OCCAM NETWORKS

Broadband Loop Carrier : Enabling Video in a Triple-Play Architecture

Executive Summary

Incumbent local-exchange carriers (ILECs) will be looking to triple-play services (voice, data, and video) to fend off cable competition and renew revenue growth. Fortunately, loop carrier technology advancements now enable networks that provide scalable bandwidth and employ an Internet protocol (IP)-based service-delivery model that allows for profitable voice, data, and video offerings.

Overview

This tutorial will discuss how current access networks must change to meet the triple-play bandwidth and service-delivery challenge. They must change to provide high-capacity bandwidth that handles the traffic efficiently to deliver IP-based broadcast video and video on demand (VoD), high speed IP-based data services including Gigabit Ethernet, and even voice over IP (VoIP) as part of a circuit-to-packet voice switch migration. Access networks based on TDM/SONET/ATM will not scale sufficiently and do not fit smoothly in an IP-based service world. Regardless of current and near-term service offerings, it may be essential to invest in a distribution plant that can support current operations as well as smooth the transition to a triple-play network for the long-term future. For lowest cost and seamless operation, an Ethernet and IP-based access network is one potential solution.

Topics

1. Introduction

ILECs find themselves in a very difficult environment. Competitive threats have grown while at the same time the economic climate has increased the pressure to reduce costs and has limited the capital available to invest in new revenue-generating services.

While the threat from competitive local-exchange carriers (CLECs) has abated, even more serious competition has emerged from cable operators. In addition to television, they lead in residential broadband services and are methodically and strategically entering residential voice and business data service markets. Increasingly, cable operators are combining these services into bundled offerings.

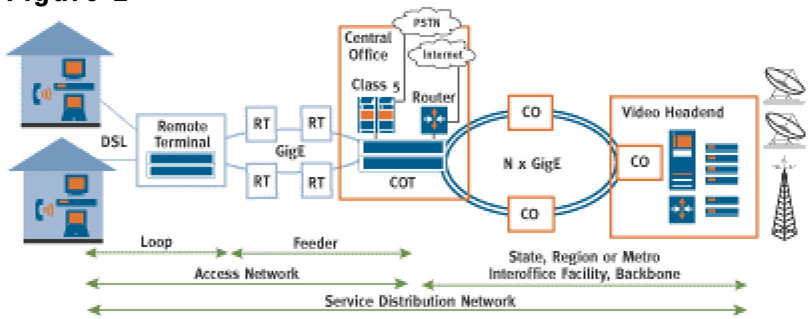
Fortunately, the technology landscape has been changing in ways that allow ILECs to remain competitive. For example, the commercial success of the Internet has driven subscriber demand for bandwidth, leading to the development of a range of digital subscriber line (DSL) technologies. Most telcos now offer high-speed connectivity to residential and business customers over existing copper lines. To deliver DSL services, telcos typically augmented their existing networks. As a result, many ILECs now have a combination of circuit and cell technologies deployed in parallel or mixed with their existing infrastructure. However, this combination of time division multiplexing (TDM) with an overlay asynchronous transfer mode (ATM) network limits the potential for significant cost reduction as well as the ability to offer innovative new revenue-producing services.

Now, by using new IP packet-based access network and switching technologies, telcos can reduce their costs and also offer new services. Many carriers are pursuing circuit-to-packet migration as their strategic technology direction in order to shift service creation and delivery to the lower-cost and more flexible IP structures. Several new product developments are key to this migration. Specifically, softswitches enable the transition for voice services; digital head ends deliver IP video; and broadband loop carrier (BLC) systems allow the convergence of voice, data, and video on a single access network infrastructure.

By leveraging packet-based technologies, ILECs can remain competitive by delivering triple-play services—voice, data, and video—over DSL links. In this paper, we examine how BLC technologies and products are used as examples of how to enable ILECs to deploy a high-performance, reliable, cost-effective access network for triple-play service delivery.

