Optical Access

Definition

The access network is that portion of a public switched network that connects access nodes to individual subscribers. More simply, it is the last link in a network between the customer premises and the first point of connection to the network infrastructure—a point of presence (PoP) or central office (CO). The access network has hitherto consisted predominantly of passive, twisted-pair copper wires.

The access network has consistently been regarded as a bottleneck in the provisioning of data communication services. This is primarily because the bandwidth available has lagged behind that provided within local-area networks (LANs) and in the upper echelons of the network (in metropolitan and core networks, for example), where concentration factors and economies of scale have allowed optical fiber to unleash significant bandwidth capacity.

The optical access network is that part of the access network implemented using optical fiber. Optical access offers the promise of greatly increased accessnetwork bandwidth by up to several gigabits per second (Gbps)—and most likely more, as technology advances.

This bandwidth availability opens up new architectural possibilities for the provisioning of high-bandwidth services. With the access network as a bandwidth bottleneck, it is necessary to place some sort of processing equipment at the customer premises to manage or control the amount of data transmitted over an access connection. Once the bottleneck is opened, new opportunities present themselves—such as the option of carrying larger quantities of data across an access link to be routed, switched, or processed in some other way at a PoP or CO. In such cases where economies of scale come into play, reducing the cost per bit of handling data, it is possible to simplify the equipment provided at the customer premises.

Overview

There is a general perception that fiber is a scarce resource. However, lack of available fiber for new optical access services is not a major factor in today's market. In fact, fiber is now a readily available access resource, especially in major urban or metropolitan areas. It is estimated that in 1999 about 65 million kilometers of optical fiber were installed in the United States, of which 70 percent was in the top metropolitan markets of the incumbent local exchange carriers (ILECs) and competitive local exchange carriers (CLECs). The quantity of fiber deployed by CLECs has been forecasted to more than double between 1999 and 2002. All of this points to a large, addressable market for high-speed services based on lighting dark optical fiber—a market with significant growth potential.

Fiber-optic infrastructure is proving to be a vital part of today's rapidly changing economic environment. The drive for interconnectivity as well as the exponential growth in data traffic as a result of new business applications will lead to the adoption of optical access solutions—as they help both end users and service providers to connect to the information superhighway. A technology is needed that can leverage the existing network as well as increase the economic viability of new network applications. High-bandwidth traffic is creating a mandate to leverage technology and carrier competitiveness to deliver the next wave in high-speed local access. The bandwidth gap can be bridged with optical access solutions. Optical-access platforms provide the solution by unblocking the bandwidth bottleneck between the customer premises unit (CPE) and CO or PoP using dark fiber solutions.

Topics

1. Introduction

The idea of using optical fiber to connect equipment at the customer premises to carrier facilities has existed for at least a couple of decades. For the concept to become a reality, several enabling factors had to be addressed, including the following:

- the availability of affordable multiplexing equipment
- the deployment of fiber cables in sufficient quantity to create a critical mass for service offerings
- the readiness of service providers to offer services

In addition, a market had to be developed to make use of the optical fiber-bandwidth capacity.

2. Need for Optical Access

Demand, ever-improving technology, and deregulation are significantly disrupting the telecommunications marketplace, presenting service providers with tremendous opportunities as well as precipitating huge changes in network alliances.

The existing infrastructure has not kept pace with the exponential network growth. New business applications such as e-commerce, high-quality videoconferencing, telemedicine, large-file transfers, data mirroring, carrier hotels, and data-storage warehousing all are driving the need for ultrahigh bandwidth services. New species of service providers, such as Internet service exchanges (ISXs), application service providers (ASPs), and storage service providers (SSPs) are emerging, experiencing rapid growth in their businesses and scrambling for market-share.

The rapid increase in bandwidth demand has also forced carriers to choose quickly among competing technologies: digital subscriber line (DSL), asynchronous transfer mode (ATM), and Internet protocol (IP) over synchronous optical network (SONET). All of these have been offering to provide customers with new high-bandwidth access services.

Unfortunately, in the rush, mismatched protocols have developed between enterprise and carrier environments. The complexity and redundancy of the equipment required and a lack of legacy integration further complicate the issue, resulting in carrier frustration and uncertainty in a scramble to support access demands by employing a complex mix of technologies. Both end users and new carriers perceive that there are no practical fiber-based access alternatives. Instead, they struggle within the finite limits of copper facilities to take LAN interconnection to ultrahigh speed levels.

