OSPF Basics

1 OSPF Basics

1.1 OSPF Overview

1.1.1 Static vs Dynamic Routing Protocols

> **Static Routes**
>
> - Manually configured.
> - Must be manually adjusted if topology changes.
> - Suitable for small or stable networks.

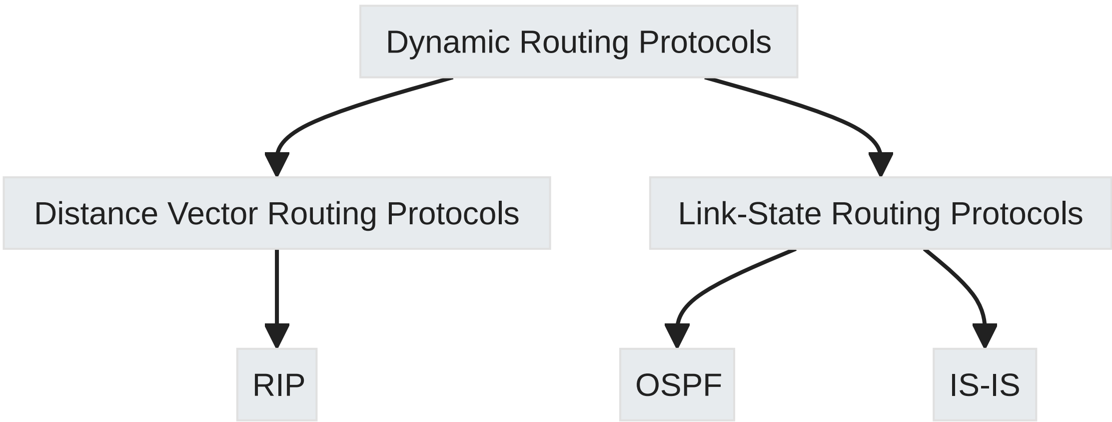
> **Dynamic Routing Protocols**
>
> - Highly flexible, reliable, and scalable.
> - OSPF is a common dynamic protocol used in live networks.

- Must be manually adjusted if topology changes.

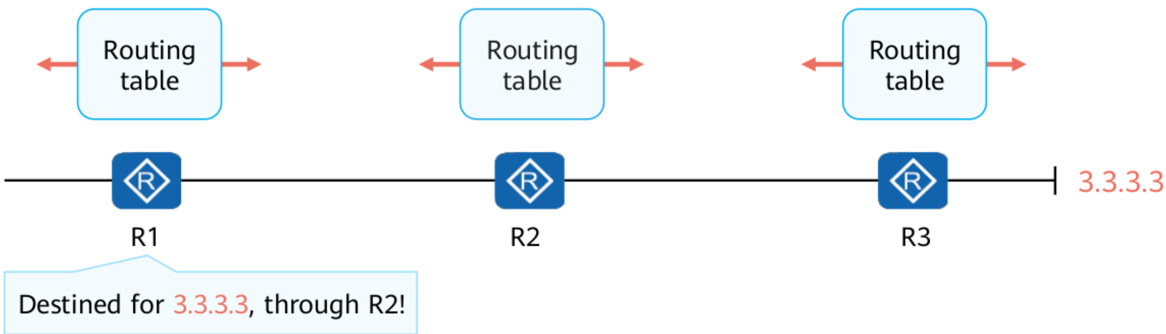
  > - Suitable for small or stable networks.

> **Dynamic Routing Protocols**
>
> - Highly flexible, reliable, and scalable.
> - OSPF is a common dynamic protocol used in live networks.

1.1.2 Classification of Dynamic Routing Protocols



1.1.3 Distance-Vector Routing Protocol

- Distance-vector routing protocols allow routers to determine the best path to a destination based on distance.
- Routers periodically share their routing tables with immediate neighbors.
- Each router has limited knowledge of the overall network topology.
- 

1.1.4 Routed Protocols:

- IPv4
- IPv6

1.1.4.1 Routing Protocol vs Routed Protocol:

- A **routing protocol**, like OSPF or BGP, defines how routers communicate with each other to distribute information that enables them to select routes between any two nodes on a computer network.
- A **routed protocol**, such as IPv4 or IPv6, is used to send user data (payload) through the established network path determined by the routing protocol.

1.1.5 Benefits of OSPF

- **Minimal Routing Traffic:** OSPF reduces control traffic overhead by sending updates only when there's a change in the topology, rather than at regular intervals.
    - OSPF uses multicast addresses 224.0.0.6 to communicate with DRs and BDRs, and 224.0.0.5 for all other OSPF routers (DROthers).

> - **Control traffic** is the signaling information exchanged between network devices to manage and maintain the network, such as routing protocols and handshakes.
> - **Data traffic** is the actual user or application information being transmitted over the network, such as emails, videos, or website content.

- **Rapid Convergence:** OSPF quickly recalculates routes when network changes occur, ensuring minimal disruption in data forwarding.

- **Scalable:** OSPF can support large networks with no limitations on hop count.
- **Accurate Route Metrics:** OSPF calculates the cost of routing paths based on various factors for efficient route selection.

1.1.6 How OSPF Works

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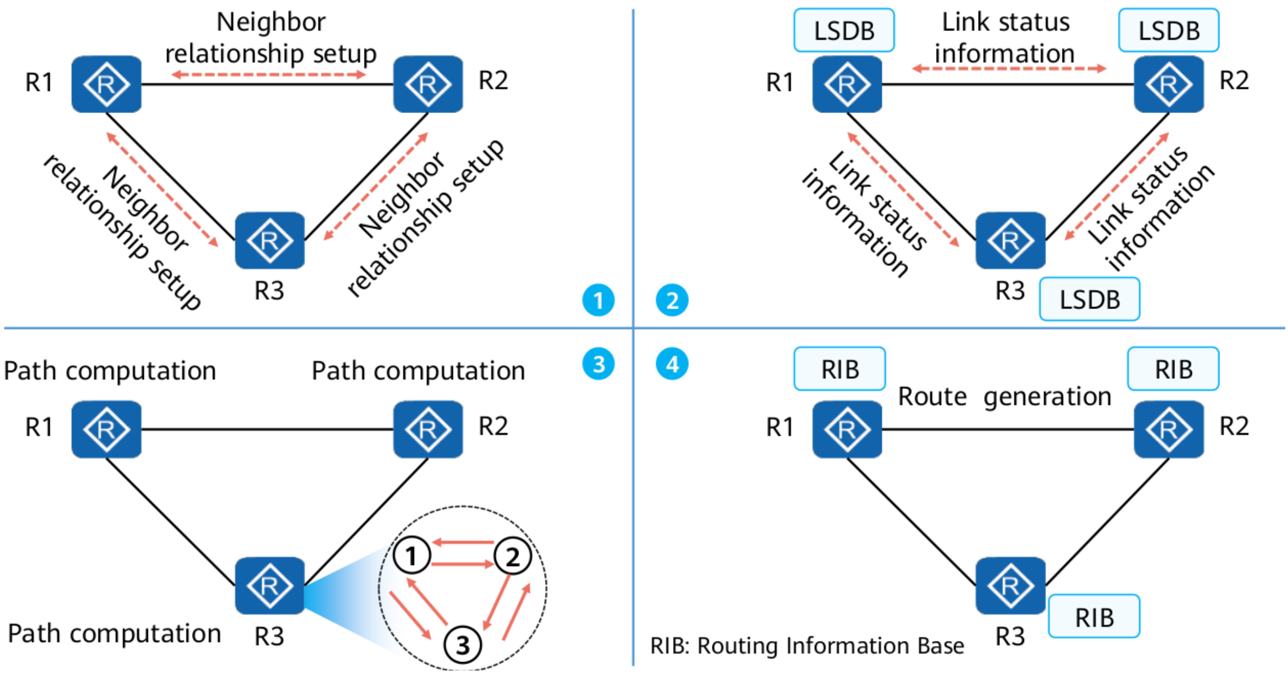
1. **LSA Flooding**: Routers share link status with LSAs (Link State Advertisements).
    - **LSAs (Link State Advertisements):** LSAs are messages that OSPF routers share to inform each other about the status and connections of their network links. contains the interface cost and the relationship between the router and its neighboring routers.
2. **LSDB**: Routers store Link-State Advertisements (LSAs) in their Link State Database (LSDB) to represent the entire network topology.
3. **SPF Algorithm**: Calculates the shortest path to each network segment forming a loop-free tree.

