IP Routing Basics

1 IP Routing Basics

1.1 Overview of IP Routing

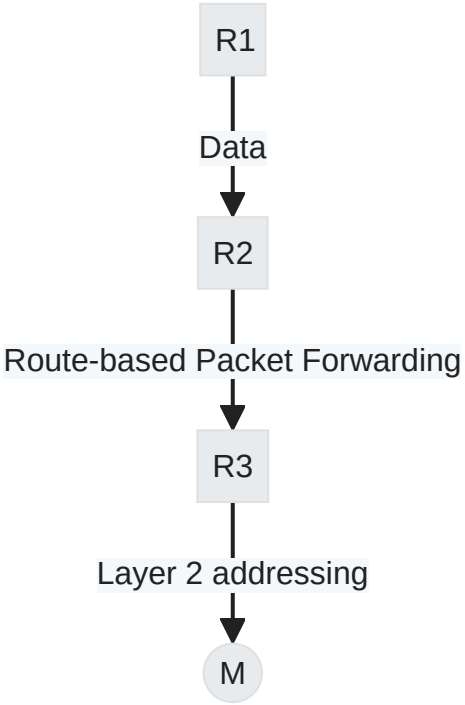
1.1.1 Basic Concepts of Routing

- **Subnet**: A segment of a network with its own unique IP address range.
- **Inter-Subnet Communication**: Necessary for different subnets to communicate.
- **Routes:** are the path information used to guide packet forwarding.
- **Routing Devices:** are crucial for directing traffic through the network based on predefined routes.

> In Huawei networking devices, physical interfaces with IP addresses also have MAC addresses for Layer 2 communication, except for logical or virtual interfaces like loopbacks or tunnels that don't handle Ethernet frames.

1.1.1.1 Routing Devices and Tables

- **Router**: determine the path for an IP packet using the destination address and forward it accordingly.
- The **last-hop router** performs Layer 2 addressing before passing the packet to its final destination.
    - translate the IP address into a format that can be understood at the local network level



1.1.1.2 Routes and Routing Information

A routing entry contains several key components:

- **Destination**: Identifies which subnet the packet is intended for.
- **Mask**: Works with the destination IP to specify the subnet.
- **Outbound Interface**: The interface from which a packet leaves the router.
- **Next Hop**: The address of the next device in line towards the packet's final destination.

> **Example of an IP routing table:**

- Routers discover routes using multiple methods.
- A router selects the optimal route and installs it in its IP routing table.
- The router forwards IP packets based on routes in the IP routing table.

Destination/Mask	Outbound Interface	Next Hop
`10.1.1.0/24`	`GE0/0/0`	`1.1.1.2`

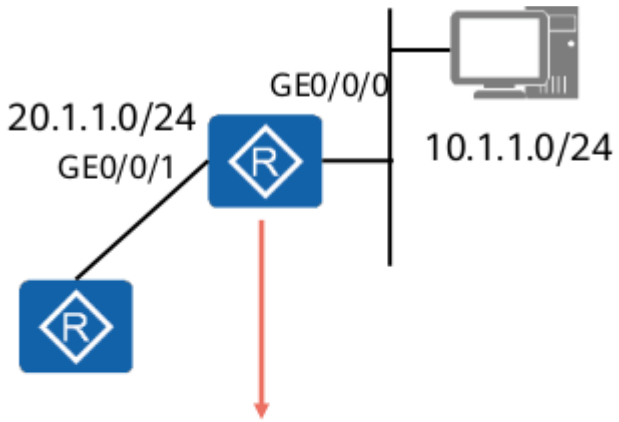
1.1.2 Generation of Routing Entries

1.1.2.1 Direct Routes

- Generated automatically for directly connected networks.

> Generated for interfaces with both physical and protocol status 'up'.

