

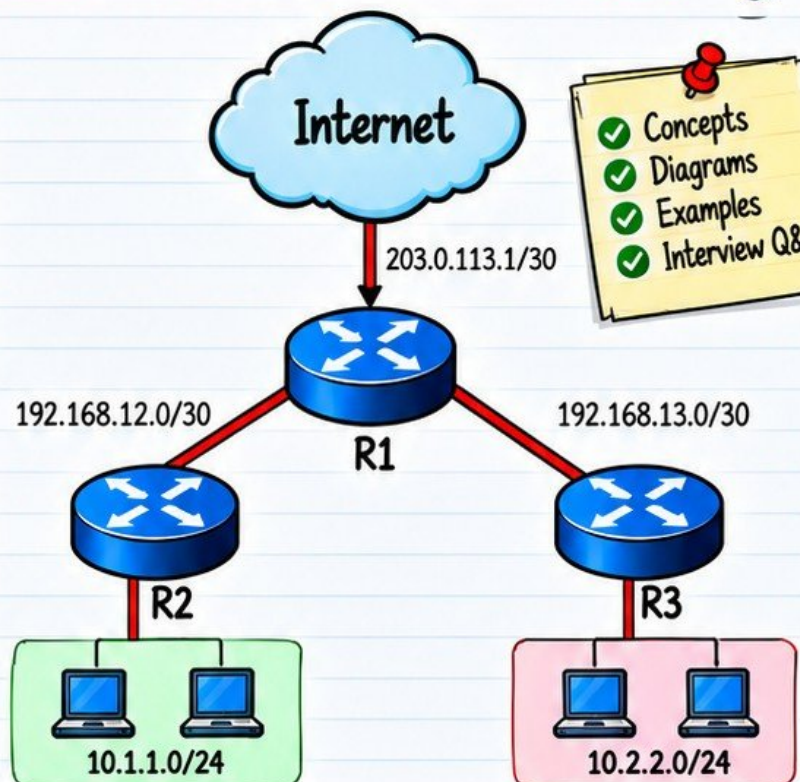
ROUTING

BASICS AND FUNDAMENTALS

Complete Guide with Concepts, Diagrams & Examples



- ✓ What is Routing?
- ✓ How Routing Works?
- ✓ Routing Table
- ✓ Static Routing
- ✓ Dynamic Routing
- ✓ Administrative Distance
- ✓ Metric
- ✓ Routing Protocols
- ✓ Real-World Examples
- ✓ CCNA to CCIE Key Points



- ✓ Concepts
- ✓ Diagrams
- ✓ Examples
- ✓ Interview Q&A



Understand
Routing
Concepts



Step-by-Step
Configuration
Examples



Real-World
Scenarios



Troubleshooting
and Verification
Commands



Key Points
for
CCNA to CCIE



LEARN
ANYTIME



CLEAR
CONCEPTS



REAL
EXAMPLES



CCNA TO CCIE
LEVEL



BUILD
REAL SKILLS

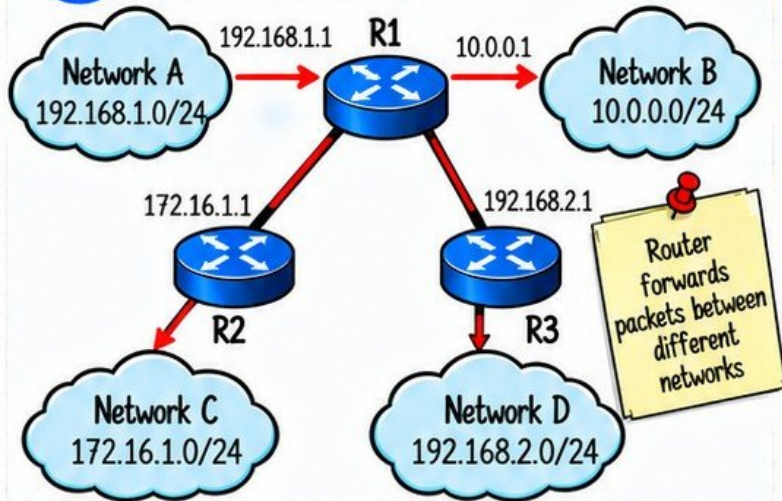
Process of finding the best path and forwarding packets to reach the destination network

Routing is the process of **selecting the best path** to reach a destination network and **forwarding packets** from one network to another using routers.
Routers use a **routing table** to make forwarding decisions.

