OPTICAL NETWORKS

New Options For The Optical Edge

Michael Finneran

As the telcos slowly push fiber toward the edge, how will end users connect to the network?

While fiber optics and wave-division multiplexing (WDM) have provided the tools to build very high-capacity core networks, the major challenge to networking remains the access or edge. The disparity could not be more dramatic: Most locations are still served with copper pairs that support up to 1.544 Mbps, while dense WDM (DWDM) systems can transport 160 10-Gbps channels—1.6 Tbps over a single pair of optical fibers. That means the trunk facility has *1 million times* the capacity of the access connection. Further, the capacity of those fiber links is nowhere near its theoretical limit.

A number of new access products are appearing as carriers try to extend fiber economically. Some come from traditional telco suppliers, while others are from startups hoping to get a share of what promises to be a multibillion dollar market. The products break into three categories:

- Next generation digital loop carrier systems (NGDLCs).
- Passive optical networks (PONs).
- Specialized optical access or multiservice provisioning platforms.

That last category is essentially a catch-all for a wide variety of new access devices that go far beyond the capabilities of a traditional loop carrier system.

Michael Finneran is president of dBrn Associates, Inc., an independent consulting firm in Hewlett Neck, NY, specializing in the design and installation of domestic and international networks. He is the instructor for several of BCR's data communications courses.

In The Beginning: DLC

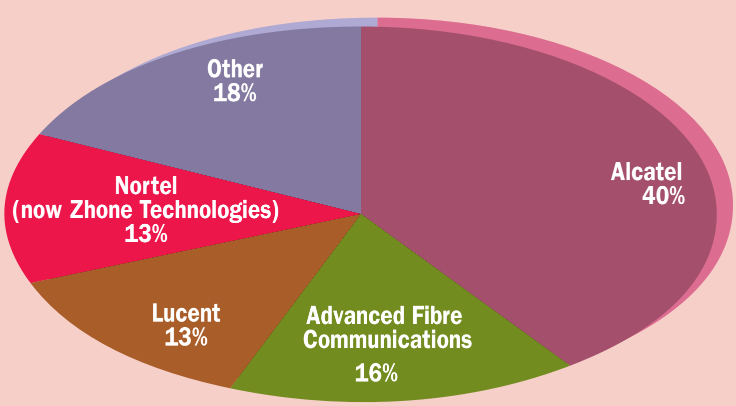
The telephone access network began with copper pairs from the central office (CO) to each customer, and each pair supported one phone line. In the mid-1970s, the telcos began deploying digital loop carrier (DLC) devices like the Lucent Technologies SLC/96 in the outside plant. These specialized channel banks or time-division multiplexers could connect up to 96 digitally encoded subscriber lines back to the CO on either two or four T1s. Later versions could connect over copper or fiber links, using standard digital interfaces designated TR-08 or GR-303.

The DLC market is well established, with some 75,000 remote terminals in service. Bob Larribeau of market research firm RHK estimates that the U.S. DLC market for 2001 generated $1.5 billion revenues—down from $2.6 billion in 2000 as the incumbent local exchange carriers (ILECs) trimmed capital spending. Market shares for the major vendors are summarized in Figure 1; Nortel recently sold its DLC business to Zhone Technologies.

According to Jim Sackman, VP and CTO of Advanced Fibre Communications (AFC), the number-two DLC supplier, 85 percent of new telephone lines are on DLC systems. Currently about 70 percent of DLC systems are connected over copper T1 or HDSL links rather than fiber.

