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1 Configuring IP Routing Basic

1.1 Introduction

1.1.1 Overview

A router receives a data packet, checks its destination address, and forwards the packet to the next router according to the routing table. The packet arrives at the destination host after being forwarded multiple times by intermediate routers. The forwarding path of the intermediate routers constitutes the routing path information.

Note

In this chapter, the term "router" refers to any network device that supports the routing function. These network devices can be Layer-3 switches, routers, or firewalls.

1.1.2 Principles

1. Composition of Routing Table

A router manages the routing table, consolidates routes sent by various routing protocols, and selects and sends preferred routes to the routing table. Routes discovered by various routing protocols are stored in the routing table. The routing table contains the following key items:

Destination: Destination address, used to identify the destination network or destination address of the IP packet.

Mask: Network mask, which identifies the network segment of the destination address together with the destination address.

Protocol: Routing protocol.

Distance: Management distance, identifying the priority of the route for joining the routing table. For the same destination address, routing management will take the route with the smallest management distance as the optimal route. The table below lists the default management distances of different routing protocols.

Table 1-1 Routing Protocols and Default Management Distances

Routing Protocol	Management Distance
Direct route	0
Static route	1
EBGP	20
OSPF	110
IS-IS	115

Routing Protocol	Management Distance
RIP	120
IBGP	200

Metric: Routing cost. For the same management distance, the route with smallest routing cost will be the optimal route.

NextHop: The next-hop IP address, the interface IP address of the packet in the next forwarding route.

Interface: Forwarding interface, indicating from which interface of the local router the packet is forwarded to the next hop.

2. Route Classification

By the source mode, routes are generally divided into the following three categories:

- Direct route: It is the route discovered by a link-layer protocol and is also called interface route.
- Static route: It is manually configured by the network administrator. A static route is easy to configure and less demanding on the system, and therefore applicable to a small-sized network that is stable and has a simple topology. However, when the network topology changes, the static route must be manually reconfigured and cannot automatically adapt to the topological changes.
- Dynamic route: It is the route discovered by a dynamic routing protocol.

3. Route Computation

- Routing function

Routing functions are classified into IPv4 and IPv6 routing functions. If the routing functions are disabled, a device is equivalent to a host and cannot forward routes.

- Dynamic Route

A dynamic routing protocol learns remote routes and dynamically updates routes by exchanging routes with neighbors. If a neighbor is the next hop of a route and this neighbor fails, the route fails as well.

Classified by the scope of action:

- Interior Gateway Protocol (IGP): Running in an autonomous system. Protocols are Routing Information Protocol (RIP), Open Shortest Path First (OSPF), and Intermediate System to Intermediate System (IS-IS).
- Exterior Gateway Protocol (EGP): Running between different autonomous systems. Protocol is Border Gateway Protocol (BGP).

Classified by the route computation algorithm:

- Distance vector routing protocols: Protocols are BGP and RIP.
- Link state routing protocols: Protocols are OSPF and IS-IS.
- Static route

On a network with a simple topology, you can configure only static routes to implement internetworking. Appropriate configuration and use of static routes can improve the network performance and guarantee the bandwidth for important network applications.

Whether a static route is active is computed based on the status of the local interface. When the exit interface of a static route is located at Layer-3 and is in Up status (the link status is Up and the IP address is configured), this route is active and can be used for packet forwarding.

A static route can go across VPN routing & forwarding (VRF) instances. The next hop or exit interface of a static route of VRF 1 can be configured on VRF 2.

- ARP-to-host conversion

Enable ARP-to-host conversion on a specified interface. If the interface is a Layer-3 interface in Up status, ARP entries will be converted into 32-bit host routes on the interface.

4. Optimal Route Selection

- Management distance

When multiple routing protocols generate routes to the same destination, the priorities of these routes can be determined based on the management distance. A smaller management distance indicates a higher priority.

- Equal-cost route

If multiple routes to the same destination have different next hops but the same management distance, these routes are mutually equal-cost routes. Packets are distributed among these routes to implement load balancing based on the balanced forwarding policy.