> Based on SPF calculation results,each router installs routes into the routing table.



> **The Routing Information Base (RIB):** is a data table stored in a router or a network switch that lists routes to particular network destinations, and in some cases, metrics associated with those routes.

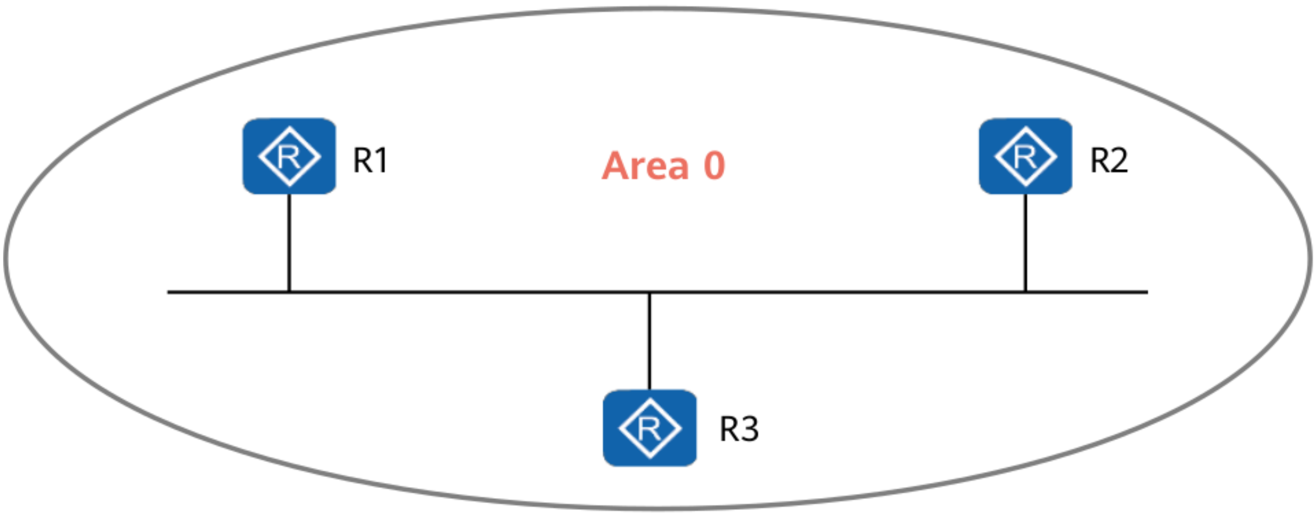
1.1.7 Introduction to OSPF

> **There are two versions:** OSPFv2 for older internet addresses (IPv4) and OSPFv3 for newer addresses (IPv6).

> Instead of sharing entire routes, OSPF routers share information about the status of connections between them.

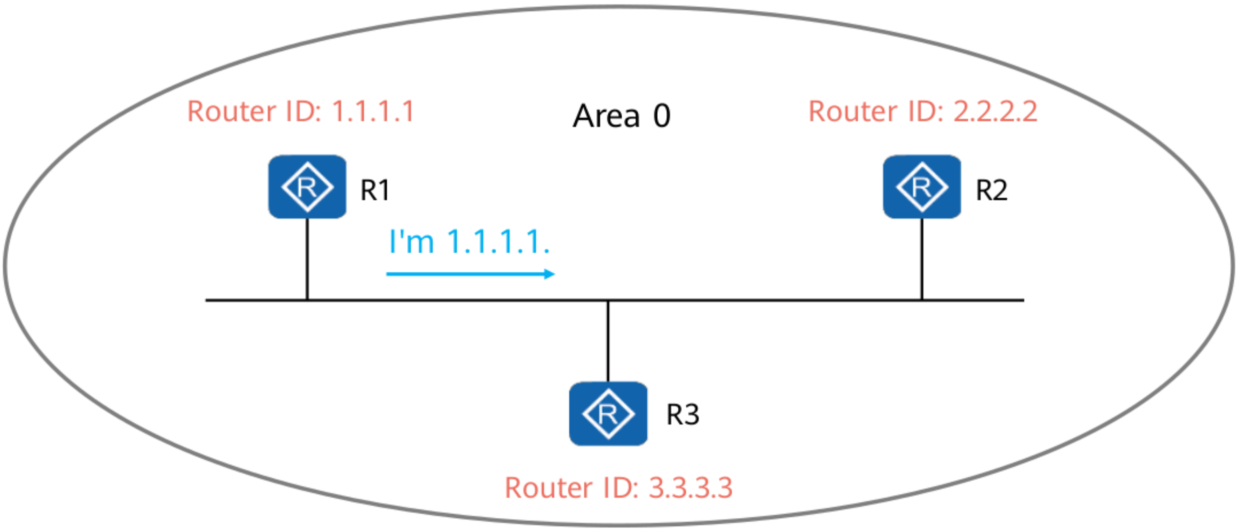
1.1.8 Key Terminology in OSPF

`Area` : Logical grouping identified by an Area ID.



`Router ID` : Unique identifier within an area;Represented same as ipv4 ex 1.1.1.1 ; The router ID can be manually specified or automatically assigned by the system.