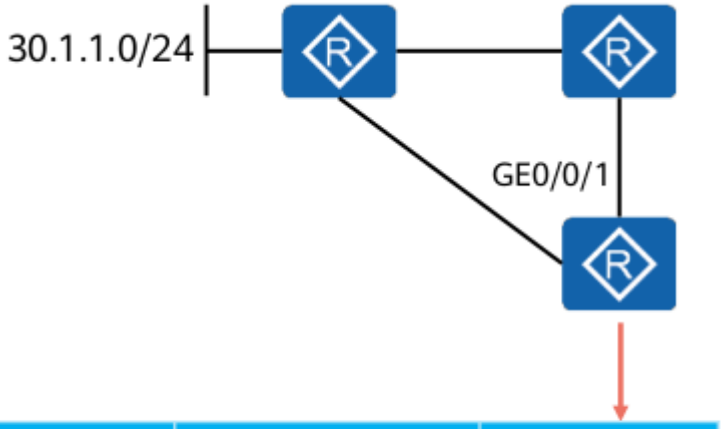
- Utilized by last-hop routers to deliver packets directly to hosts.
  - ARP entries are used to forward packets directly without a next hop since Local use **Mac**.



Protocol	Destination/Mask	Outbound Interface
Direct	10.1.1.0/24	GE0/0/0
Direct	20.1.1.0/24	GE0/0/1

1.1.2.2 Static Routes

- Manually configured by network administrators.
- Deterministic routes to specific destinations.

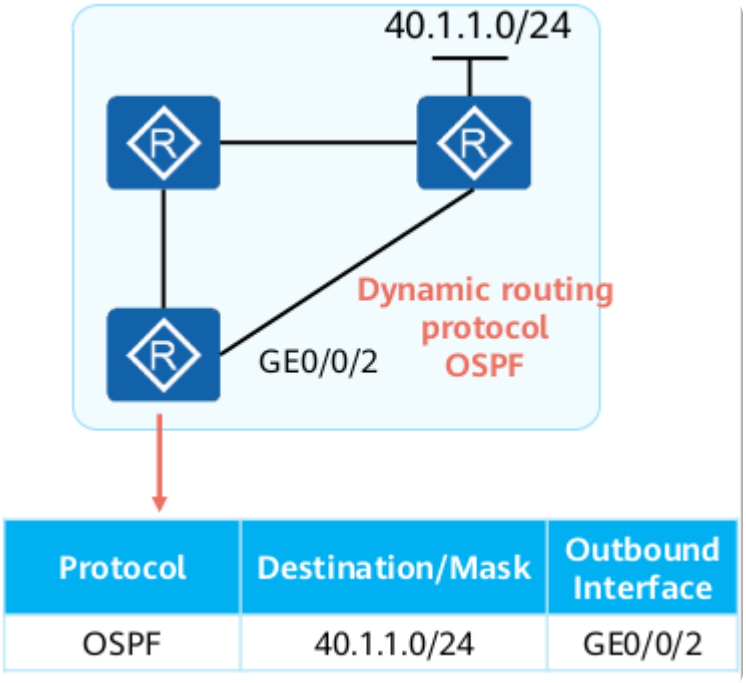


Protocol	Destination/Mask	Outbound Interface
Static	30.1.1.0/24	GE0/0/1

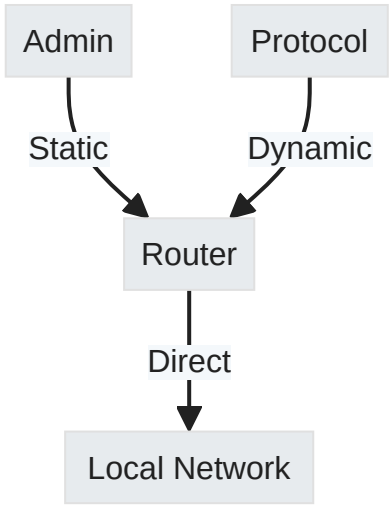
1.1.2.3 Dynamic Routes

- Learned through dynamic routing protocols such as OSPF or BGP.

> automatically adapts to network changes.



Protocol	Destination/Mask	Outbound Interface
OSPF	40.1.1.0/24	GE0/0/2



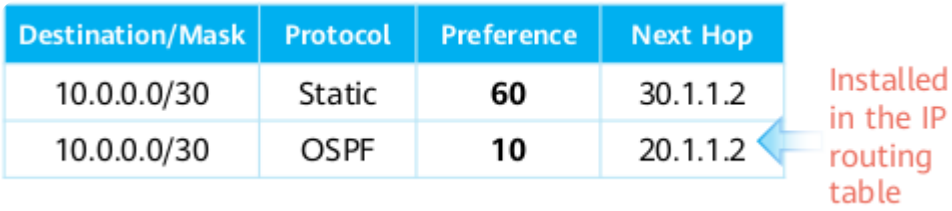
1.1.3 Optimal Route Selection

1.1.3.1 Key Terms

Destination/Mask	Protocol	Pre	Cost	Flag	NextHop	Interface
1.1.1.1/32	Static	60	0	D	0.0.0.0	NULL0
2.2.2.2/32	Static	60	0	D	100.0.0.2	Vlanif100
100.0.0.0/24	Direct	0	0	D	100.0.0.1	Vlanif100
100.0.0.1/32	Direct	0	0	D	127.0.0.1	Vlanif100