Today's furious network growth is continuing to force carriers to reassess business plans, profitability, and the deployment strategies upon which they will shape future offerings to end users. The Telecommunications Act of 1996, which effectively opened these markets to all, spawned new enterprise-access competition, and increased pressure on all carriers to differentiate themselves in the marketplace. Competitive dimensions such as cost, quality of service (QoS), reconfigurability, and future capacity have all become defining aspects in the battle for customers.

Because deregulation has opened the door for new carriers to provide local service, the traditional economic models are also affected. Voice service revenue growth is relatively flat, and the margins are plummeting. While continuing to provide voice services is important for current cash flow, carriers must gravitate to higher-margin data services, multiservice architectures, and value-added applications in order to attract and retain customers and improve profitability. On the other hand, users need—and are, in fact, counting on—order-of-magnitude improvements in high-speed access capacity. They need new network extension technologies that are protocol, topology, and geography independent.

3. How Optical Access Fulfills the Need

Optical access platforms are designed to help new carriers leverage the current telecom market disruption for their own success. The market structure rewards products and solutions that have the inherent power to push optical networks beyond the domain of carrier backbones, providing fiber access for last-mile services—the crucial missing high-performance link in data networks.

This new era in managed optical access will be marked by carriers who gain the competitive advantage by providing high-speed architectures, which lift network performance above and beyond customers' ever-increasing data traffic requirements.

These new optical access solutions are designed to allow service providers to address these opportunities effectively. New equipment can bridge the gap between voice- and data-oriented architectures with bandwidth- and protocol-independent platforms. New bandwidth-allocation features enable carriers to support different protocols and optimize them for a particular application. By separately transmitting individual protocols, each on its own wavelength, the need for tunneling or protocol conversion is minimized. With these new features, carriers can remotely provision and upgrade bandwidth via software, rather than physically restructuring equipment. They can even allow customers to control how much bandwidth they add or remove from their network capacity.

4. Technology Workings

One of the challenges to be faced when structuring an optical access network is the very broad spectrum of potential applications and the multiplicity of solutions being developed to meet its needs. Various network topologies can be successfully used to meet the needs of high-speed networking: hub and spoke, multidrop, ring, and mesh. The possibility of intermixing access network technologies within the network further complicates the situation. In the end, the performance and suitability of any combination of network configuration and technology depends on the bandwidth and scalability required as well as the nature of the current network, including any legacy systems, economic factors, and future expansion plans.

The characteristics of optical access networking are as follows:

- High data rates (up to several Gbps) are being transmitted over distances that are relatively short. The majority of access network links will be less than 35 km in length, with many much shorter than that. In the minority of cases, where new service providers are building networks with relatively few PoPs in a geographic area, links may need to be as long as 70 km. However, this is unusual.

- The most effective use of optical fiber in an access network is to carry information directly on individual wavelengths. While SONET technology has been used in some cases, its optimization for voice traffic multiplexing imposes penalties on its use for data transmission. Many modern optical access networks now use SONET–less connections between enterprises (CPE) and service provider premises (PoP or CO), minimizing cost and complexity.

- Physical layer-optical access (Layer 1) allows any protocol or service to be carried over previously unlit fiber. Physical layer connectivity is the most effective method of unblocking the bandwidth bottleneck between CPE and the CO or PoP using dark fiber solutions. Physical-layer access must still accommodate certain essential network requirements: manageability, flexibility, and affordability. Optimally, physical-layer support can be used for speeds that range from a few Mbps (e.g., T1) to several Gbps (e.g., optical carrier [OC]–48), including fibre channel and Gigabit Ethernet.

- Support will be offered for both wavelength division multiplexing (WDM) and non–WDM links—with network economics determining which makes most sense for any given application.

- All nodes in a network will have some form of processing capability—although it is likely that intelligence will be distributed around the network. Ideally, the more complex functions may be concentrated at a central node (e.g., a hub in a hub-and-spoke network) where system management can be focused.

- The most successful marriage of bandwidth and optical access network technology will make use of an embedded communications channel with a management interface. In other words, management information will actually be carried within a wavelength, alongside high-speed data without a bandwidth penalty. Also, given the dominance of signaling network management protocol (SNMP) as a de facto management tool, it can be expected to be the protocol of choice—although, over time, other management protocols may be required and will need to be supported.