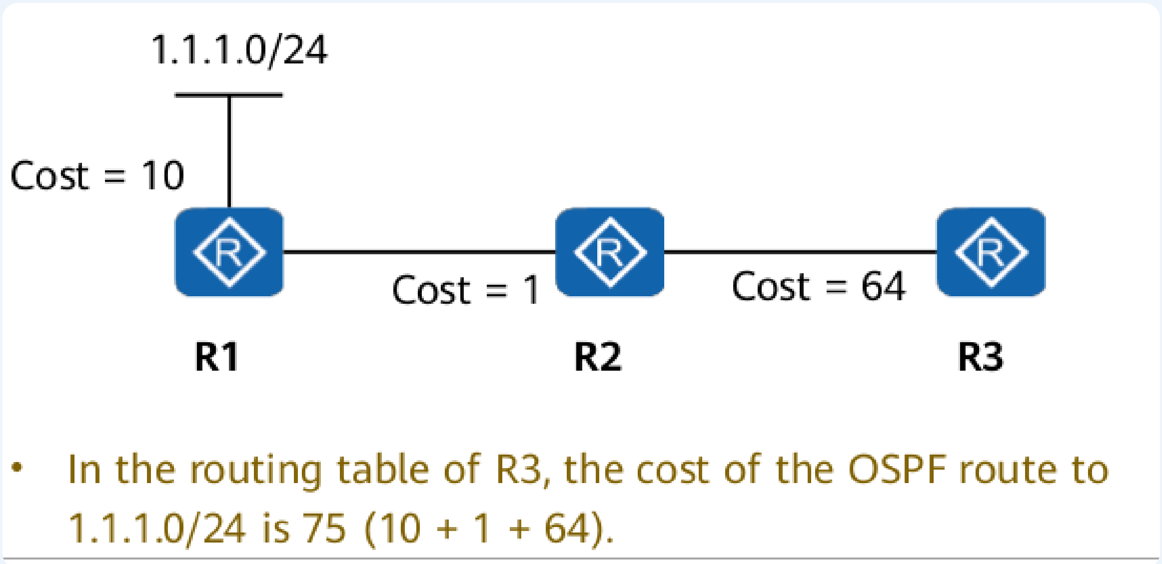
> The system assigns a `Router ID` based on the highest loopback address; if a loopback address is not present, then it selects the highest IPv4 address from the active interfaces.



`Cost Value` : Metric used to determine path selection; lower cost preferred.

Note

- Default cost value = 100 Mbit/s
- formula = $\text{Default cost value } / \text{costs of interfaces}$
- ex.Cost Value of an OSPF Interface
  - Serial interface costs of interfaces= $(1.544 Mbit/s)$
  - $100\ / 1.544$=64 (approximately)
- ex.Accumulated Costs on an OSPF Path



1.1.9 Types of Packets in OSPF

Packet Name	Function
Hello	Is periodically sent to discover and maintain OSPF neighbor relationships.
Database Description	Describes the summary of the local LSDB, which is used to synchronize the LSDBs of two devices.
Link State Request	Requests a needed LSA from a neighbor. LSRs are sent only after DD packets have been successfully exchanged.
Link State Update	Is sent to advertise a requested LSA to a neighbor.
Link State ACK	Is used to acknowledge the receipt of an LSA.

> The Hello interval in OSPF is set to 10 seconds for point-to-point (P2P) or broadcast networks, and 30 seconds for non-broadcast networks, indicating how often Hello packets are sent to maintain adjacency.

1.1.10 Three Types of OSPF Entries

OSPF Neighbor Table Entry:

- This table tracks the OSPF neighbors a router has discovered by exchanging Hello packets, detailing their relationship status and key information like router IDs and interface addresses.
- `display ospf peer` Use the command to view this table, which helps routers determine whom they can share routing information with.

```
<R1> display ospf peer
    OSPF Process 1 with Router ID 1.1.1.1
                   Neighbors
Area 0.0.0.0 interface 10.1.1.1(GigabitEthernet1/0/0)'s neighbors
Router ID:  2.2.2.2     Address:  10.1.1.2     GR State: Normal
    State: Full  Mode:Nbr is  Master  Priority: 1
    DR:  10.1.1.1  BDR: 10.1.1.2   MTU: 0
    Dead timer due in 35  sec
    Retrans timer interval: 5
    Neighbor is up for 00:00:05
    Authentication Sequence: [ 0 ]
```

> The Router Dead Interval is typically four times the Hello interval, after which a non-responsive neighbor is considered down and its adjacency with the local router is terminated.

OSPF LSDB (Link State Database) Entry:

- The LSDB holds all the Link State Advertisements (LSAs) that a router has created or received, forming a complete map of the network topology.
- Use the `display ospf lsdb` command to access this database, which includes details such as LSA type(type) and the advertising router's identity(advRouter) which indicates the router that sends the LSA..

```
<R1> display ospf lsdb
                 OSPF Process 1 with Router ID 1.1.1.1
                        Link State Database
                          Router ID: 0.0.0.0
Type      LinkState ID   AdvRouter   Age  Len   Sequence   Metric
Router    2.2.2.2        2.2.2.2      98  36    8000000B     1
Router    1.1.1.1        1.1.1.1      92  36    80000005     1
Network   10.1.1.2       2.2.2.2      98  32    80000004     0
```

OSPF Routing Table Entry:

- This table is distinct from the main router routing table and contains OSPF-specific paths with details like destination IP address, route cost, and next-hop IP address for packet forwarding decisions.

- To view this information, use the `display ospf routing` command. It shows how OSPF has calculated routes to different networks based on the LSDB.

```
<R1> display ospf routing
OSPF Process 1 with Router ID 1.1.1.1
Routing tables
Routing for Network
Destination        Cost  Type       NextHop        AdvRouter       Area
1.1.1.1/32         0     stub       1.1.1.1        1.1.1.1         0.0.0.0
10.1.1.0/20        1     Transit    10.1.1.1       1.1.1.1         0.0.0.0
2.2.2.2/32         1     stub       10.1.1.2       2.2.2.2         0.0.0.0

Total Nets: 3
Intra Area: 3  Inter Area: 0  ASE: 0  NSSA: 0
```

