Payoff
Deploying frame relay switches at each node allows the network to support voice, fax, and data over a single line for one monthly charge at each remote location. This article describes how international frame relay supports traffic such as voice and explains how to establish an international frame relay network.

Introduction
Many organizations accustomed to the convenience of domestic frame relay service are considering international service to expand their markets. Global Frame relay services facilitate this process by providing a means of linking remote LANs to international sites. A growing market demand ensures the continued increase of service nodes worldwide.

Based on revenue figures, AT&T (Warren NJ) controls 36% of the domestic Frame relay market, Sprint (Westwood KS) maintains a consistent 20%, and MCI Communications Corp. (McLean VA) controls 16%. Domestic Frame relay, in many cases, is less expensive than dedicated leased lines. As a result, more users are migrating to Frame relay now that it is possible to support voice over Frame relay.

To encourage the transition to Frame relay, service providers are offering greater discounts and conveniences such as Internet and World Wide Web access through gateways. Users must, however, carefully consider their bandwidth requirements for Internet access. Frame relay access requires 56K bps or higher. The user could be billed for 56K-bps access to the Internet when 9.6K-bps access may be all that is required.

Frame Relay-to-Atm Support
Although many users may be years away from requiring Asynchronous Transfer Mode bandwidth, frame relay service providers plan to offer Frame relay-to-ATM support. An asynchronous transfer mode (ATM) backbone will be established that can be accessed through public Frame relay to aggregate high-speed traffic between distributed, high-speed host locations. For example, Sprint recently adopted the Frame relay Forum's standard for Frame relay-to-ATM service. Sprint plans to aggregate Frame relay nodes running at 56K bps to 1.544M bps at an asynchronous transfer mode (ATM) access switch for transport to a host site operating at asynchronous transfer mode (ATM) speeds. However, asynchronous transfer mode (ATM) does not yet support voice-over-frame relay traffic, which may eliminate the business case for early asynchronous transfer mode (ATM) deployment.

Frame Relay-To-ISDN Support
Although service providers support primary rate Integrated Services Digital Network service, some have not yet offered to interface integrated services digital network (ISDN) B service. (ISDN B is a channel for transmitting voice, data, or video.) In some major market areas, the regional Bell operating companies (RBOCs) offer integrated services digital network (ISDN) anywhere, which means they will bear the cost of tie lines from the customer site to the site that supports integrated services digital network (ISDN) B. In many areas, integrated services digital network (ISDN) B service is offered at about $40
per month, which is a significant savings over the typical cost of 56K-bps access to a frame relay switch (i.e., $150–$160 or more per month).

**Frame Relay Disaster Recovery Services**

One of frame relay's greatest advantages is that it works on the basis of a Permanent Virtual Circuit. Therefore, if a link or circuit is cut or disrupted, the network simply selects another available link. This automatic rerouting ensures the reliability of a user's network. This would not hold true in the case of a multidropped dedicated System Network Architecture network, in which a break in a circuit could collapse major portions of the network. For this reason, disaster recovery is one of frame relay's strongest selling points. Because there are many rerouting options within a public frame relay network, network service can be restored before users realize that it was down. AT&T, Sprint, MCI, and LDDS Communications, Inc. (Jackson MS) offer support for disaster recovery through four basic configurations:

- Frame relay switched 56K-bps dial backup.
- Rerouting to a backup host or backup site.
- Frame relay switch diversity.
- Local access diversity.

**Frame Relay Switched 56K-bps Dial Backup**

This service is provided in the event of failure of the primary Frame relay access level. A switched 56K-bps call can be routed to a different Frame relay switch using the switched 56K-bps lines from both a Local Exchange Carrier and interexchange carrier (IXC). This service requires the additional monthly expense of a local dedicated switched 56K-bps line, a Frame relay switched 56K-bps backup port charge, backup permanent virtual circuit (PVC) charges, plus usage charges at the local exchange carrier (LEC) and IXC level. These services may not be available if international locations are involved.

