

# The Direction of the Optical-Networking Market

## Definition

The highest-growth optical-networking market is carrier-delivered wavelength services for enterprise applications. To satisfy that demand, a new class of small, power-efficient, easy-to-install optical platforms designed specifically for carrier access and enterprise deployment has emerged.

## Overview

This tutorial examines the technological developments and market dynamics that have led to the current state of optical networking, as well as trends for its future. With data-center managers around the globe seeking to outsource wavelength services, many carriers are realizing full return on their investments in optical networking platforms in less than one year. The tutorial will outline why this relationship is a win-win scenario for both enterprises and carriers, common technical requirements for wavelength-services platforms, deployment phases, enterprise case studies, and other technologies. The tutorial is paced so that it can familiarize newcomers to wavelength division multiplexing (WDM) and the market landscape, as well as confirm and expand upon the experiences and understandings of data-center managers and carrier network planners.

## Topics

1. The Evolution to Today
2. Enterprise Business Needs
3. Carrier Value Proposition
4. Common System Requirements
5. Deployment Strategies
6. Enterprise Uses and Benefits
7. The Competitive Landscape

Self-Test

Correct Answers

## 1. The Evolution to Today

The first fiber-optic communication system was installed by AT&T and GTE in 1977. Since then, optical fibers have steadily overtaken copper cables as the medium of choice for modern-day networks. The performance and reliability advantages are obvious. Fiber optics today are used almost exclusively in the physical layers of wide-area networks around the globe, and the development of metropolitan optical networks is already underway.

Today, one of the highest-growth optical-networking markets is carrier-delivered wavelength services for enterprise applications. To satisfy that demand, a new class of small, power-efficient, easy-to-install optical platforms designed specifically for enterprise deployment has emerged. This tutorial will examine the market forces and technological developments that spawned today's reality.

Large financial institutions seeking high-bandwidth solutions for disaster recovery, as well as other business applications, began deploying private fiber-based networks between facilities in the early 1990s. At the time, local-exchange carriers (LECs) were pushing existing synchronous optical network (SONET) transport or asynchronous transfer mode (ATM) access services as the best and only transport technologies for metro enterprise networking.

Enterprises, however, soon discovered SONET and ATM to be ineffective options for the higher-speed data protocols that they more and more sought to adopt: enterprise system connectivity (ESCON), coupling link, fibre channel, and Gigabit Ethernet. WDM emerged for these enterprise applications shortly after systems were defined for the long-haul telecommunications market.

Multiplexing techniques were nothing new. Frequency division multiplexing (FDM), a standard technique in analog transmission systems such as cable television, assigns a separate frequency for each communications channel. Time division multiplexing (TDM), a standard technique in digital transmission systems, combines multiple low-speed channels in specific time slots of a higher-speed channel. WDM works on the same principles as FDM and TDM—only that the channel discriminator is neither frequency nor time but wavelength.

WDM multiplies the capacity of optical fiber strands, creating virtual channels and unlocking the full bandwidth potential of fiber (beyond 25,000 Gbps). Incoming application traffic is converted to specific wavelengths and multiplexed. Multiple channels are transmitted over the same fibers. There is no performance degradation or specific protocol requirements because light waves of different lengths do not interfere with one another during transmission and are converted back to their original formats at output. Today, dense WDM (DWDM) solutions

utilizing 32 narrowly spaced channels are available through many of the leading equipment vendors.

So, in the mid 1990s, enterprises welcomed WDM as an excellent technique for improving bandwidth performance over private dark fiber. Across distances up to 50 kilometers, enterprises for the first time could transmit a multitude of disparate data protocols such as ATM, coupling link, ESCON, Ethernet, Fast Ethernet, fiber distributed data interface (FDDI), fibre channel, fiber connection (FICON), Gigabit Ethernet, SONET, symmetric remote data facility (SRDF), sysplex timer, and others simultaneously and at native speeds without impact on network performance.

Still, there were limitations. The lack of dark fiber available between facilities brought carriers into the mix. Some manufacturers of optical-networking platforms found themselves selling enterprise WDM systems to carrier customers driven to provide some solution for large enterprise networks. New platforms emerged, tailored specifically for service delivery and based on real feedback from large enterprise users and carriers. These platforms were engineered from the ground up to be integrated into carrier optical networks, relieving fiber congestion in the core network and enabling fast provisioning of end-to-end wavelength services.

