New uses for residential copper

New transport technology will bring wideband services to the home on the existing copper network

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The telecommunications industry is looking at a new capability that could extend the life of traditional copper loop plant facilities while bringing new service capabilities to customers who will not see fiber optics for some time to come.

Asymmetric digital subscriber line (ADSL) capability transports a DS1 bit stream (1.544 Mb/s) from the public telephone network to customers, without repeaters, while simultaneously providing a 16-kb/s control stream from the customer back to the network. Because of the marked difference in bit rate between the two directions of transmission, this capability is called asymmetric.

The ADSL concept grew out of Bellcore's developmental work for high-rate digital subscriber line. HDSL is a symmetric DS1 capability using two non-repeatered copper pairs and is limited to a range of 12,000 feet from the central office. ADSL, on the other hand, has a design goal of 18,000 feet on just one copper pair.

Residential customers are likely to be the primary users of ADSL, since businesses typically need higher bit-rate services that are symmetric. Within the network, these ADSL circuits are connected to high bit-rate switches. Under customer control, ADSL circuits can support a variety of interesting potential services that will offer new revenue opportunities to local exchange carriers.

Potential Services

With any new network capability, it is important to identify several specific applications. Within ADSL's target residential market, transport is an issue, both in terms of delivery bandwidth and control signaling.

Possible services based on ADSL capabilities can be organized in three broad categories: data, audio and image services.

Within the data service realm, the ADSL line can terminate in computer-based or video-based equipment. Although the differences between the two are becoming less distinct, there are continuing differences in the protocol of transmission to the customer and in the methods that the customer uses to respond.

The basic protocol requirement for computer-based equipment is the need to transmit and receive text characters and control sequences. Video-based equipment requires an analog video signal to paint the picture one line at a time. In addition, analog audio accompanies the picture information. This is accomplished using digital encoding and compression for both the picture and audio information.

Differences in the methods of control include the use of keyboards and mice in the computer environment vs. infrared remote controls and joysticks in the video equipment realm.

ADSL transport lends support to computer-based data services such as computer-aided design and manufacturing (CAD/CAM) and medical imaging. In such scenarios, the network provides fast circuit setup and tear-down. Connections are controlled by the customer and information downloading is rapid. Then the network connection can be released. The computer can print or manipulate the data. Later the connection can be re-established, and changes can be transmitted to the same destination or another one.

Catalog browsing and shopping and research services are further examples of services that are bandwidth-intensive in the direction toward the customer, but that require little control information such as page turning and item selection going back to the source. These services could be accessed using either computer-based or video-based equipment.

Digital audio services may be supported by ADSL transport in several different formats. One format could use the emerging Motion Picture Experts Group standard to transmit pictures with improved stereo audio. Cus-

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FIGURE 1 FREQUENCY DISTRIBUTION OF ADSL WORKING WITH POTS AND AN ALARM SERVICE

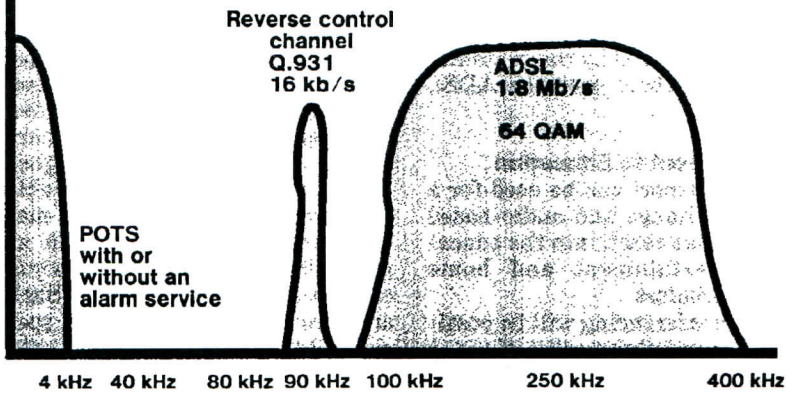
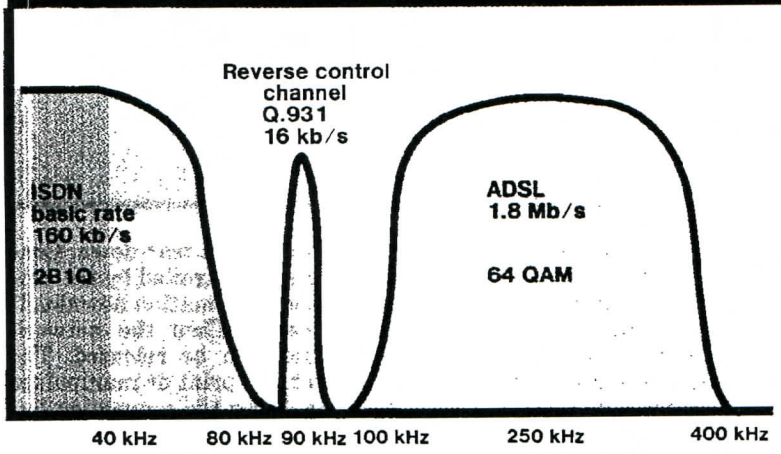