One of the most important aspects of the optical access network is its potential to provide not simply high bandwidth, but also a high QoS with corresponding performance monitoring to maintain that quality. Until now, SONET has traditionally been used to provide quality monitoring. Although its capabilities in this area are solid, they are also costly and cumbersome for data traffic. Other techniques, such as digital wrapper, make use of management bits, symbols, frames, packets, or cells wrapped around user data but inevitably incur a similar processing and cost penalty. Wrapperless techniques are beginning to emerge that offer the opportunity to manage link quality and performance measurement effectively, without the overhead of wrapper solutions.

These new solutions can not only provide service level management (service level agreements [SLAs]) economically, but also offer the use of 3R (versus 2R) techniques—retiming, regeneration, reshaping—for signal integrity in all channels in each direction and plug-and-play, high-quality network solutions.

5. Access Topologies and Applications

Various network topologies are used to meet the needs of high-speed traffic in the access network: hub and spoke, multidrop, ring, and mesh. In hub-and-spoke networks, data can be aggregated and sent point to point using either single-channel or multichannel techniques. Each method and its characteristics are presented here.

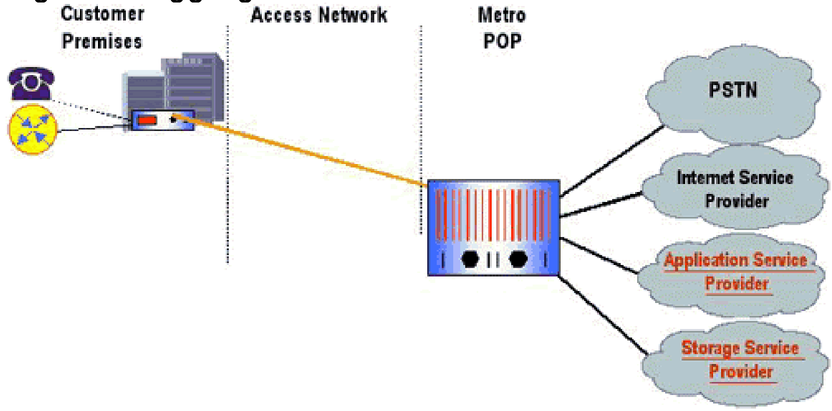
Aggregated Point to Point Using a Single Channel per Optical Fiber

- The cost of channel cards with interfaces to CPE or PoP/CO equipment can be reduced in the absence of WDM links (to which incremental cost is attached).

- Management costs can be reduced through such techniques as software-configured rates and management-initiated diagnostics.

- Where WDM can provide some benefit, either because of fiber conservation needs or because longer distances increase the cost of leasing fiber, wide WDM can be an option for single-fiber links.

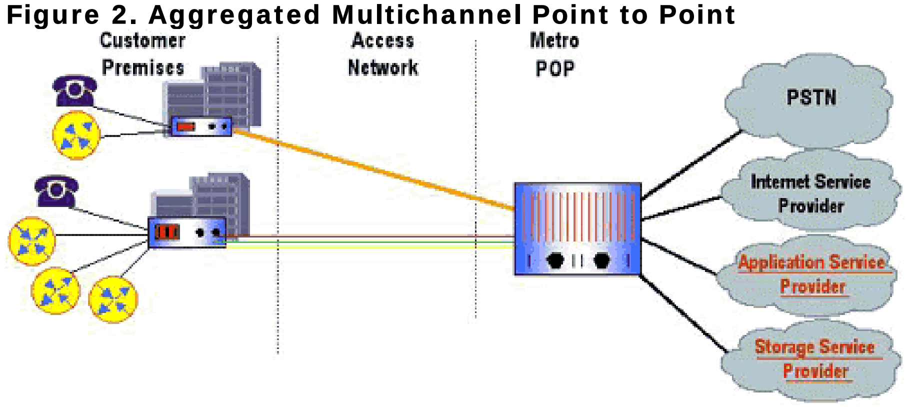
Figure 1. Aggregated Point to Point



Aggregated Multichannel Point to Point

- Coarse or wide WDM links reduce cost of optics and provide a perfectly satisfactory multichannel solution for access network links where high-density wavelength multiplexing is not required.
- It is highly likely that multichannel systems will be intermixed with single-channel, point-to-point links.