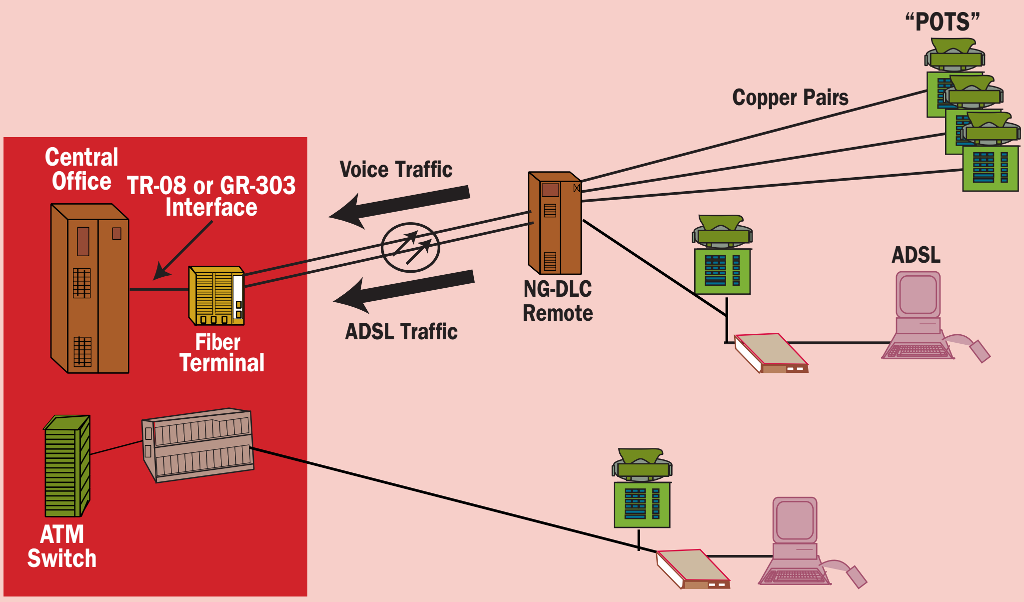
While all DLCs can support POTS and ISDN BRI services, the introduction of digital subscriber line (DSL) services in the mid-1990s

FIGURE 1 DLC Market Shares—2001 (Total Market $1.5 Billion)



Source: RHK

FIGURE 2 Next-Generation DLC



Source: dBrn Associates, Inc.

Digital loop carrier technology is getting tangled in regulatory issues

required that DLCs add functionality to support higher-bandwidth CO connections and ATM switching. The resulting next-generation DLCs (NGDLCs) (Figure 2) feature:

- Support for fiber as well as copper to the CO.
- Integrated DSL modem support without installing a separate DSL access multiplexer (DSLAM).
- ATM multiplexing for DSL services, along with traditional TDM interfaces for voice.

The traditional telco vendors that rule the DLC market also dominate in NGDLC. Alcatel has taken a commanding lead with its Litespan product line, which features integrated DSL support, according to Hamid Lalani, VP of marketing. Alcatel has been the primary supplier for SBC's Project Pronto, which uses an NGDLC-based architecture and was originally intended to provide DSL service to 80 percent of the customers in SBC's serving area. The RBOC recently announced, however, that it's scaling back these deployment plans.

Lalani points out that the incumbent suppliers' advantage comes from their intimate understanding of the peculiarities and requirements of the access plant and the buying processes of the telcos. These requirements include issues such as protection in the event of a power failure, notes AFC's Jim Sackman. He adds that, to ensure interoperability with the telcos' operations systems, DLC equipment must meet Telcordia's stringent OSMINE requirements.

Some newer players are trying to break into the market, however. Catena Networks' CN1000 Broadband Loop carrier will feature a DSL modem on every line card, which the company says will dramatically improve provisioning: When a customer orders DSL, the telco would be able to activate the service with a software command issued from the CO, saving a truck roll.

One of the biggest issues facing telcos in their NGDLC deployments is regulation. Indeed, SBC cited an "unfavorable regulatory climate" as the reason for putting Project Pronto on hold.

