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Frame Relay to ATM Network Interworking

An In Depth Explanation of FRF.5 Frame Relay/ATM PVC Network Interworking Implementation Agreement

White Paper

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Introduction

The explosive growth of frame relay services since 1994 has motivated deployment of ATM backbone infrastructure by frame relay service providers. This ATM deployment is necessary to support the large and rapidly growing amount of frame relay traffic, as can be seen in figure 1.

Beyond the general growth in the amount of frame relay services, a distinct trend exists toward higher speed frame relay interfaces. This trend results from frame relay users interconnecting a larger number of frame relay sites, deployment of applications with larger bandwidth requirements, and aggregation of data from remote sites for delivery to central locations. This upward pressure on frame relay bandwidth demand, coupled with the deployment of ATM infrastructure and the ripening of the ATM services market, has created the need for frame relay-to-ATM interworking.

The Frame Relay Forum responded to this need in 1994 and 1995 with the creation of two implementation agreements specifying how frame relay and ATM networks and services should interwork. Two types of frame relay/ATM interworking exist, network and service. FRF.5, FR/ATM PVC Network Interworking Implementation Agreement, provides guidance for interworking between frame relay and ATM terminals and networks. FRF.8, FR/ATM PVC Service Interworking Implementation Agreement, provides guidance for interworking between frame relay and ATM services. Both types of interworking are defined for permanent virtual circuits (PVCs); the Frame Relay Forum is currently engaged in the definition of FR/ATM interworking for switched virtual circuits (SVCs).

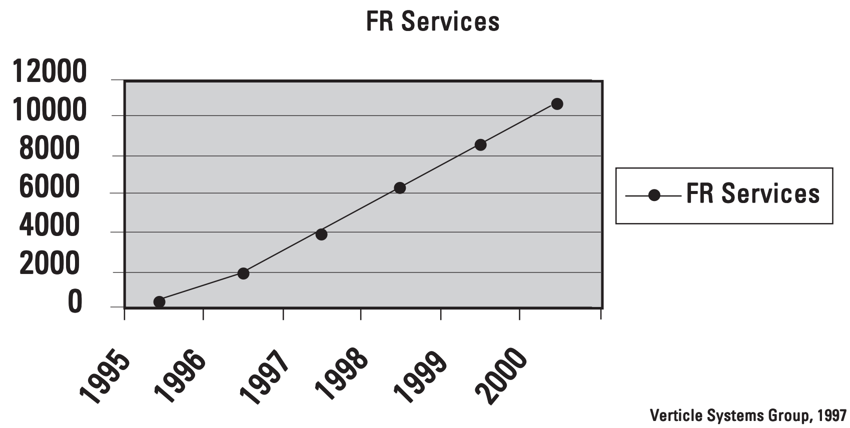

Figure 1. Worldwide frame relay service revenues

FR/ATM interworking may be used in public or private networks to allow users to select a site specific networking solution based on business and technology requirements. ATM is deployed in the core network to improve scalability and economies of scale. Individual sites are interconnected with frame relay or ATM as needed. Sites may be migrated from frame relay to ATM as business needs dictate.

This white paper explains the technical details of FR/ATM network interworking. A future paper will address frame relay to ATM service internetworking. The Frame Relay Forum implementation agreements, FRF.5 and FRF.8, are available from the Frame Relay Forum and may be found at this URL: http://frforum.com.

Network interworking, figure 2, provides a service where frame relay is used as the WAN ingress and egress technology with ATM in the WAN core network. In this model, frame relay terminals or networks communicate with other frame relay terminals or networks over an intervening ATM network. The ATM service transports the frame relay frames. Frame relay service users are unaware that ATM is involved.

Service interworking provides a service where frame relay or ATM is used as the WAN ingress and egress service technology, and ATM is, typically, used in the WAN core network. In the service interworking model, either frame relay or ATM terminals or networks may communicate with other frame relay or ATM terminals or networks. Translation takes place between the frame relay and ATM services. Neither service user is aware of communicating with a service other than its native service (frame relay or ATM).