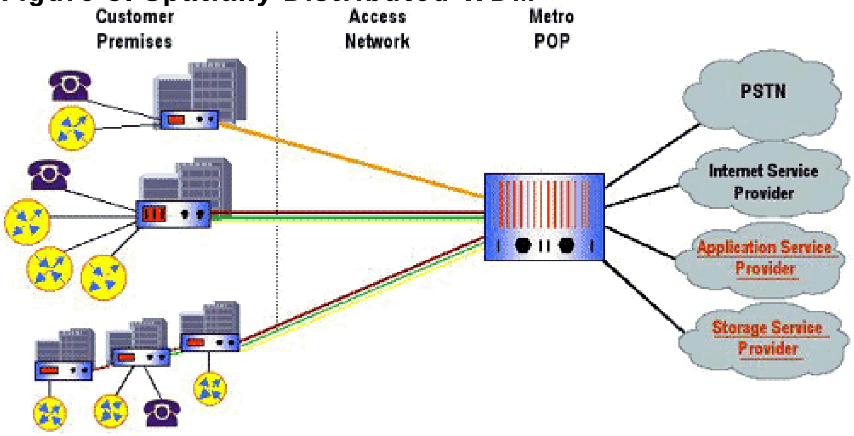
Figure 2. Aggregated Multichannel Point to Point



Spatially Distributed WDM

- This is most often evident in multidrop configurations.
- It is generally appropriate for campus and riser applications.

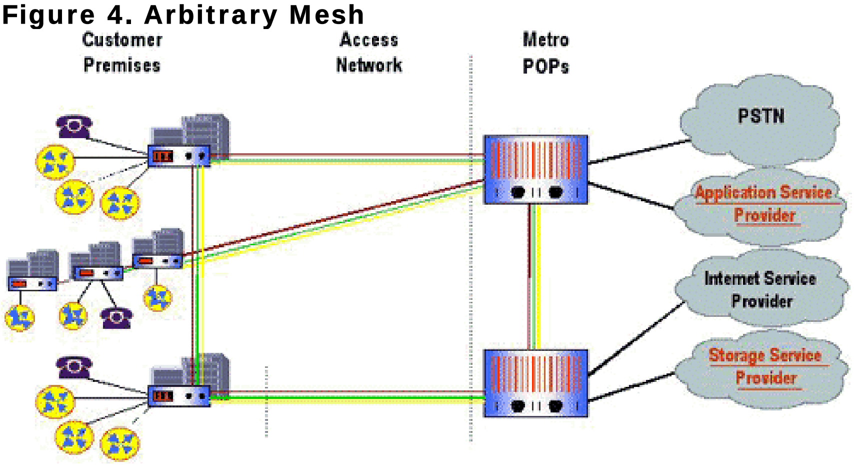
Figure 3. Spatially Distributed WDM



Arbitrary Mesh

- Inevitably, as requirements evolve, nodes in the access network will need to be linked, to connect segments of customer networks.
- Both WDM and non–WDM links will be required.
- While this stretches the meaning of "access" as defined here, it must be recognized that enterprise networking is designed to meet real customer needs—sometimes straying beyond the bounds of convenient technology definitions.

Figure 4. Arbitrary Mesh

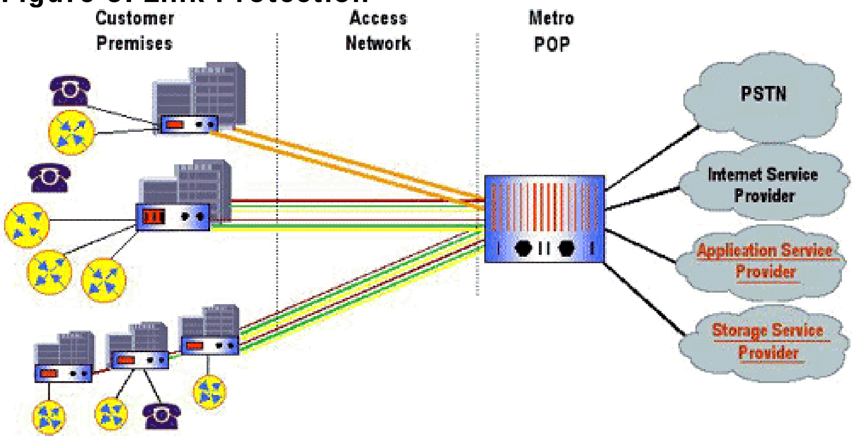


Link Protection

- Many practical network applications will require some form of redundancy or protection switching.

- The industry regards the ability to switch from one link to a backup within 50 ms as a de facto standard, even though for many data applications there is no firm basis for this figure. In practice, even shorter switching times are possible.

Figure 5. Link Protection



6. Optical Access Benefits

Networks using optical access offer superior performance in the form of manageability, flexibility, and—especially in the case of physical layer solutions—affordability. Physical layer optical access eliminates the need for protocol conversion, thus making the whole process simpler, more reliable, and more affordable.

