Routing (CCNA Focus)

Static and Dynamic Routing

- **Static Routing:**
    - The network administrator manually configures routes in the routing table.
    - Best for small networks or predictable paths.
    - Pros: Simple, predictable, and no extra CPU overhead.
    - Cons: Not scalable; requires manual updates if network topology changes.
    - **Configuration Example:**

```
ip route 192.168.2.0 255.255.255.0 192.168.1.2
```

    - **Host Route:**
        - A route to a single host rather than a network.
        - Represented using a **/32 prefix** in IPv4 (e.g., `192.168.1.10/32`).
        - Useful when specifying an exact destination, such as a loopback interface or a management IP.
        - **Example:**

```
ip route 192.168.1.10 255.255.255.255 192.168.1.1
```

    - **Default Route:**
        - A catch-all route used when no other specific route matches the destination IP.
        - Represented as `0.0.0.0/0` in IPv4 or `::/0` in IPv6.
        - Often points to the next-hop router or the ISP gateway.
        - **Example:**

```
ip route 0.0.0.0 0.0.0.0 192.168.1.1
```

    - **Floating Static Default Route:**
        - A backup default route that is only used if the primary route fails.
        - Configured by assigning a higher **Administrative Distance (AD)** than the primary route.
        - This allows the primary route (with lower AD) to be preferred under normal operation, while the floating static route provides redundancy.

        - **Example:**

- `ip route 0.0.0.0 0.0.0.0 192.168.2.1 200`

(Here, AD of 200 makes it a backup to the normal default route.)

Additional Information (Not Required for Exam but Helpful)

- **IP SLA:**
  - A Cisco feature that measures network performance by sending test traffic (e.g., ICMP, UDP, TCP probes).
  - Commonly used to monitor reachability and latency.
- **IP SLA Schedule:**
  - Defines when an IP SLA operation should start, how often it repeats, and for how long.
  - Example: scheduling an ICMP echo every 10 seconds.
- **ICMP Echo:**
  - A test method where the device sends ICMP pings to a destination to verify connectivity and measure round-trip time.
  - Often used in IP SLA operations.
- **Track:**
  - A feature that ties an object (such as an IP SLA operation) to a routing decision.
  - For example, a static route can be configured to be valid only if an IP SLA track confirms reachability.
  - Enables dynamic failover of static routes.

Dynamic Routing:

- Routers automatically learn routes and update their routing tables using routing protocols.
- Useful for large or changing networks.
- **Pros:** Scalable, adapts to topology changes automatically.
- **Cons:** More CPU and memory usage, possible routing loops if not properly configured.

- **Common Protocols:**

Protocol	Version	Type	Cisco Proprietary	Metric	IGP/EGP	Default AD
RIP	v2	Distance Vector	No	Hop count	IGP	120
EIGRP	N/A	Advanced Distance Vector	Yes	Bandwidth & Delay	IGP	90
OSPF	v2 (IPv4), v3 (IPv6)	Link State	No	Cost (based on bandwidth)	IGP	110
IS-IS	N/A	Link State	No	Cost (based on bandwidth)	IGP	115
BGP	N/A	Path Vector	No	AS Path	EGP	20 (External), 200 (Internal)

Note: OSPFv2 is used for IPv4; OSPFv3 is used for IPv6. OSPFv3 can also carry IPv4 routes via address-family extensions in later RFCs, but for CCNA focus on OSPFv2 for IPv4.

- **CCNA Tip:** Know the protocol type, version (for RIP and OSPF), metric, Cisco proprietary status, whether it is IGP or EGP, and its default administrative distance (AD).

EIGRP vs OSPFv2

- **EIGRP:**
  - Cisco proprietary (though partially standardized later).
  - Advanced distance-vector (hybrid).
  - Uses DUAL algorithm for fast convergence.
  - Metric based on bandwidth, delay (optionally reliability, load, MTU).
  - Supports unequal-cost load balancing.
  - Default AD: 90.
  - Easier to configure in Cisco-only environments.
- **OSPFv2:**
  - Open standard.
  - Link-state protocol.
  - Uses Dijkstra's SPF algorithm.
  - Metric is cost (bandwidth-based).
  - Supports equal-cost load balancing only.
  - Default AD: 110.
  - More complex but highly scalable for multi-vendor environments.
  - Multicast Addresses: 224.0.0.5 (All OSPF Routers), 224.0.0.6 (Designated Routers).

OSPF Concepts

- **Link-State Advertisements (LSAs):** Messages OSPF routers exchange to describe the network topology.
  - **Type 1 (Router LSA):** Generated by every router; lists directly connected links.
  - **Type 2 (Network LSA):** Generated by the DR on broadcast/multi-access networks.
  - **Type 3 (Summary LSA):** Generated by ABRs to advertise networks between areas.
  - **Type 4 (ASBR Summary LSA):** Generated by ABRs to advertise the presence of an ASBR.
  - **Type 5 (External LSA):** Generated by ASBRs to advertise external routes.
  - **Type 7 (NSSA External LSA):** Used in NSSA for external routes.

- **Areas and Scalability:**
    - **Single Area (Area 0 only):** All routers in the backbone area. Easier to configure but less scalable.
        - Example command to add a network to Area 0 on a single interface:

```
router ospf 1
  network 192.168.1.1 0.0.0.0 area 0
```

Note: Using a single host network ensures only this interface joins OSPF; using a broader network command will include all interfaces in OSPF.

