# Optical Metro Edge

## Definition

In a world of ever-increasing bandwidth capacity at the core and higherbandwidth applications originating from the user, an incredible amount of pressure has been placed on metropolitan edge networks. A new generation of metro on-ramps promises to relieve this pressure and to offer carriers ways to create competitive advantage in the complex, high-stakes game of providing converged voice and data services.

## Overview

Customer demand for broadband voice and data services has exploded. A new world of bandwidth-hungry, multiprotocol services is providing a tremendous opportunity for incumbent and emerging carriers alike. Services such as videoconferencing, storage-area networking, Internet audio, and telecommuting are likely to replace standard voice and 56–kbps data as the dominant profit centers in the next few years.

While local services are consuming ever-increasing amounts of bandwidth, metro and long-haul core networks are experiencing dramatic improvements in bandwidth efficiency. With the advent of technologies such as wavelength division multiplexing (WDM) and dense wavelength division multiplexing (DWDM), today's fiber technology can deliver in excess of 1 Petabit per second over a single optical cable.

This convergence of high-bandwidth applications originating from the user and high-bandwidth capacity at the core is placing a tremendous amount of pressure on the edge of metropolitan networks. A new breed of optical metro access and transport devices promises to break this bottleneck between the user and the core, bringing core bandwidth and switching intelligence right to the network edge.

This tutorial discusses the drivers that are causing pressure on today's metro edge, as well as the challenges facing service providers who wish to offer converged voice and data services. Several solutions that are available on the market today are then examined. Finally, the tutorial discusses a new class of metro access and transport platform that is built to solve modern metro networking problems.

# Topics



# 1. Market Background

The emergence of frame relay and asynchronous transfer mode (ATM), as well as the emergence of broadband access technologies such as digital subscriber line (xDSL) and cable modems, has placed considerable strain on existing metropolitan infrastructures. With data services growth averaging more than 50 percent per year and voice growth at more than 15 percent per year,[1] the need to use existing network infrastructure in a careful and cost-effective manner is of critical importance.

BancBoston Robertson Stephens predicts that to support the growth of the Internet alone, 350,000 T1s and 25,000 T3s must be provisioned over the next four years (compared to the current installed base of approximately 300,000 T1s and 2,200 T3s). Driven by Web hosting, business-to-business and business-to-consumer electronic commerce (e-commerce), IDC projects that by 2003, 55 percent of all enterprises and 71 percent of all home businesses will be on-line. The result is an Internet protocol (IP) services market of $5.75 billion and a line aggregation (ATM, frame relay, and private line) market of $21.5 billion by 2003.[2] And, as corporations deploy Internet virtual private networks (VPNs) to replace existing private-line and frame-relay networks, the U.S. Internet access market is expected to grow from less than $3 billion in 1998 to $42 billion by 2003.[3]

*Figure 1* outlines the expansion in e-commerce driving data traffic and revenue growth, while *Table 1* describes broadband data and service access revenue projections.

