Payoff

Because it provides efficient, cost-effective transfer of bursty, bandwidth-intensive applications, frame relay is now the main access protocol for wide area network communications. This article discusses the advantages and disadvantages of frame relay, as well as the reasons why training and testing are important.

Introduction

Frame relay—a network access protocol for high-speed, bursty data applications—has been a data communications buzzword for the past five years, but only recently has it begun to serve its purpose. According to Vertical Systems Group, a consulting group in Dedham MA, the number of US public frame relay network subscribers, which was only 590 in the early 1990s, is projected to increase to 8,210 by the late 1990s. The main catalyst for this explosion is the need for high-speed, local area network (LAN) interconnection. Frame relay networks provide companies with cost-effective and efficient transfer of such bursty bandwidth-intensive applications as file transfer, E-mail, graphics, and imaging applications. Frame relay decreases the cost of LAN interconnection through the use of statistical multiplexing, which allows many subscribers to utilize the bandwidth on a single circuit. The cost savings is a direct result of the reduction in the use of dedicated leased lines, which tend to be underutilized because bursty transmission is sporadic.

LANs have become so ubiquitous that subscribers expect to be able to communicate across multiple interconnected LANs just as easily as when they communicate over a single LAN. Frame relay addresses LAN interconnection extremely well (i.e., up to T1 speeds), so subscribers can enjoy the same quality data transmission over the WAN that they have come to expect over the LAN.

It is important that service providers and subscribers understand Frame relay technology and its advantages and disadvantages. For example, Frame relay has no inherent error correction. It assumes that a network successfully transmits data and avoids errors. As a result, users need to test the network for errors and comprehensively train employees on Frame relay technology to reduce errors. This article briefly reviews the features of Frame relay technology and explains some of the important tests to perform on Frame relay devices and the network.

Advantages of Packet-Switching Frame Relay Networks

The main advantage of frame relay is that it is a packet-switching technology. Packet-switching networks send data from source to destination based on each packet's unique destination address. Once the data is packetized, it can be statistically multiplexed.

Statistical multiplexing allows many subscribers to share the same bandwidth by assuming that not all subscribers will be using the bandwidth at the same time. This avoids high-cost, point-to-point connections such as dedicated leased lines that employ circuit switching. Leased lines are expensive because they are rented and dedicated for exclusive use 24-hours a day, seven days a week. With leased lines, subscribers pay for bandwidth
whether it is being used or not. Statistical multiplexing provides multiple data connections through the network simultaneously, and no single customer pays for exclusive privileges. This results in a significant cost advantage over circuit-switched networks.

A second advantage of Frame relay is that its variable-length frames and its low overhead provide excellent network throughput and low delay of data. The variable-length frames allow Frame relay to encapsulate protocols well. Frame relay is protocol independent, so its payload can carry a variety of higher-layer LAN protocols, such as the Internet protocol (IP). Because the network does not concern itself with error correction and flow control, overhead in the Frame relay network is low. Therefore, the network uses most of its resources switching user data.

Frame relay realizes another advantage through the committed information rate (CIR). The Committed Information Rates represents the data traffic level that the network plans to support under typical network conditions; it is agreed upon by the service provider and the subscriber. The advantage of a Committed Information Rates for the customer is that once it is agreed upon, the service provider should be capable of transmitting at or below the CIR. For example, if an average of 56K-bps throughput is required between two sites, then the CIR should be equal to or greater than 56K bps. Typically, data traffic sent below the CIR passes through the network at a high priority, and data sent in excess of the CIR has a lower priority. This low-priority traffic is the first to be dropped when subscribers create network congestion. The CIR serves as the basis of a well-planned network as well as a billing mechanism.

Finally, Frame relay has worldwide industry support from manufacturers, standards organizations, and service providers. This is important because it ensures that there is a high level of interoperability between devices of different manufacturers in different countries.