**Rerouting to a Backup Site**

Some users maintain an alternate host or hot site in case of disaster (i.e., fire or flood) at the principal computer center. The user is responsible for maintaining a frame relay local loop access facility at the alternate site. The user must also establish and maintain backup permanent virtual circuit (PVC) at each location. In the event of disaster at the host site, permanent virtual circuit (PVC) reroute traffic at the local level to the backup site. The service provider establishes network routes to the alternative host site from the central control facility. One-time rerouting service charges apply.

**Frame Relay Switch Diversity**

This service requires two separate serial connections on the user's local router. The serial interface connections are linked through separate Frame relay access facilities to the same local exchange and Frame relay Point Of Presence. At the POP, the user's connections are routed to separate Frame relay switches in separate switching centers.
Local Access Diversity

In some areas in the US, service providers support alternate routing from the user's premises to the local exchange. These alternate facilities are linked to the Frame relay service provider's POP. The user pays for the alternate service provider's line, a second permanent virtual circuit (PVC), and the committed information rate (CIR) monthly access charge.

Switching Voice and Data Over Frame Relay

Several vendors, including Hypercom, Inc. (Phoenix AZ) and Motorola, Inc. (Schaumburg IL) have announced products that support voice over frame relay in various forms. However, ACT Networks Inc. (Camarillo CA), Micom Communications Corp. (Simi Valley CA), and Memotec Communications Corp. (North Andover MA), who have mature multiplexer and frame relay assembler/dissembler (FRAD) product lines, were among the earliest to support voice over Frame relay. These three manufacturers have offered voice compression as a module on their multiplexers for some time, and voice over Frame relay was a natural extension. This new breed of Frame relay switches coupled with the global reach of Frame relay services has changed the entire concept of network architectures.

Memotec and Micom have taken the voice-over-frame relay process a step further by developing a comprehensive software suite that supports routing of voice and data in much the same way that digitized voice traffic is routed over the Public Switched Telephone Network. For example, the Memotec CX 1000 Frame relay switch allows the user to send multiprotocol traffic over a single dedicated link. IBM Systems Network Architecture/synchronous data link control (SNA/SDLC) traffic is transported transparently through the ability of the CX 1000 to conduct local polling (i.e., spoofing) in the manner of a local controller.

The Frame relay switches on the market all use a modular architecture that provides a common backplane for integrating a number of specialized circuit cards. Each of these cards allows the switches to operate as a FRAD, a multiplexer, Data Service Unit/Channel Service Unit, bit voice/data compressor, high-speed interface, or bridge/router. These modularized Frame relay switches can be tailored to meet specific user requirements.

Maintaining Data and Voice Quality

Frame relay switches have several design characteristics that support the integration of voice, data, and fax with consistent reliability.

Throughput Management

Each network node on a frame relay network is configured with a local access loop and a Committed Information Rates. The CIR establishes a threshold at which data traffic may be transmitted into the Frame relay network. For example, a process within the CX 1000 switch's operating system invokes a network management process that carefully monitors committed traffic against the established CIR. This process ensures that traffic does not exceed the CIR level, which could cause sensitive traffic to be discarded within the network while in transit. In this way, sensitive fax and voice traffic packets are protected against Discard Eligibility once they enter the network.
Jitter Control

Jitter can occur in the public network when an intermediate switch is busy with another packet. In this case, the second packet is held at the switch until the transmission of the first packet is complete. Because Frame relay packets can vary in length, the amount of delay is unpredictable. If the jitter exceeds the ability of the receiving device to compensate through buffering, voice quality will suffer or the signal will be completely obliterated.

To address this problem, switches such as the CX 1000 have an elastic buffering process built into the operating software that manages buffering in real time. By reconfiguring its assigned buffer space, the Frame relay switch can compensate for network jitter. Most Frame relay switches use some form of buffering as a means of controlling network jitter. In this way, the continuity of a telephone conversation is ensured because jitter can be smoothed out before the digital voice packets are converted back to their analog form.