Destination/Mask	Protocol	Pre	Cost	Flag	NextHop	Interface
127.0.0.0/8	Direct	0	0	D	127.0.0.1	InLoopBack(
127 .00 .01 /32	Direct	0	0	D	127.0.0.1	InLoopBack(

- **Routing Table**: A database used by routers to determine the best path for forwarding packets.
- **Route Preference (Pre)**: Used to select routes from different protocols; lower values indicate higher priority.



- **Flag**: indicates special statuses or attributes of a particular route

Flags

- **R** - Relay
- **D** - Downloaded to Forwarding Information Base (FIB)

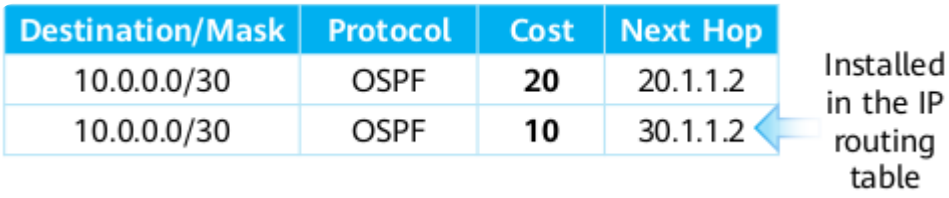
> **Forwarding Information Base (FIB):** table used by network routers and switches to determine where to forward packets; it contains the necessary information to make routing decisions for outgoing network traffic.

Forwarding Information Base (FIB) vs ip table

> The Forwarding Information Base (FIB) is primarily used in routers to make quick forwarding decisions based on pre-computed routes, whereas an IP table, often associated with firewalls or servers, holds rules for packet filtering and network address translation rather than routing.

- **Cost (Metric)**: Used when comparing routes from the same protocol; lower values indicate preferred routes.

- **Metrics** can include **hop count**, **bandwidth**, **delay**, **cost**, **load**, and **reliability**.



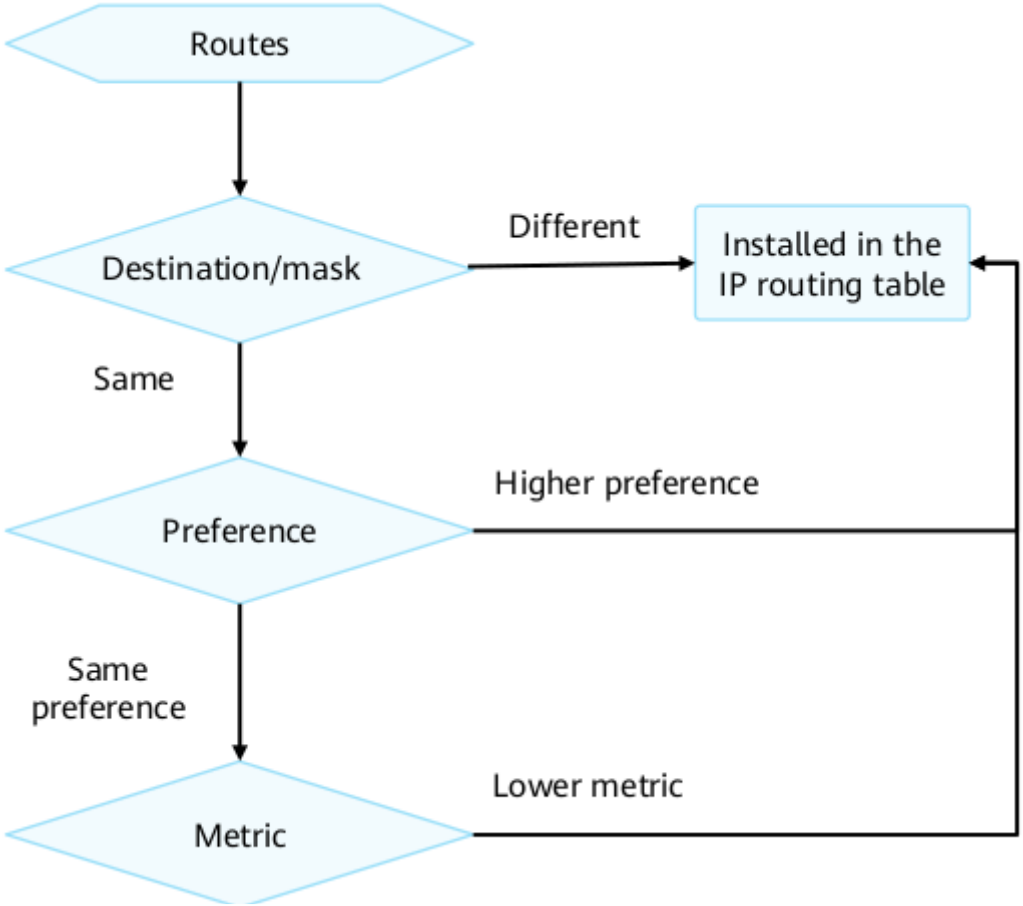
- **Next Hop**: The address of the next device packets are forwarded to en route to their final destination.
- **Interface**: The local interface through which packets are sent from the router.

