Application Note

Interworking of Frame Relay/ATM and Ethernet Services

ALCATEL

ABSTRACT

Service providers worldwide have deployed multiservice products from Alcatel to fulfill a number of service requirements, including public frame relay and asynchronous transfer mode (ATM) services. However, service providers and their customers are increasingly demanding powerful, feature-rich Ethernet services as part of the multiservice mix. Alcatel has not only responded to this trend, but in fact helped to drive it by offering a range of portfolio solutions and by taking leadership roles in standards-setting bodies. As a result, Alcatel multiservice and Internet protocol (IP) products also support seamless service interworking between Ethernet services (such as virtual private LAN service [VPLS] and virtual leased line [VLL] service) and legacy Layer 2 services (such as frame relay and ATM). This capability allows carriers to migrate legacy service subscribers to newer Ethernet-based services gracefully, which means on an appropriate schedule and without expensive upgrades to installed equipment. Alcatel service interworking solutions allow service providers to defend their existing service revenues while establishing strong, new revenue streams in an increasingly competitive environment.

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Introduction

Service providers and their customers, enterprises that use telecommunications services, have justifiably high expectations for Ethernet-based services. From the enterprise perspective, Ethernet is a familiar, powerful and high value communications technology. From the perspective of the service provider, Ethernet is a massively scalable medium with the ability to be a powerful foundation for many exciting and evolving service offerings such as storage area networking (SAN), innovative multimedia video-rich services and bandwidth-hungry supply chain management applications. Ethernet has emerged as the ideal technology for enterprise services convergence.

Ethernet has a number of roles to play in service provider networks. These include: Layer 3 virtual private network (VPN) access, high speed Internet (HSI) access, and core transportation and aggregation in wireless and wireline broadband networks. Increasingly, service providers are leveraging the power and versatility of Ethernet as the basis for next-generation Layer 2 VPN services such as VPLS and VLL. This application note describes how VPLS and VLL services can leverage installed base, legacy Layer 2 service deployments (e.g., frame relay or ATM) for the delivery of high value functionality and for commercial success in retaining and growing service revenue streams.

The installed base of frame relay and ATM services represents a huge ubiquitous resource of revenue generating connectivity that can be rapidly and easily extended and complemented by effective service interworking capabilities. Alcatel's VPLS and VLL solutions take Layer 2 VPNs to new levels of performance and functionality and, when combined with service interworking, can allow wide availability of advanced services over a large geographic area. Alcatel Ethernet services can be seamlessly introduced into existing Layer 2 VPN network and service management architectures.

This application note begins with some context on existing Layer 2 services and some background information on interworking models. The business drivers for service interworking are examined and the rationale for bringing metro Ethernet to existing frame relay/ATM networks is explored. Next, some pragmatic deployments are described based on Alcatel IP and multiservice products. Finally, a brief view of standardization status is provided.

Current Layer 2 Service Deployments

Frame relay remains the leading global packetized data service in terms of annual revenues accrued by service providers. According to IDC, almost half of U.S. enterprises use frame relay service as their primary internetworking wide area network (WAN) vehicle. In 2004, annual global revenues by frame relay service providers totaled over $U.S. 17B.

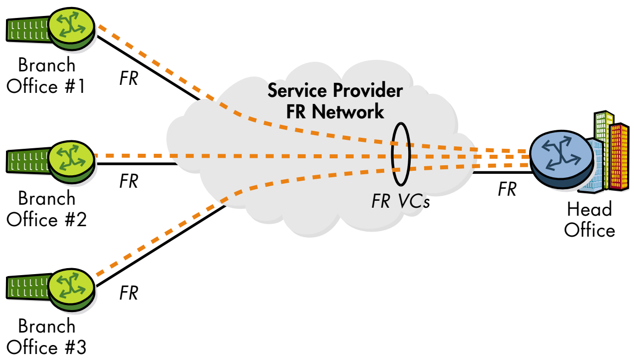
A connection-oriented, high level data link control (HDLC)-framed service, frame relay was the right technology at the right time for WAN interconnect in the late 1990s. Frame relay rode the booming buildout of small and mid-size routers in corporate data networks, helping to link branches to headquarters. Frame relay is typically deployed in hub and spoke architectures as shown in Figure 1.