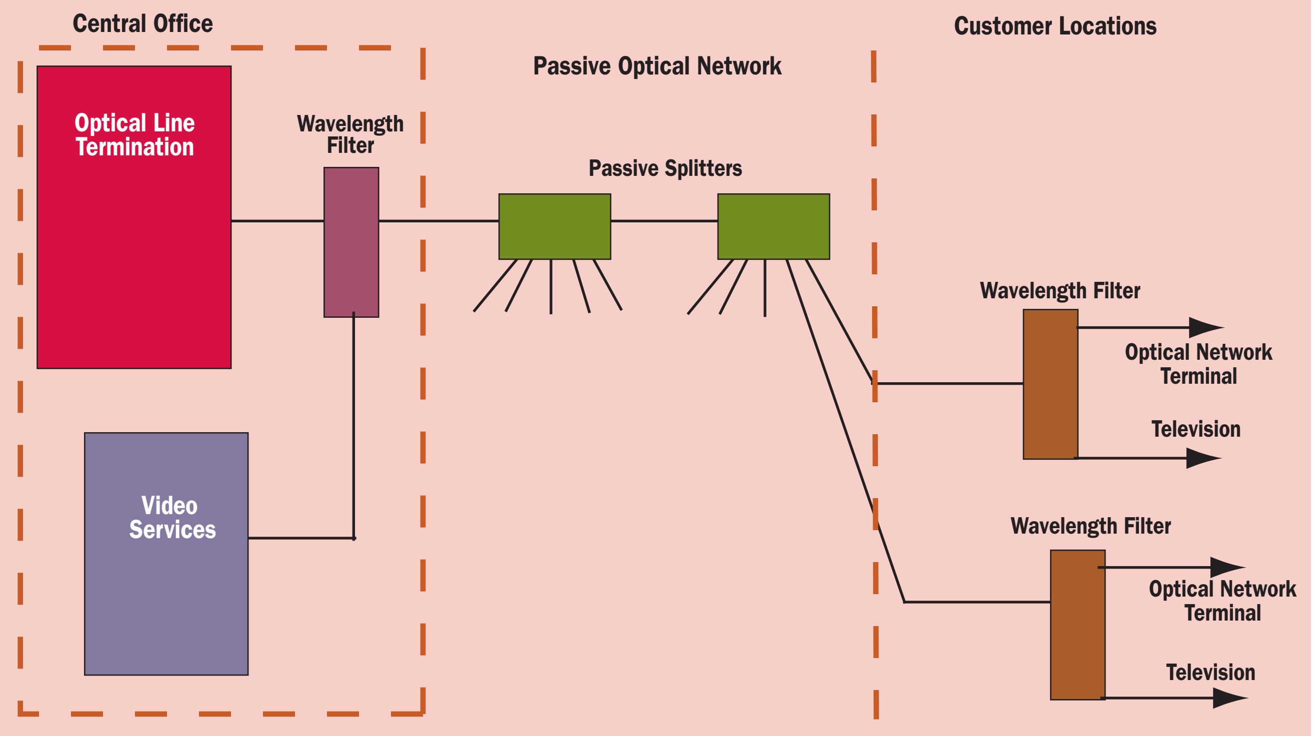
DLCs add another level of complexity to the regulatory picture, since there's a dispute over which portions of the local loop the ILECs are required to wholesale to their competitors. The FCC's rules for unbundling network elements require that ILECs unbundle the subloops running from the DLC to the subscriber location—not just the loops that originate at the CO. The ILECs claim that this removes any incentive for them to invest in DLC upgrades and are backing the Tauzin-Dingell Bill (HR-1542) now before the Congress, which would remove that requirement (see *BCR*, November 2001, pp. 56–60 and November 2000, pp. 70–76).

Passive Optical Networks

Passive optical networks (PONs) are a relatively new addition to the access space. The basic idea is to share one fiber channel among up to 32 customers, and deliver voice, data and potentially video. The major dividing line in the PON business is between the original standard that used ATM transport over the shared channel (called an APON) and products that use Ethernet (EPONs).

APON technology originated with the Full Service Access Network (www.fsanet.net)

FIGURE 3 PON Configuration



coalition, a group of carriers and equipment suppliers formed in 1995. The ITU has published the APON standards in its G.983 recommendations, while the EPON standards are being developed in the Ethernet First Mile committee, which is designated IEEE 802.3ah (http://grouper.ieee.org/groups/802/3/efm).

