Route Basics

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Foreword

- Ethernet switches work on the data-link layer for data forwarding within a network segment. However, The topology of the enterprise network will be more complex, different departments, or the headquarters and branches may be in different networks. In this situation, a router is needed to connect different networks and forward packets between them.
- This chapter focuses on routing protocol basics, routing classification and configuration.

Objectives

- Upon completion of this section, trainees will be able to:
  - Understand the basic knowledge of routing protocols;
  - Understand the classification of routing;
  - Master static-route and configuration;
  - Master the principle of VLAN routing.

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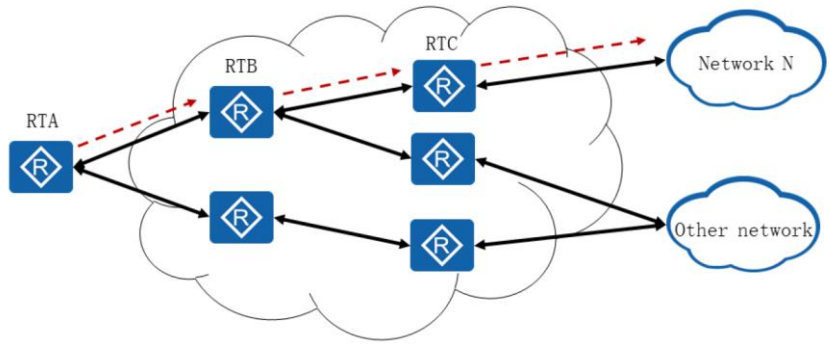
What is Routing?

- Routing is path information which can guide IP packet forwarding.



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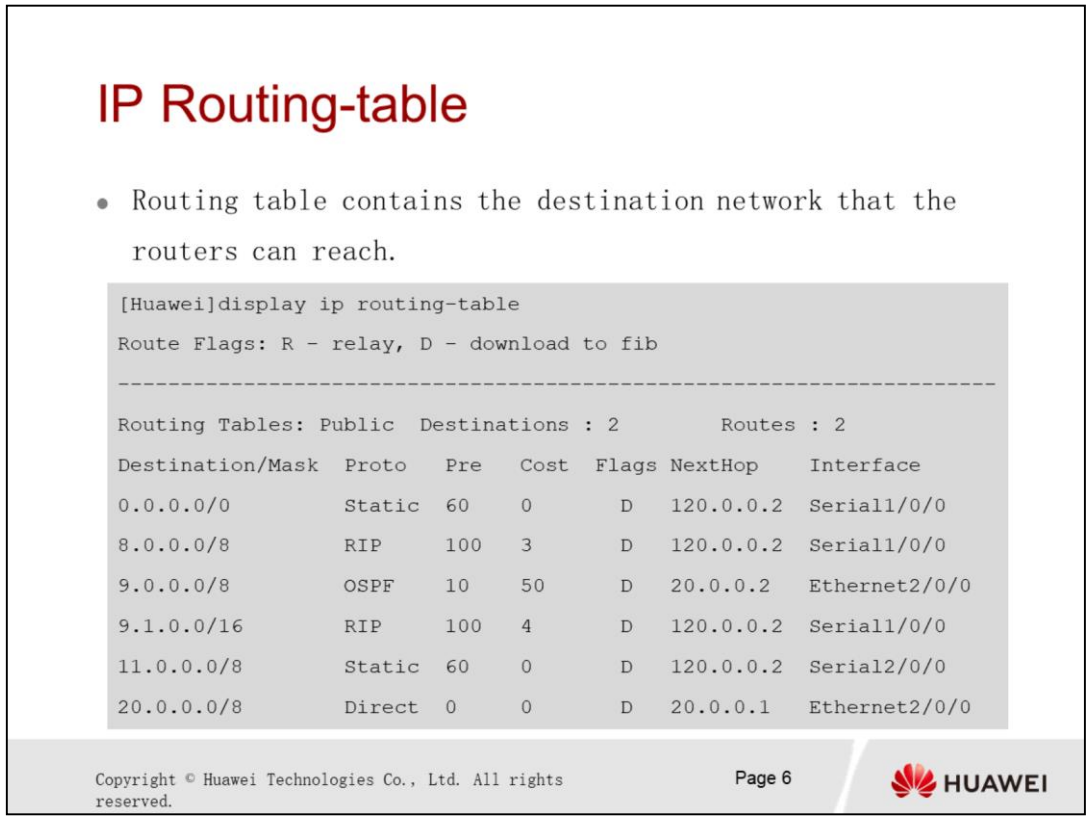
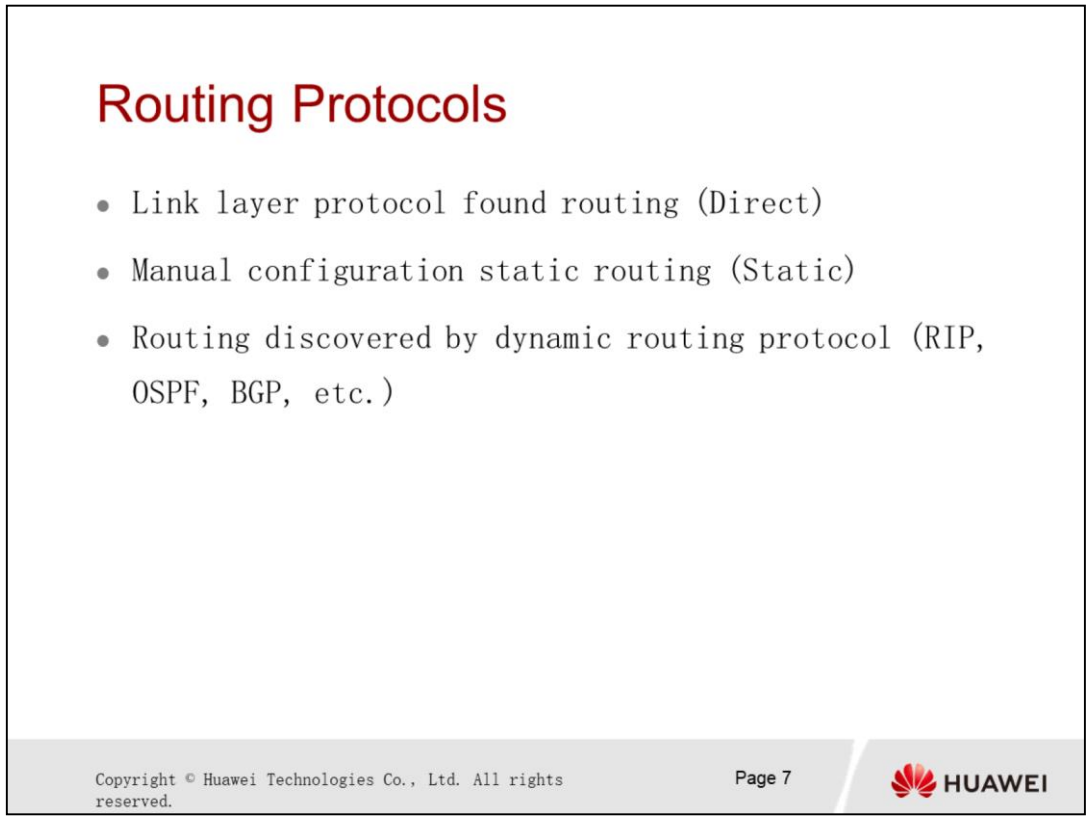
- Routers provide a mechanism for interconnecting heterogeneous networks to transmit packets from one network to another. The router selects an appropriate path (a network include one or more routers) based on the destination address of the packet header, and then sends the packet to the next router, finally the packet will be sent to the destination host.
- Routing is the path from the source to the destination of a packet. When there's multi-routes available, routers will forward packet according to the best route in the routing table.
- Depending on the destination of the routing, it can be divided into:
  - Subnet Routing: destination is a subnet
  - Host Routing: destination is a host
- According to whether the destination is directly connected to the router, it can be divided into:
  - Direct routing: the destination network is directly connected to the router.
  - Indirect Routing: the destination network is not directly connected to the router.



