Efficient NETWORKS®

White Paper

Voice Over ATM:

Integrating Voice

and Data

Transmission in

DSL Service

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Introduction

The public switched telephone network (PSTN) has traditionally offered the highest quality of service for voice communications. The system is reliable, highly distributed, and well understood, and delivers speech with exceptional clarity. But the PSTN has significant expansion limitations when it comes to meeting the evolving needs of small-to-medium sized businesses. As the need for connections at any location increases - through additional telephones, modems, and fax machines - installing additional lines can often become impractical and expensive. At issue is the effectiveness of the local loop, the "last mile" of copper that connects each business facility to a central office. A number of new technologies have sought to maximize the last mile's usefulness without requiring its modification.

These emerging technologies typically consolidate voice and data traffic, with the promise of providing customers with a one-stop shop for all their communications needs while protecting providers' investments in network infrastructure. Critical to the success of these technologies will be their ability to deliver the quality of voice communications that customers have come to expect of the PSTN. Business customers will resist adopting any alternative or new service that significantly compromises voice transmission. Any new technology must also ensure the continued use of existing equipment, networks, and features if adoption is to be swift.

This paper reviews existing voice technology services that provide PSTN alternatives, and examines new technologies for integrating voice and data over the local loop. Special emphasis is given to an emerging technology that combines asynchronous transfer mode (ATM) with digital subscriber line (DSL) service to provide multiple voice and data services over a single copper line. The intention is to serve as a guide for integrated communications providers (ICPs), local exchange carriers (LECs), network administrators, systems integrators, and others who are responsible for formulating and deploying service plans.

Voice Technologies

Voice transmission over any medium requires a process with low-loss, low-delay characteristics. This is due primarily to the human ear's sensitivity to gaps in sound. For voice traffic, delays of less than 50 milliseconds are noticeable and significantly affect the user experience. Low-loss, low-delay transmission has always been a primary requirement for quality telephone service.

The original analog PSTN made a direct end-to-end connection every time a telephone call was placed, and provided a very low delay medium for voice signals. As the system needed to expand, however, the number of installed copper lines became a limiting factor. The telephone company had to find a way to carry more traffic over the same lines, primarily between telephone company central offices (COs). A technique called time division multiplexing (TDM) was devised to digitize analog calls and combine them with other calls over the same wire. This technique provides the PSTN with smooth flow of information, does not introduce extraneous delays, and results in high-quality voice transmission.

Packet networking is a separate technology developed to carry data traffic; the widespread deployment of packet networks (PNs) has led to explorations of their use for carrying voice as well as data. Efforts to extend packet networks to voice transmission must inevitably deal with the fact that traffic flow in PNs is inherently "jerky" and that variable delays and inconsistent information flow rates are typical. These characteristics are often inconsequential for data traffic, but pose a significant challenge to quality voice transmission.

Two of the most-discussed technologies for voice over PNs - Voice over Frame Relay and Voice over IP -are capable of performing acceptably over private, delay-controlled networks that allow them to transmit voice at expected quality levels. But they are presently unable to deliver quality voice transmission over the last mile of copper that connects small-to-medium size businesses due to inherent characteristics.

Voice over Frame Relay (VoFR)

VoFR is a relatively new application of frame relay technology and is used most often by enterprise customers who want a lower-cost alternative to the PSTN. The technology is particularly attractive to corporate branch and international offices that are already interconnected via frame relay data networks. In such cases, VoFR provides economic benefits because it makes use of an existing company resource.

Frame relay came into widespread use in the 1990s following large-scale communications network quality improvements made in previous decades. Frame relay excels at carrying data traffic, is used to interconnect local area networks, is scaleable, and interoperates well with other services and networking applications. To optimize network bandwidth, frame relay uses variable packet lengths (between 128 and 4,096 bytes), a scheme that suits the bursty nature of data communications very well.

While frame relay is fast, its variable packet sizes can introduce latency that can affect voice traffic. In addition, frame relay traffic does not carry information about its contents, and traffic types cannot be prioritized according to bandwidth requirements. These potential problems are minimized as long as VoFR is used on private or controlled delay packet networks, but become serious in local loops.

