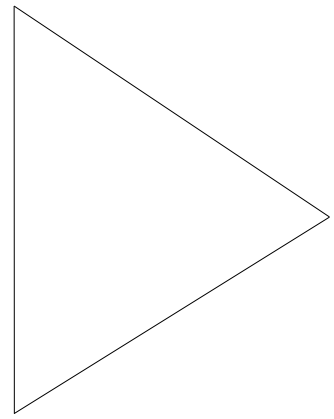


Frame Relay and ATM WAN Technology



White Paper

The Growing Demand for ATM

Over the next five years, demand for Asynchronous Transfer Mode (ATM) based networks is expected to grow at a rapid rate. This growth will see ATM emerge as a LAN technology for private enterprise networks as well as a WAN technology for carrier/public network offerings. This overall demand for ATM is generating a great deal of attention in both the ATM Data Exchange Interface (ATM-DXI) and Frame-based User-to-Network Interface (FUNI) protocols for access into ATM networks. Because of their roots in frame technology, both FUNI and ATM-DXI are often compared with Frame Relay. Although ATM has received more attention in the industry press, Frame Relay currently has a much larger installed base. As a result, protocols like Frame Relay to ATM Service/Network Interworking will play a major role in allowing existing Frame Relay networks to coexist with ATM-based network environments. This paper will clarify the issues surrounding both Frame Relay and ATM technology by covering the following points:

- An explanation of FUNI and ATM-DXI
- A comparison of FUNI, ATM-DXI, and Frame Relay
- Frame Relay to ATM Service/Network Interworking technical overview
- The PVC versus SVC debate
- The Role of Frame Relay and ATM technology in the Cisco Internetwork Operating System (Cisco IOS™) software and the overall product line

This paper covers a number of technologies, focusing on providing both technical information and a market overview. In addition, the final section reveals Cisco's direction in the Frame Relay and ATM WAN technology areas and emphasizes key differentiators in the following areas:

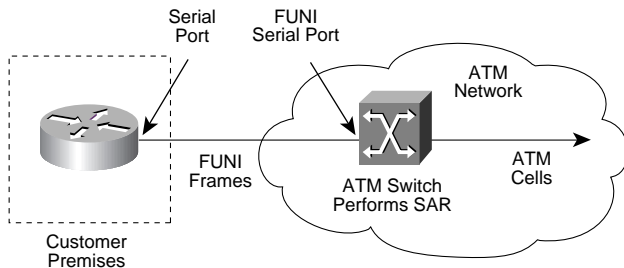
- Maximum WAN bandwidth network throughput through the use of compression
- Ease of configuration through Address Resolution Protocol (ARP) and Inverse ARP services
- Quality of Service (QoS) through virtual circuit (VC) prioritization
- Integrated LAN/WAN hardware support for seamless dial-up/Integrated Services Digital Network (ISDN) access, channelized T1/T3 interfaces, and ATM switching in workgroup and campus backbone environments
- Full Internet service access with integrated security/encryption functionality

These features build upon existing strengths in the Cisco IOS software and will deliver the best migration path for customers looking to integrate Frame Relay and ATM WAN technology into their networks.

FUNI and ATM-DXI Explained

FUNI and ATM-DXI are access protocols for ATM networks and are designed to preserve end users' investments in existing low-priced, frame-based hardware; for example, the Cisco router and its serial interfaces. Instead of requiring existing routers to provide ATM cell-based interfaces, both FUNI and ATM-DXI use frames on serial interfaces and transfer the segmentation and reassembly (SAR) of user traffic into 53-byte ATM cells to another point in the network. For FUNI (see Figure 1), this point is the ATM switch while for ATM-DXI (see Figure 2), it is an ATM Channel/Data Service Unit (CSU/DSU). Because FUNI and ATM-DXI can be run on the same routers that currently use Frame Relay (or perhaps X.25), they are appealing to end users who do not want to purchase new routers with ATM cell interfaces or to upgrade interfaces on existing routers.