- The key of a router to forward packets is the routing table. Each router has a routing table ,and the route entries inside it will indicate which physical port should be used to send a packet to the network or the host, or which next router that can reach the path. Packets with a destination that do not exist in the routing table will be discarded.
- The following key items are included in the routing table:
  - Destination: identify the destination address or destination network of IP packet.
  - Mask: together with the destination address, it identifies the address of a network segment where the destination host or router is located. The corresponding network segment information can be obtained after doing “AND” operation to the destination address and the network mask. The mask is composed of a number of continuous ″1″, which can be expressed in dot decimal notation or in the continuous number of ″1″ in the mask.
  - Interface: Indicate which interface will be used to forward the IP packet out of the router.
  - Next-Hop: Specify the interface address of the next router that the IP packet will go through..
  - We will introduce some other fields inside the routing table, such as

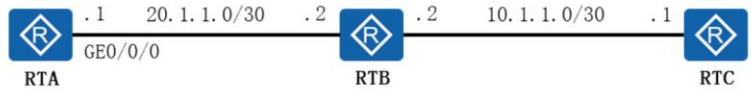
priority, metric and so on later.



- There is a Protocol field in the routing table, which indicates the source of the routing, that is, how the route is generated. There are 3 main sources of routing:
- Link layer protocol found routing (Direct)
  - Small cost, simple configuration, no manual maintenance.
  - The routing belonging to local interfaces can only be found.
- Manual configuration static routing (Static)
  - No cost, simple configuration, manual maintenance.
  - Only for simple network topologies.
- Routing discovered by dynamic routing protocol(RIP, OSPF, BGP, etc.)
  - High cost, complex configuration, no manual maintenance.
  - Can be applied to complex network topologies.

Longest Match Principle

- If multiple routing entries match the destination network, the router will choose the longest mask.




```
[RTA]display ip routing-table
Destination/Mask Proto   Pre  Cost Flags NextHop    Interface
10.1.1.0/24      Static  60   0    RD    20.1.1.2 GigabitEthernet 0/0/0
10.1.1.0/30      Static  60   0    RD    20.1.1.2 GigabitEthernet 0/0/0
```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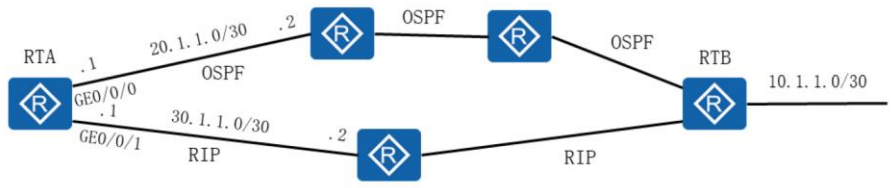
- When forwarding data, routers need to select the optimal route in the routing table. When a data packet arrives at the router, the router extracts the destination IP address of the packet, then looks up the routing table, and performs "AND" operation of the packet's destination IP address with the mask field of a table item in the routing table. The "AND" operation result will be compared with the Destination field of the routing table to see if it matches or not. After going through all routing entries, the router will choose one with the longest mask.
- In the example, two entries to the network 10.1.1.0 exist with a next-hop of 20.1.1.2. Forwarding to the destination of 10.1.1.1 will result in the longest match principle being applied, for which the network address 10.1.1.0/30 provides the longest match.

