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Performance Study of Voice Over Frame Relay

A thesis presented in partial fulfilment of the requirements for the degree of Master of Engineering in Information Engineering

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Abstract

Frame Relay (FR) represents an important paradigm shift in modern telecommunication. This technology is beginning to evolve from data only application to broad spectrum of multimedia users and potential to provide end users with cost effective transport of voice traffic for intra office communication. In this project the recent development in voice communication over Frame relay is investigated. Simulations were carried out using OPNET, a powerful simulation software. Following the simulation model, a practical design of the LAN-to-LAN connectivity experiment was also done in the Net Lab. From the results of the simulation, Performance measures such as delay, jitter, and throughput are reported. It is evident from the results that real-time voice or video across a frame relay network can provide acceptable performance.

Acknowledgement

I, at the completion of this thesis want to state that my efforts have come to function chiefly because of the help and advice received from teachers, friends and well wishers. This is the opportune moment to express my indebtness to all.

I wish to express my deep sense of gratitude to Dr. M. A. Rashid for his invaluable advice and constant guidance throughout the duration of this project.

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Chapter 1

Introduction

New applications are rapidly evolving that allows multiple users to communicate real time voice and video along with traditional file and screen sharing and other data applications. Changing from the current multiple networks into a single multi service network would usually take place in phases. Frame Relay (FR) is a high-speed communication technology that is used to connect LAN, Internet and voice applications. Frame Relay is a way of sending information over a wide area network (WAN) that divides the information into frames or packets. The frames travel through a series of switches within the FR network and arrive at their destination. Frame Relay employs a simple form of packet switching that is well suited to powerful PCs, workstations and servers that operate with intelligent protocols. As a result, FR offers high throughput and reliability that is perfect for a variety of today's business applications. FR can be used around the edges of the WAN to connect remote offices into the Intranet, or can be used as the entire backbone technology for the WAN. The inherent characteristics of Frame Relay networks can lead to substantial savings in transmitting costs, as well as increased network flexibility. The integration of packetised voice leads to design challenges such as controlling network delay, prioritizing traffic types and choosing a suitable compression algorithm.

Voice quality on a packet network is affected by delay and jitter. The objective of Quality of service (QoS) features in a packet network is to minimize delay and jitter for voice traffic.

Due to the increased number of networks in existence and their greater complexity, designing new systems and improving the performance of existing ones has become more difficult and time consuming. It is therefore more practical to use modeling and simulation tools to deal with this complexity. OPNET (Optimized Network Engineering Tools) is a comprehensive engineering system, capable of simulating small and large communication networks with detailed protocol modeling and performance analysis. It provides an opportunity to examine Frame Relay network in a simple model, which can provide the same performance as if it is the complex one.

In this research project our approach is to set up special Permanent Virtual Circuits (PVCs) for voice, compression technique is applied for two different types of voice applications to see the various parameters that affect the FR network for voice application. Several network models has been developed and simulation has been done using OPNET modeler 8.1. The results were used to evaluate the performance of voice over Frame Relay networks.

The structure of the thesis is as follows.

Chapter 2 introduces the Frame Relay technology. Some of the key aspects of FR are discussed. It explains the relationship between ISDN, OSI, and ANSI layers. It also describes the structure and operation of the Frame Relay. Error control and recovery, congestion control and management is also studied in this chapter. The internetworking with other networks and effect of different service parameters are explained.

Chapter 3 describes a detail discussion on Voice Over Frame Relay. Voice compression techniques, Voice quality of service (QoS), delay and delay variation, frame loss, fixed and variable delay components and different options of voice packet transports.

Chapter 4 gives review of literatures. In this chapter detail discussion of previous and present work has been elaborated. Different real time applications regarding Voice Over Frame Relay are also discussed.

Chapter 5 presents the simulation of the Frame Relay network model using the OPNET simulation package. This chapter discusses briefly about the OPNET programming package and provides a quick overview of various steps for building a network.