While there are differences in the link protocols, APONs and EPONs share a number of technical characteristics:

- Both operate over a single fiber and use different wavelengths for transmissions upstream (around 1300nm) and downstream (around 1500nm).
- Upstream and downstream channels are shared by multiple users. In the current APON specification, the downstream channel operates at 155 Mbps or 622 Mbps and upstream at 155 Mbps; a symmetrical 622 Mbps standard is now in development, as is dynamic bandwidth allocation on the upstream channel. EPONs typically operate symmetrically at 1.25 Gbps with a usable capacity of 1 Gbps.
- Passive optical splitters/combiners are used to split the power of the optical signal and route it to multiple customers.
- A separate wavelength around 1550nm also can be used to carry analog video like the hybrid fiber/coax configurations now used in cable TV. The ITU standard for that configuration is called broadband PON or BPON (ITU G.983.3), and the extra wavelength can be used to support either video or dedicated wavelength services.
- The maximum transmission range is about 20 km, and each splitter reduces the power of the optical signal, so the range is reduced as more splitters are added.
- The customer premises device, called an optical networking terminal (ONT), typically includes battery back-up to keep the device operating up to eight hours if a commercial power failure should occur.

Each downstream frame or cell is addressed, and each ONT picks off those addressed to it. Modifications have been made to both the ATM and Ethernet protocols to accommodate PON. Access to the upstream channel is assigned on a time-slot basis in a plan referred generically to as time-division multiple access. A timing marker in the downstream channel serves as a beacon and each ONT determines its time slot based on that beacon.

Some method of ensuring quality of service is required for voice traffic. Obviously, APONs can support ATM service categories; for example, Optical Solutions' FiberPath 400 uses dynamic allocation (i.e. VBR/rt) while Alcatel's 7340 uses fixed assignment CBR. In Alcatel's case, the capacity is assigned only when the user goes off-hook. In the EPON arena, both Alloptic and Salira Networks claim to have developed systems that deliver consistent-delay voice.

The big question in PONs is which flavor the ILECs will buy—if any (see Table 1 for equipment vendors). Traditional telcos have invested heavily in ATM; of course, the PON is only an access technology, and the CO-based device, called an optical line terminal (OLT), could pass

TABLE 1 PON Vendors

ATM PONS	Ethernet PONs
Alcatel	Alloptic
NEC Eluminant	Marconi
Oki Network Technologies	OnePath Networks
Optical Solutions Networks	Salira Optical
Paceon	Wave7 Optics
Quantum Bridge	
Terawave	

the traffic off to ATM, IP or circuit-switched services in the core.

Meanwhile, Ethernet proponents stress cost advantages. Bernie Atterboro, senior director of product marketing for EPON maker Alloptic, points out that his company's 1.25 Gbps product is roughly the same price as an APON and delivers several times the capacity.

Others see no future for PONs regardless of how they work. Bob Barrett, founder and CTO of specialized access vendor Fiberintheloop, sees the whole approach as wrong-headed. As he sees it, the big cost is installing the fiber in the first place; if you are going to spend all that money, why bother with a technology that's based on a shared channel?

Thus far, BellSouth, SBC and Verizon have announced PON trials. BellSouth's trial addressed 400 homes and delivered data and video services over separate fibers. SBC implemented a PON-based service in the Houston area to deliver DS1 to small business customers starting last May. In January 2002, Verizon announced a PON trial to be conducted with Marconi in Brambleton, VA.