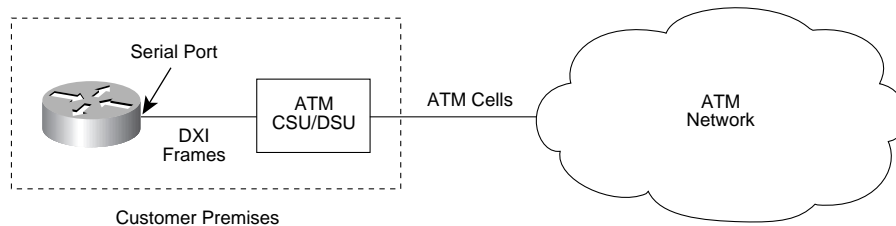
Figure 1. FUNI Connection to ATM Network



The similarity between FUNI and ATM-DXI occurs because the FUNI specification evolved from the ATM-DXI specification in the ATM Forum's standards work. Although FUNI and ATM-DXI are similar frame-based protocols, it is important to note that FUNI has more functionality for large WAN ATM networks than ATM-DXI. FUNI uses the ATM Interim Local Management Interface (ILMI) to manage the link between the FUNI Data Terminal Equipment (DTE) router and the FUNI Data Communications Equipment (DCE) switch. This link can be either a WAN or LAN link, and it will be managed by the ILMI. ATM-DXI lacks ILMI support and cannot provide information about link status to the ATM-DXI router. This makes ATM-DXI more susceptible to link problems and less appropriate for WAN networks than FUNI.

FUNI also utilizes serial line bandwidth more efficiently than cell-based ATM because the variable-length frames do not add as much overhead as ATM cells with their fixed 53-byte length that includes 5 bytes of header overhead. In cases where large payload packets are being sent, FUNI adds a fixed amount of overhead and can tolerate large packets in one frame, whereas cell-based ATM service cannot. Therefore, sending FUNI over a WAN link into an ATM network is more efficient than using ATM-DXI, converting to ATM cells in an ATM CSU/DSU, and sending the resulting cells over a WAN link into an ATM network.

Figure 2. ATM-DXI Connection to ATM Network



FUNI, ATM-DXI, and Frame Relay Technical Comparison

FUNI, ATM-DXI, and Frame Relay are quite similar in terms of frame structure. Figure 3 shows that the header structure for FUNI and ATM-DXI are identical. These two header structures are similar to the Frame Relay header in terms of bit positions, but FUNI and ATM-DXI use ATM definitions for its fields while Frame Relay uses Frame Relay definitions.

When the FUNI and ATM-DXI frames are segmented into cells, the ATM-DXI and FUNI addresses map to the ATM VPI/VCI (Virtual Path Identifier/ Virtual Connection Identifier) using identical procedures as shown in Figure 4.

This process of converting FUNI/ATM-DXI frames into ATM cells can be used as the basis for an interworking function between Frame Relay and ATM. In this mapping the following similarities exist:

- The Frame Relay DLCI address is mapped to VPI/VCI address in ATM.
- The congestion notification (CN) bit performs the same function as the Frame Relay forward explicit congestion notification (FECN) bit. The network sets this bit in frames and cells going from source to destination based upon congestion levels for traffic going in the forward direction. CN and FECN rely upon the destination user equipment upper-layer protocols to feed information back to the offending user equipment via the upper-layer protocol. As interface speeds increase, the effectiveness of FECN and CN decrease, because of the round-trip delay generated in the notification process to the offending user equipment.

Figure 3. FUNI, ATM-DXI, and Frame Relay Frame Header Structures

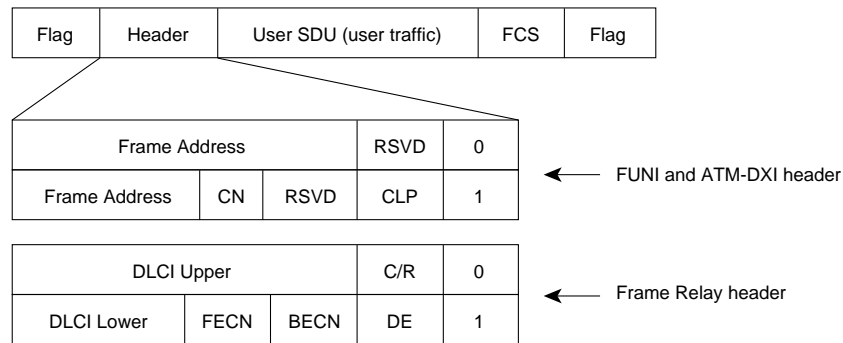
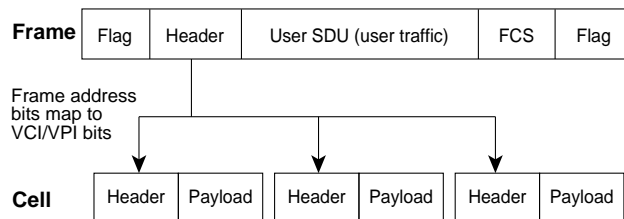