Today, carriers are focusing on wavelength services to answer exploding demand from their enterprise customers for voice, data, and Internet application support across metropolitan areas. These services significantly expand the revenue opportunity for services while controlling the incredible bandwidth potential of their dark fiber.

## 2. Enterprise Business Needs

For many enterprises and Internet service providers (ISPs) today, telecommunications and availability of data are strategic business factors of equal importance to labor and financial strength. They run mission-critical applications such as billing and accounting on mainframes or powerful client-server installations in data centers and simply cannot afford extended periods of nonavailability. Continuous backups or reliable decentralized data processing and storage have emerged as essential.

These applications, however, require real-time transfers of ever-increasing data volumes that, in some cases, already exceed several terabytes. Disaster recovery is one of the leading terabyte-bandwidth networking issues facing data-center managers today. Others include clustering high-speed computers for parallel processing, handling the facility moves associated with mergers and acquisitions, implementing multimedia business tools, etc.

Thousands of data-center managers are now looking to outsource services that support digital workflow among enterprises. Carriers offer transparent local-area network (LAN) services or virtual fiber links. The responsibilities for implementation and maintenance of the optical-networking system—and the cost and complexity inherent—reside with the carrier, not the enterprise. Enterprises spend less time and money training and deploying network support personnel and more concentrating on their core businesses. Concerns over equipment depreciation are eliminated. Networking becomes almost invisible to the enterprise, evolving into an integrated, powerful tool that quietly enables employees to work more creatively and productively but requires little attention itself. Enterprises cull greater benefit from their network infrastructures.

### 3. Carrier Value Proposition

Carriers are realizing new revenues by cost effectively introducing high-speed, protocol-transparent wavelength services via new low-initial-cost platforms. (DWDM systems are now available at a cost of about \$25,000 per wavelength, both sides.) In fact, many carriers are realizing full return on their investments in less than one year because both they and enterprises alike recognize the new relationships for what they clearly are: win-win scenarios. The affordability of the networking solutions that enable WDM services enables carriers to target market segments they could not previously support. Because the cost for the carriers is low, carriers are pricing the services aggressively; because the cost for the enterprises is low, demand is significantly increasing. Carriers can offer ESCON services that are less expensive than standard T3 services, and can provide Gigabit Ethernet, fibre channel, and others, at nearly the same price.

Until just a few years ago, incumbent carriers were reluctantly willing to sell dark fiber to enterprise customers who dealt with the networking issues themselves. Today, though, many carriers have stopped all efforts to sell dark fiber. Selling a service means winning a customer; selling dark fiber may mean feeding a competitor. The primary benefit of this business opportunity to carriers is twofold:

- **Carriers create new revenue streams today**—From a single, flexible platform, carriers can lease protocol-transparent, high-speed LAN and storage-area network (SAN) services to Fortune 500 organizations, banks, governments, and financial institutions requiring up to hundreds of high-speed connections, as well as small- and medium-sized enterprises requiring token ring, FDDI, and Ethernet services.
- **Carriers future-proof their networks**—Deployment of a sophisticated optical-networking platform lays the foundation for the all-optical network. A complete optical-network infrastructure will

include DWDM systems, optical gateways, and optical cross-connects and permeate the entire network (i.e., the enterprise access, metropolitan, regional, and long-haul backbone segments). The carrier implementing an optical-networking services platform today positions itself to be at the forefront of this developing trend.

## 4. Common System Requirements

Every networking environment is unique, but there are common denominators. Enterprises and carriers share a need for high degrees of protocol support, scalability, reliability, openness, ease of installation and management, management functionality, and system efficiency in their optical-networking platforms.

### Protocol Support

Systems should support all data-centric application traffic ranging up to 2,488 Mbps, including ATM, coupling link, ESCON, Ethernet, Fast Ethernet, FDDI, fibre channel, FICON, Gigabit Ethernet, SONET, SRDF, sysplex timer, T3/E3, and others.