Specialized Optical Access/Multi-Service Provisioning Platforms

By far the most difficult category of products to classify is specialized optical access systems, also known as multiservice provisioning platforms (MSPPs). These devices are entirely different from DLC systems and PONs, and there's wide variety within the category as well. There are, however, some basic characteristics:

- **Fiber Access:** These devices are designed to support an optical connection to the customer. Unlike PONs that address small users, fiber-access devices are typically aimed at the high end of the market. The optical interface may use SONET or some other format like Gigabit Ethernet, and may include an automatic restoration capability.
- **Digital Multiplexing:** These systems may use time-division multiplexing, a form of packet access or a combination. Many base their multiplexing on SONET and may actually serve as add/drop multiplexers in a SONET ring. Often they use the basic SONET frame structure but insert their own proprietary packet multiplexing scheme in the SONET payload. Others use a format that is entirely packet-based like MPLS or Ethernet.
- **Wave-Division Multiplexing:** Many of these devices incorporate coarse WDM so multiple customers can be supported on a single fiber pair. Where dense WDM systems space channels at 50 GHz, coarse WDM uses 200 GHz channel spacing and typically supports 8–16 wavelengths per fiber. Passive optical add/drop multiplexers are used to separate the individual wavelengths and route them to different customers.

To flesh out this category we interviewed vendor representatives to get a feel for the range of options.

LuxN: LuxN has been one of the fast starters in the specialized optical access area. According to Paul Zaloua, VP of product marketing, LuxN focuses on service requirements at DS3 and above. The LuxN WaveStation can support a number of rings with 1 to 16 wavelengths on each and up to 64 wavelengths per shelf. Each wavelength can be configured up to OC-48; OC-192 interfaces are in development.

The system uses a time-division multiplexing structure. Networks can be configured in a mesh, hub-and-spoke, linear add/drop or ring configuration using either the SONET Unidirectional Path Switched Ring (UPSR) or their own proprietary ring configuration for restoration. User interfaces include Gigabit Ethernet, Fiber Channel, DS1 and OC-3 or OC-12. LuxN systems are now in use with a number of CLECs including Yipes, Time Warner Telecom, Metropolitan Fiber Networks and Cablevision.

Coriolis: The Coriolis OptiFlow can support up to eight protected OC-48 rings (16 unprotected) with a maximum circumference of 120 km and SONET UPSR protection. When only packet traffic is supported, up to 32 devices can share one ring, and point-to-point and mesh configurations are also supported.

The system also features integrated coarse WDM with eight wavelengths per domain. The multiplexing combines SONET TDM with a 20-Gbps packet fabric. User interfaces include DS1, DS3, OC-3, OC-12, Fibre Channel, ESCON, 10/100/1000 Mbps Ethernet, ATM (DS3, OC-3, OC-12), Packet over SONET (OC-3c or 12c) and frame relay (DS1 and DS3). According to Greg Wortman, VP of marketing, the OptiFlow is undergoing OSMINE certification and its gear will let ILECs deliver what the company calls "data-generation SONET" that will help the incumbents battle the upstart metro Ethernet carriers while maintaining legacy services. The vendor's first announced customer is Marietta FiberNet.

Cisco: Cisco has a variety of optical access devices, marketed under the Complete Optical Multiservice Edge and Transport (COMET) strategy. Some of the elements were developed internally, while others were acquired with Cerent and Catena. All of these devices are part of the 15xxx product series. The 15454, which came

The expense of laying fiber could rule out more limited solutions like PON

from Cerent, is used to deliver TDM services like DS1 through OC-*N*. The Cisco-developed 15327 delivers Fast Ethernet, Gigabit Ethernet and packet-over-SONET services. The 15540 is used primarily for storage area networks and supports Fibre Channel, ESCON and Ethernet interfaces. If WDM is needed, the 15201, which came from Catena, can be used. According to Rob Koslowsky, director of marketing-optical networking, Cisco has more than 700 customers for its optical access products, including Qwest, XO Communications and many enterprises.

Lightscape: The Lightscape XDM is a longer-range, high-capacity solution for either TDM or Ethernet-based services. Normally installed on a single fiber path, the largest configuration can support 40 wavelengths, each operating at 10 Gbps across 400 km (700 km with amplifiers). According to Emanuel Nachum, acting president for North America, the XDM combines the functions of next-generation SONET (DS1 and DS3 services) with Ethernet (10/100/1000 Mbps) and storage-area network capabilities like Fibre Channel and ESCON. Primarily a time-division multiplexer, the XDM can also cross-connect channels at STS-1 and above. An optional Ethernet switching matrix also can be included. Lightscape is a part of ECI Telecom, and most of its initial sales are outside the U.S.

