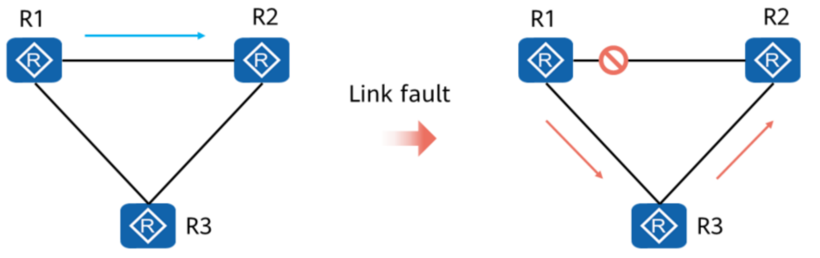
OSPF Basics

Contents

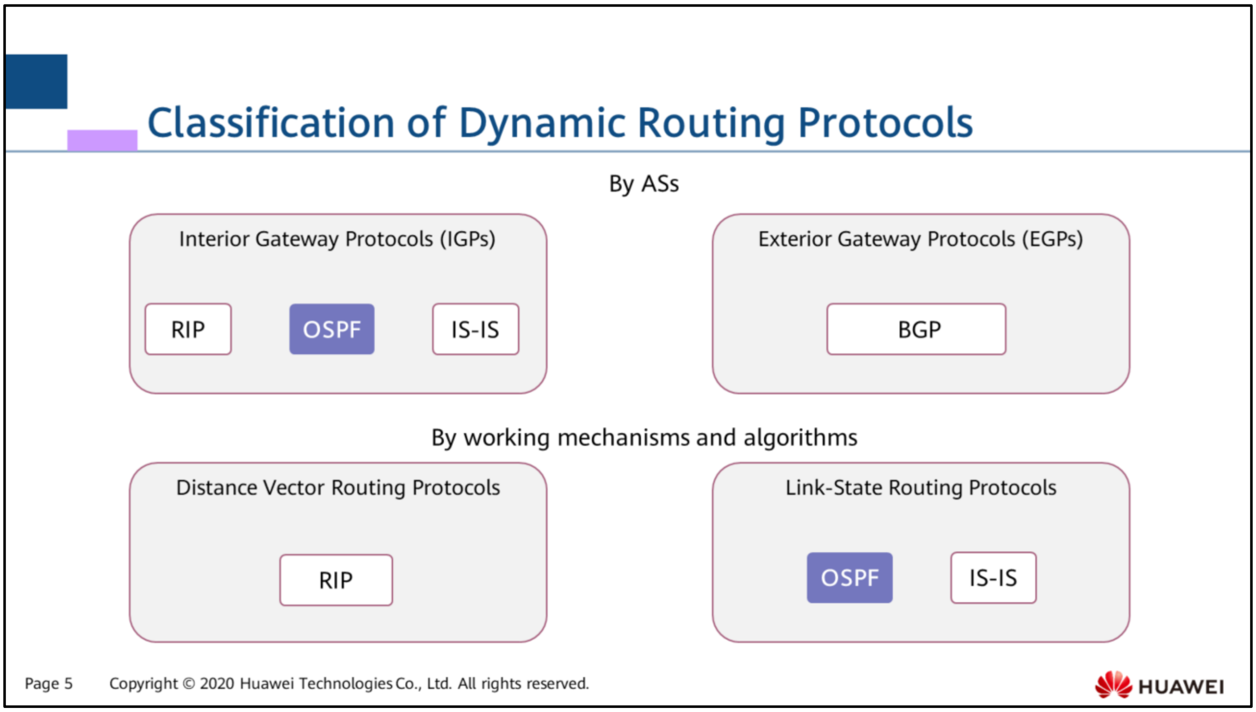
Why Are Dynamic Routing Protocol Used?

- Static routes have the following disadvantages:
  - Unable to adapt to large-scale networks
  - Unable to dynamically respond to network changes



R1-to-R2 static route

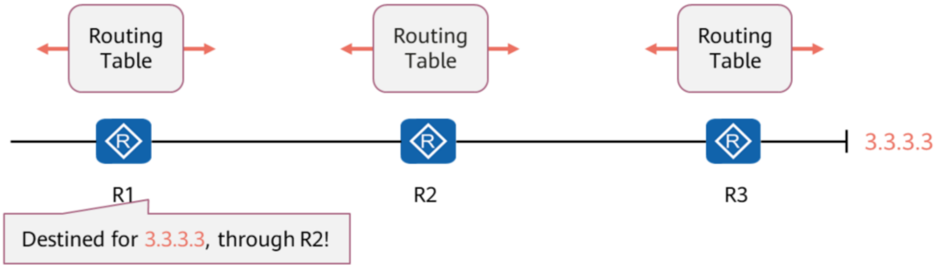
Manually configured static route R1-R3-R2



- BGP uses the path-vector algorithm, which is a modified version of the distance-vector algorithm.

Distance-Vector Routing Protocol

- A router running a distance-vector routing protocol periodically floods routes.
- Each router on a network is clear only about where the destination is and how far the destination is, but unclear about the whole network topology.



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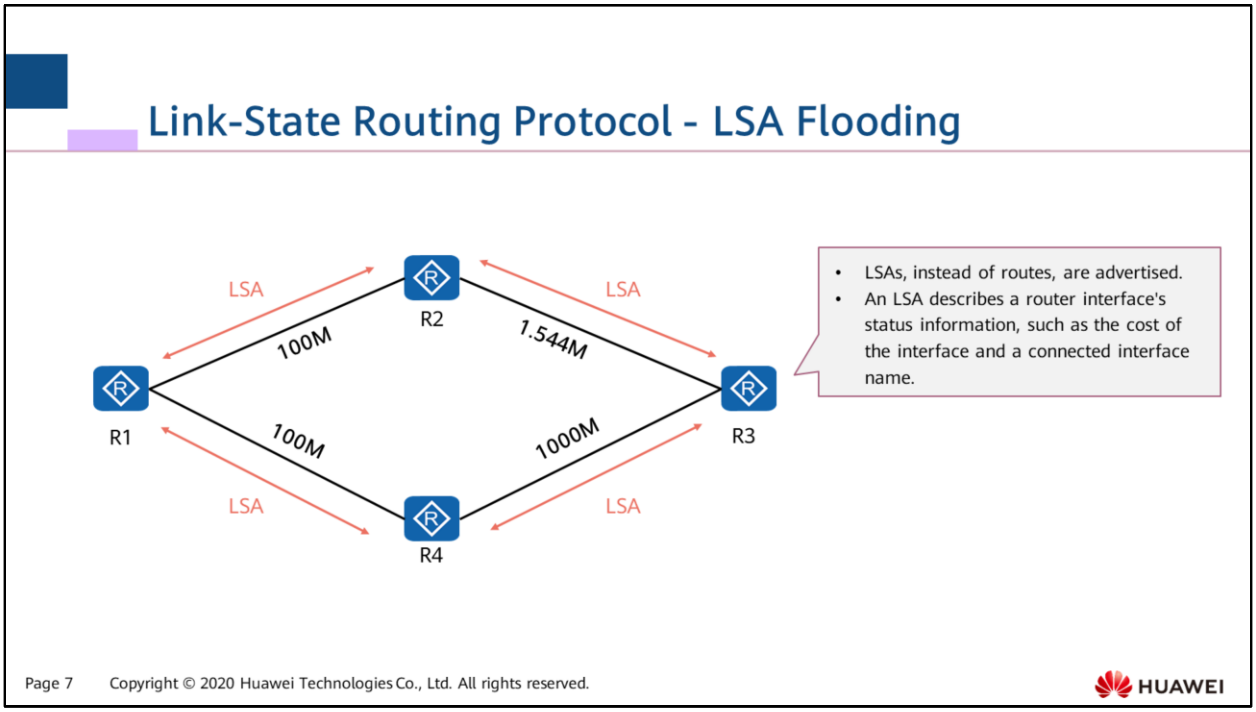
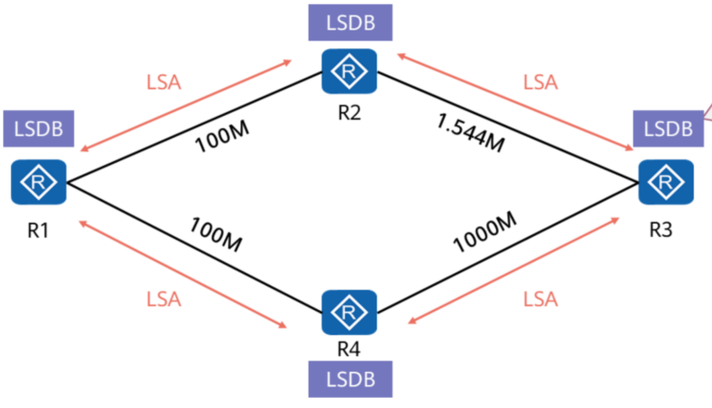


- Each router generates an LSA that describes status information about its directly connected interface. The LSA contains the interface cost and the relationship between the router and its neighboring routers.

