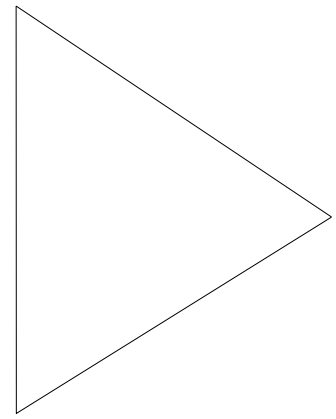


Policy-Based Routing



White Paper

The Need to Define Routing Policy

In today's high performance internetworks, organizations need the freedom to implement packet forwarding and routing according to their own defined policies in a way that goes beyond traditional routing protocol concerns. Where administrative issues dictate that traffic be routed through specific paths, policy-based routing, introduced in Cisco Internetwork Operating System (Cisco IOS™) Software Release 11.0, can provide the solution. By using policy-based routing, customers can implement policies that selectively cause packets to take different paths.

Policy routing also provides a mechanism to mark packets so that certain kinds of traffic receive differentiated, preferential service when used in combination with queuing techniques enabled through the Cisco IOS software. These queuing techniques provide an extremely powerful, simple, and flexible tool to network managers who implement routing policies in their networks.

This paper discusses the Cisco IOS software policy-based routing feature and addresses policy-based routing and its functionality. In addition, the issues related to managing an internetwork with policy-based routing implemented are described. And finally, the applications of policy-based routing in internetworks are presented.

The Benefits of Policy-Based Routing

The benefits that can be achieved by implementing policy-based routing in the networks include:

- **Source-Based Transit Provider Selection**—Internet service providers and other organizations can use policy-based routing to route traffic originating from different sets of users through different Internet connections across the policy routers.
- **Quality of Service (QoS)**—Organizations can provide QoS to differentiated traffic by setting the precedence or type of service (TOS) values in the IP packet headers at the periphery of the network and leveraging queuing mechanisms to prioritize traffic in the core or backbone of the network.
- **Cost Savings**—Organizations can achieve cost savings by distributing interactive and batch traffic among low-bandwidth, low-cost permanent paths and high-bandwidth, high-cost, switched paths.
- **Load Sharing**—In addition to the dynamic load-sharing capabilities offered by destination-based routing that the Cisco IOS software has always supported, network managers can now implement policies to distribute traffic among multiple paths based on the traffic characteristics.

Policy-Based Routing Data Forwarding

Policy-based routing (PBR) provides a mechanism for expressing and implementing forwarding/routing of data packets based on the policies defined by the network administrators. It provides a more flexible mechanism for routing packets through routers, complementing the existing mechanism provided by routing protocols.

Routers forward packets to the destination addresses based on information from static routes or dynamic routing protocols such as Routing Information Protocol (RIP), Open Shortest Path First (OSPF), or Enhanced Interior Gateway Routing Protocol (Enhanced IGRP[®]). Instead of routing by the destination address, policy-based routing allows network administrators to determine and implement routing policies to allow or deny paths based on the following:

- Identity of a particular end system
- Application
- Protocol
- Size of packets

Policies can be defined as simply as “my network will not carry traffic from the engineering department” or as complex as “traffic originating within my network with the following characteristics will take path A, while other traffic will take path B.”

Tagging Network Traffic

Policy-based routing allows the network administrator to classify traffic using access control lists¹ (ACLs) and then set the IP precedence or TOS values, thereby tagging the packets with the defined classification.

Classification of traffic through policy-based routing allows the network administrator to identify traffic for different classes of service at the perimeter of the network and then implement QOS defined for each class of service in the core of the network using priority, custom, or weighted fair queuing techniques. This process saves having to classify the traffic explicitly at each WAN interface in the core/backbone network.

1. Access control lists, enabled by the Cisco IOS software, provide packet-filtering capability.

Applying Policy-Based Routing

Policy-based routing is applied to incoming packets. All packets received on an interface with policy-based routing enabled are considered for policy-based routing. The router passes the packets through enhanced packet filters called route maps. Based on the criteria defined in the route maps, packets are forwarded/routed to the appropriate next hop.

Policy Route Maps

Each entry in a route map statement contains a combination of match and set clauses/commands. The match clauses define the criteria for whether appropriate packets meet the particular policy (that is, the conditions to be met). The set clauses then explain how the packets should be routed once they have met the match criteria.