On a specific device, the total number of equal-cost routes is limited. Routes beyond the limit do not participate in packet forwarding.

The routing protocols supporting equal-cost route are the static route, RIP, OSPF, IS-IS, and BGP.

- Floating route

If multiple routes to the same destination have different next hops and different management distances, these routes are mutually floating routes. The route with the smallest management distance will be first selected for packet forwarding. If this route fails, a route with a larger management distance is further selected for forwarding, thus preventing communication interruption caused by a network line failure.

- Routing recursion

Only the next hop directly connected can be used as the basis of router forwarding, but the next hop may not be directly connected in BGP and static route. In this case, route iteration is needed to query the routing table according to the next-hop address, find a route with the next hop directly connected or outbound interface, and use the route as the basis for forwarding.

1.2 Configuration Task Summary

The configuration of IP routing basic includes the following tasks:

- (1) (Optional) [Configuring Route Limitations](#) The following configuration tasks are optional. Select tasks for configuration according to the actual condition.
 - [Configuring the Maximum Number of Equal-Cost Routes](#)
 - [Disabling IPv4 Routing](#)
 - [Disabling IPv6 Routing](#)
-

- (2) (Optional) [Configuring Fast Convergence Fast Convergence](#) The following configuration tasks are optional. Select tasks for configuration according to the actual condition.
- o [Enabling IPv4 Recursive Routing Fast Convergence](#)
 - o [Enabling IPv6 Recursive Routing Fast Convergence](#)
- (3) (Optional) [Configuring ARP-to-host Conversion](#)
- a [Configuring the Interface to Enable ARP-to-host Conversion](#)
 - b (Optional) [Enabling Proxy ARP](#)
 - c (Optional) [Configuring BGP Redistributed ARP-host Route](#)
- (4) (Optional) [Configuring ND-to-route Conversion](#)
- a [Configuring the Interface to Enable ND Conversion to Route of Fixed-length Mask](#)
 - b (Optional) [Configuring Delayed Redistribution of ND-to-route](#)
 - c (Optional) [Configuring Tag Attribute of ND-to-route Conversion](#)
 - d (Optional) [Configuring to Ignore Warning Log of ND Conversion to Route of Specified Length](#)
 - e (Optional) [Configuring ND Proxy](#)
 - f (Optional) [Configuring BGP Redistributed ND-Route Route](#)
- (5) (Optional) [Configuring BGP Route Deletion During GR](#)

1.3 Configuring Route Limitations

1.3.1 Overview

This function limits the number of equal-cost routes and number of static routes, or disables routing.

1.3.2 Configuration Tasks

The route limitation configuration tasks are as follows and optional. Select tasks for configuration according to actual condition.

- [Configuring the Maximum Number of Equal-Cost Routes](#)
- [Disabling IPv4 Routing](#)
- [Disabling IPv6 Routing](#)

1.3.3 Configuring the Maximum Number of Equal-Cost Routes

1. Overview

Run this command to configure the maximum number of next hops in the equal-cost route.

2. Restrictions and Guidelines

In load balancing mode, the number of routes on which traffic is balanced does not exceed the configured number of equal-cost routes.

3. Procedure

- (1) Enter the privileged EXEC mode.

```
enable
```

- (2) Enter the global configuration mode.

configure terminal

- (3) Configure the maximum number of equal-cost routes.

maximum-paths *number*

The maximum number of equal-cost routes are 32 by default.

1.3.4 Disabling IPv4 Routing

1. Overview

When a device functions only as a bridge or VoIP gateway, the IPv4 routing and forwarding function is not required. In this case, the IPv4 routing function of the device can be disabled.

2. Procedure

- (1) Enter the privileged EXEC mode.

enable

- (2) Enter the global configuration mode.

configure terminal

- (3) Disable IPv4 routing.

no ip routing

The IPv4 routing function is enabled by default.

