Extending Asymmetric Digital Subscriber Line (ADSL) Services to Remote Digital Loop Carrier (DLC) Locations

Definition

Digital loop carriers (DLCs) consolidate the voice traffic of remotely located customers onto a few transport lines running back to the central office (CO), thus reducing the cost and space requirements of serving those customers. Asymmetric digital subscriber line (ADSL) technology is used to transport large amounts of data traffic over existing copper telephone lines—up to 8 Mbps downstream and 640 kbps upstream—while simultaneously supporting plain old telephone service (POTS).

Overview

This tutorial discusses the process of delivering ADSL services to remote end-users fed by DLC systems. With increasing suburbanization, areas outside urban centers are experiencing a rapid growth in both businesses and new residential communities. These new populations are prime candidates for high-speed data services such as ADSL. Therefore, as demand for high-speed data access grows, being able to cost-effectively deliver ADSL to these outlying areas, which typically receive their communications services via DLC systems, becomes increasingly important. Delivering ADSL to DLC–fed end-users is a difficult challenge to meet because ADSL does not work with DLC systems without some sort of infrastructure upgrade. However, solutions are being developed, and some of these are quite promising. This tutorial provides a brief background of the challenge of delivering ADSL to DLC–fed end users, as well as a number of ways this challenge is being addressed. The tutorial places particular emphasis on remote access multiplexer (RAM) solutions.

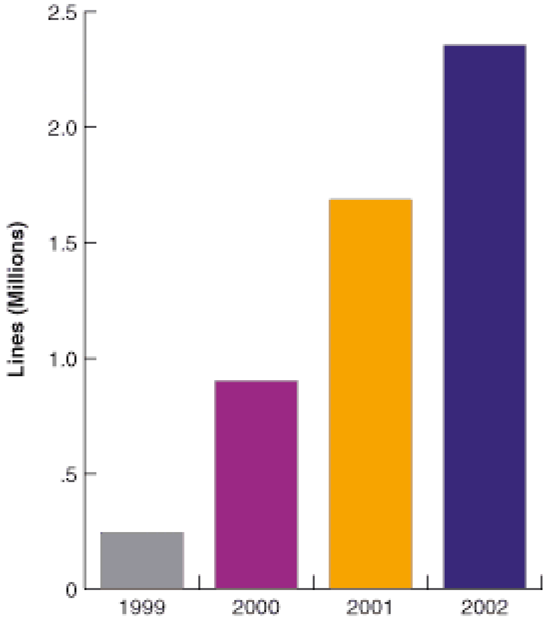
Topics

1. Market Demand: ADSL and DLC–Fed Customers

Two factors are currently driving development of ADSL solutions for remote end users served by DLC systems. First, a rising demand for data-intensive applications such as telecommuting, branch office connectivity, and residential Internet access is pushing the demand for ADSL generally. Second, rapid business and residential growth in the suburbs and other outlying areas has made DLC–fed customers a significant source of revenue for those providing communications services—as well as prime candidates for ADSL services.

ADSL has become popular with network-access providers for its ability to offer up to 8 Mbps data access, run over an existing copper-based infrastructure, support traditional POTS traffic, and reduce congestion by moving data traffic off the public switched telephone network (PSTN). As a result, most industry experts expect ADSL line deployments to grow at a steadily increasing rate over the next several years. In fact, TeleChoice projects the number of xDSL lines in the United States alone to grow from 39,000 at the end of 1998 to 248,000 by the end of 1999; 904,000 by the end of 2000; 1,687,000 by the end of 2001; and 2,355,00 by the end of 2002.