Routing Preference




```
[RTA]display ip routing-table
Destination/Mask Proto Pre Cost Flags  NextHop    Interface
10.1.1.0/30      OSPF  10  3     RD    20.1.1.2   GigabitEthernet 0/0/0
......
```

protocol type	Direct	OSPF	IS-IS	Static	RIP
preference	0	10	15	60	100

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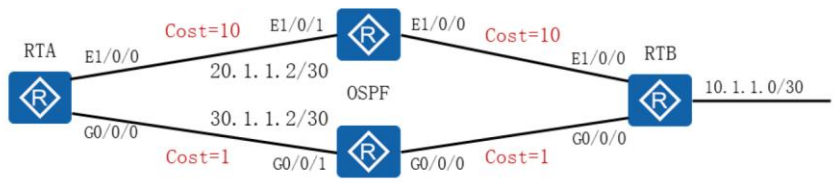
- A routing table may contain the routes originating from multiple protocols to a given destination. Not all routing protocols are considered equal, and where the longest match for multiple routes of differing routing protocols to the same destination are equal, a decision must be made regarding which routing protocol (including static routes) will take precedence.
- Different manufacturers have different requirements for priority of various routing protocols. The default priority of HUAWEI Quidway router is shown in the table:
  - The smaller the value, the higher the preference.
  - In addition to direct routing, the preference of all dynamic routing protocols can be manually configured according to user needs. In addition, the priority of each static route can be different.

Routing Metric

- The metrics of the route indicate the cost of reaching the destination address.
  - Commonly used metrics are: hop count, bandwidth, delay, cost, load, reliability, etc.

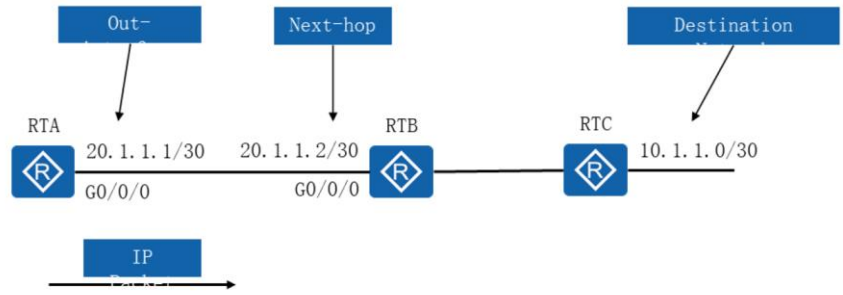



```
[RTA]display ip routing-table
Destination/Mask Proto Pre Cost Flags NextHop    Interface
10.1.1.0/30      OSPF  10  2    RD    30.1.1.2 GigabitEthernet0/0/0
```


- Where the route is unable to be distinguished by either a longest match value or preference, the cost metric is taken as the decision maker in identifying the route that should be installed in the routing table.
- Metric represents the length of a path to a destination network. Usually, the following factors will affect the routing metric.
  - Line delay, bandwidth, load, communication overhead, line reliability, hop count and maximum transmission unit.
  - Hop count refers to the number of routers that arrive at the destination.
  - Bandwidth refers to the capacity of the link, and the high speed link with low cost.
  - The smaller the Metric value, the more priority the routing is.
- Different dynamic routing protocols choose one or more of these factors to calculate the metric. The metric is only meaningful in the same routing protocol, and the routing metric between different routing protocols is not comparable and there is no conversion relationship.
- The OSPF protocol calculate the cost based on bandwidth, so the route with the Metric=1+1=2 is the optimal route to the destination, and its table item can be found in the routing table.

Next-Hop and Interface

- When a router finds a matching routing table item, it needs to know the next-hop and out-interface to forward the data.



- After receiving a packet, the router will check its destination IP address and then check the routing table. After finding out the matching routing item, the router will forward the packet according to the interface and the next-hop information indicated by the table item.

