



# Digital Loop Carrier (DLC)

## Definition

The local loop is the physical connection between the main distribution frame in the user's premises to the telecommunications network provider. Digital loop carrier (DLC) technology makes use of digital techniques to bring a wide range of services to users via twisted-pair copper phone lines

## Overview

The telecommunications infrastructure has undergone a great deal of change recently, and it seems that the rate of change increases exponentially as time passes. For example, DLC technology and the local loop will become more important in the future in delivering the new services that customers will require. This tutorial first addresses the history of subscriber carriers because it is important in providing clues to the future. It will then discuss some of the early next-generation digital loop carriers (NGDLC) that began to appear in the 1980s, as well as the NGDLC as a cost-effective solution for suburban and rural applications. Finally, it will explore the likely direction that loop technology will take in the future and how to enable the market for some of the more advanced services that are expected.

## Topics

1. History of Subscriber Carriers
2. Early Next-Generation Digital Loop Carriers
3. Next-Generation Digital Loop Carriers for Rural and Suburban Applications
4. NGDLC Applications
5. Future Directions
6. Economics
7. The Multiservice DLC

Self Test

Answers

Acronym Guide

# 1. History of Subscriber Carriers

The history of subscriber and loop carriers is based on the initial deployment of loop electronics, which was driven primarily by transmission needs (i.e., trying to obtain better-quality transmission over longer distances). Hence, deployment was not very economically influenced, nor was there much emphasis on pair-gain capabilities. There were a small number of lines and relatively few subscribers. The line subscribers, typically, were at extended distances from the central office, with no way to receive high-quality service. Some of the early subscriber carriers were actually just analog devices intended to extend service and deliver improved voice quality.

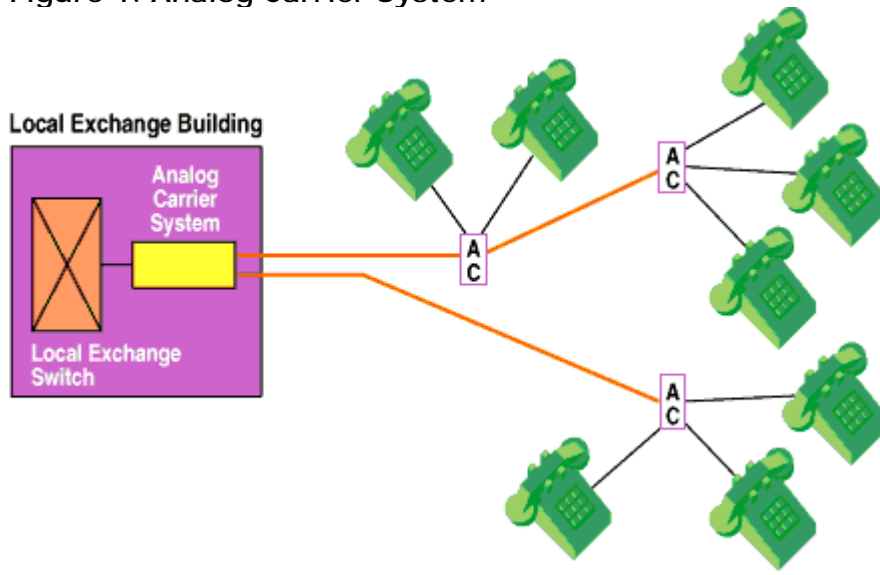
## Analog Carrier Systems

Almost every aspect of the analog carrier system was based on 1960s technology—the advent of electronics. The main driver was greatly improved voice quality over long distances. There were some modest pair-gain capabilities: up to four to one. But that was not the key element of the system. Furthermore, there were downsides to the old analog-carrier subsystems: maintenance was difficult, and quality was inconsistent. Basically, once the analog carrier was working, it was fine, but it was not easy to get it working correctly.

The analog carrier architecture was fairly simple. It consisted of an analog box deployed on the subscriber side. There was little need for many special services, and so there was minimal demand for the architecture to support them. On the network side, plain old telephone service (POTS) was analog, and this is what made the network difficult to maintain, set up, and make operational. But the system served its purpose in delivering high-level service to small numbers of subscribers when they were at distances greater than the central office could serve.

*Figure 1* depicts a typical example of the old carrier system.

Figure 1. Analog Carrier System



The analog box where the multiplexing took place was set in the central office. Signal was carried over the existing copper cable, and there were wall-mounted devices positioned close to the customer's service drop. There were usually two or three—and sometimes as many as eight—subscribers. But the system was difficult to get working, and it certainly would not be acceptable for the coming future.