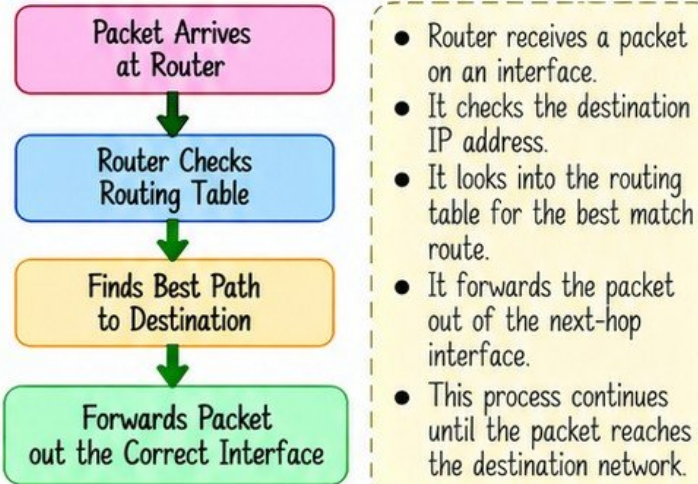
1 What is Routing?

- ✓ Routing is the process of forwarding packets from source to destination network.
- ✓ Routers use route information to choose the best path.
- ✓ Routing helps different networks to communicate with each other.
- ✓ It works at **Layer 3 (Network Layer)** of the OSI model.
- ✓ Routing can be manual (**Static**) or automatic (**Dynamic**).

2 Routing Example



3 How Routing Works?



4 Key Terms in Routing

Term	Description
Router	Device that forwards packets between networks.
Route	Path to reach a destination network.
Routing Table	Table that contains all known routes.
Next-Hop	IP address of the next router to reach the destination.
Destination Network	Network where the packet needs to go.
Metric	Value used to choose the best path (lower is preferred).
Static Routing	Manually configured routes.
Dynamic Routing	Automatically learned routes using routing protocols.

5 Routing vs Switching (Difference)

Routing (Layer 3)	Switching (Layer 2)
Works at Network Layer (L3)	Works at Data Link Layer (L2)
Forwards packets between networks	Forwards frames within the same network
Uses IP addresses	Uses MAC addresses
Uses routing table	Uses MAC address table (CAM)
Connects different networks	Connects devices in the same network
Example: Router	Example: Switch

6 Important Points

- ✓ Routing enables communication between different networks.
- ✓ Routers use the best path based on routing table.
- ✓ It works at Layer 3 (Network Layer).
- ✓ Routes can be static or dynamic.
- ✓ Dynamic routing protocols automatically learn and update routes.
- ✓ Metric is used to choose the best path.
- ✓ Routing is essential for large and complex networks.

Routing Table contains all the routes that a router knows

Routing table is a database in the router which contains all the known routes to reach different networks. It helps the router to select the best path for forwarding packets to the destination network.

1 What is Routing Table?

- ✓ A database stored in the router memory (RAM).
- ✓ Contains all known routes to reach destination networks.
- ✓ Includes connected, static and dynamic routes.
- ✓ Router uses the routing table to choose the best path (based on metric).
- ✓ Updated automatically (dynamic) or manually (static).
- ✓ You can view it using **show ip route** command in Cisco routers.

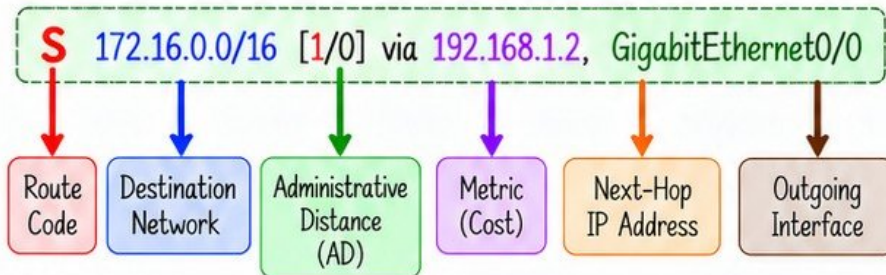
2 Routing Table Example

R1# show ip route

Codes: C - connected, S - static, R - RIP, O - OSPF, D - EIGRP, B - BGP

```
C 192.168.1.0/24 is directly connected, GigabitEthernet0/0
C 10.0.0.0/24 is directly connected, GigabitEthernet0/1
S 172.16.0.0/16 [1/0] via 192.168.1.2
R 192.168.2.0/24 [120/1] via 10.0.0.2, 00:00:12
O 192.168.3.0/24 [110/2] via 10.0.0.3, 00:00:20
D 10.1.0.0/16 [90/3072] via 10.0.0.4, 00:00:18
B 8.8.8.0/24 [200/0] via 10.0.0.5, 00:00:32
```

