Open Shortest Path First Protocol - OSPF

CCNP ROUTE: Implementing IP Routing

Objectives

- OSPF Overview
- Link-State Protocol Characteristics
- Terminology
- OSPF Operation
- Packet Types
- DR and BDR election
- Multi-area OSPF
- Troubleshooting

Open Shortest Path First (OSPF)

- OSPF is a standard-based IP routing protocol described in RFC 2328.
  - It was developed to meet RIP's inability to scale beyond 15 routers.
  - Proposed by IETF in 1988 and formalized in 1991.
  - There are 2 versions; OSPFv2 is for IPv4 and OSPFv3 is for IPv6.

OSPF Features

- OSPF is a link-state protocol
- OSPF features include:
  - Fast convergence
  - Class less - Supports VLSM
  - Efficient use of bandwidth - Routing changes trigger routing updates (no periodic updates)
  - Routing based on best path selection
  - Supports large network size
  - Grouping of members into Areas

Link-State Protocol Characteristics

- With link-state routing protocols, each router has the full picture of the network topology, and can independently make a decision based on an accurate picture of the network topology.
- To do so, each link-state router keeps a record of:
  - Its immediate neighbor routers.
  - All the other routers in the network, or in its area of the network, and their attached networks.
  - The best paths to each destination.

Link-State Protocol Advantages

- Respond quickly to network changes.
- Send triggered updates when a network change occurs.
- Send periodic updates (link-state refresh), at long intervals, such as every 30 minutes.
  - Uses LSAs to confirm topology information before the information ages out of the link-state database.

OSPF Terminology

- OSPF databases / tables:
  - OSPF adjacency database = Neighbor table
  - OSPF link-state database = Topology table
  - OSPF forwarding database = Routing table
- Link-state advertisements (LSAs)
- Shortest-Path First (SPF) Routing Algorithm
  - Dijkstra algorithm
- SPF Tree
- OSPF Areas
  - Backbone (transit) and standard areas.
- Types of OSPF routers:
  - Internal router, backbone router, Area Border Router (ABR), Autonomous System Boundary Router (ASBR)
  - Designated Router (DR) and Backup Designated Router (BDR)

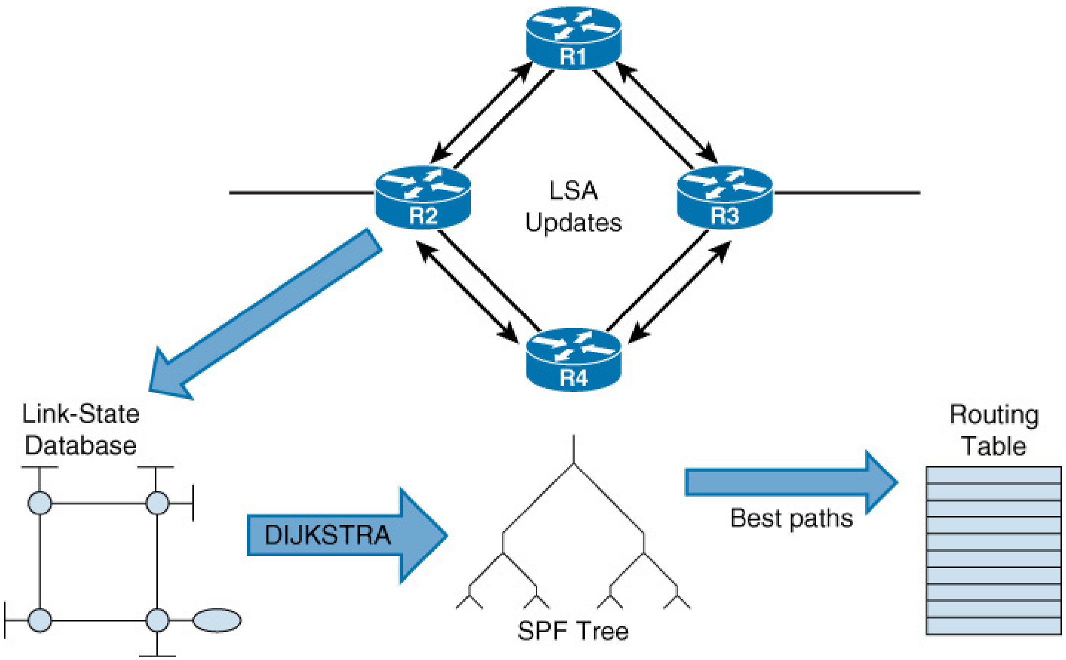
OSPF Router Tables / Databases

- OSPF maintains three databases which are used to create three tables.

Database	Table	Description
Adjacency Database	Neighbor Table	• List of all neighbors routers to which a router has established bidirectional communication. • This table is unique for each router. • Can be viewed using the show ip ospf neighbor command.
Link-state Database	Topology Table	• List of information about all other routers in the network. • The database shows the network topology. • All routers within an area have identical link-state databases. • Can be viewed using the show ip ospf database command.
Forwarding Database	Routing Table	• List of routes generated when an algorithm is run on the link-state database. • Each router's routing table is unique and contains information on how and where to send packets to other routers. • Can be viewed using the show ip route command.

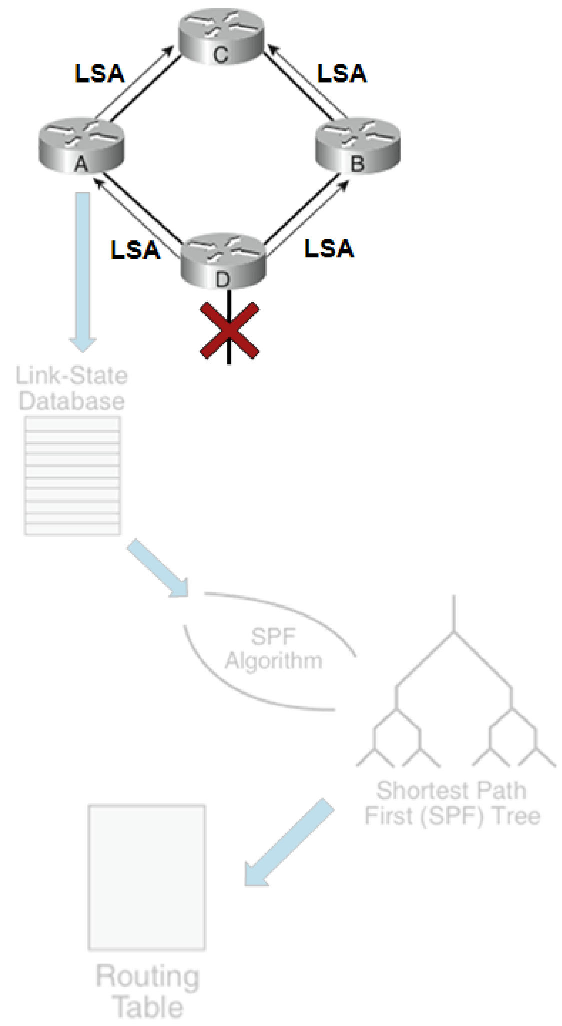
OSPF Operation

1. Establish neighbor adjacencies
2. Exchange link-state advertisements
3. Build the topology table
4. Execute the SPF algorithm
5. Build the routing table



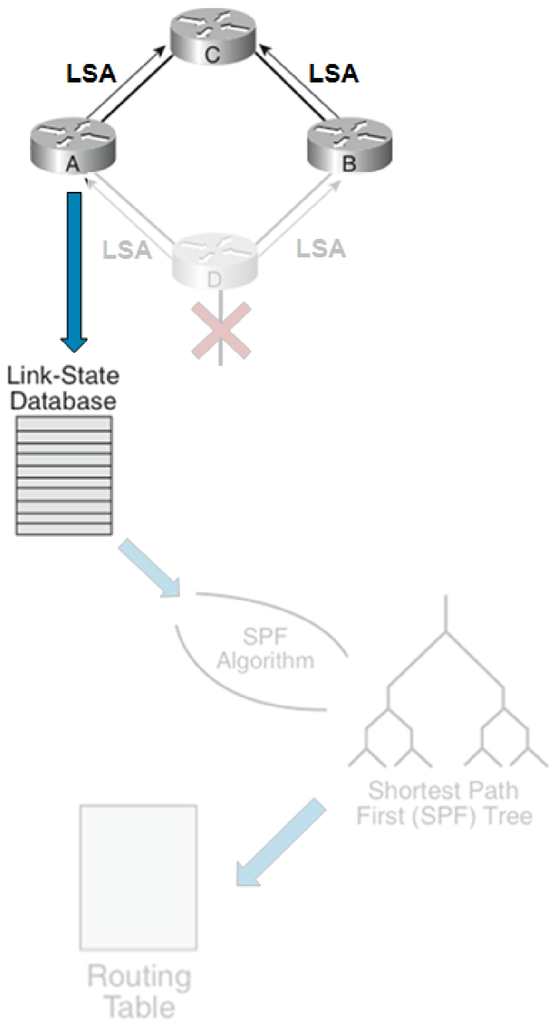
Link-State Advertisements (LSAs)

- When a change occurs in the network topology, the router that experiencing the change creates a link-state advertisement (LSA) concerning that link.
  - LSAs are also called link-state protocol data units (PDUs).
- The LSA is multicasted to all neighboring devices using either 224.0.0.5 or 224.0.0.6.
- Routers receiving the LSA immediately forward it to all neighboring routers.