Frame relay networks are simple to operate, and reliable, relative service level agreements (SLAs) can be established and are easily enforceable. However, frame relay reaches its limits at DS3 or about 45 Mb/s.

Although the service growth is slowing, frame relay remains a reliable technology and a good earnings engine for many service providers.

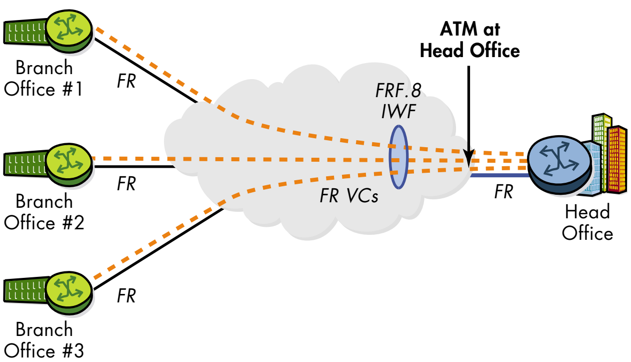
ATM has also seen some deployment as a tariffed customer service, but its main success niche has been as an infrastructure technology in packet voice networks, broadband aggregation and in the cores of frame relay service networks themselves. One successful service deployment model for ATM has been to enhance the

Figure 1 - Typical Fame Relay Hub and Spoke Network



basic frame relay hub and spoke model to allow higher bandwidth connectivity into headquarters sites as shown in Figure 2.

Figure 2 - Frame Relay to ATM Interworking



An implementation agreement (FRF.8) produced by the Frame Relay Forum (now assimilated into the MPLS Frame Alliance [MFA]) describes how to implement frame relay to ATM service interworking. The WAN access speed limit of the hub site is now raised considerably; connectivity at hub speeds of up to OC-12 (655 Mb/s) and even higher, are possible. Implementations of FRF.8 have had to resolve a number of issues that also arise when interworking to Ethernet. Issues such as resiliency, SLA creation and positioning versus other services, end-to-end quality of service (QoS) and traffic management are all important topics as are network and service management of the overall solution (see "Network and Service Interworking" below).

Network and Service Interworking

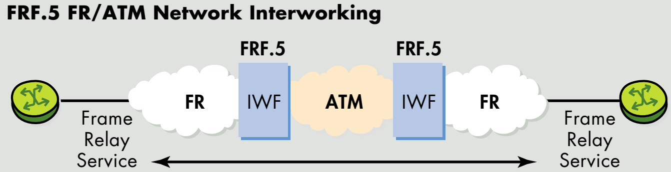
Network and service interworking for frame relay and ATM have been defined for some time by the Frame Relay Forum in implementation agreements FRF.5 and FRF.8 respectively. The diagrams below show the two interworking models.

Network interworking is a layered, tunneling approach used to transport an overlaid service (in this case, frame relay) from one point to another via a region where the transporting service technology predominates (in this case, ATM). This could be, for example, the transport of frame relay across an ATM core switch buildout.

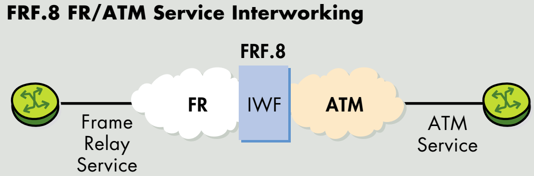
Service interworking is most useful for interconnecting adjacent generations of communications services technology to allow gradual migration to newer services where available, while retaining (and minimally impacting) the existing service overlay. FRF.8 is a well known example of a successful and broadly deployed service interworking capability. The challenges, in general, of service interworking are the fact that all (or most) constituent parts of a protocol must be mapped to some aspect of another protocol for a successful interworking solution. These components include encapsulated protocol identifiers (headers), QoS indicators, congestion signaling and even some aspects of specific higher level control protocols where these protocols have syntax and/or semantics that are media-dependent to some extent (e.g., address resolution protocol [ARP] and inverse address resolution protocol [InvARP]). A well-designed and engineered service interworking implementation will operate so seamlessly that attached customer premises equipment (CPE) will be "unaware" that it is not connected to a single service WAN.

The table below, quoted from the MPLS Frame Relay Alliance, shows a partial list of service attributes that need to be mapped and/or translated when building a service interworking solution. While this table is a good overall guide, the sections on pragmatic deployment approaches later in this application note will explain that there are other important considerations when building a complete service interworking solution including, for example, protocol encapsulation mapping and the handling of address resolution protocols across a service interworking function.