**Disadvantages of Frame Relay**

Although frame relay carries data more efficiently because it has no inherent error correction utilities, this lack of frame management can be detrimental. Frames can be errored because of transmission impairments in the network (i.e., a bit error corrupts a frame, which is then dropped by the network).

In Frame relay, the error correction is left up to the user's intelligent devices (i.e., a router), which can discover discrepancies and request a retransmission. In addition, the reliable deployment of technologies such as T1, digital data service (DDS), and fiber optics decreases the need for error correction within the network.

Network problems can occur when subscribers exceed the Committed Information Rates. As previously mentioned, the Committed Information Rates is the amount of data traffic, agreed upon by the service provider and the subscriber, the network is planned to support under normal network conditions. When too many subscribers exceed the CIR, then a situation may develop in which the network becomes congested and begins to drop frames to alleviate the congestion.

For example, 20 banks are all connected to a Frame relay network. During the day, they all transmit under their Committed Information Rates for routine electronic communication. At 2:00 p.m., however, all of these banks send their daily transactions to another location for processing, which causes network congestion. If only one bank transmits over the CIR, network congestion probably will not occur. It is the aggregate of many banks transmitting over their Committed Information Rates that causes congestion and dropped frames.
Frame relay frames are variable in length; therefore, they cause variable delay in the network. For example, a short frame can be switched quickly by the Frame relay network. However, longer frames take longer to process and switch. This creates a variable transit time between long and short frames. Integrated data, voice, and video applications cannot be delayed; therefore, these applications are not best suited to Frame relay. They are better suited to integrated switched digital networks (ISDN) or cell relay technology, such as Asynchronous Transfer Mode.

**Anatomy of the Frame Relay Frame**

Frame relay's packet-switched technology is based on its older relative, X.25. In a packet-switched network, data is subdivided into individual packets, each with a unique identification and destination address. These packets, or frames, as they are called in frame relay, are variable in length. Each frame contains a header, information field, frame check sequence (FCS), and two flags. (See Exhibit 1.)

**The Frame Relay Frame**

**The Frame Header**

The header of a frame contains information on connection identification. Connection identification is managed by the Data Link Connection Identifier. The data link connection identifier (DLCI) is an identifier (i.e., address) associated with each Permanent Virtual Circuit. A permanent virtual circuit (PVC) is the path that is set up by the service provider routing data from point A to point B. Once a Permanent Virtual Circuit is defined, it requires no setup operation before data is sent and no disconnect operation after data is sent.

**The DLCI.**

The data link connection identifier (DLCI) is usually 10 bits long, but it can be extended. Each Data Link Connection Identifier indicates a different permanent virtual circuit (PVC) or end point for data. In other words, the Data Link Connection Identifier must be unique for specific destinations. For example, for San Francisco, the data link connection identifier (DLCI) is 45; for New York, it is 49. These values ensure the proper routing of information within a network (see Exhibit 2). The data link connection identifier (DLCI) can be extended to increase addressing capabilities. There are two, one-bit Extended Address fields in the header that indicate if another octet has been added for extended data link connection identifier (DLCI) purposes.

**Sample DLCI Values**

**Congestion Control.**

Also within the header are congestion control bits, which identify whether congestion is present. These congestion bits are important because they inform the user of potential errors in the network. If congestion overloads a particular switch, frames will be discarded by the network. There are three main types of congestion control bits: Forward Explicit
Congestion Notification, Backward Explicit Congestion Notification, and Discard Eligibility. (See Exhibit 3.)

**Congestion Control**

The header also includes the Command/Response field. This one-bit field is used by many higher data link control (HDLC)-based protocols to indicate whether a frame carries a command or a response. It is passed transparently through the Frame relay network.

**The Information Field**

The information field contains variable numbers of octets (up to 4,096 octets for some implementations) and encapsulates many protocols, including Transmission Control Protocol and Internet Protocol (TCP/IP), Internetwork Packet eXchange, Sequenced Packet eXchange, Systems Network Architecture (SNA), and X.25. The information field is the largest part of the frame and contains the encapsulated protocol header as well as user data.