[1] Ryan, Hankin and Kent, 1999
[2] Ibid
[3] Forrester Research, 1999

**Figure 1. E-Commerce Revenue Projections[4] (in Millions of Dollars)**

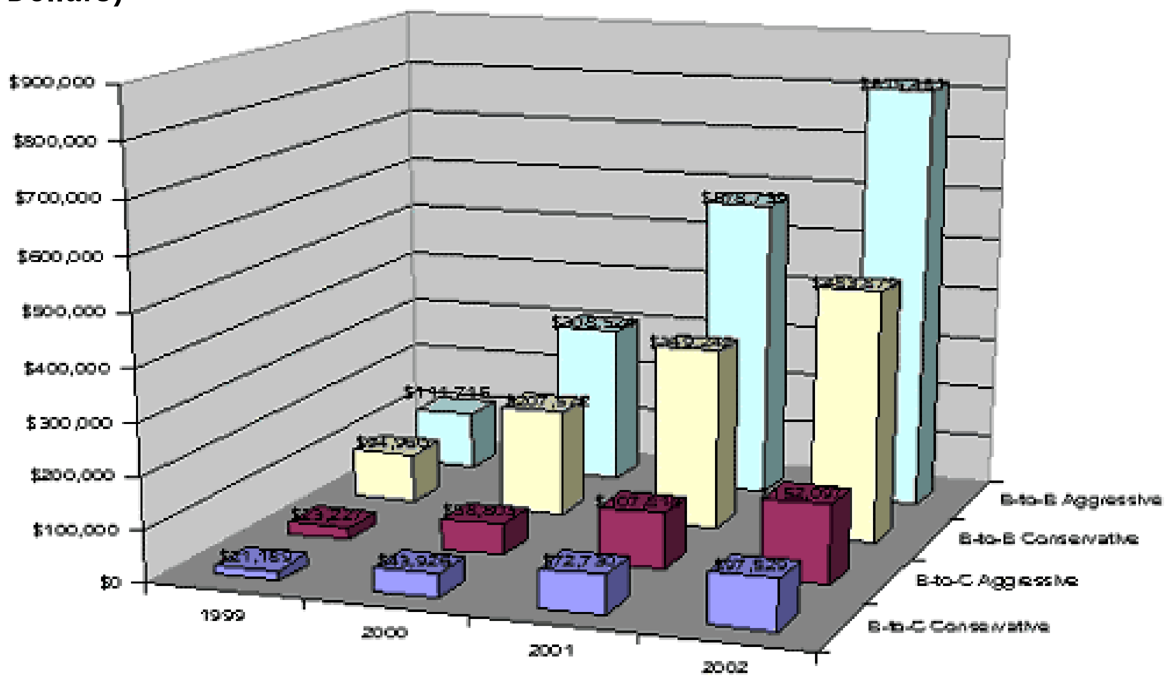



**Table 1. Access Revenue Projections[5] (All Numbers in Millions of Dollars)**

| | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** |
|---|---|---|---|---|---|---|
| Dial[1] | 1,206 | 2,302 | 3,314 | 4,458 | 5,607 | 6,627 |
| 56 kbps | 197 | 467 | 746 | 1,068 | 1,472 | 1,782 |
| DSL | — | 24 | 105 | 259 | 504 | 876 |
| Cable | 18 | 74 | 276 | 697 | 1,225 | 1,786 |
| FT1/T1 | 896 | 1,687 | 3,019 | 5,619 | 7,921 | 9,268 |
| DS3 | 255 | 568 | 1,345 | 3,696 | 7,610 | 12,657 |
| OC3 | — | 49 | 351 | 1,094 | 2,339 | 4,140 |
| Total Broadband | 1,169 | 2,402 | 5,096 | 11,365 | 19,599 | 33,569 |
| Bundled[2] | 270 | 575 | 1,151 | 2,348 | 3,615 | 4,842 |
| Total | 2,842 | 8,048 | 10,307 | 19,239 | 30,293 | 41,978 |

[1]includes integrated services digital network (ISDN)
[2]includes local loops and customer premises equipment (CPE)

[4] Forrester Research, 1999
[5] IDC, 1999

With user demand for broadband services escalating, tremendous advances have also been made in core network bandwidth capacities. Technologies such as DWDM are capable of data rates in excess of 1 Petabit per fiber.

This convergence of high-bandwidth applications originating from the user and high-speed networks at the core is placing a tremendous amount of pressure on the edge of metropolitan networks that act as on-ramps to the core networks. For the service providers in this arena, the key factors to success now include how effectively they will be able to meet burgeoning demand for high-bandwidth applications, how rapidly they can deploy and provision advanced voice and data services, how well they can protect their existing revenue base (voice still accounts for more than 65 percent of all service-provider revenues), and preserving and fully utilizing their existing network infrastructure.

# 2. Service Provider Trends and Issues

Service providers competing in this new era of converged voice and data services face a varied set of business and technical challenges as they seek to implement these services over their existing or green-field optical networks. The challenges are based not only on their service mix, but also on their installed service base, regulatory environment, and business history.