Figure 4. FUNI and ATM-DXI Frame Fragmentation into ATM Cells



- The Frame Relay BECN bit does not have a similar function in ATM either for FUNI or ATM-DXI. BECN is a backward notification to a Frame Relay source indicating that the traffic it sent has experienced congestion. BECN allows the network to notify a Frame Relay source directly about congestion in the network by setting the BECN bit in frames going in the reverse direction.
- The Frame Relay discard eligible (DE) bit and the cell loss priority (CLP) bit perform the same function. CLP/DE = 1 indicates that a cell/frame has a greater probability to be discarded in the case where network congestion requires cells/frames to be discarded.
- The Frame Relay C/R bit, which is passed transparently between Frame Relay users, does not have a corresponding bit in the FUNI/ATM-DXI header.

Although this mapping between Frame Relay and ATM is convenient, it should be noted that other mappings are possible.

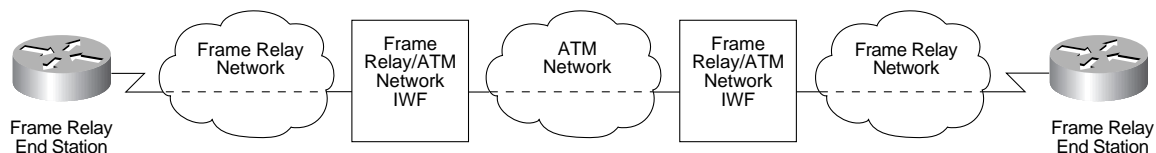
Frame Relay to ATM Service/ Network Interworking Technical Overview

Having compared Frame Relay to ATM Interworking functions in the previous section, this section will describe the two major interworking network topologies:

- Frame Relay to ATM Network Interworking, which provides an ATM transport between two Frame Relay end stations
- Frame Relay to ATM Service Interworking, which allows an ATM end station to communicate with a Frame Relay end station without either side having any knowledge about the protocol being used on the other end

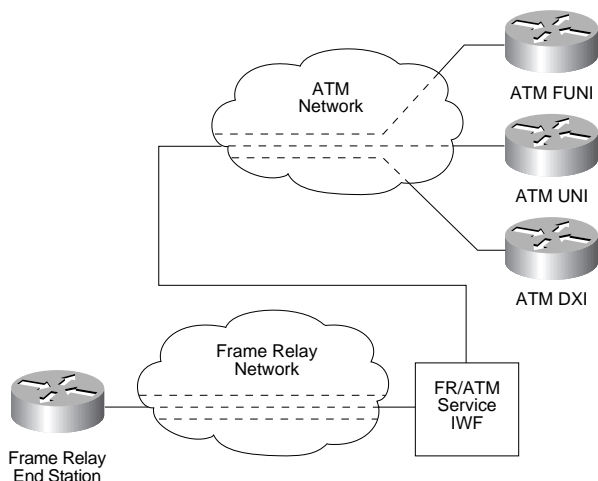
The basic topology for Frame Relay/ATM Network Interworking is shown in Figure 5. It consists of Frame Relay end stations on either side going through a Frame Relay network to the Frame Relay/ATM Network Interworking Function (IWF). The IWF is connected to an ATM network, which acts as a transport medium for the Frame Relay end stations. The Network IWF transparently transports both data traffic and PVC signaling information (the Link Management Interface (LMI)) through the ATM network and effectively tunnels Frame Relay through ATM. This facilitates Multiprotocol Encapsulation (RFC 1490) and other higher-layer functionality to be transported over the network. The location of the Network IWF can either be on a Frame Relay or an ATM switch. The Network IWF can also be in a box external to either network.