1.2 OSPF Working Mechanism

1.2.1 Neighbor Relationship and Adjacency

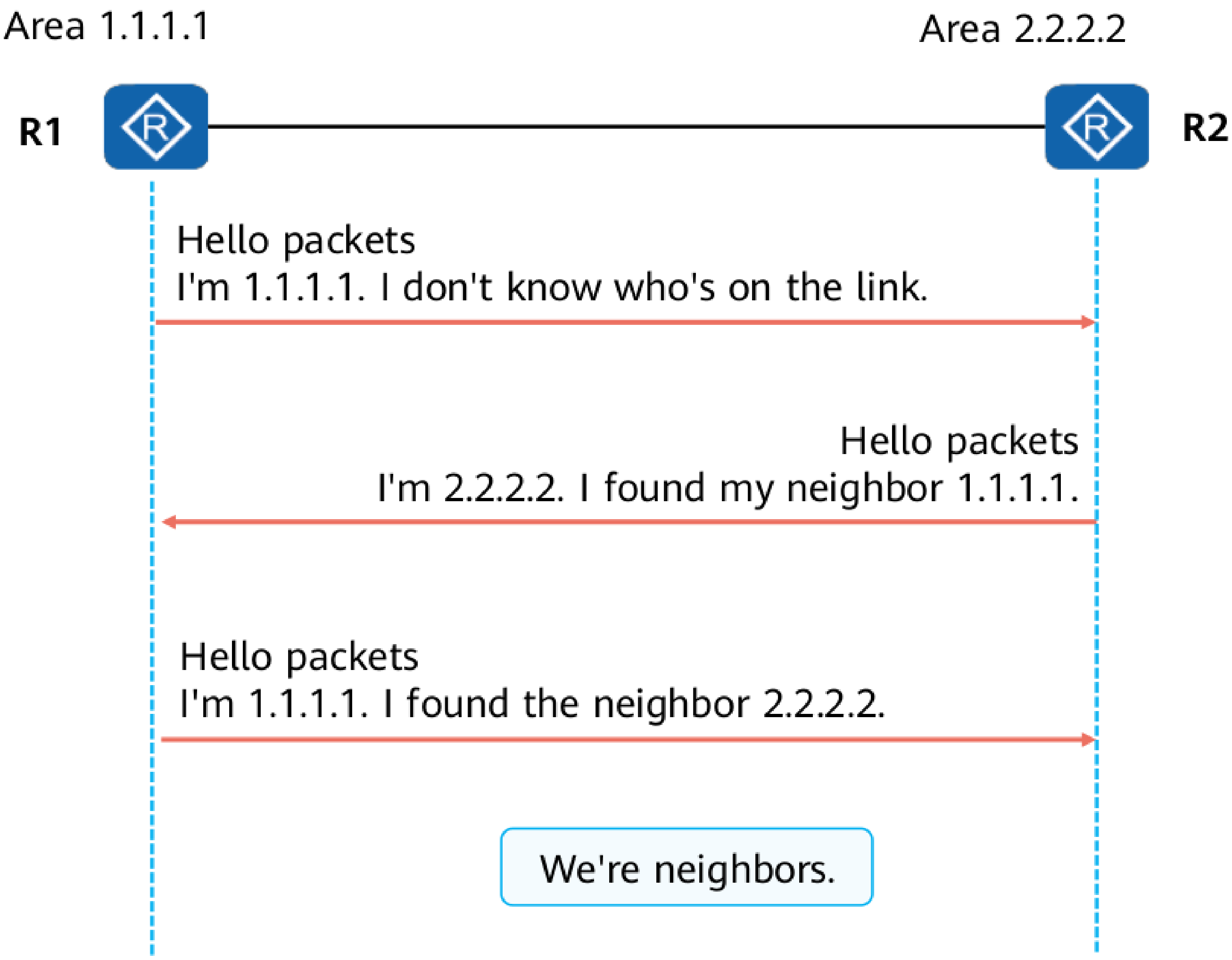
- **Neighbor Relationship**: Two routers running OSPF become aware of each other by exchanging Hello packets.
- **Adjacency**: After LSDB sync, routers calculate routes independently.

1.2.2 Establishing OSPF Adjacency - Steps Overview

1.2.2.1 Step 1: Neighbor Discovery

- Bidirectional communication is established using Hello packets.
- The `Init` phase moves to the `2-way` phase once both sides find each other.

- **Init:** phase is when one device starts communication.
- **2-way:** phase is when both devices acknowledge each other and start a two-sided conversation.



1.2.2.2 Step 2: Master/Slave Negotiation

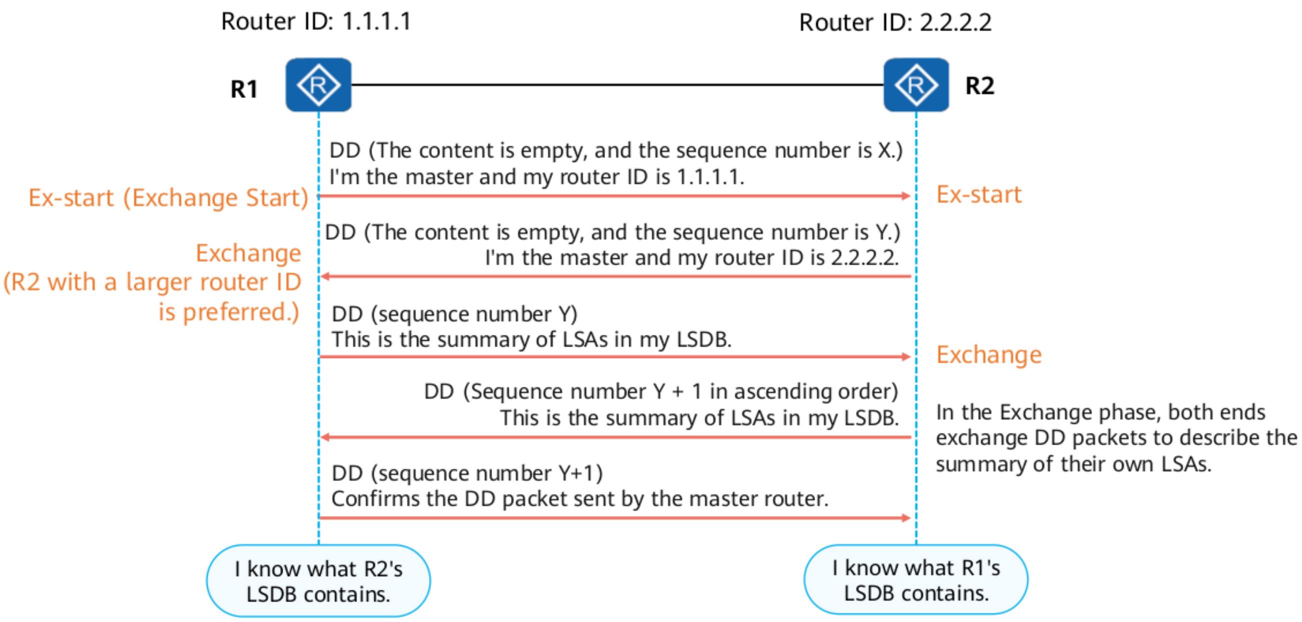
- Exchange starts (`Exstart`) with empty DD (Database Description) packets.
  - **Exstart state:** is the initial phase where routers establish adjacency by exchanging empty Database Description packets to prepare for synchronization of their link-state databases.
- Router with the higher Router ID becomes the master during negotiation.

> A router with a priority of 0 will not participate in the DR/BDR election process in OSPF, effectively opting out of the role.