Link-State Routing Protocol - LSDB Creation



- The router stores LSAs in the LSDB.
- The LSDB contains the description of all router interfaces on the network.
- The LSDB contains the description of the entire network topology.

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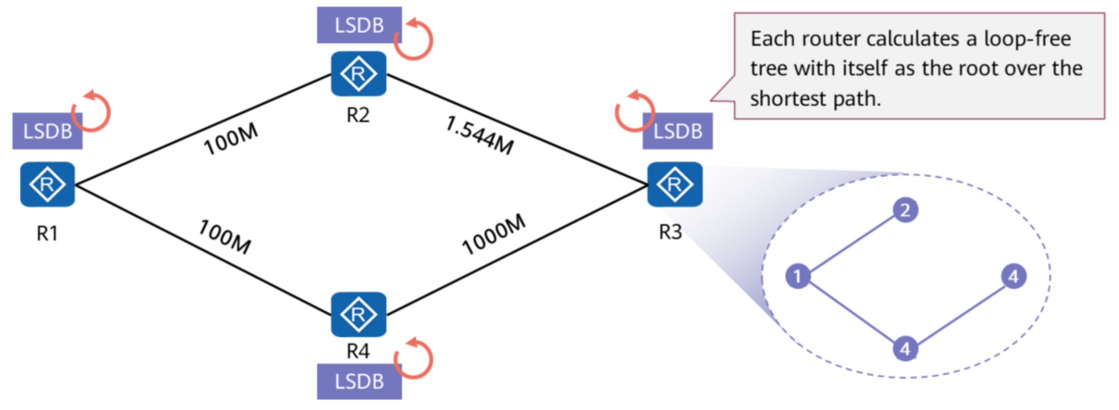
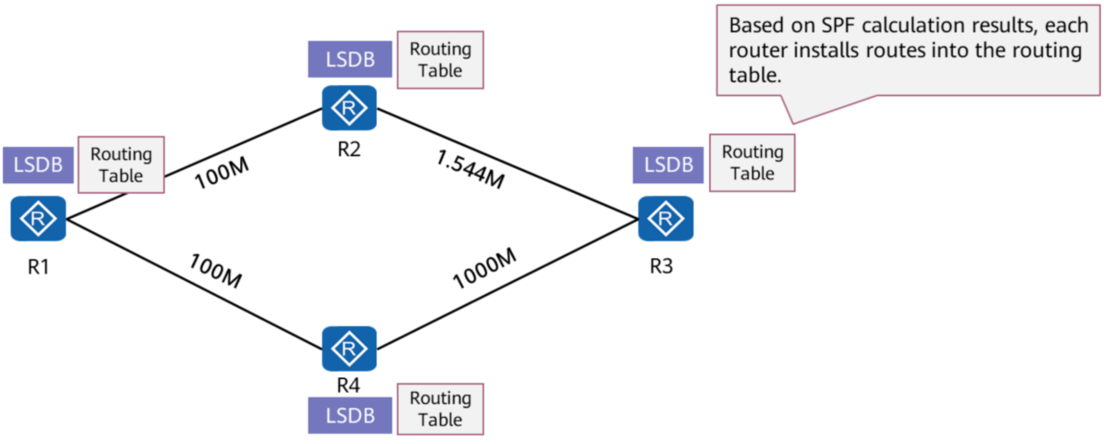
Link-State Routing Protocol - SPF Calculation



- SPF is a core algorithm of OSPF and used to select preferred routes on a complex network.

Link-State Routing Protocol - Routing Table Generation



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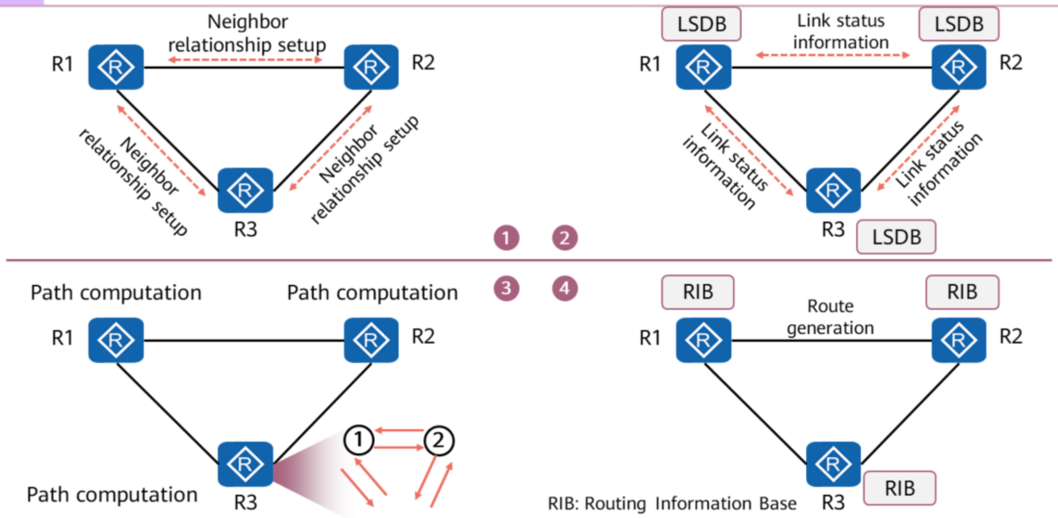
Summary of Link-State Routing Protocols



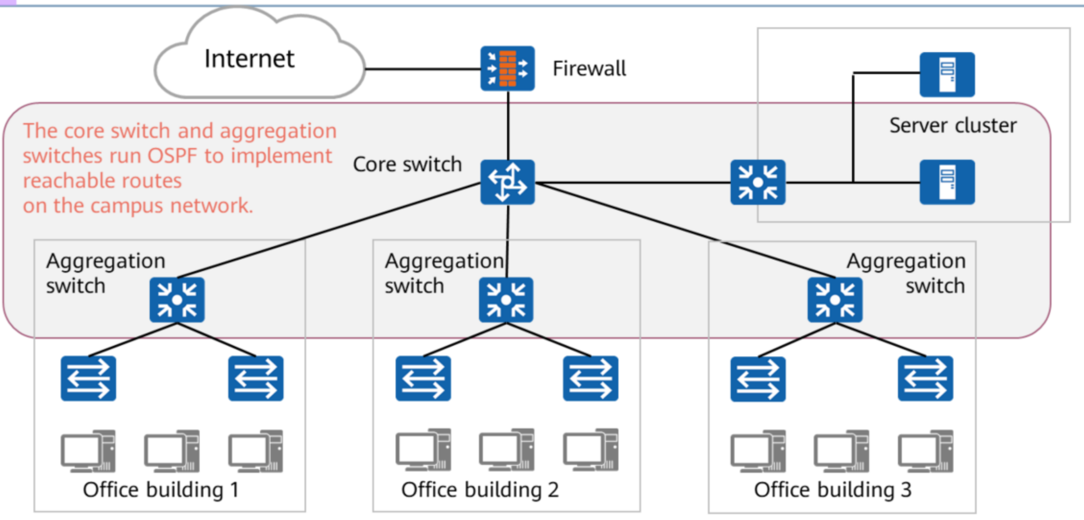
- The implementation of a link-state routing protocol is as follows:
  - Step 1: Establishes a neighbor relationship between neighboring routers.
  - Step 2: Exchanges link status information and synchronizes LSDB information between neighbors.
  - Step 3: Calculates an optimal path.
  - Step 4: Generates route entries based on the shortest path tree and loads the routing entries to the routing table.