Chapter 6 explains FR network design for voice application. The procedures for the simulation of network models, implementation procedure and the selection of attributes are discussed. A description is given of devices and tools within the OPNET program that have been used in this research. It also shows different network scenario and model used. The selected attributes are also shown in the figures obtained from print screen options. This also gives the hardware experimental setup description at the IE-Net lab.

Chapter 7 gives performance results obtained from the simulation procedure of the Frame Relay networks in graphical forms. Statistical results of different global parameters of the networks are also included in tabular form.

Finally in chapter 8 an overall conclusion on the work is added with some suggestion about further work.

Chapter 2

An Introduction to Frame Relay Technology

Frame Relay(FR) represents an important paradigm shift in modern telecommunication. A shift away from network based intelligence and complexity towards a simplified, streamline network infrastructure that provide cost effective, multiplexed information path between intelligent devices.

In the Information Age, corporate intranets, extranets, branch offices via wide area networks (WANs) or local area networks (LANs) are the channels for everyday business. Frame Relay, ATM and TCP/ IP are the principal networking techniques used to build wide area networks, among them frame relay is a good choice for transferring data and voice, especially across multiple private or public networks. The telecom industry is trending toward network convergence and favoring open system solutions that reduce networking and operating costs.

Frame Relay evolves with interoperability as a principal goal through the international standards bodies, such as ITU-T, Frame Relay Forum, and ANSI. These organizations define specifications to assure internetworking among the various vendors in large networks.

Frame Relay evolved from X.25 and ISDN in the mid-1980s. The technology promised to minimize network functions to provide a simple and flexible service to users. From X.25, Frame Relay borrowed the concept of virtual connections, which decoupled the idea that one physical interface mapped to only one connection. Many virtual circuits (VC) can exist simultaneously over the same Frame Relay link. In addition, virtual circuits may be either permanent virtual circuits (PVCs) or switched virtual circuits (SVCs). PVCs are set up administratively for dedicated point-to-point connections. SVCs are set up dynamically on a per call basis. From ISDN, Frame Relay adopted the idea of separation of functionality based on control, data, and management planes.

Initially, Frame Relay served mainly as a cheaper alternative to leased lines for establishing wide-area networks with LAN-to-LAN connections. These access connections remain the largest application for FR. Vendors have developed other applications deployed over Frame Relay, such as IP, SNA, X.25. Frame Relay is also used for high-speed access to the Internet. FR can commonly be found in corporate LANs, wireless infrastructure, travel reservations infrastructure, banking (ATM teller machines), and mainframe-based SNA systems.

Frame Relay also embodied some pioneering concepts: it removed hop-by-hop flow control and error control, moving them to the network boundaries, it specified quality of service (QoS) parameters for virtual connections, and it specified aspects of traffic management to handle congestion caused by bursty use of virtual connections. FR was ideal for data traffic and made modern high-speed WANs possible. The vast majority of connections are permanent virtual circuits (PVCs) although switched virtual circuit (SVC) service is also commercially obtainable.

FR became one of the fastest growing market segments in telecommunications. The reasons include bandwidth efficiency which means virtual circuits use bandwidth only when transporting packets, and the protocol reduces error-handling processing, improved reliability of network circuits, an avid demand for bandwidth from users, and the continued advancement of FR standards.

FR is an Integrated Services Digital Network (ISDN), packet-mode, and carrier service designed for the transport of variable length data units over a connection-oriented path. The FR protocol eliminates protocol processing in the network nodes above layer 2 of the OSI model [1, 2]. Study of voice transmission over FR networks is motivated by the flexibility of bandwidth management offered by integration of voice and data in a single network. FR networks were originally intended for data communications alone. Integration of voice and data presents technical difficulties arising from the conflicting QoS requirements for both these traffic types; data is extremely loss-sensitive but can tolerate long delays. In direct contrast, voice traffic can accommodate limited amounts of lost or corrupted information but there exists a delay constraint for acceptable voice quality. The principal challenge in supporting real-time voice applications over any packet-switching network is the need to obtain synchronous playout of voice packets in the stocking network delays. Compensation of variable delays is typically achieved by buffering received packets and voice playout algorithms differ with respect to the techniques used to estimate the delay to be introduced prior to playout.

