Access Strategies for Communication Service Providers

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In this era of competition among communication service providers, in order to provide all the services their customers need, service providers must have an end-to-end strategy for delivering services. The core of their strategy lies in their network infrastructure. Service providers must position their networks in such a way that they can provide all the services customers need in a cost-effective way. This positioning is very critical to success in a competitive environment. Many components are required to make up a network infrastructure that is capable of providing a wide range of services.

This article addresses an important component of the network—access to the customer—which is currently the bottleneck in providing a wide range of services in a cost-effective way. For this reason, a broadband access architecture that is capable of providing both broadband and narrowband services is outlined for each of the various service providers. The various access options will be discussed, along with a potential strategy for each of the service providers.

The rapidly-changing and expanding communication market will bring about many opportunities for service providers. Many initiatives related to new access technologies and architectures are currently underway, and it is certain that some will be deployed for the mass market in the future. These new access technologies will change the way that service providers such as cable companies, telephone companies (local and long distance), and others do business. No one is exactly sure which path these service providers will take, yet many providers are pursuing new technologies and architectures with the hope of expanding their service offerings. Some have chosen a specific path, while others are hedging their bets by testing several new technologies and architectures while they wait to determine what the optimal path will be.

Service providers are basically looking for end-to-end network architectures capable of handling all the services of today *and* tomorrow. Of the various segments that make up the network, customer access is the only segment currently not capable of offering all the required services—narrowband as well as broadband. The current network infrastructure can provide narrowband but not broadband services to the customer. Thus, this article outlines a broadband access architecture for each of the various service providers that is capable of providing broadband and narrowband services. The broadband architectures discussed here are:

- Hybrid fiber/coax (HFC).
- Fiber to the curb (FTTC).
- Fiber to the home (FTTH).
- Passive optical network (PON).
- Multichannel multipoint distribution service (MMDS).
- Local multipoint distribution service (LMDS).

- Integrated digital loop carrier (IDLC).
- Integrated Services Digital Network (ISDN).
- Next-generation digital subscriber line (xDSL) which includes ADSL (asymmetrical digital subscriber line), BDSL (broadband digital subscriber line), SDSL (symmetrical digital subscriber line), and VDSL (very high-speed digital subscriber line).
- DBS (direct broadcast satellite).

There are many issues related to the deployment of these architectures by service providers, and it is important to understand these issues before making any decision. Also crucial is an understanding of how the architectures and technologies work together. Some architecture implementations may use all of the technologies, while others may not.

Naturally, the costs associated with implementing and using broadband architectures and technologies are of great interest to all parties. Implementation costs vary widely depending on such factors as technology, technology maturity, and re-use of existing network components. Service providers must plan carefully to ensure that implementation costs can be recovered by providing enhanced services, and by achieving operational savings within an acceptable period of time.

Finally, differences between types of architectures need to be understood for an appreciation of the way in which each is best utilized. Once the major differences between different types of architecture are understood, issues related to their deployment need to be evaluated before planning a strategy using the technologies.

Access Technologies

Many access technologies are currently being considered to provide integrated voice, data, and video services. Service providers must select the appropriate access technology that fits their existing network and planned service strategy for both the short and long term. Following is background on some of the potential architecture and access technologies, along with potential strategies that service providers can pursue with respect to each of these technologies.

xDSL

Next-generation digital subscriber line (xDSL) technology enables telephone operating companies with existing twisted-pair loops to offer single/multiple video channels or high-speed data (symmetrical and asymmetrical bandwidth) along with telephone service. Since xDSL uses existing twisted-pair loops currently deployed around the world, it is easy to rapidly implement new services, such as high-speed data access and multimedia services. For instance, in the United States, there are currently 157 million telephone lines using twisted-pair loops. Of these, about 70% are within 18,000 feet of the central office and are therefore potential xDSL candidates. This shows the potential worldwide opportunity for this technology because twisted-pair is deployed around the world. The first generation was ADSL, which provided a one-way 1.5 Mb/s wideband channel designed to deliver a compressed digital NTSC VCR-quality video signal to subscribers up to 18,000 feet. In addition, it carried a full-duplex 16 Kb/s control/data channel that would allow the subscriber to control the video signal and a full-duplex baseband channel used for POTS or ISDN service.