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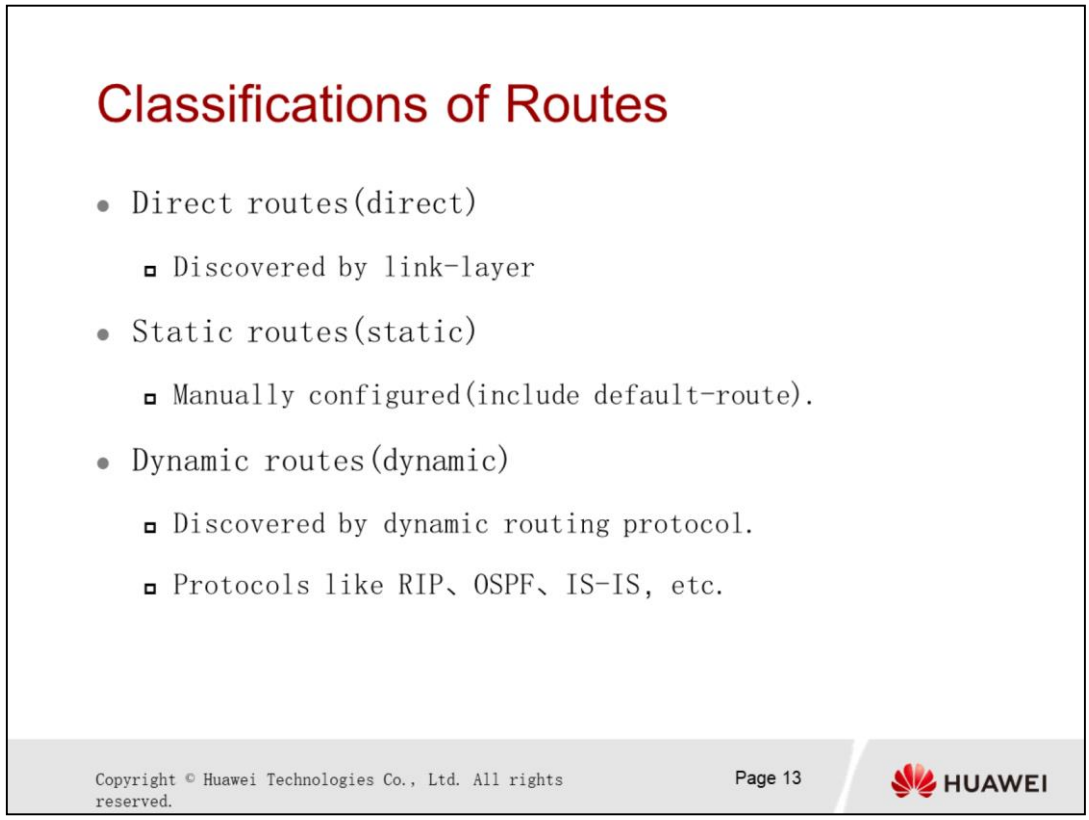
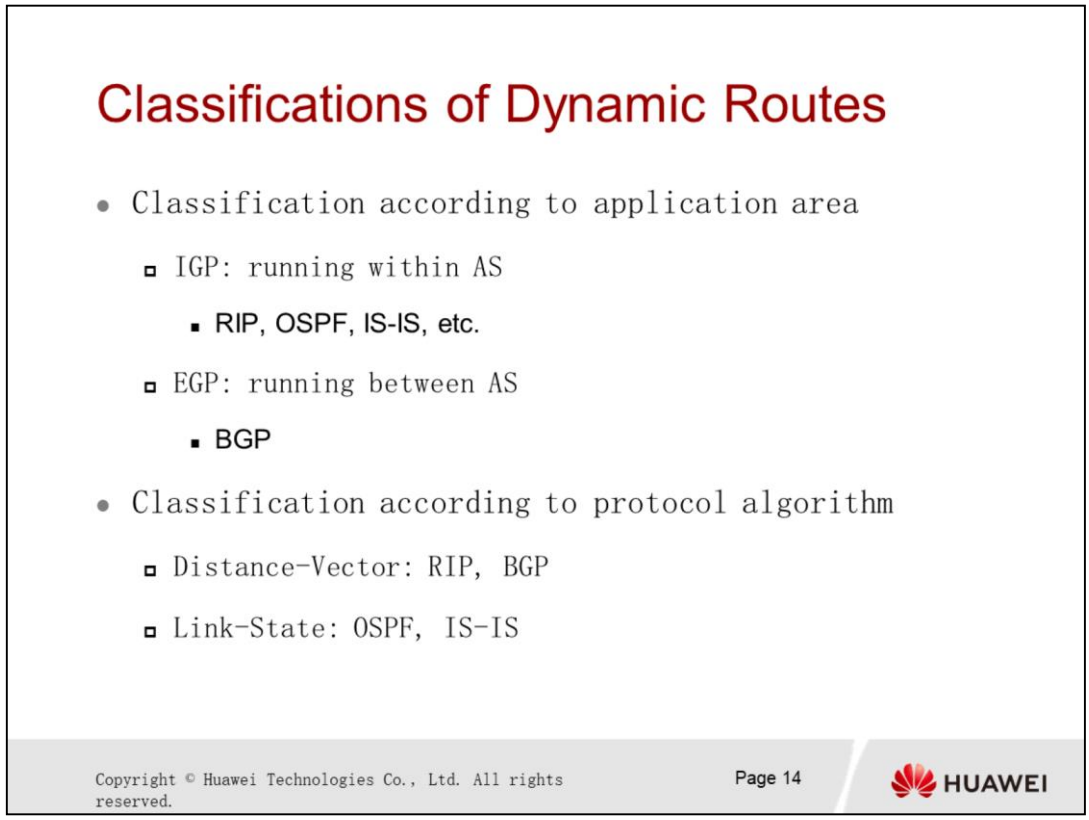