ONI Systems: The ONI Systems Online product is another high-capacity but longer-range multiwavelength optical access platform. There are four different models, most offering 33 protected or 66 unprotected wavelengths.

The Online 7000 and 9000 models operate up to 160 km, while the 11000 can reach 640 km. The product is geared for high-capacity applications and can deliver OC-3, OC-12 or OC-48 channels, Ethernet (10/100/1000 Mbps), ESCON, Fibre Channel, FICON and even FDDI.

Appian Communications: Appian's Optical Services Access Platform provides a single wavelength channel carrying either one OC-48 or one Gigabit Ethernet signal. The fundamental multiplexing is SONET-based, but other formats like IP or ATM can be carried in all or part of the SONET payload. Appian also supports a proprietary protocol called Dynamic Service-based Queuing, that allows a carrier to provide guaranteed bit and maximum burst rates on Ethernet services. User interfaces include DS1, E1, DS3 and Ethernet.

According to Mark Sebastyn, senior product manager, Appian's products let a carrier introduce Ethernet service or a mix of frame relay, ATM and Ethernet on an existing SONET structure. Appian recently announced a major contract with NTT Communications in Japan.

Interfaces on specialized optical access devices range from POTS to GigE

Metro-Optix: Metro-Optix, a spin-off from Ericsson, provides Citystream, which can support four OC-48 channels per shelf; an OC-192 interface is in the works. For multiplexing, a customer can choose one of three "fabric cards" that provide TDM, ATM or IP switching. At the user end, the Citystream can deliver DS1, DS3, 10/100/1000 Mbps and 10-Gbps Ethernet, OC-3 or OC-12 ATM and even DSL if a low speed shelf is added. Metro-Optix combines a SONET add/drop multiplexer, digital cross-connect, frame relay access device, ATM edge switch, IP router and wave division multiplexer in one box. Verizon is now using the Citystream for aggregating DSLAM traffic in its DSL service.

Luminous Networks: While many of the previously-mentioned systems are based on SONET multiplexing, Luminous is placing its bets on Gigabit Ethernet with Resilient Packet Ring (RPR). Luminous offers the M Series for the CO and the C Series for customer premises installation; the two boxes are connected with an OC-48 link and OC-192 capability is planned. The products can also support four-channel coarse WDM and run SONET on some wavelengths and Ethernet on others. Luminous is an active member of the RPR Alliance and invented MultiService RPR, which defines Ethernet-based services with QOS. According to Jay Schuler, VP of business development, the products let the carrier deploy packet services inexpensively while preserving the voice service that represents 80 percent of the revenue stream.

Integral Access: With a product line named "PurePacket." Integral Access makes it pretty clear which way they're going on their multiplexing. The PurePacket is a lower-capacity system whose trunk interface is Fast Ethernet, DS1 or DS3. OC-3 and Gigabit Ethernet interfaces are in the works. The unique feature of the PurePacket is that it uses a form of Multi-Protocol Label Switching (MPLS) to do its multiplexing. While most MPLS implementations provide guaranteed data service, Integral Access supports voice as well. Voice channels use dynamic allocation or voice activity detection for greater efficiency. According to Dan Teichman, director of business development, the system combines the functions of a digital loop carrier, DSLAM, digital cross-connect, add/drop multiplexer and voice-over-DSL gateway. (It does not do windows.) At the user end, the system can support POTS, ISDN BRI/PRI, DS1, E1, OC-3 packet over SONET, Gigabit Ethernet and DSL.