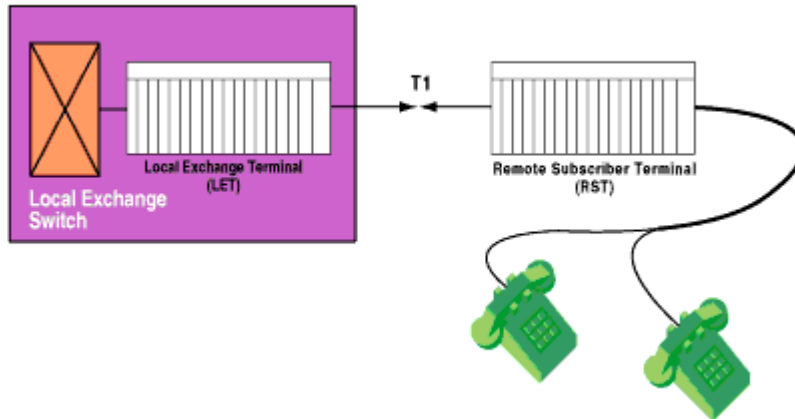
## Digital Loop Technology

The early 1970s brought digital loop carrier technology. This new type of carrier was based on digital-technology electronics, and it aimed for the performance benefits of digital transmission. It offered the voice-quality upgrade that subscribers were looking for. In essence, the new system was economically driven. There were significant pair-gain capabilities, usually 12 to 1. It was more feature-rich than the old analog carrier system and capable of deploying some of the newer services such as digital data service (DDS) and some of the analog specials. But more importantly, it was more reliable, easier to install, and easier to maintain.

The architecture of the new system was not very different from the analog system—it is just based on digital technology. On the subscriber side, there was, again, analog POTS along with DDS and a TR57-type suite of electronics. The network side typically was digital, which allowed for the pair-gain capabilities.

*Figure 2* shows a universal DLC configuration.

Figure 2. Universal DLC Configuration  
Local Exchange Building



There is a central office terminal or a local exchange terminal near the subscriber. A remote subscriber terminal could usually pick up 1 to 96 lines. A good example of this is the old 96-type carrier system, in which T1 carrier electronics between the terminals provided the pair-gain benefit. In addition, it was very economical to deploy.

## 2. Early Next-Generation Digital Loop Carriers

The 1980s brought the advent of the next-generation digital loop carrier (NGDLC), which is now common. The NGDLC was based primarily on very-large-scale integration (VLSI) technology, so it took advantage of many of the electronics enhancements that computers were driving. That technology began to be integrated into the local loop and resulted in very cost-effective electronics. It was used primarily as a service-delivery tool. ISDN was the buzzword then—many of the NGDLC architectures were actually designed to be able to deploy ISDN to every single customer. Although that need did not materialize, it was still a good system for delivering high bit-rate services such as T1, ISDN specials, and DDS.

As far as transport on the network side, most of these systems were designed for fiber. So, the key element as far as deployment of this system was concerned was making sure that fiber ran between the central office and the remote subscriber's terminal. Unfortunately, that was not always the case. Nonetheless, if fiber was in place between the two locations, this was a very good system and the intent was to serve large numbers of customers.

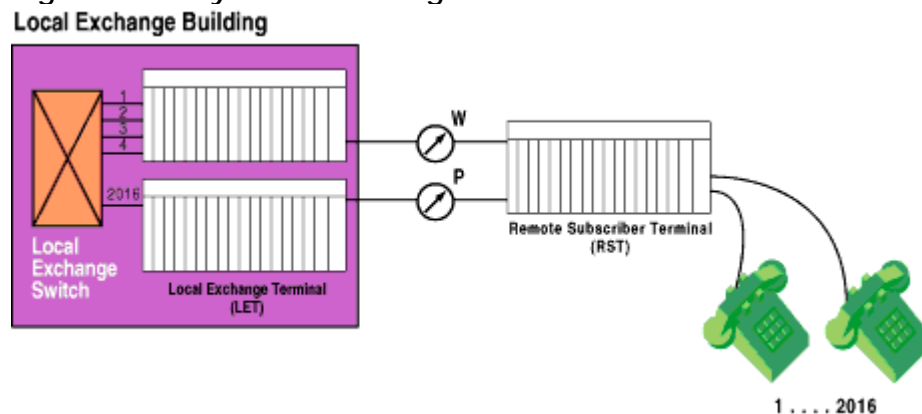
Early NGDLC was optimized for high concentrations of subscribers, up to 2000 lines. As with the previous carrier system, this system was economically driven. The key was to connect high concentrations of subscribers over fiber very