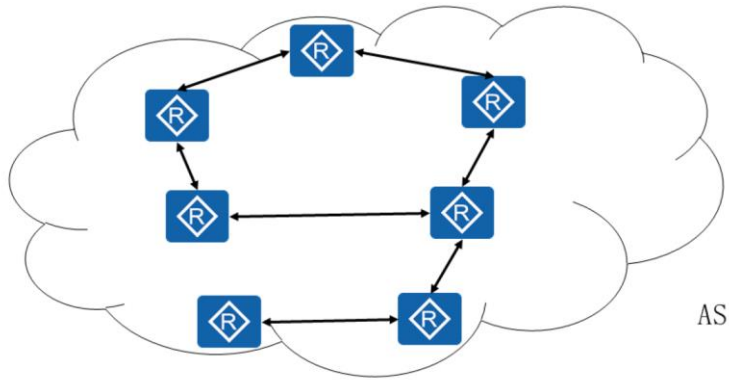
- There are many ways to classify routes. There are three sources of routing, Therefore, if classify routes according to the source, it can be divided into:
  - Direct routes: Small cost, simple configuration, routes belong to local interfaces can only be found.
  - Static routes: No cost, simple configuration, manual maintenance. When topology changes, static routes won't change. Only for simple network topologies.
  - Dynamic routes: High cost, complex configuration, no manual maintenance. Can be applied to complex network topologies. When topology changes, dynamic routes can change.



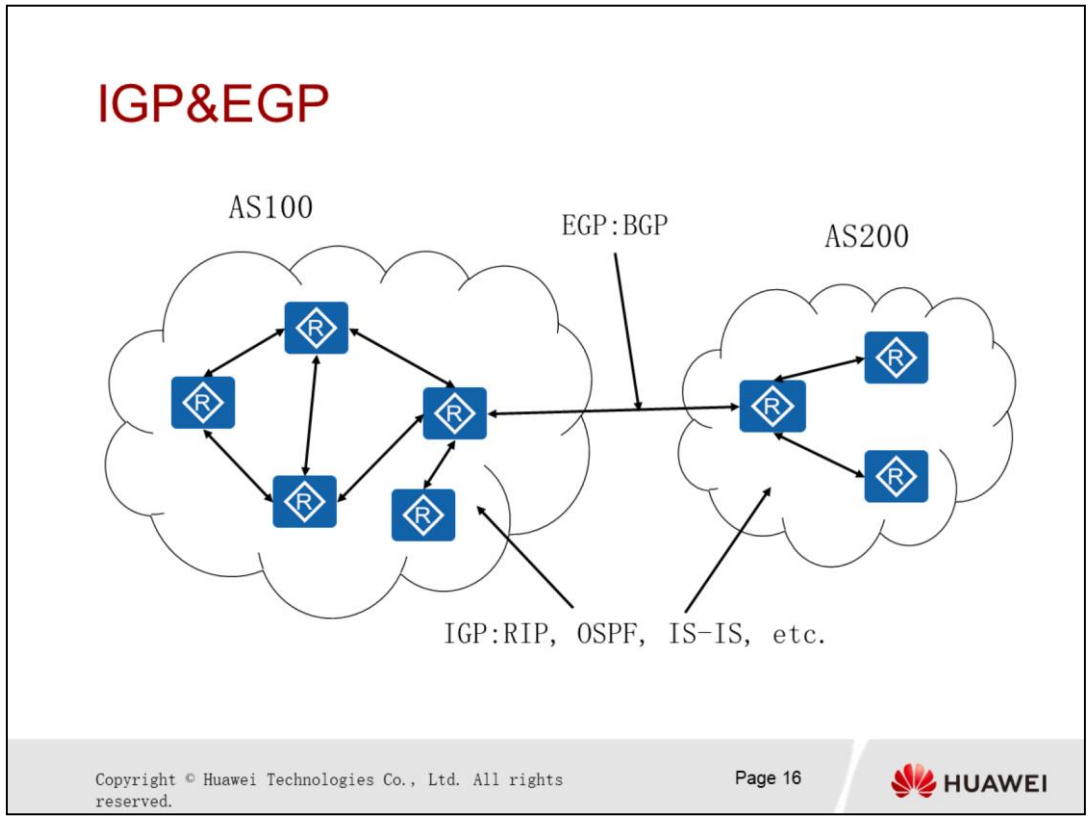
- According to the application area, routing protocols can be divided into:
  - IGP(Interior Gateway Protocol): The routing protocol used to exchange routing information inside AS is called the IGP. Common protocols such as RIP, OSPF and ISIS belong to IGP protocol.
  - EGP(Exterior Gateway Protocol): The routing protocol used to exchange routing information between AS is called the EGP. BGP belongs to the EGP.
- According to the algorithm used, the routing protocol can be divided into:
  - Distance-Vector protocol: include RIP and BGP. BGP is also called Path-Vector protocol.
  - Link-State protocol: include OSPF and IS-IS.
  - The main difference between these two algorithms is the method of discovering routes and calculating routes: distance vector protocols pay attention to the number of hops to the destination (the number of forwarding), link state protocol concerns the topology of the network, and the link resources like bandwidth.
- What is the meaning of the autonomous system(AS) mentioned here?

Autonomous Systems (AS)

- An IP network, or networks, controlled by one or more operators with a clear policy that governs how routing decisions are made.



- An AS is a set of routers that share similar routing policies and run in a single management domain. An AS can be a set of routers that run a single IGP (internal Gateway Protocol) protocol, or a set of routers that run different routing protocols but belong to the same organization. In either cases, the outside world regards the whole Autonomous System as an entity.
- Each Autonomous System has a unique AS number, which is assigned by the Internet authorized authority IANA. Its basic idea is to distinguish different AS by different numbers. In this way, when the network administrator does not want his communication data to pass through an AS, this numbering method is very useful. For example, the network administrator's network can be fully accessible to an AS, but it may be managed by a competitor or lack sufficient security mechanism, it should be avoided. By using routing protocols and AS numbers, routers can determine the path and routing information exchange methods.
- The numbering range of AS is 1 to 65535, of which 1 to 65411 are registered Internet numbers, and 65412 to 65535 are dedicated network numbers.