3 Routing Table Components



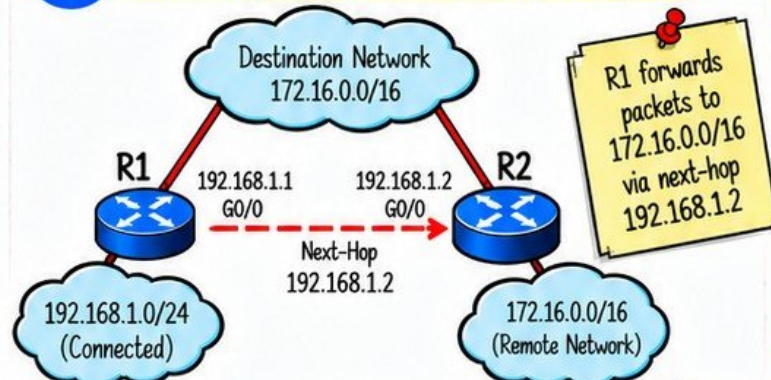
Common Route Codes

Code	Route Type	Description
C	Connected	Directly connected network
S	Static	Manually configured route
R	RIP	Learned via RIP protocol
O	OSPF	Learned via OSPF protocol
D	EIGRP	Learned via EIGRP protocol
B	BGP	Learned via BGP protocol
L	Local	Local interface address (/32)

4 How Router Uses Routing Table?

- 1 Packet arrives at the router.
- 2 Router checks the destination IP address.
- 3 It searches the routing table for the best match (longest prefix match).
- 4 Selects the best path based on metric.
- 5 Forwards the packet out of the next-hop interface.

5 Routing Table in Action (Example)



4. Static Routing

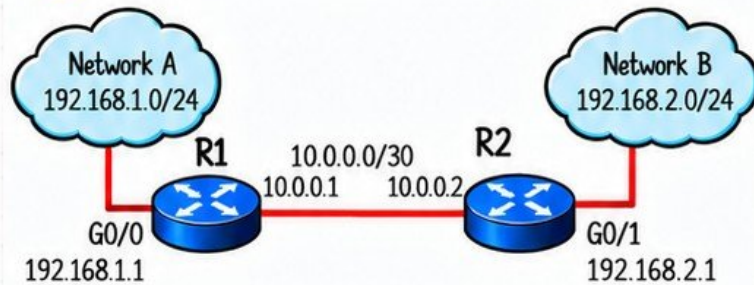
Manually configured route to reach a destination network

Static routing is a **manually configured route** in the router. The administrator specifies the destination network and the next-hop IP address or outgoing interface. It is simple, secure and commonly used in small networks or for specific routes.

1 Key Points of Static Routing

- ✓ Manually configured by network administrator.
- ✓ Used to reach specific destination networks.
- ✓ Does not change automatically (no dynamic updates).
- ✓ Less resource usage (no routing protocol).
- ✓ More secure and predictable.
- ✓ Commonly used in small networks, branch offices or for default route.
- ✓ If the next-hop or path fails, route is lost until manually updated.

2 Static Routing Topology Example



In this example:

- R1 needs a route to reach 192.168.2.0/24 via 10.0.0.2
- R2 needs a route to reach 192.168.1.0/24 via 10.0.0.1

3 Static Route Configuration (CLI)

R1 Configuration

```

R1# configure terminal
R1(config)# ip route
192.168.2.0 255.255.255.0
10.0.0.2
  
```

- This route tells R1 to reach 192.168.2.0/24 via next-hop 10.0.0.2

R2 Configuration

```

R2# configure terminal
R2(config)# ip route
192.168.1.0 255.255.255.0
10.0.0.1
  
```

- This route tells R2 to reach 192.168.1.0/24 via next-hop 10.0.0.1

4 Verify Static Route

```

R1# show ip route static
S 192.168.2.0/24 [1/0] via 10.0.0.2

R1# show ip route
Codes: C - connected, S - static, R - RIP, O - OSPF,
D - EIGRP, B - BGP

C 192.168.1.0/24 is directly connected, G0/0
C 10.0.0.0/30 is directly connected, G0/1
S 192.168.2.0/24 [1/0] via 10.0.0.2
  
