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Frame Relay
(FR) Connectivity

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1. Introduction

1.1. The Frame Relay Solution

Frame relay is a data transmission technique that combine the high speed and low delay of circuit switching with the port sharing and dynamic bandwidth allocation capabilities of X.25 packet switching. Like X.25, frame relay divides transmission bandwidth into numerous virtual circuits and allows for bursts of data. But, unlike X.25, frame relay does not require a lot of processing at each node.

Frame Relay only uses the first two levels of the OSI reference model: the physical layer and the data link layer. Moreover, it uses only some of the layer two functions, relying on a combination of intelligent end-user devices and clean transmission lines to ensure data integrity. The result is improved response times and dramatically reduced transmission costs.

Congestion is handled through vendor implementation of the congestion management techniques described in the frame relay standards. Standards-compliant congestion management means that, even during congestion, each end-user device has guaranteed access to a defines amount of bandwidth.

1.2. Frame Relay Standards

The Frame relay concept was initially defined in ITU Recommendation I.122, which provided a general outline of how the LAPD protocol could be used in applications other than ISDN. Not long thereafter, ANSI also became involved in defining standards for frame relay.

As a result of the co-operative efforts of ITU and ANSI, the principal frame relay standards have been defined clearly and completely by both organisations.

The standards specifying frame relay are listed in the following figure.

Topic	***ANSI***	***ITU***
Framework	-	I.122
Service Description	T1.606	I.233.1
Data Transfer Protocol	T1.618	Q.922
Congestion Management	T1.606	I.370
Access Signalling	T1.617	Q.933

Table 1 : Frame Relay Standards

2. Physical Layer

The frame relay network can be accessed via a leased line at speed from 64 kbps to 1984 kbps. The interfaces that can be provided are G.703, X.21 and V.35.

2.1. E1 Interface

This service is offered by the Belgacom leased line service. The physical interface shall be 120 Ohm symmetrical shielded pair.

The E1 120 Ohm interface meets the ETSI 300.011 physical layer requirements.

2.2. V.35 Interface

The V.35 interface meets the ITU-T V.35 electrical specifications

2.3. X.21 Interface

The X.21 interface meets the ITU-T X.21 electrical specifications.

3. Data Link Layer

3.1. Class of Service Parameters

Throughput has been defined as part of the service description in ANSI T1.606 and ITU I.233.1. Belgacom frame relay switches adhere to these standards from source end-user device through the network to destination end-user device. The entire end-to-end connection is fully standards compliant, allowing for sustained bursts of data as long as the bandwidth is available.

The amount of data that can be transmitted on a given DLC is determined by the class of service requested. The absolute limit on DLC throughput is determined by the amount of physical bandwidth allocated to the DLC's frame stream. This is known as the access rate.

Class of service parameters can be defined for each DLC so the amount of bandwidth consumed by any one DLC is controlled. This prevents a large burst of traffic on one DLC from unfairly depriving others of the bandwidth shared on a given frame stream.

Belgacom frame relay service implements the following four class of service parameters, as defined in ANSI T1.606 and ITU I.233.1 :

- **Committed Information Rate (CIR)** : the CIR defines the rate that the network commits to transfer data under normal conditions.
- **Committed Burst Size (Bc)** : the Bc defines the maximum of bits of user data that the network commits to transfer over the Committed Rate Measurement Interval (Tc) under normal conditions.
- **Excess Burst Size (Be)** : the Be defines the maximum number of bits of uncommitted user data in excess of Bc that the network will attempt to transfer over Tc.
- **Committed Rate Measurement Interval (Tc)** : this parameter is not user-configurable. It is calculated as Bc/CIR and is the time interval over which the user may transfer Bc bits of committed data, or Bc+Be bits of uncommitted data. It is not a periodic measurement interval, but rather a sliding window used to measure the rate of incoming data.

A DLC may transmit a maximum of Bc bits over a time interval of Tc seconds. This defines the CIR for the DLC. Under normal conditions, the DLC is guaranteed this rate of throughput.

A DLC may transmit a burst in excess of its CIR provided the total number of bits transmitted over Tc seconds is not more than Be+Bc. The discard eligibility bit is set in frames transmitted within the Bc to Be range.