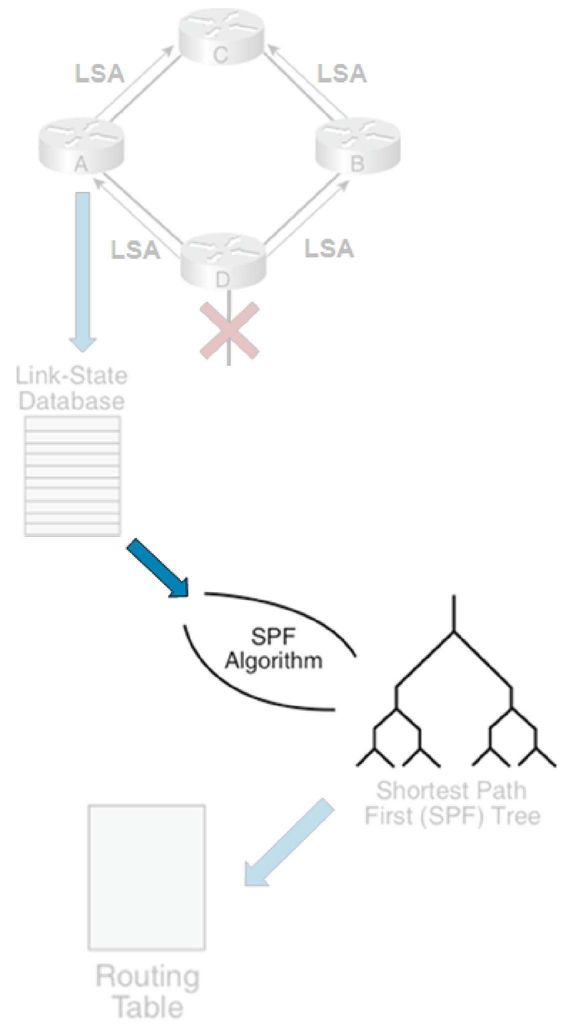
Link-State Database (LSDB)

- Receiving routers add the LSA to their link-state database (LSDB).
- The LSDB is used to calculate the best paths through the network.
- OSPF best route calculation is based on Edsger Dijkstra's shortest path first (SPF) algorithm.



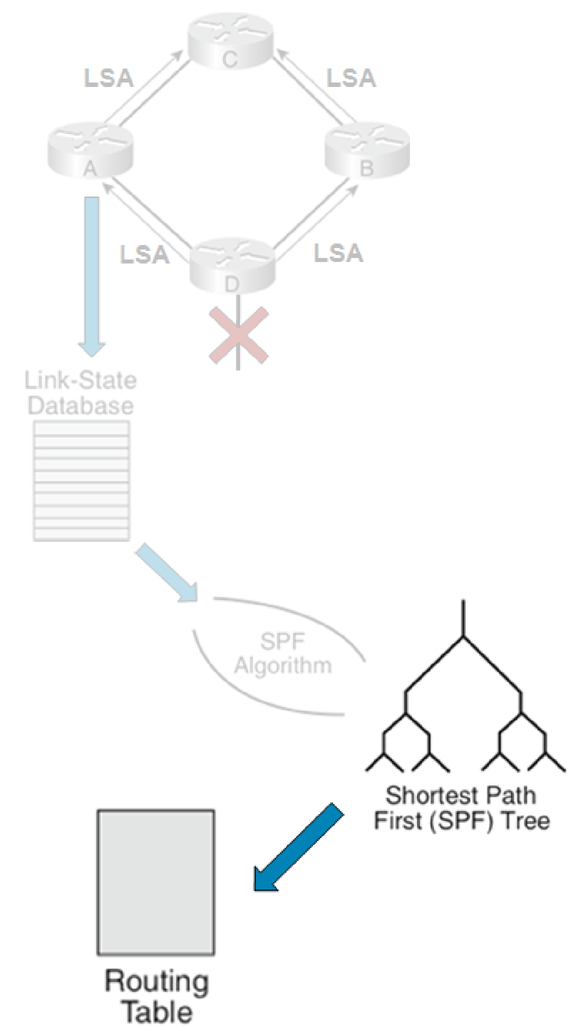
SPF Routing Algorithm

- The SPF algorithm accumulates costs along each path, from source to destination.
  - The accumulated costs is then used by the router to build a topology table.



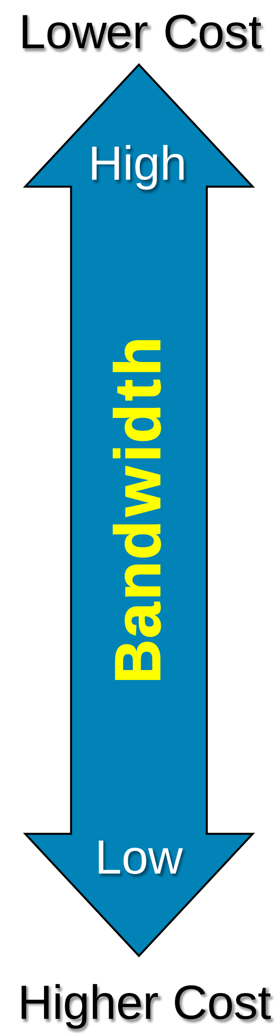
SPF Tree and Routing Table

- The topology table is essentially an SPF tree which contains a listing of all OSPF networks and the costs to reach them.
- The resulting best routes are then considered to be added to the routing table.



OSPF Metric Calculation

- The OSPF metric calculation is based on cost.
- Cost is an indication of the overhead required to send packets across a certain interface.
- The cost of an interface is inversely proportional to the bandwidth of that interface.
  - A higher bandwidth is attributed a lower cost.
  - A lower bandwidth is attributed a higher cost.



OSPF Cost Formula

- **Cost = 100,000,000 / Bandwidth (bps)**
- For example:
  - 10BaseT = 100,000,000 / 10,000,000 = **10**
  - T1 = 100,000,000 / 1,544,000 = **64**

Interface Type	10^8/ bps = Cost
Fast Ethernet and faster	10^8/ 100,000,000 bps = 1
Ethernet	10^8/ 10,000,000 bps = 10
E1	10^8/2,048,000 bps = 48
T1	10^8/ 1,544,000 bps = 64
128 kbps	10^8/ 128,000 bps = 781
64 kbps	10^8/64,000 bps = 1562
56 kbps	10^8/56,000 bps = 1785

OSPF Packet Types

- Five packet types make OSPF capable of sophisticated and complex communications.

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them.
2	DBD	Database description Checks for database synchronization between routers.
3	LSR	Link-state request Requests specific link-state records from another router.
4	LSU	Link-state update Sends specifically requested link-state records.
5	LSAck	Link-State Acknowledgment Acknowledges the other packet types.

Type 1 - OSPF Hello Packet

- Hello packets are used to:
  - Discover directly connected OSPF neighbors.
  - Establish and maintain neighbor adjacencies with these directly connected neighbors.
  - Advertise parameters on which two routers must agree to become neighbors.
  - Elect the Designated Router (DR) and Backup Designated Router (BDR) on multi-access networks like Ethernet (and Frame Relay).

Type 1 - OSPF Hello Packet

- Hello packet fields must match on neighboring routers for them to establish an adjacency:
  - Hello interval
  - Dead interval
  - Network type
  - Area id
  - Authentication password
  - Stub area flag
- Two routers on the same network segment may not form an OSPF adjacency if:
  - They are not in the same area
  - The subnet masks do not match, causing the routers to be on separate networks
  - The OSPF Hello or Dead Timers do not match
  - The OSPF network types do not match
  - The OSPF **`network`** command is missing or incorrect

Type 1 - OSPF Hello Packet

- By default, OSPF Hello packets are transmitted to 224.0.0.5 (all OSPF routers) every:
  - **10 seconds** (Default on multiaccess and point-to-point networks).
  - **30 seconds** (Default on NBMA networks – Frame Relay).
- The Dead interval is the period, expressed in seconds, that the router will wait to receive a Hello packet before declaring the neighbor "down"
  - If the Dead interval expires before the routers receive a Hello packet, OSPF will remove that neighbor from its link-state database.
  - The router floods the link-state information about the "down" neighbor out all OSPF enabled interfaces.
- Cisco uses a default of 4 times the Hello interval.
  - **40 seconds** (Default on multiaccess and point-to-point networks).
  - **120 seconds** (Default on NBMA networks – Frame Relay).

Type 2 - OSPF DBD Packet

- The Database Description (DBD) packets contain an abbreviated list of the sending router's link-state database and is used by receiving routers to check against the local link-state database.
- The link-state database must be identical on all routers within an area to construct an accurate SPF tree.

Type 3 - OSPF LSR Packet

- The Link State Request (LSR) packet is used by the receiving routers to request more information about any entry in the DBD.