```

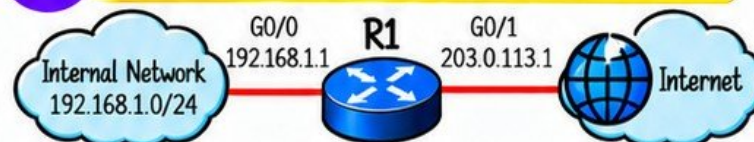
5 Static Route Using Outgoing Interface

```

R1# configure terminal
R1(config)# ip route 192.168.2.0 255.255.255.0 g0/1
  
```

- Instead of next-hop IP, you can also specify the outgoing interface.
- Useful in point-to-point links.

6 Default Static Route (Internet Access)



```

R1(config)# ip route 0.0.0.0 0.0.0.0 203.0.113.2
  
```

- This is called a **Default Route**.
- Used when the router needs to send all unknown destinations to the Internet.

Automatically learns and updates routes

Dynamic routing protocols allow routers to automatically discover networks, exchange routing information and update their routing tables when there is any change in the network. They use routing protocols like RIP, OSPF, EIGRP and BGP.

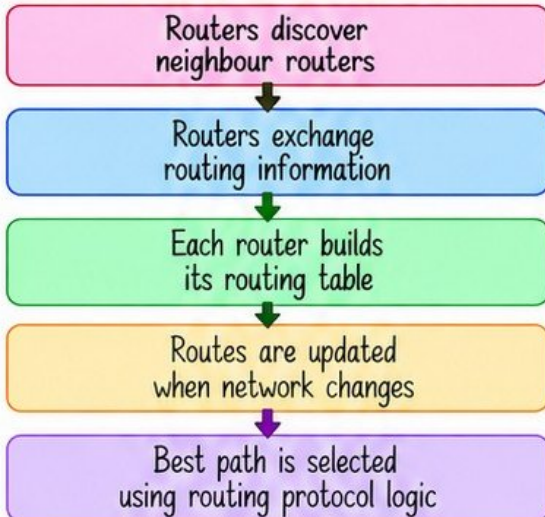
1 What is Dynamic Routing?

- ✓ Routes are learned automatically using routing protocols.
- ✓ Routers exchange routing information with each other.
- ✓ Routing table is updated automatically when network changes.
- ✓ More suitable for medium to large networks.
- ✓ Reduces manual configuration.
- ✓ Common protocols: **RIP, OSPF, EIGRP, BGP.**

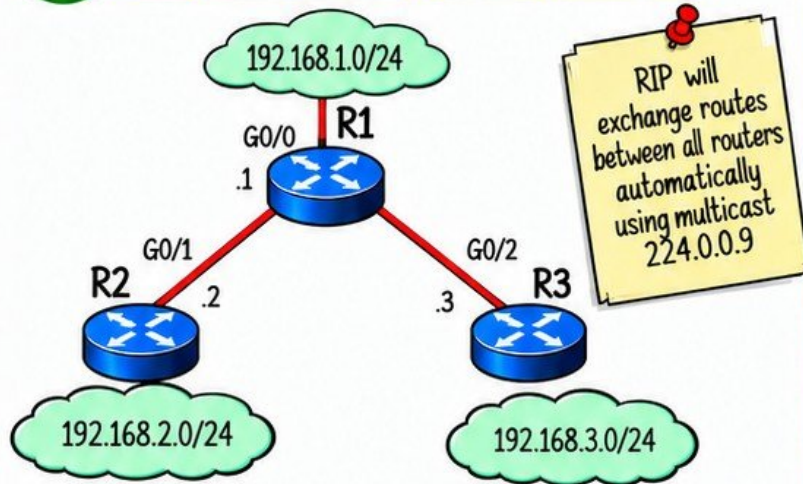
2 Dynamic vs Static Routing (Comparison)

Feature	Static Routing	Dynamic Routing
Configuration	Manual	Automatic (using protocols)
Route Learning	Manually configured	Learns automatically
Updates	No automatic updates	Updates automatically
Resource Usage	Less	More (uses bandwidth & CPU)
Best for	Small networks	Medium to large networks
Scalability	Limited	High
Example	Static route	RIP, OSPF, EIGRP, BGP