The second generation, called VDSL/BDSL, is capable of transmitting higher bandwidth video or data services downstream. It has been demonstrated[1] that ADSL can provide 3 Mb/s to 10 Mb/s bandwidth for up to 12,000 feet. In BDSL, the bandwidth can be increased to 25 Mb/s if the loop length is 3,000 feet and 52 Mb/s if the loop length is 1,000 feet. Table 1, based on 1983 survey data, shows the potential in the United States for deployment of xDSL technologies. With twisted-pair deployed around the world, the potential opportunity for this technology is unlimited.

Other types of digital subscriber loop technologies are HDSL, SDSL, and VDSL, which provide variations of ADSL such as symmetrical and variable asymmetrical bandwidth-based services. They use the same or

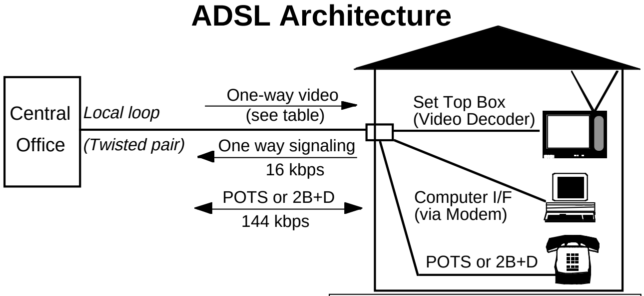
Table 1
LEC Loop Plant Distribution

	1983 Survey
Residential	63% of loop is </= 12 kft 53% of loop is </= 10 kft 15% of loop is </= 3 kft 5% of loop is </= 1 kft
Business	75% of loop is </= 12 kft 60% of loop is </= 10 kft 33% of loop is </= 3 kft 10% of loop is </= 1 kft

Source: BOC Notes on the LEC Network (1990) modified encoding schemes such as CAP-16, QAM, or 2B1Q to meet the quality of service. Of these different xDSL versions, ADSL and BDSL are more suitable for Internet type applications that require high bandwidth downstream and low return channel bandwidth.

All of the xDSL technologies are designed for point-to-point applications. Thus, they are designed for switched architectures such as the ones used by telephone operating companies. Figure 1 shows the ADSL architecture in a typical LEC environment.

Figure 1
ADSL Architecture



One-way Video			
Technology	Coding	Capacity	Loop length
ADSL 1	MPEG1	1.5 Mbps	18 kft
ADSL 2	MPEG2	3-10 Mbps	10 kft
BDSL	MPEG2	25 Mbps	3 kft
BDSL	MPEG2	52 Mbps	1 kft

Source: B. Kumar

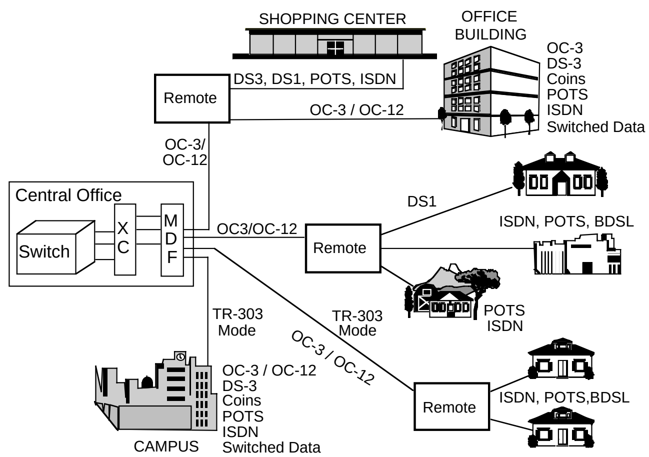
IDLC (Integrated Digital Subscriber Loop)