Voice over IP (VoIP)

VoIP is often touted as a promising means for integrating voice and data. Since many customers are already connecting to the Internet using the Internet Protocol (IP), it seems natural and convenient to use the same link to carry a voice connection as well. As in the voice over frame relay case, VoIP is also packet-based and operates on a network designed for data traffic: the IP network that is the foundation of the Internet.

Developed as the network layer protocol that provides Internet addressing and routing functions, IP is a "best-effort delivery" mechanism. By its very nature, IP is designed to tolerate data losses and delays. This scheme works well for data but is less than adequate for voice, as its quality suffers from the latency introduced. Moreover, IP also uses variable packet lengths which, as in the frame relay case, means that lost or misdirected packets can also produce a negative effect on voice quality.

Consequently, VoIP on the public Internet has until recently been relegated to the realm of hobbyists and others who sought low cost voice connections over long distances and were willing to endure delays and poor audio quality. Only companies with access to internal or controlled delay networks have been able to use VoIP with success although, even in this case, the best performance is obtained on lightly loaded networks. Thus, VoIP is a reasonable approach for large companies with private networks (e.g., to interconnect PBX systems between separate offices) but is not likely to be a viable voice option for use over the public Internet for some time.

The standard protocol used for VoIP, H.323, defines telephony gateways, gatekeepers, and the process for call initiation and termination. But H.323 was not designed for the demands imposed on it by business voice communications: it does not support a rich set of telephony features nor guarantee QoS. And because it runs over IP, H.323 cannot overcome the packet transmission latency characteristics inherent to IP. To improve matters, new protocols such as the Media Gateway Control Protocol (MGCP) and the Session Initiation Protocol (SIP) are in the works. But even with the proposed enhancements, drawbacks and questions remain about VoIP viability for use in the local loop. For example, the more robust protocols for interoperability between VoIP and traditional systems are still in flux. And when the new protocols are approved, interoperability issues will remain a concern. Existing IP equipment will have to be upgraded and/or replaced in order to support these enhancements, making implementation of the new protocols a potentially costly and complex process.

Voice and Digital Subscriber Line (DSL)

The advent of DSL has improved communications options for many residential and small-to-medium sized business customers. As a data communications solution, in price and capability, DSL is positioned between common, inexpensive analog modem dial-up service and much more expensive, dedicated T1/E1 services.

Most asymmetric DSL solutions combine one voice channel with data communications over a single twisted pair connection. In the typical configuration, a splitter on the telephone line separates the voice and data portions of the signal. The DSL access device installs on the data side of the splitter, connects to the customer's computer, and provides "always-on" access to the Internet or other networks. The voice line operates as before, with the same telephones, calling options, and QoS to which the customer is accustomed. DSL does not optimize the copper plant for voice communications, however. Customers who need more voice lines face the same expansion limitations as before. As a result, significant work is underway to extend voice over DSL so that it can offer a complete solution that optimizes the last copper mile to the customer site.

Integrated Services: VoATM and DSL

Voice over ATM (VoATM) unites ATM and DSL technologies to deliver on the promise of fully integrated voice and data services. VoATM meets all requirements in terms of QoS, flexibility, and reliability because the underlying technology is ATM, a highly effective network architecture developed specifically to carry simultaneous voice and data traffic. VoATM makes sense economically because it works on the equipment infrastructure in which providers have already invested. It allows ILECs, CLECs, and PTTs to continue using ATM as the Layer 2 transport protocol above DSL. Customers benefit from the expansion of services that can be provided through a single copper line.

ATM Suitability for Voice Traffic

Sometimes mistakenly associated with VoIP, VoATM is a completely separate technology that predates VoIP. In contrast to IP and frame relay, ATM uses small, fixed-length data packets of 53 bytes each that fill more quickly, are sent immediately, and are much less susceptible to network delays. (Delays experienced by voice in a frame relay or IP packet network can typically be 10 times higher than for ATM and increase on slower links.) ATM's packet characteristics make it by far the best suited packet technology for guaranteeing the same QoS found in "toll-quality" voice connections.

The part of ATM responsible for converting voice and data into ATM cells, the ATM Adaptation Layer (AAL), allows various traffic types to have data converted to and from the ATM cell and translates higher layer services (e.g., TCP/IP) into the size and format of the ATM protocol layer. A number of AAL definitions exist to accommodate the various types of network traffic. Those AAL types most commonly used for voice traffic are AAL1, AAL2, and AAL5.

