# Internet Access

## Definition

Internet service is expanding rapidly. The demands it has placed upon the public network, especially the access network, are great. However, technological advances promise big increases in access speeds, enabling public networks to play a major role in delivering new and improved telecommunications services and applications to consumers.

## Overview

In today's environment, twisted-pair access using voiceband data modems is the norm for residential and small business users. With new technologies, speeds of 500 kbps, 1.5 Mbps, or even 10 Mbps are promised for residential users.
How will access systems evolve to provide such capabilities ubiquitously? This tutorial describes existing and emerging access technologies used to provide Internet access for residential and business applications.

## Topics

1. Where Is Access in the Network?
2. Access Evolution Drivers
3. Overview of Access Alternatives
4. Twisted-Pair Solutions
5. Twisted-Pair Access—Remote
6. Fiber and Coax
7. Wireless
8. All Fiber—PON
9. All Fiber—SONET
10. Conclusion

Self-Test

Correct Answers

Glossary

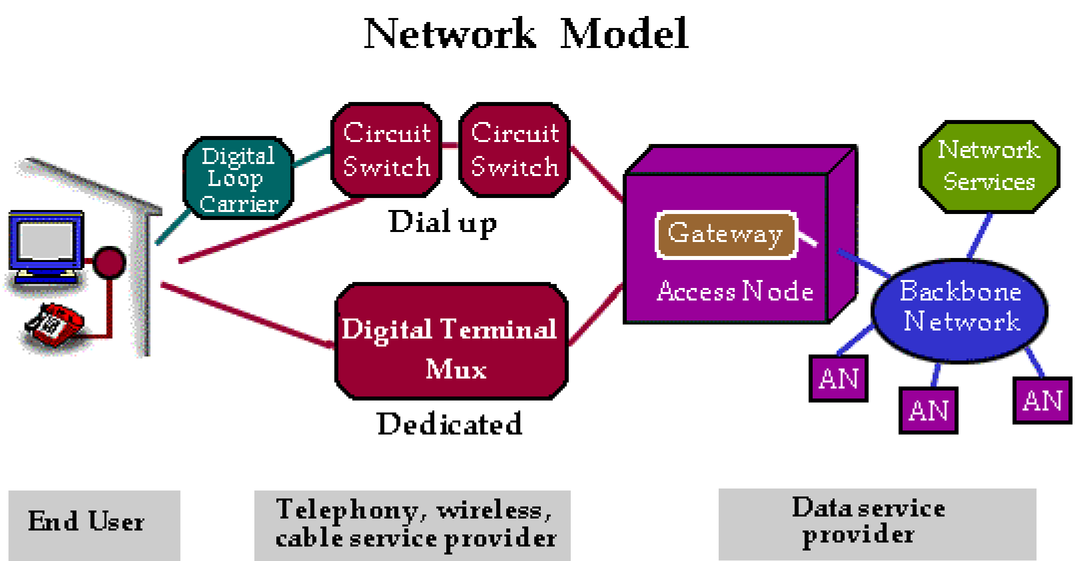
# 1. Where Is Access in the Network?

Internet access has different meanings to different people. In this section, the concept of access will be explained for consistency within this tutorial.

*Figure 1* delineates three major entities in the provision of Internet service:

- end users who want to have Internet service as well as other services, such as telephony or cable TV
- data service providers who want to supply Internet access, content services (like AOL), or other data services, such as virtual private networking
- telephony, wireless, and cable service providers who want to provide connectivity between end users and data-service providers

**Figure 1. Network Model**




Note that, at times, the last two entities are combined. For example, several companies such as MCI, AT&T, or Pacific Bell provide both telephony and Internet access.

Now to the question: "What is access?" To the telephony, wireless, or cable service provider, access is the network connection from the end user's home or business to the outside-plant termination point within the service node. In traditional telephony architecture, this is most commonly thought of as the twisted-pair, cross-connect point and is referred to as the main distribution frame (MDF). The remainder of the telephony's provider's network would be referred to as the switching and transport network.

In contradistinction, an Internet service provider (ISP) views access as the connection from its customer to its network. Here, access is the connection from the end-user's home or business to the gateway-access node belonging to the ISP. Thus, to the ISP, the telephony's access, switching, and transport network is all part of access.