Because it is a means to bring digital technology closer to subscribers, IDLC is currently the most widely-deployed equipment in the telco network. IDLC equipment uses fiber technology to support various services. The access rates are DS-3, STS-1, DS-1, fractional DS-1, POTS, digital data service up to 56 Kb/s, and ISDN. The trunk transport rate is usually OC-3 or OC-12. Most deployed equipment is SONET-compatible and based on Bellcore specifications (as contained in TR-303). IDLC provides a migration path from current analog to SONET-based transport, and is designed to support both basic and enhanced telephony services. The hardware architecture and software features vary from vendor to vendor. In general, the following system features are supported by most of them:

- Remote software provisioning capability.
- Compact and rugged shelf design to sustain outside plant operation.
- OAM&P features that are SONET-compatible.
- Flexible hardware architecture to accommodate future software upgrades.
- Digital service to end users.

This architecture can be complemented with xDSL technology as the next phase of migration toward an end-to-end broadband network designed to handle the convergence of services. This system architecture is depicted in Figure 2.

Figure 2
IDLC/FTTC Architecture



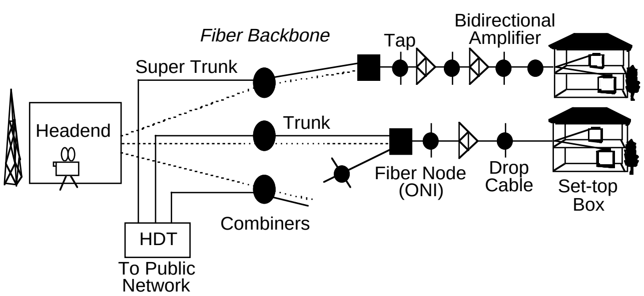
Source: B. Kumar

Hybrid Fiber Coax

Because of the high bandwidth coax drop to each customer, the hybrid fiber/coax (HFC) architecture is currently considered to be the easiest and most logical way to provide all the services to the end user by means of the existing CATV infrastructure. Theoretically, HFC is capable of supporting all existing and emerging narrowband and broadband services including telephony, TV broadcasting, advanced video services, VOD (video on demand), and distance learning. HFC can support both analog and digital services and offers a migration path to pure optical service and an all-digital network in the last mile.

Figure 3 shows the HFC architecture from the headend down to the interface node between the fiber and coaxial cable. Modulation techniques such as QPSK, QAM, or VSB are used between the headend and optical network interface (ONI), where the signal is mapped to a particular frequency and carried onto the network until it is converted back to the original

Figure 3
HFC Access Technology



Source: B. Kumar

format for the subscriber. Digital or analog information within the frequency is upconverted to a narrowband channel at a high frequency for the transmission. Analog signals can be upconverted using any frequency modulator. Thus, QPSK, QAM, or VSB technology enables multiplexing several sources, each modulated with one or more frequency signal, which can be combined optically in a CATV network.

In HFC-based CATV systems, the broadcast video and switched video signals are transported via fiber to the ONU or ONI. The ONI connects the fiber backbone to the coaxial cable distribution plant. At the ONI, the signals are frequency-shifted to the appropriate channel and fed to an amplifier for transmission over coaxial cable. The conventional analog, video, data, and voice signals can be carried simultaneously in different frequencies.

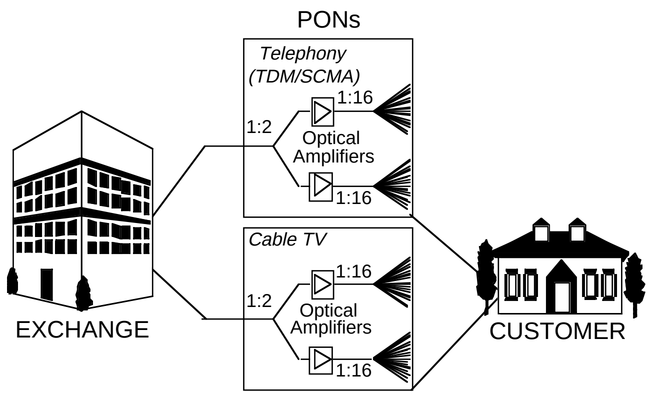
The final segment of coaxial cable requires two-way amplifiers for the bi-directional signals on the cable. The ONU performs additional functions like separation of upstream and downstream signals.