Figure 5. Frame Relay/ATM Network Interworking Topology



The basic topology for Frame Relay/ATM Service Interworking is shown in Figure 6. The Frame Relay/ATM Service IWF acts as a protocol converter that allows communication between a Frame Relay end station/network on one end and an ATM end station/network on the other end. (Note that the ATM end station can use the more standard ATM User Network Interface (UNI) as well as either FUNI or ATM-DXI.) The protocol conversion or mapping function is similar to that described in the "FUNI, ATM-DXI, and Frame Relay Technical Comparison" section. Because protocol conversion is performed, the Service IWF converts Frame Relay Multiprotocol Encapsulation (RFC 1490) to ATM Multiprotocol Encapsulation (RFC 1483) to ensure internetworking of upper-layer protocols. This conversion is known as the translation mode in the FRF.8 specification, and it also allows Inverse ARP to function between RFC 1293 for Frame Relay and RFC 1577 for ATM. There is also a transparent mode that does not require this conversion. When there are compatible upper-layer protocols between the terminal equipment at both ends for applications such as packetized voice, the transparent mode can be used.

Figure 6. Frame Relay/ATM Service Interworking Topology



For further details on either of these techniques, please refer to FRF.5 and FRF.8 published by the Frame Relay Forum.

The PVC Versus SVC Debate

Another important issue for both Frame Relay and ATM technology is the debate surrounding whether these services should be based upon Permanent Virtual Circuits (PVCs) or Switched Virtual Circuits (SVCs). PVCs are virtual circuit connections between two locations that

remain permanently set up as shown in Figure 7. SVCs, by contrast, are virtual circuit connections between two locations that get set up and torn down (switched) based upon whether data is actually being sent as shown in Figure 8. PVCs only require a one-time initial setup between the switch and the router, but become cumbersome and costly in networks requiring any-to-any connectivity (that is, where the number of PVCs required is proportional to n^2 where n is the number of sites in the network). In contrast to this, SVCs are continually being set up or torn down based upon data traffic patterns. Although SVCs entail this overhead, the benefit is that virtual circuits are only established based upon data demand. Therefore, the number of virtual circuits is proportional to the number of actual conversations between sites rather than the number of sites. SVCs are preferred in networks that require any-to-any connectivity and dynamic VC setup, whereas PVCs are better for partially meshed networks designed to mimic leased-line topologies.

Figure 7. PVC Connection Schematic

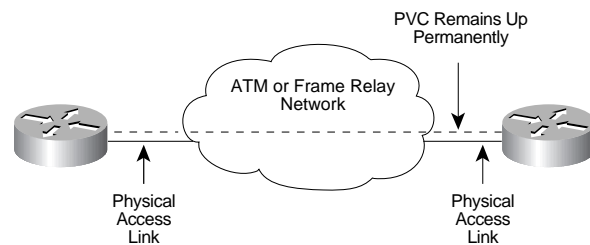
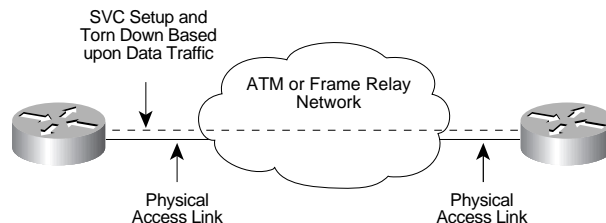


Figure 8. SVC Connection Schematic



Currently, Frame Relay is PVC based in both carrier/service provider network offerings and private Frame Relay networks. During 1996, Frame Relay SVC offerings will begin to emerge in private networks requiring any-to-any connectivity as well as a few small trial implementations in service provider offerings. Despite this fact, the majority of Frame Relay networks will remain PVC based through at least 1997.

In terms of ATM, PVCs and SVCs are both used depending upon the application. For ATM-DXI, a static PVC is used for the connection from the router through the ATM DSU to the ATM edge switch as shown in Figure 9. Inside the ATM network, a PVC is also used. For FUNI, both PVCs and SVCs can be used. FUNI PVCs offer users the same benefits of Frame Relay PVCs in the WAN with the ability to have an end-to-end ATM solution with Quality of Service and seamless-service ATM switches in the LAN. FUNI SVCs offer similar capabilities with the added benefit of dynamic setup and teardown of VCs based upon data traffic. It is expected that FUNI will eventually be more common as an SVC service, although early implementations may be PVC-based.