1.1.3.2 Route Types and Preferences

Protocol	Route Type	Default Preference
Direct	Direct route	0
Static	Static route	60
OSPF	Internal route	10
OSPF	External route	150

1.1.3.3 Route Installed procedure

> Routes —> Destination/mask —> Preference —> Metric



1.1.4 Route-based Forwarding

1.1.4.1 Key Concepts

- **Longest Match Forwarding**: Routers compare the destination IP address bit by bit with routing table entries to find the longest matching prefix.

Longest Matching Mechanism

- Given Destination IP: `172.16.2.1`
  - **Routing Entries:**
  - 172.16.0.0/16 (255.255.0.0)
  - 172.16.2.0/24 (255.255.255.0)

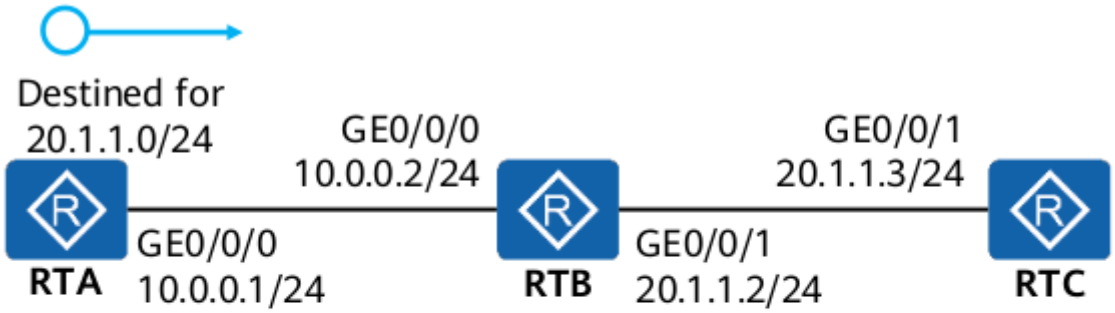
> The router will select `172.16.2.0/24` as it has a longer match (more specific network).

1.2 Static Routing

1.2.1 Key Points

- **Manually Configured**: Network administrators need to manually set up static routes.
- **System Requirements**: Static routes have lower system requirements compared to dynamic routing protocols.
- **Network Size**: Ideal for simple, stable, and small networks.
- **Lack of Adaptability**: One disadvantage is that static routes cannot automatically adapt to network changes.

1.2.1.1 Scenario Example



Destination	Protocol	Next Hop
20.1.1.0	Static	10.0.0.2
10.0.0.0	Direct	10.0.0.1

> In the example above, `RTA` needs to route traffic destined for `20.1.1.0/24` via `RTB` at `10.0.0.2`.