3 How Dynamic Routing Works?



4 Dynamic Routing Example (RIP)



5 RIP Configuration Example

```

R1(config)# router rip
R1(config-router)# version 2
R1(config-router)# no auto-summary
R1(config-router)# network 192.168.1.0
R1(config-router)# network 192.168.2.0
  
```

6 RIP Routing Table Example

```

R1# show ip route
Codes: C - connected, R - RIP, S - static, O - OSPF
       D - EIGRP, B - BGP
C    192.168.1.0/24 is directly connected, G0/0
C    192.168.2.0/24 is directly connected, G0/1
R    192.168.3.0/24 [120/1] via 192.168.2.2, 00:00:16
  
```

Routing protocols are classified into different types based on their operation and usage.

Each type has its own algorithm, metric and use case. Choosing the right protocol helps in better network performance and scalability.

1 Classification of Routing Protocols

- ✓ IGP (Interior Gateway Protocol)
- ✓ EGP (Exterior Gateway Protocol)
- ✓ Distance Vector
- ✓ Link State
- ✓ Hybrid

Different Types
Different Roles!

2 IGP vs EGP

Feature	IGP (Interior Gateway Protocol)	EGP (Exterior Gateway Protocol)
Scope	Within an autonomous system (AS)	Between different AS
Example	RIP, OSPF, EIGRP, IS-IS	BGP
Used By	Internal networks	Internet / ISP networks
Metric	Hop count, cost, bandwidth, load, etc.	Path attributes (AS Path, Local Preference, MED, etc.)

3 Distance Vector Routing Protocols

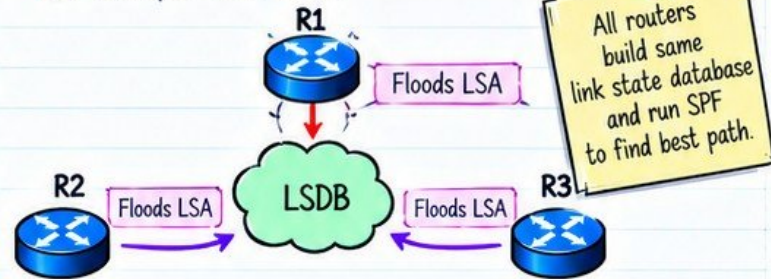
- ✓ Works on the principle of "distance" (hop count).
- ✓ Each router shares its routing table with neighbors.
- ✓ Uses Bellman-Ford algorithm.
- ✓ Convergence is slower compared to link state.
- ✓ Example: RIP (hop count metric).



Example: RIP

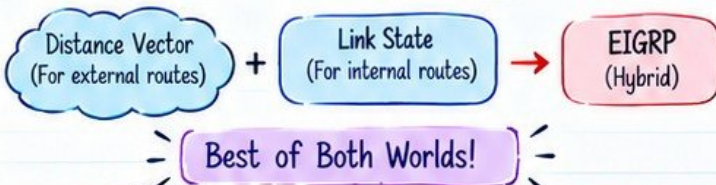
4 Link State Routing Protocols

- ✓ Uses link state advertisements (LSA).
- ✓ Builds a complete view of the network.
- ✓ Uses Dijkstra's algorithm (SPF).
- ✓ Faster convergence and more scalable.
- ✓ Example: OSPF, IS-IS.



5 Hybrid Routing Protocols

- ✓ Combines features of both distance vector and link state.
- ✓ Uses different methods for different parts of the network.
- ✓ Provides better scalability and stability.
- ✓ Example: EIGRP (Cisco proprietary).



6 Real-World Example

```
R1# show ip route
Gateway of last resort is not set
C 10.0.0.0/8 is directly connected, GigabitEthernet0/0
O 172.16.0.0/16 [110/2] via 192.168.1.2, 00:00:12, GigabitEthernet0/1
D 192.168.10.0/24 [90/1] via 10.0.0.2, 00:00:20, GigabitEthernet0/2
E 203.0.113.0/24 [170/20] via 198.51.100.1, 00:00:30
```

Key Takeaway:
Different protocols, different strengths.
Use the right protocol for the right network.

Each routing protocol uses a metric to choose the best path.

Metric is the value used by a routing protocol to determine the best path to a destination.
Lower metric value is always preferred.

1 What is Routing Metric?

- ✓ A value used to compare different routes.
- ✓ Helps the router to select the best path.
- ✓ Each routing protocol has its own metric calculation.
- ✓ Lower metric is always preferred.
- ✓ Metrics can be based on hop count, bandwidth, delay, load, etc.