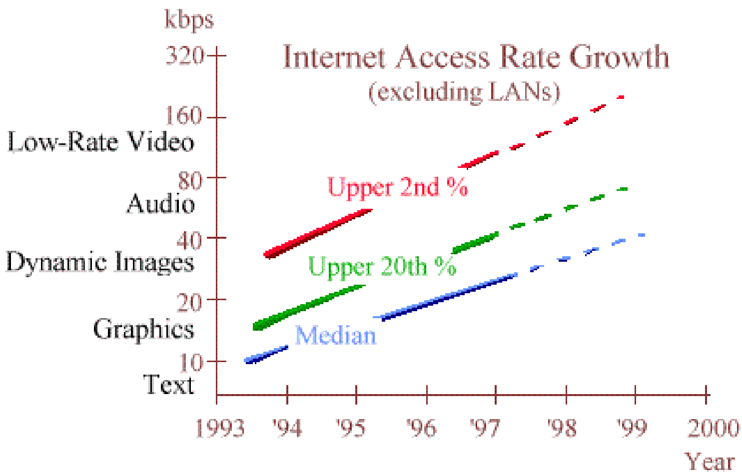
Within this tutorial, the telephony, wireless, and cable service provider's view of access is the focus of our discussion of new and emerging technologies.

## 2. Access Evolution Drivers

Access evolution is being driven primarily by strong demands for increasing bandwidth to support a growing variety of user services. Prior to 1994, traffic sent over the Internet was largely text-based information with file transfer and e-mail being among the most popular services. The surge in growth of the Internet during 1995 was in part due to the graphical nature of the World Wide Web (WWW). A significant aspect of this shift is that graphical images generally consist of a large number of bits. To transfer large graphical image files quickly with satisfactory performance meant that higher-speed access technologies were needed than those used to deliver relatively small text files. The WWW also became the base for nurturing other capabilities such as animated graphics, audio, and low-rate video. Each of these capabilities have been pushing the need for increasingly higher-speed access.

*Figure 2* is an example of the data rates needed to support various user services and the access rates that have become available over time. (The chart represents average user rates, not peak burst rates on shared media.) The chart shows curves for three segments of the user population: the median, the upper twentieth percentile, and the upper second percentile early adopters. Users are eager for audio and video services, so the challenge is for access systems to meet that demand.

**Figure 2. Internet Access Rate Growth**



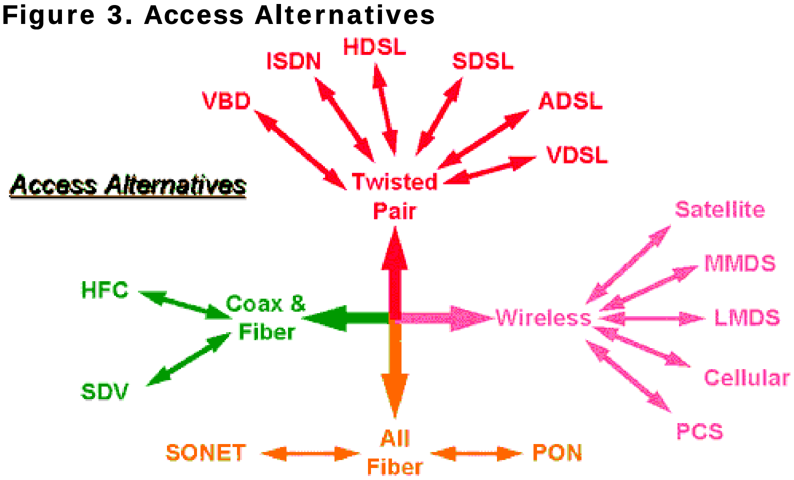

# 3. An Overview of Access Alternatives

Internet-access technologies fit into four broad categories:

- twisted pair
- fiber/coax
- wireless
- all fiber

As shown in *Figure 3*, several technologies and implementations exist within each of these broad categories.

**Figure 3. Access Alternatives**



Twisted-pair telephone lines are the access media used by the vast majority of individual residential subscribers today. Over time, a number of technologies have been introduced to provide faster data speeds over this medium.

Fiber/coax systems were originally introduced for video-broadcast applications. Because these systems are inherently broadband, techniques have been developed to use this advantage to provide high-speed data transmission, principally for residential Internet access.

Wireless Internet access has two origins: satellite systems established for broadcast video have the ability to distribute Internet data at high speeds, and cellular/personal communications service (PCS) systems are designed to serve mobile users.

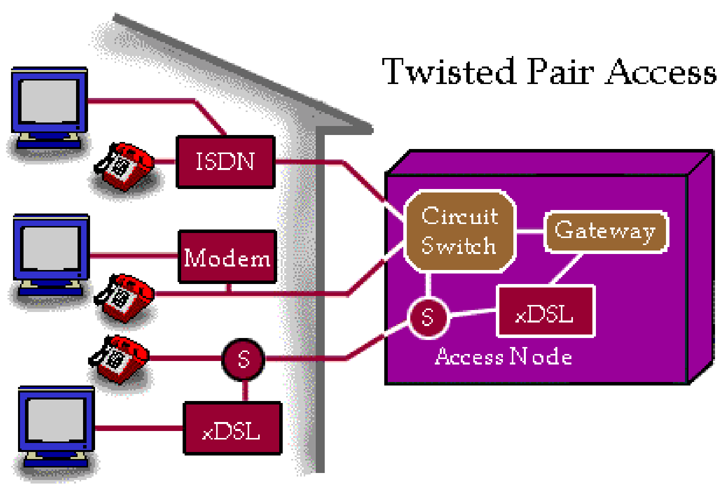
The predominant access systems for business users are optical-fiber synchronous optical network (SONET) and synchronous digital hierarchy (SDH) systems. In the future, passive optical network (PON) systems are expected to become an all-fiber access medium for residential users as well.