2. The Triple Play Architecture

Figure 1



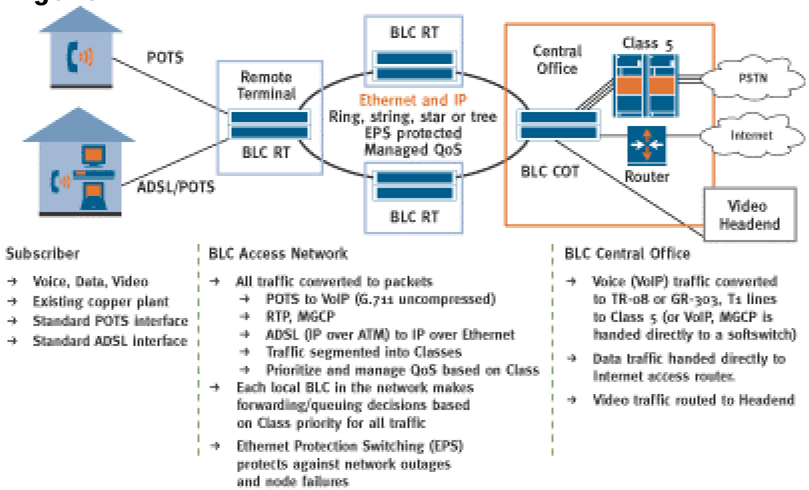
In a triple-play local-loop architecture, as illustrated in *Figure 1*, a single loop system carries the voice, data, and video traffic flow from residential and business customers to remote terminals (RTs) using standard telephony and DSL interfaces. The RTs are interconnected by access network feeder to the central office terminal (COT). Customers connected on copper pairs directly to the central office (CO) can receive all of the same services directly from the COT. The COT provides access to the public switched telephone network (PSTN) via a traditional Class-5 switch or softswitch (using VoIP with softswitch signaling), provides Internet access via a router, and provides access to video services via interconnection with a video head end.

BLC solutions, for example, combine two innovative technology approaches to deliver telcos a cost-effective, scalable, flexible architecture.

First, the solution leverages standard IP and Ethernet technologies. Technically, this approach rips out layers of complexity. Economically, it drastically reduces the cost of building and operating a high-bandwidth access network. In a BLC access network, all traffic between remote terminals and central offices is carried as IP packets across high-speed, fiber-based Ethernet links.

Second, the solution consolidates line access and aggregation functions into a single device. Specifically, the RTs and COTs integrate digital loop carrier (DLC), optical transport, DSL access multiplexer (DSLAM), and line access gateway (i.e., softswitch VoIP gateway) functionality into one network element.

Figure 2



In terms of traffic flow, residential and business customers connect to a BLC deployed in an RT or CO via traditional interfaces, such as analog / POTS lines, T1 / E1, or DSL connections. Any non-IP traffic is converted to packets at the RT; for example, analog voice is converted to VoIP. RTs are connected to COs via fiber-based Ethernet links in whatever topology—ring, string, star, or tree—best suits the ILEC. IP-based traffic flows from the BLC RTs to the BLC COT in the CO. The BLC COT connects to Class-5 switches via a TR-08 or GR-303 interface and connects to Internet access routers, softswitches, and video head ends via Ethernet. The traffic flow in the BLC triple-play architecture is illustrated in *Figure 2*.

In *Figure 2*, the integration of key access and aggregation functions into a single network element simplifies network design and implementation and significantly reduces operational costs. The architecture in the figure also positions ILECs to move into new markets, such as expanded data services for businesses and video services for residential customers. It enables telcos to offer competitive analog voice and data services today while positioning them to compete with the full range of triple-play services, including VoIP, tiered data services, and a range of video services, in the near future.

Delivering these services will require more bandwidth than is available in today's distribution networks. Video, in particular, requires large amounts of bandwidth. It is important to plan today's networks to meet the bandwidth requirements for future video offerings.