economically. The system aimed at advanced services distributed over wide areas, which was the important downfall of this type of device. Another important feature enhancement of this device was software-based remote provisioning. It became the de facto standard that as one wanted to increase service capacity or change services, everything had to be software downloadable. Finally, early NGDLC had a time-slot interchanger. This is a key aspect of the cost-effectiveness of the technology.

This architecture builds on earlier ones. On the subscriber side, it carried a host of analog services: analog POTS and private line; DS-0 switch 56; DS-1/E1; ISDN basic-rate and primary-rate interface; analog specials; DDS, and subrate data. All of those services were important factors in deploying this type of system. On the network side, the system was typically fiber. Eventually, some of the systems migrated to copper because it became apparent that fiber was not always available in those types of network pathologies. So, the primary interface on the network side was generally OC-1 or OC-3. Later there was some nxT1/E1 and digital-transmission capability over copper.

*Figure 3* shows a typical network architecture of an early NGDLC configuration.

**Figure 3. Early NGDLC Configuration**



There was a central office terminal which was typically a large device—it contained a whole shelf worth of common control. The fact that there had to be an investment in the shelf of common control in order to get the first subscriber up and running made the system less cost-effective than was ideal at low line sizes. It was, however, very cost-effective at high numbers of subscribers. A remote terminal would be deployed close to a heavily populated area and the plan was to serve about 2,000 subscribers in order to obtain the maximum benefit.

### 3. Next Generation Digital Loop Carriers for Rural and Suburban Applications

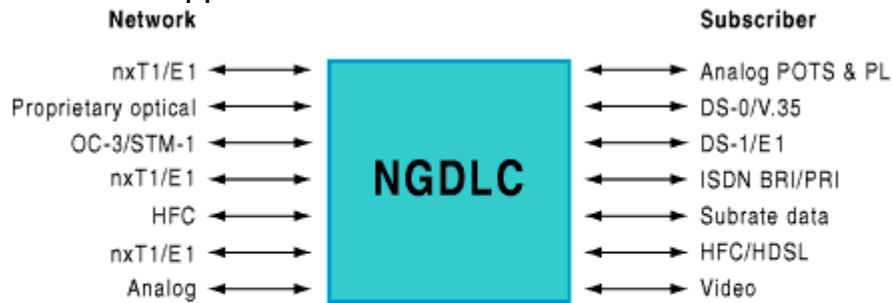
NGDLC is the market where Advanced Fibre Communications (AFC) entered the local loop access industry. Some of AFC's founders had a rich history in the digital loop carrier business and the next generation loop carrier business. Almost immediately, they realized that fiber was not ubiquitous in the infrastructure. In fact, fiber is rare and inconsistently used from place to place. Sometimes there are T-carriers; sometimes not even that, and other times there is no infrastructure at all. This understanding was the basis for the NGDLC for rural and suburban applications.

The NGDLC for rural and suburban applications uses 1990s technology to take advantage of the newly developed power of computing and integrated-circuit technology. It is heavily based on software control and intelligence. A carryover from the last product, it is used as a service-delivery tool, and the most important attribute of this type of system is the fact that it is designed for mixed-media transmission. Media migration is made simple: the system takes advantage of whatever infrastructure is in place, whether T carrier, analog, fiber, or coax. In achieving that simple migration, the network offers a very economic solution for low to moderate concentrations of subscribers.

The common control remains low. NGDLC offers low common control and flexibility. Another one of the keys in this type of technology is a dynamic time-slot interchanger, although this is not widely used. As yet, many customers do not have the proper billing processes in place to accommodate it. The fault does not lie within the ability of the electronics to peel subscribers off, but rather in the company's ability to bill them. The last key element of this type of system is its mixed-network architecture. That is, it is not based on a point-to-point or ring architecture but rather on a mesh topology using the infrastructure that is in place. This is helpful, as most housing developments do not develop in rings—they develop in mesh topologies. The ability to overlay the electronics on top of that network topology is key to the success of this system.

*Figure 4* lists the range of services that such systems offer.