- According to the working area, routing protocols can be divided into IGP and EGP:
  - IGP(Interior Gateway Protocols): the main purpose of IGP is to discover and calculate routing information within an AS.
  - EGP(Exterior Gateway Protocols): mainly use routing policy and routing filtering to control routing information exchange between AS.

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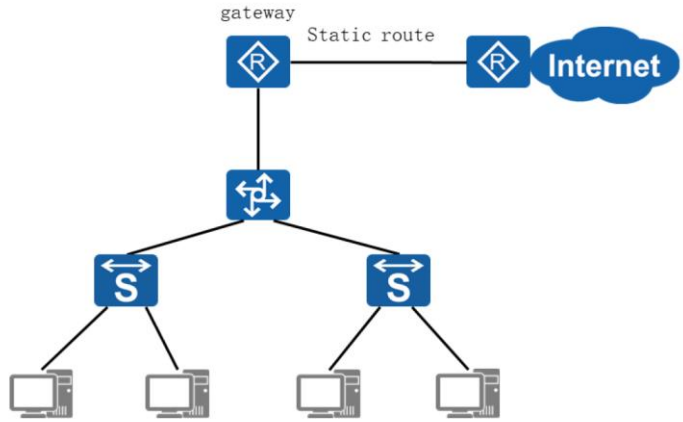
Application for Static Route

- A static route is a special route that is manually configured and managed by a network administrator.



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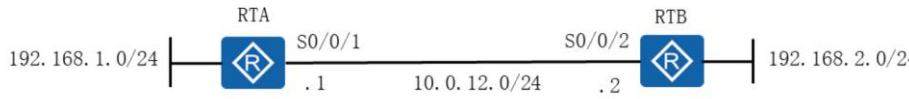
- A static route is a special route that is manually configured by a network administrator.
- The disadvantage of static routes is that they cannot adapt to the change in a network automatically, so network changes require manual reconfiguration.
- Static routes are fit for networks with comparatively simple structures. It is not advisable to configure and maintain static routes for a network with a complex structure. Static routes do however reduce the effect of bandwidth and CPU resource consumption that occurs when other protocols are implemented.

Configuring a Static Route (1)

- On the serial interface, static routing can be configured by specifying the next-hop address or out-interface.

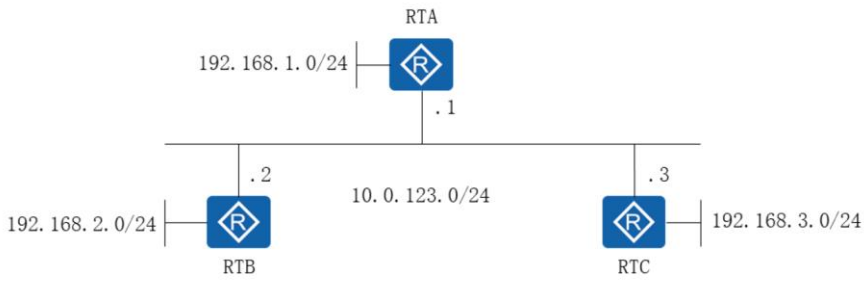



```
[RTB]ip route-static 192.168.1.0 255.255.255.0 10.0.12.1
[RTB]ip route-static 192.168.1.0 255.255.255.0 Serial 0/0/2
[RTB]ip route-static 192.168.1.0 24 Serial 0/0/2
```


- Static routing can be applied to serial networks or Ethernet, but configuration is different in these two networks.
- ip route-static ip-address { mask | mask-length } interface-type interface-number [nexthop-address]. The parameter IP-address specifies a network or a host address, the parameter mask specifies a subnet mask or mask length. The last part specifies the next-hop or out-interface.
- When configuring static routing in a serial network, you can specify only the next-hop address (such as 10.0.12.1), or only use parameters interface-type and interface-number (such as Serial 0/0/2) to configure the out-interface. In HUAWEI ARG3 series routers, the serial interface encapsulates the PPP protocol by default. For this type of interface, the next-hop address of static routing is the address to the end interface connected to the interface, so it's OK to use the interface only when configuring static routing in a serial network.
- So, what about the configuration on Ethernet ?

Configuring a Static Route (2)

- When configuring static routing on a broadcast interface (such as Ethernet interface), the next-hop address must be specified.




```
[RTA]ip route-static 192.168.2.0 255.255.255.0 10.0.123.2
```


- When configuring static routing on a broadcast interface, the next-hop address must be specified explicitly. The network in Ethernet may be connected to multiple routers. If only an interface is specified when configuring static routing, the router can not forward the message to the right next-hop. In this example, RTA needs to forward the data to the 192.168.2.0/24 network, and when configuring static routing, you need to specify that the next-hop address is 10.0.123.2, otherwise RTA will not be able to forward the message to the 192.168.2.0/24 network connected by RTB, because RTA does not know wether RTB or RTC can reach the destination.

