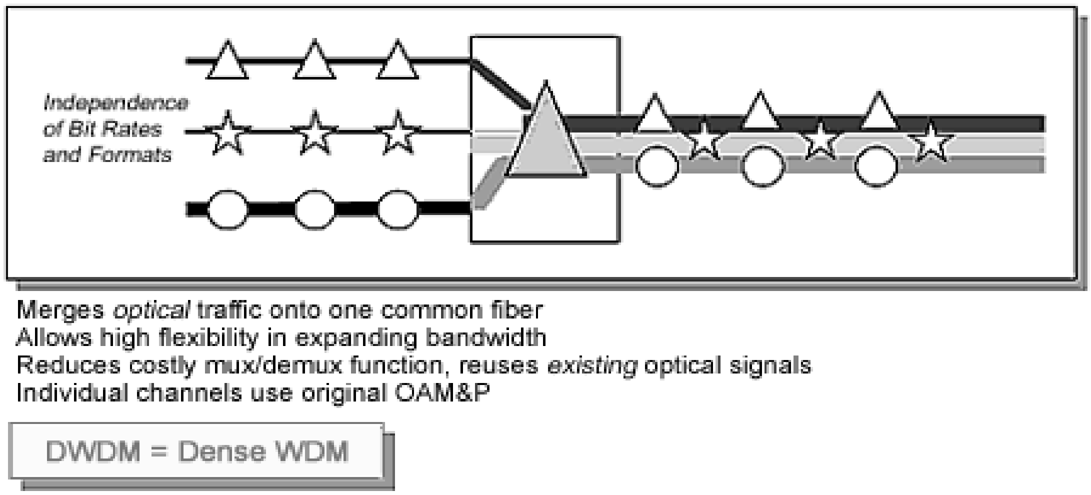

Figure 1. Increased Network Capacity—WDM

The technology that allows this high-speed, high-volume transmission is in the optical amplifier. Optical amplifiers operate in a specific band of the frequency spectrum and are optimized for operation with existing fiber, making it possible to boost light wave signals and thereby extend their reach without converting them back to electrical form. Demonstrations have been made of ultra wideband optical-fiber amplifiers that can boost light wave signals carrying over 100 channels (or wavelengths) of light. A network using such an amplifier could easily handle a terabit of information. At that rate, it would be possible to transmit all the world's TV channels at once or about half a million movies at the same time.

Consider a highway analogy where one fiber can be thought of as a multilane highway. Traditional TDM systems use a single lane of this highway and increase capacity by moving faster on this single lane. In optical networking, utilizing DWDM is analogous to accessing the unused lanes on the highway (increasing the number of wavelengths on the embedded fiber base) to gain access to an incredible amount of untapped capacity in the fiber.

An additional benefit of optical networking is that the highway is blind to the type of traffic that travels on it. Consequently, the vehicles on the highway can carry ATM packets, SONET, and IP.

3. GROWTH

A DWDM infrastructure is designed to provide a graceful network evolution for service providers who seek to address their customers' ever-increasing capacity demands. Because a DWDM infrastructure can deliver the necessary capacity expansion, laying a foundation based on this technology is viewed as the best place to start. By taking incremental growth steps with DWDM, it is possible for service providers to reduce their initial costs significantly while deploying the network infrastructure that will serve them in the long run.

Some industry analysts have hailed DWDM as a perfect fit for networks that are trying to meet demands for more bandwidth. However, these experts have noted the conditions for this fit: a DWDM system simply must be scalable. Despite the fact that a system of OC–48 interfacing with 8 or 16 channels per fiber might seem like overkill now, such measures are necessary for the system to be efficient even two years from now.

Because OC–48 terminal technology and the related operations support systems (OSSs) match up with DWDM systems today, it is possible for service providers to begin evolving the capacity of the TDM systems already connected to their network. Mature OC–192 systems can be added later to the established DWDM infrastructure to expand capacity to 40 Gbps and beyond.