Figure 4. Next Generation Digital Loop Carriers for Rural and Suburban Applications



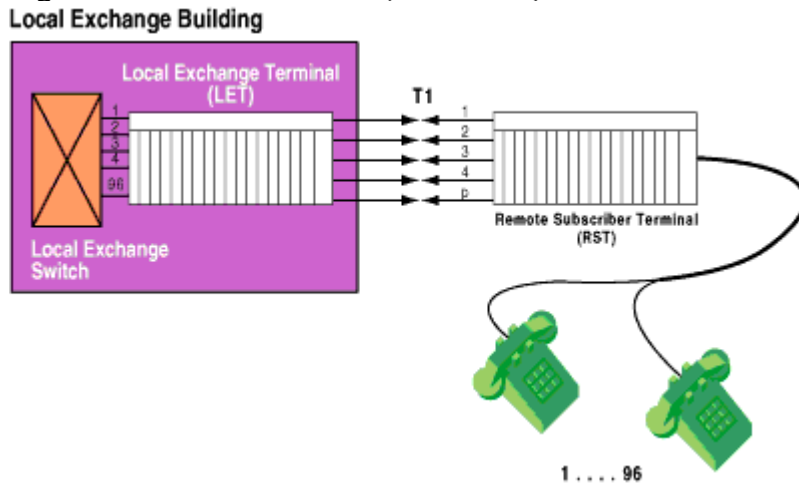
The demand is higher than ever for more services and more bandwidth. Although analog POTS and private line must be covered just as cost-effectively as ever, the infrastructure must be put in place to carry some of the higher bit-rate services: ISDN, subrate data, and more T1 services, along with HDSL/HFC to corporate locations. On the network side, nxT1 or E1 are usually used. What is different from the previous architecture is that NGDLC has the ability to take advantage of any of the network infrastructure that is in place, whether it be HFC, coaxial fiber, OC-3, or proprietary optical.

## 4. NGDLC Applications

Given that NGDLC can effectively utilize any number of available networks, what are the important applications for this type of system? First and foremost is DLC emulation because many customers still have analog carriers, and they want to install an infrastructure that will support some of the broader-band services being developed without paying up front for that capability. They still want to be able to deploy POTS very cost effectively.

*Figure 5* shows a system for universal DLC emulation in which POTS lines can be picked up off the central office switch.

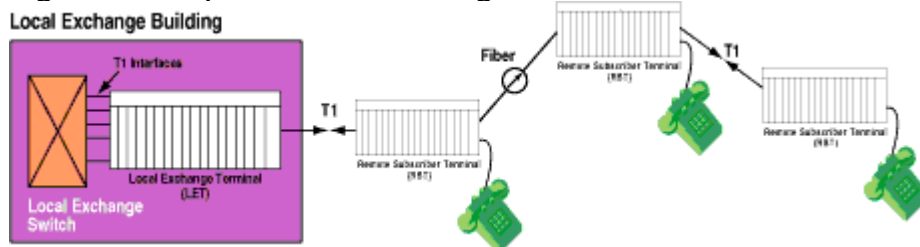
Figure 5. DLC Emulation (Universal)



It does not require much modification for this system to support the old integrated TR08 with just a stand-alone terminal. It is probably not the most cost-effective way to deploy one of these systems, but those types of applications must be supported.

More important is the ability to drop and insert; that is, to fit the network topology that actually exists today instead of trying to make the network fit the architecture of the system being applied. *Figure 6* again shows a central-office terminal that could use T1 interfaces or analog.