        - To disable OSPF hello packets on an interface (passive interface):

```
router ospf 1
  passive-interface g0/1
```

    - **Multi-Area:** OSPF is divided into areas connected to the backbone (Area 0), reducing LSDB size and improving scalability.
- **Router Types:**
    - **Backbone Router:** At least one interface in Area 0.
    - **Internal Router:** All interfaces in the same area.
    - **ABR (Area Border Router):** Connects Area 0 to one or more non-backbone areas.
    - **ASBR:** Connects the OSPF domain to external networks (e.g., redistributing BGP).
- **Router ID:**
    - Unique 32-bit number to identify an OSPF router.
    - Selection order: manual Router ID, highest loopback IP, highest active interface IP.
    - Example manual configuration:

```
router ospf 1
  router-id 1.1.1.1
```

    - To apply a new Router ID:

```
clear ip ospf process
```

- **Default Information Originate:**
    - Allows an OSPF router to advertise a default route into the OSPF domain.
    - Useful for routers connected to the Internet or external networks.
    - Configuration example:

```
router ospf 1
  default-information originate
```

    - Optional keyword `always` can be added to advertise the default route even if the router doesn't have a default route itself:

```
router ospf 1
  default-information originate always
```

CCNA Tip:

- EIGRP is easier for Cisco-only networks; OSPF is better for multi-vendor setups.
- Know LSA types, router roles, Router ID selection rules, multicast addresses, interface-specific network commands, and default-information originate for propagating default routes.

IGP vs EGP

- **IGP:** Routing within a single AS (RIP v2, OSPF v2/v3, EIGRP, IS-IS).
- **EGP:** Routing between ASes (BGP).

Autonomous System (AS)

- Networks under common administration sharing a routing policy.
- Unique AS numbers identify each system for protocols like BGP.

CCNA Tip:

- Understand IGP vs EGP distinctions and AS concepts for exam scenarios.

OSPFv2 Packets and States

OSPF Packet Types:

- **Hello Packet:** Establishes and maintains neighbor relationships.

    - Sent to multicast address 224.0.0.5 (All OSPF Routers).
    - To form a neighbor relationship:
        - Router ID must be unique
        - Area ID must match
        - Authentication must match
        - Network type and other parameters must match
- **Database Description (DBD) Packet:** Summarizes the contents of the link-state database for synchronization.
- **Link-State Request (LSR) Packet:** Requests more recent or missing LSAs from a neighbor.
- **Link-State Update (LSU) Packet:** Contains LSAs to update neighbors about the network topology.
- **Link-State Acknowledgment (LSAck) Packet:** Confirms receipt of LSAs to prevent retransmission.

OSPFv2 Router Port States:

- **Down:** Initial state of the interface before OSPF starts.
- **Attempt:** Used only on non-broadcast multi-access (NBMA) networks; router actively tries to contact a neighbor.
- **Init:** Hello received from a neighbor, but two-way communication not yet established.
- **Two-Way:** Bidirectional communication established; neighbor recognized; DR/BDR election occurs on broadcast networks.
- **ExStart:** Routers negotiate master/slave roles for sequence number exchange during DBD synchronization; may occur due to MTU mismatch.
- **Exchange:** DBD packets are exchanged; neighbor LSDB summaries compared.
- **Loading:** Link-State Requests (LSR) sent for missing or outdated LSAs; receiving LSU responses.
- **Full:** Fully adjacent; LSDBs synchronized and neighbor relationships complete.

OSPFv2 Network Types, DR/BDR Election, and Metrics

OSPF Network Types:

OSPF supports several network types that affect neighbor discovery, DR/BDR election, timers, and packet handling:

- **Broadcast:** Ethernet and most LANs.
    - Neighbors discovered dynamically via multicast Hellos.
    - DR/BDR election occurs automatically.
    - Default Hello interval: 10 sec, Dead interval: 40 sec.
- **Non-Broadcast Multi-Access (NBMA):** Frame Relay, X.25.
    - No automatic neighbor discovery; neighbors must be configured manually.
    - DR/BDR election occurs manually or via configuration.
    - Default Hello interval: 30 sec, Dead interval: 120 sec.
- **Point-to-Point (P2P):** Direct link between two routers.
    - Neighbors discovered dynamically.
    - No DR/BDR election.
    - Default Hello interval: 10 sec, Dead interval: 40 sec.
- **Point-to-Multipoint:** Treated as multiple P2P links.
    - Neighbors discovered dynamically or statically depending on configuration.
    - No DR/BDR election.
    - Default Hello interval: 30 sec, Dead interval: 120 sec.
- **Point-to-Multipoint Non-Broadcast:** NBMA networks using point-to-multipoint topology.
    - Neighbors must be configured manually.
    - No DR/BDR election.
- **Loopback:** Special interface; always considered up; used for router ID.
    - No DR/BDR election.
    - Hello/Dead timers do not apply.

DR/BDR Election:

- **Designated Router (DR):** Reduces OSPF LSA flooding on broadcast networks.
    - It uses multicast address 224.0.0.6
- **Backup Designated Router (BDR):** Standby to DR if it fails.
- Election Criteria:
    - **Highest** OSPF interface priority (default 1).
    - If tied, **highest** Router ID wins.
- On NBMA networks, DR/BDR can be manually configured.

OSPF Metrics:

- **Cost:** Based on the bandwidth of the interface.
- Formula: `Cost = Reference Bandwidth / Interface Bandwidth`

    - Default reference bandwidth = 100 Mbps.
- Default cost examples (with 100 Mbps reference):
    - 10 Mbps: 10
    - 100 Mbps: 1
    - 1 Gbps: 1 (needs adjustment with modern links)
    - 10 Gbps: 1 (needs adjustment)

Setting Reference Bandwidth:

To properly calculate cost for higher-speed links, adjust the OSPF reference bandwidth:

```
R1(config)# router ospf 1
R1(config-router)# auto-cost reference-bandwidth 10000
```

- The value is in Mbps.
- Example above sets the reference bandwidth to 10,000 Mbps (10 Gbps).