FRF.5 FR/ATM Network Interworking



FRF.8 FR/ATM Service Interworking



	Frame Relay	**ATM**	**Ethernet**
Circuit Identifier	PVC: DLCI	PVC: VPI/VCI	EVC: Port#, VLAN ID
Sevice Classes	Priority	CBR	802.1 QVLAN
	CIR	rt-VBR	802.1 Q Priority
	Zero CIR	nrt-VBR	
		UBR	
Traffic Parameters	AR, CIR, Bc, Be	PCR, SCR, MBS	PIR, SIR, CBS, PBS
Priority Indication	DE	CLP	P-Bits
Congestion Indication	FECN/BECN	EFCI	MEF Defined

Business Drivers for Service Interworking

By almost any measure, frame relay has been a successful telecommunications service. However, frame relay service growth is slowing rapidly as price and performance expectations drive subscribers to consider other technologies. Can Ethernet support a service that will be "the next frame relay" but better in many dimensions? By interworking with and extending the installed base of frame relay service, Ethernet can remove bandwidth constraints, reduce cost via the elimination of proprietary core technologies and deliver a low latency, meshed capability very rapidly or more gradually as business drivers dictate. This scalability plus the inherent multicasting capability of Ethernet allows service providers to take Layer 2 service offerings to a new value plateau.

Service providers are already engaged in deployments of new services based on Ethernet technology. New capabilities being defined by the standards bodies and forums, and strong product capabilities from suppliers such as Alcatel support this momentum.

One of the main business drivers for interworking Ethernet with legacy Layer 2 services is the opportunity to upsell an installed base of customers, that is, to transition that installed base to the next technology level. Using demonstrably superior interworking capabilities (versus basic network-to-network interface [NNI] type handoffs) allows carriers to present compelling propositions to their subscribers.

Allowing subscribers to make their technology transitions gradually as their economics and business goals dictate is possible with a service interworking model. This, plus the ability to support interworking on the installed product base, allows effective gradual edge services migration and the ability to leverage installed assets. For example, in certain areas, Ethernet service may be slow to arrive but T1 (carrying frame relay or even multi-link frame relay) links may be plentiful. Conversely, certain metro areas may be well served by high speed Ethernet. Alcatel's service interworking capability allows subscribers to gradually turn up new services at selected locations as the need and the capability arise.

One concern for service providers when introducing new services is how to control revenue cannibalization from existing services. Having an effective service interworking business and technology strategy can assist greatly in deterring defections to rival service providers and boost loyalty. This is particularly important in a transition period (from frame relay to next generation WAN services for example) when subscribers are examining and renegotiating carrier relationships.

> *"VPLS in the context of Ethernet is at the core of Ethernet services today. We'll see frame and ATM gradually supplanted by connectionless services, though for the time being, integration with legacy services will be a major criterion for the success of Ethernet."*
>
> *RALPH BALLART, VICE PRESIDENT OF BROADBAND INFRASTRUCTURE AND SERVICE AT SBC LABS, APRIL 2005*

Alcatel's service interworking solution also allows gradual core migration typically from an ATM core to a fully converged IP/multiprotocol label switching (MPLS) model with various (ATM/Gigabit Ethernet [GigE]/packet over SONET [POS]) underlying transport media, as business drivers and technology availability dictate.

The issue of effective network and service management is an important one for any service provider developing a strategy for service interworking. The Alcatel 5620 management portfolio eases the task of introducing service interworking to an existing network. Investments in operational support systems (OSSs) are leveraged and full end-to-end service and network management is provided.

Finally, an effective deployment of service interworking allows the service provider to build a base for offering higher value services. For example, having established the value of Ethernet point-to-point services (e.g., VLL), a transition to VPLS or the use of Ethernet as an access to RFC-2547 IP-VPN service is possible.