# 4. Twisted-Pair Solutions

There are three major categories of twisted-pair solutions that are being used for Internet access (see *Figure 4*):

- voiceband data (VBD) modems
- ISDN digital subscriber line (DSL)
- other DSL approaches (xDSL)

**Figure 4. VBD and ISDN**



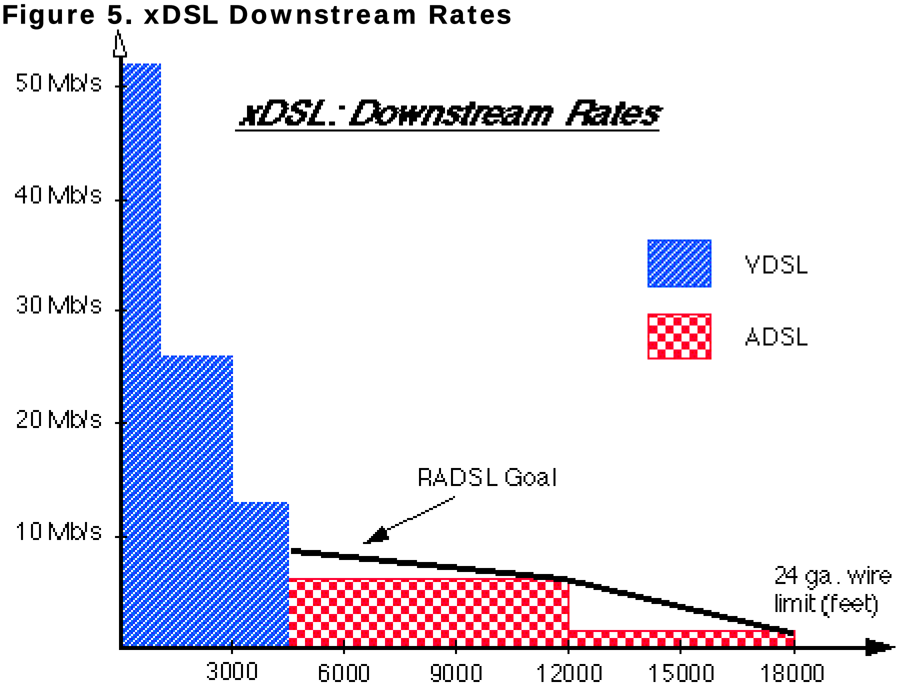
VBD modems are well known and understood by residential and small-business users. They operate by using the voice-frequency band of the twisted-pair facility to transmit data, using frequency shift keying (FSK) or quadrature amplitude modulation (QAM) transmission techniques. Symmetric rates exist up to 33.6 kbps, with the majority running at 14.4 and 28.8 kbps. Emerging is an asymmetric capability with a nominal server rate of 56 kbps and return-path rate operating up to 33.6 kbps.

Integrated services digital network (ISDN) is a digital baseband technology that operates with a 144–kbps bidirectional payload rate using 2B1Q encoding scheme. The 144–kbps rate is divided into two 64–kbps (B) channels and one 16–kbps (D) channel. The B channels can be used for two separate voice calls, two 64–kbps data calls, a separate voice and data call, or a combined 128–kbps data call. The wire limit for ISDN is 18,000 feet on standard twisted pair.

## xDSL Technologies

A variety of xDSL rates and technologies have been standardized, or are in the process of standardization, by American National Standards Institute (ANSI) and the Asymmetric Digital Subscriber Line (ADSL) Forum. As *Figure 5* shows, the higher rates are for customers that are a short distance away from the network provider's xDSL modem. This modem may be located either in a central office (CO) or at a remote terminal site closer to many end users.

**Figure 5. xDSL Downstream Rates**



## ADSL

ADSL is one of several types of xDSL technologies. ADSL has two main standards: ADSL–1 specifies a downstream rate of 1.5 or 2 Mbps and an upstream rate of 16 to 64 kbps; ADSL–3 specifies a downstream rate of up to 6.144 Mbps and a bidirectional channel of up to 640 kbps.

Good twisted-pair lines with no bridged taps can support ADSL–1 rates up to 18,000 feet (24-gauge wire), and ADSL–3 up to 12,000 feet.

ANSI and the ADSL Forum have endorsed discrete multitone (DMT) technology. However, carrierless amplitude and phase (CAP) technology has the most market-share thus far, with 30 times as many ADSL lines using CAP. DMT and CAP modems are incompatible, but the issue is not nearly as great as with VBD modems. VBD modems must be compatible end-to-end, from end user to end user. But ADSL modems only operate over the end user's twisted pair, from end user to network provider.