For each combination of match and set commands in a route map statement, all sequential match clauses must be met simultaneously by the packet for the set clauses to be applied. There may be multiple sets of combinations of match and set commands in a full route map statement.

The route map statements can also be marked as permit or deny. If the statement is marked as a deny, the packets meeting the match criteria are sent back through the normal forwarding channels (in other words, destination-based routing is performed). Only if the statement is marked as permit and the packets meet the match criteria are all the set clauses applied. If the statement is marked as permit and the packets do not meet the match criteria, then those packets are also forwarded through the normal routing channel.

Note: Policy routing is specified on the interface that receives the packets, not on the interface from which the packets are sent.

Match Clauses—Defining the Criteria

The IP standard or extended ACLs can be used to establish the match criteria. The standard IP access lists can be used to specify the match criteria for source address; extended access lists can be used to specify the match criteria based on application, protocol type, TOS, and precedence.

The match clause feature has been extended to include matching packet length between specified minimum and maximum values. The network administrator can then use the match length as the criterion that distinguishes between interactive and bulk traffic (bulk traffic usually has larger packet sizes).

The policy routing process proceeds through the route map until a match is found. If no match is found in the route map, or the route map entry is made a deny instead of a permit, then normal destination-based routing of the traffic ensues.

Note: There is an implicit deny at the end of the list of match statements.

Set Clauses—Defining the Route

If the match clauses are satisfied, one of the following set clauses can be used to specify the criteria for forwarding packets through the router; they are evaluated in the order listed:

- 1 List of interfaces through which the packets can be routed—If more than one interface is specified, then the first interface that is found to be up will be used for forwarding the packets.
- 2 List of specified IP addresses—The IP address can specify the adjacent next hop router in the path toward the destination to which the packets should be forwarded. The first IP address associated with a currently “up” connected interface will be used to route the packets.

- 3 List of default interfaces—If there is no explicit route available to the destination address of the packet being considered for policy routing, then route it to the first up interface in the list of specified default interfaces.
- 4 List of default next hop IP addresses—Route to the interface or the next hop specified by this set clause only if there is no explicit route for the destination address of the packet in the routing table.
- 5 IP TOS—A value or keyword can be specified to set the type of service in the IP packets.
- 6 IP precedence—A value or keyword can be specified to set the precedence in the IP packets.

The set commands can be used in conjunction with each other.

The next hop router specified in the set clauses must be adjacent to the policy router, sharing a subnetwork with the policy router.

If the packets do not meet any of the defined match criteria (that is, if the packets fall off the end of a route map), then those packets are routed through the normal destination-based routing process. If it is desired not to revert to normal forwarding and to drop the packets that do not match the specified criteria, then interface Null 0 should be specified as the last interface in the list by using the set clause.

Management Implications

The route specified by configured policies might differ from the best route as determined by the routing protocols, enabling packets to take different routes depending on their source, length, and content. As a result, packet forwarding based on configured policies will override packet forwarding based on the routing entries in the routing tables to the same destination. For example, the management applications might discover a path that will pertain to the path discovered by a dynamic routing protocol or specified by static route mapping, whereas the actual traffic might not follow that path, based on the configured policies.

Similarly, the traceroute command might generate a path that is a different from the route taken by the packets generated by the user application. For example, in Figure 1, the best path between X and Y is through the T1 line, but policy routing can be used to send some traffic over the Frame Relay link.

Because the added flexibility to route traffic on user-defined paths rather than the paths determined by routing protocols may make the environment more difficult to manage and might cause routing loops, policies should be defined in a deterministic manner to keep the environment simple and manageable.

Applications

The following sections list applications of policy routing.

Equal-Access and Source-Sensitive Routing

Policy routing enables the network administrator to provide equal-access and source-sensitive routing. (See Figure 2.)

In Figure 2, Organization X has directed that traffic from address range A go through Internet Service Provider (ISP) 1 and traffic from address range B go through ISP2.