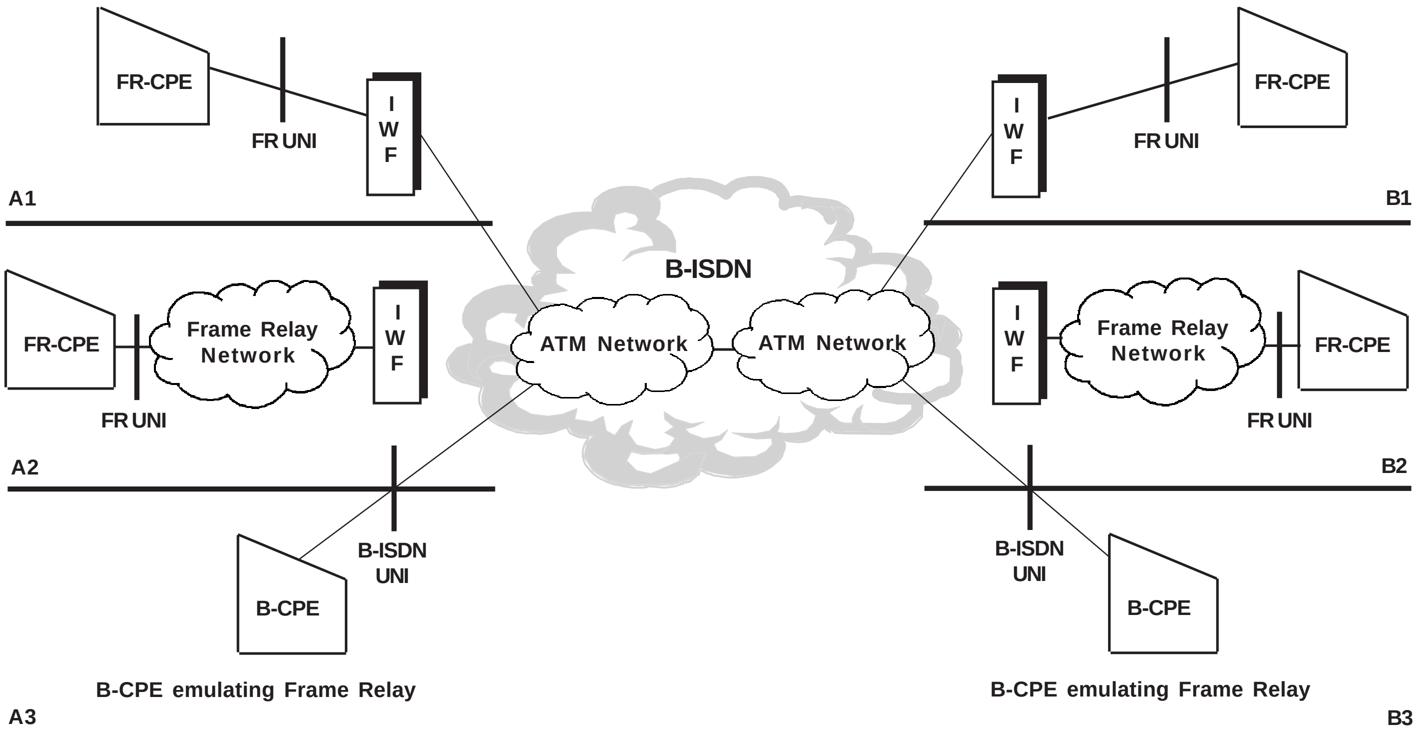

Figure 2. FR/ATM Network Interworking courtesy of the Frame Relay Forum

Network Interworking Overview

Network interworking, defined in FRF.5, can be viewed as the transport of frame relay frames over ATM, an interworking function (IWF) performs the actual frame relay and ATM interworking. The location of the interworking function is not specified by FRF.5 and is left as an implementation detail. As a matter of practice, the IWF is located in the ingress switch. AAL 5 is employed, and there are two network interworking scenarios, which are defined in ITU-T I.555.