Default Static Routes

- The default route is a special route use 0 as the destination address and the mask.
- If the destination address of a packet can not match any of the routing table entries, the router will forward the message according to the default route.


```
[RTA]ip route-static 0.0.0.0 0.0.0.0 10.0.12.2
```


- When there is no table item in the routing table matching with the destination address of the packet, the device can choose the default route as the forwarding path of the packet. In the routing table, the destination network address of the default route is 0.0.0.0 and the mask is also 0.0.0.0.
- In this example, RTA uses a default route to forward packet to an unknown destination address. The default priority of the default static routing is also 60. In the routing process, the default route will be finally matched.

Default Static Route Check

- After configuration, use command to view the detail.

```
[RTA]display  ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 5        Routes : 5
Destination/Mask Proto Pre Cost Flags NextHop    Interface
 0.0.0.0/0       Static  60  0    RD   10.0.12.2  GigabitEthernet 0/0/1
 10.0.12.0/24    Direct  0   0     D   10.0.12.1  GigabitEthernet 0/0/1
 10.0.12.1/32    Direct  0   0     D   127.0.0.1  GigabitEthernet 0/0/1
 127.0.0.0/8     Direct  0   0     D   127.0.0.1  InLoopBack0
 127.0.0.1/32    Direct  0   0     D   127.0.0.1  InLoopBack0
```


- After configuring the default route, you can use the “display IP routing-table” command to see the details of the routes.
- In this example, all packet with the destination address that does not match the routing table will be forwarded to the next hop address 10.0.12.2 through the GigabitEthernet 0/0/1 interface.

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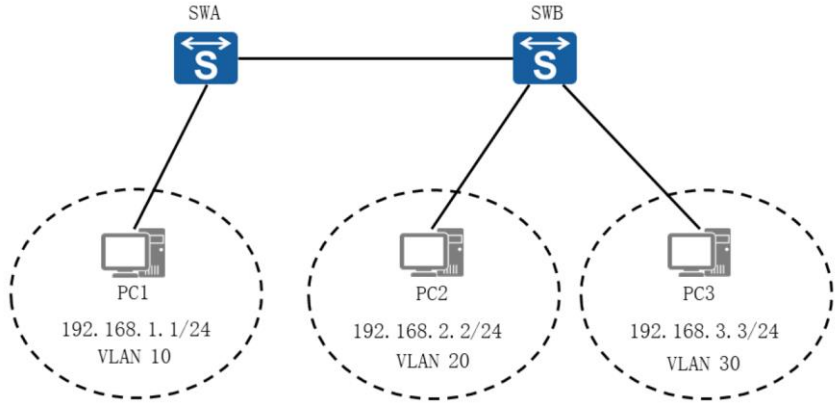
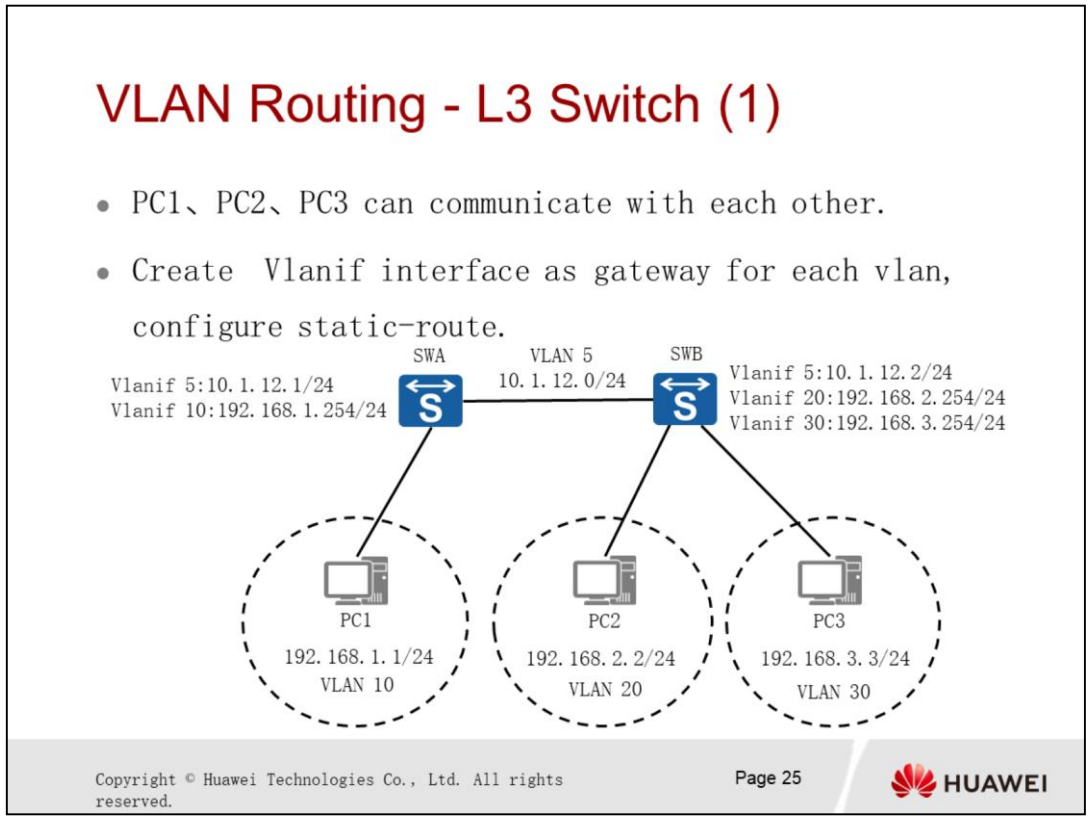
VLAN Limitations

- VLAN restricts the communication between two hosts in different VLAN while splitting the broadcast domain.