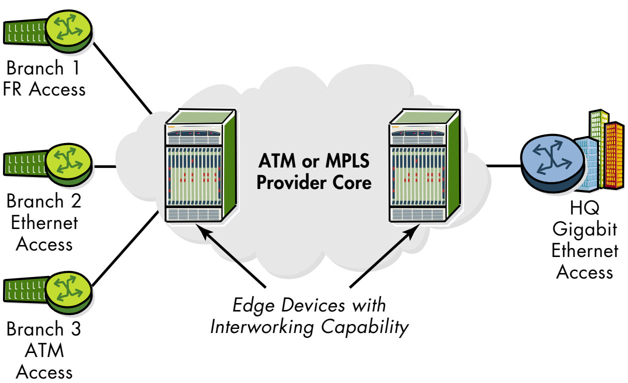
Bringing (Metro) Ethernet to Existing Frame Relay/ATM Networks

Service interworking of frame relay to ATM service has been successfully deployed (according to FRF.8) in a number of service provider networks. However it suffers from a few limitations as an overall networking solution:

> It does not scale well for high bandwidth access
> It does not leverage an MPLS core efficiently
> It does not support end-to-end traffic prioritization

Using an Ethernet user-to-network interface (UNI) in conjunction with a well-designed and engineered interworking function can resolve these issues, providing the massive scalability required to support demanding voice and video applications and services like SAN and bandwidth-hungry supply chain management systems. All this is possible while also interworking smoothly with an installed legacy base of Layer 2 services. This aids in responding to the business drivers identified in the previous section, especially in retaining and upselling an installed customer base.

Figure 3 - Opportunities for Service Interworking



As Ethernet is increasingly deployed in metropolitan buildouts, the opportunities for interworking with frame relay and ATM services rise proportionally (see Figure 3). Ethernet will start to be used for headquarters and major site connections initially while branch sites will migrate more slowly to Ethernet as business requirements dictate and technology availability allows.

The advantages that accrue to the service provider in making this step to offering Ethernet interworking to frame relay and ATM connections are:

> Lifting of the bandwidth ceiling on site access and also allowing incremental offerings with fine bandwidth granularity at speeds up to 10 Gb/s
> Retaining and upselling the existing, installed customer base and improving customer loyalty and satisfaction
> Cannibalizing own revenues and those of less swift-moving competitors
> Providing relatively inexpensive, high performance network interface with full QoS as a result of Ethernet technology's compatibility with CPE evolutionary directions

While there are many possible interworking combinations involving both routed and switched access CPE technologies and different access media, an exhaustive treatment of all of these scenarios is beyond the scope of this paper. The following sections focus on the main pragmatic deployments that will yield high value solutions for service providers and their customers.

Pragmatic Deployment Approaches

Before looking at specific equipment configurations, it is worth taking the time to examine and define the 'problem space' — that is, the set of requirements that should be used to drive and evaluate the suitability of the solution. The following are basic requirements:

> No changes necessary to installed branch CPE
> QoS options available to create a tiered SLA
> Avoidance or mitigation of single points of failure
> Availability of traffic contracts (service classes) with parameter driven attributes
> Strong service and network management capability

EXTENDING LAYER 2 SERVICES WITH ETHERNET SERVICE INTERWORKING

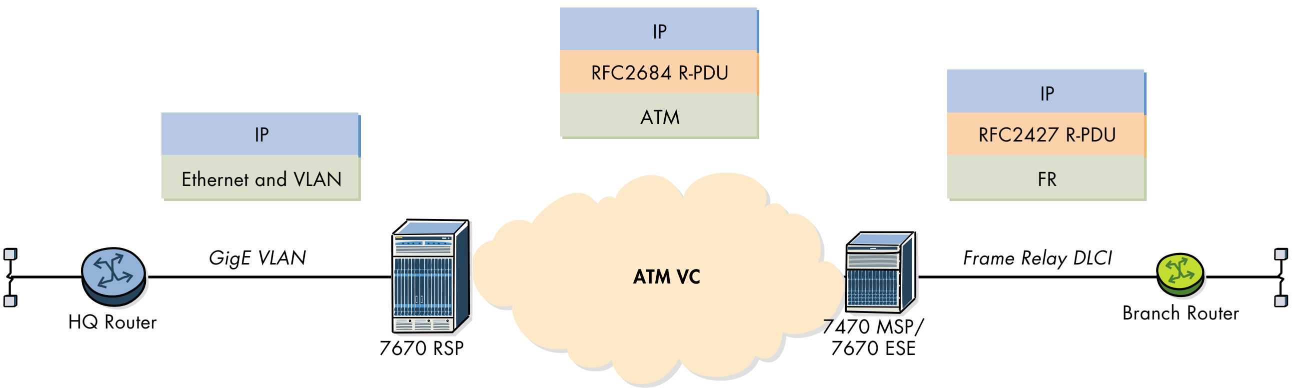
It has been established that the hub and spoke model predominates in Layer 2 WANs (frame relay, ATM and frame relay/ATM). It is logical to start with this model and describe a valuable evolutionary step to incorporating Ethernet into this network.