Type 4 - OSPF LSU Packet

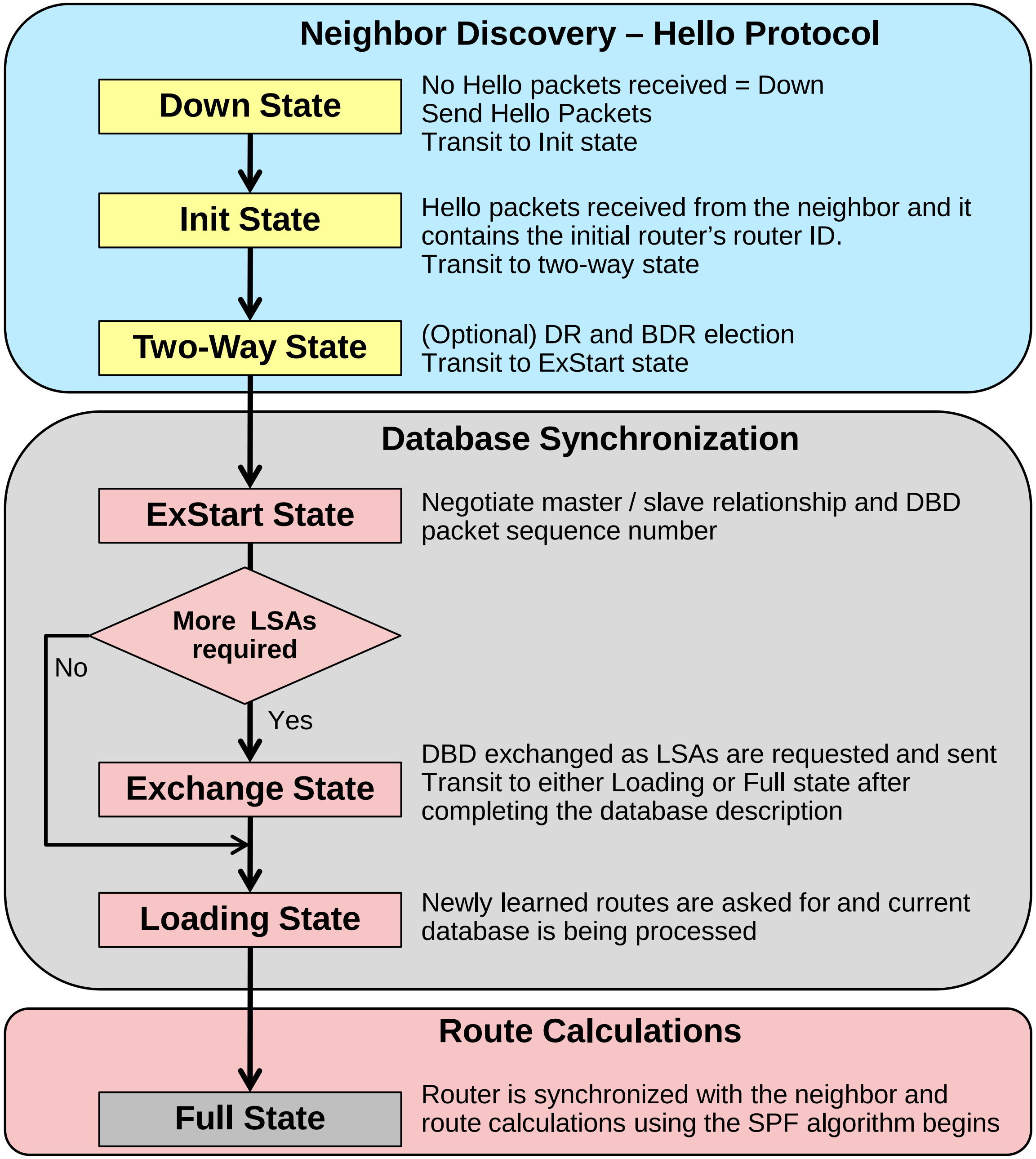
- The Link-State Update (LSU) packets are used for OSPF routing updates.
  - They reply to LSRs as well as to announce new information.
- LSUs contain different types of Link-State Advertisements (LSAs).
- LSUs contains the full LSA entries.
  - Multiple LSA entries can fit in one OSPF update packet.

Type 5 - OSPF LSAck Packet

- LSAck - Link-State Acknowledgement Packet:
  - When an LSU is received, the router sends a LSAck to confirm receipt of the LSU.
  - The LSAck data field is empty.

OSPF States

- When an OSPF router is initially connected to a network it attempts to create adjacencies with neighbors.
- To do so, it progresses through these various states using the 5 OSPF packet types.



Adjacent OSPF Neighbors

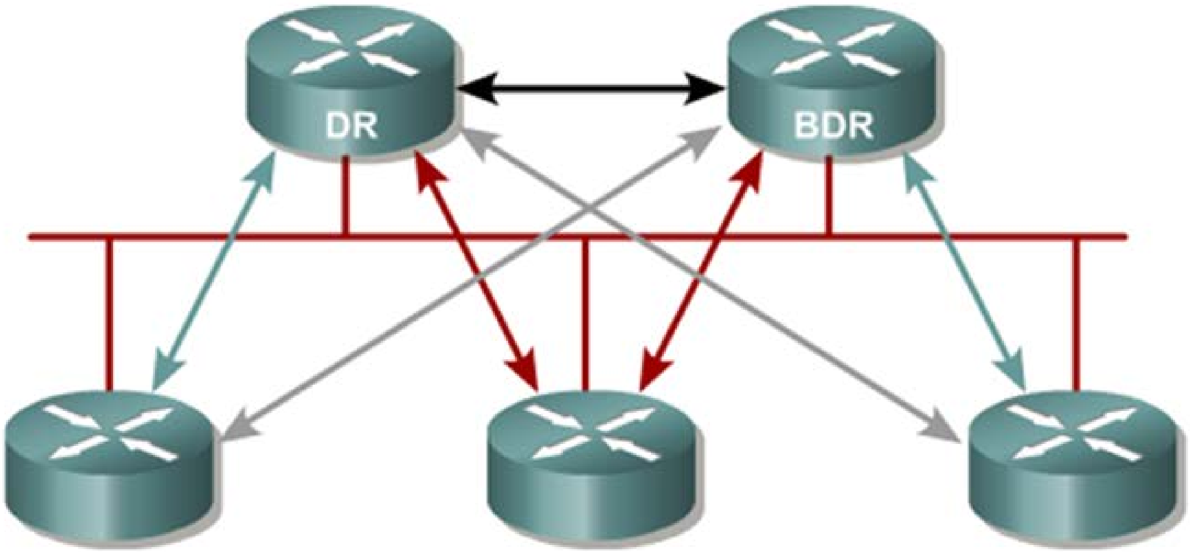
- Once neighbor adjacencies have been established, the Hello packet continues to be transmitted every 10 seconds (default) between neighbors.
  - As long as the other routers keep receiving the Hello packets, the transmitting router and its networks reside in the topology database.
- After the topological databases are synchronized, updates (LSUs) are sent only to neighbors when:
  - A change is perceived (Incremental updates)
  - Every 30 minutes (Condensed version is forwarded).

OSPF Router ID

- A router is known to OSPF by the OSPF router ID number.
  - LSDBs use the OSPF router ID to differentiate one router from the next.
- By default, the router ID is the highest IP address on an active interface at the moment of OSPF process startup.
  - For stability reason, it is recommended that the **`router-id`** command (or a loopback interface) is used to configure the router ID.

Broadcast Challenge: Adjacencies

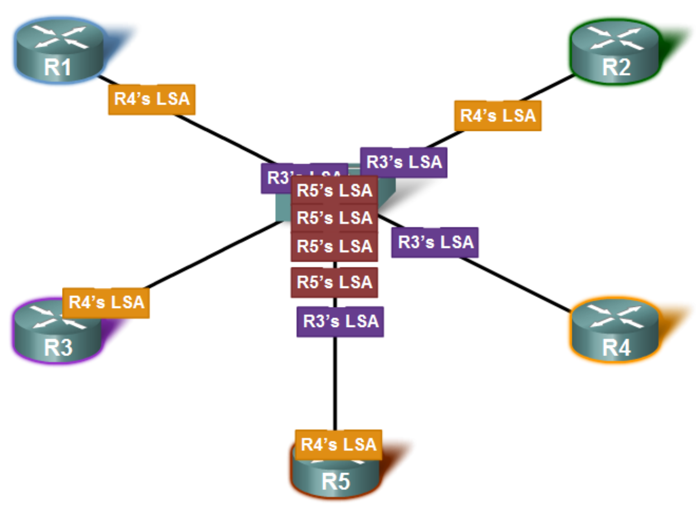
- Number of adjacencies
- Establishing adjacencies with all routers in a broadcast network would easily overload a router due to the overhead of maintaining those adjacencies.



Broadcast Challenge: Extensive LSAs

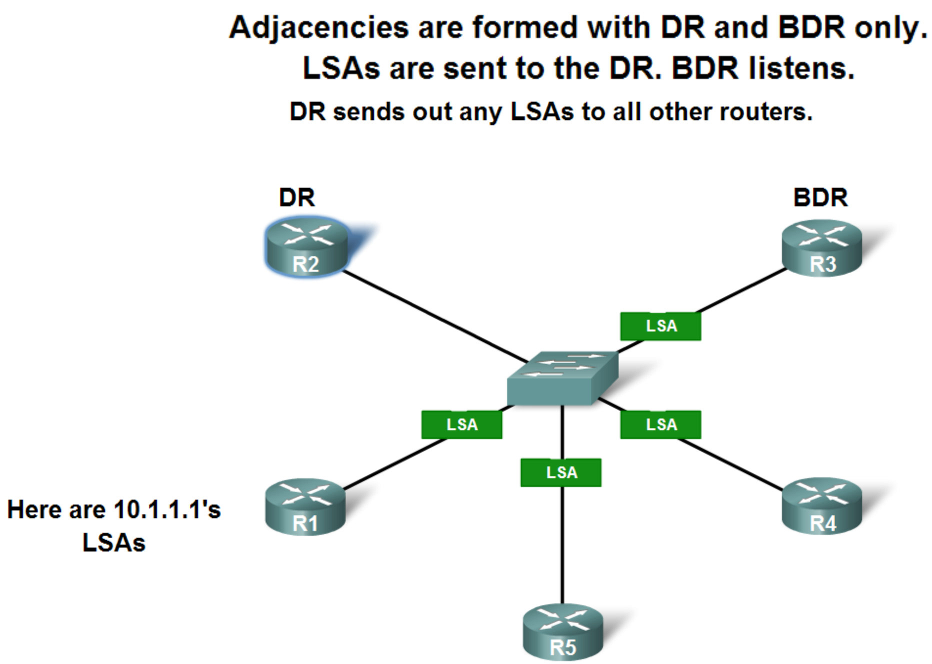
- Another challenge is the increase in network LSAs.
  - Every LSA sent out also requires an acknowledgement.
- Consequence:
  - Lots of bandwidth consumed
  - Chaotic traffic

LSA Flooding Scenario



Solution: Designated Router

- A designated router (DR) and backup designated router (BDR) solve these challenges:
  - OSPF routers form full adjacencies with the DR and BDR only
  - Reduce routing update traffic
  - Manage link-state synchronization



Designated Router (DR)

- The DR is elected and becomes responsible for maintaining the topology table for the segment.
- This DR has two main functions:
  - To become adjacent to all other routers on the network segment.
  - To act as a spokesperson for the network.
- As spokesperson the DR becomes the focal point for collecting and sending routing information (LSAs).
- Packets to all OSPF routers are forwarded to 224.0.0.5.
- Packets to the DR / BDR are forwarded to 224.0.0.6.