Contents

Introduction to OSPF

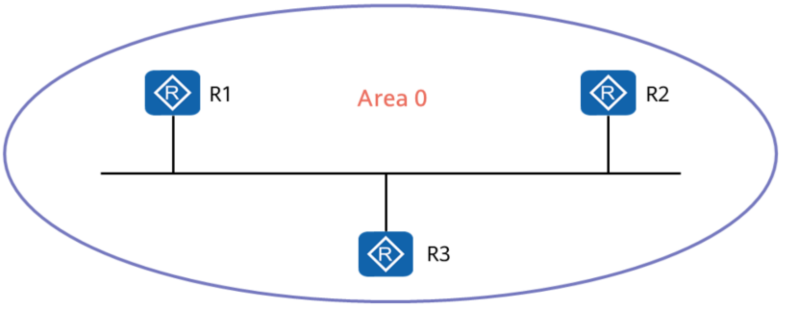
- OSPF is a typical link-state routing protocol and one of the widely used IGPs in the industry.
- OSPFv2, as defined in RFC 2328, is designed for IPv4. OSPFv3, as defined in RFC 2740, is designed for IPv6. Unless otherwise specified, OSPF in this presentation refers to OSPFv2.
- OSPF routers exchange link status information, but not routes. Link status information is key information for OSPF to perform topology and route calculation.
- An OSPF router collects link status information on a network and stores the information in the LSDB. Routers are aware of the intra-area network topology and be able to calculate loop-free paths.
- Each OSPF router uses the SPF algorithm to calculate the shortest path to a specific destination. Routers generate routes based on these paths and install the routes to the routing table.
- OSPF supports the variable length subnet mask (VLSM) mechanism and manual route summarization.
- The multi-area design enables OSPF to support a larger network.

OSPF Application on a Campus Network



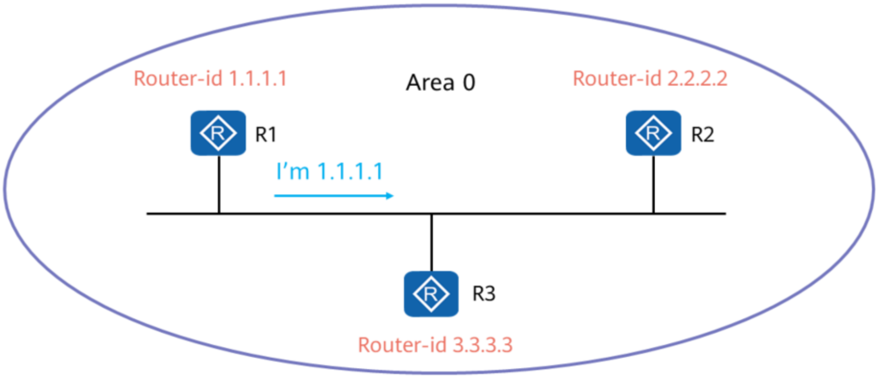
Basic OSPF Concepts: Area

- The OSPF area keyword identifies an OSPF area.
- The area is considered as a logical group, and each group is identified by an area ID.



Basic OSPF Concepts: Router ID

- A router ID uniquely identifies a router in an OSPF area.
- The router ID can be manually specified or automatically assigned by the system.

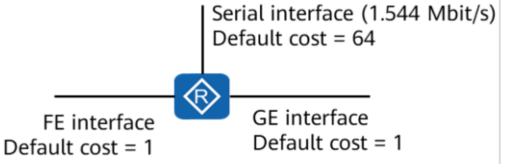


- In actual projects, OSPF router IDs are manually set for devices. Ensure that the router IDs of any two devices in an OSPF area are different. Generally, the router ID is set the same as the IP address of an interface (usually a Loopback interface) on the device.

Basic OSPF Concepts: Cost Value

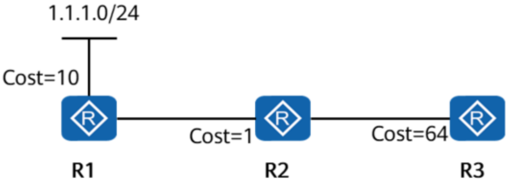
- OSPF uses costs as route metric values. Each OSPF-enabled interface maintains a cost value. Default cost value = $\frac{\text{100 Mbit/s}}{\text{Interface bandwidth}}$, where, 100 Mbit/s is the default reference value specified by OSPF and is configurable.

Cost Value of an OSPF Interface



- Each OSPF interface has a specific cost because of the particular bandwidth value.

Accumulated Costs on an OSPF Path



- In the routing table of R3, the cost of the OSPF route to 1.1.1.0/24 is 75 (10 + 1 + 64).

OSPF Packet Types

- There are five types of OSPF protocol packets and implement different functions in interaction between OSPF routers.

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.

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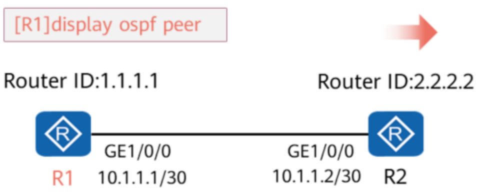
Three Types of OSPF Entries - Entries in the Neighbor Table

- OSPF provides entries in three important tables: OSPF neighbor table, LSDB table, and OSPF routing table. For the OSPF neighbor table, you need to know:
  - Before OSPF transmits link status information, OSPF neighbor relationships must be established.
  - OSPF neighbor relationships are established by exchanging Hello packets.
  - The OSPF neighbor table describes the status of the neighbor relationship between OSPF routers. You can run the **display ospf peer** command to view status information.



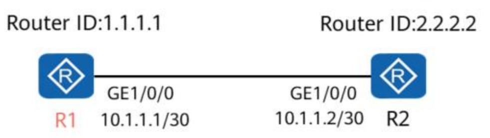

```
<R1> display ospf peer
   OSPF Process 1 with Router ID 1.1.1.1
                 Neighbors
Area 0.0.0.0 interface 10.1.1.1(GigabitEthernet1/0/0)'s neighbors
Router ID: 2.2.2.2    Address: 10.1.1.2    GR State: Normal
   State: Full  Mode:Nbr is  Master  Priority: 1
   DR: 10.1.1.1  BDR: 10.1.1.2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


- The OSPF neighbor table contains much key information, such as router IDs and interface addresses of neighboring devices. For more details, see "OSPF Working Mechanism".

Three Types OSPF Entries - Entries in the LSDB Table

- For the OSPF LSDB table, you need to know:
  - An LSDB stores LSAs generated by a router itself and received from neighbors. In this example, the LSDB of R1 contains three LSAs.
  - The **Type** field indicates an LSA type, and the **AdvRouter** field indicates the router that sends the LSA.
  - Run the **display ospf lsdb** command to query the LSDB.

[R1]display ospf lsdb



<R1> display ospf lsdb

OSPF Process 1 with Router ID 1.1.1.1

Link State Database

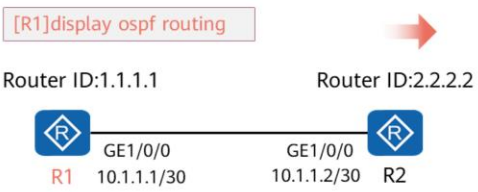
Area: 0.0.0.0

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

- For more information about LSAs, see information provided in HCIP-Datacom courses.

Three Types of OSPF Entries - Entries in the OSPF Routing Table

- For the OSPF routing table, you need to know:
  - The OSPF routing table and the router routing table are different. In this example, the OSPF routing table contains three routes.
  - An OSPF routing table contains information, such as the destination IP address, cost, and next-hop IP address, which guides packet forwarding.
  - Run the **display ospf routing** command to query the OSPF routing table.