System Tuning

Frame relay switches such as the ACT SDM-FP, Micom Netrunner, and Memotec CX 1000 can be tuned as the network manager monitors performance under a variety of circumstances. Both the CX 1000 and the SDM-FP have default parameters that define the frame sizes for fax, voice, asynchronous, or synchronous data. However, fragmentation is built into the CX 1000, which allows the network administrator to change the size of the Frame relay packets in which fax, voice, or data is encapsulated. This control process is based on network monitoring procedures that determine optimal levels of traffic.

The ability to reconfigure the discard eligibility status of individual channels is unique to the CX 1000. Channels with the Discard Eligibility indicator set indicate that the information that passes through the marked channels are discard eligible. Through this process, channels can be managed to ensure that critical information can be presented to the network without being discarded.

Traffic Prioritization

Frame relay switches use schemes to set up priorities for each voice/fax channel defined on a data channel link identifier (DCLI). The highest default priority is automatically assigned to any channel configured to support either fax or voice traffic. The network administrator can also assign individual priority codes to selected data channels as well as establish a prioritization scheme within DCLIs. This prioritization facility allows data traffic to be buffered until all higher-priority fax and voice packets have been presented to the network.

Optimizing Bandwidth

Frame relay switches deploy various techniques to optimize bandwidth. One popular technique takes advantage of pauses during a conversation or periods of silence to further reduce bandwidth requirements. This process, known as digital speech interpolation, eliminates much of the bandwidth that might otherwise be wasted through the creation of empty packets.

Another technique is to deploy various forms of data compression. For example, the CX 1000 and Netrunner can support data compression on all data channels, which allows these switches to increase overall data throughput fourfold. This process supports the movement of much higher volumes of traffic over the public Frame relay network without a corresponding increase in CIR levels.
Both the ACT SDM-FP and the Memotec CX 1000 use a multiprotocol encapsulation scheme (i.e., Regional Financial Center 1490). This process supports the optimization of the Frame relay access link supporting the packing of all outbound traffic over a single DCLI.

**Routing Voice Over Frame Relay**

Originally, voice over frame relay involved the point-to-point transmission of digitized voice. In early FRAD devices, the transmission of voice traffic was accomplished in much the same manner as a dedicated circuit. However, these devices supported the routing of voice over the public Frame relay network according to specific routing instructions.

Comprehensive software suites have been developed to support switching strategies across the Frame relay network. For example, CX 1000 software emulates the switching process used in the Public Switched Telephone Network. The CX 1000 achieves this by setting up a number of telephone hunt groups that are usually associated with hunt groups of other company nodes on the network.

As a number is dialed for a specific extension located on a hunt group, the CX 1000 listens to the dual-tone multifrequency (DTMF) signals, which are mapped to a specific location on the network based on hunt group listings. This information is used to support a routing scheme for sending a call to its ultimate destination.

Hunt groups can be programmed on the switch so that outbound calls emanating from a single location are routed to any location across the network. Several users might have their calls routed to many different locations across the company's internal network. There are a variety of routing schemes for sending faxes, voice, or data to virtually any location on the network.

**Voice Digitization**

The digitization of voice coupled with the application of efficient compression algorithms makes it possible to route voice traffic over Frame relay. However, digitized voice is not new. Telephone companies have long agreed on the Pulse Code Modulation standard, which runs at 64K bps. To advance this standard, various enhancements were developed, such as adaptive pulse code modulation (PCM) (ADPCM), which compresses the voice component down to 32K bps and enables T1 multiplexers to make better use of T1 bandwidth, allowing the integration of additional voice traffic.

A T1 link can support up to 48 voice channels. As more companies began to employ T1 backbone networks, the T1 multiplexer manufacturers developed better digitization algorithms that provided for voice compression at 16K bps, 8K bps, and 4.8K bps, down from 32K bps.