**The FCS Field and Flags**

The frame check sequence field is used for error detection. The transmitting end devices (i.e., routers) apply a complex algorithm to the data in the frame and then place the result in this field as the frame is sent to the receiving equipment (i.e., the router at the far end). Each node along the way recalculates the Frame Check Sequence based on the received data and compares the result to the FCS within the frame. If the results are not identical, then the frame is discarded by the switching node or the end device. Flags serve as eight-bit idle codes that delineate frames on the circuit.

**Local Management Interface**

The Local Management Interface, a signaling protocol, was instituted by Cisco Systems, Inc. (Menlo Park CA), Digital Equipment Corp. (Maynard MA), Northern Telecom, Inc. (McLean VA) and StrataCom, Inc. (San Jose CA). It allows the subscriber and the network devices to share information on the status of data link connection identifier (DLCI) on the link.

In addition, the local management interface (LMI) provides a mechanism for the network to recognize that end devices are operating correctly. The local management interface (LMI) proposal was accepted with minor additions by the American National Standards Institute (ANSI) and the International Telecommunications Union (ITU). These standards organizations slightly modified and standardized the local management interface (LMI), which is now represented by ANSI T1.617, Annex D, and International Telecommunications Union Q.933, Annex A.

**The Importance of Testing**

Frame relay networks sacrifice function for speed by relying on intelligent devices and an efficient network to prevent errors and retransmissions. With such a reliance on the network, it is imperative that users test the physical medium, the Permanent Virtual Circuit, and the internetwork, both out of service and in service, when implementing frame relay. Specifically:
Out-of-service testing is performed when a circuit is taken offline, or when no subscribers are active on the circuit being tested.

In-service testing can be done while a circuit is active. The testing of the transmission facilities, as well as testing the internetwork service, ensures that the service itself, the internetwork devices, and the physical media provide seamless network performance for customers.

Testing the WAN Facilities

Users need to carefully test the transmission facilities before implementing a Frame relay network. There are three parts to a comprehensive test strategy: testing the transmission facilities between the subscriber and the point-of-presence (POP) switch, testing the permanent virtual circuit (PVC) through the network, and conducting a lost frames analysis.

Bit Error Rate Testing.

To test the transmission facilities between the subscriber and the POP switch, an out-of-service Bit Error Rate test should be performed. This test examines the transmission facilities by evaluating the percentage of bits received in error compared to the total number of bits received.

Typically, the bit error rate (BER) test set generates one or more complex sets of pseudorandom bit patterns and then transmits these patterns along network segments at rates dependent on the facilities. The bit error rate (BER) test set provides the stimulus as well as the receiver to monitor the response of the transmission segment being tested. This test can pick up bit errors, Bipolar Violation (BPVs), cycle redundancy check (CRC) errors, and other errors that may cause the network to drop frames. When these errors occur, an end device requests retransmission, which costs money and consumes valuable bandwidth.

Because the pseudorandom patterns used in the bit error rate (BER) test do not pass through the switches, this test is useful only between the customer and the POP switch. However, because of frame relay's lack of error correction utilities, bit error rate (BER) testing is vital. A clean transmission line must be ensured before any additional investigation can be done.

PVC Testing.

Once the transmission facilities are verified, the permanent virtual circuit (PVC) should be tested. This test verifies end-to-end connectivity between two or more subscribers on a specific permanent virtual circuit (PVC).

This test is performed by generating and receiving a variety of Frame relay traffic loads with the proper Data Link Connection Identifier and Local Management Interface support over each valid permanent virtual circuit (PVC). The test should be able to transmit frames with control of various header bits, like data link connection identifier (DLCI), Forward Explicit Congestion Notification, Backward Explicit Congestion Notification, and Discard Eligibility. Successful test results indicate that the transmission facilities are operating with minimal errors and the correct link management parameters and that the network is properly routing frames across the permanent virtual circuit (PVC) being tested.