Before describing the issues surrounding the transport of Voice over Frame Relay (VoFR), it is necessary to briefly review the concept of FR since many of the obstacles to transporting voice calls in a public network are inherent in Frame Relay's technology.

2.1 Frame Relay Protocol

Frame Relay is a standardized packet interface protocol and does not define the backbone switching protocols or topologies. American National Standards Institute (ANSI) and the International Telecommunications Union-Telecom sector (ITU-T) define the standards.

The standards defining it specifically as an interface between the FR network and the attached devices like LAN router, front-end processor. Any type of packets can be carried over FR, but it should inter-networked with Link Access Protocols for ISDN D channel at layer two. The fundamental assumption to success the FR networks is the reliability of the transmission medium; the devices using the network generating bursty traffic and the end systems should be intelligent.

FR standards implemented this technology in three different ways. Frame Relay as an interface, as a signaling protocol and as a network service, these are the key aspects which will improve the wide area networking problems.

2.2 Frame Relay as an Interface

Frame Relay standards are developed by ITU and ANSI specifying as an access interface that provides the statistical multiplexing capability, allowing many logical connections over a physical link. These connections were maintained via PVCs.
FR standards evolved from ISDN interface standards. Which is the only interface can operate over basic rate access (BRI); primary rate access integrated digital access networks (PRI ISDN), V-series, digital data systems (DDS) and DDN. Manufacturers of FR access devices (FRADs), Routers and other equipment's used in FR networks are given some of the facilities like traffic priorities, methods for congestion control and

congestion recovery procedures have been implemented in their own ways. Some of the benefits of using FR as an interface are:

- Multiple users per physical access line
- Reduce the network access hardware costs
- Wide industry support
- Can maintain the interface standards
- High speed of access due to low packet demand
- Provide higher throughput

2.3 Frame Relay as a signaling protocol

Frame Relay is a high-performance WAN protocol that operates at the physical and data link layers of the OSI reference model. FR comes under fast packet technologies. This is an extension of X-25. Some of the benefits of FR using as a protocol are:

- Variability of the frame size.
- Improved performance over older packet protocols
- In band customer service and link management
- Discards error frames and excess data
- Protocol Flexibility
- Transparent to the higher layer protocols

2.4 Frame Relay as a network service

Nowadays Frame Relays network services are offering in both public and private networks. Because of it virtual networking capability and pay only to the actual bandwidth consumed by the user and this can be implemented over a surplus bandwidth of T1/E1 line, which is already using TDM multiplexing [3]. FR as a network service offers some benefits as follows

- Higher network availability
- Single network with multiple protocols
- Dynamic network architecture
- Fills the need for high speed LAN to LAN connectivity

2.5 Frame Relay layers and its relation ship to ISDN, OSI and ANSI layers

It uses variable length frames and routing of the packets will be done through data link layer by binding the data link connection identifiers (DLCI), some of the operations of upper sub layer of the data link layer like error recovery, flow control will be done on users end to end basis. Some of the core functions are added to the data link lower sub layer such as frame delimiting, multiplexing. The capability supports the internetworking of different type of networks like LANs and WANs. These variable data units will generate variable delays, because of this reason the delay sensitive data (voice and video) was not suitable to this type of networks. But nowadays the transport technology used in frame relay network is based on cell relay technology. The Frame Relay frames are splits in to cells and transported through backbone and reassembled as frames at the other end.