1.3.5 Disabling IPv6 Routing

1. Overview

When a device functions only as a bridge or VoIP gateway, the IPv6 routing and forwarding function is not required. In this case, the IPv6 routing function of the device can be disabled.

2. Procedure

- (1) Enter the privileged EXEC mode.

enable

- (2) Enter the global configuration mode.

configure terminal

- (3) Disable IPv6 routing.

no ipv6 unicast-routing

The IPv6 routing function is enabled by default.

1.4 Configuring Fast Convergence of Recursive Routing

1.4.1 Overview

When link discovery changes or is interrupted, the recursive routing query of dynamic route may converge 2 seconds later. The convergence time is unacceptable in some scenarios with high reliability requirements. When the fast convergence function of recursive routing is enabled, the intermediate next hop information will

be added to the route sending information. Even if the intermediate link fails, it can be sensed by routing management to shorten the convergence time.

1.4.2 Configuration Tasks

The recursive routing configuration tasks are as follows and optional. Select tasks for configuration according to actual condition.

- [Enabling IPv4 Recursive Routing Fast Convergence](#)
- [Enabling IPv6 Recursive Routing Fast Convergence](#)

1.4.3 Enabling IPv4 Recursive Routing Fast Convergence

1. Overview

Enabling IPv4 recursive routing fast convergence can shorten the convergence time of IPv4 network intermediate link failure to a value less than 1 second.

2. Procedure

- (1) Enter the privileged EXEC mode.

enable

- (2) Enter the global configuration mode.

configure terminal

- (3) Enable IPv4 recursive routing fast convergence.

ip recur-route fastswitch-nextthop

The fast convergence function of recursive routing is disabled by default.

- (4) Forbid recursion to the default route.

ip recur-route over default-route disable

Recursion to the default route is allowed by default.

1.4.4 Enabling IPv6 Recursive Routing Fast Convergence

1. Overview

Enabling IPv6 recursive routing fast convergence can shorten the convergence time of IPv6 network intermediate link failure to a value less than 1 second.

2. Procedure

- (1) Enter the privileged EXEC mode.

enable

- (2) Enter the global configuration mode.

configure terminal

- (3) Enable IPv6 recursive routing fast convergence.

ipv6 recur-route fastswitch-nextthop

1.5 Configuring ARP-to-host Conversion

1.5.1 Overview

If other routing protocols are needed to distribute the direct route or instruct forwarding routes, the information in ARP table can be converted into host routes, and then redistributed by other routing protocols.

1.5.2 Restrictions and Guidelines

- The interface must be a Layer-3 interface in Up status.

1.5.3 Configuration Tasks

ARP-to-host conversion configuration includes the following tasks:

- (1) [Configuring the Interface to Enable ARP-to-host Conversion](#)
- (2) (Optional) [Enabling Proxy ARP](#)
- (3) (Optional) [Configuring BGP Redistributed ARP-host Route](#)

1.5.4 Configuring the Interface to Enable ARP-to-host Conversion

1. Overview

This function can be used to convert ARP entries into 32-bit host routes on a specified interface.

2. Procedure

- (1) Enter the privileged EXEC mode.
enable
- (2) Enter the global configuration mode.
configure terminal
- (3) Enable ARP-to-host conversion on a specified interface.
ip route arp-to-host interface *interface-type interface-number*

The ARP-to-host conversion function is disabled on an interface by default.

1.5.5 Enabling Proxy ARP

1. Overview

After receiving an ARP request, the device uses a proxy to send an ARP response with its own Ethernet MAC address. In this case, hosts communicate with each other through Layer-3 routes.

2. Procedure

- (1) Enter the privileged EXEC mode.
enable
- (2) Enter the global configuration mode.
configure terminal
- (3) Enter the VLAN interface mode.
interface VLAN *vlan-id*

- (4) Enable the proxy ARP.

local-proxy-arp

The local proxy ARP function is disabled by default on the SVI interface.

1.5.6 Configuring BGP Redistributed ARP-host Route

1. Overview

BGP redistributes the host routes converted from the ARP table.