For interworking ATM and Frame Relay, a variety of permutations possible. At present, only PVC-based ATM/Frame Relay Interworking is being specified in the ATM and Frame Relay Forums. The ATM/Frame Relay Network Interworking is PVC based, allowing a single Frame Relay PVC to be mapped to a single ATM PVC and for all Frame Relay PVCs to be mapped into a single ATM PVC. The ATM/Frame Relay Service Interworking is also PVC based and requires a one-to-one mapping between Frame Relay and ATM PVCs.

The Role of Frame Relay and ATM Technology in Cisco IOS Software and Overall Product Line

This section highlights the future directions of Frame Relay and ATM technology in the Cisco IOS software. Frame Relay/ATM Interworking technology will also be covered in this context.

In terms of Frame Relay technology, the Cisco IOS software already has a large suite of features for Frame Relay PVCs and will build upon this by providing the following:

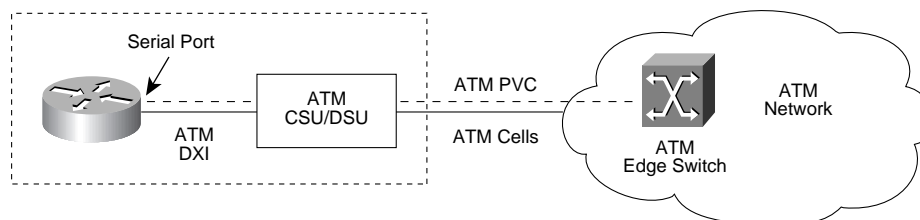
- Compression functionality based upon the Frame Relay Forum's FRF.9 Implementation Agreement (IA); this complements the existing Payload and TCP/IP Header Compression
- Enhanced security capabilities with Encryption over Frame Relay
- Improved Prioritization with Per-VC Queuing; this complements the existing Priority/Custom/Weighted Fair Queuing (PQ/CQ/WFQ) and provides a further degree of granularity

Cisco will also begin to offer Frame Relay SVC (DTE) functionality in the Q4 '96 timeframe. The Frame Relay SVC features will emphasize similar functionality as the PVC effort but will be more suited to any-to-any connectivity networks.

In terms of ATM technology, Cisco already offers support for the ATM-DXI 1a standard. In the FUNI area, Cisco plans to deliver support for both FUNI DTE and DCE functionality. The major differentiators in Cisco's offering will include:

- Integrated Internet Service access with security via encryption for both the DTE and DCE devices
- Dial-up access (ISDN) as well as leased line services for both the DTE and DCE devices
- Channelized T1 access for increased port density for DCE devices
- Point-to-multipoint support for both the DTE and DCE devices
- Integrated IP address resolution services for both the DTE and DCE devices
- Compression over low-speed FUNI WAN links for DTE devices

Figure 9. ATM-DXI PVC Connection to ATM Network



These features will enable Cisco to offer an industry leading FUNI implementation that is complementary to existing Cisco IOS WAN services.

In terms of Frame Relay/ATM Interworking technology, Cisco will emphasize Frame Relay/ATM Service Interworking. Major differentiators in the Service Interworking area include:

- Translation of multiprotocol Inverse ARP to permit auto-configuration of Frame Relay and ATM endpoint devices
- Interoperability of existing Frame Relay Compression (FRF.9) to allow interoperation with Frame Relay devices using compression to maximize network throughput
- Per-VC queuing to allow end-to-end QoS with ATM end users. This will be useful for mission-critical SNA environments requiring fast response times
- Integral encryption for both Frame Relay and ATM to provide seamless security

The Service Interworking functionality will initially be PVC based.

Conclusion

Frame Relay and ATM WAN technologies are growing at a rapid rate. New services like Frame Relay SVCs, Frame Relay/ATM Service Interworking, and FUNI are emerging to permit migration and integration of today's PVC-based Frame Relay landscape into the SVC-based ATM fabric of tomorrow. The Cisco IOS software provides industry-leading functionality in these areas to support all common industry standards. In addition, Cisco is committed to providing its customers with value-added implementations that give superior traffic prioritization, Internet access, security, cost-optimizing data compression, and integrated LAN/WAN software support. Cisco continues to build on these defining characteristics of the Cisco IOS software as Frame Relay and ATM WAN technologies permeate into networks worldwide.