Figure 1. U.S. xDSL Line Deployment, 1999–2002



Source: TeleChoice

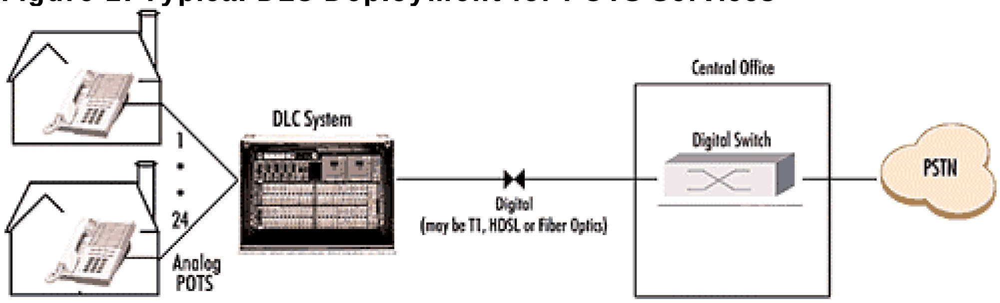
A significant, and perhaps critical, portion of this growth will occur in businesses and residences served by DLC systems. DLCs are deployed in remote locations, such as suburbs and new business complexes, to consolidate multiple user lines onto a few transport lines running back to the CO, reducing the cost and space requirements of serving those customers. Significantly, these outlying locations are growing much faster than urban areas and, in fact, are becoming home to just the kind of user communities ADSL providers are likely to target: new residential developments populated by families with disposable income, telecommuters, branch offices, business parks, and the like. As a result, although it is generally estimated that around 20 percent of all end users currently receive their communications services through DLC systems, it also is likely that ADSL services to the DLC–fed population may well account for significantly more than 20 percent of new ADSL deployment. Having an infrastructure in place to provide ADSL services to DLC–fed end users is therefore of critical importance.

2. The Challenge: Why Traditional DLCs and ADSL Do Not Mix

Unfortunately, traditional DLC systems do not support ADSL solutions. Legacy DLC systems, designed primarily to provide high-quality voice services, have significant constraints that prohibit their ability to support the amount of bandwidth demanded by ADSL. And although newer generation DLCs typically offer greater access to bandwidth at the line-card level, they are not ideally engineered for data services either. For instance, loading these systems up for ADSL can seriously constrain the DLC's capacity for POTS.

The bulk of DLCs presently deployed are legacy DLCs; systems designed before the early 1990s outnumber newer generation DLCs four to one. The earliest of these systems were designed in the 1970s, when a network access provider's sole focus was to provide high-quality voice services. DLCs are still used today to support customers located remotely from the CO by combining multiple voice channels together onto a few transport lines running back to the CO, typically multiplexing twenty-four subscribers onto a single T1 line. This DLC use allows network access providers to save both time and money, because fewer and smaller cables are required to expand services. DLCs also make the task of serving growing business and residential areas quicker and easier by eliminating the need to design and build an entirely new telecommunications infrastructure.

Figure 2. Typical DLC Deployment for POTS Services

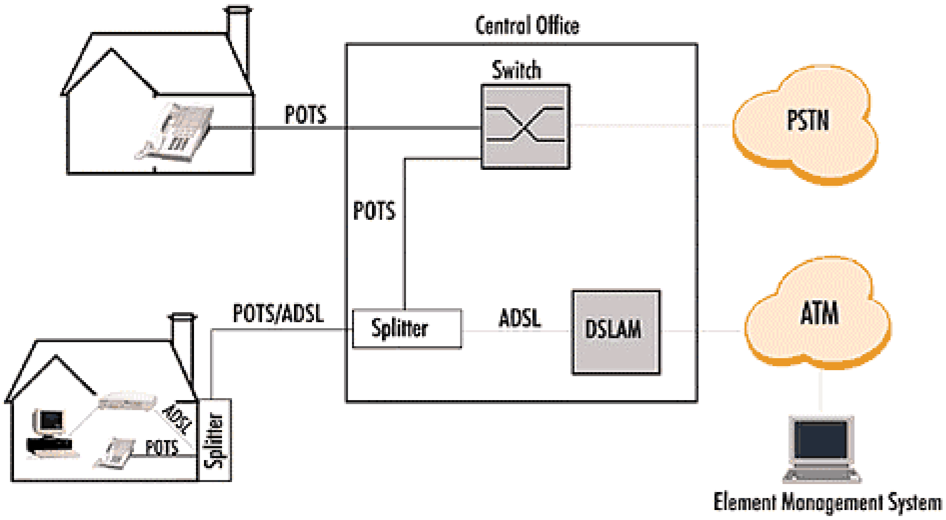


DLC deployment allows the multiplexing of 24 subscribers onto a single DS–1. DLC line sizes vary from approximately 24 to more than 1,000 lines, depending on the type and size of the DLC.