## VDSL

Very-high-speed DSL (VDSL) promises even higher speeds than ADSL, although over much shorter distances. Standardization is underway in four different standards bodies: ANSI, the ADSL Forum, the ATM Forum, and the Digital Audio-Visual Council (DAVIC). There are four different technologies proposed (CAP, DMT, DWMT, and subscriber line charge [SLC]), aiming at a goal of lower power and less cost than ADSL.

## RADSL

As the name implies, rate-adaptive DSL (RADSL) modems adjust the data rate to match the quality of the twisted-pair connection. Emerging software should make this an automated process with little human intervention.

## HDSL and SDSL

High-data-rate DSL (HDSL) modems transmit 1.5 Mbps in each direction. Two twisted pairs of wires are used, with half of the traffic on each pair. A 2.0–Mbps transmission rate is also available, using three pairs of wires (one-third of the traffic on each pair). The wire limit is 12,000 feet (24 ga.) or 9000 feet (26 ga.)

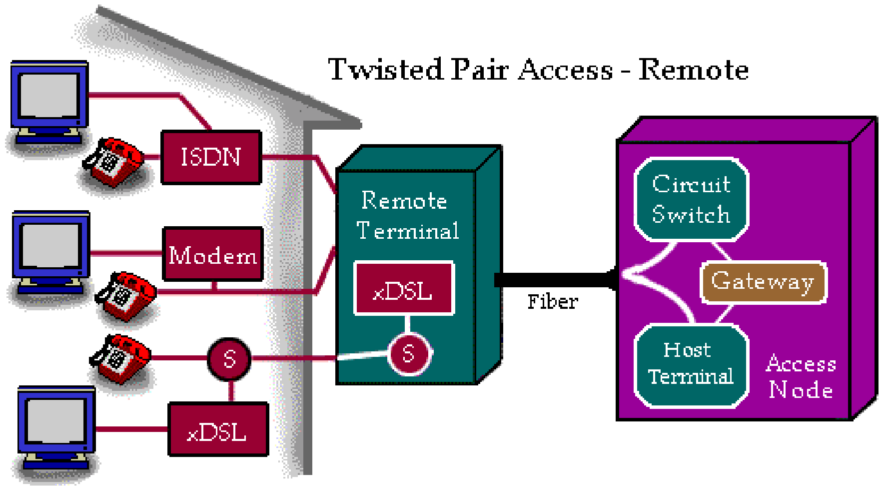
Symmetrical digital subscriber line (SDSL) is similar to HDSL but requires only one pair of wires. Transmission speed ranges from n x 64 kbps to 2.0 Mbps in both directions.

HDSL and SDSL are intended as lower-cost replacements for dedicated T1 and fractional–T1 lines, rather than for residential access.

# 5. Twisted-Pair Access—Remote

The three major twisted-pair categories discussed under "twisted-pair access" can all be remoted, as is shown in *Figure 6*.

**Figure 6. Twisted-Pair Access—Remote**



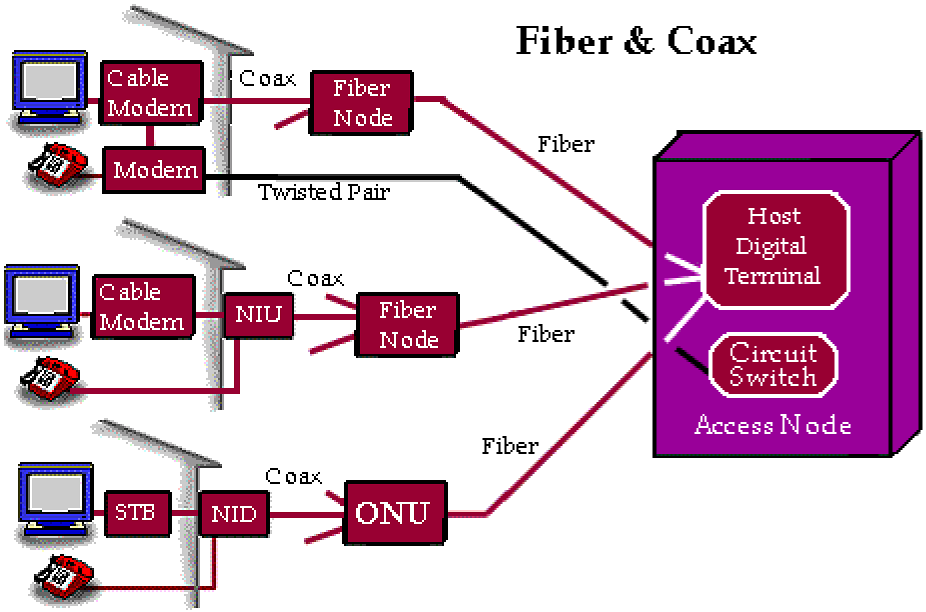

Remoting mechanisms, such as digital loop–carrier systems, enable fiber migration into loop-access plant. They are a cost-effective way of bringing service to end users who are not located near access nodes. As shown in the *Figure 6*, services are ultimately provided to end users over twisted pairs from remote terminals that connect via fiber facilities to the serving node.