Figure 6. Drop and Insert Configuration



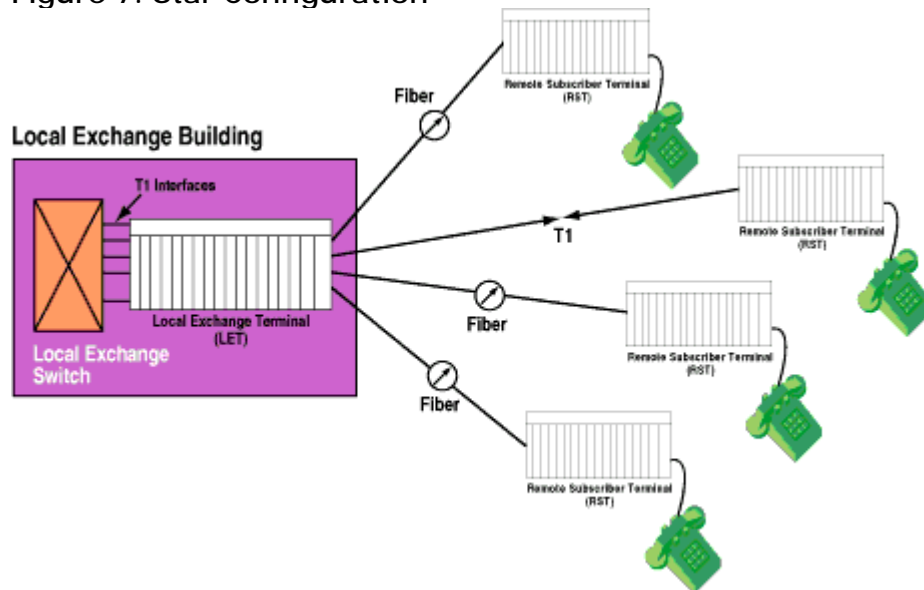
The essential aspect is a drop-and-insert configuration. Notice that the connection between the central office terminal and the first remote subscriber terminal happens to be T1. This customer did not have fiber between the first two terminals, only T1. Because it is very expensive to upgrade that network fiber, it is important to be able to use the media that is in place.

There is fiber between the second and third terminals. Between the third and fourth terminals is actually T1 again. Moving deeper in the network, it is less likely that there will be fiber deployment. The key to this type of architecture is to use whatever infrastructure exists. Being able to operate in a mixed configuration such as this is what makes the system economical to deploy.



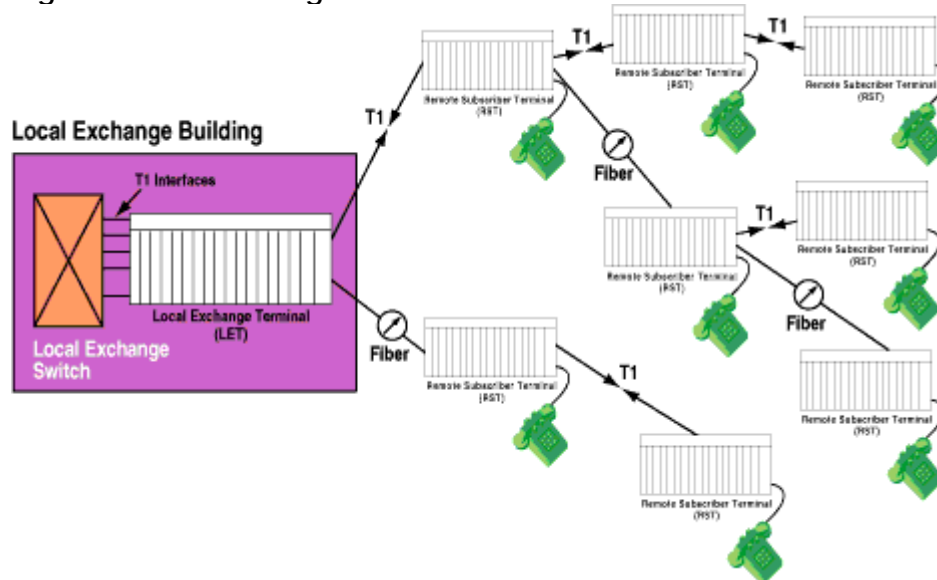
Another typical configuration being deployed by customers is a star topology, represented in *Figure 7*.

Figure 7. Star Configuration



In this case, there are remote subscriber terminals configured in a star shape off of the central-office terminal, and the facilities that must be used would be T1, fiber, HDSL, or coax. Finally, *Figure 8* represents what most network topologies look like.

Figure 8. Tree Configuration

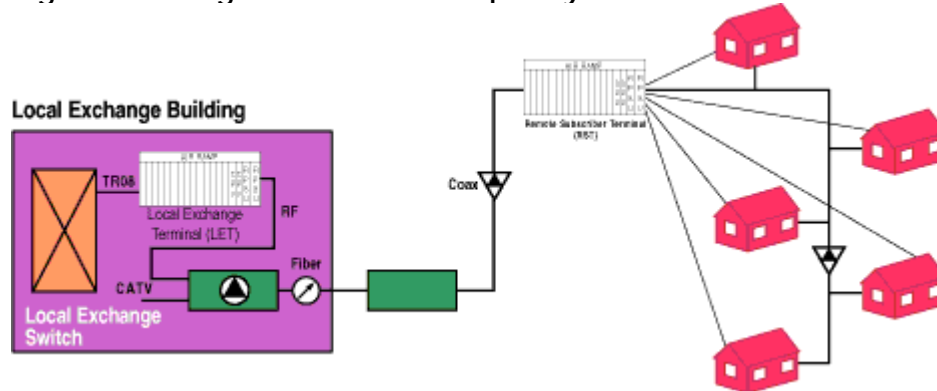


It is actually a tree- or mesh-type architecture, not a ring, and is a mixture of the drop-and-insert and the star topologies discussed above. There is a central-office