FIGURE 2 FREQUENCY DISTRIBUTION OF ADSL WORKING WITH ISDN BASIC RATE



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tomers will perceive this sound to be equal or better than FM broadcast material. In addition, the ADSL pipe is large enough to support a compact disc (CD) digital bit stream. In this arrangement, a CD digital signal requires about 1400 kb/s, leaving additional bandwidth for in-band error correction coding if needed. Customers could use it as an audio jukebox, requesting previews of newly released albums or lining up a session of prerecorded favorites.

Image services can draw heavily on the MPEG standard. The MPEG is completing work on an ISO standard that describes a compression scheme for entertainment video with stereo audio. The compressed digital signal will be carried within a DS1 facility. The full-motion color video is expected to have a quality approximately equal to a home entertainment VCR. The network can switch digitized, compressed video signals as ordered by the customer and deliver them over the ADSL transport.

Entertainment to Education

ADSL transport can be used for a variety of image and audio-based services that reach into the education, entertainment and home business realms.

Videoconferencing will be possible with computer workstations at which the customer can receive full-motion video and from which still frames can be transmitted back through the network.

Computer games are another application in which the customer receives elaborate screen displays or replacement game scenarios in response to the few keystrokes that travel back through the network. ADSL also could be used to provide interactive gaming, which allows one game to be played by many people at several locations.

ADSL also allows compressed video and audio to be provided upon request and gives customers control of material that goes beyond what is currently available on a typical home VCR. This material includes functions such as pause, fast forward, stop, rewind, camera angle and selection. Such an arrangement facilitates specialized training, medical and other uses such as home schooling.

The Technology

ADSL is basically a means to transport DS1 channels from the network to customers using non-loaded, twisted copper-pair facilities. The anticipated range of ADSL equipment using quadrature amplitude modulation (QAM) signals is from 0 feet to 18,000 feet. About 75% of residential telephone customers are served today on non-loaded facilities less than 18,000 feet from the CO.

The customer's basic telephone service, carried on the same copper pair, is unaffected by the addition of ADSL. The two services are independent and transparent to each other even though they both use the same transmission facility.

One potential implementation of ADSL has a total derived digital line rate of about 1800 kb/s from the network to the customer. This derived line rate is slightly higher than the DS1 rate of 1.544 Mb/s, but it is used to carry the 1.544-Mb/s DS1 channel, a 16-kb/s control channel from the network to the customer, and about 10% overhead for forward error correction prior to QAM coding. This combined total then may be scrambled to improve density and framed to simplify the receiver design for signal recovery.

One possible scheme for modulating this 1800-kb/s digital stream is 64 QAM, which represents an encoding scheme that offers a 6-bit/hertz efficiency. By using 64 QAM the total bandwidth required would be 300 kHz (1800/6-300). Figures 1 and 2 show this bandwidth in a bandpass arrangement between 100 kHz and 400 kHz. These figures also show the associated reverse control channel, and basic service with or without alarm services. Figure 2 illustrates the 64 QAM signal with ISDN basic rate service.

A second proposed method would use 16 QAM, which because of its lower 4-bit/hertz efficiency requires a larger bandwidth of 450 kHz. More robust signal recovery is available at 16 QAM, but the larger bandwidth would require greater loss margin for the receive