## CLECs

Competitive local exchange carriers (CLECs) face many access challenges, especially in delivering direct access to unbundled local loops or bundled services to a multitenant dwelling. To meet these challenges, CLECs require the following:

- a cost-effective method of maximizing expensive carrier co-location space
- an efficient means of delivering multiple voice and data services on a cost-competitive basis
- a clear method of limiting capital expenditures on a point-of-presence (PoP) by PoP basis, thereby allowing the CLEC to expand its geographic footprint rapidly and cost effectively
- a simple means of provisioning and billing multiple voice and data services

## ISPs

Internet service providers (ISPs), often delivering Internet access services in conjunction with a CLEC or incumbent local exchange carrier (ILEC), require fast and reliable interconnection of their IP/ATM and router-based networks to optical metro access networks. To deliver the next-generation, IP–based services that are critical to their success, ISPs require the following:

- an effective method of aggregating traffic from multiple metropolitan synchronous optical network (SONET)/synchronous digital hierarchy (SDH) rings
- an efficient method of linking SONET/SDH and IP/ATM network cores
- a cost-effective method of maximizing co-location space (where necessary)
- the ability to deliver next-generation access services without the requirement to replace existing network infrastructures

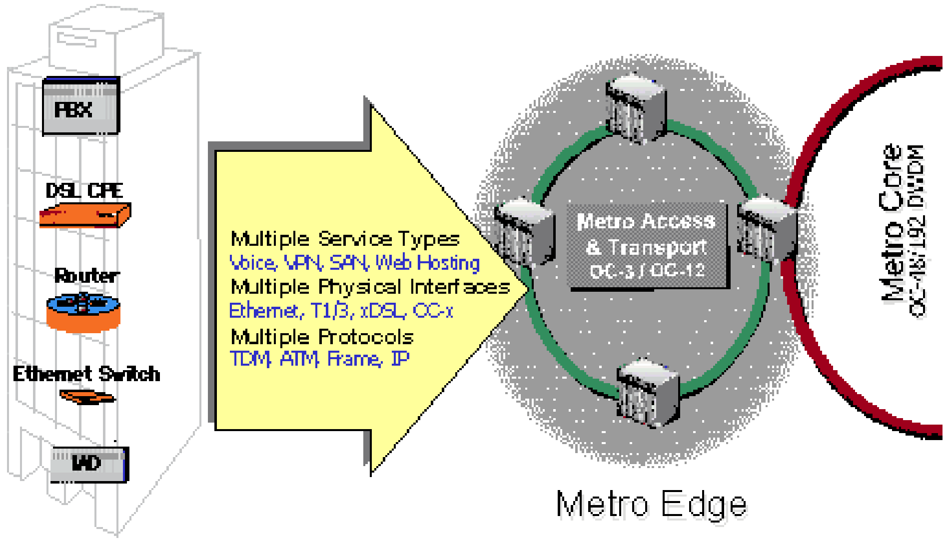
## ILECs

Incumbent local exchange carriers (ILECs) face strong competitive pressure from all sides. Critical to their success is their ability to protect their established base of customers and services while developing and delivering the next-generation voice and data services their customers demand. To accomplish this transition successfully, they must find a means of optimizing existing infrastructures as they utilize them to deliver new, competitive service offerings. ILEC optical metro access requirements therefore include the following:

- a means of delivering next-generation voice and data services without disturbing existing SONET/SDH infrastructures
- a method of optimizing that SONET/SDH infrastructure for nonvoice traffic
- an efficient way of delivering combined voice and data services
- a simple means of provisioning and billing emerging voice and data services

To comprehend the complexities that today's competitive service provider faces, consider the task of offering bundled voice and data services in a multitenant dwelling such as a high-rise, as shown in *Figure 2*.