Backup Designated Router (BDR)

- For fault tolerance, a second router is elected as the BDR.
  - The BDR must also become adjacent to all routers on the network and must serve as a second focal point for LSAs.
  - The BDR is not responsible for updating the other routers or sending network LSAs.
- The BDR keeps a timer on the DR's update activity to ensure that it is operational.
  - If the BDR does not detect activity from the DR after the timer expires, the BDR immediately becomes the DR and a new BDR is elected.

The Election of the DR

1. All neighbors with a priority > 0 are listed.
    - Default priority = 1
2. The router with highest priority is elected as DR.
    - If there is a tie, the highest router IDs are used.
3. The router with the second highest priority is elected BDR.
    - If there is no DR, the BDR is promoted as DR.

Manipulating the Election Process

- The DR / BDR maintain these roles until they fail even when more routers with higher priorities show up on the network.
- To influence the election of DR & BDR, do one of the following:
  - Boot up the DR first, followed by the BDR, and then boot all other routers.

  OR

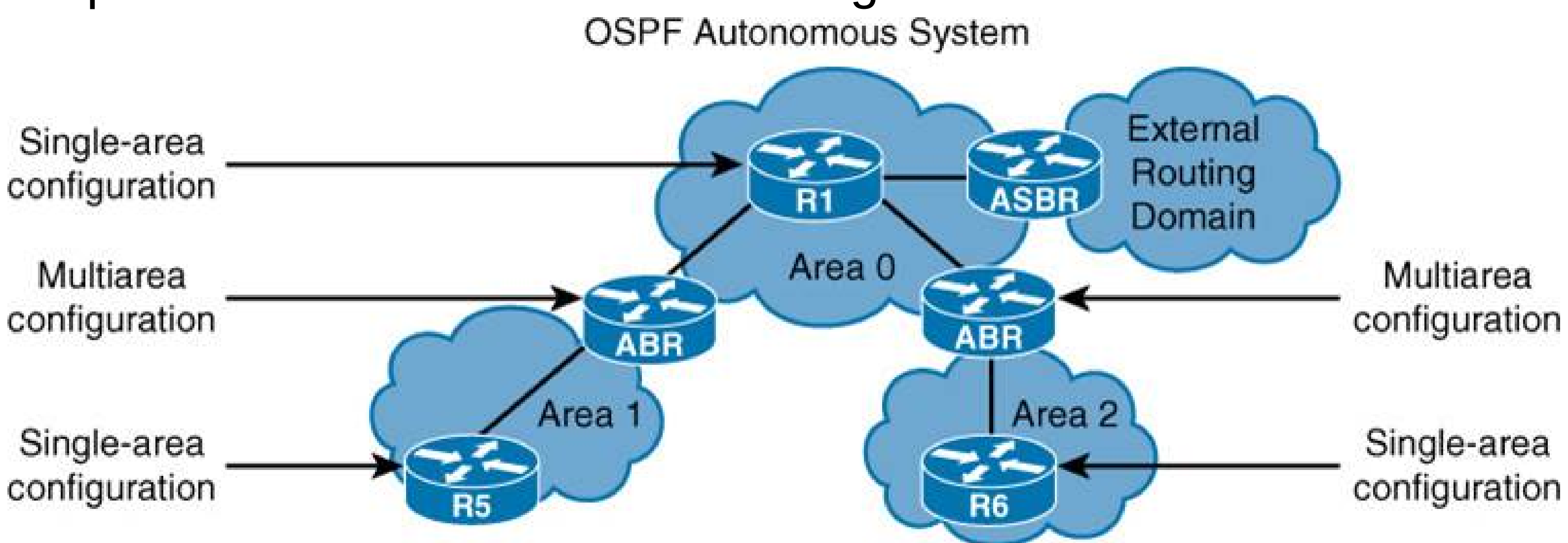
  - Shut down the interface on all routers, followed by a **`no shutdown`** on the DR, then the BDR, and then all other routers.

Point-to-Point

- Both routers become fully adjacent to each other.
- Usually a serial interface running either PPP or HDLC.
  - May also be a point-to-point subinterface running Frame Relay or ATM.
- No DR /BDR election required since there are only two devices.
- OSPF autodetects this type of network.
- Packets are sent to 224.0.0.5.

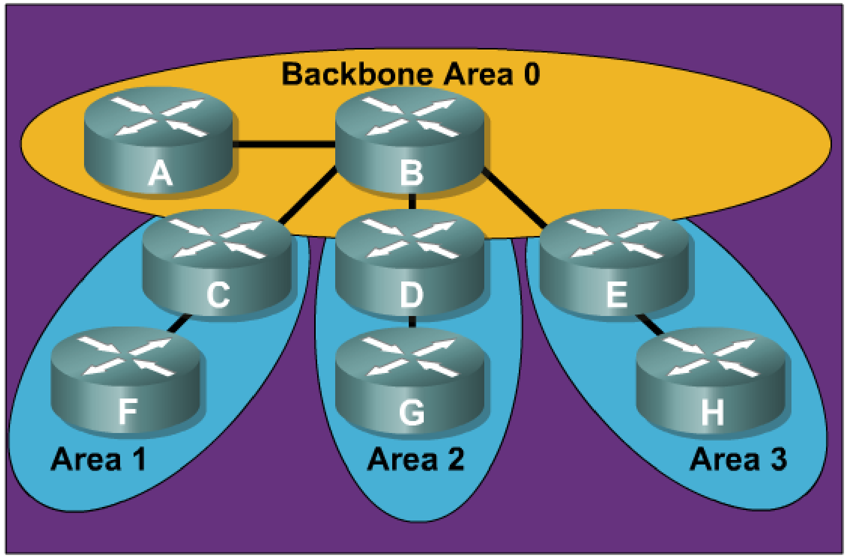
OSPF Areas

- To minimize processing and memory requirements, OSPF can divide the routing topology into a two-layer hierarchy called areas.
- Characteristics of OSPF areas include:
  - Minimizes routing table entries.
  - Localizes impact of a topology change within an area.
  - Detailed LSA flooding stops at the area boundary.
  - Requires a hierarchical network design.



OSPF Two-Layer Hierarchy

- **Backbone Area**
  - Referred to as Area 0
  - Also known as the Transit Area.
- **Regular (Standard) Areas**
  - Also known as a nonbackbone areas.
  - All standard areas must connect to the backbone area.
  - Standard areas can be further defined as stub areas, totally stubby areas, and Not-so-stubby areas (NSSAs).



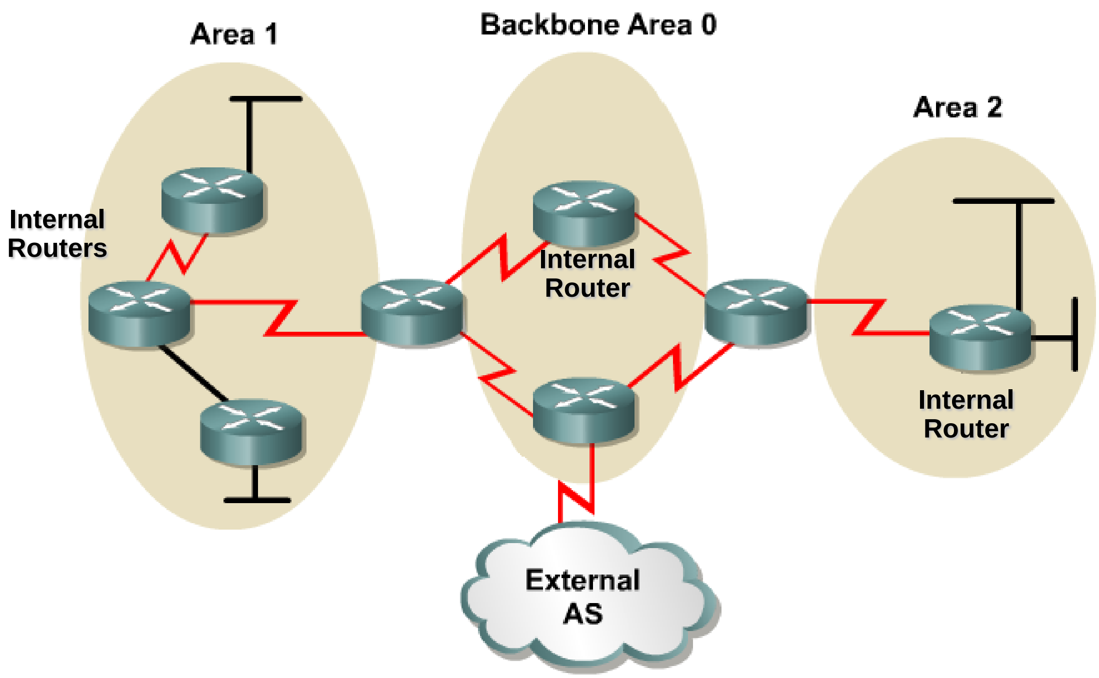
- The optimal number of routers per area varies based on factors such as network stability, but Cisco recommends:
  - An area should have no more than 50 routers.
  - A router should not be in more than 3 areas.

OSPF Router Types

- How OSPF routers exchange information is based on:
  - The function of the router.
  - The type of LSAs it can forward.
  - The type of area it resides in.
- OSPF routers may function as either:
  - Internal router
  - Backbone router
  - Area Border Router (ABR)
  - Autonomous System Boundary Router (ASBR)
- Note:
  - A router can exist as more than one router type.