terminal, and between terminals there could be T1, HDSL, fiber, or coax, depending on what is in place in the network. All of those services are connected back into the central-office terminal. They can be brought into the switch either via T1, analog, or maybe even routed to another location. All of that capability must be available in this type of system to make it cost-effective.

*Figure 9* shows an example of an integrated video/telephony point-to-point architecture.

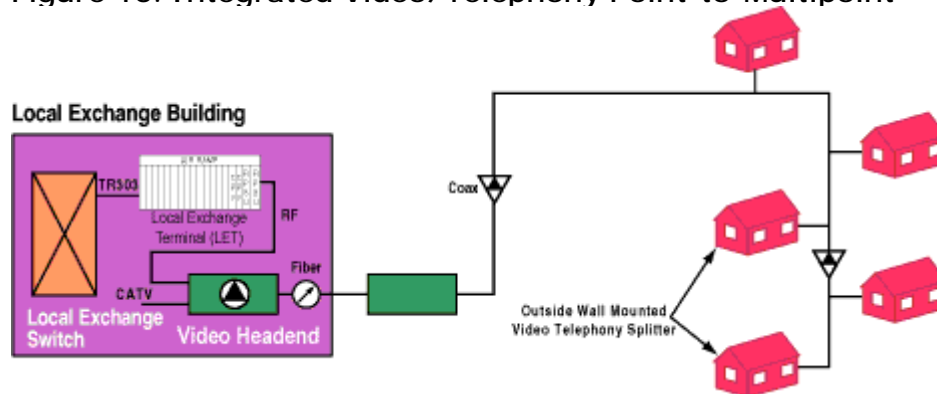
**Figure 9. Integrated Video/Telephony Point-to-Point**



The central office terminal could pick up subscribers over a TR08 or an analog link and multiplex those subscribers onto an RF carrier. This will help the RF carrier use the existing coax network that is in place. A remote subscriber terminal is installed at the end of the coax system which will demultiplex the RF carrier, extract the POTS subscribers, and put them out over the twisted pair that is there. Cable TV will be deployed uninterrupted across the existing coax network.

Another example of this type of topology is the point-to-multipoint network (see *Figure 10*). In this case, there is no reason to deploy a remote subscriber terminal.

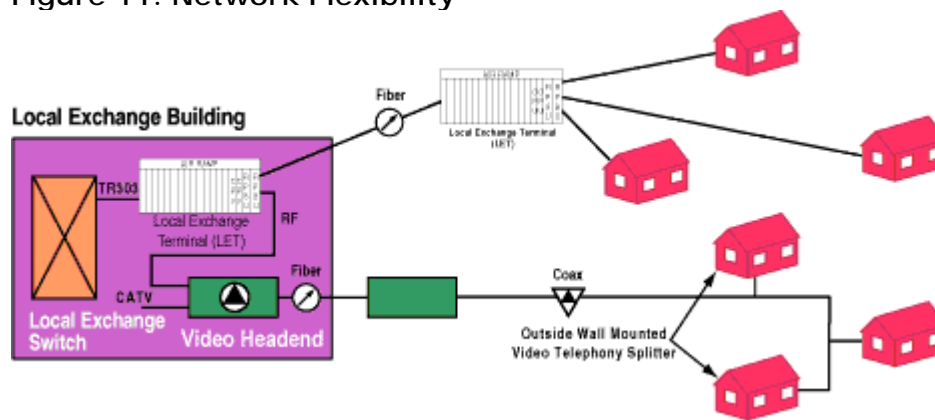
**Figure 10. Integrated Video/Telephony Point-to-Multipoint**



There is the same RF transceiver at the central office that multiplexes all of the lines onto an RF carrier, which is used as the input to an existing cable-TV network. In this system, wall-mounted video-telephony splitters on the customer's house is used to break out the RF, demultiplex the POTS subscriber, and input it into the existing wire in the home. Inside the house is the existing coax feed.