The Alcatel 7670 Routing Switch Platform (RSP) provides a powerful virtual connection (VC) to virtual LAN (VLAN) coupling capability, which allows an IP routed overlay hub and spoke solution to be provided via a heterogeneous set of access media. Let's start by exploring the frame relay access case.

A number of large frame relay network buildouts exist, implemented on the Alcatel 7670 RSP (acting as an ATM core switch) and using either the Alcatel 7470 Multiservice Platform (MSP) or the Alcatel 7670 Edge Services Extender (ESE) as the access vehicle for frame relay service implementation. The majority of branch access CPE devices are routers using an IP routed encapsulation (with no media access control [MAC] layer). An end-to-end service interworking configuration is shown in Figure 4.

In tracking the datapath across the diagram, the frame relay-attached router presents IP packets encapsulated according to RFC-2427 to the Alcatel 7470 MSP/7670 ESE. This is, by far, the most commonly deployed access model for router-to-frame relay attachment. In the ATM core, the IP packet is encapsulated according to RFC-2684. At the GigE card, the ATM VC is connected to a configured VLAN for presentation to the GigE-attached

Figure 4 - End-to-End Frame Relay to GigE Interworking



router. On the GigE media, IP packets are conventionally and efficiently encapsulated directly upon the Ethernet media including the VLAN header if appropriate.

ARP packets from the GigE-attached router will be intercepted on the Alcatel 7670 ESE GigE card and a proxy response returned containing the MAC address of that attachment point (where that GigE link enters the Alcatel 7670 ESE). InvARP will be inactive on a branch device running in point-to-point routed mode.

Quality of service

Different classes of service can be established on a per-customer basis. This allows a tiered SLA to be created based on delay, delay variation and delivery ratio targets. Up to eight discrete service classes can be established as part of a range of service offerings. At the GigE interface, a per-packet QoS treatment is possible. Encapsulated data packets are classified, by either their 802.1p marking or a multiple-field IP header inspection if preferred. Based on this classification, traffic entering the network can be policed and traffic leaving the network can be queued and scheduled onto the link appropriately according to the provisioned QoS (see Figure 5).

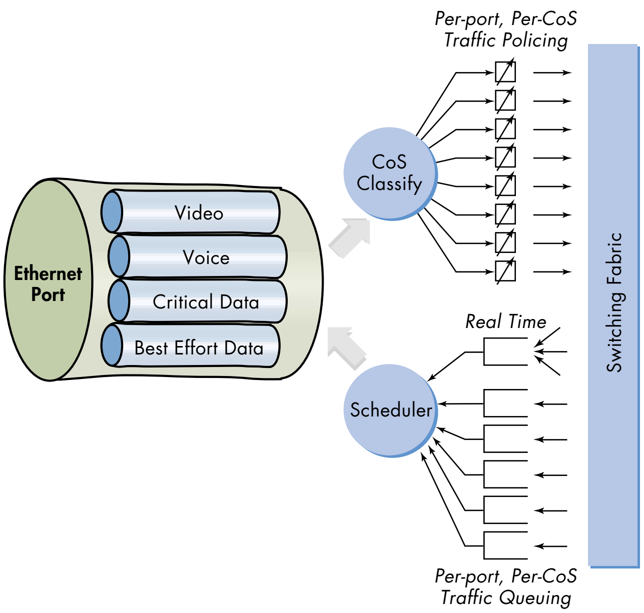
Traffic contracts can be established based on standard parameters to flow limit and police the offered traffic according to the subscribed limits. Available bandwidth on both frame relay and GigE interfaces can be provisioned in granular increments.