In order to transport voice traffic between end-user telephones and digital-switching equipment in the CO, DLCs also must convert analog signals into digital ones and vice versa. The DLC must sample analog voice signals at a rate of approximately 8,000 times per second to translate them properly into digital signals, and each sample must be converted into eight bits of information. Hence individual subscriber interfaces of legacy DLCs can handle only up to 64 kbps (or 8 bits/sample x 8,000 samples/second). In addition, their basic structure (i.e., backplane, common units, etc.) does not allow the entire DLC to support bandwidth beyond a single T1 (1.54 Mbps, or 64 kbps/circuit x 24 circuits/digroup).

ADSL, by contrast, involves the transmission of information at speeds of up to 8 Mbps, far more bandwidth than what DLCs are designed to handle. ADSL was developed in 1989 in Bell Labs, ostensibly for the purpose of supporting video services over ordinary copper wires. Today, ADSL is widely regarded as the primary technology for handling a range of data-intensive applications such as telecommuting and high-speed Internet connectivity.

Figure 3. Typical ADSL/POTS Deployment from a Central Office (Home-Run Applications)



ADSL uses the existing copper infrastructure to transmit both POTS and ADSL data traffic over the same copper pair. However, as a result of the large amount of data that must be transmitted, ADSL solutions are not naturally supported by legacy DLC systems. ADSL services are typically deployed by installing a digital subscriber line access multiplexer (DSLAM) in the CO. The DSLAM facilitates the transmission of ADSL data traffic between ADSL customer-premises equipment (CPE) modems and a wide-area network (WAN). The DSLAM cannot send traffic directly to the modems of DLC–fed customers, however, because the customers are connected to the CO through the DLC. Nor can the DSLAM send ADSL traffic through the DLC, because 8 Mbps, or even 1.54 Mbps, per subscriber, is too much data for the DLC to handle.

In addition, while newer generation DLCs do provide greater access to bandwidth at the line-card level, using newer generation DLCs with ADSL line cards can place serious constraints on POTS traffic, in addition to introducing other, nonbandwidth-related problems. *Topic 5* discusses these issues in more detail.

3. Solution Options: Overview

Vendors have devised several ways to meet the challenge of providing ADSL to DLC–fed end users. Among the most notable ones are the following:

- remote DSLAM solutions
- ADSL line-card solutions

- RAM solutions

Each of these options has its own set of advantages and disadvantages. Remote DSLAMs, for instance, are highly scalable but also present high installation costs. By contrast, line-card solutions are much more cost-effective, but often introduce serious administration problems and constrain the DLC's capacity for POTS. Among the three, perhaps RAM solutions exhibit the most promise, combining the strengths of the other two solutions, while minimizing the drawbacks.

The next three topics explore these options in more detail, discussing both the advantages and disadvantages of each solution.

4. Remote DSLAM Solutions

Remote DSLAMs are exactly what the name implies. The CO–based DSLAM is environmentally hardened and placed inside a cabinet, which can then be installed in the field, typically close to the existing DLC cabinet. From there, the remote DSLAM negotiates the transmission of ADSL data traffic between the ADSL CPE modems and a WAN. Remote DSLAMs also can be rack mounted in huts or controlled environment vaults (CEVs).

Advantages

- Remote DSLAMs are useful for serving large numbers of ADSL subscribers. They scale easily, usually by adding line cards into a chassis. For instance, a typical remote DSLAM can serve 60 to 100 ADSL lines.

- Because element management of a remote DSLAM used in the provisioning and monitoring of ADSL lines is similar to that of a CO–based DSLAM, it requires no additional management systems or training for network-operations personnel.