3. Meeting the Video Bandwidth Challenge

Figure 3

	Channels/VOD Streams	Bandwidth Requirement (Gigabit /sec)	# of OC-3's needed	# of Gigabit Ethernet needed
Interoffice Facility Bandwidth Requirements				
Broadcast Channels	300			
Concurrent VOD users	2160			
Total Interoffice Facility peak time useage	2460	9.35	61	10
Access Network Feeder Bandwidth Requirement				
Without IGMP multicast at RT				
Total peak time individual video streams	900	3.42	23	4
With IGMP multicast at RT				
Individual peak time Broadcast Channels Requested	240			
Concurrent peak time VOD users	135			
Total access network peak time useage	375	1.43	10	2

Depending on compression technology used, each channel coming from a video head end or distribution point needs as much as 3.8 Mbps of bandwidth. Broadcast video channels are multicast in nature. If handled properly by the network infrastructure (with IGMP multicast at the network RTs), the amount of total bandwidth that multicast video consumes between the head end and RT can be minimized. In addition, video services such as VoD are unicast in nature-requiring individual bandwidth streams from the head end to the subscriber.

Video network bandwidth-capacity requirements depend mostly on the number of subscribers, the number of broadcast channels offered, and the concurrent use rate for VoD programs. *Figure 3* provides an example of the amount of bandwidth required in a distribution network to support viable video services.

As indicated in the example, delivering sufficient bandwidth in the access network is a stretch for synchronous optical network (SONET) in current networks, and the cost of upgrades to speeds beyond optical carrier (OC)-3 or the addition of coarse wavelength division multiplexing (CWDM) equipment is prohibitive. GigE and N x GigE are the solution.

In *Figure 3*, the use of IP and Ethernet in the access network ensures that bandwidth is used efficiently. Although Ethernet is available at very high speeds and a Gigabit Ethernet (GbE) port is a fraction of the cost of an OC-48 port, efficient use of bandwidth is still essential. IGMP multicast at the RTs creates that efficiency, and an IP/Ethernet infrastructure for all services allows for dynamic bandwidth use. That is, bandwidth is consumed only when customer traffic—be it a voice call, data interchange, or video stream—is flowing.

4. The IP/Ethernet Advantage

In recent years, IP has emerged as the network-layer and service protocol of choice. IP is broadly deployed in the core of service-provider networks, as well as in business and even residential networks, putting it on both "sides" of the access network. Using IP in the local loop means greater efficiencies, as no conversions to intermediary protocols are needed. From the service perspective, a large number of IP-based applications covering the triple-play gamut are available, including VoIP, Internet access, virtual private networks (VPNs) and other data services, and broadcast video and VoD.

IP itself has been expanded over the years to encompass a broader set of network services. For example, the differentiated services (DiffServ) architecture defines a set of IP-based quality of service (QoS) mechanisms based on the classification and marking of packets for special handling within the network. Similarly, IP-based multicasting protocols allow for the efficient delivery of a given information stream to multiple recipients.

Ethernet has emerged as a viable alternative to the combination of SONET and ATM in the local loop. Until recently, TDM, SONET, and ATM have been the primary transport protocols in the access network. However, SONET/ATM gears have very low unit and port volumes compared to Ethernet/IP, and there is little room left for realizing significant further cost savings. Likewise, due to the complexity of these technologies, a SONET/ATM infrastructure carries heavy operations, provisioning, management, and maintenance costs. In addition, the service provider generally has the additional cost of training its workforce because the talent pool for experienced technicians is limited.

Another drawback to SONET/ATM in the access network is that the available feeder bandwidth has only recently upgraded to OC-3 (155 Mbps). These networks require other costly upgrades to get to OC-12 (622 Mbps), and even newly planned networks at OC-48 (2.4 Gbps) will be limited if VoD and higher-speed data services achieve their expected growth. The available bandwidth divided among all of the triple-play services and video services alone (as shown in *Table 1*) can quickly consume even this seemingly large amount of bandwidth in a moderate-sized access network.