3 RIP Metric (Hop Count)

- ✓ Metric = Number of hops to reach destination.
- ✓ Max hop count = 15 (16 = unreachable).
- ✓ Choose the path with the lowest hop count.
- ✓ Simple metric but does not consider bandwidth or link quality.



R1 to reach 192.168.2.0/24 = 2 hops
(1 via R2).

5 EIGRP Metric (Composite Metric)

- ✓ Default Metric = Based on Bandwidth + Delay.
- ✓ Formula (default):

$$\text{Metric} = 256 \times \left(\frac{10^7}{\text{Min_Bandwidth}} + \text{Total_Delay} \right)$$
- ✓ Lower metric is preferred.
- ✓ More accurate than hop count (considers link quality).

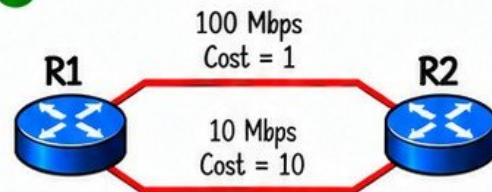
EIGRP can also include Load and Reliability in the metric (optional).

2 Common Routing Protocol Metrics

Protocol	Metric	Based On	Default Value / Notes
RIP	Hop Count	Number of hops	Max 15 hops (16 = unreachable)
OSPF	Cost	Bandwidth	Cost = 10^8 / Bandwidth (bps)
EIGRP	Composite Metric	Bandwidth + Delay (+ Load + Reliability)	By default uses Bandwidth + Delay
BGP	Path Attributes	Different attributes (AS Path, Local Pref, etc.)	Chooses best path based on multiple attributes
IS-IS	Cost	Bandwidth	Similar to OSPF, but configurable

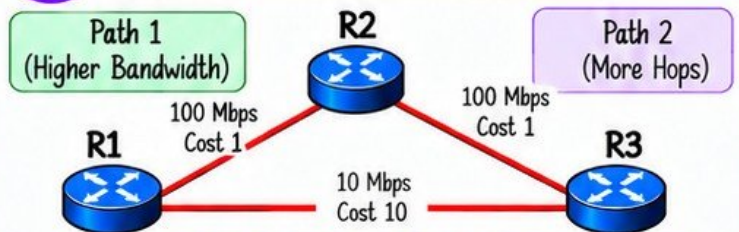
4 OSPF Metric (Cost)

- ✓ Metric = Cost (based on interface bandwidth).
- ✓ Formula: Cost = 108 / Bandwidth (in bps)
- ✓ Lower cost path is preferred.
- ✓ Faster links (higher bandwidth) have lower cost.
- ✓ Default reference bandwidth = 100 Mbps (10^8).



OSPF chooses the 100 Mbps link because it has lower cost (1 < 10).

6 Metric Comparison Example



- Path 1 (via R2) total cost = 2 (1 + 1)
- Path 2 (direct) total cost = 10
- Router will choose Path 1 (lower metric).

How a Router Chooses the Best Route?

When a packet arrives at a router, it checks the destination IP address in the routing table and selects the best route based on longest prefix match, AD, metric and other factors.

1 Routing Decision Process - Steps

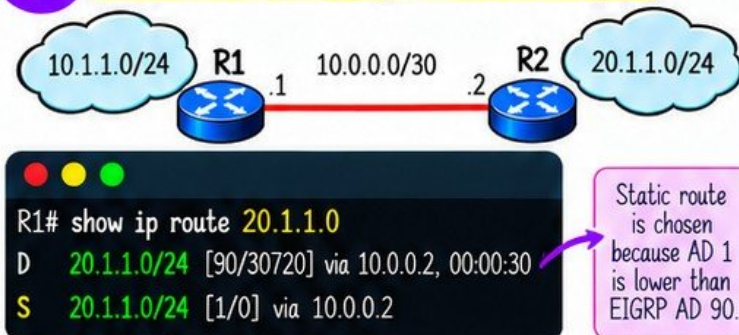
- Router receives a packet with destination IP.
- Checks the routing table for matching routes.
- Uses Longest Prefix Match to find the best match.
- If multiple routes exist, checks the Administrative Distance (AD).
- If AD is same, uses the routing metric (lowest).
- If still same, uses load balancing or other tie-breakers.
- Forwards the packet to the next-hop or outgoing interface.