3.2. Congestion Management

Congestion occurs in a frame relay network when resources, such as network bandwidth of processing capacity, become depleted. Techniques to deal with congestion in frame relay networks are described in ANSI T1.606 and ITU I.370.

Before it transmits data, an end-user device determines now the pending transmission will meet the service required. If it must transmit more bits than allowed by its Committed Burst Rate (Bc) - but less than its Excess Burst Rate (Be) - frames identifies as less important may be marked as Discard Eligible (DE).

This notifies downstream network devices that, should they experience congestion, these frames may be discarded. Higher level protocols detect the discard and take care of retransmission. If the end-user device must transmit more than Bc+Be bits, all affected frames are immediately discarded.

3.3. Explicit congestion notification bits

When a network device experiences congestion, it notifies end-user devices and other network devices by setting Forward Explicit Congestion Notification (FECN) and Backward Explicit Congestion Notification (BECN) bits in frames switched by the network device.

The Belgacom Frame Relay switches implement the BECN and FECN bits as described in ANSI T1.606 and CCITT I.370 and as summarised here :

- **BECN bit**
  The BECN bit is set in any frame switched from a DLC whose frame stream has entered a congested state. This informs the receiving device that any frame transmitted in reply on this DLC is likely to experience congestion.
- **FECN bit**
  The FECN bit is set in any frame switched onto a DLC whose frame stream has entered a congested state. This informs the receiving device that the frame is experiencing congestion.

End-user and network devices can pass congestion notification to higher level protocols that may initiate flow control or rerouting to relieve congested resources.

4. Link Management Protocols

Link management protocols are used to communicate PVC status information and configuration changes between end-user devices, such as routers, bridges or FRADs (Frame Relay Access Devices), and network devices, such as high-speed frame relay switches.

Belgacom frame relay switches implement the three accepted protocols for communicating frame relay link status information :

4.1. LMI

The LMI protocol, which was developed by the Frame Relay Forum, was the first protocol to define the various control functions not originally defined by either ITU or ANSI. DLCI 1023 is reserved for the LMI protocol.

The following LMI protocol types are commonly supported :

- **LMI-user**

LMI-user is used when the frame stream terminates on a network device that supports LMI-network.

- **LMI-network**
  LMI-network is used when the frame stream terminates on a end-user device that supports LMI-user.

The LMI protocol provides three main services :

- It provides a heartbeat (or keep-alive) signal to ensure both end-user and network device are functioning properly.
- It informs the end-user device of the addition and deletion of PVCs.
- It reports the current operating status of each PVC (this status reflects the state of the entire end-to-end connection, not just the state of the local DLC).

4.2. Annex D of ANSI T1.617

The Annex D protocol, which is part of ANSI standard T1.617, performs the same basic functions as the LMI protocol. DLCI 0 is reserved for the Annex D protocol.

There are three Annex D protocol types :

- **Annex D-user**
  Annex D-user is used when the frame stream terminates on a network device that supports Annex D-network.
- **Annex D-network**
  Annex D-network is used when the frame stream terminates on a user device that supports Annex D-user.
- **Annex D-bidirectional**
  Annex D-bidirectional is user when the frame stream originates and terminates on network devices that support Annex D-bidirectional.

4.3. Annex A of ITU Q.933

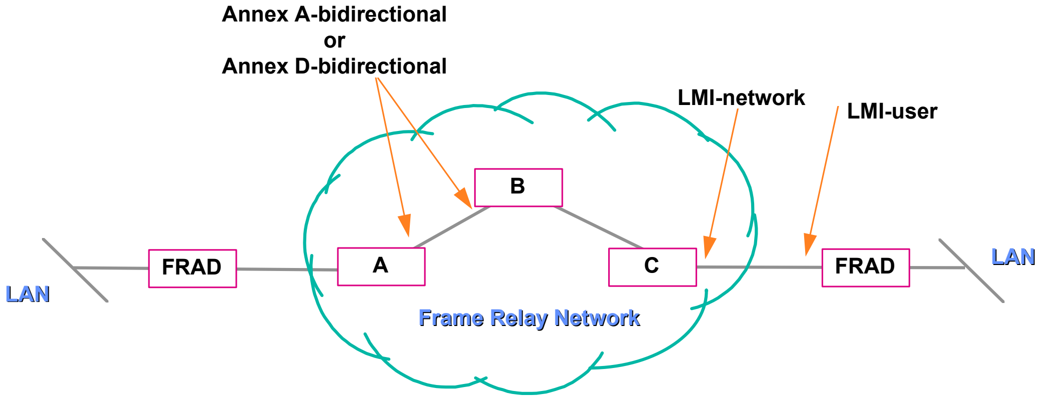
The Annex A protocol, which is part of ITU Q.933, is the ITU link management protocol specification and is very similar to both the Annex D and the LMI protocols. DLCI 0 is reserved for the Annex A protocol.