High availability

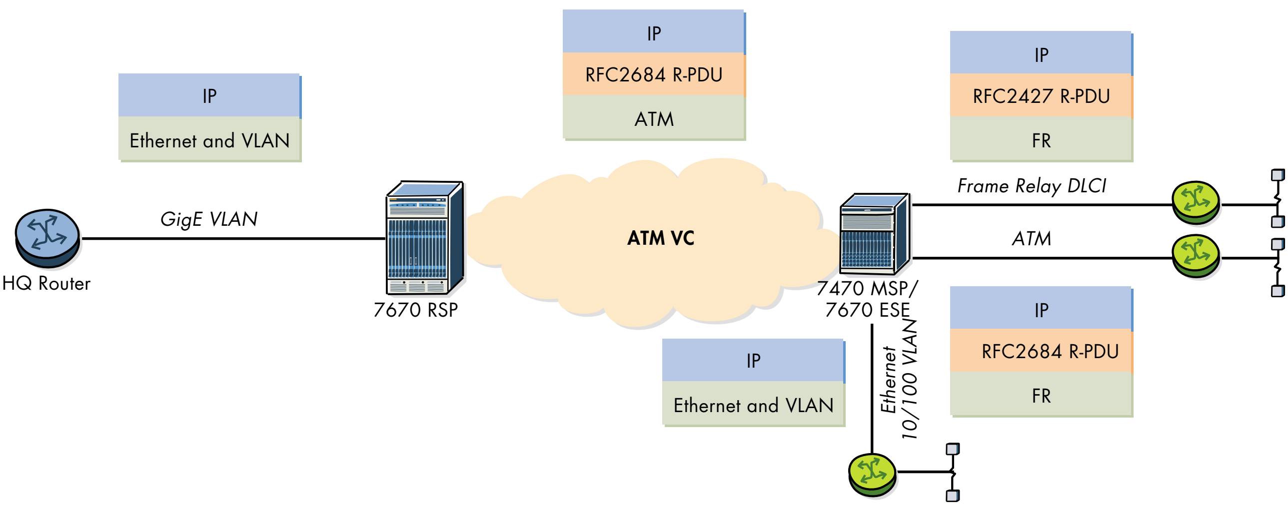
In any mission-critical service it is important to avoid a single point of failure that can compromise the transported traffic. Such events can have serious consequences for higher layer applications and can result in SLA-triggered financial penalties being extracted from the service provider. The Alcatel 7670 RSP offers high availability capabilities. It is highly resilient to failure at the switch level, in the core transport and at the edge. At the switch level, redundant control processors and sub 50 msec automatic protection switching (APS) ensure that component or protected link failures will not impact the solution integrity. The core transport is further protected by re-routing capabilities in private network-to-network interface (PNNI) (for an ATM-based infrastructure) or fast reroute (FRR) if the infrastructure is based on MPLS. At the edge, GigE link aggregation can be used to provide an effective solution to media or router port failures.

A full suite of service and network monitoring and troubleshooting tools is available including alarm monitoring, trace and Ping. Detailed statistics gathering allows SLA verification and reporting.

Figure 5 - Classification, Queuing and Scheduling Mechanisms



Figre 6 - Comprehensive Point-to-Point Solution



A complete overlay point-to-point solution

Having explored the frame relay to GigE possibilities, the basic model can be expanded to include simultaneous ATM bearer service branch access (with routed encapsulation) and even 10/100 Ethernet access via VLL, also known as point-to-point Ethernet. A complete solution could be envisaged as shown in Figure 6.

It should be noted that the core networking technology can be migrated from ATM to MPLS as needed, even as these interworking services are being rolled out. In an MPLS scenario, core traffic is carried in IP pseudowires.

USING VPLS TO LEVERAGE AND COMPLEMENT EXISTING LAYER 2 SERVICES

The Alcatel 7750 Service Router (SR) and Alcatel 7450 Ethernet Services Switch (ESS) deliver powerful VPLS capabilities. The router interconnect mode of VPLS can be used in conjunction with the Ethernet/frame relay/ATM interworking solution already described to produce an innovative overall solution. Within a metropolitan area, for example, a VPLS network may be built out. GigE connectivity into a conventional Layer 2 network can be used to extend the reach to a widely installed base (see Figure 7).