In scenario 1, a frame relay terminal or end point communicates with a second frame relay terminal over the ATM network; this is referred to as frame relay transport over ATM. Scenario 1 network interworking is represented by points A1 and A2 communicating with points B1 and B2 in figure 2.

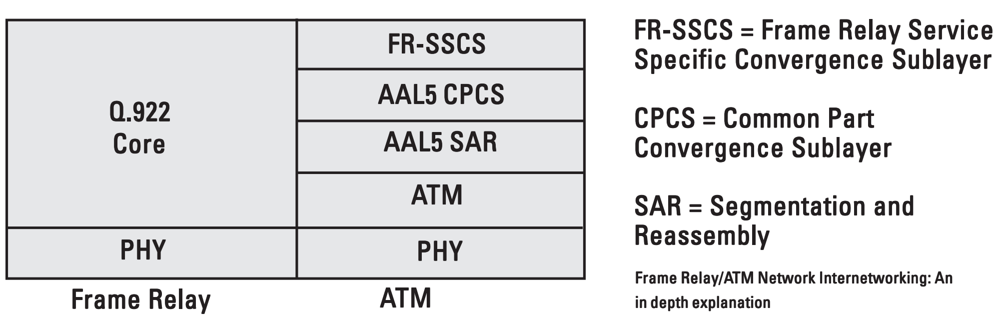

Figure 3. Frame Relay and ATM Protocol Stacks with FR-SSCS

In scenario 2, a frame relay terminal communicates with an ATM terminal over the ATM network. Points A1 (B1) and A2 (B2) communicating with point B3 (A3), in figure 2, depict scenario 2 network interworking. The ATM terminal must support the frame relay service specific convergence sublayer (FR-SSCS) as part of the ATM protocol stack. Figure 3 depicts the FR-SSCS and the AAL 5 ATM protocol stack. The FR-SSCS is defined in ITU-T I.365.1 and is identical to the ITU-T Q.922 core aspects frame relay frame definition, without the 16-bit FCS, flags and zero-bit insertion. The FR-SSCS PDU is a direct mapping of the frame relay frame, shown in figure 4. FR/ATM interworking supports 2-octet frame relay headers and may support 4-octet headers; support for 3-octet headers is for future study.

Network interworking provides a functional mapping between frame relay and ATM AAL 5 and supports the following frame relay features, which are defined in ITU-T Q.922:
1. Variable length PDU formatting and delimiting
2. Error detection
3. Connection multiplexing
4. Loss priority indication
5. Congestion indication (forward and backward)
6. PVC status management

MSB							LSB
Upper DLCI						C/R	EA = 0
Lower DLCI				FECN	BECN	DE	EA = 1
Information Field: an integral number of bytes from 1 to 1600							

DLCI = Data Link Connection Identifier
C/R = Command/Response bit
EA = Address Extension bit
FECN = Forward Explicit Congestion Notification Bit
BECN = Backward Explicit Congestion Notification Bit

Figure 4. FR-SSCS PDU for 2 Octet Headers

Frame Formatting and Delimiting

Frame relay frame formatting and delimiting is provided by the FR-SSCS and common-part convergence sublayer (CPCS) of ATM adaptation layer 5 (AAL 5) segmentation and reassembly functions. Frame relay frame error detection is performed by the AAL5 CPCS 32-bit CRC, which is calculated over the FR-SSCS PDU. It is these delimiting and error checking functions that allow for the stripping for the frame relay flags, zero-bit insertion and FCS.

PVC Connection Multiplexing

The FR-SSCS supports connection multiplexing by use of the DLCI field. The ATM layer supports connection multiplexing through the use of the VPI/VCI fields. ITU-T I.555 defines two methods of connection multiplexing for FR/ATM interworking.

Connection multiplexing provides for the direct mapping of a single DLCI (frame relay logical connection) to a single ATM VCC; connection multiplexing is then performed by ATM VPI/VCI. This is known as one-to one multiplexing. A FR-SSCS DLCI value in the range of 16 to 991 should be agreed upon by the ATM end-systems, or the default value of 1022 must be used.