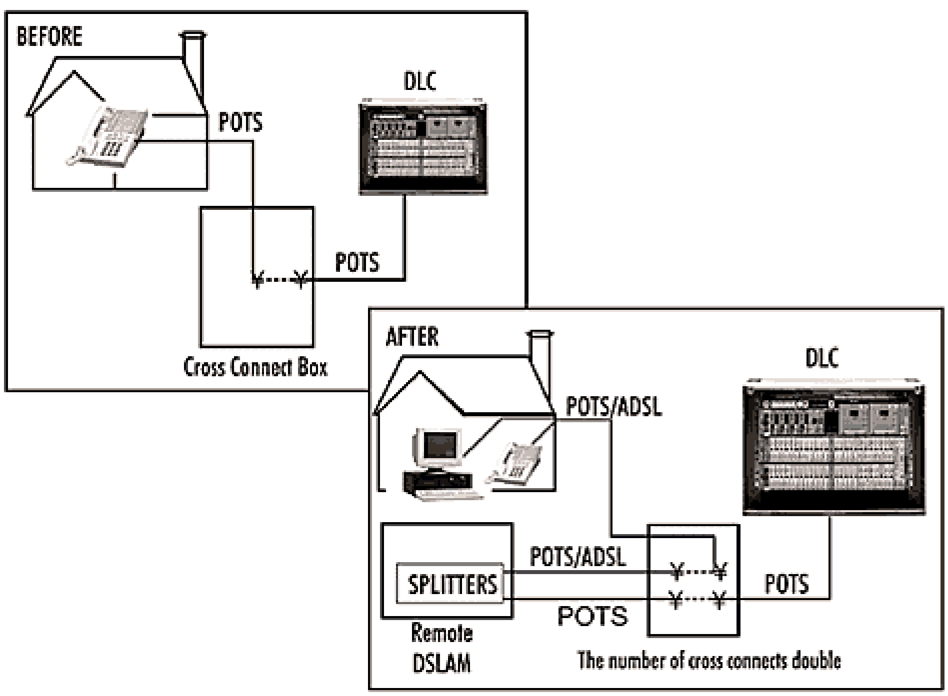
- Remote DSLAMs can be used with any DLC system with no impact on POTS service because remote DSLAMs are independent from the deployed DLC system. The remote DSLAM simply splits POTS traffic off and sends it back to the DLC while in its analog form.

Disadvantages

- A remote DSLAM can be an expensive solution. Because the remote DSLAM is external to existing DLC cabinets, installation requires that the network-access provider obtain a right of way, pour concrete for a pad, install the cabinet, power the electronics, and deploy wiring to and from the existing DLC. As a result, the initial investment in both time and money is quite significant. Although this investment can easily be amortized over a large number of subscribers, the fact that ADSL is in its infancy means that initial take rates typically cannot cost justify this level of expense. Furthermore, in small-line-size DLC environments where the potential number of subscribers is limited, a remote DSLAM may never be cost justified.

- Remote DSLAMs also can impose significant problems concerning the size and configuration of cross-connect boxes. Typically, a network-access provider places one or more cross-connect boxes close to the DLC cabinet where all the subscriber tip-ring pairs are cross-connected to the tip-ring pairs going to the remote terminal cabinet. Because ADSL service can ride over the same pair of copper wires as POTS service, rerouting at least some of the pairs is required. Specifically, the pairs carrying ADSL/POTS traffic must be routed to the remote DSLAM where the POTS and ADSL signals are split. The POTS traffic must then be routed back to the cross-connect for connection to the DLC cabinet.

Figure 4. Cross-Connects Before and After Remote DSLAM Deployment



A problem often arises with these cross-connect configurations because cross-connect boxes are usually designed to support the number of pairs the DLC supports, with only limited spares. Thus, with the additional cross-connections needed to support the remote DSLAM, it may be necessary to add cross-connects or resize the existing ones. The situation is compounded further in cases where remote terminals have incorporated the use of multiple cross-connect boxes, because there is no way to forecast realistically which subscribers will want to add ADSL services.

Therefore, although remote DSLAMs offer the greatest flexibility for the largest number of subscribers, they also require considerable up-front financial and engineering commitment if they are to be seriously pursued as an option.

5. ADSL Line-Card Solutions

Another solution is the use of line cards that fit into open slots in existing DLC systems. Line-card solutions generally take one of two forms. In one, the channel bank is used only for mechanical stability and all connections are made through cables. This type of configuration is typical of legacy DLC systems. In the second, the line card is an integrated piece of the DLC operation. The ADSL traffic and the voice traffic share the same backplane, are aggregated by the system, and may share the same transport facilities back to the CO. Typically, integrated line-card solutions represent the approach of newer-generation DLC systems.