A Brief Primer on VPLS

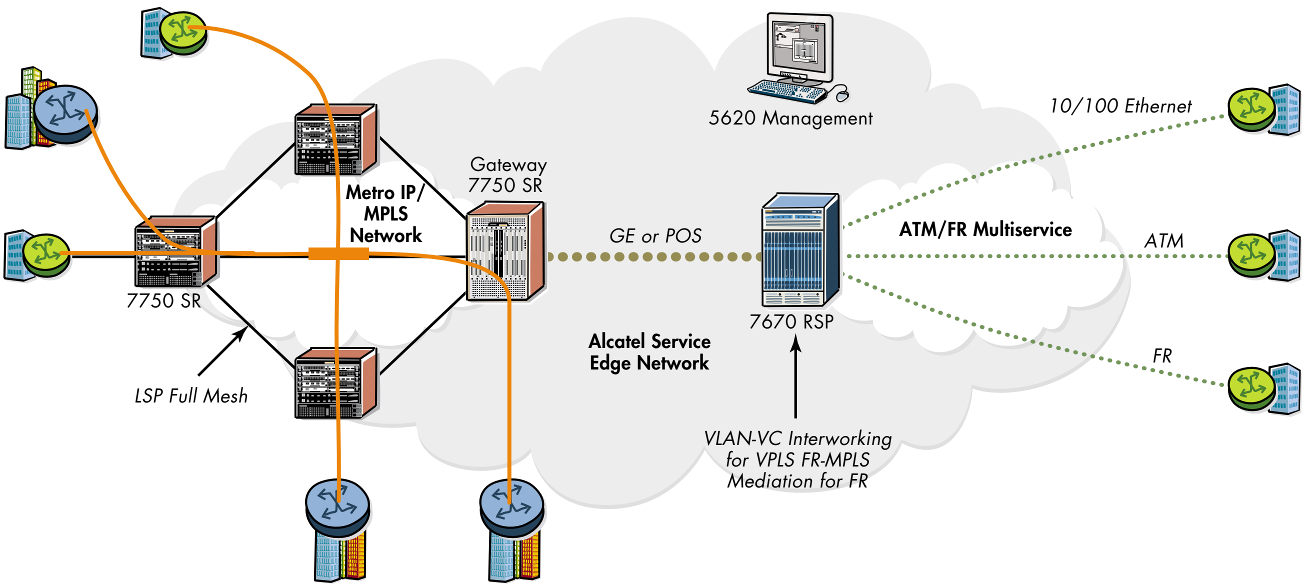
Virtual private LAN service (VPLS) is a new class of VPN technology that provides a simple, cost-effective alternative to frame relay or ATM for the interconnection of multiple customer sites by a single bridged domain operating on a provider-managed IP/MPLS-based WAN. From the customer's perspective, all sites appear to be on a single LAN segment regardless of their location. VPLS is described by Internet Draft draft-ietf-l2vpn-vpls-ldp-04.txt produced by the Internet Engineering Task Force (IETF) PPVPN working group.

Customer edge (CE) devices connect to the provider edge (PE) via Ethernet. The PE devices are connected via a full mesh of MPLS label switched paths (LSPs) or transport tunnels. In order to maintain separation of multiple customer traffic flows within the transport tunnel, targeted label distribution protocol (LDP) is used to negotiate a set of ingress and egress VCs or pseudowire labels for each VPLS service. The VC labels are appended to customer packets before they are sent into the network and used to de-multiplex traffic arriving at the PE device.

When a packet arrives on an access interface or pseudo-wire, the PE device examines the source MAC address. The MAC addresses, along with the access port identifier or VC label of the pseudowire on which the packet was received, are stored internally in a forwarding information base (FIB). A separate FIB is maintained for each VPLS service. The destination MAC address of the packet is compared against the appropriate FIB to determine which access port or pseudowire the packet should be sent over. If the MAC address is not found in the FIB then the packet is flooded on each pseudowire or port (except for the pseudowire or port on which the packet was received) associated with the service. If the destination address is a multicast or broadcast address then the packet is simply flooded as described above.

Bridging functions, as described above are implemented in a virtual bridge (VB). A VB (with associated FIB) exists for each VPLS instance deployed on a particular PE.