As *Figure 6* illustrates, remote systems can be terminated in two ways. One is a termination directly into a circuit switch; this is called the integrated access approach. The second approach has a host digital-terminal termination in the service node; this called the universal access approach. Both integrated and universal remote-access arrangements are used to provide Internet access. The choice of approach in any specific case depends on the embedded network and on the capabilities that must be provided to end users in addition to Internet access.

# 6. Fiber and Coax

There are three significant categories of combined cable and fiber systems used for Internet access. According to *Figure 7*, they are as follows:

**Figure 7. Fiber and Coax**




## Cable TV Hybrid Fiber/Coax (HFC) System (Top)

Traditional systems have only downstream broadcast capability. These traditional cable–TV systems broadcast downstream in the 50- to 550/750-MHz band with 6-MHz channels.

Cable modems are used to allow Internet and data transmission in the downstream direction of the HFC system. Internet data speeds up to the 30–Mbps range can be realized in a nominal 6-MHz video channel. The upstream signal is provided by an existing telephone channel using VBD or ISDN.

## Bidirectional HFC system (Middle)

These newer systems have transmission capability in both directions. Such bidirectional cable–TV systems typically broadcast downstream in the 50- to 750-MHz bandwidth of the coax within the 6-MHz nominal video channels. The upstream bandwidth is shared among all the homes passed by the coax cable and is nominally limited to the 5- to 40-MHz frequency band.

Downstream Internet data speeds up to the 30–Mbps range in 6-MHz channels can be realized. Upstream data is contention based and operates at claimed speeds of up to 10 Mbps. In practical multiuser environments, however, actual throughput speeds will be significantly less.

Cable modems can either be overlaid onto the HFC system or be an integrated part of the HFC system.

## Switched Digital Broadband (SDB) Systems (Bottom)

SDB is classified as a baseband digital system with nominal 50–Mbps point-to-point downstream rates that can be apportioned as desired between digital video and data. For data, a 1.5–Mbps nominal, contention-based, upstream data bandwidth is available. Though the system is contention based, there is always a minimum guaranteed upstream data rate available—typically in the order of 16 kbps.

The three architectures described all have provisions for both analog and digital video broadcast capability.

Both the bidirectional HFC and SDB systems are broadband systems that are applicable to telephony, video, Internet/data, and PCS wireline access. Note that the architectures have a number of similar characteristics and components. The bidirectional HFC system provides fiber distribution to the fiber node. At the fiber node, signals are collected and distributed to multiple-coax feeds that cover a given residential area. Fiber nodes are designed to serve from 500 to 2000 homes.

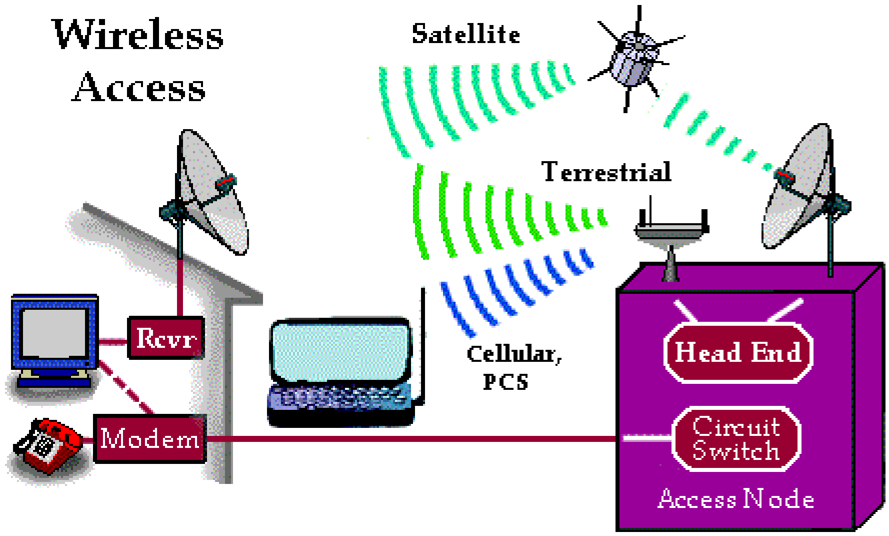
SDB systems push fiber closer to the end-user. In typical systems, feeder fiber can be optically split. Optical network units (ONUs) terminate the fiber and provide individual coax (and twisted-pair) drops to subscribers. A typical ONU can serve from 4 to 60 homes. Thus, SDB provides fiber closer to the customer.

In many ways, HFC, SDB, and PON (discussed shortly) can be viewed as a continuum of technology where fiber moves ever closer to the customer premises.