There are three Annex A protocol types :

- **Annex A-user**
  Annex A-user is used when the frame stream terminates on a network device that supports Annex A-network.
- **Annex A-network**
  Annex A-network is used when the frame stream terminates on a user device that supports Annex A-user.
- **Annex A-bidirectional**
  Annex A-bidirectional is used when the frame stream originates and terminates on network devices that support Annex A-bidirectional.

4.4. Protocol usage

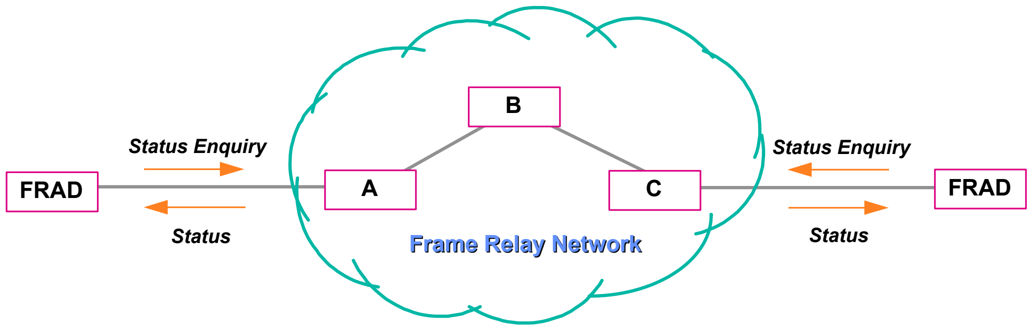
The figure hereunder illustrates Annex A, Annex D and LMI protocol usage. The end-user device supports the « user » portion of the protocol while the network device it is attached to support the « network » portion. The bidirectional protocol is used between network devices.



With the user and network protocols, the end-user device sends a Status Enquiry message to the network device every polling interval (or heartbeat polling cycle). The network device responds with a Status message that verifies the integrity of the link between the two devices.

After a set number of these exchanges (status message rate), the end-user device requests a full status update from the network device. The full status update includes changes made to all PVCs between the two devices.

With the Annex A-bidirectional or Annex D-bidirectional protocols, these same polling exchanges take place. In addition, random full status updates are sent from the network device to the end-user device so the end-user device is kept up to date about PVC changes between full status polls.



The status message rate parameters are :

- **Heartbeat**
  The heartbeat is the interval (in seconds) at which the end-user equipment sends a status enquiry message to the network device. It is configurable if the protocol type is LMI-user, Annex A-user, Annex D-user, Annex A-bidirectional or Annex D-bidirectional.
- **Time-out**
  The time-out is the maximum interval (in seconds) between the time a status message is transmitted and a status enquiry message is received. It is configurable if the protocol type is LMI-network, Annex A-network, Annex D-network, Annex A-bidirectional or Annex D-bidirectional.

- **Status rate**
  The status rate is the rate at which the end-user device sends the status of all configured PVCs from the network device. It is configurable if the protocol type is LMI-user, Annex A-user, Annex D-user, Annex A-bidirectional or Annex D-bidirectional.

5. Terms and Acronyms

ANSI :	American National Standard Institute
Bc :	Committed Burst Size
Be :	Excess Burst Size
BECN :	Backward Explicit Congestion Notification
CIR :	Committed Information Rate
DE :	Discard Eligibility
DLC :	Data Link Connection
FECN :	Forward Explicit Congestion Notification
FR :	Frame Relay
FRAD :	Frame Relay Access Device
ISDN :	Integrated Services Data Network
ITU-T :	International Telecommunication Union - Telecom
LAN :	Local Area Network
LAPD :	Link-Layer Access Protocol D-channel
LMI :	Link Management Interface
OSI :	Open System Interconnection
PVC :	Permanent Virtual Circuit
Tc :	Commited Rate Measurement Interval