Figure 7 - VPLS Complementing Existing Layer 2 Services



In the Metro IP/MPLS network, the 'gateway' Alcatel 7750 SR supports a virtual bridge (VB) for each VPLS instance with at least one member attached directly to the ATM/frame relay multiservice network. Each of these VBs supports one or more VLANs to provide connectivity to service instances in the ATM/frame relay multiservice network. The Alcatel 7670 RSP (connected via GigE to the Alcatel 7750 SR) interconnects these VLANs to VCs to provide connection oriented transport to ATM or frame relay attached CPE and to provide VLL connectivity to Ethernet users on the multiservice network. As a fully system-tested solution with live deployment, Alcatel delivers a full service offering beyond just basic protocol conversion and connectivity. In a typical deployment, traffic shaping can be implemented on the Alcatel 7750 SR and policing functions at the edge of the multiservice network. A comprehensive set of network statistics can be gathered and spooled for processing and report generation. Reports can be generated to validate SLA compliance or to assist in re-engineering if it appears that there are performance issues in the end-to-end network. This solution allows a full featured VPLS service to be offered in heavy investment metro areas, for example, while still providing seamless integration to branch locations where the technology is either not available or not yet deployed for business or technology reasons.

Standardization and Industry Development Status

The importance of service interworking of frame relay/ATM to Ethernet has been widely recognized and has helped to launch work activities in a number of organizations.

The IETF has been at the forefront of VPLS standardization in the l2vpn working group. VPLS capabilities are at the heart of Alcatel's suite of Ethernet-based services, and Alcatel has been very active in shaping the drafts that describe the architecture and implementation of VPLS services. The IETF has also worked on the concept of pseudowires in the pwe3 working group. Pseudowires enable the carriage of point-to-point connections and are key to the evolution of interworked service offerings over an MPLS core.

The Metro Ethernet Forum (MEF) has approved a technical specification on Ethernet service definitions. An approved draft exists for the Frame Relay service interworking function technical specification.

The MPLS Frame Relay Alliance (MFA) is working on the topic "Multiservice interworking over MPLS with heterogeneous attachment circuits". With Alcatel leadership in this area, implementation agreements on Ethernet interworking with ATM and frame relay will be going to formal ballot in the second half of 2005.

Conclusion

Ethernet's future as the underpinning of a range of powerful services is assured — in fact this future is unfolding now with the tremendous uptake that is being seen in carrier Ethernet-based services.

An important factor in that success is the ability of Ethernet services to interwork effectively with legacy services such as frame relay and ATM to deliver end-to-end solutions that bring value to enterprise subscribers.

Alcatel is strongly engaged and committed to continue to lead in the design, development and standardization of these capabilities for the benefit of service providers deploying Alcatel solutions.

GLOSSARY

APS	automatic protection switching
AR	access rate
ARP	address resolution protocol
ATM	asynchronous transfer mode
Bc	committed burst size
Be	excess burst size
BECN	backward explicit congestion notification
CBR	committed bit rate
CBS	committed burst size
CE	customer edge
CLP	cell loss priority
CLR	cell loss ratio
CPE	customer premises equipment
DE	discard eligible
DLCI	data link connection identifier
EFCI	explicit forward congestion indication
EVC	Ethernet virtual circuit
FECN	forward explicit congestion notification
FIB	forwarding information base
FR	frame relay
FRF	Frame Relay Forum
FRR	fast reroute
GigE	Gigabit Ethernet
HDLC	high level data link control
HSI	high speed Internet
IETF	Internet Engineering Task Force
InvARP	inverse address resolution protocol
IP	Internet protocol
IWF	interworking function
LDP	label distribution protocol
LSP	label switched path
MAC	media access control
MBS	maximum burst size
MEF	Metro Ethernet Forum
MFA	MPLS Frame Relay Alliance
MPLS	multiprotocol label switching
NNI	network-to-network interface
nrt-VBR	non real time variable bit rate
OSS	operations support system
PBS	peak burst size
PCR	peak cell rate
PE	provider edge
PIR	peak information rate
PNNI	private network-to-network interface
POS	packet over SONET
PVC	permanent virtual circuit
QoS	quality of service
rt-VBR	real time variable bit rate
SAN	storage area network
SCR	sustainable cell rate
SIR	sustainable information rate
SLA	service level agreement
UBR	unspecified bit rate
UNI	user-to-network interface
VB	virtual bridge
VC	virtual connection
VCI	virtual connection identifier
VLAN	virtual local area network
VLL	virtual leased line
VPI	virtual path identifier
VPLS	virtual private LAN service
VPN	virtual private network
WAN	wide area network

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