Cisco Systems Worldwide Offices

Corporate Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
World Wide Web URL:
<http://www.cisco.com>
Tel: 408 526-4000
800 553-NETS (6387)
Fax: 408 526-4100

Cisco Systems has more than 125 sales offices worldwide. To contact your local account representative, call Cisco's corporate headquarters (California, USA) at 408 526-4000 or, in North America, call 800 553-NETS (6387).

European Headquarters
Cisco Systems Europe s.a.r.l.
Parc Evolic - Batiment L2
16, Avenue du Quebec
BP 706 Villebon
91961 Courtaboeuf Cedex
France
Tel: 33 1 6918 61 00
Fax: 33 1 6928 83 26

Intercontinental and Latin American Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
Tel: 408 526-7660
Fax: 408 526-4646

Japanese Headquarters
Nihon Cisco Systems K.K.
Seito Kaikan 4F
5, Sanbancho, Chiyoda-ku
Tokyo 102
Japan
Tel: 81 3 5211 2800
Fax: 81 3 5211 2810

Austria
Cisco Systems Austria GmbH
World Trade Center
A-1300 Vienna Airport
Austria
Tel: 43 1 7007 6256
Fax: 43 1 7007 6027

Belgium
Cisco Systems Bruxelles
Complex Antares
71 avenue des Pleiades
1200 Brussels
Belgium
Tel: 32 2 778 42 00
Fax: 32 2 778 43 00

Denmark
Cisco Systems
Larsbjoernsstraede 3
DK-1454 Copenhagen K
Denmark
Tel: 45 33 37 71 57
Fax: 45 33 37 71 53

Finland
Cisco Systems
Maistraatiportti 2A
FIN-00240 Helsinki
Finland
Tel: 358 1594 3090
Fax: 358 1594 3093

Germany
Cisco Systems GmbH
Max-Planck-Strasse 7, 3rd Floor
85716 Unterschleissheim
Germany

Tel: 49 89 32 15070
Fax: 49 89 32 150710

Ireland
Cisco Systems Ltd.
Europa House, 4th Floor
Harcourt Street
Dublin 2
Ireland
Tel: 35 3 1 475 4244
Fax: 35 3 1 475 4778

Italy
Cisco Systems Italy Srl
Centro Direzionale Milano Oltre
Palazzo Raffaello Scala B 4P
Via Cassanese 224
20090 Segrate (Mi)
Italy
Tel: 39 2 26 97 31
Fax: 39 2 26 92 9006

The Netherlands
Cisco Systems
Stephensonweg 8
4207 HB Gorinchem
The Netherlands
Tel: 31 183 622 988
Fax: 31 183 622 404

Norway
Cisco Systems
Holmens Gate 4
N-0250 Oslo
Norway
Tel: 47 22 83 06 31
Fax: 47 22 83 22 12

Portugal
Cisco Systems Portugal
Avda. da Liberdade 114-134
1250 Lisboa
Portugal
Tel: 351 1 340 45 31/2
Fax: 351 1 340 4575

South Africa
Cisco Systems South Africa
Meintjie Parker House
328 Rivonia Blvd.
Rivonia, Gauteng
South Africa
Tel: 27 11 807 4444
Fax: 27 11 807 4447

Spain
Cisco Systems Spain
Avenida de Burgos, 17 Pl. 11
Edificio Triada II
28036 Madrid
Spain
Tel: 34 1 383 2178
Fax: 34 1 383 8008

Sweden
Cisco Systems AB
Arstaangsvagen 13
117 60 Stockholm
Sweden
Tel: 46 8 681 41 60
Fax: 46 8 19 04 24

Switzerland
Cisco Systems Switzerland
Grossrietstrasse 7
CH-8606 Naenikon/ZH
Switzerland
Tel: 41 1 905 20 50
Fax: 41 1 941 50 60

United Arab Emirates
Cisco Systems (Middle East)
PO Box 26095
City Tower 2
Sheik Zayed Road
Dubai, UAE
Tel: 971 4 318 7888
Fax: 971 4 313 681

United Kingdom
Cisco Systems Ltd.
4 New Square

Bedfont Lakes
Feltham, Middlesex TW14 8HA
UK
Tel: 44 1 81 818 1400
Fax: 44 1 81 893 2824