1.2.2.3 Step 3: LSDB Information Exchange

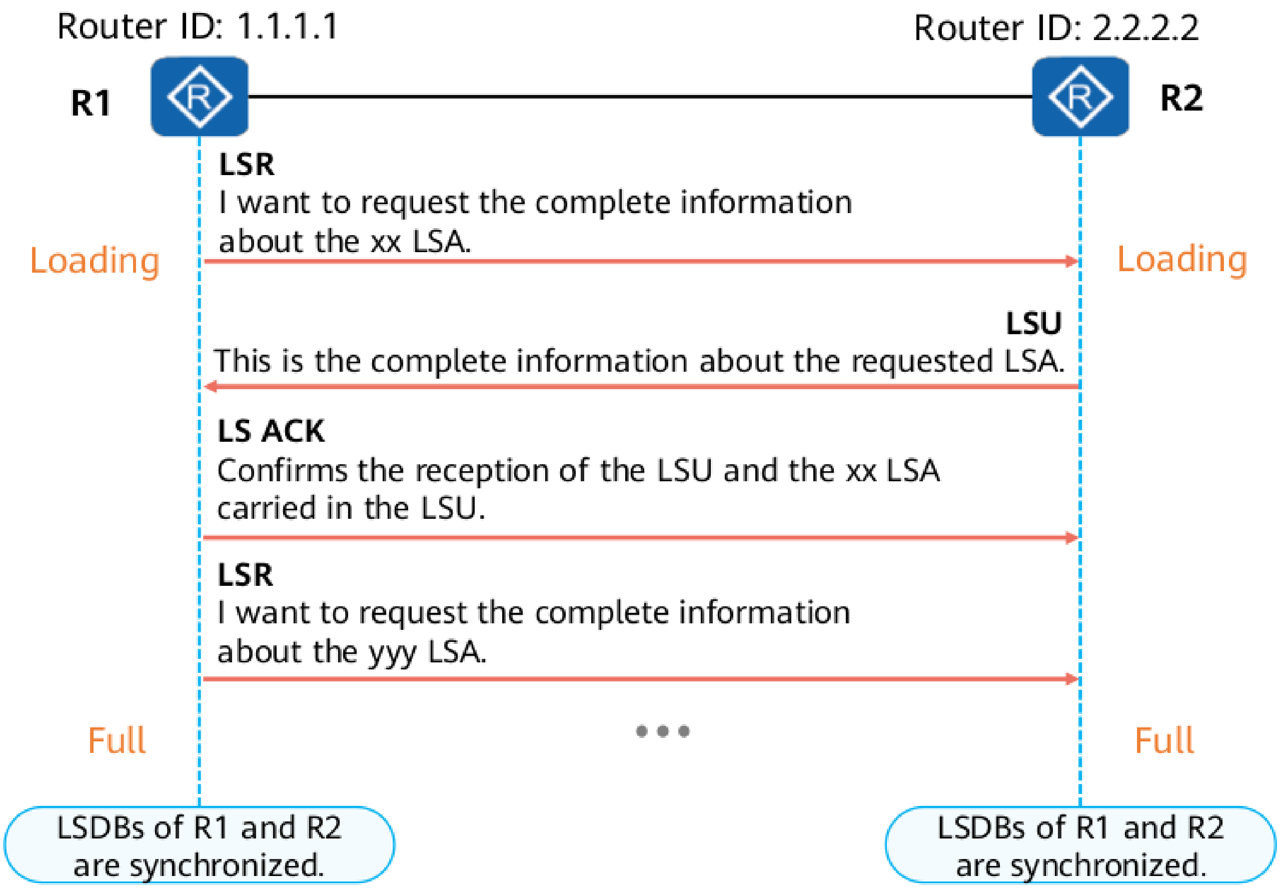
- Exchange of DD packets containing summaries of LSAs (Link-State Advertisements).
- The neighbor status changes from `Exstart` to `Exchange`.
  - **Exchange state:** is when neighboring routers send each other their respective link-state advertisements (LSAs) to construct a complete and accurate map of the network topology.

- After sending the last DD packet, R1 changes the neighbor status to `Loading`.
  - **Loading state:** indicates that a router is receiving and processing database description packets (DD) from a neighbor to synchronize its link-state database with that of the neighbor's.



1.2.2.4 Step 4: LSDB Synchronization

- LSR (Link-State Request), LSU (Link-State Update), and LSAck exchanged for detailed LSA information.

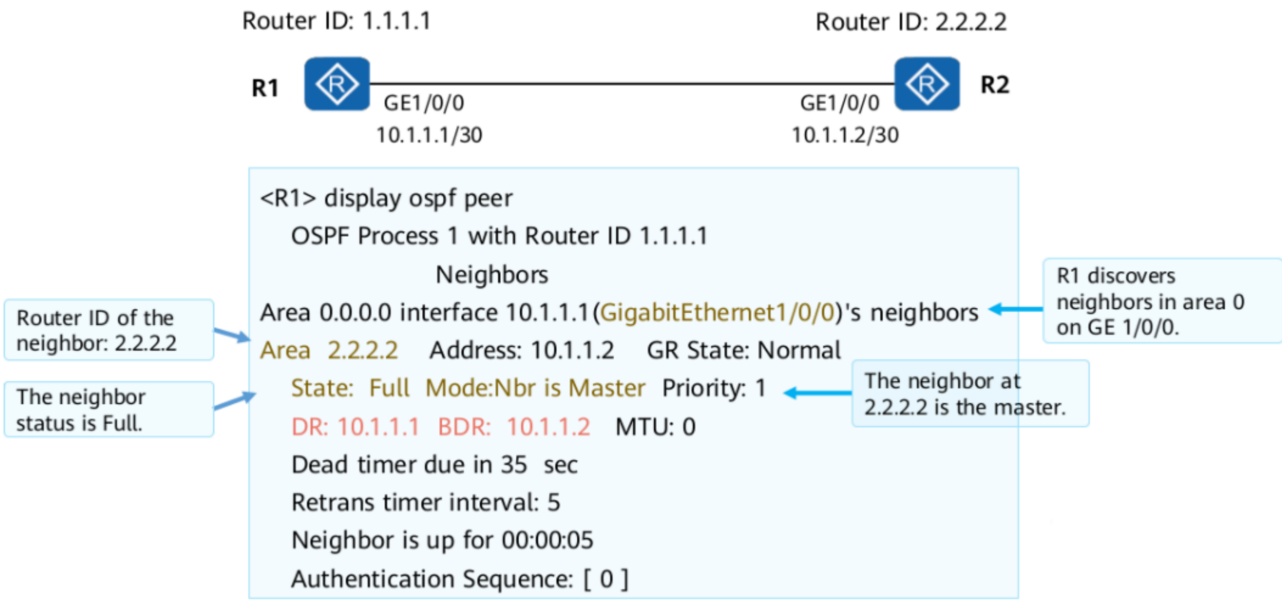


> The Link State Database (LSDB) must be consistent across all routers within the same OSPF area to ensure accurate network topology representation and routing.

1.2.2.5 Step 5: Route Calculation

- Performed independently on each router after synchronization.