Figure 1. Best Path and Configured Path

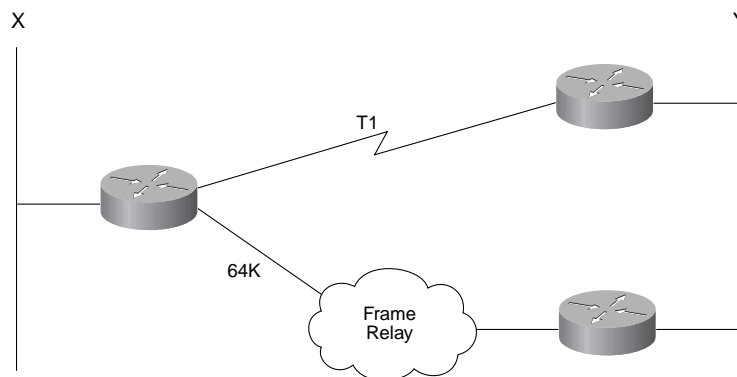
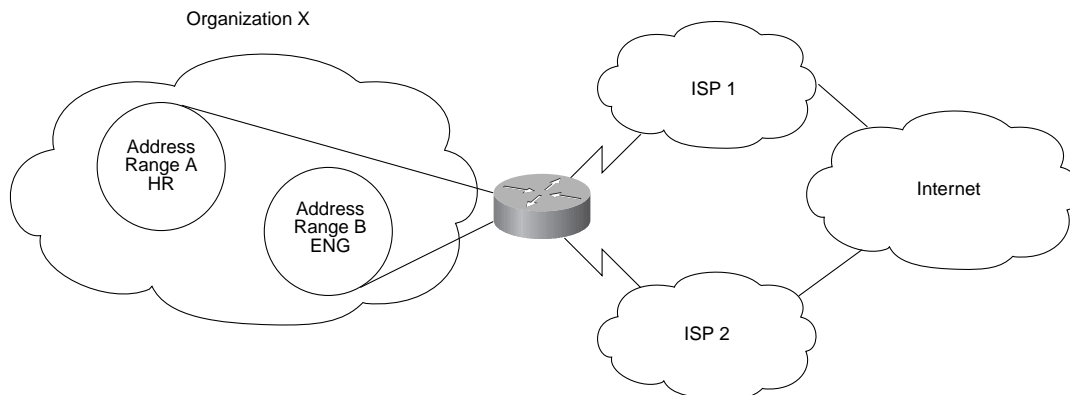


Figure 2. Source-Sensitive Routing



Quality of Service

By tagging packets with policy routing, network administrators can classify the network traffic at the perimeter of the network for various classes of service and then implement those classes of service in the core of the network using priority, custom or weighted fair queuing. This setup improves network performance by eliminating the need to classify the traffic explicitly at each WAN interface in the core or backbone network. (See Figure 3.)

Cost Savings

An organization can direct the bulk traffic associated with a specific activity to use a higher bandwidth, high-cost link for a short time, and continue basic connectivity over a lower bandwidth, low-cost link for interactive traffic. For example, Figure 4 shows a dial-on-demand Integrated Services Digital Network (ISDN) line brought up in response to traffic to the finance server for file transfers selected by policy routing.

Figure 3. Type of Service Prioritization

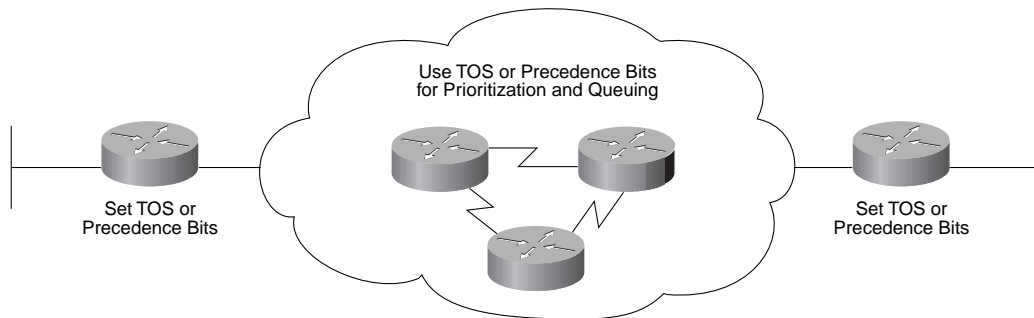
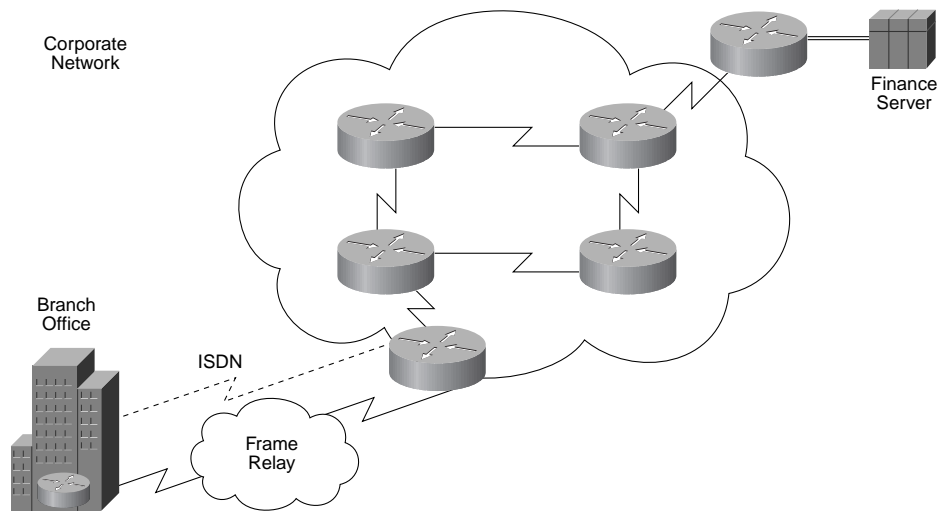