```
<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
```


- For more information about the OSPF routing table, see information provided in HCIP-Datacom courses.

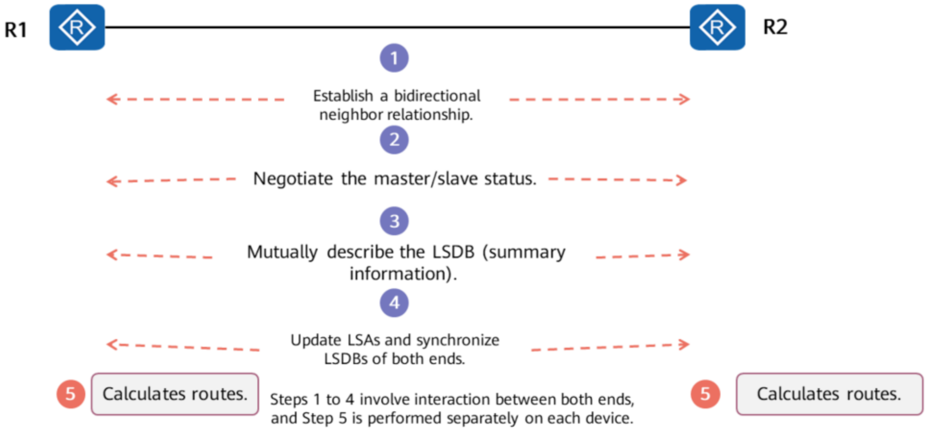
Contents

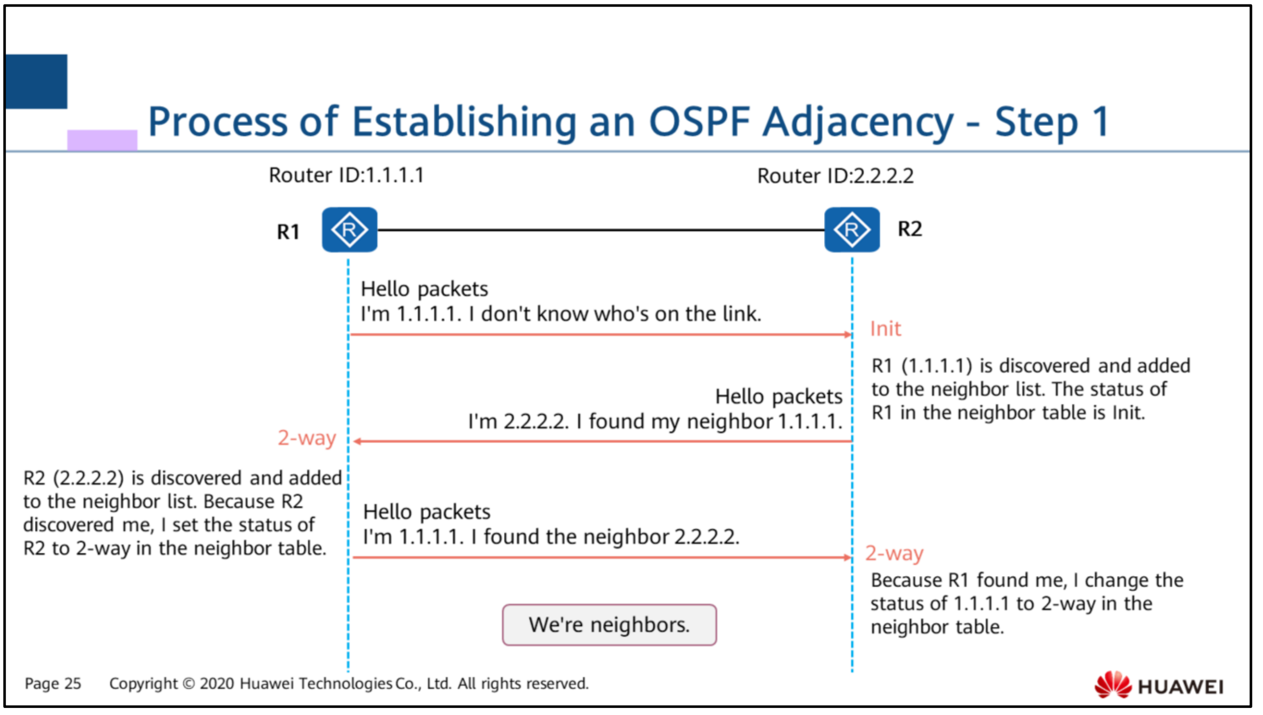
Relationships Between OSPF Routers

- There are two important concepts about the relationship between OSPF routers: neighbor relationship and adjacency.
- On a simple network, two routers are directly connected. OSPF is enabled on interconnected interfaces. The routers start to send and listen to Hello packets. After the two routers discover each other through Hello packets, they establish a neighbor relationship.
- The establishment of a neighbor relationship is just the beginning. A series of packets, such as DD, LSR, LSU, and LSAck packets, will be exchanged later. When LSDB synchronization between two routers is complete and the two routers start to calculate routes independently, the two routers establish an adjacency.

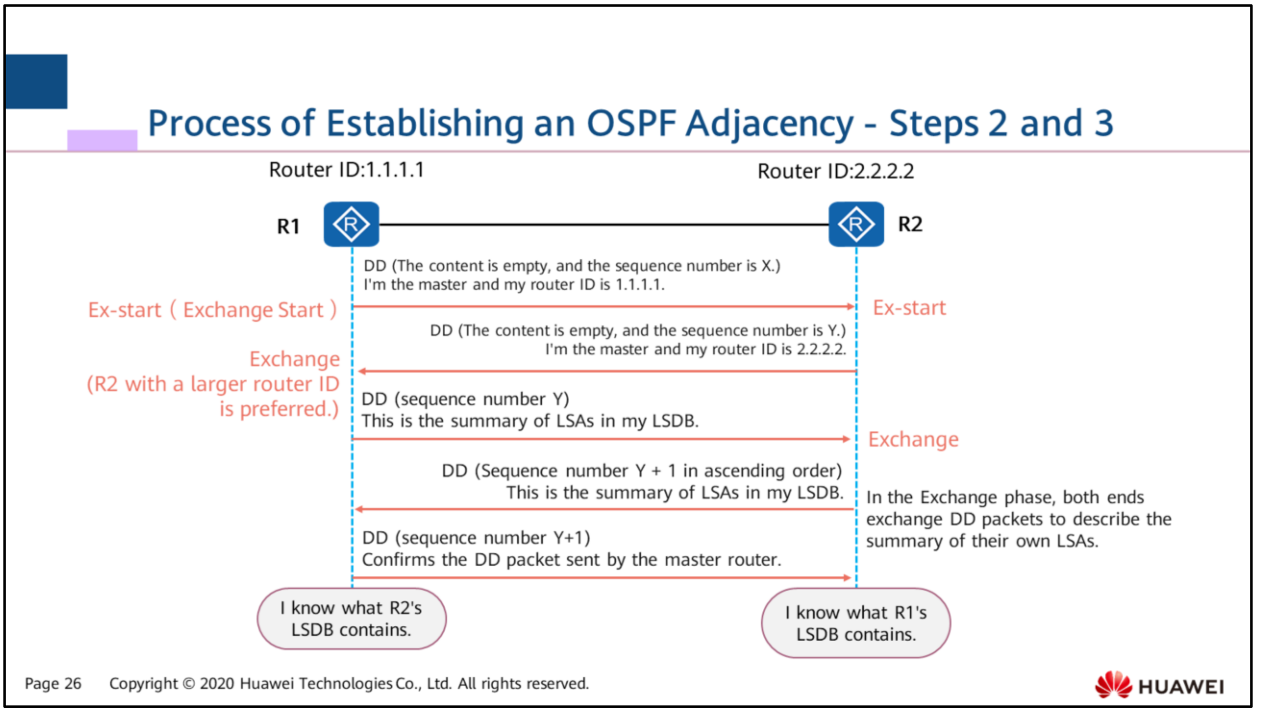
Process of Establishing an OSPF Adjacency Relationship

- OSPF adjacency relationship establishment involves four steps: establishing a neighbor relationship, negotiating the master/slave status, exchanging LSDB information, and synchronizing LSDBs.

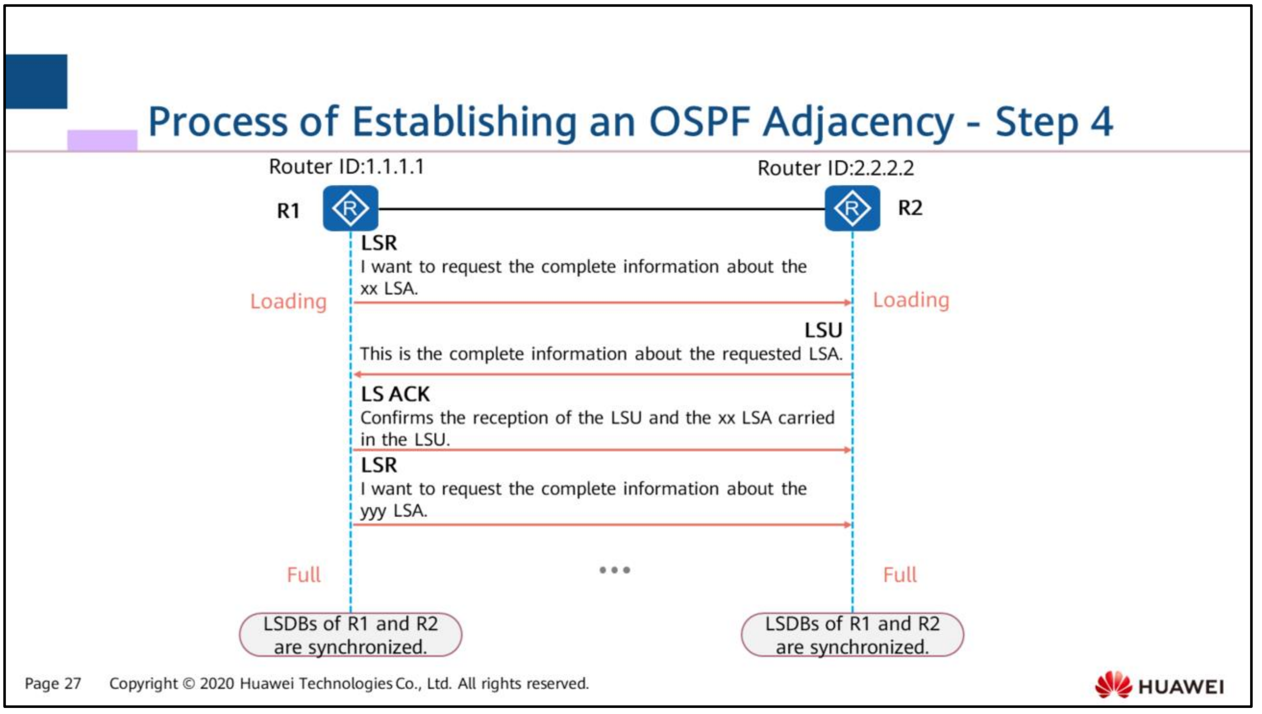




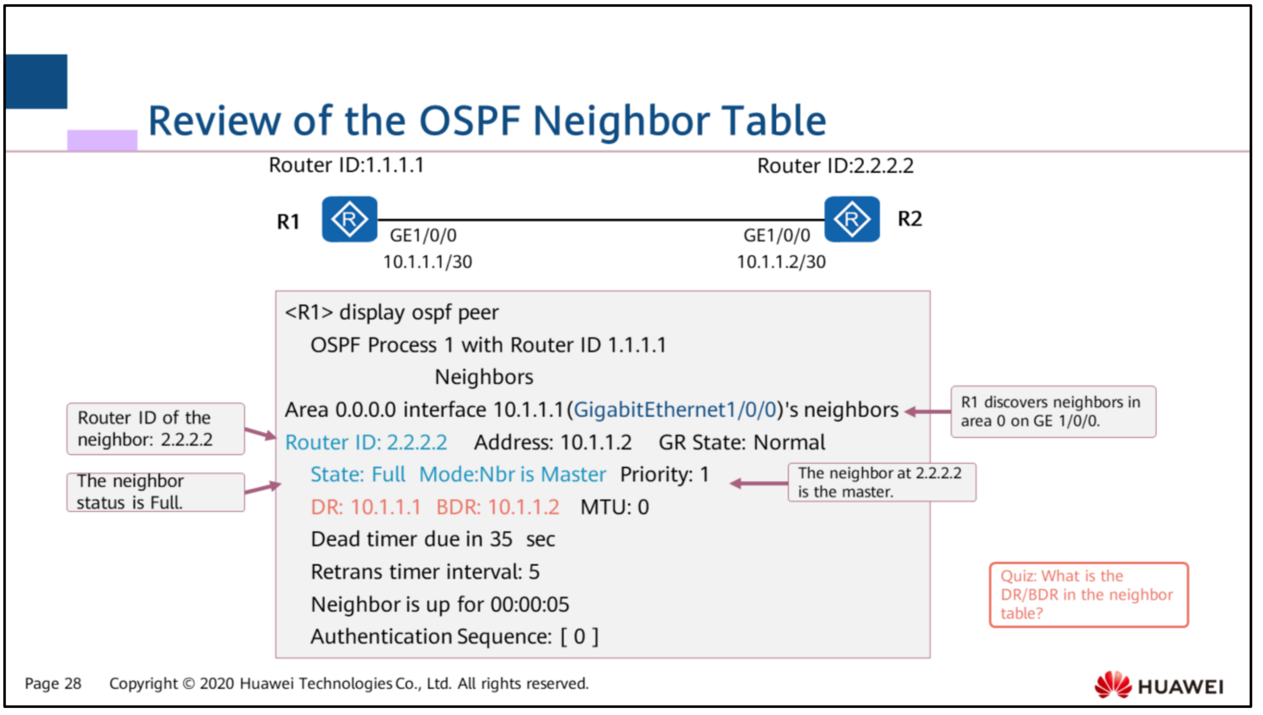
- When an OSPF router receives the first Hello packet from another router, the OSPF router changes from the Down state to the Init state.
- When an OSPF router receives a Hello packet in which the neighbor field contains its router ID, the OSPF router changes from the Init state to the 2-way state.



- After the neighbor state machine changes from 2-way to Exstart, the master/slave election starts.
  - The first DD packet sent from R1 to R2 is empty, and its sequence number is assumed to be X.
  - R2 also sends the first DD packet to R1. In the examples provided in this presentation, the sequence number of the first DD packet is Y.
  - The master/slave relationship is selected based on the router ID. A larger router ID indicates a higher priority. The router ID of R2 is greater than that of R1. Therefore, R2 becomes the master device. After the master/slave role negotiation is complete, R1's status changes from Exstart to Exchange.
- After the neighbor status of R1 changes to Exchange, R1 sends a new DD packet containing its own LSDB description. The sequence number of the DD packet is the same as that of R2. After R2 receives the packet, the neighbor status changes from Exstart to Exchange.
- R2 sends a new DD packet to R1. The DD packet contains the description of its own LSDB and the sequence number of the DD packet is Y + 1.
- As a backup router, R1 needs to acknowledge each DD packet sent by R2. The sequence number of the response packet is the same as that of the DD packet sent by R2.
- After sending the last DD packet, R1 changes the neighbor status to Loading.



- After the neighbor status changes to Loading, R1 sends an LSR to R2 to request the LSAs that are discovered through DD packets in the Exchange state but do not exist in the local LSDB.
- After receiving the LSU, R2 sends an LSU to R1. The LSU contains detailed information about the requested LSAs.
- After R1 receives the LSU, R1 replies with an LSAck to R2.
- During this process, R2 also sends an LSA request to R1. When the LSDBs on both ends are the same, the neighbor status changes to Full, indicating that the adjacency has been established successfully.

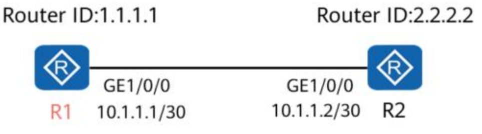


- Fields displayed in the **display ospf peer** command output are as follows:
  - OSPF Process 1 with Router ID 1.1.1.1: The local OSPF process ID is 1, and the local OSPF router ID is 1.1.1.1.
  - Area ID of the neighboring OSPF router.
  - Address: address of the neighbor interface.
  - GR State: GR status after OSPF GR is enabled. GR is an optimized function. The default value is Normal.
  - State: neighbor status. In normal cases, after LSDB synchronization is complete, the neighbor stably stays in the Full state.
  - Mode: whether the local device is the master or backup device during link status information exchange.
  - Priority: priority of the neighboring router. The priority is used for DR election.
  - DR: designated router.
  - BDR: backup designated router.
  - MTU: MTU of a neighbor interface.
  - Retrans timer interval: interval (in seconds) at which LSAs are retransmitted.
  - Authentication Sequence: authentication sequence number.

Contents

OSPF Network Types

- OSPF has four network types: broadcast, NBMA, P2MP, and P2P.



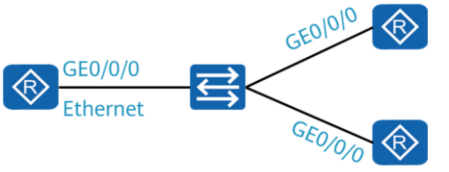