Ethernet offers a variety of advantages over SONET/ATM. Like IP, Ethernet is a mature, well-understood technology. Due to its wide deployment and broad market support, Ethernet is a low-cost technology, both in terms of equipment costs and operations and management costs. Unlike SONET/ATM, Ethernet has a volume of commercial deployments driving its cost and technology evolution.

Likewise, Ethernet and IP are easy to provision, and a large pool of technicians exists.

High bandwidth in scalable increments is another compelling advantage of Ethernet. During its more than 25-year life span, Ethernet's bandwidth has increased from 10 Mbps up to 10 Gbps, with 1 Gbps interfaces readily available. In addition, the Ethernet 802.3ad link aggregation standard allows operators to increase the bandwidth between connected devices by logically combining multiple links into a trunk. The BLC dynamically uses all of the available bandwidth for services delivery—increasing network efficiency and, ultimately, customer satisfaction.

Figure 4 provides a summary of the similarities and advantages of an Ethernet / IP infrastructure compared to a TDM / SONET / ATM infrastructure.

Figure 4

Criteria	Occam Networks Ethernet/IP Network	TDM/SONET/ATM Network
Carrier standard failover protection	Yes, under 50 msec with Ethernet Protection Switching	Yes, under 50 msec with SONET protection switching
Fully capable QoS management	Yes, easy Service Quality Management based on standard Ethernet and IP techniques	Yes, but complex ATM QoS techniques
QoS traffic isolation and service provisioning	Yes, Traffic separation with IP tagging and VLANs; simple to set-up and manage	Yes, but ATM VC-based; complex to set-up and manage
QoS priority enforcement	Yes, Strict priorities for connection-oriented services (T1, voice, etc); Weighted priorities for connectionless data and best efforts Internet	Yes, but ATM VC-based; complex to set-up and manage
Edge aggregation	Yes, service traffic aggregated at the remote terminal	No, ATM virtual circuits provisioned through to core aggregation device
Network topologies	Unlimited, ring, string, star, tree with no practical limits	Limited, TDM: string, star, tree within equipment architecture planning constraints SONET: ring with 16 node limit
High bandwidth scalability	Economical, N x GigE without practical limit	Expensive, current networks top out at OC-3 (155 Mbps), planned networks at OC-48 (2.4 Gpps) Greater bandwidth at much greater added cost
Use all available network bandwidth	Yes, traffic load balanced between primary and alternate paths	No, alternate paths are idle during normal conditions
Dynamic bandwidth usage	Yes, all services dynamically use all bandwidth according to QoS parameters	No, mixed TDM and Cell networks separate circuit and cell traffic. (Cell traffic does dynamically share the bandwidth reserved for cell traffic.)
Ethernet service ready	Yes, Transparent LAN Service over copper, GigE over fiber; easy granular provisioning from existing modules to match enterprise needs	No, current networks do not support Ethernet services, planned networks require additional modules with limited granularity
Video service ready	Yes, integral IP aware with IGMP Multicast included at every node	No, Current networks require IGMP router add-on. Planned networks require additional ATM processing capability
Softswitch ready	Yes, integral VoIP signaling supports Softswitch at cost savings.	No, requires addition of Line Access Gateway device or function
Techincian availability	Widely available technicians; local, outside education	Specialized technicians and tools; carrier paid training

5. Making IP and Ethernet into Public Carrier Technologies

ILECs are in the lifeline-POTS and multiservice delivery business. Technical advancements were needed to make IP and Ethernet into public carrier technologies. For instance, with Ethernet protection switching (EPS) and service-quality management techniques deliver the advantages of IP and Ethernet without compromising the integrity of the public carrier network.