**Figure 2. Offering Bundled Services in a Multitenant Environment**




Offering services in a multitenant environment requires not only a myriad of physical interfaces (such as T1/E1, T3/E3, Ethernet, optical carrier [OC]–x) but a diverse array of protocols (such as time division multiplexed [TDM], ATM, frame relay, xDSL, IP) as well. For example, to offer customers transparent local-area network (LAN) over Ethernet, the access device must be able to perform Layer-3 routing, including the support of routing protocols such as border gateway protocol (BGP), open shortest path first (OSPF), and routing information protocol (RIP). Another customer might have the need to concentrate digital signal (DS)–1s into a DS–3 for transport to a corporate headquarters; hence the access device must have the functionality of an M13. To access the service provider's SONET ring, the device must also perform the functions of an add/drop multiplexer (ADM) and perhaps a digital cross-connect (DCS) switch. This resulting heterogeneous mix of traffic types, protocols, and multilayer processing calls for a very advanced architecture optimized for the metro edge.

# 3. Evolution of Optical Metro Access Technologies

To address the increasing customer demand for high-bandwidth applications and converged voice and data services, and to address the shortcomings of traditional metro access and transport equipment, a wide array of solutions has been proposed by equipment vendors. These solutions tend to fall into four main categories: WDM and DWDM, virtual path ATM, passive optical networking (PON), and Gigabit/Terabit Ethernet routers that handle both data and voice traffic.

While each has propelled the market toward simplification and cost improvements, they all have their shortcomings for the metro edge.

## WDM and DWDM

WDM and DWDM technology is the new de facto standard for core transport applications. By multiplexing many wavelengths of light onto fiber-optic cable, service providers are able to transport mass amounts of data over very long distances. Because metro DWDM solutions are derived from their more expensive upstream cousins in the core networks, they are still very expensive to deploy and very difficult to manage. Additionally, there are still no standards for DWDM, making every vendor's solution proprietary and non-interoperable with other DWDM systems, let alone SONET or SDH. While there is no doubt that WDM technologies are the end game for metropolitan access and transport networks, the economics and technology are simply not there at this point in time.

## VP ATM

Virtual path ATM (VP ATM) solutions try to solve the access and transport efficiency problem by overlaying the ATM protocol on top of existing SONET/SDH physical infrastructures. The key problem with this technology is that of interoperability. VP ATM sits on top of (or overlays) existing SONET infrastructures utilizing only the physical characteristics of the protocol. In this type of network, an existing SONET ADM would be configured in a pass-through mode; in other words; traffic originating from an existing ADM cannot talk with the new VP ATM device and vice versa.

## Passive Optical Networking

PON technology operates by basically shooting a single high-bandwidth pipe to a densely populated area, then splitting that pipe out into smaller pipes for access and transport. While these solutions bring bandwidth closer to the user and are protocol-insensitive, they are basic Layer-1 devices, with no switching or grooming intelligence. As there are no standards as of yet, every PON system is proprietary and requires both optical networking units (ONUs) to access the transport network and optical modems for the actual local access. Finally, PON systems are not interoperable with existing SONET/SDH infrastructures, making them unattractive for more established networks.

## Gigabit/Terabit Ethernet

Gigabit Ethernet (GigE) for metro networks is an extension of basic LAN access technology. While GigE is well suited for moving massive amounts of data over mesh-oriented networks, it overlooks the complexities of grooming and transporting bundled voice and latency-sensitive data services. Until these vendors can standardize network-wide quality-of-service (QoS) provisioning and better control jitter and delay, GigE will most likely remain in the domain of core data networks.

# 4. Next-Generation Optical Access and Transport Solutions

One company believes that the best way to break the metro access and transport bottleneck is to take a new approach to metro on-ramp design—a smarter approach. The next-generation metro access and transport platforms feature five key elements that are necessary to create a smarter metro edge:

- interoperability
- access flexibility
- transport efficiency
- provisioning simplicity and flexibility
- network management and operations support systems (OSSs)

## Interoperability

With over 150,000 SONET systems in the United States and over 150,000 SDH systems in the rest of the world, SONET/SDH is the dominant metro access and transport technology. The economics are simple: existing SONET/SDH infrastructures must be leveraged, and current services and revenues based on SONET/SDH must be protected. While many vendors claim SONET/SDH interoperability, most are in fact incapable. An access device may collapse many of the current devices needed to provide multiple services, but in many cases, these devices will only talk with peers of like type on the SONET/SDH ring, as in the case of virtual path ATM solutions. True SONET/SDH interoperability mandates that the device must communicate with existing SONET/SDH ADMs at not only the physical layer, but at the control and signaling layers as well. True interoperability gives carriers the ability to replace legacy equipment in their network over time with next-generation equipment that is more flexible, scalable, and efficient. Given today’s requirements for rapid return on investment (ROI), full interoperability assures lower risk and faster payback migration strategy.