```
[R1-GigabitEthernet1/0/0] ospf network-type ?
  broadcast  Specify OSPF broadcast network
  nbma       Specify OSPF NBMA network
  p2mp       Specify OSPF point-to-multipoint network
  p2p        Specify OSPF point-to-point network
```

OSPF Network Types (1)

Point-to-Point (P2P)

- P2P indicates that only two network devices can be connected on a link.
- A typical example is a PPP link. When an interface uses PPP encapsulation, the default network type of the OSPF interface is P2P.

Broadcast Multiple Access (BMA)

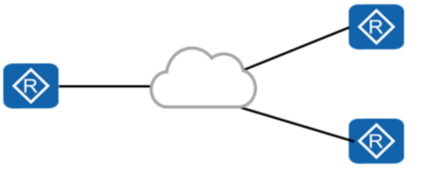


- BMA is also called broadcast. It refers to an environment that allows multiple devices to access and supports broadcast.
- A typical example is an Ethernet network. When an interface uses Ethernet encapsulation, the default network type of the OSPF interface is BMA.

OSPF Network Types (2)

Non-Broadcast Multiple Access (NBMA)	Point-to-Multipoint (P2MP)

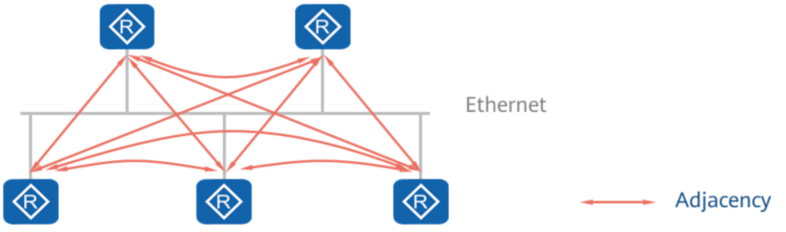
- NBMA refers to an environment that allows multiple network devices to access but does not support broadcast.
- A typical example is a Frame Relay (FR) network.



- A P2MP network is formed by bundling endpoints of multiple P2P links.
- No link layer protocol is considered as a P2MP network by default. This type must be manually changed from another network type.

Background of DR and BDR

- On an MA network, if each OSPF router establishes OSPF adjacencies with all the other routers, excessive OSPF adjacencies exist on the network, which increases the load on the devices and the number of OSPF packets flooded on the network.
- Once the network topology changes, LSA flooding on the network may waste bandwidth and device resources.



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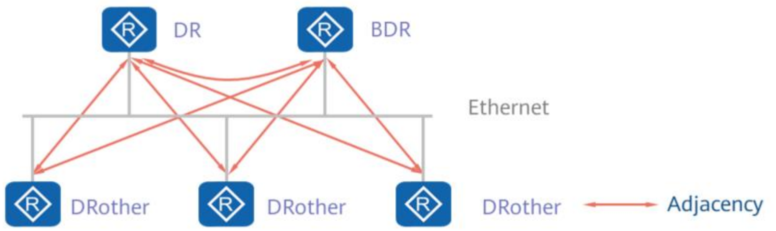
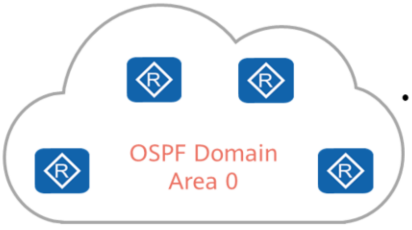
DR and BDR

- To optimize OSPF neighbor relationships on an MA network, the OSPF protocol specifies three types of OSPF routers: DR, BDR, and DRother.
- Only the DR and BDR can establish adjacencies with other OSPF routers. DRothers do not establish OSPF adjacencies with one another, and their relationship is in the 2-way state.
- The BDR monitors the status of the DR and takes over the role of the DR if the existing DR fails.



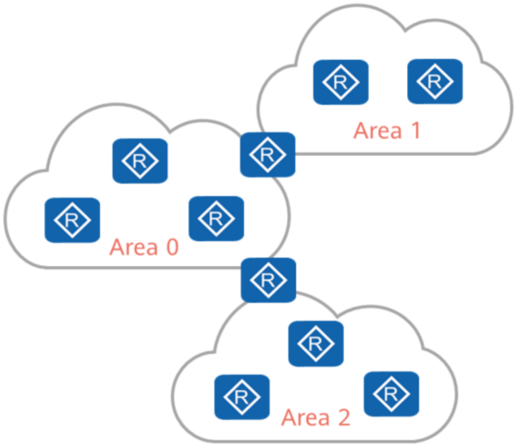
- Election rule: The interface with a higher OSPF DR priority becomes the DR of the MA. If the priorities (default value of 1) are the same, the router (interface) with a higher OSPF router ID is elected as the DR, and the DR is non-preemption.

OSPF Domain and Single Area



- An OSPF domain is a network that consists of a series of contiguous OSPF network devices that use the same policy.
- An OSPF router floods LSAs in the same area. To ensure that all routers have the same understanding of the network topology, LSDBs need to be synchronized within an area.
- If there is only one OSPF area, the number of OSPF routers increases with the network scale. This causes the following problems:
  - The LSDB becomes larger and larger, and the size of the OSPF routing table increases. A large number of router resources are consumed, device performance deteriorates, and data forwarding is affected.
  - It is difficult to calculate routes based on a large LSDB.
  - When the network topology changes, LSA flooding and SPF recalculation on the entire network bring heavy loads.

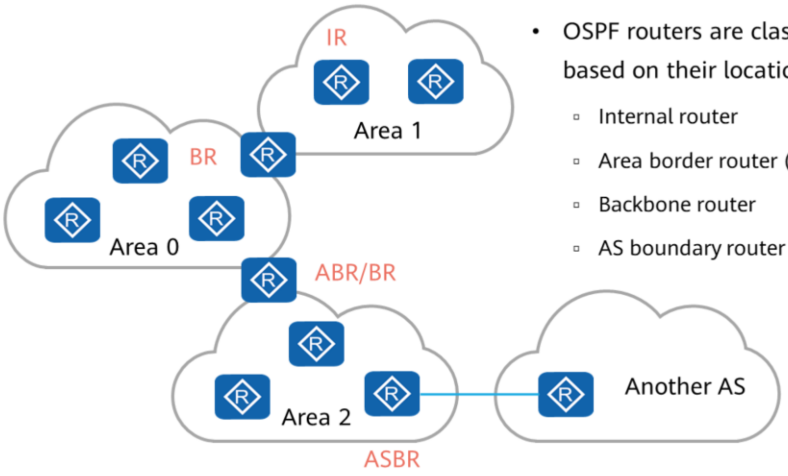
Multi-Area OSPF



- OSPF introduces the concept of area. An OSPF domain is divided into multiple areas to support larger-scale networking.
- The OSPF multi-area design reduces the flooding scope of LSAs and effectively controls the impact of topology changes within an area, optimizing the network.
- Routes can be summarized at the area border to reduce the size of the routing table.
- Multi-area improves network scalability and facilitates large-scale network construction.

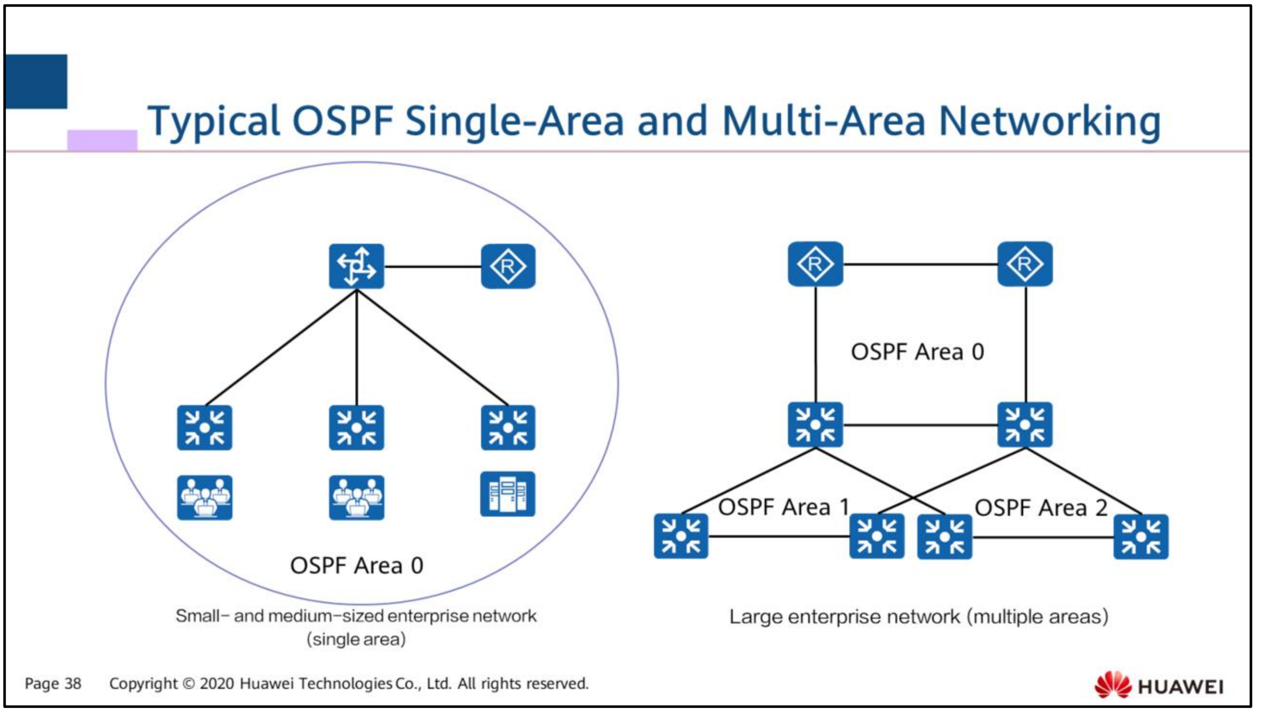
- Types of areas: Areas can be classified into backbone areas and non-backbone areas. Area 0 is a backbone area. All areas except area 0 are called non-backbone areas.
- Multi-area interconnection: To prevent inter-area loops, non-backbone areas cannot be directly connected to each other. All non-backbone areas must be connected to a backbone area.

Types of OSPF Routers



- OSPF routers are classified into the following types based on their locations or functions:
  - Internal router
  - Area border router (ABR)
  - Backbone router
  - AS boundary router (ASBR)

- Internal router: All interfaces of an internal router belong to the same OSPF area.
- ABR: An interface of an ABR belongs to two or more areas, but at least one interface belongs to the backbone area.
- Backbone router: At least one interface of a backbone router belongs to the backbone area.
- ASBR: exchanges routing information with other ASs. If an OSPF router imports external routes, the router is an ASBR.



- Small- and medium-sized enterprise networks have a small scale and a limited number of routing devices. All devices can be deployed in the same OSPF area.
- A large-scale enterprise network has a large number of routing devices and is hierarchical. Therefore, OSPF multi-area deployment is recommended.

Contents

Basic OSPF Configuration Commands (1)

1. (System view) Create and run an OSPF process.

   [Huawei] **ospf** [*process-id* | **router-id** *router-id*]

   The *process-id* parameter specifies an OSPF process. The default process ID is 1. OSPF supports multiple processes. Multiple OSPF processes can separately run on the same device. The **router-id** command is used to manually specify the ID of a device. If no ID is specified, the system automatically selects the IP address of an interface as the device ID.

2. (OSPF view) Create an OSPF area and enter the OSPF area view.

   [Huawei] **area** *area-id*

   The **area** command creates an OSPF area and displays the OSPF area view.
   The *area-id* value can be a decimal integer or in dotted decimal notation. If the value is an integer, it ranges from 0 to 4294967295.

3. (OSPF area view) Specify the interface that runs OSPF.

   [Huawei-ospf-1-area-0.0.0.0] **network** *network-address wildcard-mask*

   The **network** command specifies the interface that runs OSPF and the area to which the interface belongs. The *network-address* parameter specifies the network segment address of the interface. The *wildcard-mask* parameter is the wildcard of an IP address, which is equivalent to the reverse mask of the IP address (0 is converted to 1, and 1 to 0). For example, 0.0.0.255 indicates that the mask length is 24 bits.

- A router ID is selected in the following order: The largest IP address among Loopback addresses is preferentially selected as a router ID. If no Loopback interface is configured, the largest IP address among interface addresses is selected as a router ID.

Basic OSPF Configuration Commands (2)

4. (Interface view) Set an OSPF interface cost.

   [Huawei-GE1/0/1] **ospf cost** *cost*

   The **ospf cost** command sets a 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.

5. (OSPF view) Set an OSPF bandwidth reference value.

   [Huawei-ospf-1] **bandwidth-reference** *value*

   The **bandwidth-reference** command sets a 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.

6. (Interface view) Set the priority of an interface for DR election.

   [Huawei-GigabitEthernet0/0/0] **ospf dr-priority** *priority*

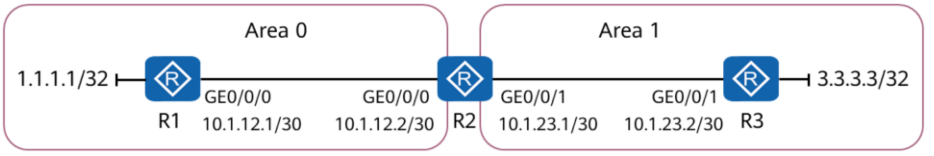
   The **ospf dr-priority** command sets a priority for an interface that participates in DR election. A larger value indicates a higher priority. The value ranges from 0 to 255.

Contents

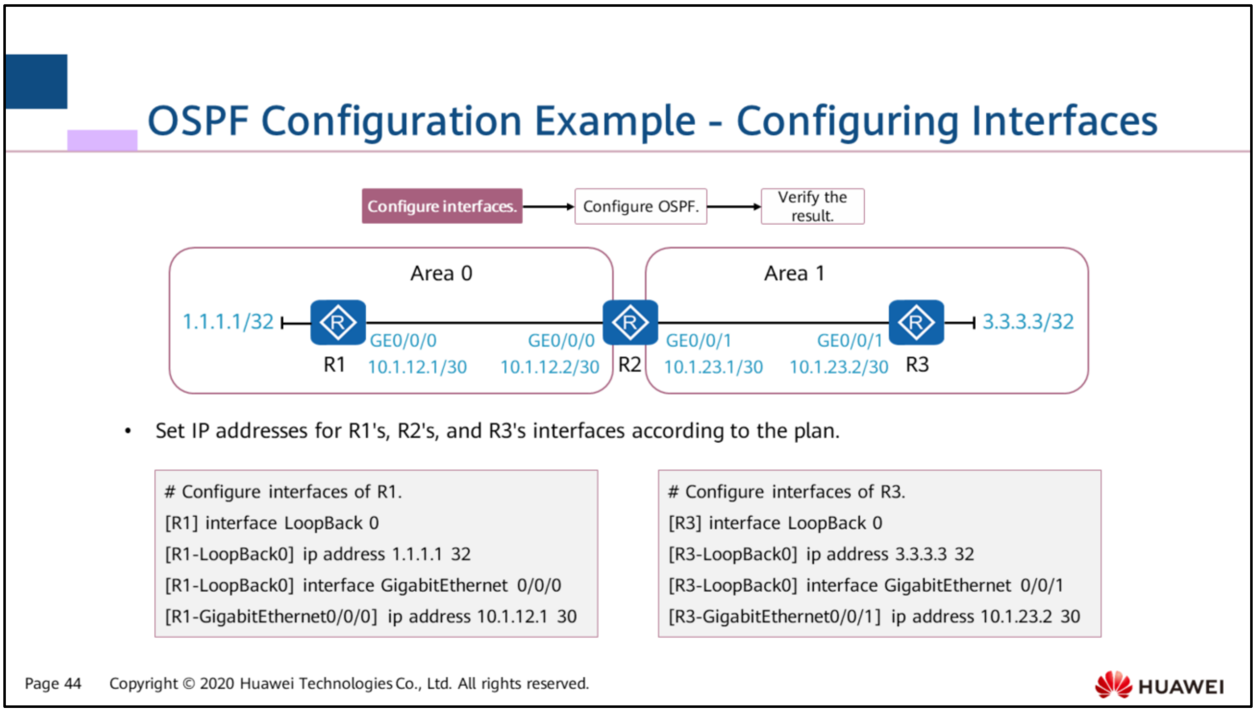
OSPF Configuration Example

Description:

- There are three routers, R1, R2, and R3. R1 and R3 are connected to networks 1.1.1.1/32 and 3.3.3.3/32 (simulated by Loopback 0), respectively. OSPF needs to be used to implement interworking between the two networks. Detailed topology was as follows:

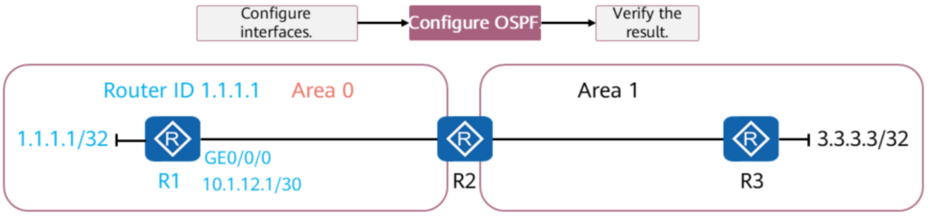


- The configuration process consists of three steps: configuring device interfaces, configuring OSPF, and verifying the result.



- Configure interfaces of R2.
  - [R2] interface GigabitEthernet 0/0/0
    [R2-GigabitEthernet0/0/0] ip address 10.1.12.2 30
    [R2-GigabitEthernet0/0/0] interface GigabitEthernet 0/0/1
    [R2-GigabitEthernet0/0/1] ip address 10.1.23.1 30

OSPF Configuration Example - Configuring OSPF (1)

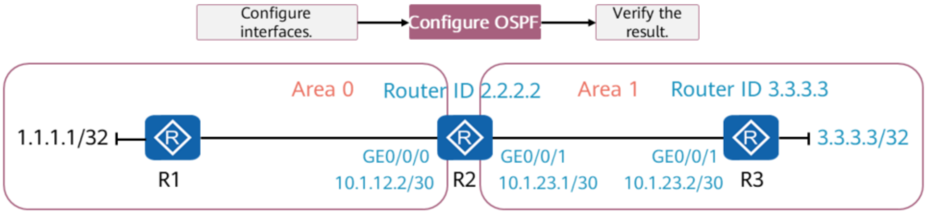


- Planned OSPF parameters: The OSPF process ID is 1. Router IDs of R1, R2, and R3 are 1.1.1.1, 2.2.2.2, and 3.3.3.3 respectively.
- Procedure:
  - Create and run an OSPF process.
  - Create an OSPF area and enter the OSPF area view.
  - Specify the interface that runs OSPF..