Advantages

- The primary advantage of line-card solutions is that they take advantage of unused card slots inside the DLC. In this way, many of the costs associated with remote DSLAM solutions, stemming from such things as external building, installation, and powering, are eliminated.

- In addition, integrated line-card solutions can virtually eliminate the need for any cabling or rewiring within the cabinet.

Disadvantages

- Line-card solutions introduce significant administration problems in cases where network-access providers have DLCs from different vendors. In such cases, network-access providers are forced to perform the cumbersome task of matching up proprietary CPE modems and proprietary line-card solutions developed by their various DLC vendors. This is a serious issue in today's ADSL environment, where interoperability simply does not exist. A number of groups, most notably the Universal ADSL Working Group (UAWG), have made significant efforts to obtain interoperability with respect to G.Lite, but unfortunately full-rate interoperability is still lagging. Therefore, currently the selection of the ADSL chip set used on the ADSL line card entirely dictates the type of CPE modem that can be used at the end-user location. As a result, any line-card solution necessitates the administration of compatible modems at customer-premises sites. For almost all network-access providers that deploy multiple types of DLC systems with different proprietary ADSL line-card solutions, this task can become cumbersome or even impossible. In addition, in many of the regional Bell operating companies (RBOCs), the unregulated side handles the modems and the regulated side handles the delivery of the ADSL service, which further exacerbates the issue of matching modems to the means of delivery.

- Because line-card solutions use card slots, filling these slots with ADSL line cards impacts the network-access provider's ability to expand other services in the future. Typically, the decision regarding the size and type of DLC cabinet deployed was based on a growth plan. Using a line-card solution that fills up slots with ADSL line cards therefore impacts the network-access provider's ability to provide additional POTS services. This becomes an even greater issue if and when subloop unbundling becomes a reality. In this case, transport back to the CO may be shared with voice traffic, further complicating the determination of cost and priority of service in subloop unbundling applications.

- The problem with multiple DLC vendors discussed above also introduces complications with regards to training and network management. Each separate ADSL solution raises separate training issues concerning installation and turn-up. Additionally, each vendor providing an ADSL solution will require a separate element-management system (EMS) for provisioning and monitoring. Multiple DLC vendors, each providing a separate line-card solution, will require multiple EMSs, each with its own unique interface. As a result, training, support, and integration into any upper-level operations support systems (OSSs) for each EMS must be considered.

- Line-card solutions that use the DLC chassis for mounting (as opposed to an integrated solution) may require significant rewiring of the DLC. The extent of this rewiring depends on the particular vendor and solution deployed.

- Finally, restrictions regarding the placement and quantity of line cards that can be installed in a DLC also are typically involved, further increasing the engineering requirements associated with the solution.

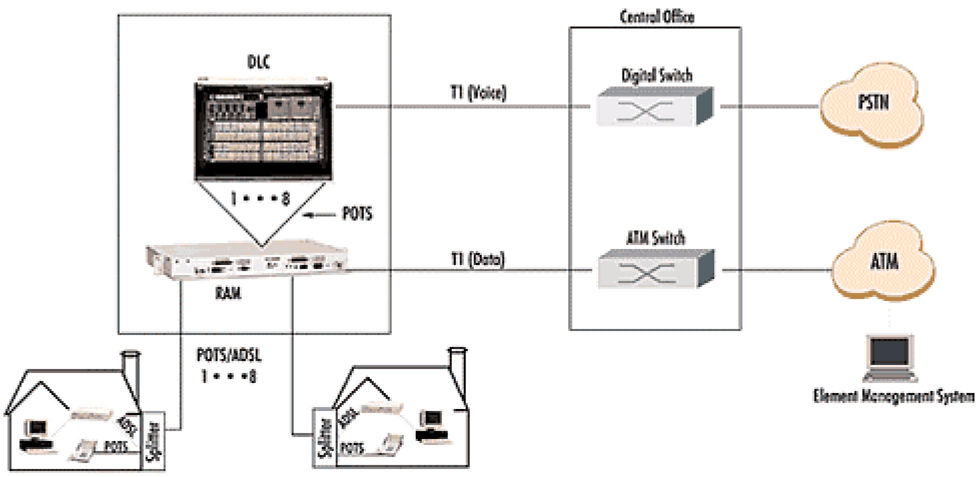
In summary, although line-card solutions do avoid many of the cost issues inherent in remote DSLAM solutions, they introduce a host of other problems. Line-card solutions bring into play a series of administrative, training, and management issues arising from the need to juggle various, incompatible systems. In addition, they can add significant constraints to the DLC's capacity from a POTS perspective.