- VLAN isolated two broadcast domains, and also strictly isolated layer 2 traffic between VLAN. Users belonging to different VLAN could not manage Layer 2 communication.



- One way to solve the problem of communication between VLAN is to use layer three switch:
- The Vlanif interface is configured as a gateway on the L3 switch to achieve inter VLAN routing. If there are multiple VLAN on the network, you need to configure a Vlanif interface for each VLAN and configure an IP address for each Vlanif interface. The default gateway set by user PC is the IP address of the Vlanif interface in the L3 switch. Meanwhile, when check the IP routing table of the switch, Only the direct route can be found, so it is necessary to establish the route to the non-direct network segment, which can use the static routing.

VLAN Routing - L3 Switch (2)

- After configuring default-route on SWA, path to PC2/3 will be found by checking routing-table. so as SWB.

```
[SWA]ip route-static  0.0.0.0 0 10.1.12.2
[SWB]ip route-static  0.0.0.0 0 10.1.12.1
[SWA]display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 7        Routes : 7

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

        0.0.0.0/0   Static  60   0           RD  10.1.12.2       Vlanif5
       10.1.12.0/24 Direct  0    0           D   10.1.12.1       Vlanif5
       10.1.12.1/32 Direct  0    0           D   127.0.0.1       Vlanif5
       127.0.0.0/8  Direct  0    0           D   127.0.0.1       InLoopBack0
       127.0.0.1/32 Direct  0    0           D   127.0.0.1       InLoopBack0
     192.168.1.0/24 Direct  0    0           D   192.168.1.254   Vlanif10
   192.168.1.254/32 Direct  0    0           D   127.0.0.1       Vlanif10
```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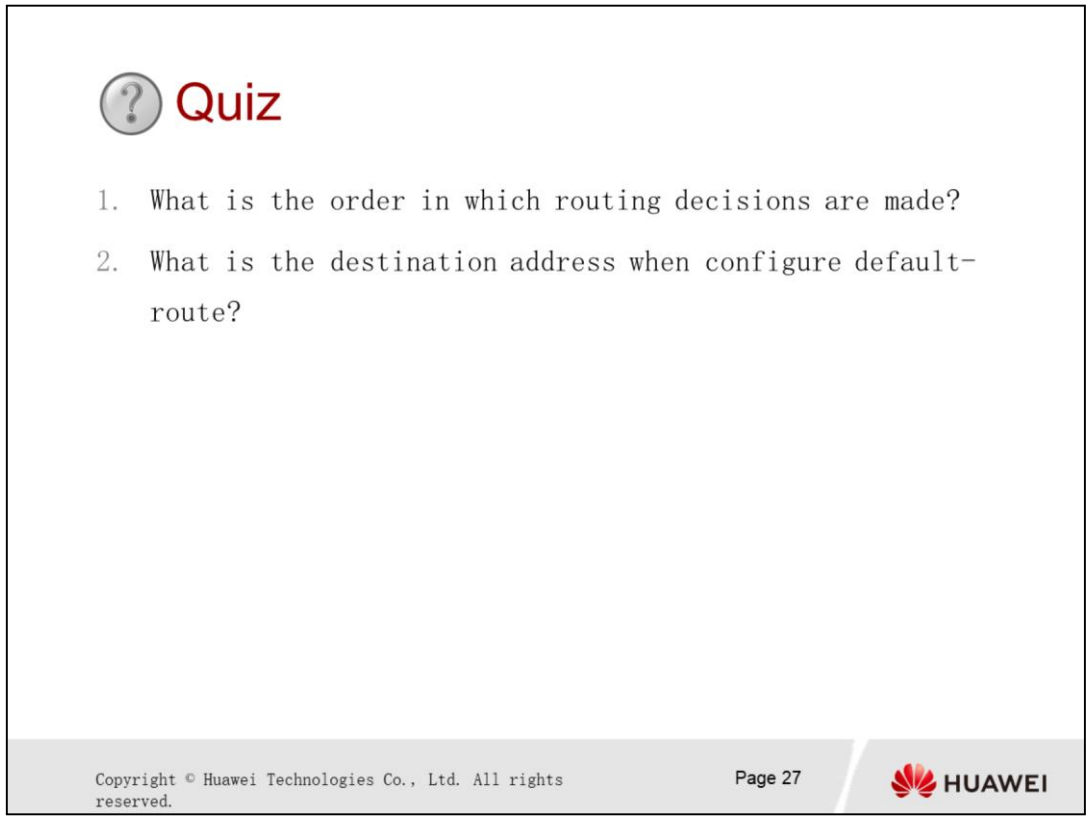
- Static routing is configured on both SWA and SWB, where default routing is used, and the next-hop address respectively points to Vlanif5:10.1.12.2 of SWB and Vlanif5:10.1.12.1 of SWA.



- Answer:
  1. When the routers choose the optimal routing, they will firstly based on the longest mask matching principle; if the length of the mask is consistent, the priority of the routing protocol is compared; if the priority is the same, then the metric value is compared. If the metric value is the same, multiple equal routes will achieve load-balancing.
  2. When configuring the default route, the destination network address is 0.0.0.0, which represents any network.

Thank You

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