3 Administrative Distance (AD)

- Used to choose the best route when multiple sources have the same destination.
- Lower AD value is preferred.
- Different routing sources have different AD values.

Route Source	AD (Default)	Notes
Connected	0	Directly connected network
Static	1	Manually configured
EIGRP (internal)	90	Within same AS
OSPF	110	Common in enterprises
RIP	120	Used in small networks
EIGRP (external)	170	From another AS
BGP	200	Used between different AS

6 Real-World Routing Decision Example



2 Longest Prefix Match (Most Specific Route)

- Router always chooses the most specific route (longest prefix).
- More specific network = longer subnet mask.
- Even if another route has lower metric, longest prefix match wins.

Longest Prefix Match is always checked first!

Example: Destination IP: 192.168.1.10

Route	Subnet Mask	Match?	Result
192.168.0.0	/16	Yes	Less specific
192.168.1.0	/24	Yes	More specific
192.168.1.8	/29	Yes	Most specific

4 Metric Comparison

- If AD is same, router compares the metric value.
- Each protocol has its own metric calculation.
- Lower metric is preferred.

Example:

- Two OSPF routes to the same destination:
 - Route 1: 192.168.3.0/24 metric 20
 - Route 2: 192.168.3.0/24 metric 10
- Router will choose Route 2 (lower metric).

AD first then Metric!

5 Tie-Breaking (If AD and Metric are Same)

- If both AD and metric are same, router can use:
 - Load balancing (use both paths)
 - Router ID (lower Router ID)
 - Next-hop IP (lowest IP)
 - Route age (older route)

In most cases, AD and Metric are enough to choose the best route!

Key Takeaways:

- Router uses longest prefix match first.
- Then checks Administrative Distance.
- Then compares the metric value.
- Lower values are preferred.
- If same, uses tie-breaking methods.
- This process ensures the best and most efficient path is selected.

Reduce Routing Table Size and Improve Network Efficiency

Route summarization (aggregation) combines multiple routes into a single summary route. It reduces routing table size, saves bandwidth and improves network performance.

1 Why Route Summarization?

- ✓ Reduces routing table size.
- ✓ Saves bandwidth (fewer update messages).
- ✓ Faster convergence.
- ✓ Hides internal network details.
- ✓ Improves network stability and scalability.

3 Example of Summarization

Individual Networks	Summary Route
192.168.0.0/24	192.168.0.0/22 (1024 addresses)
192.168.1.0/24	
192.168.2.0/24	
192.168.3.0/24	

5 Configuring Summarization (EIGRP)

```

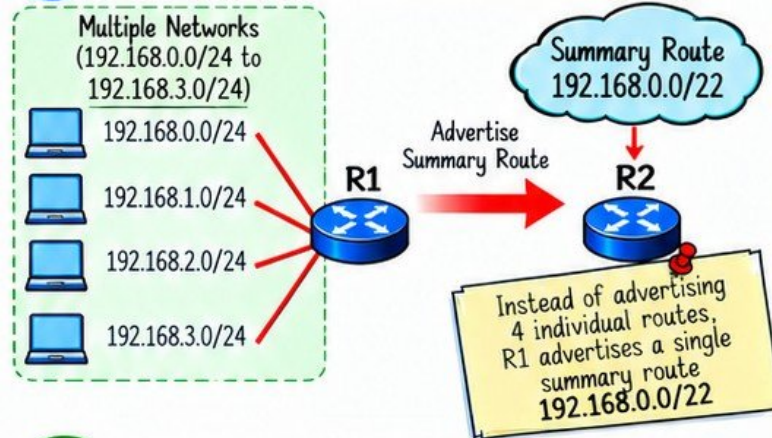
R1(config)# router eigrp 100
R1(config-router)# network 192.168.0.0
R1(config-router)# auto-summary
R1(config-router)# end
R1# show ip route eigrp
D 192.168.0.0/22 [90/2172416] via 10.0.0.2, 00:00:08
    
```

- EIGRP can summarize routes automatically (classful)
- Use auto-summary for classful networks.
- For manual summarization use summary-address.

7 Important Points

- ✓ Choose a summary that covers continuous networks.
- ✓ Summarization works best at area or AS boundaries.
- ✓ Avoid summarizing if networks are not contiguous.
- ✓ Careful planning is required to avoid blackholing traffic.
- ✓ Always verify with show ip route and neighbour/client output.