### Scalability

The optical-networking solutions that have been developed from the ground up for metro enterprise transport support pay-as-you-grow expansion. The solutions enable customers to run only a few or up to 32 channels of native-speed traffic and evolve their network topologies—point-to-point, star, rings—with the same platform. Furthermore, in-service traffic is not interrupted by the installation of additional hardware or software upgrades (including reboots). Additional channels can be added, and capacity can be extended at each network node via add-and-drop capabilities.

### Reliability

Enterprises and carriers demand pure line protection for point-to-point links, as well as full path protection for ring structures. In either case, service restoration of less than 50 milliseconds is of paramount importance; otherwise, the performance of time-critical applications such as voice over Internet protocol (VoIP) could be jeopardized.

Additionally, all system components must be redundant with multiple fail-over scenarios. Enterprises and carriers frequently seek optical platforms with redundant power supplies and hot-standby functionality, for example.

## Openness

Standards compliance can be a make-or-break factor in buying decisions in any area of networking.

Support for these three key network-management protocols ensures that the optical-networking platform can be easily integrated with most existing enterprise and carrier infrastructures:

- **signaling network management protocol (SNMP)**—the simple network management language most widely used by enterprises and emerging carriers
- **TL-1**—the interface used in most North American incumbent carrier environments
- **Q3**—a protocol used extensively in Europe and gaining prominence globally

Enterprises and carriers choosing an optical platform are also interested in standards regarding single-mode fiber (ITU-T G.652, G.653, G.654, and G.655), electromagnetic compatibility (EN 55022 class B, EN 61000-4-2 electrostatic discharge immunity tests; EN 61000-4-4 electrical fast transient/burst immunity test; EN 61000-4-6/ENV 50141 immunity to conducted disturbances, induced by radio frequency fields; EN 61000-4-8 power frequency magnetic field immunity test; EN 61000-4-3/ENV 50140; ENV 50204/EN 50082-2 and 47CFR part 15 subpart B FCC class A, VCCI Class B), mechanical and electrical safety (IEC 950, EN 60950, and UL 1950), optical safety (IEC 825-1, 2, and EN 825-1, 2), and Y2K compliance (BSI PD2000-1).

## Ease of Installation and Management

Because they rely on the network-management protocols so prevalent in both enterprise and carrier environments SNMP, TL-1, and Q3, today's leading optical platforms are user-friendly. Network administrators can become well versed on using the systems with no more than a week of training.

Some vendors' products support plug-and-play installation, of particular benefit to enterprises and carriers whose network support staffs are strapped for time. Other platforms, originally intended for carrier deployment, require complex software configuration during installation.

## Management Functionality

Enterprises and carriers require sophisticated management functionality such as configuration management, service provision and activation, service testing, and fault monitoring. In the area of system monitoring, for example, some carriers require specially designed multi-clocks and fixed clocks that can be remotely controlled, enabling the network operators to provide distinguished tariff speed for each customer and service according to service value (rather than flat rate). The carriers must be able to monitor, control, or even configure bit rates via the management system.

## System Efficiency

System size is no small concern, and—as with ease of installation—it varies greatly among the various vendors' platforms. Many of the products available with enterprise listed among their target applications were initially designed for carrier deployment and, accordingly, are too big. Some require separate refrigeration units. Enterprises and carriers want platforms that fit standard 19-inch networking cabinets. A full-loaded chassis should not exceed 25 kilograms or 150 watts in power consumption.

## 5. Deployment Strategies

The development of metro optical networks is not a simple, two-step story of rings and then mesh networks but a more gradual evolution. Carriers have been establishing point-to-point optical links to enterprise customers to take advantage of immediate revenue opportunities for the last 18 months. Star and ring topologies will accommodate a boom in network traffic and growing demand for ubiquitous services over the next year. Eventually, carriers will build out full cross-connect, optical-fiber meshes as carrier infrastructures naturally begin to emulate traditional data networks, starting in 2001 and 2002.

## Point-to-Point Links

The revenue potential of gigabit-speed services rivals that of traditional leased-line services, but legacy transport systems are not up to the opportunity. Carriers' most advantageous option is adding high-speed, point-to-point optical links outside their existing core networks. The carrier must deploy only a customer-premises device for converting application traffic to specific wavelengths and multiplexing. Carriers today can extend their local networks as large-customer opportunities arise, and, one day, these island links can be integrated with the core.