These early attempts at reducing voice information down to the lowest bit level met with mixed results. A standard was needed to measure these new proprietary algorithms against the already established Adaptive Differential Pulse Code Modulation standard. Although somewhat subjective, one method that evolved for judging the differences in voice quality produced by the various proprietary algorithms was the mean opinion score (MOS). This method assigned an Metal Oxide Semiconductor. rating for a given compression level when compared against the 64K-bps standard. For example, Plug-Compatible Manufacturer is rated at 4.4, and ADPCM might be rated as 4.1. Another algorithm, adaptive transform coding (ATC), supports variable-rate schemes and may have an Metal Oxide Semiconductor. (pronounced “moss”) of between 2.0 to 3.8, depending on the digitization rate.
Although Improved MultiBand Excitation, another hybrid algorithm that uses either 2.4 or 8K bps, may be rated at a lower Metal Oxide Semiconductor. (pronounced “moss”), it can still achieve an acceptable level of communications quality.

**Algorithms for Voice Compression.**

Algebraic code-excited linear prediction (ACELP) has followed as the result of earlier attempts to develop algorithms that made better use of bandwidth. ACELP is a comprehensive algorithm that involves modeling of the vocal track, a sophisticated technique for voice pitch extraction and coding, and a special excitation modeling and coding process.

This algorithm has produced the best-quality voice levels at 16K bps, 8.0K bps, and in some cases 4.8K bps, achieving an Metal Oxide Semiconductor. (pronounced “moss”) rating of 4.2 out of a possible 5.0. The Memotec CX 1000 uses the ACELP algorithm in conjunction with its network switching matrix to support advanced Frame relay switching.

**Anatomy of the New Frame Relay Switch**

In the case of the CX 1000 frame relay switch, a special module (i.e., MC 600) serves as a data compressor that interfaces with the multiplexer on the network interface side. The Alternating Current 600 is the voice compression module. This module contains a computer chip that drives the ACELP algorithm software to achieve the bit-compression level suitable for transmitting voice over frame relay. The ACELP algorithm is the software model used by Micom and Memotec to support voice compression.

The Memotec CX 1000, Micom Netrunner, and the ACT SDM-FP chassis can be configured with various multiples of specialized function modules. For example, the CX 1000 could be configured with two Alternating Current 600 voice compression modules to support up to 16 compressed voice channels. Another specialized module, PX 670, supports asynchronous, X.25, System Network Architecture, or SDLC traffic. This module can be used to poll remote SNA terminals in the same manner as an IBM remote controller. In this way, SNA traffic can be transported over Frame relay transparent to the SNA network monitoring process. This module links to the X.25 interface on the network side.

The CX 1000 is configured with an Simple Network Management Protocol (system network management protocol) controller that allows it to be managed remotely by an SNMP network manager. The ACT and Micom switches use proprietary net managers.

A special Frame relay module (i.e., FR 600) for the CX 1000 supports the packetizing process associated with Frame relay, Switched Multimegabit Data Service, and Asynchronous Transfer Mode networks. This module links to the Frame relay SMDS/ATM interface on the network side of the switch.

Another special circuit card, the Control Language 600, supports a LAN bridge/router function. This card houses a special computer chip that contains the routing software that supports a comprehensive routing scheme. It is this routing system that emulates the network switching function similar to the Public Switched Telephone Network. The Micom Netrunner uses a special router card to provide a similar function as well as support for asynchronous transfer mode (ATM) technologies.

The CX 1000 has a built-in Data Service Unit/Channel Service Unit for 56K-bps access as part of the standard configuration. However, a special module (i.e., ISU 5600 and
IDM 1500) is available that can serve as a multi-rate or high-speed CSU/DSU supporting the interface of Fractional T1 or full T1 service. Both the Memotec and Micom switches provide an interface for the integration of Integrated Services Digital Network access.