Some of the current issues with HFC architectures for providing telephony are the quality of service, network powering requirement, and ingress noise generated by non-cable subscribers. Also, the reverse channel currently uses the low-frequency range that is bandwidth limited. For data services, the issue is still reverse bandwidth and ingress noise. Recently, alternative proposals for reverse bandwidth, such as using telephone lines, are being considered.

Passive Optical Networks

Passive optical network (PON) technology uses passive optical components such as couplers, wave division multiplexers, and optical branching devices to provide service to end users. This architecture can be deployed in LEC and CATV environments. Initial target services to customers are telephony, video broadcasting, or primitive interactive video services. But, due to current technological limitations in passive devices, their limited flexibility with respect to operating wavelength, and the limited number of available channels within a wavelength, services using a PON architecture are restricted. This is in addition to the cost of deploying fiber to the end user. With development of other technologies that complement these technologies, however, these limitations can be addressed in a more effective way in the long term. The PON architecture has potential if fiber technologies mature and if the fiber penetration is close to the home (see Figure 4).

Figure 4
PON Architecture



Source: B. Kumar

FTTH or FITL/FTTC

These are similar to IDLC, with the exception that fiber is being used as the transmission medium in the distribution plant. If the fiber is used all the way to the home, it is called fiber to the home (FTTH) or fiber in the loop (FITL). If the fiber is used up to the curb of the home, it is called fiber to the curb (FTTC). This fiber, combined with switching network elements like ATM switches that are capable of handling all services (voice, video, and data), will enable a network that can provide all services to the customers.

In an FTTC architecture, digital signals travel from the service provider to the central office via backbone links. The signals from the CO are routed through to an optical network unit. At the ONU, the optical signal from the fiber is converted into an electrical signal which is at the curbside and transmitted over coaxial cable or twisted pair to the customers' premises.

For telephone operating companies providing services, twisted-pair wires from the curb are used to connect to the customer premises. For CATV services, coaxial cables may be used. FTTC is usually implemented as a switched network with multiple fibers for bi-directional signal flow. Figure 2 also illustrates an FTTC architecture in a typical telephone environment. FTTC can be considered as the next step to IDLC.

Telephone companies have a special interest in FTTC because it offers a smooth migration from current architectures and to the future FTTH architecture. In fiber to the home, a physical fiber goes all the way to the customer premises. All services are multiplexed into the appropriate customer's fiber. British Telecom has conducted a few trials in the United Kingdom in this area.

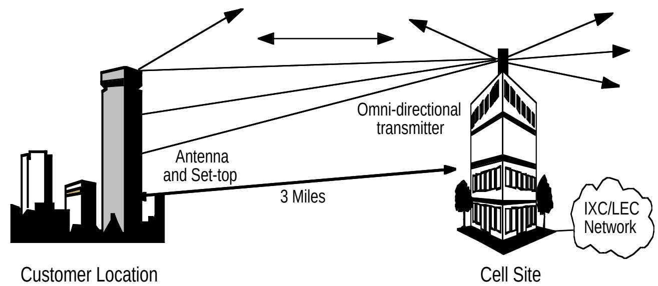
Local Multipoint Distribution System

Of all the different wireless technologies that exist, local multipoint distribution system (LMDS) is mentioned because it is the only wireless technology that addresses two-way broadband multimedia on wireless media.

The FCC has allocated a 1 GHz frequency on a 38 GHz to 40 GHz frequency band for a wide range of wireless broadband services. This wireless system is capable of providing all the advanced two-way multimedia services including telephony and high-speed data. This service enables service providers like interexchange carriers who don't have the infrastructure to provide local access in a cost-effective way to both residential and business customers in the least amount of time.