2. Procedure

- (1) Enter the privileged EXEC mode.

enable

- (2) Enter the global configuration mode.

configure terminal

- (3) Enter the BGP configuration mode.

router bgp *as-number*

- (4) Configure BGP redistributed ARP-host route.

redistribute arp-host

ARP-host routes are not redistributed by default.

1.6 Configuring ND-to-route Conversion

1.6.1 Overview

Similar to ARP-to-host conversion, the device can generate direct route information using neighbor discovery (ND) table entries. Other routing protocols can distribute routes according to the generated direct route information, and can specify the mask length of ND-to-route conversion.

1.6.2 Restrictions and Guidelines

- The interface must be a Layer-3 interface in Up status.

1.6.3 Configuration Tasks

ND-to-route conversion configuration includes the following tasks:

- (1) [Configuring the Interface to Enable ND Conversion to Route of Fixed-length Mask](#)
 - (2) (Optional) [Configuring Delayed Redistribution of ND-to-route](#)
 - (3) (Optional) [Configuring Tag Attribute of ND-to-route Conversion](#)
 - (4) (Optional) [Configuring to Ignore Warning Log of ND Conversion to Route of Specified Length](#)
 - (5) (Optional) [Configuring ND Proxy](#)
 - (6) (Optional) [Configuring BGP Redistributed ND-Route Route](#)
-

1.6.4 Configuring the Interface to Enable ND Conversion to Route of Fixed-length Mask

1. Overview

After receiving an ARP request, the device uses a proxy to send an ARP response with its own Ethernet MAC address. In this case, hosts communicate with each other through Layer-3 routes.

2. Restrictions and Guidelines

- If neither the IPv6 network segment nor the IPv6 prefix is specified, the ND learned on the interface generates a 128-bit route by default.

If no IPv6 network segment is specified and only IPv6 prefix is specified, all NDs on the interface generate the specified IPv6 prefix.

If the IPv6 network segment is specified but no IPv6 prefix is specified, this network segment generates a 128-bit route by default.

If both the network segment and IPv6 prefix are specified, when ND is learned, the prefix will be checked to find out the network segment it matches, and the configured IPv6 prefix is generated after the specified network segment matched is found.

If both the network segment and IPv6 prefix are specified and the IPv6 prefix of an unspecified network segment is configured at the same time, a route will be generated according to the IPv6 prefix of the network segment if the network segment is matched, and a route will be generated according to the IPv6 prefix without network segment if the network segment is not matched.

- If you configure the IPv6 address of an interface before configuring the IPv6 prefix for the network segment of this interface address to generate a route with fixed-length mask, a configuration error occurs when the prefix-len is shorter than or equal to the mask of the IPv6 address. In addition, the IPv6 prefix command for the network segment of this interface address fails. For example, if you first configure IPv6 address 10::1/64 on the interface of VLAN 40, and then configure **ipv6 route nd-to-route interface vlan 40 ipv6-prefix 10::1/58 prefix-len 60** in global configuration mode, the configuration fails.
- If you configure the IPv6 address of an interface before configuring the IPv6 prefix of an unspecified network segment, a configuration error occurs when the IPv6 prefix length is shorter than or equal to the mask length of any of the IPv6 addresses on the interface. In addition, the IPv6 prefix configuration command for the unspecified network segment fails. For example, if you first configure IPv6 address 10::1/64 on the interface of VLAN 40, and then configure **ipv6 route nd-to-route interface vlan 40 prefix-len 60** in global configuration mode, the configuration fails.
- If you configure the IPv6 prefix of an unspecified network segment before configuring the IPv6 address of this interface, syslog is displayed and the IPv6 prefix configuration of the unspecified network segment is canceled when the mask length of one of the IPv6 addresses is longer than or equal to the IPv6 prefix of the unspecified network segment. For example, if you first configure **ipv6 route nd-to-route interface vlan 40 prefix-len 60** in global configuration mode, and then configure address 10::1/64 on the interface of VLAN 40, syslog alarm is displayed and the configuration **ipv6 route nd-to-route interface vlan 40 prefix-len 60** is deleted.
- If you configure the IPv6 prefix of the specified network segment and then configure the IPv6 address of the corresponding network segment of the interface, syslog is displayed and the IPv6 prefix configuration of the specified network segment is canceled when the IPv6 address mask of the corresponding network segment is longer than or equal to the IPv6 prefix of the specified network segment. For example, if you first configure

