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Introduction

One of the intriguing aspects of Cisco routers, especially for those new to routing, is how the router chooses which route is the best among those presented by routing protocols, manual configuration, and various other means. While route selection is much simpler than you might imagine, to understand it completely requires some knowledge about the way Cisco routers work.

Prerequisites

Requirements

There are no specific prerequisites for this document.

Components Used

This document is not restricted to specific software and hardware versions.

Conventions

For more information on document conventions, see the Cisco Technical Tips Conventions.

Processes Involved

There are three processes involved in building and maintaining the routing table in a Cisco router:

- Various routing processes, which actually run a network (or routing) protocol, such as Enhanced Interior Gateway Routing Protocol (EIGRP), Border Gateway Protocol (BGP), Intermediate System-to-Intermediate System (IS-IS), and Open Shortest Path First (OSPF).

- The routing table itself, which accepts information from the routing processes and also replies to requests for information from the forwarding process.
- The forwarding process, which requests information from the routing table to make a packet forwarding decision.

Let's examine the interaction between the routing protocols and the routing table to understand how the routing table is built.

Building the Routing Table

The main considerations while building the routing table are:

- **Administrative distance** – This is the measure of trustworthiness of the source of the route. If a router learns about a destination from more than one routing protocol, administrative distance is compared and the preference is given to the routes with lower administrative distance. In other words, it is the believability of the source of the route.
- **Metrics** – This is a measure used by the routing protocol to calculate the best path to a given destination, if it learns multiple paths to the same destination. Each routing protocol uses a different metric.
- **Prefix length**

As each routing process receives updates and other information, it chooses the best path to any given destination and attempts to install this path into the routing table. For instance, if EIGRP learns of a path toward 10.1.1.0/24, and decides this particular path is the best EIGRP path to this destination, it tries to install the path it has learned into the routing table.

The router decides whether or not to install the routes presented by the routing processes based on the administrative distance of the route in question. If this path has the lowest administrative distance to this destination (when compared to the other routes in the table), it's installed in the routing table. If this route isn't the route with the best administrative distance, then the route is rejected.

To understand this better, let's look at an example. Assume a router has four routing processes running: EIGRP, OSPF, RIP, and IGRP. Now, all four of these processes have learned of various routes to the 192.168.24.0/24 network, and each has chosen its best path to that network through its internal metrics and processes.

Each of these four processes attempts to install their route toward 192.168.24.0/24 into the routing table. The routing processes are each assigned an administrative distance, which is used to decide which route to install.

Default Administrative Distances	
Connected	0
Static	1
eBGP	20
EIGRP (internal)	90
IGRP	100
OSPF	110
IS-IS	115

RIP	120
EIGRP (external)	170
iBGP	200
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Since the internal EIGRP route has the best administrative distance (the smaller the administrative distance, the higher the preference), it's installed in the routing table.

Backup Routes

What do the other protocols, RIP, IGRP, and OSPF, do with the routes that weren't installed? What if the most preferred route, learned from EIGRP, fails? Cisco IOS® Software uses two approaches to solve this problem: The first is to have each routing process attempt to install its best routes periodically. If the most preferred route fails, the next best route (according to administrative distance) succeeds on the next attempt. The other solution is for the routing protocol that failed to install its route in the table to hang on to the route, and tell the routing table process to report if the best path fails.

For protocols that don't have their own routing information tables, such as IGRP, the first method is used. Every time IGRP receives an update about a route, it attempts to install the updated information in the routing table. If there's already a route to this same destination in the routing table, the installation attempt fails.

For protocols that have their own database of routing information, such as EIGRP, IS-IS, OSPF, BGP, and RIP, a backup route is registered when the initial attempt to install the route fails. If the route installed in the routing table fails for some reason, the routing table maintenance process calls each routing protocol process that has registered a backup route, and asks them to reinstall the route in the routing table. If there are multiple protocols with registered backup routes, the preferred route is chosen based on administrative distance.

Adjusting the Administrative Distance

The default administrative distance might not always be right for your network; you may want to adjust them so that RIP routes are preferred over IGRP routes, for instance. Before explaining how to adjust the administrative distances, we need to look at the implications of changing the administrative distance.