Figure 4. Dial-on-Demand ISDN Line Responding to Traffic



Load Sharing

In addition to the dynamic load-sharing capabilities offered by destination-based routing that the Cisco IOS software has always supported, network managers can now implement policies to distribute traffic among multiple paths based on the traffic characteristics.

The Cisco Commitment to Policy-Based Routing

Policy-based routing offers significant benefits in terms of implementing user-defined policies to control traffic in the internetworks and can provide solutions where legal, contractual, or political constraints dictate that traffic be routed through specific paths. Policy routing also provides a mechanism to mark packets so that differentiated preferential service can be provided to types of traffic in

combination with queuing techniques available in the Cisco IOS software. Policy-based routing adds flexibility in a difficult-to-manage environment, providing the network administrator the ability to route traffic based on user defined concerns. For network managers who implement routing policies in their networks, the Cisco IOS software provides an extremely powerful, simple, and flexible tool.

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 network traffic queuing techniques become a necessary technology in 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 L1/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 Brussels
Complex Antares
71 Avenue des Pleiades
1200 Brussels
Belgium
Tel: 32 2 778 42 00
Fax: 32 2 778 43 00

Denmark

Cisco Systems
Larsbojomsstraede 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 6
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 45 75

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
S-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 4 318 788
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 Beijing Representative Office

Add. Unit 751
New Century Hotel Office Tower
No. 6 Southern Road Capital Gym
Beijing, 100044
China, PRC
Tel: 86-10-8492398
Fax: 86-10-8492395

Cisco Systems (HK) Ltd

New Delhi Liaison Office
Suite 119, Hyatt Regency Delhi
Bhikaiji Cama Place, Ring Road
New Delhi 110 066
India
Tel: 91-11-616-7688
Fax: 91-11-616-7688

Cisco Systems, (HK) Ltd

Level 12, Wisma Bank Dharmala, Jl
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 (Malaysia) Sdn. Bhd.

14.05, 14th Floor
Menara Multi-Purpose, Capital Square
8 Jalan Munshi Abdullah
50100 Kuala Lumpur
Malaysia
Tel: 0203-292-8398
Fax: 0203-292-8389

Cisco Systems Manila Office

The Executive Tower Centre
Room 9, 24/F, Pacific Star Building
Sen. Gil J. Puyat Corner
Makati Avenue, Makati City
Metro Manila
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

Taiwan Representative Office
16F/B 333 Tunhua South Road
Sec 2
Taipei
Taiwan, ROC
Tel: 886-2-738-6667
Fax: 886-2-377-0611

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
(1010) 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

Chile

Cisco Systems-Chile
Avenida Tajamar 481, Ofi. #101
Las Condes
Santiago, Chile
Tel: 562-339-7000
Fax: 562-339-7022

Colombia

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

Costa Rica

Cisco Systems-Costa Rica
De las Tunas 100 metros Norte
50 metros Este
Sabana Norte
San Jose
Costa Rica
Tel: 506-296-1885
Fax: 506-296-3607

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
PO. Box 6624
Auckland
New Zealand
Tel: 64 9 358 3776
Fax: 64 9 358 4442

Venezuela

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