EPS Reliability

EPS technology enhances Ethernet's reliability. EPS protects the access network against link and node failures. Like SONET's protection scheme, EPS designates primary and alternate paths for network traffic, with failure detection and switchover to alternate facilities occurring in less than 50 msec.

In standard operation mode, EPS supports "load balancing," enabling traffic to be carried over both primary and alternate paths. Although telcos still need to traffic engineer their networks to ensure that primary paths have sufficient bandwidth to meet all service-level agreements (SLAs) in the event of a failure, this EPS feature increases customer satisfaction by providing more available bandwidth during normal network operation. EPS, combined with standard Ethernet and IP reliability features, ensures that the BLC architecture is telco-ready, i.e., capable of "five-nines" operation.

Service-Quality Management

In its BLC implementation, Occam Networks leverages several other standard Ethernet features, including virtual LAN (VLAN) and QoS capabilities, as defined by the Institute of Electrical and Electronics Engineers (IEEE) in the 802.1q and 802.1p specifications. VLANs enable telcos to segregate network traffic; that is, traffic within a given VLAN, including broadcasts and multicasts, is restricted to that VLAN. Traffic is allocated to a particular VLAN based on a tag that Ethernet switching devices insert into Ethernet frames.

Within the VLAN tag is a field for priority information. The 802.1p specification allows network operators to specify eight levels, or classes, of priority. This QoS mechanism enables network operators to control network latency and throughput without the complexity of ATM.

Video Play: From Subscriber to RT

In terms of video, the technologies relevant today are ADSL, ADSL2 Plus, and VDSL. (Ethernet can be supported over VDSL links.) Each has its advantages and disadvantages. Today, residential customers will need 9 to 10 Mbps of bandwidth downstream to support triple-play services, including plain old telephone service (POTS), data service at between 384 kbps, and 1.5 Mbps; at least two MPEG-2 video streams; and network overhead. In the near future, improved video compression techniques, such as better MPEG-2 and the newer MPEG-4 standards, promise to reduce the bandwidth required for each residence to below 7 Mbps.

ADSL: Asymmetric DSL (ADSL) has the advantage of being well understood, broadly supported in customer premises equipment (CPE), and widely deployed. However, as a transport for video, it has limitations. The key drawback is that ADSL doesn't offer sufficient downstream bandwidth over long enough distances to be able to reach all customers. Specifically, ADSL cannot deliver 8 Mbps beyond 6,000 feet to 8,000 feet. Many telco customers are 12,000 feet to 18,000 feet from the nearest RT.

ADSL S=1/2: Covered in the current ADSL standard, S=1/2 encoding provides an important improvement to ADSL—pushing the rate and reach to 9 or 10 Mbps out to 10,000 feet and thus making ADSL S=1/2 a viable service offering for many telcos.

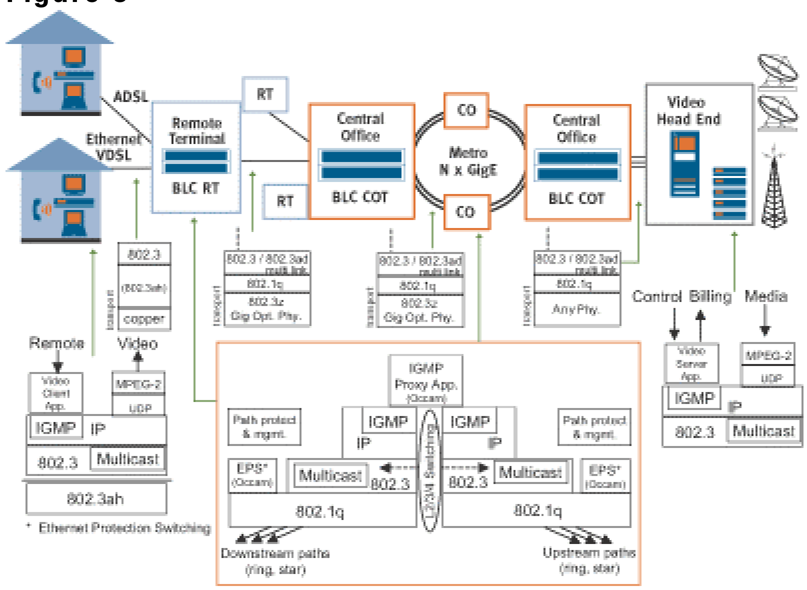
VDSL: Reliable up to 13 Mbps, very-high-data-rate DSL (VDSL) provides a lot of bandwidth but over very short distances-3,000 feet to 5,000 feet. Some telcos are interested in VDSL because it is available today, and they want to offer customers at least three concurrent video streams. A few are redesigning their serving areas to approximately 4,000 feet between subscribers and RTs so they can use VDSL.