The basic architecture of this system is illustrated in Figure 5. In this architecture, the last mile or the local loop is a wireless interface. The antenna at the customer's location must be in line-of-sight with the cell site. The cell site is connected to the network which provides all the customer-required services. The distance between the cell site and the customer should be less than three miles. This is because, at very high frequencies such as 40 GHz, the signal fades rapidly and is susceptible to external environmental noises (i.e., rain). Like other architectures, LMDS is point-to-point and therefore can easily interface with the star architecture. The antenna at the cell site is a modified microwave antenna capable of receiving signals from all directions. The signal received at the

Figure 5
LMDS Architecture



Source: B. Kumar

cell site is then carried via wireline to the public network, where appropriate call routing is performed.

Multichannel Multipoint Distribution Service

Multichannel multipoint distribution service or microwave multipoint distribution system is a type of broadcast network similar to LMDS but operating at a frequency of 2.4 GHz. Also, the operating bandwidth range in this frequency is limited to provide a variety of services. Currently, this frequency is used by CATV providers to connect multiple headend locations for broadcasting video. With telecom deregulation, the use of this frequency is open to other services such as telephony and interactive services.

Unlike LMDS, MMDS is less susceptible to interference from external environmental conditions such as rain and thunderstorms. Thus, it is less stringent in terms of distance from the cell site. Typically, MMDS covers a radius of 50 miles, whereas LMDS has a radius of one to three miles.

Direct Broadcast Satellites

The current version of DBS is the third-generation of satellite-based video broadcast services. Recently, this service has become very attractive with the advent of digital technology and smaller dish antennas at the customer location. This, in turn, enables better quality video and audio. DBS provides a type of service similar to that currently provided by conventional analog satellite systems. The attractiveness of DBS is that the signal is transmitted in a digital format, which is decoded by the set-top box at each customer's location. This set-top box, in addition to converting digital signals to analog, has built-in intelligence to provide many new advanced services such as interactive TV and information on demand. The basic DBS architecture is shown in Figure 6.

Architecture Comparison Summary

Table 2 summarizes all the different access technologies based on the type of transmission medium used to transport the signal to the customer. This is done because service providers will use one of the transmission media mentioned to provide access to the customer.