The second connection multiplexing scheme is many-to-one multiplexing, where many frame relay connections are mapped to a single ATM VCC. Multiplexing is accomplished at the FR-SSCS by the use of multiple DLCIs. Many-to-one multiplexing is limited to frame relay PVCs that terminate on the same ATM end system. The FR-SSCS DLCI values must be agreed upon by the ATM end system.

Discard eligibility and cell loss priority

Two operational modes perform the interworking of discard eligibility (DE) and cell loss priority (CLP). In mode 1, for the frame relay-to-ATM direction, the DE bit is copied directly into the FR-SSCS PDU DE bit, which is mapped to the AAL 5 CLP bit of every cell generated by the segmentation of the FR-SSCS PDU. Figure 5 shows the mapping of DE to CLP bits. For mode 1, in the ATM to frame relay direction, if one or more of the cells associated with the reassembled FR-SSCS PDU has its CLP bit set to one, or if the FR-SSCS PDU DE bit is set, then the frame relay DE bit is set by the interworking function, as is shown in figure 5.

In mode 2, the frame relay-to-ATM direction, the frame relay DE bit is copied into the FR-SSCS PDU DE bit unchanged, and the AAL 5 CLP bit of every cell generated from the segmentation of the FR-SSCS PDU is set or reset (1 or 0). The CLP bit value is agreed upon when the connection is established (provisioned), as is shown in figure 5. The mode 2 ATM to frame relay direction provides for no mapping between ATM and frame relay layers. The FR-SSCS PDU DE bit is copied unchanged to the frame relay DE bit. All AAL CLP indications are ignored, see figure 5.

FR-to-ATM (Mode 1)

From Q.922 Core DE	Mapped to FR-SSCS DE	Mapped to ATM layer CLP
0	0	0
1	1	1
		(Note 1)

FR-to-ATM (Mode 2)

From Q.922 Core DE	Mapped to FR-SSCS DE	Mapped to ATM layer CLP
0	0	Y
1	1	Y
		(Note 2)

ATM-to-FR (Mode 1)

From ATM Layer CLP	From FR-SSCS DE	To Q.922 Core DE
0	0	0
1	X	1
X	1	1
(Note 3)		

ATM-to-FR (Mode 2)

From ATM Layer CLP	From FR-SSCS DE	To Q.922 Core DE
X	0	0
X	1	1

Note 1: For all cells generated from the segmentation process of that frame.

Note 2: Y can be 0 or 1.

Note 3: For one or more cells of the frame, X indicates that the value does not matter (0 or 1).

Figure 5. DE/CLP mapping courtesy of the Frame Relay Forum

FR-to-ATM

Q.922 FECN	SSCS FECN	ATM EFCI
0	0	0
1	1	0

ATM-to-FR

ATM EFCI	SSCS FECN	Q.922 FECN
0	0	0
X	1	1
1	X	1

Note: 0 indicates congestion not experienced
1 indicates congestion experienced
X indicates that the value does not matter (0 or1)

Figure 6. Forward Congestion Indication Mapping courtesy of the Frame Relay Forum

Congestion Indication

Frame relay provides for explicit congestion indication in both the forward and backward directions. Frame relay signals forward congestion by setting the Forward Explicit Congestion Notification (FECN) bit, and signals backward congestion by setting the Backward Explicit Congestion Notification (BECN) bit. At the cell layer, ATM only provides forward congestion indication by setting the Explicit Forward Congestion Indication (EFCI) bit. Network interworking provides for the mapping of forward congestion indication between frame relay and ATM.

In the frame relay-to-ATM direction, forward congestion indication is not mapped to cell level or EFCI congestion indication. The Q.922 FECN bit is copied directly into the FR-SSCS FECN bit, and the EFCI bit of all associated cells is set to "congestion not experienced." In the ATM-to-frame relay direction, forward congestion indication is mapped between the services. If the EFCI field of an ATM cell, or the FECN of the received FR-SSCS PDU, is set to "congestion experienced," then the FECN bit of the resulting Q.922 frame relay PDU is set to "congestion experienced," as in figure 6.