ADSL2 Plus: The technology is solidifying for ADSL2 Plus, which will increase ADSL bandwidth for shorter distances. It provides the approximately 13.5 Mbps needed today to deliver a triple-play service with three video streams out to 6,000 feet or 7,000 feet.

Clearly, no standard xDSL technology provides the ideal "10 Mbps at 12,000 feet" solution today. Telcos must make trade-offs between bandwidth and distance. However, the industry is improving compression technology, which will enable MPEG-2 to run at lower encoding rates (2.8 to 3 Mbps, for example). Implementation and uptake of MPEG-4, which requires less than 2 Mbps per video stream, will also increase. Technology and pricing trends are converging to enable telcos to offer profitable video services.

By investing in a BLC access network today, telcos can immediately increase revenue by offering POTS and high-speed data services while at the same time positioning themselves to move quickly into the video market. Whichever DSL technology (or fiber, for that matter) a telco opts to use, the most important issue is to architect the RT to CO feeder delivery network to economically support the total bandwidth needed for all offered services.

Figure 5



From BLC RT to CO and Beyond

Between the RT and the CO, the BLC architecture transports all triple-play services as IP-based traffic over Ethernet. The architecture leverages key IP and Ethernet capabilities to support video transmission. IP is unicast by nature; to support multicasting, the Internet Engineering Task Force (IETF) has defined a number of multicast protocols.

Multicasting is based on the concept of a host group, which is a set of network hosts (in this case, the set-top boxes used by subscribers) that share a common multicast address. The originator of a multicast session, such as a video server, selects the multicast address to be used for a given transmission. Network hosts join and leave a multicast group using the Internet Group Management Protocol (IGMP). IGMP is also responsible for forwarding multicast traffic from a router to members of the multicast group. The BLC architechture supports IGMP in its BLC RT in the form of an IGMP proxy; that is, the BLC RT appears as a multicast router to the downstream set-top boxes and as a host to the upstream router or video server. By functioning as an IGMP proxy, the BLC RT streamlines multicast transmissions.

For example, when a set-top box requests to join a multicast group, the BLC RT intercepts the join request and checks whether it is already receiving that multicast session and whether the subscriber has access rights to the session. If so, then the BLC RT forwards that multicast channel to the subscriber line that requested it. If the BLC RT is not receiving a particular multicast channel, it forwards the join request upstream, where it is processed by the next BLC RT in the network, the BLC COT, or the head end, which then begins forwarding the requested multicast channel to the requesting BLC RT.

There are several advantages to having the BLC RT act as an IGMP proxy. Because the BLC RT handles multicasting, subscribers see a quick response to channel changes. For telcos, bandwidth is conserved throughout because individual video channels are only forwarded to those BLC RTs that need to distribute them downstream to subscribers. By conserving bandwidth, a BLC architecture allows more video streams to be carried over a given access network.