## Stars/Rings

At the onset of this phase in the development of metro optical networks, carriers are delivering more and higher-speed access services. The traffic burden on their networking infrastructures is mounting. Some carriers increase their transport capacity offers to other carriers, and, thus, fiber exhaustion develops in some parts of their metro networks.

As this phase develops, the creation of star topologies or linear rings will be undertaken gradually, with the simple connection of separate point-to-point links as revenue opportunities dictate. This will be of prime benefit to carriers' network planners, whose primary consideration must be relying on optical-networking solutions that utilize open network-management systems.

As the number of customers requesting high-speed services explodes and bandwidth-on-demand services begin to appear, carriers with linear-ring topologies will evolve toward full rings based on optical add-drop-multiplexer platforms. Despite some vendors' suggestions to the contrary, carriers generally have not yet reached this stage, as the number of customers demanding gigabit services is still small.

But, in fact, data traffic is growing at an enormous pace, and it is critical for carriers to build a networking infrastructure that anticipates tomorrow's realities. With full optical rings, time to market with services will be slashed and carriers will save via reduced labor costs managing their networks.

Configurable protection capabilities will be of prime importance in the services platforms enabling this phase. A carrier will be able to determine whether an individual channel is to be fully protected on the optical layer or entrusted to already-implemented protection mechanisms from the SONET/synchronous digital hierarchy (SDH) layer. As a result, reselling capacity to other carriers and service providers will be made more cost-effective.

## Meshes

The day is approaching where the logical infrastructure of glass fiber rings, present in today's cities, ceases dictating network design. High-end users will seek flexible lambda services, and carriers will need to optimize the optical network for this demand.

With the introduction of metro optical cross-connects, optical metro networks will be transformed into fully flexible platforms. The transformation of the traditionally voice-based network to a data-centric infrastructure will be complete.

The most important technologies in optical-networking solutions for this phase will be cost-effective optical-electrical-optical cross-connects with node-management and network-signaling software functionality similar to that of open shortest path first (OSPF) and multiprotocol label switching (MPLS).

## 6. Enterprise Uses and Benefits

A leading technology manufacturer, a financial services giant, and a regional power utility each has unique needs and networking environments, but each turned to the same solution: wavelength services.

### Case Study I: Immediate Relief

A Fortune 500 technology manufacturer was seeking relief for the fiber backbone running between two of its facilities. ATM, Fast Ethernet, and Gigabit Ethernet application traffic had exhausted the bandwidth capacity of 24 optical-fiber strands.

The company first considered merely leasing additional fibers. This strategy, though, would not only have been expensive but also effectively unfeasible. Securing the necessary regulatory permits to lease, bury, and connect additional fiber strands would have taken perhaps as long as 18 months—a delay the company was unwilling to endure.

Instead, the manufacturer turned to WDM. No additional fiber strands would have to be installed (only an active optical-networking system at each of the two facilities) to improve network performance for its 11,000 employees.

In choosing a specific system, ease of installation was a primary consideration. Plug-and-play installation capabilities ensured that the system the manufacturer selected would demand minimal labor from the company's 16-person network support staff. Other systems, originally intended for carrier deployment, would have required complex software configuration during installation.

The benefit: The WDM system has multiplied available bandwidth by up to 16 times, providing ample support for 25 terabytes of high-speed, LAN application traffic between the enterprise's two sites. In addition, the technology manufacturer's product development and other mission-critical data is continuously mirrored. There has been no negative impact to network performance; all protocols run at their native speeds.

## Case Study II: Disaster Recovery

No industry has been more eager than finance to put into action the new range of disaster recovery technologies. Here, millions of dollars in revenue per hour are jeopardized in the event of a data-center failure.

One leading global financial services company with more than 50,000 employees worldwide needed to replace a SONET-based infrastructure that linked its three data centers within a metropolitan area. The customer sought a more effective disaster recovery strategy that would not cut into network availability for mission-critical ESCON traffic.