6. Remote-Access Multiplexer Solutions

A RAM performs much the same functionality as a remote DSLAM, but a RAM integrates into existing DLC environments without the need for a costly infrastructure upgrade. In fact, RAMs, often called pizza boxes or cigar boxes because of their small physical size, are designed primarily for deployment inside DLC cabinets. These types of devices have been used successfully to add integrated services digital network (ISDN) services in DLC environments.

Today's RAMs combine many of the advantages of both remote DSLAM and line-card solutions, while avoiding many of the disadvantages.

Figure 5. Typical RAM Deployment



Advantages

- Like remote DSLAMs, RAMs are independent from DLC systems, giving them the flexibility to work with any DLC system without impacting POTS capacity. This independence also means that RAMs avoid the problem of multiple DLC vendors associated with line-card solutions. A RAM requires only a single EMS for management and administration of only one type of CPE modem.

- Like line-card solutions, the RAM is housed inside a DLC cabinet, thus avoiding the serious cost and rewiring issues inherent in remote DSLAM solutions. With a RAM, there are no rights of way, powering, or cross-connect issues to deal with. Typically, a RAM requires only a minimal amount of cabinet rewiring. In addition, the RAM lends itself to other deployment alternatives, such as deployment within an adjunct cabinet (a small cabinet that attaches to the side of an existing cabinet) if the existing cabinet is filled with equipment.

Disadvantages

- The main issue with RAMs is scalability. Currently RAMs are best suited for small line sizes, meaning that as more lines are required, more RAMs must be installed into the cabinet. On a case-by-case basis, the space available in the cabinet will determine whether or not scalability is an issue. At the same time, it should be noted that the scalability issue is being aggressively addressed with newer, denser RAMs that take advantage of digital signal processor (DSP) technology to share ADSL transceivers.

In conclusion, RAMs succeed in providing a low-cost solution for extending ADSL services to remote end users fed by DLC systems. Their prime advantages are cost-effectiveness and ease of deployment. At the same time, RAMs provide a universal solution that works with all DLC systems, thus avoiding the administrative, training, and management issues inherent in line-card solutions.

7. RAM Deployment Considerations

Just as a network-access provider must assess its individual infrastructure and deployment considerations when choosing among the various remote DSL access solutions, so too must a network-access provider who opts for a RAM solution consider how different RAMs might meet its unique requirements. It is important to realize that not all RAMs are identical. The following key factors should be kept in mind when considering the deployment of a RAM solution.

Physical Size / Line Size

RAM size raises several significant issues. On the most basic level, it is important to note that RAMs come in various sizes. In addition, the number of rack units the RAM requires may be limited not only by the physical dimensions, but also by any space requirements for heat dissipation. Finally, the ability to stack RAMs in 23-inch racks may differ from the ability to stack them in 19-inch racks. Ultimately, it is probably safest to look for a small-sized RAM to provide maximum deployment flexibility and ease.

POTS Splitters

Offering both ADSL data access and POTS requires POTS splitters. If these POTS splitters are not incorporated into the design of the RAM, they will require additional cabinet space and design effort. For this reason, integrated POTS splitters are desirable. In addition, the design of the splitters should be passive to prevent any failure of the ADSL circuitry from impacting lifeline POTS.

Cabling Requirements

It is important to know that any RAM must obtain access to the tip and ring pairs. Either this access must occur after the primary protection, or the RAM itself must provide that primary protection. When selecting a RAM, therefore, the amount of cabinet rewiring, the associated down-time of the POTS traffic, and the operational impact on other subscribers must be considered.

Craft Interface

Ideally, RAM installation and turn-up will not require the installer to have ADSL knowledge. DLC craft interfaces, such as T1 access and go/no-go light emitting diodes (LEDs), will significantly reduce training requirements. The network-access provider should even review the types of connectors and cables provided for any special tool requirements.