## Access Flexibility

To provide bundled services based on both voice and data, these devices will terminate, switch, and route a vast array of traffic types and services. Today this requires the purchase of optical access equipment such as ADMs, multiplexers (MUXs), and DCS switches, in addition to Layer-2 and 3 switching and routing equipment. The price tag of this equipment is high, not including the costs to install, manage, and maintain it. Next-generation metro optical access devices will collapse the functionality of many of these traditional devices, aggregating, switching, and transporting TDM, frame, IP, and ATM–based traffic from DS0 all the way up to OC–48 and beyond.

## Transport Efficiency

By incorporating the functionality of 3/1/0 DCS switches, these devices are able to distribute core DS0–level switching decisions at the edge of the metro network, significantly increasing SONET/SDH transport efficiency and increasing central office (CO) port efficiency as well.

Consider the task of switching DS0–level services in a traditional network. Traffic originating from the user side of the network must traverse the entire transport network and enter the CO (where the DCS switches traditionally reside) to be processed and switched. This not only wastes a tremendous amount of transport bandwidth but precious CO ports. By pushing DCS functionality and intelligence to the network edge, these devices tremendously increase bandwidth utilization in the transport network and increase port efficiency in the core.

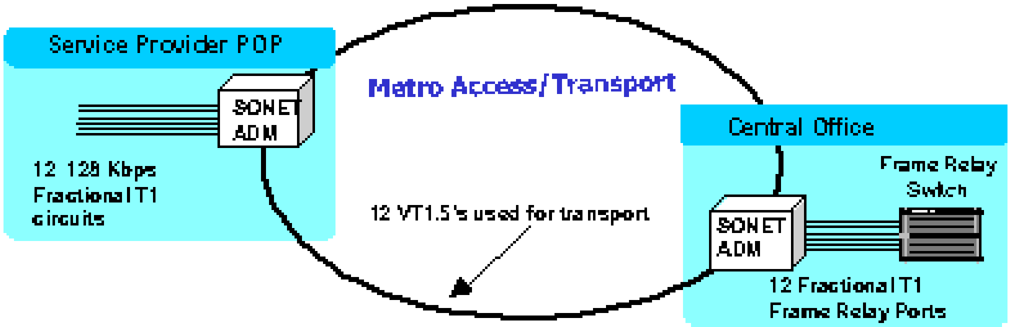
A classic application utilizing fractional T1 circuits is that of branch office interconnect to corporate frame-relay VPNs.

## Application: Optimizing SONET for Fractional T1

### Typical Fractional T1 Deployment

At a remote site, 12 fractional T1s are connected to a SONET ADM, as depicted in *Figure 3*. These 12 T1s are carried around the ring in 12 separate VT1.5s, where they are then connected to 12 T1 ports on a frame-relay switch. If we assume that the fractional T1s are 128–kbps services, the actual used bandwidth is approximately 1.54 Mbps. This represents a bandwidth efficiency of approximately 8 percent (1.54 Mb of data carried over 18 Mb of transport). This grossly inefficient transport not only wastes ring bandwidth, but quickly exhausts switching ports in the CO.