ipv6 route nd-to-route interface vlan 40 ipv6-prefix 10::1/58 prefix-len 60 in global configuration mode, and then configure the address 10::1/64 on the interface of VLAN 40, the syslog alarm is displayed and the configuration **ipv6 route nd-to-route interface vlan 40 ipv6-prefix 10::1/58 prefix-len 60** is deleted.

- If you configure the IPv6 prefix of an unspecified network segment and the IPv6 prefix of the specified network segment, and then configure the IPv6 address of the interface, please check whether the mask of each IPv6 address is longer than or equal to the IPv6 prefix of the specified/unspecified network segment. If so, syslog is displayed and the IPv6 prefix configuration of the corresponding network segment is canceled. For example, if you first configure **ipv6 route nd-to-route interface vlan 40 prefix-len 62** and **ipv6 route nd-to-route interface vlan 40 ipv6-prefix 10::1/58 prefix-len 60** in global configuration mode, and then configure address 10::1/64 on the interface of VLAN 40, the syslog alarm is displayed and the two configuration commands are removed.

3. Procedure

- (1) Enter the privileged EXEC mode.

enable

- (2) Enter the global configuration mode.

configure terminal

- (3) Enable ND conversion to a route with fixed-length mask on the specified interface.

```
ipv6 route nd-to-route interface interface-type interface-number [ ipv6-prefix X:X:X:X:<0-128> ] [ prefix-len masklen ]
```

The ND-to-route conversion function is disabled on a specified interface by default.

1.6.5 Configuring Delayed Redistribution of ND-to-route

1. Overview

To prevent route jitter caused by change to an ND entry, you can delay conversion of the ND entry into a route.

2. Procedure

- (1) Enter the privileged EXEC mode.

enable

- (2) Enter the global configuration mode.

configure terminal

- (3) Configure delayed redistribution of ND-to-route.

```
ipv6 route nd-to-route delay-time delay-time
```

The delayed redistribution function of the routes converted by ND is disabled by default. The delayed redistribution time is 0 seconds.

1.6.6 Configuring Tag Attribute of ND-to-route Conversion

1. Overview

This function sets the tag value of ND-to-route conversion to facilitate subsequent route control and management.

2. Procedure

- (1) Enter the privileged EXEC mode.
enable
- (2) Enter the global configuration mode.
configure terminal
- (3) Configure the tag attribute of ND-to-route conversion.
ipv6 route nd-to-route tag *tag-number*

The tag attribute function of the ND-converted route is disabled by default.

1.6.7 Configuring to Ignore Warning Log of ND Conversion to Route of Specified Length

1. Overview

After you configure to ignore the warning log of ND conversion to route of specified length, the alarm that the same port ND generates the same network segment route is ignored. If this command is not configured, the warning log that the same port ND generates the same network segment route is printed (only once). The alarm that different ports generate the same network segment route is not controlled by this function.

2. Procedure

- (1) Enter the privileged EXEC mode.
enable
- (2) Enter the global configuration mode.
configure terminal
- (3) Configure to ignore the warning log of ND conversion to a route of specified length.
ipv6 route nd-to-route warning-ignore

The function of ignoring warning log of ND conversion to a route of specified length is disabled by default.

1.6.8 Configuring ND Proxy

1. Overview

When the device receives an ND request, it will send an ND response. The MAC address of the response is the local Ethernet MAC address, so that the interconnection among different hosts is implemented by Layer 3 routing.