As was the case with the technology manufacturer, installing additional dark fiber strands was quickly ruled out as too expensive and time consuming. The financial services firm identified DWDM as the ideal technology. Because of its ability to create virtual channels, DWDM enables enterprises to perform more extensive SRDF protocol disc mirroring. And, in the event of a data-center failure, the network switches over to mirrored data automatically and recovers taped data more rapidly and affordably than ever before.

The financial services company deployed DWDM platforms at each of its three data centers. Because it features an SNMP module, the system is managed and monitored simply, from the enterprise's existing software-management platform.

The benefit: The financial services company has uncovered more bandwidth for ESCON and other multiprotocol application traffic. Most importantly, the primary goal of establishing an effective disaster recovery strategy has been met. The company's on-line transaction revenues are now safe because data is backed up continuously. In the event of catastrophic failure at any of its three data centers, users would never know the difference; their requests on the network would automatically and seamlessly fail over to an in-service data center.

## Case Study III: Evolving Needs

A U.S. power utility already faced tapped capacity along the 6- and 16-kilometer pairs of 36 optical fibers linking its utilities. Seeking not only expanded capacity for ATM, ESCON, Fast Ethernet, and SRDF traffic, the utility also was intent on positioning its infrastructure for easy future upgrades. If the utility was one day to implement advanced protocols such as Gigabit Ethernet or fibre channel, it did not want to be required to replace modules or configure data rate changes.

The utility went through a normal progression of decisions. Additional fibers would be too expensive and require too long of a delivery time. SONET was too costly with too many limitations. Once again, the clear choice was WDM, a

solution delivering true protocol independence across existing fiber infrastructures.

A key determinant in the utility's decision on a particular system was footprint. Like many enterprises, it could afford to devote only so much floor space for the devices it purchased. Size varied greatly among the vendors. The utility settled on a 19-inch, rack-mount device with a hot-swappable architecture.

The benefit: Nine fully independent applications are running on the same fiber pair. The performance boost the utility sought has been achieved. Furthermore, a high-speed module on the WDM solution that the utility selected enables upgrades from Fast Ethernet to Gigabit Ethernet, ESCON to FICON, or SRDF to fibre channel with no change in hardware. The utility's network can grow flexibly with its networking needs.

## 7. The Competitive Landscape

Carriers have invested heavily in SONET/SDH- and ATM-based transport platforms to enable service delivery to enterprise customers, but these legacy systems are not ideal for the new age of gigabit-speed services. How do these two and other techniques, in comparison to WDM, stack up as the foundation of the emerging services infrastructure?

- **SONET/SDH**—SONET/SDH is an effective technology for aggregating multiple low-speed (<optical carrier-level 3 [OC-3]) data applications and multiple sites onto a common infrastructure linked out to the wide area. But the cost and reduced performance of protocol-conversion equipment required to convert ESCON applications, for example, to OC-3 or T3 links is prohibitive, and there is no viable SONET service available today for even higher-speed protocols such as 1.062-Gbps fibre channel and FICON.
- **ATM**—Like SONET/SDH, ATM is suitable for aggregating sub-OC-3 data applications. But ATM solutions offer no interfaces for speeds faster than 622 Mbps, and they are cost prohibitive for a variety of reasons, not least among which is the overhead cell tax (5 bytes per 48-byte payload) that proves costly for file transfer of large data volumes.
- **Internet protocol (IP)**—Although IP is widely promoted as the single and only protocol for data transfer, the inherent limitations of maximum packet length presently do not enable IP to provide an adequate substitute for ESCON and fibre channel protocols.

WDM, which is high-performance, protocol-transparent, reliable, scalable, and simply installed and managed, is carriers' most affordable approach for aggregating traffic and penetrating markets immediately with first-class services.