Backward congestion indication is only supported at the frame level; the indication is directly mapped from the FR-SSCS PDU to the frame relay PDU in the ATM-to-frame relay direction. For interworking from the frame relay to the ATM direction, two criteria exist for setting the FR-SSCS BECN bit to congestion experienced. If the frame relay PDU BECN is set, or if the EFCI bit of the last received cell in the ATM to frame relay direction was set to congestion experienced, then the FR-SSCS FECN bit is set to congestion experienced.

Traffic Management

Traffic management, including the mapping of frame relay conformance parameters (throughput, Bc, Be and access rate) to ATM traffic conformance parameters (PCR, CDV, SCR, MBS) is accomplished by use of the generic cell rate algorithm (GCRA) configuration found in section 3 of the ATM UNI 3.0 specification.

PVC Management

PVC management for the ATM layer and the frame PVC status management of the FR-SSCS layer can operate independently, where each layer is responsible for its own layer management. When determining the frame relay PVC status, the FR-SSCS uses the ATM layer status. Frame relay PVC management at the frame relay NNI and UNI remains unchanged; the network interworking management functions pertain only to the management of the frame relay PVC carried by the ATM network.

FR-SSCS layer management is performed by the bi-directional (symmetric) procedures defined in ITU-T Q.933 Annex A. These procedures specify that both sides of the network-to-network interface (NNI) perform the PVC management procedures defined for the user-to-network interface (UNI). This provides for symmetrical, complementary management procedures across the NNI for both networks. FRF.2.1, Network-to-network Interface Implementation Agreement, specifies a set of Q.933 Annex A options used for PVC management by the FR/ATM interworking function. For the PVC status management of frame relay PVCs carried by ATM VCCs, DLCI 0 is used by the FR-SSCS PVC management entity.

When one-to-one multiplexing is used, the following changes are made to the Q.933 Annex A procedures:

1. The Full Status Polling Counter, N391, is set to 1
2. The Link Integrity Verification Timer, T391, is set to 180 seconds
3. The Polling Verification Timer, T392, is set to 200 seconds
4. The use of the Q.933 Annex A asynchronous message is recommended

ATM VCC link integrity verification is accomplished by the F5 OAM cell flow, and the information is conveyed to the Q.933 Annex A PVC management entity for frame relay link integrity verification of interworked frame relay PVC.

Upper Layer Protocol Encapsulation

Protocol encapsulation provides for the multiplexing and demultiplexing of upper-layer protocols over the frame relay connection. The use of protocol encapsulation is configured when the frame relay PVC is provisioned. The rules governing protocol encapsulation are found in FRF.3.1, Multiprotocol Encapsulation Implementation Agreement. In the event that scenario 2 interworking (ATM terminal implementing FR-SSCS) is used, the ATM terminal must implement the FRF.3.1 protocol encapsulation procedures.

Summary

The explosive growth in frame relay services and the trend to higher speed interfaces, coupled with today's higher degree of remote site interconnection and resulting data aggregation, are a perfect match for deployment of ATM services. Service providers are aggressively deploying ATM in their network infrastructures, as well as marketing ATM and frame relay services. This has set the stage for the need to interwork frame relay and ATM on a site by site basis.

Recognizing this evolutionary trend early on, the Frame Relay Forum addressed the need by producing implementation agreements for the interworking of frame relay and ATM. Frame relay/ATM interworking is widely deployed, and the market continues to grow. Network managers must be familiar with this technology so that they can make intelligent service purchase decisions and maintain and troubleshoot installations. Armed with the information in this white paper and an advanced troubleshooting tool, such as the Agilent Internet Advisor, network managers can ensure the highest service levels for their users. More information on the Internet Advisor and frame relay and ATM troubleshooting may be found at this URL: http://www.agilent.com/comms/onenetworks

References

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Thanks is given to the Frame Relay Forum for permission to use various figures from the relevant Implementation Agreements.

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