Transport

Transport back to the CO can be performed in two ways: (1) it can be proprietary and require termination on a DSLAM, or (2) it can be a standard transport method such as a digital service level 1 (DS–1) user-network interface (UNI). Requiring termination on the DSLAM will use up available ports on the DSLAM. By contrast, standard interfaces allow for more options such as termination directly onto an ATM switch, aggregation in a concentrator, or, in many cases termination on other vendors' DSLAMs. The advantage of a standard interface is that it does not require a DSLAM and that it offers flexible options for terminating transport.

Modem Interoperability

Because interoperability between ADSL chip sets does not exist today at the full-rate level, RAM compatibility with CPE modems should be considered, as should the RAM's ability to support G.Lite. In addition, the capability of upgrading via software download will provide interoperability that will help enable the RAM to grow with the ADSL market.

Element Management

Any RAM will require some form of element management. Consequently, compatibility with existing platforms, graphic user interface (GUI), interfaces for integration into higher-level network-management systems (NMS), and general ease of use, should be reviewed carefully. Typically, costs associated with an EMS are based on the number of lines it supports. For this reason, it is important to understand the total cost of usage.

Self-Test

1. Suburban populations are prime candidates for high-speed data services such as ADSL.

    a. true

    b. false

2. Traditional DLC systems easily support the bandwidth associated with ADSL.

    a. true

    b. false

3. RAM solutions enable vendors to provide ADSL from an existing DLC cabinet in a cost-effective way.

    a. true

    b. false

4. Which remote ADSL solution requires high take rates (many subscribers) to be cost-effective?

    a. remote DSLAMs

    b. ADSL line cards

    c. RAMs

5. Line-card solutions are beneficial in that the same card may be used in any DLC system.

    a. true

    b. false

6. Which of the following is not a characteristic of remote DSLAM solutions?

    a. useful for serving very large numbers of ADSL subscribers

    b. use the same network-management system as the CO DSLAM

    c. can be used with any DLC system with no impact on POTS

    d. low level of expense associated with installation

    e. scale easily by adding line cards

7. Which of the following is not a characteristic of ADSL line-card solutions?

    a. low level of expense associated with installation

    b. may impact the network-access provider's long-term ability to provide additional POTS

    c. compatible with all CPE modems

    d. take advantage of unused card slots inside the DLC

    e. easily scalable

8. Which of the following is currently not a characteristic of RAM solutions?

    a. ability to be housed in a DLC cabinet

    b. small physical size

    c. low installation costs

    d. ease of deployment

    e. scalability to very large line sizes

9. Some key factors to consider when deploying RAM include all but which of the following?

    a. how to make the RAM independent from DLC systems

    b. size of the RAM

    c. incorporation of POTS splitters into the design

    d. compatibility with CPE modems

    e. element management

10. Which of the following statements is true of the three solutions presented?

    a. ADSL line-card solutions do not impact the network's future ability to provide POTS

    b. a remote DSLAM does not have high installation costs

    c. RAMs work with any DLC system without impacting POTS capacity

    d. RAMs require the installation of a new cabinet

    e. a single line-card solution can work across multiple DLC systems

Correct Answers

1. Suburban populations are prime candidates for high-speed data services such as ADSL.

    a. true

    b. false

    See Topic 1.

2. Traditional DLC systems easily support the bandwidth associated with ADSL.

    a. true

    b. false

    See Topic 2.

3. RAM solutions enable vendors to provide ADSL from an existing DLC cabinet in a cost-effective way.

    a. true

    b. false

    See Topic 6.

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    See Topics 6 and 7.

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    d. RAMs require the installation of a new cabinet

    e. a single line-card solution can work across multiple DLC systems

    See Topics 4, 5, and 7.

Acronym Guide

ADSL
asymmetric digital subscriber line

CEV
controlled environment vault

CO
central office

CPE
customer-premises equipment

DLC
digital loop carrier

DS–1
digital service, level 1

DSLAM
digital subscriber line access multiplexer

DSP
digital signal processor

EMS
element-management system

G.Lite
DSL–Lite

GUI
graphical user interface

ISDN
integrated services digital network

LED
light-emitting diode

NMS
network-management system

OSS
operations-support system

POTS
plain old telephone service

RAM
remote access multiplexer

RBOC
regional Bell operating company

UNI
user-network interface

WAN
wide-area network