Kestrel: Kestrel's Talon 1000 is a point-to-point optical multiplexing system that can combine

64 OC-3 channels and deliver a combination of OC-3, OC-12, ESCON, FICON and Gigabit Ethernet services. The system has a total capacity of 10 Gbps protected or 20 Gbps unprotected. The basic granularity is OC-3, and user services like Gigabit Ethernet, Fibre Channel and OC-*N* are each mapped into one or more OC-3 payloads. According to Kristen Foss, director of product development, the Talon uses a unique multiplexing scheme. Each OC-3 channel is converted into an RF signal, and the RF channels are then frequency-division-multiplexed into one high-bandwidth radio channel. That channel is then used to modulate a light source. The system has a span length of 70 km.

Fiberintheloop: The name gives you a pretty good idea what Fiberintheloop is about. Their Fast 4 product uses a symmetrical 150-Mbps trunk, and functions like an Ethernet repeater. The user interfaces are DS1, E1 and 10/100-Mbps Ethernet; the product uses time-division multiplexing. According to founder and CTO Bob Barrett, the goal is to provide the ILECs with a device to fit into the existing TDM structure while allowing them to deploy Ethernet-based services with management capability.

Conclusion

While the original market for many of these systems was the CLECs, it has now become apparent that the ILECs are the only ones with any capital budget to spend. Virtually every vendor indicated that the ILECs are their primary target and "fitting in with the existing structure" was a recurring theme in the product pitches.

Since the ILECs are the target, OSMINE compatibility will be essential, but the real question is: What services are the ILECs looking to deploy? Since POTS and ISDN are going to remain, there is certainly an ongoing market for digital loop carrier systems. Unless the ILECs are willing to abandon the broadband access market to the cable modem and wireless suppliers, a next-generation DLC that can deliver DSL services will likely be their primary platform. The major variable will be developments on the regulatory front, which might make it less attractive for an ILEC to invest in plant upgrades.

Passive optical networks have the advantage of being standards based, and the APON would likely have the inside track given the ILECs' existing investments in ATM switching. However, the idea of a limited-capacity shared channel looks like a dead end when you consider how data requirements have grown in the past decade. Further, EPONs are currently delivering 1.25 Gbps rather than 155 Mbps or 622 Mbps for about the same price, and if the ILECs are looking to deliver Ethernet-based network services, is there any reason to get ATM involved?

The most perplexing issue is the fate of specialized optical access. Certainly, these devices offer flexibility far beyond what we see in NGDLC and far greater capacities than PONs, but will the ILECs be willing to invest in what is essentially a proprietary technology? At this stage the capacity and capability of these devices far outstrips NGDLC or PON systems, but NGDLC suppliers like Alcatel and AFC are planning new service interfaces that will blur the distinction.

The technical pieces are falling into place, but the future of optical access will be based on having the right technology and the right market perception in a regulatory environment that provides incentives for the delivery of new services□

The big question: Which solution will the ILECs choose?

Companies Mentioned In This Article

Advanced Fibre Communications
Alcatel (www.alcatel.com)
Alloptic (www.alloptic.com)
Appian (www.appiancom.com)
Bell South (www.bellsouth.com)
Cablevision (www.cablevision.com)
Cisco (www.cisco.com)
Coriolis (www.coriolisnet.com
ECI Telecom (www.ecitele.com)
Ericsson (www.ericsson.com)
Fiberintheloop (www.fiberintheloop.com)
Integral Access (www.integralaccess.com)
Kestrel (www.kestrelsolutions.com)
Lightscape (www.lightscapenetworks.com)
Lucent (www.lucent.com)
Luminous Networks (www.luminousnetworks.com)
LuxN (www.luxn.com)
Marconi (www.marconi.com)
Metro-Optix (www.metro-optix.com)
Metropolitan Fiber Networks (www.mfn.com)
NTT Communications (www.ntt.com/index-e.html)
ONI Systems (www.oni.com)
Optical Solutions (www.opticalsolutions.com)
Salira Networks (www.salira.com)
SBC Communications (www.sbc.com)
Telcordia (www.telcordia.com)
Time Warner Telecom (www.twtelecom.com)
Verizon (www.verizon.com)
Yipes (www.yipes.com)