## Self-Test

1. In the early 1990s, when enterprise market demand initially intensified for high-bandwidth solutions for business applications, LECs relied on what two technologies for access services?
  - a. TDM and SONET
  - b. SONET and ATM
  - c. ATM and frame relay
  - d. frame relay and TDM
2. Which multiplexing technique differentiates on wavelength to multiply the capacity of optical-fiber strands and create virtual channels?
  - a. WDM
  - b. MPLS
  - c. FDM
  - d. TDM
3. Enterprises are demanding optical-networking services to deliver more bandwidth for key business applications, including which of the following?
  - a. handling user moves, additions, and changes
  - b. enabling more frequent, comprehensive data backups
  - c. clustering high-speed computers for parallel processing
  - d. all of the above
4. Carriers today focus mostly on selling dark fiber to enterprise customers, avoiding the complexity of managing networking issues.
  - a. true
  - b. false

5. The all-optical network will one day include DWDM systems, optical gateways, and optical cross-connects. It will permeate the entire public network, including the enterprise access, metropolitan, regional, and long-haul backbone segments.
  - a. true
  - b. false
6. What is the simple network management language most widely used by enterprises and emerging carriers today?
  - a. LCI
  - b. Q3
  - c. SNMP
  - d. TL-1
7. What traditional network structure will full cross-connect optical-fiber meshes more likely emulate?
  - a. voice
  - b. data
8. Enterprises find that leasing additional fibers is not only expensive but also often effectively unfeasible. This is because securing the necessary regulatory permits to lease, bury, and connect additional fiber strands takes \_\_\_\_\_.
  - a. usually about a month
  - b. up to six months
  - c. a year
  - d. perhaps as long as 18 months
9. SONET/SDH is an effective technology for aggregating multiple low-speed (less than OC-3) data applications and multiple sites onto a common infrastructure linked out to the wide area. But it is not best suited as the underlying technology for the emerging carrier services infrastructure. Why?
  - a. SONET protocol conversion equipment is expensive.

- b. SONET protocol conversion equipment hinders application performance.
- c. No viable SONET service exists today for fibre channel and FICON traffic.
- d. all of the above

## Correct Answers

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- b. SONET and ATM**
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See Topic 1.

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- d. TDM

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3. Enterprises are demanding optical-networking services to deliver more bandwidth for key business applications, including which of the following?

- a. handling user moves, additions, and changes
- b. enabling more frequent, comprehensive data backups
- c. clustering high-speed computers for parallel processing
- d. all of the above**

See Topic 2.

4. Carriers today focus mostly on selling dark fiber to enterprise customers, avoiding the complexity of managing networking issues.

a. true

**b. false**

See Topic 3.

5. The all-optical network will one day include DWDM systems, optical gateways, and optical cross-connects. It will permeate the entire public network, including the enterprise access, metropolitan, regional, and long-haul backbone segments.

**a. true**

b. false

See Topic 3.

6. What is the simple network management language most widely used by enterprises and emerging carriers today?

a. LCI

b. Q3

**c. SNMP**

d. TL-1

See Topic 4.

7. What traditional network structure will full cross-connect optical-fiber meshes more likely emulate?

a. voice

**b. data**

See Topic 5.

8. Enterprises find that leasing additional fibers is not only expensive but also often effectively unfeasible. This is because securing the necessary regulatory permits to lease, bury, and connect additional fiber strands takes \_\_\_\_\_.
- a. usually about a month
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See Topic 6.

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- a. SONET protocol conversion equipment is expensive.
  - b. SONET protocol conversion equipment hinders application performance.
  - c. No viable SONET service exists today for fibre channel and FICON traffic.
  - d. all of the above**

See Topic 7.

## Glossary

### **ATM**

asynchronous transfer mode

### **DWDM**

dense wavelength division multiplexing

### **ESCON**

enterprise system connection

### **FDDI**

fiber distributed data interface

**FDM**

frequency division multiplexing

**FICON**

fiber connection

**FSP**

fiber service platform

**IP**

Internet protocol

**ISP**

Internet service provider

**LAN**

local-area network

**LEC**

local-exchange carrier

**MPLS**

multiprotocol labeling system

**OC**

optical carrier

**OSPF**

open shortest path first

**SAN**

storage-area network

**SNMP**

signaling network management protocol

**SONET/SDH**

synchronous optical network/synchronous digital hierarchy

**SRDF**

symmetric remote data facility

**T3**

45-Mbps leased line

**TDM**

time division multiplexing

**TL-1**

transaction language 1

**UPSR**

unidirectional path switched ring

**VoIP**

voice over IP

**WDM**

wavelength division multiplexing