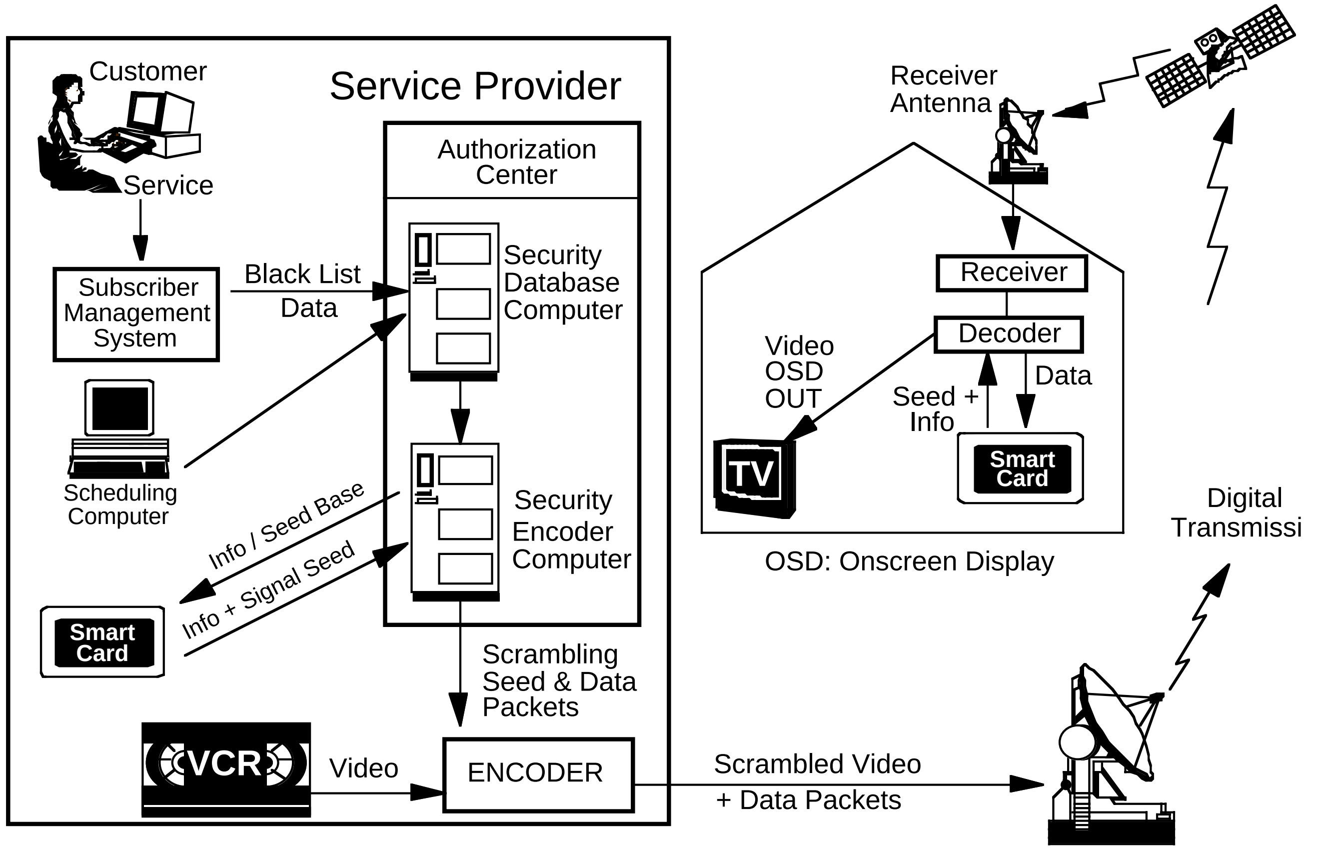
Strategic Options for Service Providers

Each service provider will utilize their infrastructure to pursue certain strategies in terms of gaining market share and additional revenue by being first to provide new services. In this section, we will discuss those service providers—CATV companies, LECs (local telephony providers), and IXCs (long distance telephony providers)—who have the potential to influence the direction of future services. Other providers such as CAPs, cellular companies, and satellite providers will be niche players who target specific services and markets. For example, DBS targets digital broadcast video with limited interactive capability in terms of bandwidth and reverse channel.

CATV Strategy

CATV providers like Tele-Communications, Inc., Cox Cablevision, and Time Warner have facilities with a tree and branch architecture. In the United States, CATV has 60% household penetration of coaxial cable. This architecture is designed for one-way broadcast video. The CATV evolution is to upgrade the backbone network with fiber; this phase of architecture is called HFC. Contrary to popular belief, this architec-

Figure 6
DBS Architecture



Source: B. Kumar

Table 2
Summary of Access Technologies

Transmission Media	Twisted	Coax	Fiber	Wireless	Broadcast RF	Satellite
Service Providers	Telco, Utility, CAP	CATV, CAP	CAP, Telco	Cellco, New Players	CATV Providers	Satellite Providers, New Players
Customer	Residential/ Business	Residential	Business	Business	Residential/ Business	Residential/ Business
Bandwidth Availability	Broadband	Broadband	Broadband	Narrowband	Broadband	Wideband
Technology	MPEG1/2, ADSL, BDSL, HDSL, TDM	MPEG1/2, ATM, AM, FM	MPEG1/2, ATM, TDM, AM, FM, PON, WDM	TDMA, CDMA	FDM, TDMA, AM, FM (28 GHz)	FDM, TDMA, AM, FM, ATM
Advantages	Widely Deployed (Global)	High Bandwidth, Widely Deployed	Unlimited Band-width, Good Reach	Mobility	Mass Distribution	Coverage, Mass Distribution
Issues	Lack of OSS	CATV Reliability; Limited 2-Way	Infrastructure Cost	Expensive Frequency; Need License	Shared Bandwidth	Shared Bandwidth
High-Speed Internet	High	Medium	High	Limited	Limited	Limited
Multimedia	High	Medium	High	Limited	Medium	Medium