1.2.2 Configuration Commands

1.2.2.1 Static Route

```Markdown
[Huawei] ip route-static ip-address { mask | mask-length } <nexthop-address>
```

> Used in Broadcast interface (for example, an Ethernet interface) or a virtual template (VT) interface, you must specify the next hop. since in Broadcast their usually switch and switch connected to multiple port but in router side it connected with one port only

1.2.2.2 Outbound Interface Specification

```Markdown
[Huawei] ip route-static ip-address { mask | mask-length } <interface-type> <interface-number> [nexthop-address]
```

> Used in point-to-point interface (such as a serial interface), you must specify the outbound interface. since in point-to-point interface their is just two port.

1.2.2.3 Configuration Example

```Markdown
[RTA] ip route-static 20.1.1.0 255.255.255.0 10.0.0.2
[RTC] ip route-static 10.0.0.0 255.255.255.0 S1/0/0
```

1.2.3 Default Routes

- Default routes (`ip route-static 0.0.0.0 0.0.0.0`) are special static routes that match any destination address not found in the routing table.

1.2.3.1 Application Scenarios

> Default routes are typically used at the egress of an enterprise network or on edge devices connecting to larger networks like the Internet.

1.2.3.1.1 Configuration Example

```Markdown
[RTA] ip route-static 0.0.0.0 0 10.0.0.2
```

1.3 Dynamic Routing

1.3.1 Dynamic Routing Overview

Dynamic routing protocols automatically manage the routing process, adapting to topology changes and reducing administrative workload.

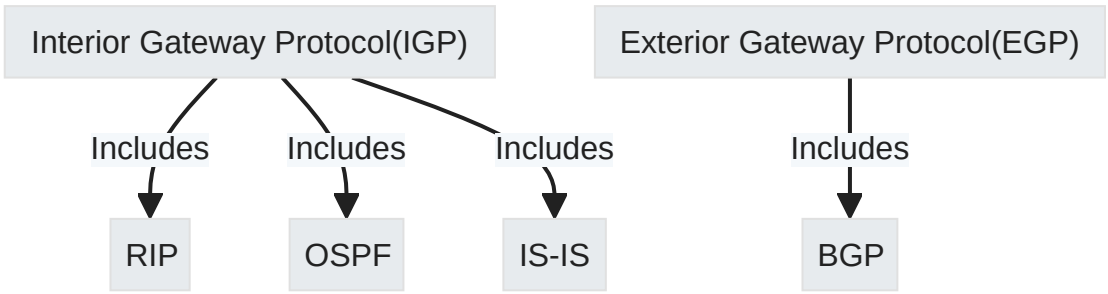
> **Administrative workload:** tasks and activities that network administrators must perform to keep a network running smoothly. This includes configuring routers, updating routing tables, fixing network issues, and adjusting settings when the network changes.

1.3.1.1 Advantages of Dynamic Routing

- **Automatic Discovery**: Routes are learned without manual configuration.
- **Adaptability**: Can adjust to network topology changes dynamically.