Planning An International Network

It is now possible to configure international networks through the application of global frame relay service providers such as AT&T, MCI, LDDS, and Sprint. In Europe, international service providers include Unisource Business Networks and Scitor International Telecomm Services. Exhibit 1 provides a list of Frame relay switch vendors and service carriers.

**Resources for Frame Relay Equipment and Service**

<table>
<thead>
<tr>
<th>Frame Relay Service Carriers</th>
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<tbody>
<tr>
<td>MCI Corp., 1801 Pennsylvania Avenue, Washington DC 20006, (202)887-3325</td>
</tr>
<tr>
<td>AT &amp; T, 295 North Maple Avenue, Basking Ridge NJ 07920, (908)221-9000</td>
</tr>
<tr>
<td>Sprint, 3100 Cumberland Circle, Atlanta GA 30339, (800)733-2287</td>
</tr>
<tr>
<td>LDDS WorldCom, Cherry Tree Corporate Center, Cherry Hill NJ, 08002, (800)929-0722</td>
</tr>
<tr>
<td>Scitor International Telecom Services, 26020 Acero Street, Suite 200, Mission Viejo CA 92691, (714)470-6300</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frame Relay Switch Vendors</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT Networks, Inc., 188 Camino Ruiz, Camarillo CA 93012, (805)388-2474</td>
</tr>
<tr>
<td>Memotec Communications Corp., 1 High Street, North Andover MA 01845, (508)681-0600</td>
</tr>
<tr>
<td>Micom Communications Corp., 4100 Los Angeles Avenue, Simi Valley CA 93063, (805)583-8600</td>
</tr>
</tbody>
</table>

Exhibit 2 includes some of the countries around the world that are provisioned with Frame relay switches to support Sprint global Frame relay services. AT&T, MCI, and LDDS all have similar network arrangements. If a service provider does not have a Frame relay switch in an area convenient to the user’s location, an extended access line can be used to link the user to the Frame relay network. However, because each service provider has a different distribution of Frame relay switches, the cost of installing an extended access varies depending on the distance the user is located from the nearest Frame relay switch. This is usually the cost of a dedicated international circuit. Planning an international network should include consultation with several vendors.

**International Locations for Sprint Frame Relay Switches**
International Service Costs

As carriers establish more Frame relay switching centers overseas, the cost for service will drop. Costs vary for installation of service, local loop access, and monthly access, and depend on the user's location relative to the carrier's Frame relay switch.

Overseas, the issue of Network-to-Network Interface may not be uniform between competing carriers. For example, domestically, The network-to-network interface between the Local Exchange Carrier and interexchange carrier has been clarified, but the same is not true for overseas service providers. However, some domestic service providers do offer a level of NNI between their domestic network and their overseas facilities. For example, MCI, LDDS, and Sprint all support NNI between their domestic and common market facilities. The advantage is that these networks offer relatively low intercontinental transmission costs.

Exhibit 3 shows the monthly costs for the international network initially proposed by Sprint. Although the overall monthly costs are higher than the US locations, the monthly local loop and PVC/CIR are fairly uniform for all of the European locations. These prices are subject to final negotiations that could result in lower costs if a long-term contract is established.

Sample Two-Year Pricing For Global Frame Relay

Other price quotes might include higher installation costs because of the need to install an international dedicated circuit at one location to connect to the service provider's Frame relay switch. In this situation, the local loop access price would be inordinately high because of the monthly cost for a dedicated international circuit.

European Service Providers.

International European Frame relay service providers have different pricing plans than US domestic service providers. European pricing plans are aimed at supporting networks with high monthly traffic volumes. As a result, if a user is planning to increase the level of traffic, the European service provider will offer dial-up access over Integrated Services Digital Network. This arrangement does not facilitate linking an integrated network with a North American affiliate because typical NNI would not be possible. A dial-up arrangement over integrated services digital network (ISDN) would not support voice over Frame relay, either.
Support in the Host Country.