Optical access managed either from the end user's equipment or from a central point at the physical layer can allow service providers to satisfy a number of enterprise network needs:

- Hand off traffic on a per-port basis.
- Deliver traffic to appropriate service clouds (e.g., IP, ATM, storage network, public switched telephone network [PSTN]).
- Provide optical link protection.

The flexibility of bandwidth- and protocol-independent technologies can help carriers bridge circuit-switched and packet-centric infrastructures, supporting both traditional voice services and high-speed data traffic. Carriers will save time and money by upgrading, not removing, their existing infrastructure to meet the unpredictable and quickly changing bandwidth demands of customers. In addition, because of significantly boosted end-user access capacity, service providers will have profitable new service packaging options, including applications hosting, storage networks, fiber channel extension, and Internet access for commerce servers.

7. Optical Access Summary

Optical access offers the following benefits:

- very high-data rates over short-to-medium distances (up to several Gigabits per second, including Gigabit Ethernet and fibre channel—up to 35 km in most cases, but up to 70 km under extreme conditions)
- SONET–less connection between enterprise (CPE) and service provider (PoP)
- wrapperless link performance measurement
- physical-layer support for T1 through OC–48
- support for WDM and non–WDM links

Optical access can unblock the access network bottleneck by accomplishing the following:

- managing optical access traffic from end users' equipment
- handing off traffic on a per-port basis
- delivering traffic to appropriate service clouds

Self-Test

1. The access network is that portion of the public switched network that connects access nodes to individual subscribers.

    a. true

    b. false

2. Fiber is actually a scarce resource.

    a. true

    b. false

3. The idea of using optical fiber to connect CPE to carrier facilities is a new one.

   a. true

   b. false

4. The most effective use of optical fiber in an access network is to carry information directly on individual wavelengths.

   a. true

   b. false

5. Which of the following is not one of the 3R techniques for signal integrity?

   a. retiming

   b. removal

   c. regeneration

   d. reshaping

6. Which of the following is most evident in multidrop configurations?

   a. aggregated multichannel point to point

   b. arbitrary mesh

   c. spatially distributed WDM

   d. aggregated point to point using a single channel

7. It is not very likely that multichannel systems will be intermixed with single-channel, point-to-point links.

   a. true

   b. false

8. Which of the following is generally appropriate for campus and riser applications?

   a. aggregated multichannel point to point

   b. arbitrary mesh

   c. spatially distributed WDM

d. aggregated point to point using a single channel

9. Which of the following is not characteristic of new optical access solutions?

   a. New equipment can bridge the gap between voice- and data-oriented architectures.

   b. The need for protocol conversion is minimized.

   c. Customers may control how much bandwidth they add or remove.

   d. Carriers physically restructure equipment.

10. Both WDM and non–WDM links will be required for arbitrary mesh topologies.

   a. true

   b. false

Correct Answers

1. The access network is that portion of the public switched network that connects access nodes to individual subscribers.

   a. true

   b. false

   See Definition.

2. Fiber is actually a scarce resource.

   a. true

   b. false

   See Overview.

3. The idea of using optical fiber to connect CPE to carrier facilities is a new one.

   a. true

   b. false

   See Topic 1.

4. The most effective use of optical fiber in an access network is to carry information directly on individual wavelengths.

   a. true

   b. false

   See Topic 3.

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   See Topic 3.

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   See Topic 5.

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   b. The need for protocol conversion is minimized.

   c. Customers may control how much bandwidth they add or remove.

   d. Carriers physically restructure equipment.

   See Topic 4.

10. Both WDM and non–WDM links will be required for arbitrary mesh topologies.

    a. true

    b. false

    See Topic 4.

Glossary

ASP
application service providers

ATM
asynchronous transfer mode

CLEC
competitive local exchange carrier

CO
central office

CPE
customer premises equipment

Dark Fiber
optical fiber that has been buried or deployed, but does not currently transport traffic; this fiber is considered "dark" or "unlit"

DSL
digital subscriber line

Gbps
Gigabits per second

ILEC
incumbent local exchange carrier

IP
Internet protocol

ISX
Internet service exchange

LAN
local-area network

OC
optical carrier

PoP
point of presence

PSTN
public switched telephone network

QoS
quality of service

SLA
service-level agreement

SNMP
signaling network management protocol

SONET
synchronous optical network

WDM
wavelength division multiplexing