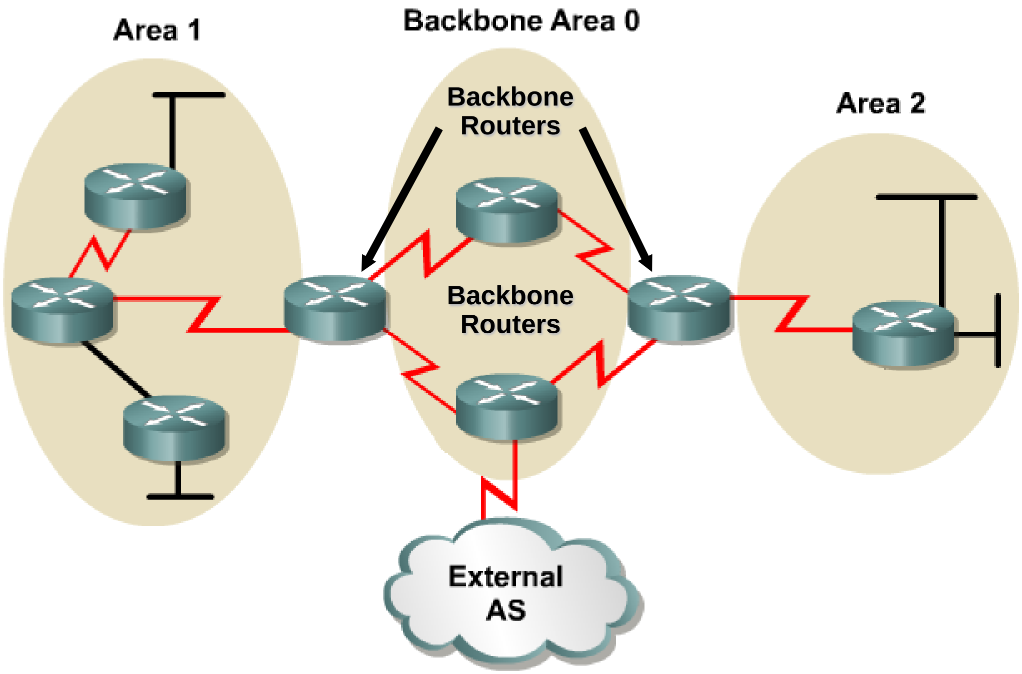
OSPF Router Types - Internal Router

- Routers that have all their interfaces within the same area.
- Internal routers in the same area:
  - Have identical LSDBs.
  - Run a single copy of the routing algorithm.



OSPF Router Types - Backbone Router

- OSPF design rules require that all areas are connected to a single backbone area (Area 0).
  - Area 0 is also known as Area 0.0.0.0
- An Area 0 router is referred to as a backbone router.
  - Depending on where it resides in Area 0, it may also be called an Internal router, an ABR, or an ASBR.

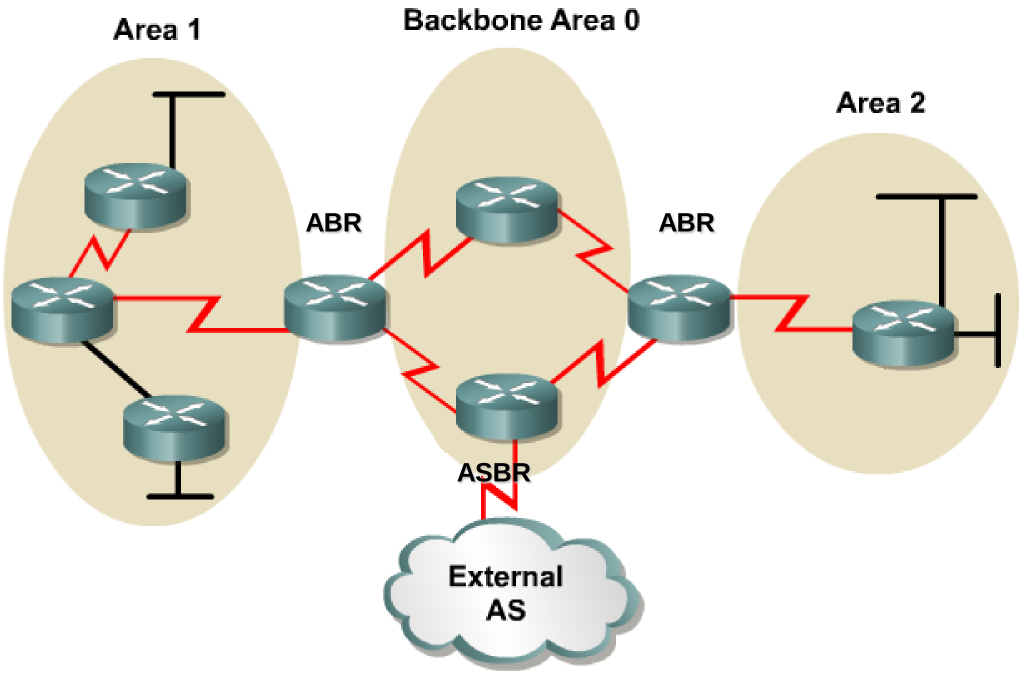


OSPF Router Types- Area Border Router (ABR)

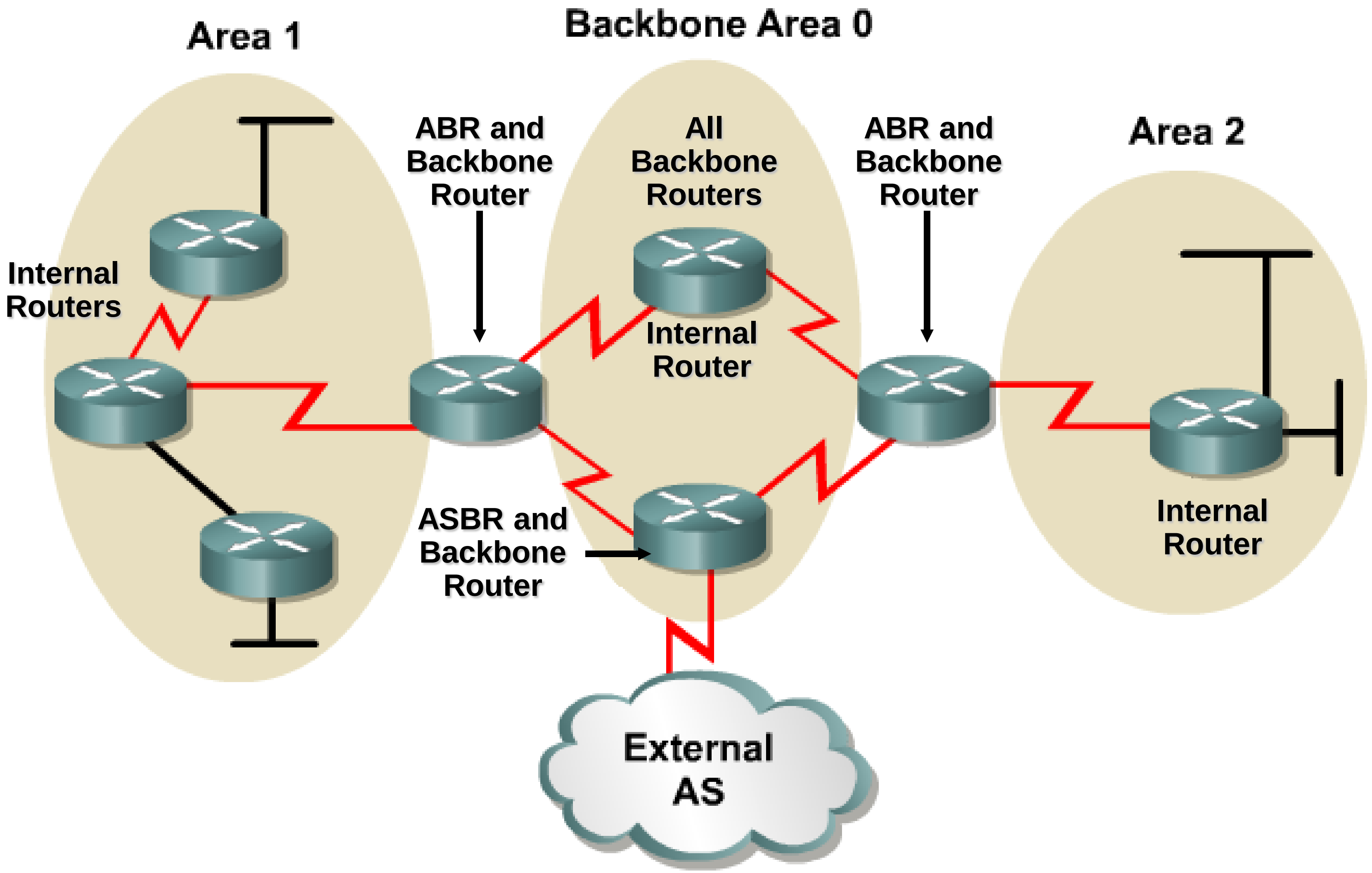
- Routers with interfaces attached to multiple areas and responsible for:
  - Joining areas together.
  - Maintaining separate link-state databases for each area.
  - Routing traffic destined to/arriving from other areas.
  - Summarizing information about each area connected and flooding the information through area 0 to the other areas connected.
  - An area can have one or more ABRs.
- ABR cannot send LSU's to other areas until the entire intra-area is synchronized.

OSPF Router Types - Autonomous System Boundary Router (ASBR)

- Routers that have at least one interface connected to another AS, such as a non-OSPF network.
- ASBRs support redistribution.
  - They can import non-OSPF network information to the OSPF network.
- Should reside in the backbone area.