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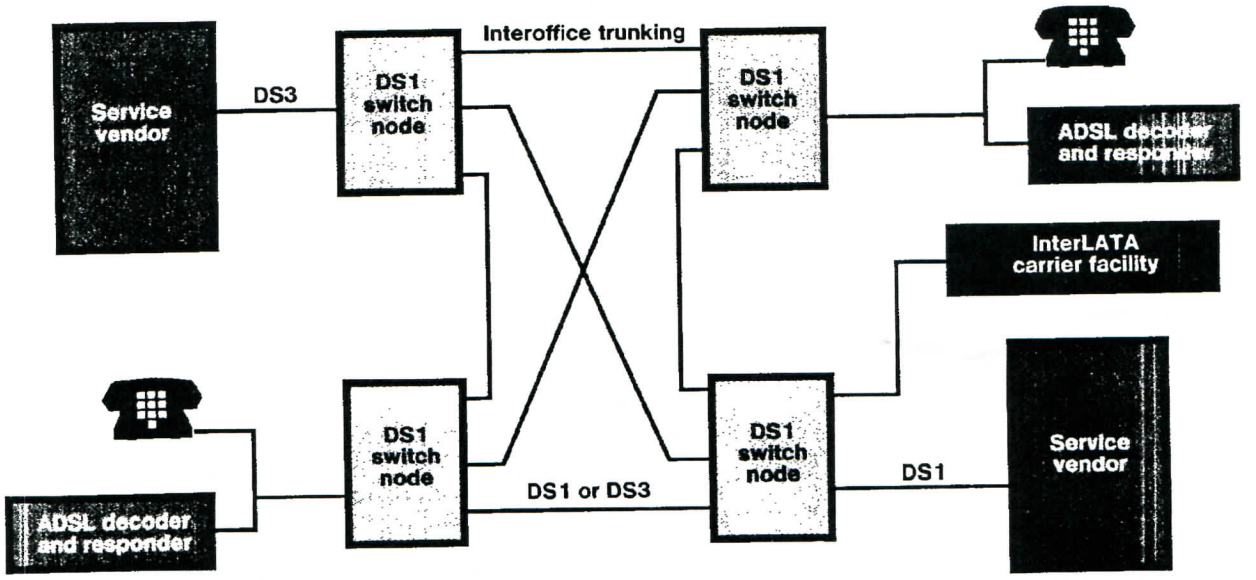
FIGURE 3 SWITCHED DS1 LATA TRUNKING



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signal. In addition to bidirectional basic service and unidirectional DS1 capabilities, a reverse channel is required to carry data at about 16 kb/s.

It could be assigned at perhaps 90 kHz. In fact, this channel could use the Q.931 D channel protocol used in ISDN. The advantage of this strategy is that some of the issues for operations, maintenance and migration to future broadband services become much easier to address.

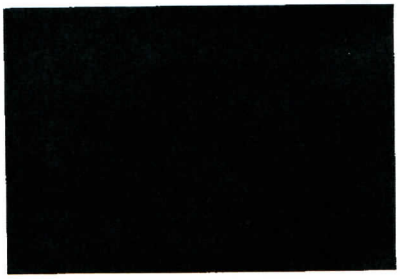
The data carried on this 16-kb/s channel can be categorized into three message sets covering performance, customer information including service requests, and service control signals.

The performance message will indicate whether the DS1 signal is being received by the customer equipment, whether the customer equipment has "framed" to this incoming signal, and the level of error performance. Here performance messages will constitute less than 1-kb/s data. In addition, it is anticipated that a performance message will be generated about once a second.

The second message set includes customer service requests, customer address information, service provider selections and item selections.

The third message set concerns service control signals. These signals will request actions concerning the DS1 stream content and are transmitted by the network back to the service provider. Included in the message set are flow control and such functions as VCR controls for start, stop, fast forward, rewind and pause.

Very large-scale integration chips are expected to be available for ADSL by 1994. New chips will be needed for both network COs and customer premises equipment. Customer equipment must



be inexpensive because overall service costs are very sensitive to CPE costs.

Network Architecture

Within the network, the ADSL line can terminate on an electronic switch that can interconnect asymmetric and symmetric DS1 together with interoffice DS1s and DS3s. Some of the control messages would be used within the switch for routing, charging and operations, administration and maintenance functions. The remaining control messages would be groomed and forwarded to the selected service provider. Figure 3 shows how these DS1/DS3 switches could be interconnected within a LATA.

Another unique feature of this new switch would be its ability to multicast one signal to many customers. For instance, if there is a live video event being transmitted, many customers could request connection to this event, and they all would receive a copy of the digital signal.

Most people agree that the majority of residential customers will not be served by fiber to the curb any time soon. Methods that can deliver larger bandwidths across existing copper facilities will fulfill customer requirements for high-speed services and will allow a graceful migration to the fiber world of the 21st century. ADSL is one method that can provide significant near- and longer-term benefits for customers and network providers. ■

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