# 7. Wireless

As *Figure 8* illustrates, three means are used to provide Internet access using wireless technology: satellite broadcast, terrestrial broadcast, and cellular/PCS.

**Figure 8. Wireless Access**




## Cellular

Internet access can be provided via existing cellular systems using voiceband modems. Because cellular channels are narrowband, access rates are limited to 9.6 kbps for advanced mobile phone service (AMPS) and time division multiple access (TDMA) systems and to 14.4 kbps for code division multiple access (CDMA) systems. Cellular digital packet data (CDPD) is a technique that enables the data rate of AMPS to be extended to 19.2 kbps. CDPD achieves the higher rate by inserting Internet protocol (IP) packets directly into cellular channels that do not contain voice traffic (i.e., channels that are temporarily idle).

Techniques are being investigated to provide Internet access and other data services using personal communications services (PCS). PCS data standards are being investigated by a joint technical committee of ANSI T1 and the Telecommunications Industry Association (TIA), the International Telecommunication Union–Telecommunications Standardization Sector (ITU–T), and others.

## Terrestrial Broadcast

The multichannel multipoint distribution service (MMDS), sometimes called "wireless cable," can provide Internet-access downlinks over a distance of about 50 km from a central-transmitter site. MMDS downlinks combined with telephony uplinks provide a complete Internet-access arrangement. MMDS operates in the 2-GHz frequency band with 33 channels, each capable of supporting downlink data rates that are currently about 10 Mbps. Technology improvements are expected to increase data rates to 27 Mbps in the future.

Local multipoint distribution service (LMDS) is similar to microwave multipoint distribution service (MMDS) in that it will use microwave transmission to provide Internet-access downlinks and wireline telephony to provide uplink access. LMDS will use transmitters operating in the 28-GHz frequency band with each transmitter covering a distance of about 5 km. The relatively close transmitter spacing, coupled with the fact that LMDS will have about four times the bandwidth of MMDS, should enable LMDS to serve a much higher density of Internet users than MMDS.

## Satellite Broadcast

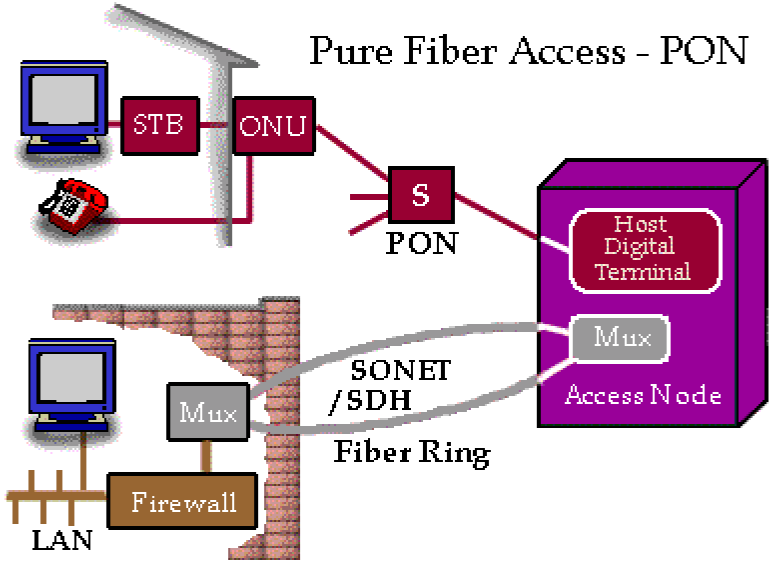
Several approaches have been proposed for using satellites to provide Internet-access downlinks. Some proposals are based on using a single fixed-position satellite, whereas others would use clusters of satellites. Proposed data rates vary from low-speed, single-user channels to shared channels with rates greater than one Mbps.

The first widely available system operates in the 12-GHz band and uses a data rate of 400 kbps. Equipment at the end-user location consists of a dish antenna, approximately 52 cm in diameter, a microwave receiver, and a digital decoder card that plugs directly into a PC computer bus. Satellite systems also use telephony circuits for uplink access.

# 8. All Fiber—PON

This all-fiber access system called a PON is intended for residential applications for Internet and other services access. The architecture shown in the top of *Figure 9* has fiber from the service node to the optical splitter. At the splitter, multiple fibers fan out to terminate on a single-home ONU. The ONU then splits out to provide individual service to the home. There are many schemes for technical realization of PONs, the more interesting one consists of wave division multiplexing (WDM) for up to 16 ONU drops from the optical splitter. WDM techniques would again be used in the upstream direction to realize a highly secure point-to-point PON architecture.

**Figure 9. Pure Fiber Access—PON**




As it is all fiber, PON has many advantages. All fiber yields a robust outside plant that has low maintenance costs associated with it. All fiber point-to-point architecture allows for secure transmissions and broadband service applications.