1.3.1.2 Classification of Dynamic Routing Protocols

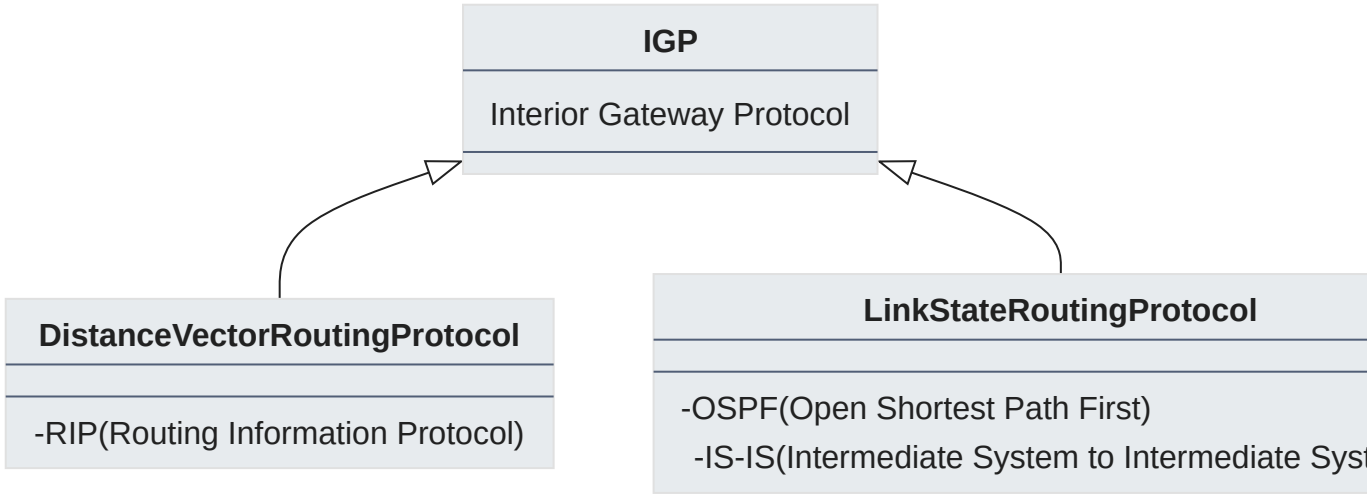
1.3.1.2.1 By Application Scope



- **IGPs:** run within an autonomous system (AS)
- **EGP:** runs between different (ASs)

> **Autonomous System (AS):** is a collection of IP networks and routers under the control of one or more network operators that presents a common routing policy to the internet.

1.3.1.2.2 By Working Mechanism (Classification under IGP)



> **BGP (Border Gateway Protocol):** is sometimes classified as a path-vector protocol due to its enhancement over distance-vector algorithms.

> **A path-vector protocol:** is a network routing protocol that keeps track of the full paths (or sequences of autonomous systems) that data packets travel through to reach their destination, rather than just the distance or metric to the next hop.

1.4 Advanced Routing Features

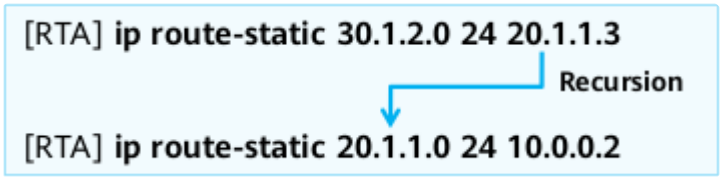
1.4.1 Route Recursion

- **Definition**: Recursive lookup in IP routing table when next-hop is not directly connected.

Example

- Static route to `30.1.2.0/24` via `20.1.1.3` on RTA.
- If no directly connected route to `20.1.1.3`, route is not usable and cannot be installed in the IP routing table.

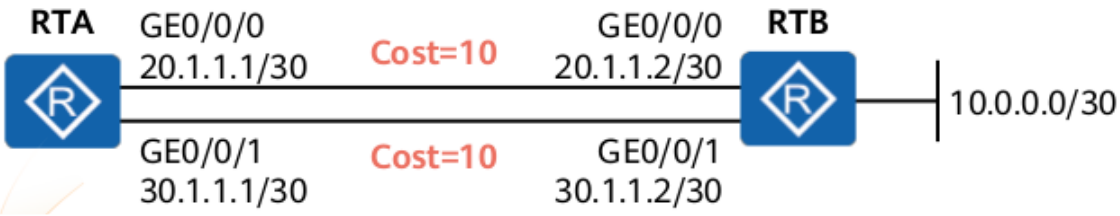
- **Solution**:
  - Configure static route to next-hop's network (e.g., RTA's route to `20.1.1.0/24` via `10.0.0.2`).
  - like configure another static route to learn about the next hop of static route in the example `20.1.1.3`



> **Main Benefit:** Minimized Routing Information**: It keeps the routing information concise on RTA without the need to know all the individual subnets behind other routers.

1.4.2 Equal-Cost Route

- Routes with identical costs used for load balancing.