Because Frame relay switching has matured into a more comprehensive product, the user would be remiss if strong consideration was not given to voice over Frame relay. Domestically, there would be no problem finding suitable equipment to support network nodes; however, it is quite different overseas.

Each country's PTT—the government agency that handles postal, telegraph, and telephone services—may have its own special requirements for Customer Premises Equipment that interfaces directly with the public network. For this reason, it is important to establish that the network equipment chosen has been approved by the host country's Postal, Telephone, and Telegraph Administration. Furthermore, the manufacturer of the equipment may also have in-country representatives that the network planner should contact. The user cannot simply show up with equipment and set up shop, because only vendors licensed by the PTT will be allowed to connect equipment to the public network.

Configuring an International Network

It is possible to configure an international network using Frame relay services in which users have no responsibility for network management. All of the arrangements for local loop access in the overseas locations can be handled by the domestic carrier's overseas offices and the host country can assume responsibility for services. In a network configuration in which the user has deployed Memotec CX 1000 as the Frame relay access and switching solution, network costs are reduced to a single high-speed local loop access line that carries voice, fax, and data traffic for one monthly charge. The CX 1000 switch, for example, has features that allow the user to switch both voice and data across domestic and international public Frame relay networks. Global Frame relay service eliminates the high costs for what might be associated with more traditional international transmission services.

The global reach of this network also allows the user to support a worldwide customer base and provide for the timely management of all company resources. The advantage is that users can leverage the attractive pricing of a global Frame relay service through the application of Frame relay switches. These same switches might also be deployed in a hybrid integrated network supporting a combination of Frame relay and leased lines, where the combination of facilities would produce the most cost-effective arrangement.

Rules of Thumb for Buying Global Services

There is not a great deal of technical support available in the global services arena yet. It is important to obtain specific installation costs for each network node and for monthly local loop access, port costs, and Committed Information Rates levels. Carriers may want to lump some costs together, which makes it difficult to determine the best network arrangement. The possibility of cost negotiation is not out of the question with most vendors, especially when a long-term service contract is concerned.

Levels of service for all nodes on the network should be established in the beginning. Provisioning integrated services digital network (ISDN) at the local loop level is still somewhat mysterious to many users and therefore should be explicitly established at the start of negotiations. Where integrated services digital network (ISDN) service is planned as the local loop access to the Frame relay network, some vendors offer rebates for
installation and conversion to traditional 56K-bps access if the integrated services digital network (ISDN) service does not interface to the Frame relay network.

Some service providers offer zero-level CIR, which lowers costs for the customer. However, traffic levels should be carefully evaluated before the rates are negotiated for bursting above an agreed upon CIR level. If users plan to integrate voice over Frame relay they should plan on a CIR of at least 32 K bps.

The Frame relay premises equipment should work on the service provider's network at all of the user's locations. This is particularly important for overseas locations.

**Conclusion**

Global frame relay service can be a cost-effective, high-performance solution for international networking of voice, LANs, and host systems. Like legacy X.25 networks, Frame relay uses transmission facilities efficiently—only when needed. Like a dedicated leased line service, Frame relay transports information quickly with high reliability and few delays in network processing.

Global Frame relay service simplifies interconnectivity because all service can be transported over a single composite link with each network node fully accessible. As a result, all of the benefits and product services of the domestic service provider can be extended to the user's international locations.

**Author Biographies**

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Andres Llana, Jr. is a telecommunications consultant with Vermont Studies Group, Inc., in King of Prussia PA. He attended Temple University, the US Army Signal School, and the US Army Communications College.
<table>
<thead>
<tr>
<th>Location</th>
<th>Local Loop Per/Month</th>
<th>PVC/CIR Per/Month</th>
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<tbody>
<tr>
<td>Buffalo NY</td>
<td>$ 412</td>
<td>$ 133</td>
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<td>Potenkill NY</td>
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