Changing the administrative distance on routing protocols can be very dangerous! Changing the default distances can actually lead to routing loops and other oddities in your network. We recommend you change administrative distance with caution, and only after you have thought through what you want to achieve, and all the consequences of your actions.

For entire protocols, changing the distance is relatively easy; simply configure the distance using the **distance** command in the routing process sub-configuration mode. You can also change the distance for routes learned from one source only in some protocols, and you can change the distance on just some routes.

For static routes, you can change the distance of each route by entering a distance after the **ip route** command:

ip route network subnet mask next hop distance

You can't change the administrative distance for all the static routes at once.

How Metrics Determine the Route Selection Process

Routes are chosen and built in the routing table based on the routing protocol's administrative distance. The routes learned from the routing protocol with the lowest administrative distance are installed in the routing table. If there are multiple paths to the same destination from a single routing protocol, then the multiple paths would have the same administrative distance and the best path is selected based on the metrics. Metrics are values associated with specific routes, ranking them from most preferred to least preferred. The parameters used to determine the metrics differ for different routing protocols. The path with the lowest metric is selected as the optimal path and installed in the routing table. If there are multiple paths to the same destination with equal metrics, load balancing is done on these equal cost paths. For more information on load balancing see [How Does Load Balancing Work?](#)

Prefix Lengths

Let's look at another scenario to see how the router handles another common situation: varying prefix lengths. Assume, again, that a router has four routing processes running on it, and each process has received these routes:

- EIGRP (internal): 192.168.32.0/26
- RIP: 192.168.32.0/24
- OSPF: 192.168.32.0/19

Which of these routes will be installed in the routing table? Since EIGRP internal routes have the best administrative distance, it's tempting to assume the first one will be installed. However, since each of these routes has a different prefix length (subnet mask), they're considered different destinations, and they will all be installed in the routing table.

Let's see how the forwarding engine uses the information from the routing table to make forwarding decisions.

Making Forwarding Decisions

Let's look at the three routes we just installed in the routing table, and see how they look on the router.

```
router# show ip route
.....
D   192.168.32.0/26 [90/25789217] via 10.1.1.1
R   192.168.32.0/24 [120/4] via 10.1.1.2
O   192.168.32.0/19 [110/229840] via 10.1.1.3
.....
```

If a packet arrives on a router interface destined for 192.168.32.1, which route would the router choose? It depends on the prefix length, or the number of bits set in the subnet mask. Longer prefixes are always preferred over shorter ones when forwarding a packet.

In this case, a packet destined to 192.168.32.1 is directed toward 10.1.1.1, because 192.168.32.1 falls within the 192.168.32.0/26 network (192.168.32.0 to 192.168.32.63). It also falls within the other two routes available, but the 192.168.32.0/26 has the longest prefix within the routing table (26 bits versus 24 or 19 bits).

Likewise, if a packet destined for 192.168.32.100 arrives on one of the router's interfaces, it's forwarded to 10.1.1.2, because 192.168.32.100 doesn't fall within 192.168.32.0/26 (192.168.32.0 through 192.168.32.63), but it does fall within the 192.168.32.0/24 destination (192.168.32.0 through 192.168.32.255). Again, it also falls into the range covered by 192.168.32.0/19, but 192.168.32.0/24 has a longer prefix length.

IP Classless

Where the **ip classless** configuration command falls within the routing and forwarding processes is often confusing. In reality, IP classless only affects the operation of the forwarding processes in IOS; it doesn't affect the way the routing table is built. If IP classless isn't configured (using the **no ip classless** command), the router won't forward packets to supernets. As an example, let's again place three routes in the routing table and route packets through the router.

Note: If the supernet or default route is learned via IS-IS or OSPF, the **no ip classless** configuration command is ignored. In this case, packet switching behavior works as though **ip classless** were configured.

```
router# show ip route
.....
      172.30.0.0/16 is variably subnetted, 2 subnets, 2 masks
D       172.30.32.0/20 [90/4879540] via 10.1.1.2
D       172.30.32.0/24 [90/25789217] via 10.1.1.1
S*    0.0.0.0/0 [1/0] via 10.1.1.3
```

Remembering that the 172.30.32.0/24 network includes the addresses 172.30.32.0 through 172.30.32.255, and the 172.30.32.0/20 network includes the addresses 172.30.32.0 through 172.30.47.255, we can then try switching three packets through this routing table and see what the results are.