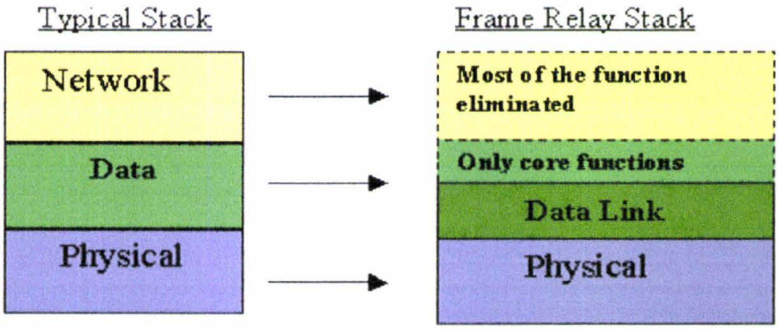


Figure 2.1 Comparison of typical and Frame Relay stack

The figure 2.1 explains the comparison between a typical and FR stack. The left side of the block diagram represents a typical data communication protocol stack. It contains physical, data link and network layers. The physical layer is responsible for modulation, encoding and decoding data etc. The data link layer is responsible for the error checking and retransmission of error traffic, and proper framing at the receiver. The network layer is responsible for routing and managing the traffic within the network and establishes a virtual connection etc.

The right side of the figure explains the frame relay stack. It eliminates most of the network layer and several functions of the data link layer.

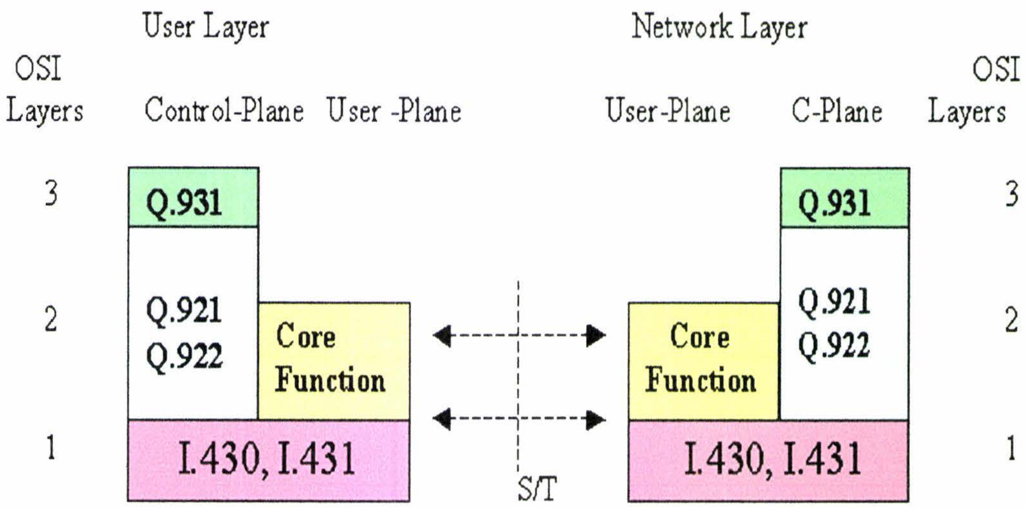


Figure 2.2 The User –to- Network Element interfaces (CCITT)

The FR service model has been shown as OSI and ISDN layer architecture in figure 2.2. The FR network only supports the core functions of the Q.922 layer 2 protocol. Which is an extended version of Q.921. This is the specification for the frame mode bearer service at data link layer.