Finally, with a mesh-type topology, customers do not typically have exclusively HFC or exclusively not HFC. They typically have both. *Figure 11* shows once again the importance of network flexibility, or being able to use what already exists.

Figure 11. Network Flexibility



The bottom half shows the point-to-multipoint-type HFC configuration, while the top half is a traditional DLC-type application. Both must be served out of the same box.

This type of technology is very economical for suburban and rural applications. It is cost-effective at low line-sizes and has a low amount of common control overhead. It is able to use the existing infrastructure, which is very important. It is becoming more common for customers to ask for more advanced services and features—they need more bandwidth, and they want to invest in infrastructure by deploying fiber. The key is for a company to be able to deploy the system and upgrade it as needed, yet not pay for the upgrade until the company is ready to put it in place. The future evolution is going to be exciting—an extension of the existing technology with more bandwidth.

## 5. Future Directions

To understand the future of the local loop, we have to examine the elements that will drive its evolution. One of the main drivers is competition, including telcos using HFC. By utilizing cable modems, HFC networks can deliver 6–8 Mbps. One

of the things that may be driving xDSL technology is fear on the part of the telco market about being able to provide the same types of services.

The Internet is another important driver of evolution. xDSL gives telephone companies the opportunity to become Internet service providers (ISPs), which can provide another \$20 to \$30 a month per subscription. In addition, there is a growing demand for bandwidth-intensive services: services to the home for telecommuters, video-on-demand, videoconferencing, and high-definition television (HDTV). Service providers who want to be able to deploy bandwidth need an architecture that can support bandwidth as the demand for it occurs.

The infrastructure must be able to support increasing bandwidth as well as cost-effectively support existing narrowband deployment. Nobody wants to pay more for a POTS subscriber today just because they want to put in an infrastructure that has the ability to support more bandwidth. The infrastructure must also continue to support standard loop capabilities, such as POTS and other special services offered today. Furthermore, migration must be simple; as simple as plugging in a card. The migration is paid for when the card is purchased, which leads to the final requirement—the economics of migration must be solid.

## 6. Economics

The economics of local loop access equipment must be modular, and a common control must remain low—it is simply not economical to pay for ATM common control to deploy twenty-five lines of POTS. Although it must have the minimum subset of frame relay-type capabilities (just enough to get it in the box), these should not be paid for until services are about to be deployed. It must be possible to enlarge the system, starting with one shelf to keep the common control low. As more services become necessary, shelves and more common control can be added. If there is a reason to move to ATM, a lot more common control can be put in place.

As the subscription rate increases for some of the high-bandwidth services, the corporate user working at home will want a LAN extension. In this vein, most architectures will probably move to a three-stage architecture in which there is a high-speed SONET bus capable of supporting four or five gigabits per second of traffic coming in and out: drop-and-insert type of traffic. At the same time, there will be a high-speed cell bus capable of some very basic functionality, just enough to fully utilize bandwidth between terminals. The cell bus provides a very low-cost muxing solution with the capability to add more administration as it is needed, again without paying for it up front in the initial deployment of the box. Finally, the traditional TDM bus will be kept for some of the low-speed services and transport.

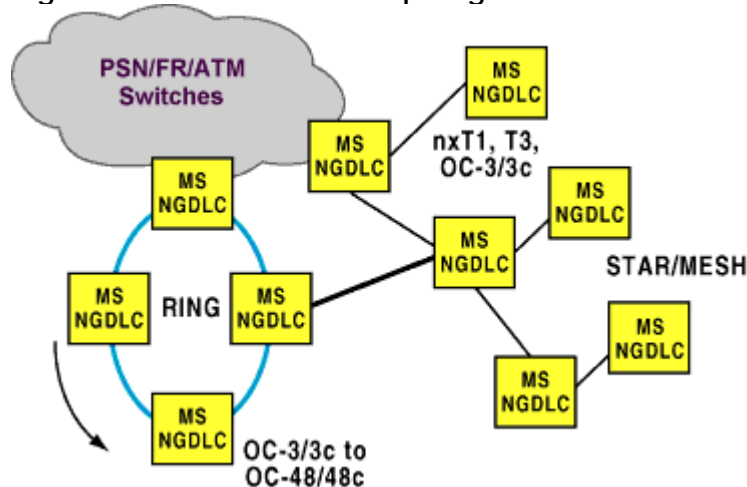
There must be some common control that has the ability to bridge all three of those types of traffic and it should be upgradable. In one possible scenario, all of the channel slots are universal and can accommodate either transport, common control, or service cards. This keeps the common control low. There are a couple of dedicated slots to allow bare minimum common control capability. In this way, more common control can be added to the common slots or the multipurpose slots as the movement from the TDM world to the cell-bus world takes place and capabilities are added.