Source: B. Kumar

ture does not easily provide two-way broadband services. In order to get to two-way service capability, other elements of the network, such as two-way amplifiers and ONUs serving a small number of subscribers, have to be upgraded. This upgrade has hidden costs that are usually ignored. This fact, along with the limited capability and the need to introduce new services to the market in a short time, has led CATV providers to adopt a strategy of offering limited services with their available capability. Thus, their strategy is as follows:

(1) Upgrade the network to HFC with the objective of improving the quality of existing services. This enables CATV to provide data services like Internet access. In initial service offerings, the control information is carried via telephone lines using a modem. The reasons CATV pursues data-type services are increased demand for high-speed Internet access, fewer regulatory constraints, no powering requirement from the network, no QOS, and an architecture that easily supports data traffic.
(2) Upgrade the amplifiers to bi-directional and higher capacity to support the reverse channel and new limited interactive services.
(3) Once the set-top box issues—protocols, cost, location of the set-top within customer premises (inside or outside and what functions need to be included)—are resolved, interactive multimedia services will be targeted.
(4) CATV providers will target telephony services as a means of positioning their networks against the

telcos, i.e., they will provide the minimum services, such as transport of long distance telephone calls to other providers, with long distance service providers providing the OSS and other features.

CATV Service Strategy*—Using HFC technology, CATV providers will upgrade the network for data (Internet) access, then switched video services, followed by telephony. This is in addition to current CATV service offerings such as broadcast video and PPV.*

LEC Strategy

LEC providers like NYNEX, Pacific Bell, U S WEST, Southwestern Bell, Ameritech, BellSouth, and Bell Atlantic have facilities that are designed to deliver telephony service over a star architecture. LECs have 97% household penetration, with about 157 million twisted copper pairs, in the United States. The LEC evolution is to upgrade with fiber to a broadband network using technologies like SONET/SDH, ATM, and then migrate to BISDN. The current phase is to upgrade the backbone network to SONET/SDH to increase capacity in the trunk network and better manage remote facilities.

Contrary to popular belief, the star architecture is capable of providing asymmetric/symmetric, two-way broadband services while, at the same time, maintaining the current grade of service. In order to get two-way capability, the access component of the network needs to be addressed. This upgrade can be achieved by using technologies like ADSL/BDSL/HDSL. Thus, the LECs' access strategy toward an integrated network capable of providing all services is as follows:

(1) LECs plan to use wireless MMDS/LMDS as an interim solution to get into the broadcast video business and into multimedia in the future.
(2) LECs will upgrade the backbone with SONET and next-generation digital loop carrier to enhance the manageability of their current services.
(3) LECs will strategically deploy ADSL for high-speed Internet access and other data service needs of customers.
(4) LECs will continuously deploy a fiber-based architecture such as FTTC, and will later move to FTTH as the business case justifies. At the same time, they will upgrade the loop plant initially with ADSL and later with BDSL, thus increasing the bandwidth on existing copper wire from 10 Mb/s to 52 Mb/s (depending on the loop length). *Note*: British Telecom estimates that FTTC could be justified for telephony service alone and upgraded to provide advanced services with the incremental cost of $80 per subscriber.