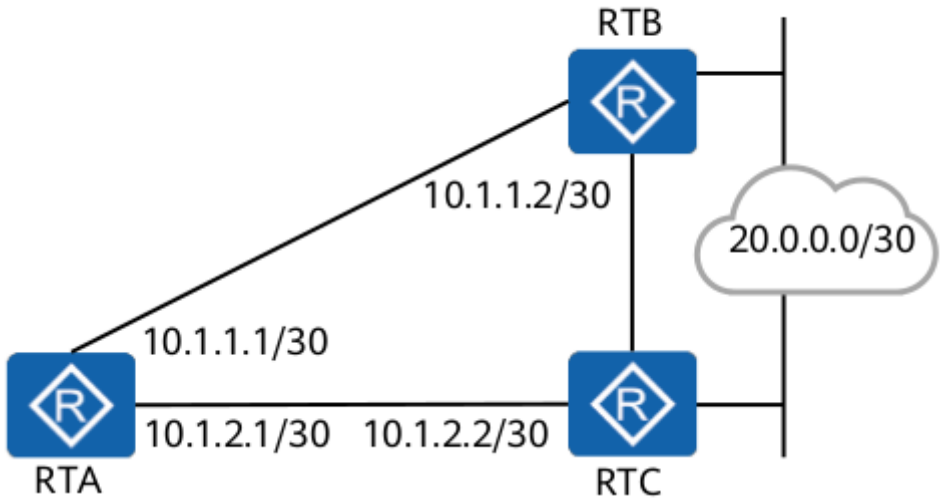


RTA's IP routing table

Destination/Mask	Next Hop
10.0.0.0/30	20.1.1.2
	30.1.1.2

1.4.3 Floating Route

- Backup routes with higher preference values than primary routes.
- Used when the primary route is down.

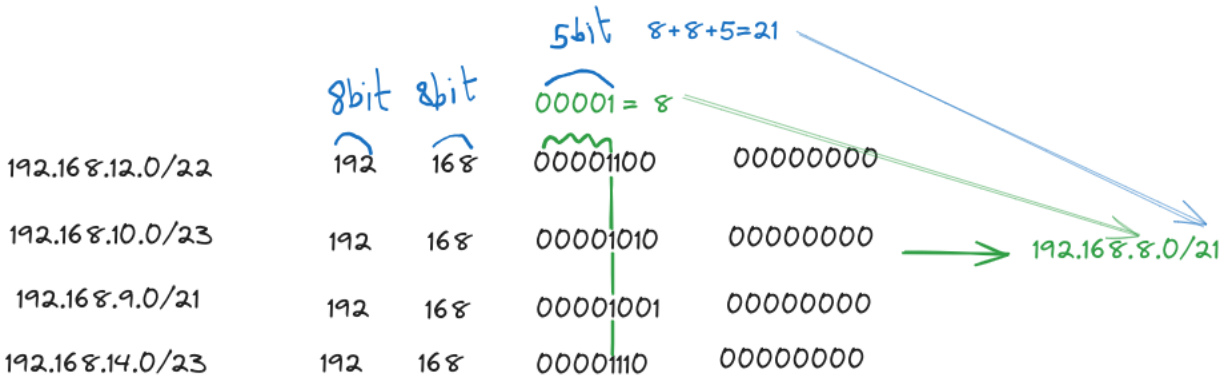


Configure a floating route on RTA.

```
[RTA] ip route-static 20.0.0.0 30 10.1.1.2
[RTA] ip route-static 20.0.0.0 30 10.1.2.2  preference 70
```

1.4.4 CIDR (Classless Inter-Domain Routing)

- Replaces classful addressing with variable subnet masks (VLSM).
- Allows for more efficient use of IP space through aggregation.



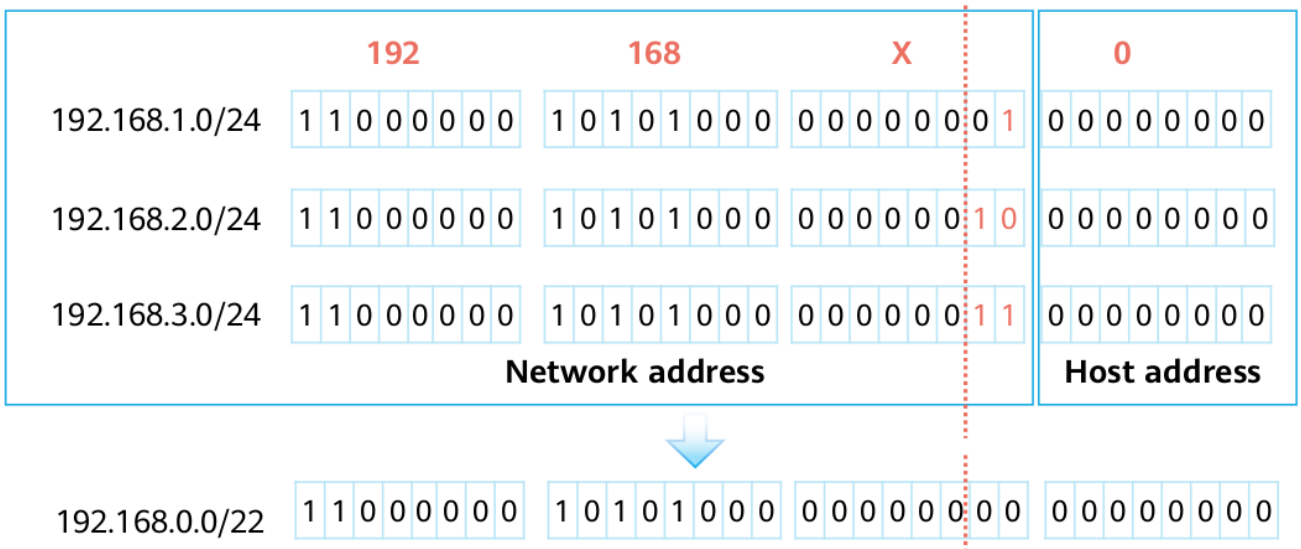
> take the all bit similar until reaching different bit