When testing transmission facilities, permanent virtual circuit (PVC), and local management interface (LMI), monitoring of layer -two and layer -one (i.e., transmission
facility and permanent virtual circuit (PVC)) phenomena is also important. For example, users can determine that a bipolar violations at the physical layer (layer one) coincides with a Frame Check Sequence error on a layer -two analysis, which indicates a transmission facilities problem and not a Frame relay problem.

A Lost Frames Analysis.

Another important feature of Frame relay testing is determining if any transmitted frames are lost. This test is performed by placing a sequential counter in the data field of the test frames. The test set receiver tracks gaps in the test frames’ sequence count. There are usually several reasons the network may be dropping frames: FCS errors are occurring, the attempted throughput exceeds the Committed Information Rates, too many frames per second are being transmitted, or the network may be experiencing congestion.

This test also discovers dribbling errors that cause network bottlenecks and the determination of critical thresholds of Frame relay devices. The lost frame analysis gives customers a final assurance when verifying network performance because it can discover errors that previous tests did not catch.

Frame Relay Internetwork Service Testing

The most important reason to test the internetwork service is the increasing number of premium services being offered. These premium services, such as the end-to-end management of network services, rely on LAN/WAN analysis at the higher-level functions that only internetwork testing can verify.

Internetwork service testing begins with the Frame relay devices themselves. These devices generate and receive the Frame relay frames. Simultaneous monitoring of both sides of these devices can be done to verify that LAN traffic to the router is correctly forwarded and encapsulated in Frame relay. This verification of connectivity across the router also ensures correct configuration. The user should test all routers before installation on the network and before calling the provider's wide area support group when switch problems occur.

The Echo Test.

Another internetwork device test that can be performed to verify connectivity across the network is the echo test. The echo test’s key applications are for implementation and installation of routers when establishing connectivity, for in-service measurements on in-service and out-of-service equipment, and for performing round-trip delay measurements through the network.

The echo test eliminates the need to take down the service when testing network connectivity. In an echo test, the test equipment bounces (pings) a packet across the network to the far-end router (or host) and awaits a response. It checks the connections through the WAN by monitoring both the outgoing ping packet and the returning response from the remote host.

Simultaneous Monitoring of the WAN and LAN.

Simultaneous monitoring of the WAN and LAN should also be performed. By looking at encapsulated LAN protocols, users can verify that customer traffic is correctly addressed, encapsulated, and transmitted over the WAN. In the opposite direction, users should track
packets to ensure that Frame relay information is removed and that they are correctly routed to their destination on the LAN.

Multiport analysis provides the ability to test an internetwork at various access points simultaneously. For example, users could access LAN segments. Once the link is established, users can stress the circuit using a traffic generator.

**Commissioning the Frame Relay Service**

Once the testing of the Frame relay devices and network is complete, users can concentrate on commissioning the Frame relay service. This application focuses on emulating the data communications equipment (DCE) and Data Terminal Equipment by generating Frame relay packets to see how the network reacts to these packets.

First, the test should provide for Annex D (ANSI signaling protocol) and local management interface (LMI) emulation to imitate network conditions. This action ensures that the network can process the frames across the LAN and the WAN. Once this is accomplished, the user can monitor layer-two and local management interface (LMI) signaling statistics. The test equipment should then stress test the line by generating frames to ensure that the network stands up to agreed communication rates. The commissioning process verifies and sectionalizes inside and outside the Frame relay cloud.

**End-to-End Analysis**

Finally, users want to take advantage of the verification of end-to-end LAN/LAN connectivity. End-to-end analysis ensures the integrity of the entire internetwork. With this application, users can generate traffic to remote LANs to verify connectivity or capacity handling. In addition, users can monitor both local and remote trends in network operation to plan for network changes and expansion.

**Training Issues Unique to Frame Relay**

One aspect that is often overlooked in technical articles, books, and magazines is the training of personnel in technology, network applications, and troubleshooting methodology. Yet training is extremely important when implementing a new technology such as frame relay.