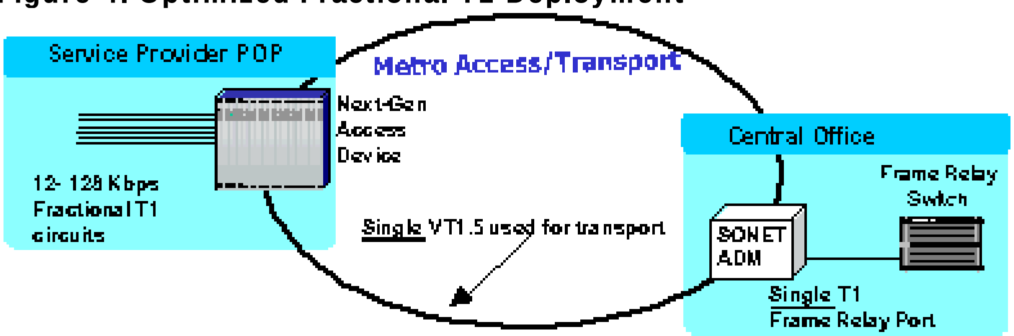
**Figure 3. Typical Fractional T1 Deployment**




## Optimized Fractional T1 Deployment

When a next-generation optical metro access device is placed at the remote location, as depicted in *Figure 4*, ring bandwidth efficiency and port efficiency can be dramatically enhanced. The new device, with its built-in 3/1/0 DCS capabilities, will take the same 12 fractional T1 frame-relay circuits and combine them into one DS1 for transport in a single VT1.5 on the SONET ring. When the traditional SONET ADM at the CO drops the DS–1 signal out of the ring, the result is a completely standard T1 frame-relay signal that uses only one port on the frame-relay switch. While typical frame-relay services are data-only, these devices can effectively aggregate, groom, and switch voice traffic at a DS0 level, as well.

**Figure 4. Optimized Fractional T1 Deployment**




## Provisioning Simplicity and Flexibility

Voice and data services of the past were based on fairly standardized technologies, and demand was fairly easy to predict. Today, the traffic mix is more heterogeneous in nature and not as predictable. The challenge is to innovate new ways to address multiple types of traffic with new, scalable, bundled service offerings that are easy to provision, manage, and scale.

By decoupling physical interfaces from protocol processing, these new devices allow fast turnup of new services, easy service migration, and the ability to add capacity on a port basis quickly. With these devices, a service provider can migrate from simple voice and data services to more advanced ATM and IP services within minutes versus weeks. For example, the service provider may want to incorporate only traditional Layer-1 functions such as circuit switching, multiplexing, and cross-connecting at initial deployment. Then, when demand warrants, they may gracefully migrate to more advanced Layer-2 and Layer-3 services such as ATM and frame relay VPNs, packet over SONET, and even IP over DWDM.

In addition to provisioning local services over individual network elements, next-generation access and transport devices will be able to provision end-to-end services fully over a multitude of network elements, including integrated access devices (IADs), other ADMs, and fast data switches and routers.

## Network Management and OSSs

To deliver a multiplicity of voice and data services capably, carriers of all types must integrate the management of a variety of network technologies and platforms. Today's emerging optical metro access platforms offer service providers the management and operations integration support and capabilities that are required to offer next-generation voice and data services from existing SONET/SDH architectures. Key enabling management technologies that are delivered in emerging optical metro access platforms include the following:

- **point-and-click provisioning**—equipment, facilities, cross-connects, protocols, service-level agreements (SLAs), static routing, VPNs
- **fault management**—alarm notification and propagation, root-cause correlation, and reporting
- **performance management**—performance monitoring of all access and SONET/SDH facilities as well as traffic management
- **security management**—IP– and UNIX–based security
- **accounting management**—call and traffic detail reports
- **protocols**—full SONET DCC mess transport, Web-based user interface, command line interface, transaction language 1 (TL1), signaling network management protocol version 2 (SNMP v2), common object request broker architecture (CORBA), common management information protocol (CMIP) Q3

Utilization of these robust management and OSS technologies allow service providers to consolidate services and therefore realize significant savings in capital investment, operations management support systems, and personnel, while delivering the high availability and robust services that enterprise customers demand.

# 5. Conclusion

The next generation of optical metro access and transport platforms offer service providers a unique opportunity to leverage existing SONET/SDH infrastructures while meeting existing and emerging requirements for aggregated voice and data services. Additionally, these devices offer a means for service providers to prepare their optical network infrastructures to deliver the e-business and application-centric transmission facilities that their customers will require in an increasingly competitive global economy.