1.2.3 OSPF Neighbor Table



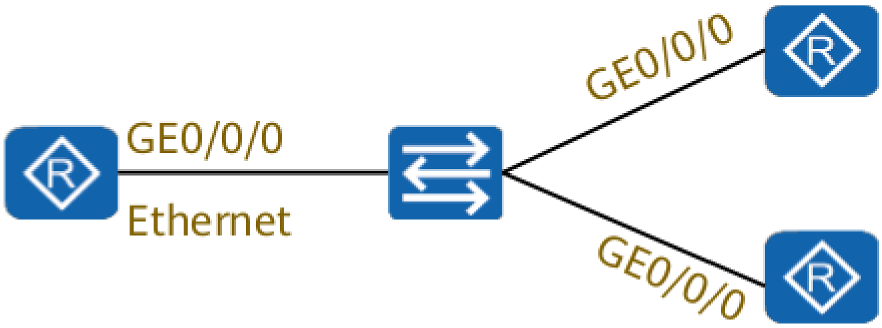
Field	Explanation	
OSPF Process	Identifier for the local OSPF process and router ID.	
Area ID	Unique identifier for the area to which the neighbor belongs.	
Address	IP address of the neighbor's interface.	
GR State	Graceful Restart status, showing if it is normal or in a GR state.	
State	Current state of the OSPF neighbor relationship.ex(Init, 2-Way, ExStart, Exchange, Loading, or Full)	
Mode	Indicates if the local device is master or backup during exchanges.	
Priority	Neighbor's priority for Designated Router (DR) election.	
DR	IP address of the Designated Router on the link.	
BDR	IP address of the Backup Designated Router on the link.	
MTU	Maximum Transmission Unit size on the neighbor's interface.	
Retrans timer interval	Time interval for retransmitting Link State Advertisements (LSAs).	
Authentication Sequence	Number used to identify authentication sequence with neighbor.	

Field	Explanation	
	adcast Network Type `(NBMA)`	

1.2.4 OSPF Network Types

> To establish a neighbor relationship, the OSPF interface network types on both sides of a link must match.

1.2.4.1 Broadcast Network Type `(BMA)`

- Typical on Ethernet networks. Supports broadcast.
- 

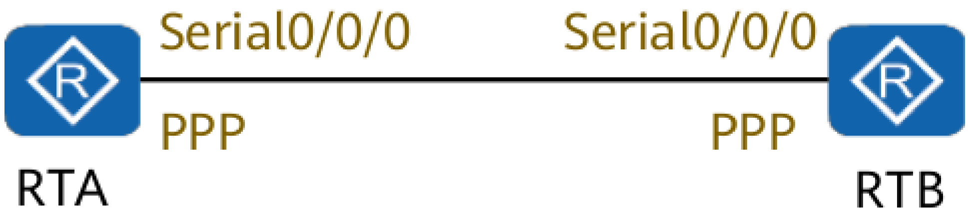
1.2.4.2 Non-Broadcast Network Type `(NBMA)`

- environment that allows multiple network devices to access but does not support broadcast.

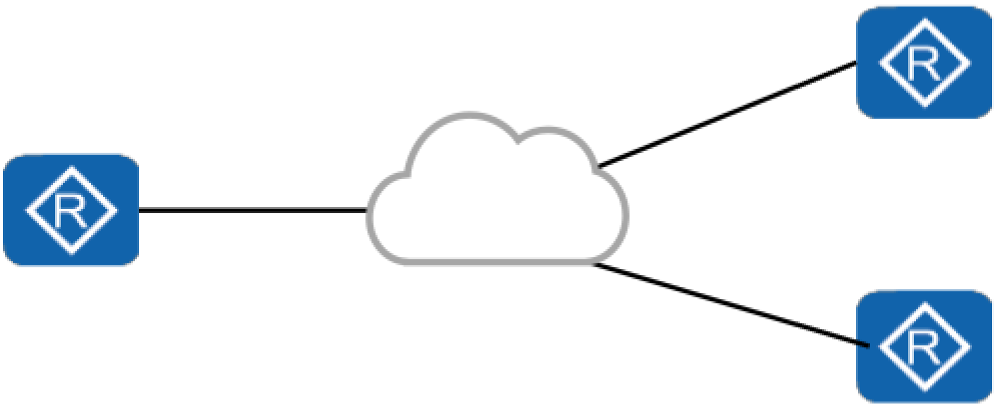
> an NBMA network connects multiple devices so they can communicate but restricts them from sending data to all devices at once through broadcasting. Instead, communication must be directed specifically from one device to another using pre-established paths or addressing methods.

- **Example:** Frame Relay networks. Does not support broadcast.

1.2.4.3 Point-to-point `(P2P)`

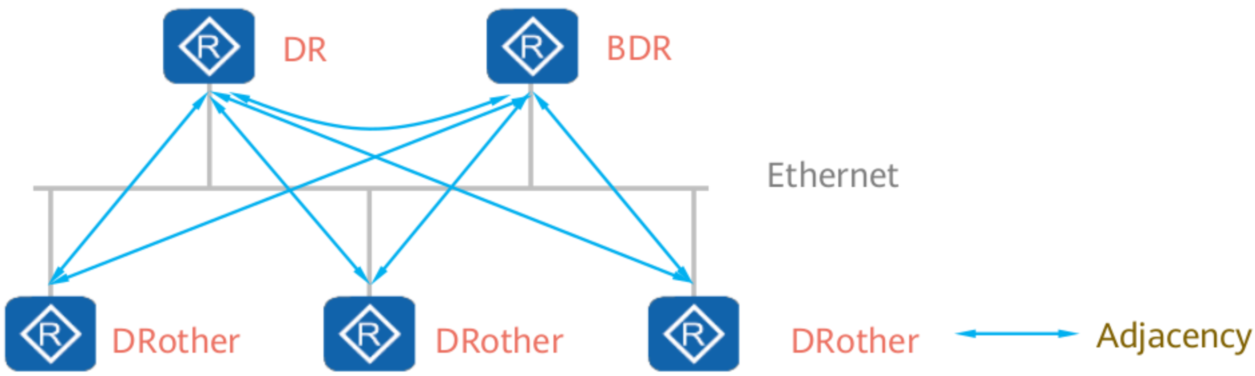
- A link that connects exactly two routers. Common with PPP.
- Default network type of the OSPF interface is P2P.
- 

1.2.4.4 Point-to-Multipoint `(P2MP)`

- single source transmits data to multiple destinations or users.
- Bundles multiple P2P links. Not a default type; set manually when needed.
- 

1.2.5 DR and BDR Concept

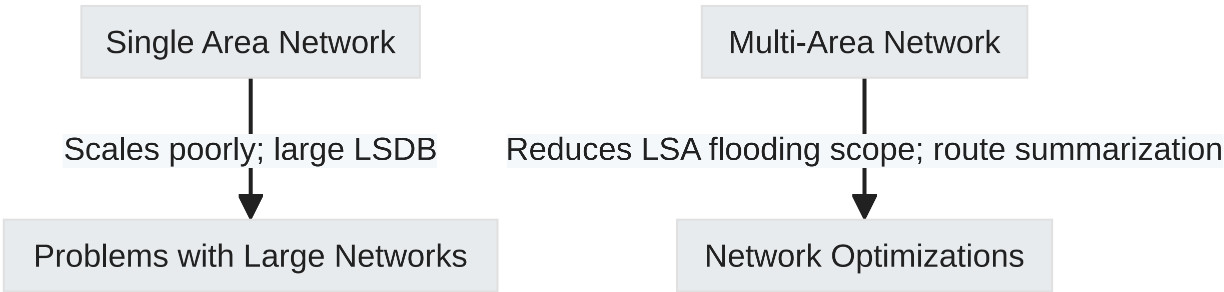
> Designated Router (DR) and Backup Designated Router (BDR) reduce the number of adjacencies needed on MA networks like Ethernet.