OSPF Router Types



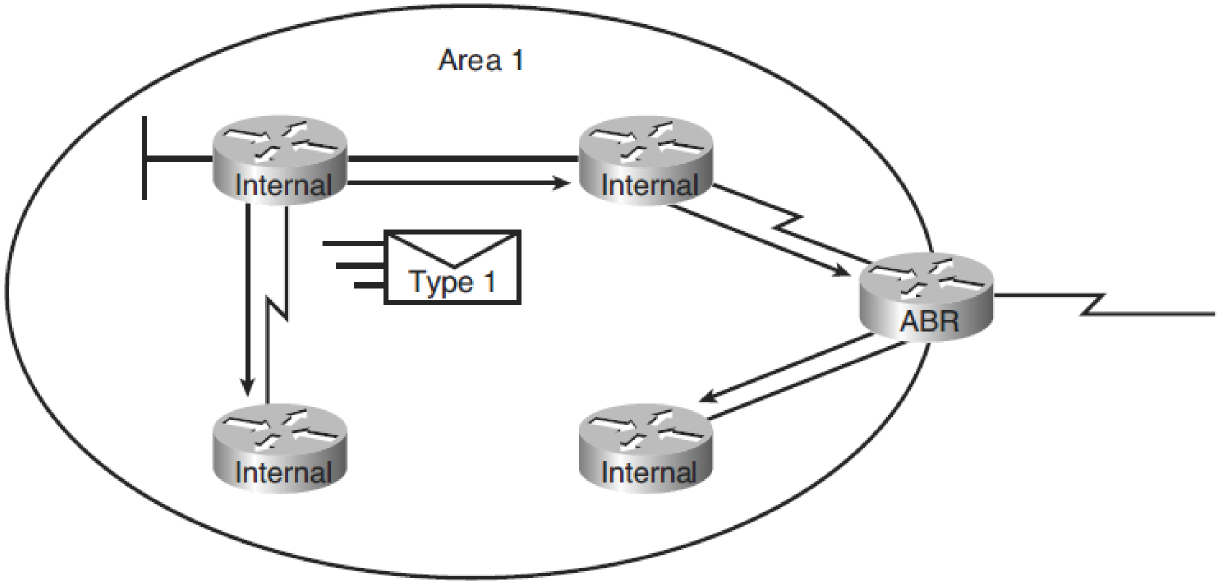
LSAs

- LSAs are the building blocks of the OSPF LSDB.
  - Individually, LSAs act as database records.
  - When combined, they describe the entire topology of an OSPF area.
- There are several types of OSPF network LSAs
  - Not all are in use.

LSA Type	Description
1	Router LSA
2	Network LSA
3 and 4	Summary LSAs
5	AS external LSA
6	Multicast OSPF LSA
7	Defined for NSSAs
8	External attributes LSA for Border Gateway Protocol (BGP)
9, 10, or 11	Opaque LSAs

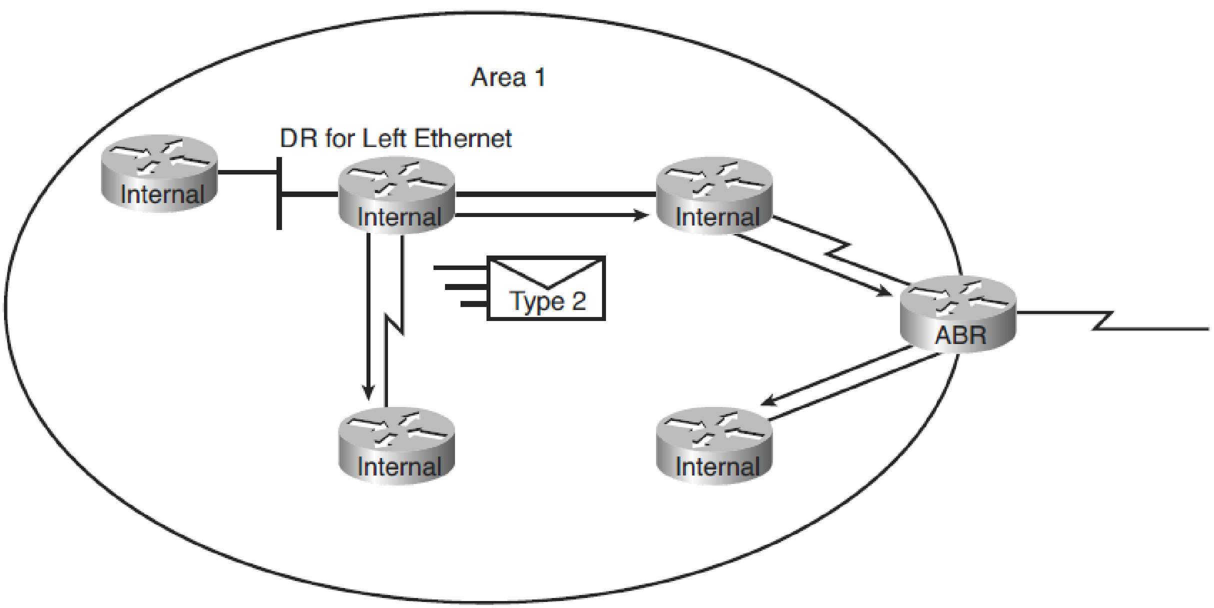
LSA Type 1: Router LSA

- Generated by all routers in an area to describe their directly attached links (Intra-area routes).
  - Floods within its area only and cannot cross an ABR.
  - LSA includes a list of directly attached links and is identified by the router ID of the originating router
  - Routing Table Entry = **O**



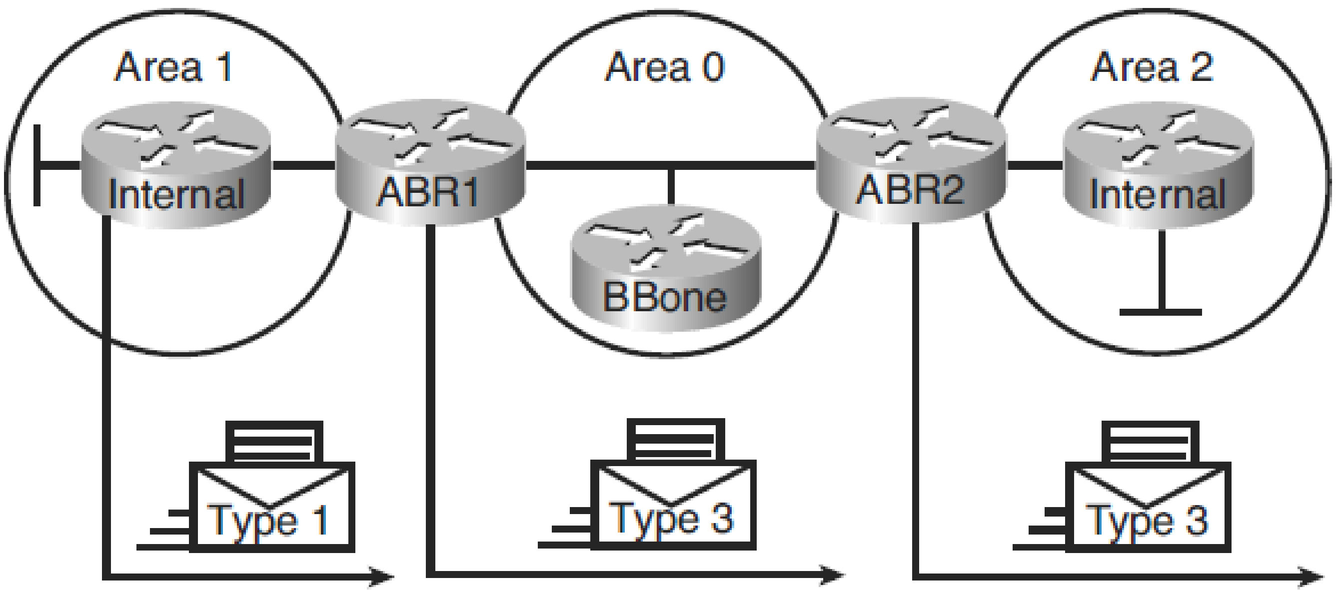
LSA Type 2: Network LSA

- Advertised by the DR of the broadcast network.
  - Floods within its area only; does not cross an ABR.
  - Link-state ID is the DR.
  - Routing Table Entry = **O**



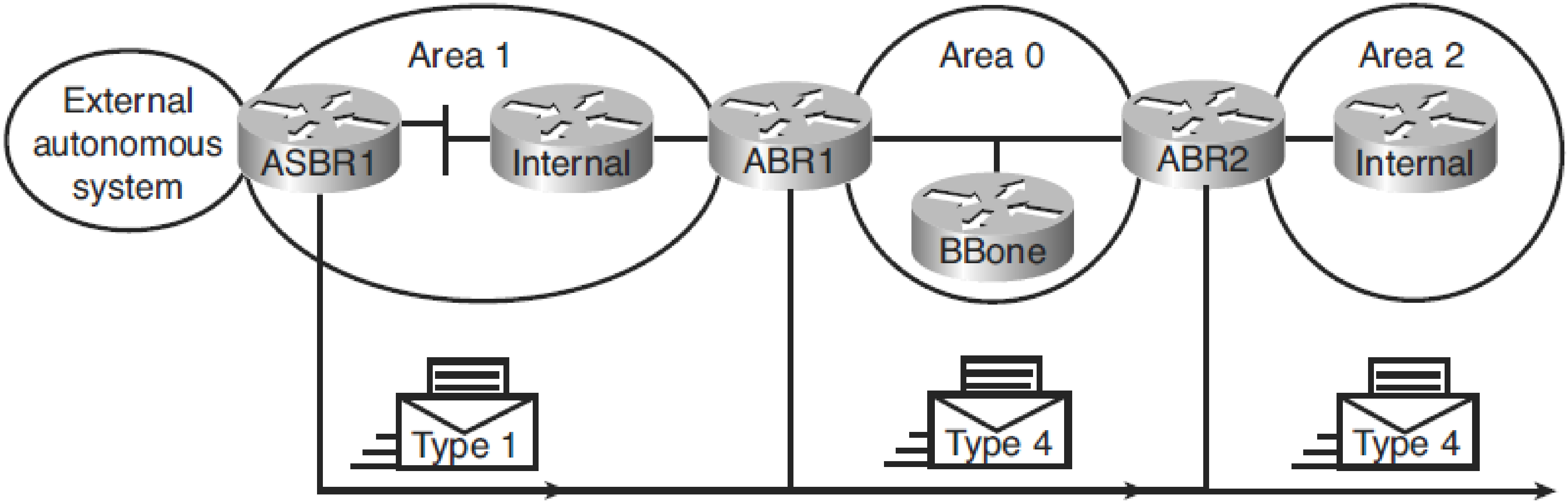
LSA Type 3: Summary LSA

- Advertised by the ABR of originating area.
  - Regenerated by subsequent ABRs to flood throughout the autonomous system.
  - By default, routes are not summarized, and type 3 LSA is advertised for every subnet.
  - Link-state ID is the network or subnet advertised in the summary LSA
  - Routing Table Entry = **O IA**