```
# Configure OSPF on R1.
[R1] ospf 1 router-id 1.1.1.1
[R1-ospf-1] area 0
[R1-ospf-1-area-0.0.0.0] network 1.1.1.1 0.0.0.0
[R1-ospf-1-area-0.0.0.0] network 10.1.12.0 0.0.0.3
```

An inverse mask is specified here.

OSPF Configuration Example - Configuring OSPF (2)



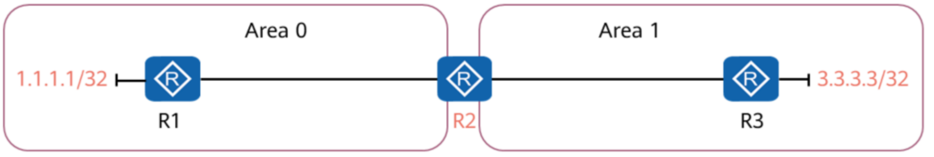
- When configuring OSPF multi-area, be sure to advertise the route destined for a network segment that responds to a specified area.

```
# Configure OSPF on R2.
[R2] ospf 1 router-id 2.2.2.2
[R2-ospf-1] area 0
[R2-ospf-1-area-0.0.0.0] network 10.1.12.0 0.0.0.3
[R2-ospf-1-area-0.0.0.0] area 1
[R2-ospf-1-area-0.0.0.1] network 10.1.23.0 0.0.0.3
```