Asia
Cisco Systems (HK) Ltd
Suite 1009, Great Eagle Centre
23 Harbour Road
Wanchai
Hong Kong
Tel: 852 2583 9110
Fax: 852 2824 9528

Cisco Systems (HK) Ltd
Beijing Office
Room 821/822, Jing Guang Centre
Hu Jia Lou, Chao Yang Qu
Beijing 100020
China, PRC
Tel: 86 10 501 8888 x821/822
Fax: 86 10 501 4531

Cisco Systems (HK) Ltd
New Delhi Liaison Office
Suite 119, Hyatt Regency Delhi
Bhikaji Cama Place, Ring Road
New Delhi 110 066
India
Tel: 91 11 688 1234 x119
Fax: 91 11 611 7688

Cisco Systems, (HK) Ltd
Level 12, Wisma Bank Dharmala, JI
Jenderal Sudirman Kav. 28
Jakarta Selatan 12910
Indonesia
Tel: 62 21 523 9132
Fax: 62 21 523 9259

Cisco Systems Korea
Samik Rabilod Building 5th floor
720-2 Yuksam-2-dong, Gangnam-ku
Seoul, 135-082
Korea
Tel: 82 2 3453 0850
Fax: 82 2 3453 0851

Cisco Systems (HK) Ltd
Kuala Lumpur Office
Level 5, Wisma Goldhill
67 Jalan Raja Chulan
50200 Kuala Lumpur
Malaysia
Tel: 60 3 236 5147
Fax: 60 3 236 5146

Cisco Systems Manila Office
The Executive Tower Centre
Room 9, 24/F, Pacific Star Building
cor. Buendia Street, Makati Avenue
Makati City
Philippines
Tel: 632 892 4476
Fax: 632 811 5998

Cisco Systems (USA) Pte Ltd
501 Orchard Road
#04-11 Lane Crawford Place
Singapore 238880
Tel: 65 738 5535
Fax: 65 738 2202

Cisco Systems (HK) Ltd
Taipei Office
4F, 25 Tunhua South Road, Section 1
Taipei
Taiwan, ROC
Tel: 88 62 577 4352
Fax: 88 62 577 0248

Cisco Systems (HK) Ltd
7th Floor, The Park Place Building
231 Sarasin Road, Pathumwan
Bangkok 10330
Thailand
Tel: 662 253 5315
Fax: 662 253 8440

Argentina
Cisco Systems Argentina
Cerrito 1054, Piso 9
(1001) Buenos Aires
Argentina
Tel: 54 1 811 7526
Fax: 54 1 811 7495

Australia
Cisco Systems Australia Pty Ltd
Level 17
99 Walker Street
North Sydney NSW 2060
Australia
Tel: 61 2 9935 4100
Fax: 61 2 9957 4077

Brazil
Cisco Systems Do Brasil
Rua Helena 218, 10th Floor
Cj 1004-1005 Vila Olimpia
Sao Paulo, SP CEP 04552-050
Brazil
Tel/Fax: 55 11 822 6095
Tel/Fax: 55 11 822 6396

Canada
Cisco Systems Canada Limited
150 King Street West
Suite 1707
Toronto, Ontario M5H 1J9
Canada
Tel: 416 217-8000
Fax: 416 217-8099

Central America / Caribbean
Cisco Systems, Inc.
790 NW 107th Avenue, Suite 102
Miami, Florida 33172
USA
Tel: 305 228-1200
Fax: 305 222-8456

Colombia
Cisco Systems Colombia
Cra. 18 #86A-14
Bogota
Colombia
Tel: 57 1 296 0067
Fax: 57 1 616 3030

Mexico
Cisco Systems de México, S.A. de C.V.
Ave. Ejecito Nacional No. 926
3er Piso
Col. Polanco C.P. 11560
Mexico D.F.
Tel: 52 5 328 7600
Fax: 52 5 328 7699

New Zealand
Cisco Systems New Zealand
Level 16, ASB Bank Centre
135 Albert Street
P.O. Box 6624
Auckland
New Zealand
Tel: 64 9 358 3776
Fax: 64 9 358 4442

Venezuela
Cisco Systems Venezuela
Calle Bajada de Los Curtidores
Qta. Jakaranda - Alto Hatillo
Caracas
Venezuela
Tel/Fax: 58 2 963 6140

0396R