Figure 5 summarizes the transport and video-related protocols supported at each leg of traffic flow through BLC triple-play architecture. To ensure that video traffic gets the handling it needs for high-quality service, the architecture leverages both IP and Ethernet QoS mechanisms. BLC RTs and COTs perform fine-grained traffic classification, looking at source and destination address fields, IP source and destination ports, DiffServ code point (DSCP) markings, and other fields within a packet's header. Once the BLC RT orCOT determines what type of traffic is coming in on a given port—voice, data, or video—it marks each packet with a priority, using Ethernet 802.1p structures.

The BLC architecture has also mapped priority levels into service levels, creating strict priority profiles. For example, circuit emulation service is priority 7, VoIP is priority 6, and video is priority 5, with lower priorities allocated to data services. The BLC RT and COT queue and forward packets based on their priority marking, ensuring that each traffic type gets the level of handling it needs. At each priority level, each traffic source is policed per its SLA and the traffic shaped per network engineering parameters. In addition, the architecture uses VLANs to provide virtual separation and security between services. For example, broadcast video is carried in one VLAN, while data services destined to a given Internet service provider (ISP) is carried in another VLAN.

This QoS implementation is more flexible and less costly to manage than ATM QoS. For example, because ATM handles QoS on a virtual-circuit (VC) basis, ATM-based DSLAMs can only look at the VCI/VPI in determining QoS handling. VC-based QoS entails more management overhead than Ethernet-based QoS, resulting in higher management costs.

6. Conclusion

Telcos need to offer a combination of voice, data, and video services to remain competitive and build a greater long-term revenue stream. They must pick the right access network architecture for triple-play services delivery. Only Ethernet offers the scalable, low-cost bandwidth needed for mass-market consumption of broadband services. Only IP provides the efficiency for viable video and data services and enables the circuit-to-packet transition to softswitches—and an IP access network eliminates investment in costly, high-overhead ATM technologies.

Self-Test

1. The predominate threat to ILECs today is __________.

    a. Cable operators

    b. Economic climate

    c. Lack of available capital to invest in new technologies

    d. All of the above

2. In a BLC network, the traffic between the RT and COT is carried by ____________.

   a. Twisted copper pair lines

   b. ATM packets over PONs

   c. IP packets across fiber-based Ethernet links

   d. Virtual circuit switches

3. The BLC COTs connect to Class-5 switches via _______________.

   a. TR-08, GR-303

   b. H.323

   c. 803.11g

   d. None of the above

4. Video services such as VoD are unicast in nature.

   a. True

   b. False

5. Which primary transport protocol has a larger port volume?

   a. TDM

   b. SONET

   c. ATM

   d. Ethernet/IP

6. Residential customers need __________ to support triple-play services.

   a. 3–5 Mbps

   b. 6–10 Mbps

   c. 9–10 Mbps

   d. 8–11 Mbps

7. Telcos need to offer a combination of voice, data, and video services to remain competitive?

   a. True

   b. False

8. ADSL can deliver reliable throughput at 8 Mbps beyond 8,000 feet?

   a. True

   b. False

9. VDSL can deliver reliable throughput at 13 Mbps beyond 2,000 feet.

   a. True

   b. False

10. Residential and business customers can connect to a BLC deployed in an RT or CO via traditional interfaces, such as __________.

   a. Analog / POTS lines

   b. T1 / E1

   c. DSL connections

   d. All of the above

Correct Answers

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Glossary

Acronyms Guide

ATM
asynchronous transfer mode

BLC
Broadband loop carrier

CLEC
Competitive local-exchange carriers

CO
Central Office

COT
Central-office terminal

CWDM
Coarse wavelength division multiplexing

DSL
Digital Subscriber Line

DSLAM
DSL access multiplexer

ILEC
Incumbent Local-Exchange Carrier

IP
Internet protocol

POTS
Plain old telephone service

PSTN
Public Switched Telephone Network

RT
Remote Terminal

SONET
Synchronous Optical Network

TDM
Time Division Multiplexing

VC
Virtual circuit

VLAN
Virtual LAN

VoD
Video on demand

VPN
Virtual Private Network