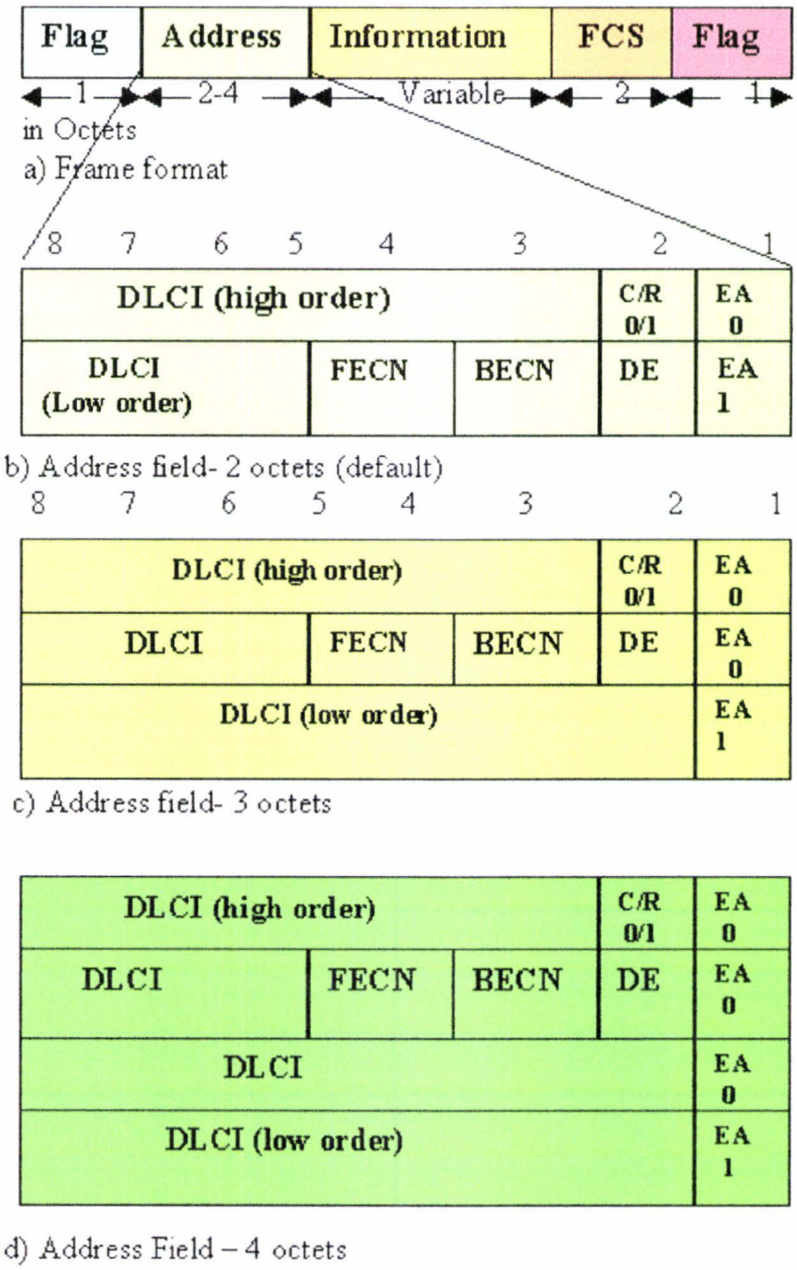
Some of the core functions are

- Frame delimiting& bit level transparency
- Virtual circuit multiplexing and demultiplexing
- Octet alignment of the traffic
- Check the maximum and minimum frame sizes
- Error detection and congestion management

The remaining operations are implemented on an end-to-end basis. The Q.931 is a user network interface layer 3 specifications for call control. I.430 is an ISDN user network Interface layer 1 recommendation.

2.6 Frame Structure

The frame relay frame derived from the HDLC (High level data link control) and it is another form of LAPD protocol. There is one major difference is that there is no control field. Frame structure is shown in the figure 2.3.



C/A- Command/Response indicator
EA- Extended Address
F- Flag
FCS- Frame Check Sequence
DE- Discard Eligibility
DLCI- Data Link Connection Identifier
FECN- Forward Explicit Congestion Notification
BECN- Backward Explicit Congestion Notification

Figure 2.3 Frame Relay frame structure

This was defined in ANSI Standard T1.618. The flag field is a unique string of bits, which indicates the start and end of a frame. There are two octets of address field. The address field can vary from 2 to 4 octets in size. The primary function of the address field is to carry the DLCI. This allows multiple connections to be carried over a single channel (multiplexed). The Data Link Control Indicator field indicates that octet is an extended or not extended DLCI. The data field can vary in size up to 4096 octets long. Frame Relay is able to support multiple higher level protocols by encapsulating the other protocol data units (PDUs) inside the data field of FR frame. This allows the FR network to be transparent to these upper layer protocols. This size of the data field is limited by the integrity of the frame check sequence (FCS). If any error was found at the receiving end, that frame will be discarded. Discard Eligibility (DE) is set to indicate that a certain frame should be dropped in preference to other frames without the bit set when and if the link becomes congested. The frame also contains three bits, which are used for congestion notification.