## 7. The Multiservice DLC

The NGDLC will soon be replaced by a multiservice DLC. The multi-service NGDLC will become a network cloud that consists of a couple of different networks: a data network and a TDM network, which is the Class-5 switching infrastructure. The multiservice NDGLC will have to be able to take in wideband ATM frame relay video. It will need to be able to split that traffic off back at the network POTS, possibly sending the POTS subscribers to the Class-5 infrastructure. The data customers can be sent through data network—an ATM network or a frame relay network, whatever the case may be.

The local access network topologies of the future will be yet another extension of what was seen in the earlier 1990s DLC topologies. As shown in *Figure 12*, there will be a number of OC-12 and OC-48 type of rings going in, which currently does not exist in the local loop at all.

Figure 12. Local access Topologies—Multiservice NGDLC



Housing developments are not deploying ring topologies; they are deployed in mesh topologies. So a key attribute of the system that needs to be available very soon is the ability to support high-bandwidth services and transmission facilities (i.e., T1, T3, etc.) and mix them in anyway the network is configured—in a mesh,

or a ring. Another key attribute will be not overlaying the network topology onto the system architecture.

The future evolution of the multiservice DLC network will be another extension of what has already been discussed. However, not only are analog POTS, T1/E1, and ISDN supported, there is also some frame-relay and ATM traffic. That is where the future is, and the multiservice DLC will need to be able to support those frame-type traffic rates. On the network side, there will probably be a need for wireless local loop service since there will be some places where there is no infrastructure. Where copper or fiber cannot be delivered to subscribers, the use of spread-spectrum between terminals is becoming prevalent. For high-bandwidth services there will be a need for capabilities such as OC-3, OC-12, OC-48, and xDSL as a transport between terminals. If all of those elements can be utilized, there will be an ideal, cost-effective solution for the short term and an excellent migration strategy for the long term.

## Self-Test

1. Local-loop technology was originally driven by \_\_\_\_\_ considerations.
  - a. economic
  - b. environmental
  - c. service-quality
2. The latest NGLDC networks are based on \_\_\_\_\_ media.
  - a. ring
  - b. fiber
  - c. mixed
3. The earliest digital loop technology offered pair-gain improvements of \_\_\_\_\_.
  - a. 4 to 1
  - b. 96 to 1
  - c. 12 to 1
4. Early NGDLC aimed at \_\_\_\_\_.
  - a. high concentrations of subscribers

- b. wide coverage
  - c. software-based service provisioning
  - d. all of the above
5. Early NGDLC \_\_\_\_\_ relatively high degree of common control.
- a. required
  - b. did not require
6. The maximum number of subscribers for an analog system was \_\_\_\_\_.
- a. twelve
  - b. eight
  - c. three
7. Early NGDLC systems were optimized for high concentrations of subscribers up to \_\_\_\_\_.
- a. 2,000 lines
  - b. 5,000 lines
  - c. 10,000 lines
8. Most network topologies are \_\_\_\_\_.
- a. star
  - b. ring
  - c. mesh
9. NGDLC technology is particularly effective because it \_\_\_\_\_.
- a. offers low common control
  - b. can be easily expanded as the subscriber base expands
  - c. can be used with whatever architecture already exists
  - d. all of the above

10. The use of cable modems allows the delivery of up to \_\_\_\_\_.
- a. 64 kbps
  - b. 1–2 Mbps
  - c. 6–8 Mbps
  - d. 1–2 Gbps

## Correct Answers

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## Acronym Guide

### **ATM**

asynchronous transfer mode

### **DDS**

digital data services

### **DLC**

digital loop carrier

### **HDSL**

high bit-rate digital subscriber line

### **HDTV**

high-definition TV

### **HFC**

hybrid fiber/coax

### **ISDN**

integrated synchronous digital network

### **ISP**

internet service providers

### **LAN**

local-area network

### **NGDLC**

next-generation digital loop carrier

### **POTS**

plain old telephone service

### **RF**

radio frequency

### **SONET**

synchronous optical network

### **TDM**

time division multiplexing

**VLSI**  
very-large-scale integration