LEC Service Strategy*—Initially, target broadcast video via MMDS, IDLC with ADSL/BDSL/HDSL/SDSL for data (Internet), and FTTC with ADSL/BDSL/HDSL/SDSL for switched digital video along with broadcast video, telephony, and data.*

Acronyms

ADSL	Asymmetrical Digital Subscriber Line
ATM	Asynchronous Transfer Mode
BDSL	Broadband Digital Subscriber Line
BISDN	Broadband Integrated Services Digital Network
CAP	Competitive Access Provider
CATV	Cable Television
CDMA	Code Division Multiple Access
CO	Central Office
DBS	Direct Broadcast Satellite
FCC	Federal Communications Commission
FDM	Frequency Division Multiplexing
FTTC	Fiber to the Curb
FTTH	Fiber to the Home
HDSL	High bit rate Digital Subscriber Line
HFC	Hybrid Fiber/Coax
IDLC	Integrated Digital Loop Carrier
ISDN	Integrated Services Digital Network
ISP	Internet Service Provider
ITU	International Telecommunications Union
IXC	Interexchange Carrier
LEC	Local Exchange Carrier
LMDS	Local Multipoint Distribution Service
MMDS	Multichannel Multipoint Distribution Service
MPEG	Moving Pictures Expert Group
NTSC	National Television System Committee
OAM&P	Operations, Administration, Management, and Provisioning
OC	Optical Carrier
ONI	Optical Network Interface
ONU	Optical Network Unit
OSS	Operational Support System
PON	Passive Optical Network
POTS	Plain Old Telephone Service
PPV	Pay-Per-View
QAM	Quadrature Amplitude Modulation
QOS	Quality of Service
QPSK	Quadrature Phase Shift Keying
SDH	Synchronous Digital Hierarchy
SDSL	Symmetrical Digital Subscriber Line
SONET	Synchronous Optical Network
STS	Synchronous Transport Signal
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
VDSL	Very High-Speed Digital Subscriber Line
VOD	Video On Demand
VSB	Vestigial Side Band
WDM	Wave Division Multiplexing

IXC Strategy

IXC providers like MCI and AT&T do not have access facilities like the LECs or CATV providers. Thus, in the short term, IXCs have to depend on other providers to provide access to customers. However, not having any existing access infrastructure has its advantages. They have the opportunity to be selective in planning their access strategy from a variety of access technologies and local access service providers. With these limitations, the IXC strategy will be as follows:

(1) IXCs will use wireless DBS as an entry solution to get into the broadcast video business as a means to get a foothold into future multimedia environments.
(2) IXCs will leverage the new wireless LMDS technology to deliver a wide range of integrated services if they have access to an LMDS wireless frequency license. Or, IXCs will make use of local service providers such as LECs, CAPs, or CATV companies to deliver a wide range of integrated services. Or, IXCs will use a combination of the above strategies to get access to the customer.
(3) IXCs as ISPs (Internet service providers) will deploy ADSL as a suitable solution for high-speed Internet access and the other data service needs of customers (leasing loop facilities from the LECs).
(4) IXCs will continuously deploy fiber closer to the home as the business case justifies and, at the same time, pursue some of the above strategies.

IXC Service Strategy*—Initially, target broadcast video via DBS and LMDS for data (Internet). Partner with other service providers using ADSL/BDSL/ HDSL/ SDSL for switched digital video along with telephony and data, while deploying fiber closer to the home.*

Conclusion

Each one of the three major types of service providers has advantages and disadvantages in attempting to gain market share in the new industry. Of the three, LECs have the greatest risks and benefits. If the LECs don't succeed, their market share will be slowly eroded by other service providers. Losses that look negligible in the short term could add up to huge ones over a longer period of time. If the LECs plan and position themselves, however, they will be in a good position to address market demand.

IXCs, on the other hand, have the least to lose and the most to gain. Given their past experience in the competitive environment, they are better situated than other service providers. IXCs are positioned to pick-and-choose the markets and services they want to enter. This will enable them to reduce their risks and leverage emerging access technologies to optimize the cost and gain market share.

CATV providers also have real potential, but significant growth will depend on their ability to upgrade their networks in time, which means availability of capital. Without it, their market share will decline, and their monopoly status will be threatened. This can already be seen from the loss in market share to DBS since its introduction in 1994. ntq

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[1] Demonstration by U S WEST in Denver, Colorado. The results were published in *Telephony* (January 1996).

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