**The Provider's Perspective.**

From the service provider's perspective, training is critical in overcoming a technician's lack of protocol or packet-switching knowledge. These technicians, who must install the Frame relay equipment and services, may know how to install Dataphone Digital Service or T1 links, but they may have limited protocol experience and most likely have never been exposed to Frame relay. Frame relay training provides the technology background these technicians need. It also provides the installation and troubleshooting background they need to maintain the service.

Training can point out to the technician the prospective problems that occur when testing Frame relay and how to solve them. For example, the physical layer may work but the service may not. This is often caused by switch configuration problems, such as the switch not being configured, being configured incorrectly, or the provider and subscriber configuring their switches incompatibly.

**The Subscriber's Perspective.**

From the subscriber's point of view, training issues on Frame relay technology are less critical, but training on its test applications may be more important. These technicians are
comfortable working with circuits and services focused on protocols. For example, an IS department professional may have extensive experience with the technology and the testing of X.25. However, Frame relay, unlike X.25, has no error correction, which introduces a series of testing issues. Although the technology may be similar, the test applications are different.

For subscribers, Frame relay training provides technology specifics, such as how Frame relay applies to their particular network, taking issues like Committed Information Rates, Data Link Connection Identifier connections, and link management into account. The traditional classroom setting is still popular in many companies. If the company does not have a training department, the data communications manager should consider sending technicians on staff to an outside organization whose specific purpose is to increase workers’ comprehension or knowledge level of technology or product use. These sessions can take the form of seminars, classroom sessions, field training, video, distance learning (i.e., teleconferencing), or auditorium-style lectures. Computer-based training might also be available, which provides a self-paced environment that can cover multiple knowledge levels at the same time. As microprocessor technology and memory storage become more advanced, users are able to run complex instruction disks on their personal computers. They can take in the training at their own pace, at home, in the office, or on the road.

### The Benefits of Training

Training offers a critical advantage to an organization through increased production, reduced cost, and maximized efficiency with respect to Frame relay network performance parameters. Training helps employees avoid pitfalls encountered during a new installation. It does this by increasing employee knowledge levels about Frame relay technology and then having them apply this knowledge to everyday work and even future upgrades.

In addition, training enables users to test and manage a Frame relay network from the first day of implementation. This kind of knowledge about the network decreases downtime and outages, as well as return trips to the subscriber's premises.

The key to reducing cost and downtime of a Frame relay network is to plan and implement training before circuit implementation, because the training offers insight on potential problems before they actually occur. Subsequently, service providers and subscribers save money as downtime is reduced because the job was completed efficiently the first time. Training is an expense, but it provides a company with a return on investment through knowledgeable employees who can efficiently run a frame relay network.

### Conclusion

Frame relay is now the main access protocol for WAN communications and will likely stay that way for the rest of the decade. But that is not the end for frame relay. The future of Frame relay lies in its capability as an access network for Asynchronous Transfer Mode-based services, which many consider to be the communication services of the future. Hybrid frame relay/ATM networks will provide the transition between the two networking technologies. Eventually users will run integrated multimedia applications and services over their asynchronous transfer mode (ATM) networks, making full use of technologies for which Frame relay helped pave the way.

### Author Biographies

Steve Greer
Steve Greer is a product marketing manager at Telecommunications Techniques Corp. (TTC), which is a Dynatech company headquartered in Germantown MD. TTC designs, manufactures, and markets communications test products and systems, and is known for its line of T-BERD and FIREBERD analyzers.

Peter Luff
Peter Luff is a marketing manager at TTC in Germantown MD.

Sean Yarborough
Sean Yarborough is a product marketing engineer at TTC in Germantown MD.

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Key:

BECN  backward explicit congestion notification
C/R   command/response
DE    discard eligibility
DLCI  data link connection identifier
EA    extended address
FCS   frame check sequence
FECN  forward explicit congestion notification