2 How Route Summarization Works?



4 Configuring Summarization (OSPF)

```

R1(config)# router ospf 1
R1(config-router)# area 0 range 192.168.0.0 255.255.252.0
R1(config-router)# end
R1# show ip route ospf
0 192.168.0.0/22 [110/20] via 10.0.0.2, 00:00:12
    
```

- R1 summarizes 192.168.0.0/24 - 192.168.3.0/24 into 192.168.0.0/22 and advertises it to other routers in area 0.

6 Configuring Summarization (BGP)

```

R1(config)# router bgp 65001
R1(config-router)# network 192.168.0.0 mask 255.255.252.0
R1(config-router)# end
R1# show ip bgp
*> 192.168.0.0/22 0.0.0.0 0 32768 i
*> 203.0.113.0/24 0.0.0.0 0 32768 i
    
```

- BGP summary is configured using the network command with appropriate mask.
- Advertises only the summary route to external peers.
- Reduces the number of routes in the global routing table.

8 Best Practices

- ✓ Summarize at distribution, area or AS boundary.
- ✓ Use summarization only for stable and continuous networks.
- ✓ Keep summarization simple and logical.
- ✓ Verify reachability after configuration.
- ✓ Monitor for any traffic loss or routing issues.

Key Concepts, Comparison and Next Steps

Let's quickly recap all the important concepts of routing covered in this series and see how they fit together in real networks from CCNA to CCIE level.

1 Routing Protocols Recap

Protocol	Type	Metric	Key Point
RIP	Distance Vector	Hop Count	Simple, max 15 hops
OSPF	Link State	Cost (Bandwidth)	Fast convergence, scalable
EIGRP	Hybrid	Composite (BW + Delay)	Fast, reliable, Cisco proprietary
BGP	Path Vector	Path Attributes	Used for Internet, best for large networks
IS-IS	Link State	Cost	Used in large enterprise / ISP

2 Administrative Distance (Default)

Route Source	AD Value	Notes
Connected	0	Directly connected network
Static	1	Manually configured
EIGRP (internal)	90	Within same AS
OSPF	110	Common in enterprises
RIP	120	Used in small networks
EIGRP (external)	170	From another AS
BGP	200	Used between different AS

3 Metric Comparison

Protocol	Metric	Preferred For
RIP	Hop Count	Small networks
OSPF	Cost (Bandwidth)	Enterprise networks
EIGRP	Composite Metric	Enterprise networks
BGP	Path Attributes	Internet / ISP networks
IS-IS	Cost (Bandwidth)	Large networks (ISP)

4 Route Types Recap

- ✓ Connected Route - directly connected networks
- ✓ Static Route - manually configured
- ✓ Dynamic Route - learned via routing protocols
- ✓ Default Route - used when no specific route is found
- ✓ Summary Route - combines multiple routes
- ✓ Floating Static Route - backup route
- ✓ Blackhole Route - drop traffic intentionally
- ✓ Null0 Route - used for route summarization

Different route types are used in different scenarios!

5 Routing Process Recap

- 1 Receive packet with destination IP.
- 2 Check routing table for best match (Longest Prefix Match).
- 3 If multiple routes, check Administrative Distance.
- 4 If AD is same, compare metric.
- 5 Select best route and forward the packet.
- 6 If no match, use default route.
- 7 Update routing table dynamically (for dynamic protocols).

Longest Prefix Match + Lowest AD + Lower Metric = Best Route!

6 Best Practices

- ✓ Choose the right routing protocol for your network size.
- ✓ Use route summarization to reduce table size.
- ✓ Keep routing simple and scalable.
- ✓ Verify routes and connectivity after configuration.
- ✓ Monitor routing updates and neighbor relationships.
- ✓ Use redundancy (backup routes) for high availability.
- ✓ Plan addressing and hierarchy properly.

Good routing design = Stable, Scalable and Efficient Network!



Key Takeaways

- ✓ Routing helps packets reach the correct destination.
- ✓ Each routing protocol uses a metric to find the best path.
- ✓ Lower metric and lower AD are preferred.
- ✓ Route summarization improves efficiency.
- ✓ Choose the right protocol based on network size and requirements.
- ✓ Always verify and monitor your routing configuration.



You Did It!

You have completed the complete Routing Basics and Fundamentals series from CCNA to CCIE level!

Keep Learning | Keep Practicing
Keep Growing | Follow Technetworkk