> The interface with the highest priority becomes the Designated Router (DR); if priorities equal, the highest router ID wins, and once elected, DR does not change unless there's a restart or topology change.

1.2.6 OSPF Area Concepts

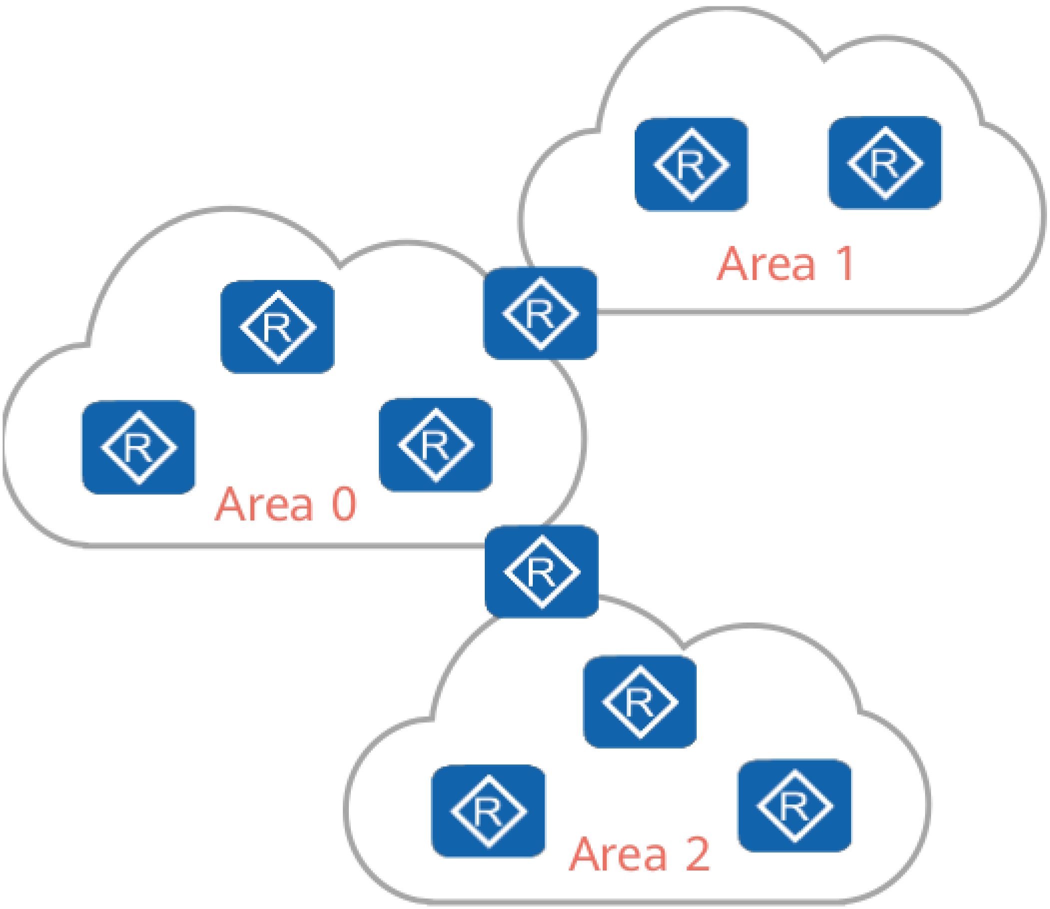
1.2.6.1 Single Area vs Multi-Area Networking



> Routers within the same area share and keep their map of the network's layout Uniform

> Domain is a group of connected devices using the same rules to exchange routing information.

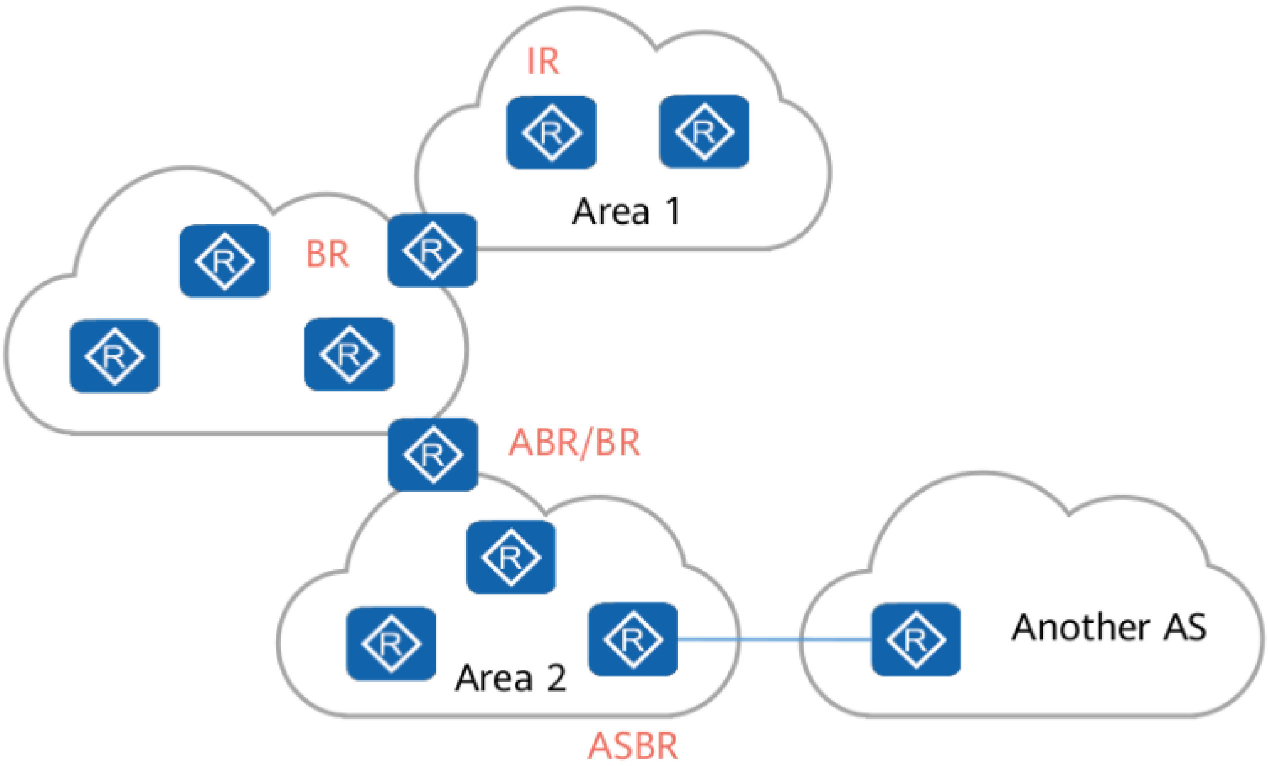
1.2.6.2 Types of Areas in OSPF



Area Type	Description	Notes
Backbone Area (Area 0)	Core area through which all other areas communicate	Mandatory for multi-area networks
Non-backbone Area	Any area that isn't the backbone	Must connect to backbone area