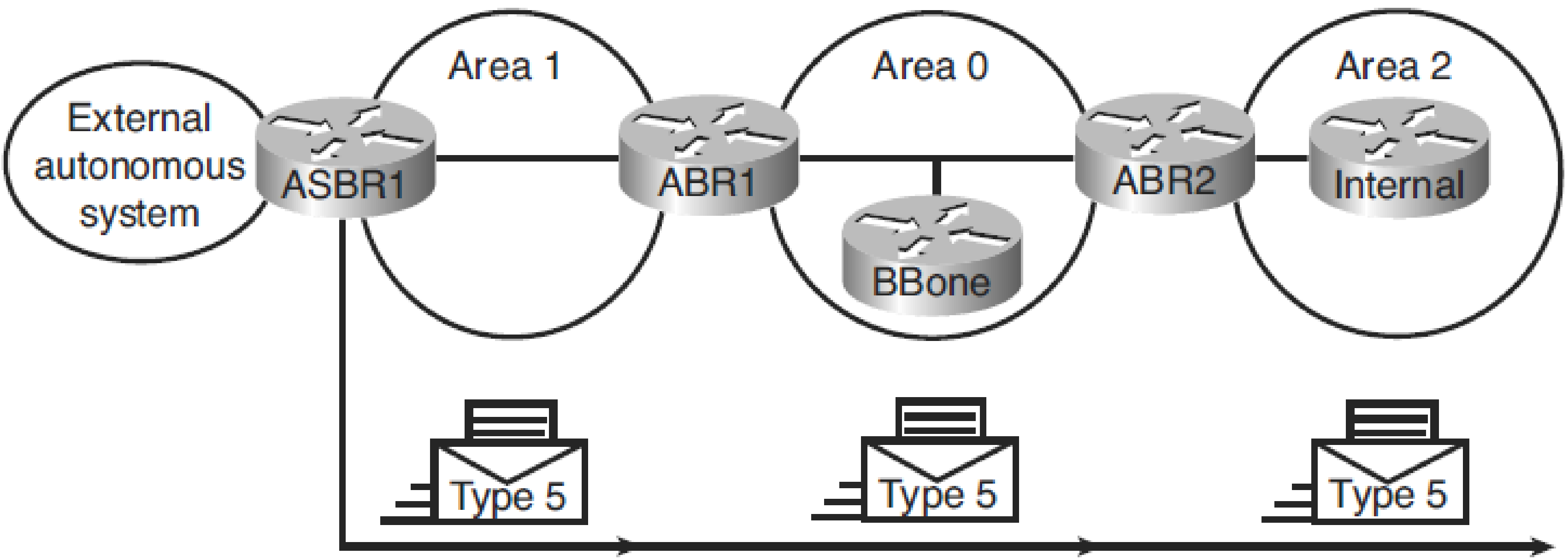
LSA Type 4: Summary LSA

- Generated by the ABR of the originating area to advertise an ASBR to all other areas in the autonomous system.
  - They are regenerated by all subsequent ABRs to flood throughout the autonomous system.
  - Link-state ID is the router ID of the ASBR.
  - Routing Table Entry = **O IA**



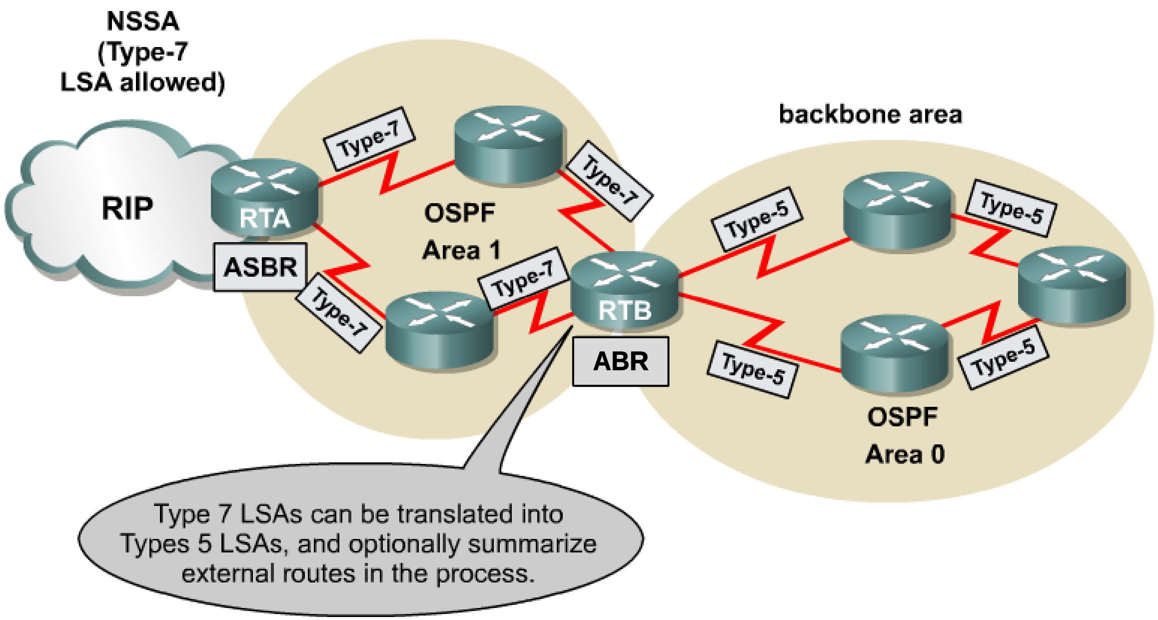
LSA Type 5: External LSA

- Used by the ASBR to advertise networks from other autonomous systems.
  - Type 5 LSAs are advertised and owned by the originating ASBR.
  - The Link-state ID is the external network number.
  - Routing Table Entry = **O E1** or **O E2**



LSA Type 7: NSSA LSA

- Generated by an ASBR inside a Not-so-stubby area (NSSA) to describe routes redistributed into the NSSA.
  - LSA 7 is translated into LSA 5 as it leaves the NSSA.
  - Routing Table Entry = **O N1** or **O N2**
  - Much like LSA 5, N2 is a static cost while N1 is a cumulative cost that includes the cost up to the ASBR.



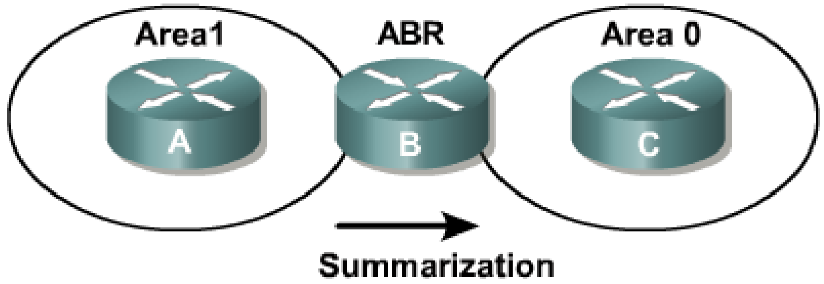
Best Path Calculation

1. All routers calculate the best paths to destinations *within their area (intra-area) and* add these entries to the routing table.
    - Includes type 1 and 2 LSAs, noted with a designator of **O**.
2. All routers calculate the best paths to the *other areas.*
    - Includes type 3 and 4 LSAs, noted with a designator of **O IA.**
3. All routers calculate the best paths to the external autonomous system (type 5) destinations.
    - Includes either external type 1 (E1), indicated with an **O E1** or external type 2 (E2), indicated with an **O E2**.

Route Summarization

- Route summarization involves consolidating multiple routes into a single advertisement.
- Proper route summarization directly affects the bandwidth, memory and CPU, that are consumed by the OSPF process.
  - If a network link fails or flaps, the topology change will not be propagated into the backbone or other areas.
  - It protects routers from needless routing table recalculations.
  - Because the SPF calculation places a significant demand on the router's CPU, proper summarization is an imperative part of OSPF configuration.
- Useful in ABR or ASBR to summarize multiple LSAs into one summary LSA

Using Route Summarization



Routing Table for B

```
O 172.16.8.0 255.255.255.0
O 172.16.9.0 255.255.255.0
O 172.16.10.0 255.255.255.0
O 172.16.11.0 255.255.255.0
O 172.16.12.0 255.255.255.0
O 172.16.13.0 255.255.255.0
O 172.16.14.0 255.255.255.0
O 172.16.15.0 255.255.255.0
O 172.16.16.0 255.255.255.0
O 172.16.17.0 255.255.255.0
O 172.16.18.0 255.255.255.0
O 172.16.19.0 255.255.255.0
```

LSAs Sent to Router C

```
IA 172.16.8.0 255.255.248.0
IA 172.16.16.0 255.255.252.0
```

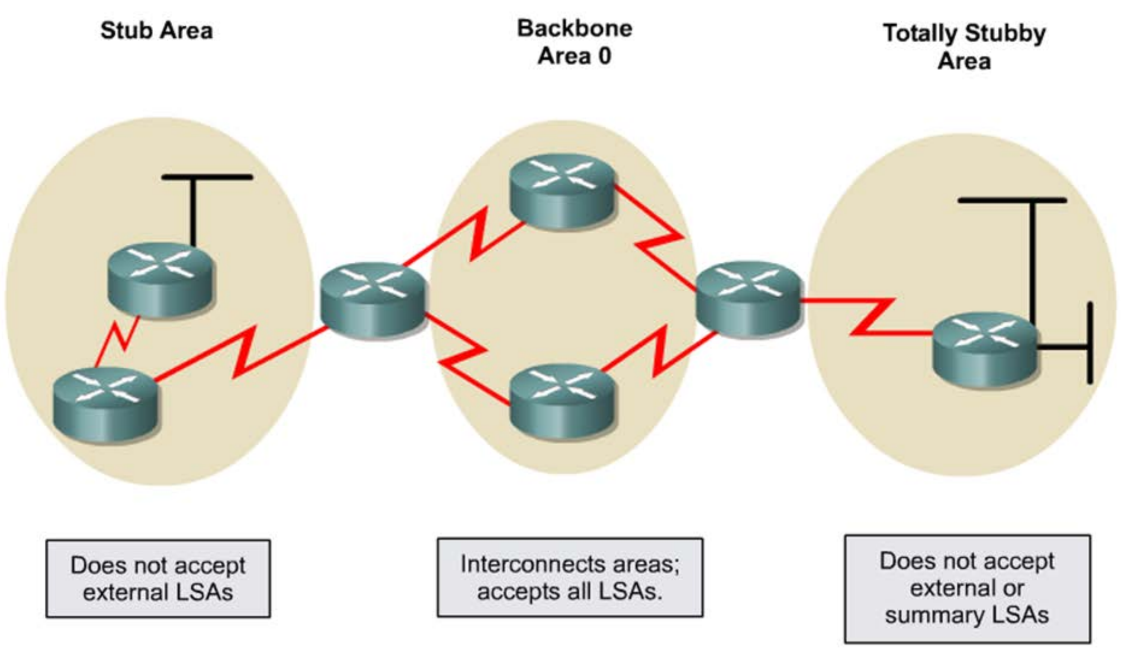
- Interarea summary link carries mask.
- One or more entries can represent several subnets.