```
# Configure OSPF on R3.
[R3] ospf 1 router-id 3.3.3.3
[R3-ospf-1] area 1
[R3-ospf-1-area-0.0.0.1] network 3.3.3.3 0.0.0.0
[R3-ospf-1-area-0.0.0.1] network 10.1.23.0 0.0.0.3
```

OSPF Configuration Example - Verification (1)

Configure interfaces. → Configure OSPF. → **Verify the result.**



- Check the OSPF neighbor table on R2.

```
<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
----------------------------------------------------------------------------
```

Area ID of a neighbor

Neighbor status
Verify that the neighbor status is Full, indicating that the adjacency has been established successfully.

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OSPF Configuration Example - Verification (2)

- Check the routing table on R1 and ping 3.3.3.3 from 1.1.1.1.

Route to 3.3.3.3/32 learned using OSPF

Set the source IP address to 1.1.1.1 and ping 3.3.3.3.

```
<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
...
```

Summary

- OSPF is a widely used routing protocol on the live network. This presentation describes basic concepts, application scenarios, and basic configurations of OSPF.
- The router ID, area, OSPF neighbor table, LSDB table, and OSPF routing table are basic OSPF concepts. Describe the establishment of OSPF neighbor relationships and adjacencies, which helps you better understand the link-state routing protocol.
- OSPF has more interesting details, such as LSA types, the SPF calculation process, and the OSPF special area. For more OSPF information, please continue your Huawei HCIP-Datacom certification courses.