2.7 Frame Relay Operation

Frame Relay uses the 10-bit DLCI to identify the destination end user address. These bits can be extended as shown earlier. DLCIs are pre-mapped to the destination node. So total process was simplified at the router. Now the nodes only need to see their routing table, for this DLCI and route the traffic to the proper output port based on the address. This translation of user address to DLCI is not defined in the FR standards. Some of the Switch vendors strip-off the FR header and trailer at the sending User Network Interface (UNI) and add their control fields to transfer the data to the receiving UNI. At the receiving end, FR header will replaces the internal network header.

2.8 Error Control and Recovery

One of the basic assumptions under the FR is the transmission media should be free from error. However, current digital transmission technologies, in particular optical fiber, have very low error rates. In FR the end user equipment does correction and retransmission. The network can detect the errors in the frame by using cyclic redundancy check (CRC) operation only on the header field. If it detects any error in the address field it will just discard the frame.

2.9 Congestion control and Management

All of the users of FR network are sharing the same medium capacity. It might happen that all the users may try to access the network simultaneously. As a result congestion will happen in the network. In FR, congestion identification and control will be done in different ways, and it all depends on the vendor of the switch.

Mainly these congestion mechanisms will come under two categories. One is implicit congestion control. Usually in this type of networks the top layers will control this function. By seeing the delays of the acknowledgement packets it will control the speed of the packets, which are sending, into the frame relay port. Second one is explicit congestion control. This will use Forward Explicit Congestion Notification (FECN) and Backward Explicit Congestion Notification (BECN) bits of the FR frame. Suppose the congestion occurs at one Nodal processor the FECN will be set to 1 and it will be forwarded to the next processor. The traffic coming from the destination side knows about the congestion. The congested processor will set same way the BECN bit, which are going in the opposite side. Now the both ends of the networks know where the congestion happened. This mechanism implementation is depends on the user equipment and provider of the network [4]. This has been explained in the figure 2.4.

Congested portion of the Network

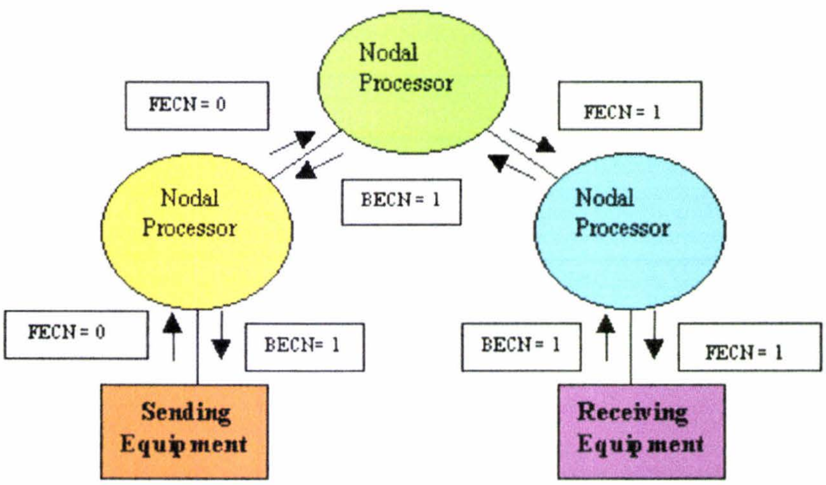


Figure 2.4 FECN and BECN action

The vendor has to fix the time interval Tc and it was not defined by the standards. CIR can be calculated by Bc/Tc. This was implemented by Leaky bucket algorithm [5] and the values of the different parameters are adjusted. Some of the vendors will use the rate control mechanism. By decreasing and increasing the transmission speeds at a fixed step, it will control the congestion. This has been implemented by British Telecom Networks [6]. Differences between the 2 types of congestion control methods concern response time, data flows and switch processing capabilities.

2.10 Internetworking with Other Networks

The interconnection with FR can be implemented in different ways. Some of the strategies are

- Over a point-to-point line, connected two routers directly.
- Using Single or multiple mode mixed media processors.
- Data only service for any type of networks through Public Networks.
- Hybrid Network implementation.