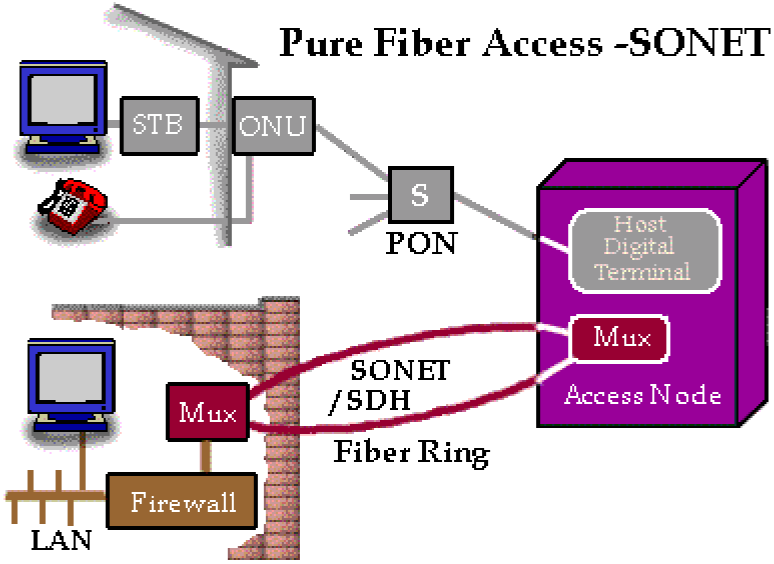
The PON architecture represents the target wireline architecture because of its versatility and evolution-proof capabilities. However, initial costs of PON systems are still higher than most all of the other alternatives discussed within this tutorial.

# 9. All Fiber—SONET

All-fiber access systems consisting of SONET or SDH fiber rings are commonly used to provide high-capacity, multiservices (including Internet) access to and from campus and business locations. SONET is a North American–based standard for such an architecture with interface rates from 1.544 Mbps (DS–1) to 10 Gbps (OC–192). Similarly, SDH is the European-based standard for equipment with similar capabilities.

The bottom portion of *Figure 10* shows a SONET/SDH connection from a service node to a business. The SONET/SDH ring provides service assurance via path-diversity ring architecture. In a campus environment, the ring could be extended through the various buildings that make up the campus.

**Figure 10. Pure Fiber Access—SONET**




On the customer premises, the customer's intranet, depicted by the local-area network (LAN), is connected to the public network via a firewall. The firewall provides data and security protection for the business. Firewalls provide security by isolating undesired Internet traffic from the traffic that is carried on intranet LANs. Multiplexers (Mux) provide transport efficiency by combining separate data streams onto a single fiber-optic facility. Synchronous transfer mode (STM) multiplexers widely deployed in telecommunications networks carry data streams within discrete tributaries. Asynchronous transfer mode (ATM) multiplexers can provide more interface-rate granularity because individual user data streams are concatenated into a single high-speed cell stream for transport within the network. In addition, ATM multiplexers can provide further efficiency by combining variable-rate data streams using statistical multiplexing.

# 10. Conclusion

All Internet end users want access systems to provide increasingly higher speeds at a reasonable cost. Many users also want their Internet access to be closely coupled with the means they use to access other services. What are the challenges to measure against in meeting these needs of Internet users?

As described in this paper, the first challenge—the technology challenge—has been met vigorously by ingenious network providers and equipment vendors who have created a wide variety of high-speed access systems.

The second challenge is cost. New technology is usually costly, and the difficult challenge of meeting cost targets can take longer than access providers and end users wish. Today, the lag from technology creation to economic prove-in is the throttle regulating the pace at which emerging high-speed technologies gain widespread acceptance.

As access providers conquer the first two challenges and become successful in providing low-cost, high-speed access systems, it is already clear that new challenges will arise. For example, some access systems achieve high peak burst rates by sharing broadband-access media among many users. Eventually, all systems may find it beneficial to use shared links in portions of the access network. Shared systems have different network-engineering considerations from individual circuit-based systems, so we can expect shared systems to spawn new network engineering challenges for dealing with congestion, quality of service (QoS), and other performance criteria.

Finally, there are challenges in meeting the needs of users who see benefits in having Internet access combined with access to other services such as entertainment video and work-at-home intranets. Solutions such as virtual networks are being considered to address these needs, and access is an important enabler of these multiservice, multimedia solutions.