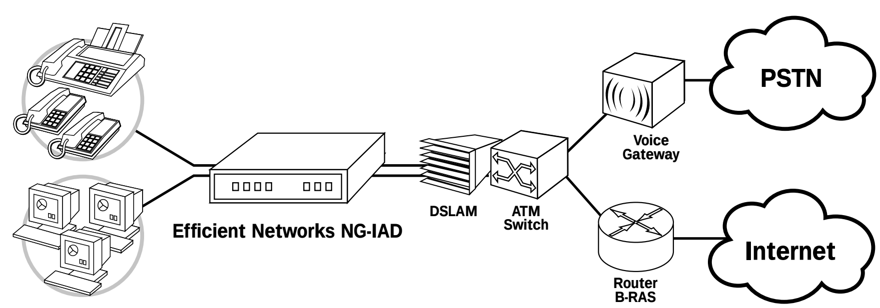
VoATM with AAL1 is the traditional approach for constant bit rate (CBR), time-dependent traffic such as voice and video and provides circuit emulation for trunking applications. ATM with AAL1 is still suitable for voice traffic, but is not the ideal solution for voice services in the local loop because its design for fixed bandwidth allocation means network resources are consumed even when no voice traffic is present. AAL5 is used by some equipment manufacturers to provide VoATM, provides support for variable bit rate (VBR) applications, and is a better choice over AAL1 in terms of bandwidth used. However, the means for carrying voice traffic over AAL5 is not yet fully standardized or widely deployed, and implementations are usually proprietary.

ATM with AAL2 is the newest approach to VoATM. AAL2 provides a number of important improvements over AAL1 and AAL5, including support for both CBR and VBR applications, dynamic bandwidth allocation, and support for multiple voice calls over a single ATM permanent virtual circuit (PVC). An additional and significant advantage of AAL2 is that cells carry content information. This feature allows traffic prioritization for packets (cells) and is the key to dynamic bandwidth allocation and efficient network use.

VoATM and DSL

Since DSL links are ready-made for voice and data, and ATM excels at carrying varied traffic, using VoATM over DSL over the local loop to the customer is a natural extension of these services. To enable the combination, equipment that supports VoATM is needed at each end of the local loop: a next generation integrated access device (NG-IAD) at the customer premises, and a voice gateway at the CO.

FIGURE 1:



By extending the data capabilities of DSL to include multiple voice line service, VoATM expands the range of communications services available to small-to-medium sized businesses and residential customers.

Use of an NG-IAD at the customer premises keeps the impact on the customer voice and data equipment to a minimum. There, the NG-IAD operates in place of a data-only DSL access device. The NG-IAD connects customer PCs on the LAN to the DSL service by encapsulating IP data into ATM for DSL transmission, and handles routing and IP address management. On the voice side, the NG-IAD provides the DSL-to-voice interface for the customer's already-installed telephony equipment - telephones, fax machines, key systems, and PBXs, with all features intact - and sends and receives voice over ATM on the same DSL line. The result is toll-quality voice service with full CLASSTM feature support (e.g. call waiting and three-way calling) and high-speed Internet or remote LAN access over a single copper line. No new equipment is needed at the customer premises to take advantage of the functionality provided by the NG-IAD.

At the carrier's CO, a voice gateway receives encapsulated voice traffic from the carrier's DSL Access Multiplexer (DSLAM), converts it from voice over ATM to traditional formats used in existing phone networks, and then forwards the traffic to a Class 5 voice switch. Data received at the CO's DSLAM is directed as data traffic to its destination just as in current DSL service.

VoATM and DSL Benefits

As ILECs, CLECs, and PTTs have standardized on ATM as the Layer 2 DSL transport protocol, VoATM integrates into existing networks with minimal impact on existing voice and data equipment. VoATM also capitalizes on the infrastructure already in place for data services: VoATM significantly extends the benefits of DSL by enabling multiple phone lines over a single DSL connection to the customer premises. The benefits of ATM are easily extended to residential and small-to-medium sized business customers. There is no need to run additional copper lines or upgrade service to the customer site in order to implement VoATM.