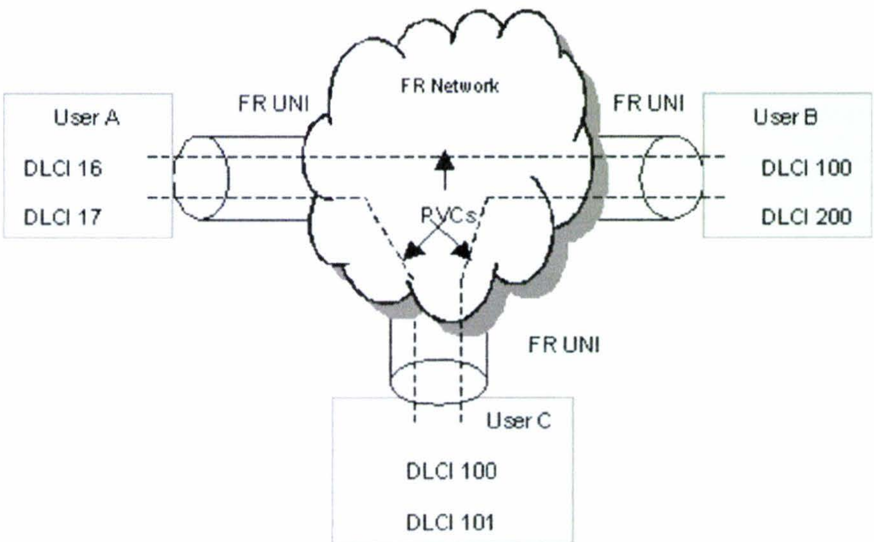


Figure 2.5 Frame Relay UNI and PVC

The procedure of the interconnection between user equipment and network is called user network interface (UNI). The PVC, which is passing more than one network, is called multi-network PVC as shown in the figure 2.5 and 2.6. The procedure for implementing UNI and NNI was published in ANSI T1.617 Annex D.

Figure 2.5 illustrates the FR network environment, with three users accessing the FR network through a UNI, each with a PVC to the other site, and each PVC end point identified by a DLCI.

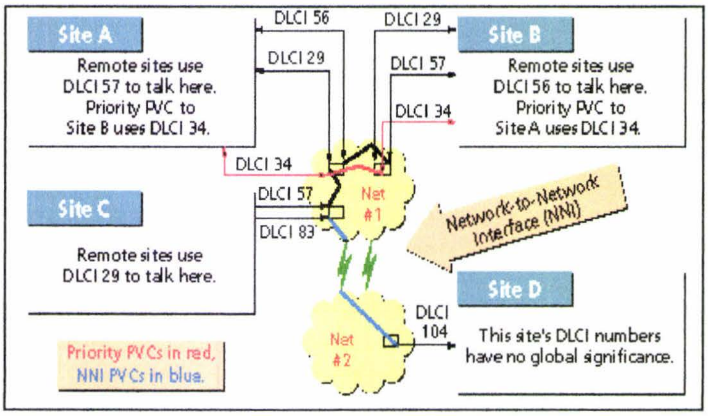


Figure 2.6 Logical layout of a Frame Relay Network (Cisco press)

The FR network to network Interface (NNI) is defined by the standards as a method for two FR networks to interconnect, pass FR traffic, and manage the logical connections (PVCs) which originate on one FR network and terminate on another. Figure 2.6 shows an example of utilization of priority PVCs. Frame Relay Data link Connection Identifiers (DLCIs) are mapped by carrier switch into permanent virtual circuits. Here in figure 2.6 Site A, B and C use DLCIs to identify sites. Sites A and B use a common DLCI number to identify a circuit whereas site D does not assign any meaning to DLCIs.

2.11 Effect of different Service Parameters

Figure 2.7 explains different FR network service parameters affecting the virtual circuit.