# Self-Test

1. HFC is a(n) _____________ technology.

    a. twisted-pair

    b. wireless

    c. coax and fiber

    d. all fiber

2. LMDS is a(n) ________________ technology.

    a. twisted-pair

    b. wireless

    c. coax and fiber

    d. all fiber

3. SONET is a(n) ________________ technology.

    a. twisted-pair

    b. wireless

c. coax and fiber

d. all fiber

4. ISDN is a(n) _______________ technology.

a. twisted-pair

b. wireless

c. coax and fiber

d. all fiber

5. Fiber/coax systems are the access media used by the vast majority of individual residential users.

a. true

b. false

6. The earliest Internet traffic was primarily text-based traffic.

a. true

b. false

7. Wireless Internet has two origins: satellite systems and cellular.

a. true

b. false

8. The predominant access system for business users is twisted pair.

a. true

b. false

9. Currently, VBD modems run primarily at 144 kbps.

a. true

b. false

10. XDSL modems offer higher rates but only for customers who are relatively close to a provider's xDSL modem.

a. true

b. false

11. ISDN operates with a _______________ connection speed.

a. 33.6–kbps

b. 16–kbps

c. 14.4–kbps

d. 128–kbps

12. How many main standards does ADSL have?

a. 1

b. 2

c. 3

d. 4

13. How far can good twisted-pair lines support ADSL–1 rates?

a. 6,000 ft

b. 12,000 ft

c. 18,000 ft

d. 24,000 ft

14. Currently, PCS is _______________ of providing Internet access.

a. capable

b. not capable

15. Internet access via microwave transmission is _________________ by MMDS and LMDS.

a. provided

b. not provided

16. The initial costs associated with the deployment of the passive optical network _______________.

    a. are high

    b. are low

17. PON systems are primarily designed to provide ___________ services.

    a. residential

    b. corporate

18. The European-based standard for all-fiber access systems is ______________.

    a. SDH

    b. ADH

19. Which transfer mode multiplexers combine individual data streams into a single high-speed cell stream?

    a. synchronous

    b. asynchronous

20. Which transfer mode multiplexers carry data streams within discrete tributaries?

    a. synchronous

    b. asynchronous

# Correct Answers

1. HFC is a(n) ____________technology.

    a. twisted-pair

    b. wireless

    **c. coax and fiber**

    d. all fiber

    See Topic 6.

2. LMDS is a(n) ________________ technology.

   a. twisted-pair

   **b. wireless**

   c. coax and fiber

   d. all fiber

   See Topic 7.

3. SONET is a(n) ________________ technology.

   a. twisted-pair

   b. wireless

   c. coax and fiber

   **d. all fiber**

   See Topic 8.

4. ISDN is a(n) _______________ technology.

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   b. wireless

   c. coax and fiber

   d. all fiber

   See Topic 4.

5. Fiber/coax systems are the access media used by the vast majority of individual residential users.

   a. true

   **b. false**

   See Topic 3.

6. The earliest Internet traffic was primarily text-based traffic.

   **a. true**

b. false

See Topic 2.

7. Wireless Internet has two origins: satellite systems and cellular.

   **a. true**

   b. false

   See Topic 3.

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   **b. false**

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    **a. residential**

    b. corporate

    See Topics 8 and 9.

18. The European-based standard for all-fiber access systems is ______________.

    **a. SDH**

    b. ADH

    See Topic 9.

19. Which transfer mode multiplexers combine individual data streams into a single high-speed cell stream?

    a. synchronous

    **b. asynchronous**

    See Topic 9.

20. Which transfer mode multiplexers carry data streams within discrete tributaries?

    **a. synchronous**

    b. asynchronous

    See Topic 9.

# Glossary

**2B1Q**
2 binary 1 quaternary

**ADSL**
asymmetric digital subscriber line

**AMPS**
advanced mobile phone service

**AN**
access node

**ANSI**
American National Standards Institute

**ATM**
asynchronous transfer mode

**CAP**
carrierless amplitude and phase modulation

**CDMA**
code division multiple access

**CDPD**
cellular digital packet data

**DMT**
discrete multitone

**DSL**
digital subscriber line

**DWMT**
discrete wavelet multitone

**FSK**
frequency shift keying

**FTTC**
fiber-to-the-curb

**HDSL**
high-bit-rate digital subscriber line

**HDT**
host digital terminal

**HFC**
hybrid fiber/coax

**ISDN**
integrated services digital network

**ISP**
Internet service provider

**LAN**
local-area network

**LMDS**
local multipoint distribution service

**MDF**
main distribution frame

**MMDS**
multichannel multipoint distribution service

**NID**
network interface device

**NIU**
network interface unit

**ONU**
optical network unit

**PCS**
personal communications service

**PON**
passive optical network

**QAM**
quadrature smplitude modulation

**RADSL**
rate adaptive digital subscriber line

**S**
splitter

**SDB**
switched digital broadband

**SDH**
synchronous digital hierarchy

**SDSL**
symmetrical digital subscriber line

**SLC**
simple line code

**SMDS**
switched multimegabit data service

**SONET**
synchronous optical network

**STB**
set-top box

**STM**
synchronous transfer mode

**TDMA**
time division multiple access

**TIA**
Telecommunications Industry Association

**VBD**
voiceband data

**VDSL**
very-high-speed digital subscriber line

**WWW**
World Wide Web