Benefits to the Provider

CLECs in particular need a technology that allows them to implement a broadband access network which leverages the ILEC's last mile copper network, and DSL technology meets that need. The recurring cost for each phone line is reduced, and the CLEC is thus less dependent on another network operator for access to copper lines. When dealing with customers too small to justify the high cost of a leased T1, the only alternative for providers has been to re-sell the incumbent's voice services (purchased at a modest discount), or to lease one copper loop per phone line. The combination of VoATM and DSL allows a single copper line to be leased, but multiple voice lines to be sold to the customer.

VoATM enables carriers to offer bundled services in a way that makes them easier to sell as a unit, with discounts as incentives for signing up, where appropriate. The ability to share a common transmission facility for multiple services also results in lower operating costs.

In summary, VoATM benefits to the communications provider include:

- ***Re-use of existing infrastructure -*** *Capitalizes on the vast number of existing copper lines and the thousands of DSLAMs and data switches already installed to support Internet access. Carriers' significant investment in local voice switching equipment is maximized as well. Requires no change to the existing network architectures, and no additional copper lines need be added to the customer site.*

- ***Seamless integration into existing networks -*** *An NG-IAD at the customer site ensures that the impact on existing customer premises equipment (CPE) is small. Similarly, a VoATM-to-PSTN gateway at the CO converts voice traffic between Voice over ATM and the traditional formats used in existing phone networks.*

- ***Continued support for CLASS features -*** *Maintains an important part of the provider's revenue stream.*

- ***Effective use of network bandwidth -*** *Network traffic is prioritized according to its content and handled accordingly. Carriers can support more traffic and therefore more customers.*

- ***Expansion of customer base** - Offers integrated services to millions of small-to-medium sized businesses, and ultimately to residential customers. Service package bundles offer better value to customers and reduce turnover.*

- ***Scalability as customer needs change** - Future needs of customers are easily accommodated. Modularity features in NG-IADs allow subscriber-side and wide area network (WAN) ports to be scaled as customer needs change.*

Benefits to the Customer

ATM has provided substantial communications benefits to large companies for several years. The advent of DSL and VoATM extends ATM's advantages to smaller businesses and residences , and converges all communications services. Customers enjoy business quality voice, multiple lines, and always on access to the Internet.

As providers implement VoATM, customers will be able to purchase all voice and data services from a single provider and may realize cost savings as result. Customers also benefit from having a single point of contact for customer service, billing, expansion of services, and management.

In summary, the benefits of VoATM and DSL for the customer include:

- ***Compatibility with existing equipment** - No changes in telephone and computer equipment are required. NG-IADs are compatible with existing telephone and computer equipment.*

- ***Flexible communications options** - NG-IAD modularity features allow services to be configured as needs change. Multiple voice lines are easily added to a site over a single copper line.*

- ***Business quality voice services** - Guarantees toll quality voice and complete feature transparency for such features as call waiting and caller ID.*

- ***Single point of contact for support and service** - Simplifies setup, maintenance, and modification of service options.*

- ***Superior network traffic management** - Dynamic allocation of resources makes effective use of network bandwidth. Under-used data bandwidth is allocated to voice traffic and vice versa.*

Conclusion

With the NG-IAD class of product, VoATM and DSL technologies are easily combined to expand the communications services providers can offer. Providers benefit from technology that protects their investments and fits logically with customers' demands for greater service. Customers benefit from multiple service options while they retain the use of existing equipment and features.

NG-IAD products were first demonstrated in mid-1999, and trials began in the second half of the year. Deployment of NG-IADs will begin in 2000.

About Efficient Networks, Inc.

Building upon our core expertise in ATM networking equipment, Efficient Networks has been developing high-speed customer premises access products for DSL services since 1996. Efficient Networks' SpeedStream line of DSL CPE is deployed as a key component of DSL services world wide. By working in partnership with companies that offer best-of-breed DSL equipment for central offices, Efficient Networks can ensure that its DSL products are compatible with most major DSLAMs and with the DSL interfaces present on voice switching equipment and digital loop carrier systems.For more information on Efficient's new products, please contact us through any of the means listed below.

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