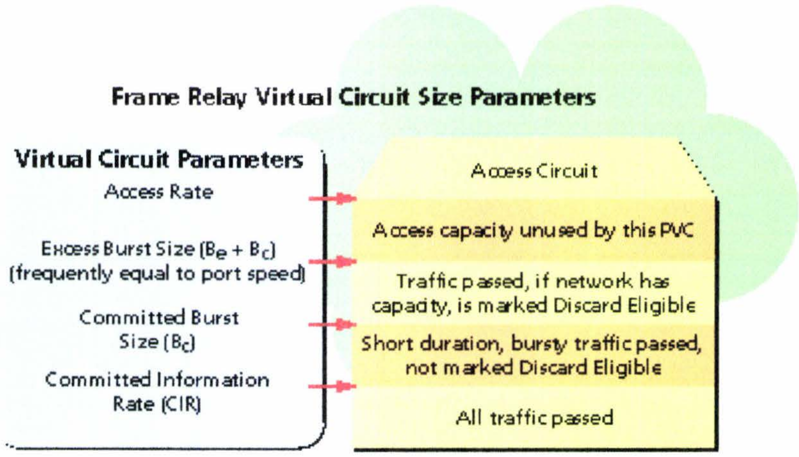


Figure 2.7 Important parameters for virtual circuits (Cisco press)

Access rate is the rate at which the access circuits join the FR network and are typically at 56 Kbps, T1 (1.536 Mbps) or Fractional T1 (a multiple of 56 Kbps or 64 Kbps). It is not possible to send data at higher than access rate.

Port speed is the rate at which the port on the FR switch is clocked. It is not possible to send data at higher than port speed.

Committed burst size (Bc) is the maximum amount of data that the network will transfer in a burst, defined over a (short) interval. All frames received at this level will be passed.

Committed information rate (CIR) is the amount of data that the network will receive from the access circuit. All frames received at this level will be passed. CIR can be computed by dividing the committed burst size by the measurement interval as CIR=Bc / Tc

Excess burst size (Be) is the amount of data above Bc that the network will try to deliver. Frames submitted at this level may be marked as "Discard Eligible," indicating that they may be dropped if there is not capacity in the cloud.

A Data-Link Connection Identifier (DLCI) identifies a virtual circuit to user equipment. This is an end point for a PVC. Based on the standard, this number doesn't describe anything more than that, and has no significance beyond the single link. In practice, however, many designers assign some significance to it. It often represents either a site or a circuit.

When using Frame Relay, overhead is little and overhead decreases as the frame size increases. Larger the frame size accepted by the network, the greater the throughput. [7] Throughput can be calculated based upon number of data bit successfully transferred from one boundary to another within a set period of time. From the FR throughput graphical representation of figure 2.8, the relationship between CIR, Bc and access rate can be explained. As explained earlier, all data below the CIR line will be received. Frames above CIR and below Maximum Burst Rate will be tagged Discard Eligible (DE). Frames above MBR will be discarded.

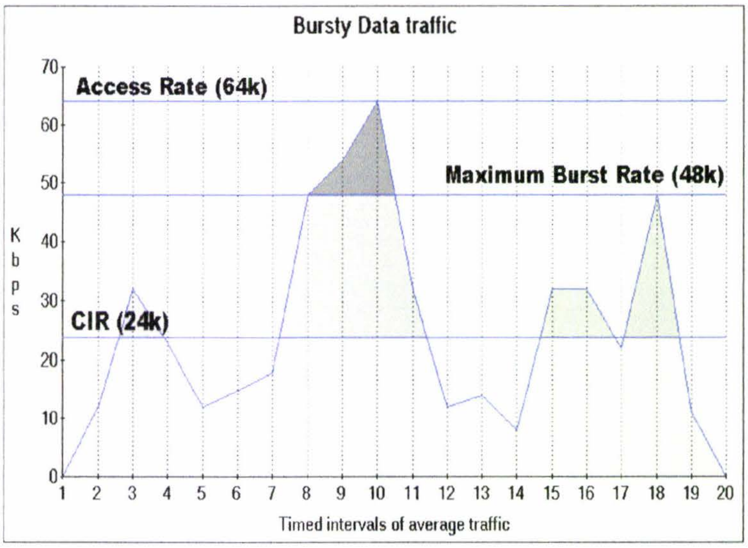


Figure 2.8 FR Throughput graph (PVC / Port level)