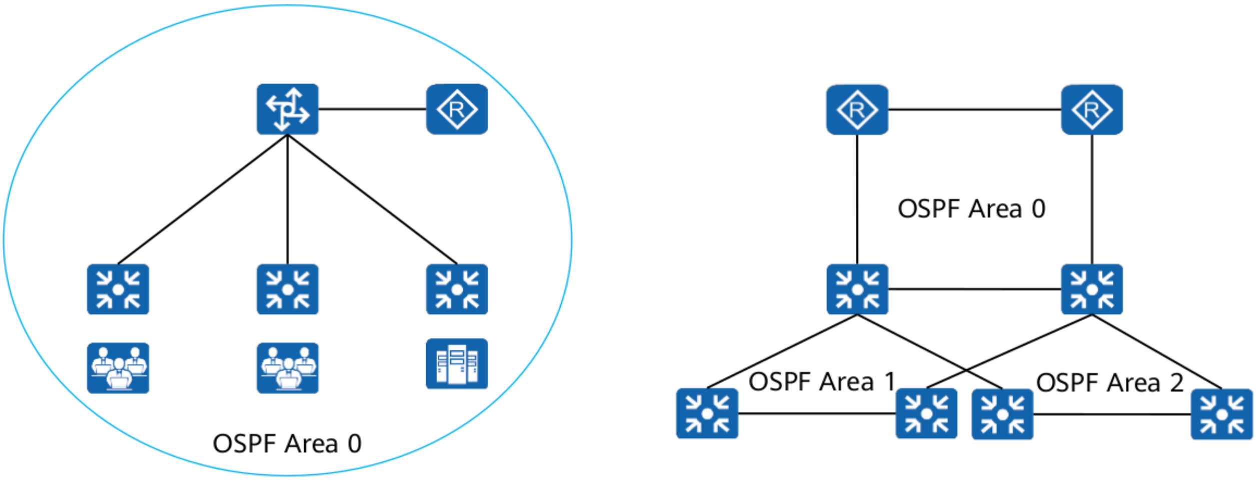
> The backbone area (Area 0) acts as a central hub that connects all other areas to prevent routing loops. Non-backbone areas only know how to reach the backbone and trust it to route to other areas. Direct connections between non-backbone areas are avoided to prevent routing inconsistencies and looping paths.

1.2.6.3 Types of OSPF Routers Based on Function



Router Type	Description
Internal Router (IR)	All interfaces within one area
Area Border Router (ABR)	Connects multiple areas; has an interface in Area 0
Backbone Router (BR)	At least one interface in the backbone area
Autonomous System Boundary Router (ASBR)	Exchanges routes with external AS; imports external routes

1.2.6.4 Typical Networking Scenarios



Small- and medium-sized enterprise network (single area)

Large enterprise network (multiple areas)

- For small-scale enterprises:

> Use a single-area network due to limited scale and simplicity.

- For large-scale enterprises:

> Adopt a multi-area approach to enhance scalability and performance.

1.2.7 OSPF authentication

> OSPF supports multiple levels of authentication; when configured on an interface, routers must share the same password to establish a neighbor relationship.

> An OSPF silent interface is configured to prevent forming neighbor relationships over that interface, useful for security or topology reasons.

1.3 Typical OSPF Configuration

1.3.1 Creating and Running an OSPF Process

- Syntax: `ospf [<process-id> | router-id <router-id>]`
  - Default process ID is `1`.

> The process-id is a unique identifier for a single instance of the OSPF routing protocol running on a router, allowing for multiple separate OSPF processes on the same device, its benefit to separating and managing different networks or traffic classes.

- Multiple processes can run on the same device.
- The `router-id` specifies the ID of a device.

Note

Always ensure that each OSPF router has a unique `router-id`.

Example

```
[Huawei] ospf 1 router-id 1.1.1.1
```

1.3.2 Configuring OSPF Area

1.3.2.1 Creating OSPF Area and Entering View

- **Syntax:** `area <area-id>`
  - Area IDs can be decimal or dotted decimal notation.

Example

```
[Huawei-ospf-1] area 0
```

1.3.3 Interface Configuration for OSPF

1.3.3.1 Specifying Interface for OSPF

- **Syntax:** `network <network-address> <wildcard-mask>`
- Used for interfaces on a router will participate in OSPF.
- `<network-address>` : is the IP address that represents the network you want to include in OSPF.
- `<wildcard-mask>` : Reverse of Mask

Example

```
[Huawei-ospf-1-area-0.0.0.0] network 10.1.12.0 0.0.0.3
```

1.3.4 Setting Interface Cost and Priority

1.3.4.1 Setting an Interface Cost

```markdown
[Huawei-GE1/0/1] ospf cost <cost-value>
```

- Cost for an OSPF interface.
- By default, OSPF automatically calculates the cost of an interface based on the interface bandwidth.

- The cost value is an integer ranging from 1 to 65535.

1.3.4.2 Setting Bandwidth Reference Value for Cost Calculation

```markdown
[Huawei-ospf-1] bandwidth-reference <value>
```

- Bandwidth reference value that is used to calculate interface costs.
- The value ranges from 1 to 2147483648, in Mbit/s. The default value is 100 Mbit/s.

1.3.4.3 Setting DR Priority of an Interface

```markdown
[Huawei-GigabitEthernet0/0/0] ospf dr-priority <priority-value>
```

- Priority for an interface that participates in DR election.
- The value ranges from 0 to 255.

1.3.5 Verification Commands

> **Tip**
>
> After configuring OSPF, always verify that neighbors are established and routes are learned properly.

1.3.5.1 Check Neighbor Table

Markdown

```
<R2> display ospf peer brief
```

```
<R2> display ospf peer brief
          OSPF Process 1 with Router ID 2.2.2.2
                   Peer Statistic Information
 ----------------------------------------------------------------------------
 Area Id        Interface                   Neighbor id      State
 0.0.0.0       GigabitEthernet0/0/0          1.1.1.1          Full
 0.0.0.1       GigabitEthernet0/0/1          3.3.3.3          Full
 ----------------------------------------------------------------------------
```

1.3.5.2 Check Routing Table

Markdown

```
<R1> display ip routing-table
```

```
<R1>display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing tables: Public
         Destinations : 10       Routes : 10
Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface
        1.1.1.1/32      Direct   0    0           D   127.0.0.1         LoopBack0
        3.3.3.3/32      OSPF    10   2           D   10.1.12.2       GigabitEthernet 0/0/0
      10.1.12.0/30     Direct   0    0           D   10.1.12.1       GigabitEthernet 0/0/0
...
<R1>ping -a 1.1.1.1 3.3.3.3
  PING 3.3.3.3: 56  data bytes, press CTRL_C to break
    Reply from 3.3.3.3: bytes = 56 Sequence = 1 ttl = 254 time = 50 ms
...
```