- A packet destined to 172.30.32.1 is forwarded to 10.1.1.1, since this is the longest prefix match.
- A packet destined to 172.30.33.1 is forwarded to 10.1.1.2, since this is the longest prefix match.
- A packet destined to 192.168.10.1 is forwarded to 10.1.1.3; since this network doesn't exist in the routing table, this packet is forwarded to the default route.
- A packet destined to 172.30.254.1 is dropped.

The surprising answer out of these four is the last packet, which is dropped. It's dropped because its destination, 172.30.254.1, is within a known major network, 172.30.0.0/16, but the router doesn't know about this particular subnet within that major network.

This is the essence of classful routing: If one part of a major network is known, but the subnet toward which the packet is destined within that major network is unknown, the packet is dropped.

The most confusing aspect of this rule is that the router only uses the default route if the destination major network doesn't exist in the routing table at all.

This can cause problems in a network where a remote site, with one connection back to the rest of the network, is running no routing protocols, as illustrated.



The remote site router is configured like this:

```
interface Serial 0
  ip address 10.1.2.2 255.255.255.0
!
```

```

interface Ethernet 0
  ip address 10.1.1.1 255.255.255.0
  !
  ip route 0.0.0.0 0.0.0.0 10.1.2.1
  !
no ip classless

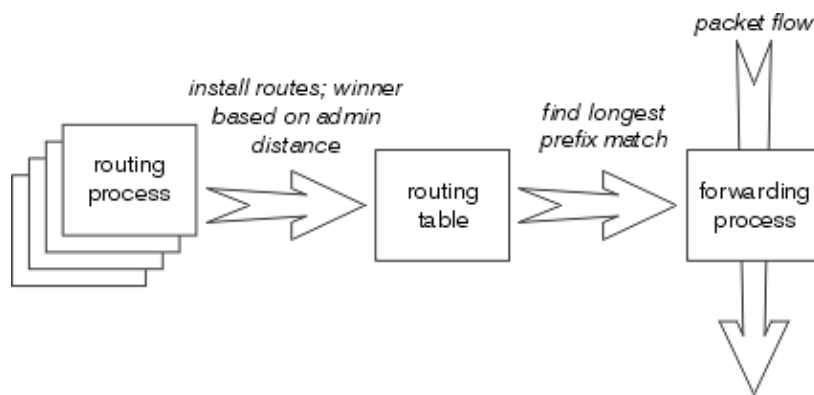
```

With this configuration, the hosts at the remote site can reach destinations on the Internet (through the 10.x.x.x cloud), but not destinations within the 10.x.x.x cloud, which is the corporate network. Because the remote router knows about some part of the 10.0.0.0/8 network, the two directly connected subnets, and no other subnet of 10.x.x.x, it assumes these other subnets don't exist and drops any packets destined for them. Traffic destined to the Internet, however, doesn't ever have a destination in the 10.x.x.x range of addresses, and is therefore correctly routed through the default route.

Configuring **ip classless** on the remote router resolves this problem by allowing the router to ignore the classful boundaries of the networks in its routing table and simply route to the longest prefix match it can find.

Summary

In summary, making a forwarding decision actually consists of three sets of processes: the routing protocols, the routing table, and the actual process which makes a forwarding decision and switches packets. These three sets of processes are illustrated, along with their relationship, below.



The longest prefix match always wins among the routes actually installed in the routing table, while the routing protocol with the lowest administrative distance always wins when installing routes into the routing table.

Related Information

- [How Does Load Balancing Work?](#)
- [What is Administrative Distance?](#)
- [EIGRP Support Page](#)
- [BGP Support Page](#)
- [IGRP Support Page](#)
- [IP Routed Protocols Support Page](#)
- [IP Routing Support Page](#)
- [IS-IS Support Page](#)
- [OSPF Support Page](#)
- [RIP Support Page](#)
- [Technical Support – Cisco Systems](#)

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Updated: Apr 06, 2006

Document ID: 8651