4. THE OPTICAL LAYER AS THE UNIFYING LAYER

Aside from the enormous capacity gained through optical networking, the optical layer provides the only means for carriers to integrate the diverse technologies of their existing networks into one physical infrastructure. DWDM systems are bit-rate and format independent and can accept any combination of interface rates (e.g., synchronous, asynchronous, OC–3, –12, –48, or –192) on the same fiber at the same time. If a carrier operates both ATM and SONET networks, the ATM signal does not have to be multiplexed up to the SONET rate to be carried on the DWDM network. Because the optical layer carries signals without any additional multiplexing, carriers can quickly introduce ATM or IP without deploying an overlay network. An important benefit of optical networking is that it enables any type of cargo to be carried on the highway.

But DWDM is just the first step on the road to full optical networking and the realization of the optical layer. The concept of an all-optical network implies that the service provider will have optical access to traffic at various nodes in the network, much like the SONET layer for SONET traffic. Optical wavelength add/drop (OWAD) offers that capability, where wavelengths are added or dropped to or from a fiber, without requiring a SONET terminal. But ultimate bandwidth management flexibility will come with a cross-connect capability on the optical layer. Combined with OWAD and DWDM, the optical cross-connect (OXC) will offer service providers the ability to create a flexible, high-capacity, efficient optical network with full optical bandwidth management. These technologies are today's reality: DWDM has been utilized in the long-distance network since 1995, OWAD will be available in products in 1998, and the first OXC was showcased at industry conventions in 1997.

5. VALUE OF DWDM IN THE METROPOLITAN AREA

DWDM is the clear winner in the backbone. It was first deployed on long-haul routes in a time of fiber scarcity. Then the equipment savings made it the solution of choice for new long-haul routes, even when ample fiber was available. While DWDM can relieve fiber exhaust in the metropolitan area, its value in this market extends beyond this single advantage. Alternatives for capacity enhancement exist, such as pulling new cable and SONET overlays, but DWDM can do more. What delivers additional value in the metropolitan market is DWDM's fast and flexible provisioning of protocol- and bit rate-transparent, data-centric, protected services, along with the ability to offer new and higher-speed services at less cost.

The need to provision services of varying types in a rapid and efficient manner in response to the changing demands of customers is a distinguishing characteristic of the metropolitan networks. With SONET, which is the foundation of the vast majority of existing MANs, service provisioning is a lengthy and complex process. Network planning and analysis, ADM provisioning, Digital Crossconnect System (DCS) reconfiguration, path and circuit verification, and service creation can take several weeks. By contrast, with DWDM equipment in place provisioning new service can be as simple as turning on another lightwave in an existing fiber pair.

6. CONCLUSION

Potential providers of DWDM-based services in metropolitan areas, where abundant fiber plant already exists or is being built, include incumbent local exchange carriers (ILECs), competitive local exchange carriers (CLECs), inter-exchange carriers (IXCs), Internet service providers (ISPs), cable companies, private network operators, and utility companies. Such carriers can often offer new services for less cost than older ones. Much of the cost savings is due to reducing unnecessary layers of equipment, which also lowers operational costs and simplifies the network architecture.Carriers can create revenue today by providing protocol-transparent, high-speed LAN and SAN services to large organizations, as well as a mixture of lower-speed services (Token Ring, FDDI, Ethernet) to smaller organizations. In implementing an optical network, they are ensuring that they can play in the competitive field of the future.

Optical networking provides the backbone to support existing and emerging technologies with almost limitless amounts of bandwidth capacity. All-optical networking (not just point-to-point transport) enabled by optical cross-connects, optical programmable add/drop multiplexers, and optical switches provides a unified infrastructure capable of meeting the telecommunications demands of today and tomorrow. With DWDM, the transport network is theoretically unconstrained by the speed of available electronics. There is no need for optical-electrical-optical (OEO) conversion when using optical amplifiers, rather than regenerators, on the physical link. Although not yet prevalent, direct optical interfaces to DWDM equipment can also eliminate the need for an OEO function.

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