2. Procedure

- (1) Enter the privileged EXEC mode.
enable
 - (2) Enter the global configuration mode.
configure terminal
 - (3) Enter the SVI interface mode.
interface vlan *vlan-id*
-

- (4) Configure the IPv6 address of the SVI interface.

```
ipv6 address ipv6-address/prefix-length
```

- (5) Enable the ND proxy.

```
local-proxy-nd enable
```

The local ND proxy is disabled by default on the interface.

1.6.9 Configuring BGP Redistributed ND-Route Route

1. Overview

In BGP protocol mode, this command is used to redistribute ND-route to BGP.

2. Procedure

- (1) Enter the privileged EXEC mode.

```
enable
```

- (2) Enter the global configuration mode.

```
configure terminal
```

- (3) Enter BGP mode.

```
router bgp as-number
```

- (4) Enter BGP IPv6 address family configuration mode.

```
address-family ipv6
```

- (5) Configure BGP redistributed ND-Route route.

```
redistribute nd-route [ route-map map-tag ] [ metric metric-value ]
```

By default, BGP does not redistribute ND-Route route.

1.7 Configuring BGP Route Deletion During GR

1.7.1 Overview

When a graceful restart (GR)-enabled router is restarted on the control plane, data forwarding can continue on the forwarding plane. In addition, actions (such as neighbor relationship re-forming and route computation) performed on the control plane do not affect functions of the forwarding plane. If the function is enabled, the BGP route deletion configuration takes effect immediately during GR to prevent routing black hole.

1.7.2 Procedure

- (1) Enter the privileged EXEC mode.

```
enable
```

- (2) Enter the global configuration mode.

```
configure terminal
```

- (3) Configure direct deletion of the BGP route during GR.

```
ip route notify delete always
```

Deletion of the BGP route is disabled by default.

1.8 Monitoring

Run the **show** commands to check the running status of a configured function and verify the configuration effect.

Run the **debug** command to display the output debugging information.

⚠ Caution

The output debugging information occupies system resources. Therefore, disable the debugging function immediately after use.

Run the **clear** command to clear the routing table cache.

Table 1-1 Monitoring

Command	Purpose
clear ip route [<i>vrf vrf-name</i>] { * <i>network [mask]</i> }	Clears the routing table cache.
show ip route [[<i>vrf vrf-name</i>] [arphost aggregate count] [ecmp fast-reroute normal] [<i>network [mask]</i>] <i>network [mask [longer-prefix]</i>] <i>route-protocol [process-id]</i> weight tag]	Displays the IPv4 routing table.
show ipv6 route [[<i>vrf vrf-name</i>] [[fast-reroute] <i>ipv6-prefix / prefix-length [longer-prefixes]</i>] <i>route-protocol [process-id]</i> weight]]	Displays the IPv6 routing table.
show ip route [<i>vrf vrf-name</i>] recursive <i>ipv4-network/mask-length</i>	Displays the recursive information of an IP route.
show ip route [<i>vrf vrf-name</i>] static bfd	Displays the BFD correlation information of an IP route.
show ip route [<i>vrf vrf-name</i>] summary	Displays the statistics of a single routing table.
show ip route [<i>vrf vrf-name</i>] track-table	Displays the track information of IPv4 route correlation.
show ipv6 route [<i>vrf vrf-name</i>] static bfd	Displays the BFD correlation information of an IPv6 route.
show ipv6 route [<i>vrf vrf-name</i>] summary	Displays the statistics of all the IPv6 routing tables.
show route-res usage [all slot slot-id]	Displays the usage of routing resources.
debug nsm kernel ucast-v4	Debugs IPv4 route management.
debug nsm kernel ucast-v6	Debugs IPv6 route management.
debug nsm kernel frr	Debugs fast reroute management.
debug nsm kernel default-network	Debugs default network management.

Command	Purpose
debug nsm events	Debugs internal events of route management.
debug nsm packet send	Debugs sending of route management and routing protocol messages.
debug nsm packet recv	Debugs receiving of route management and routing protocol messages.