In summary, these devices enable the following:

- a cost-effective means of delivering multiple Layer-1 (DS0 to DS3, Ethernet, xDSL, OC–x), Layer-2 (ATM, frame relay, private line), and Layer-3 (IP routing, multiprotocol labeling system [MPLS], DiffServ) services from a high-density, small-footprint, integrated hardware platform

- a more efficient method of transporting data traffic on SONET/SDH transmission facilities versus traditional ADM TDM–based multiplexers

- interoperability and optimization of existing SONET/SDH network infrastructures

- an integrated platform for provisioning, management, and billing of voice and data access services

In a highly competitive telecommunications environment, next-generation optical metro access technologies will enable service providers to limit capital investment while leveraging existing optical assets more efficiently. The result will be the ability to deliver voice and next-generation services more cost effectively and efficiently. Optical metro access is a linchpin technology for service providers focused on delivering competitive voice and data access services today and tomorrow.

# Self-Test

1. Data services growth averages more than _________ percent per year.

   a. 20

   b. 30

   c. 40

   d. 50

2. ______________ technology is the new de facto standard for core transport applications.

   a. VP ATM

   b. PON

   c. Gigabit/Terabit Ethernet

   d. WDM and DWDM

3. Which of the following overlays the ATM protocol on top of existing SONET/SDH physical infrastructures?

   a. VP ATM

   b. PON

   c. Gigabit/Terabit Ethernet

   d. WDM and DWDM

4. Which of the following is an extension of basic LAN access technology?

   a. VP ATM

   b. PON

   c. Gigabit/Terabit Ethernet

   d. WDM and DWDM

5. Which of the following shoots a high-bandwidth pipe into a densely populated area and then splits it into smaller pipes for access and transport?

   a. VP ATM

b. PON

c. Gigabit/Terabit Ethernet

d. WDM and DWDM

6. Standards are now in place for DWDM.

   a. true

   b. false

7. SONET/SDH is the dominant metro access and transport technology.

   a. true

   b. false

8. Typical fractional T1 deployment uses ring bandwidth efficiently.

   a. true

   b. false

9. Integrated management of a variety of network technologies and platforms is a must for carriers.

   a. true

   b. false

10. ADM– and TDM–based multiplexers are more efficient than next-generation optical metro access devices.

    a. true

    b. false

# Correct Answers

1. Data services growth averages more than _________ percent per year.

   a. 20

   b. 30

   c. 40

**d. 50**

See Topic 1.

2. ______________ technology is the new de facto standard for core transport applications.

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    b. PON

    c. Gigabit/Terabit Ethernet

    **d. WDM and DWDM**

    See Topic 3.

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a. true

**b. false**

See Topic 5.

# Glossary

**ADM**
add/drop multiplexer

**ATM**
asynchronous transfer mode

**BGP**
border gateway protocol

**CLEC**
competitive local exchange carrier

**CMIP**
common management information protocol

**CO**
central office

**CORBA**
common object request broker architecture

**CPE**
customer premises equipment

**DCS**
digital cross-connect system

**DS**
digital signal

**DSL**
digital subscriber line

**DWDM**
dense wavelength division multiplexing

**e-commerce**
electronic commerce

**GigE**
Gigabit Ethernet

**IAD**
integrated access device

**ILEC**
incumbent local exchange carrier

**IP**
Internet protocol

**ISP**
Internet service provider

**ISDN**
integrated services digital network

**LAN**
local area network

**MPLS**
multiprotocol labeling system

**OC**
optical carrier

**ONU**
optical networking unit

**OSPF**
open shortest path first

**OSS**
operations support system

**PON**
passive optical network

**PoP**
point of presence

**QoS**
quality of service

**RIP**
routing information protocol

**ROI**
return on investment

**SDH**
synchronous digital hierarchy

**SLA**
service-level agreement

**SNMP**
signaling network management protocol

**SONET**
synchronous optical network

**TDM**
time division multiplexed

**VP ATM**
virtual path ATM

**VPN**
virtual private network

**WDM**
wavelength division multiplexing