1.4.5 Route Summarization (Aggregation)

- Combines multiple routes into one summary route to reduce routing table size and conserve resources.

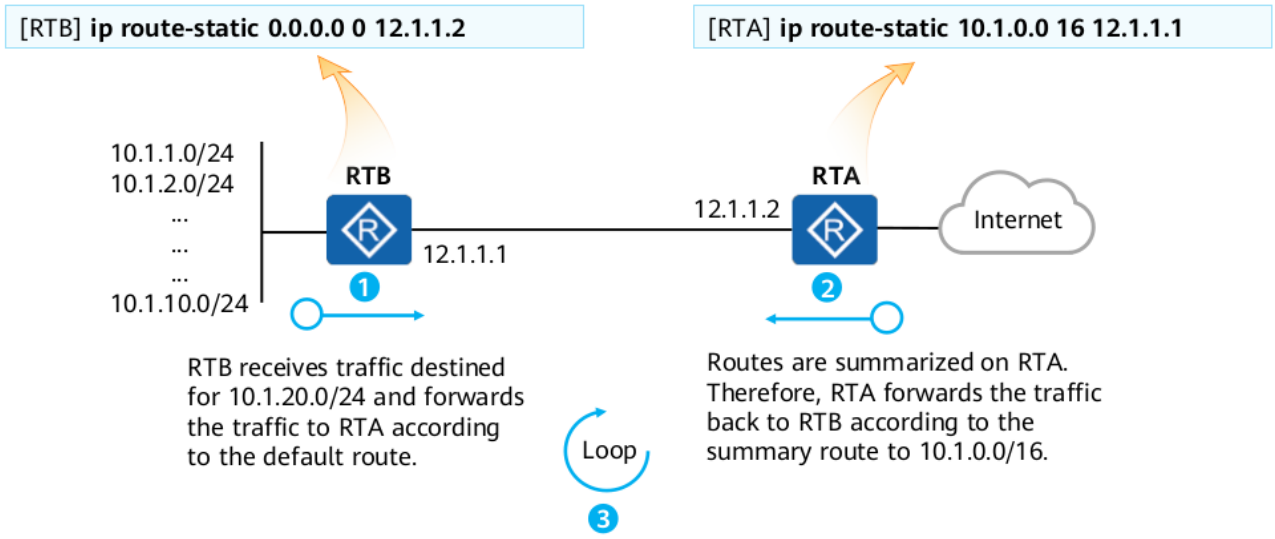
Example

- Before Summarization:
  - $10.1.1.0/24, 10.1.2.0/24, \ldots\ldots, 10.1.10.0/24$
- After Summarization:
  - $10.1.0.0/16$ (covers all above subnets)



1.4.6 Problems with Summarization

1.4.6.1 Routing Loops



> Route summarization on RTA for the 10.1.0.0/16 network can cause a routing loop. When RTB receives traffic for a non-existent subnet like 10.1.20.0/24, it sends it to RTA based on its default route. However, due to the summary route, RTA sends the traffic back to RTB, creating a loop.

> **Solving Routing Loops:**
> Configure routes pointing to Null interface (e.g., Null0) as a safety measure since the interface is always up and its do discard for every packet Therefore, such a route is called a black-hole route.

1.4.6.2 Accurate Summarization

- Ensure that summarized routes are accurate and do not include unintended networks.
- Use Exact mask lengths to avoid over-summarizing.