Types of Route Summarization

- Inter-area summarization
  - Performed at the ABR and creates Type 3 LSAs.
- External summarization
  - Performed at the ASBR and creates Type 5 LSAs.
- Both have the same fundamental requirement of contiguous addressing.
- If summarization is not configured correctly and there are multiple ASBRs, or multiple ABRs in an area, suboptimal routing is possible.
  - For example, summarizing overlapping ranges from two different routers can cause packets to be sent to the wrong destination.

OSPF Special Area Types

- The OSPF standard area can be further divided into four types of stub areas:
  - Stub area
  - Totally stubby area
  - NSSA
  - Totally stubby NSSA

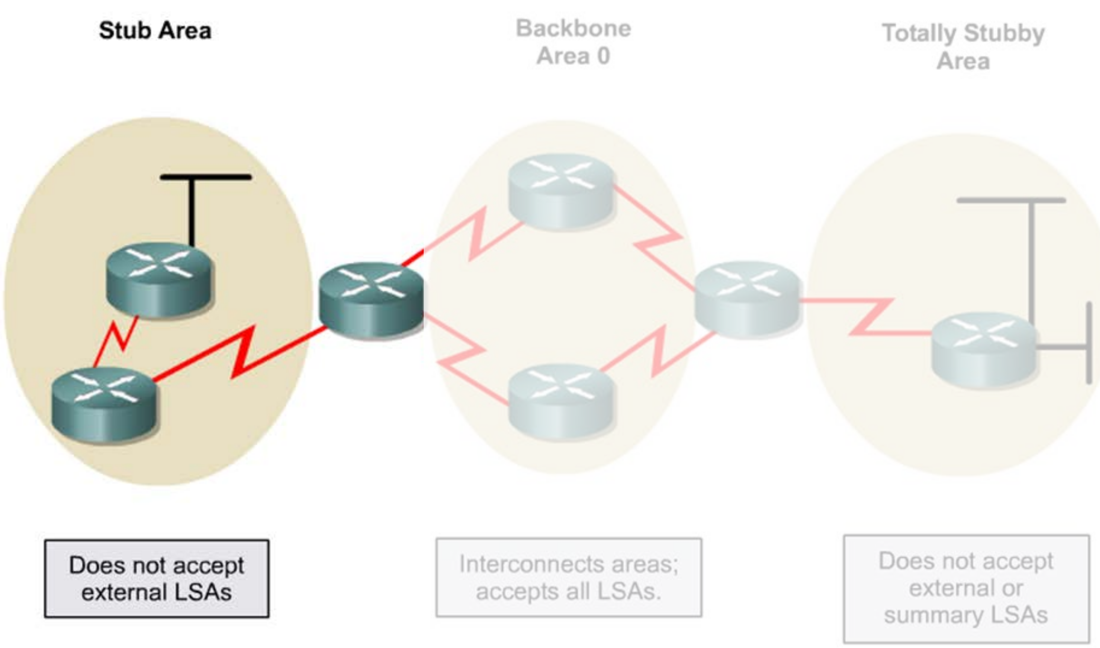


Stub and Totally Stub Area Characteristics

- An area qualifies as stub or totally stubby area if it has the following characteristics:
  - The area is not the backbone area (area 0).
  - There is a single exit point from that area.
    - If there are multiple exits, one or more ABRs should inject a default route into the stub area however suboptimal routing paths might occur.
  - There is no ASBR inside the area.
  - The area is not used as a transit area for virtual links.

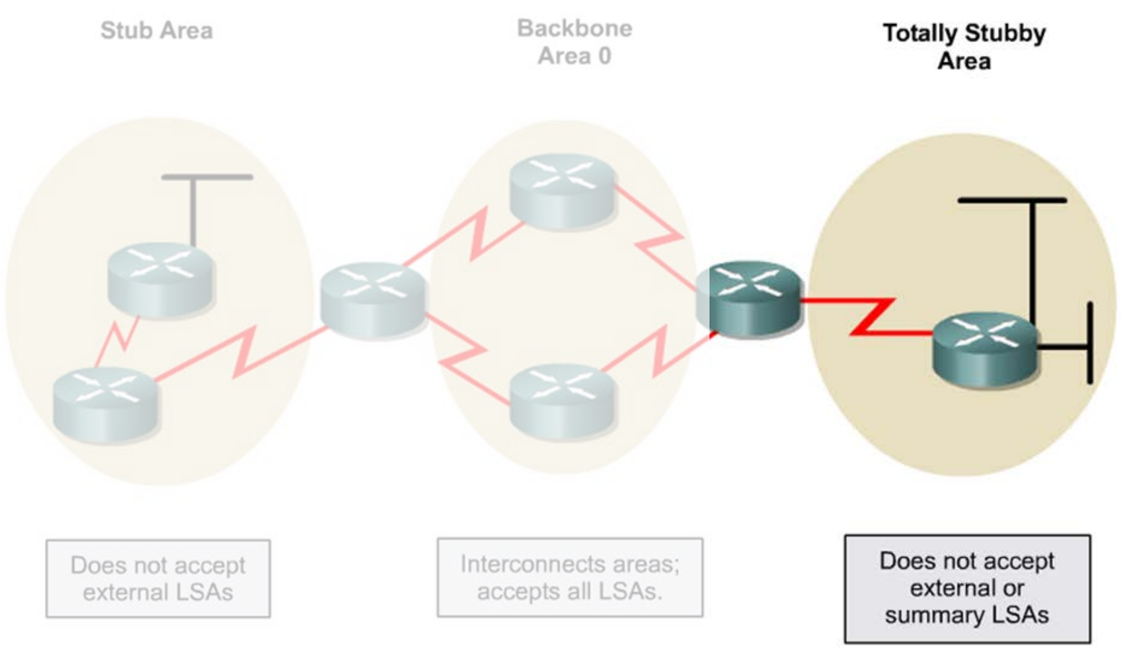
Stub Area

- A Stub Area does not accept external summary routes from non-OSPF sources (e.g., RIP, EIGRP).
  - Specifically, it does not accept Types 4 and 5 LSAs.
  - A default route (0.0.0.0) is propagated throughout the area to send a packet to an external network.



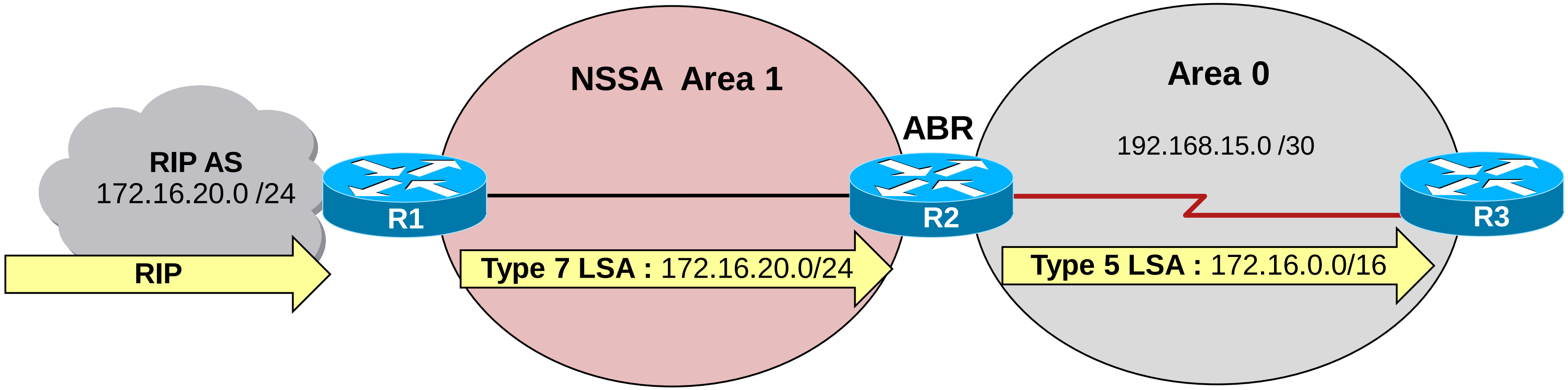
Totally Stubby Area

- Cisco proprietary solution that is better than stub area.
- Area does not accept external AS routes or inter-area routes.
  - Specifically, it does not accept Types 3, 4 and 5 LSAs.
  - It recognizes only intra-area routes and the default route 0.0.0.0.
  - A default route (0.0.0.0) is propagated throughout the area.



Not-So-Stubby Area (NSSA)

- Similar to a Stub Area, except that it is primarily used to connect to ISPs, or when redistribution is required.
  - Specifically, it does not accept Types 4 and 5 LSAs.
  - Allows the importing of external routes as Type 7 LSAs and converts them to Type 5 LSAs on the ABR.
  - Better than creating stub areas and also useful for spokes.



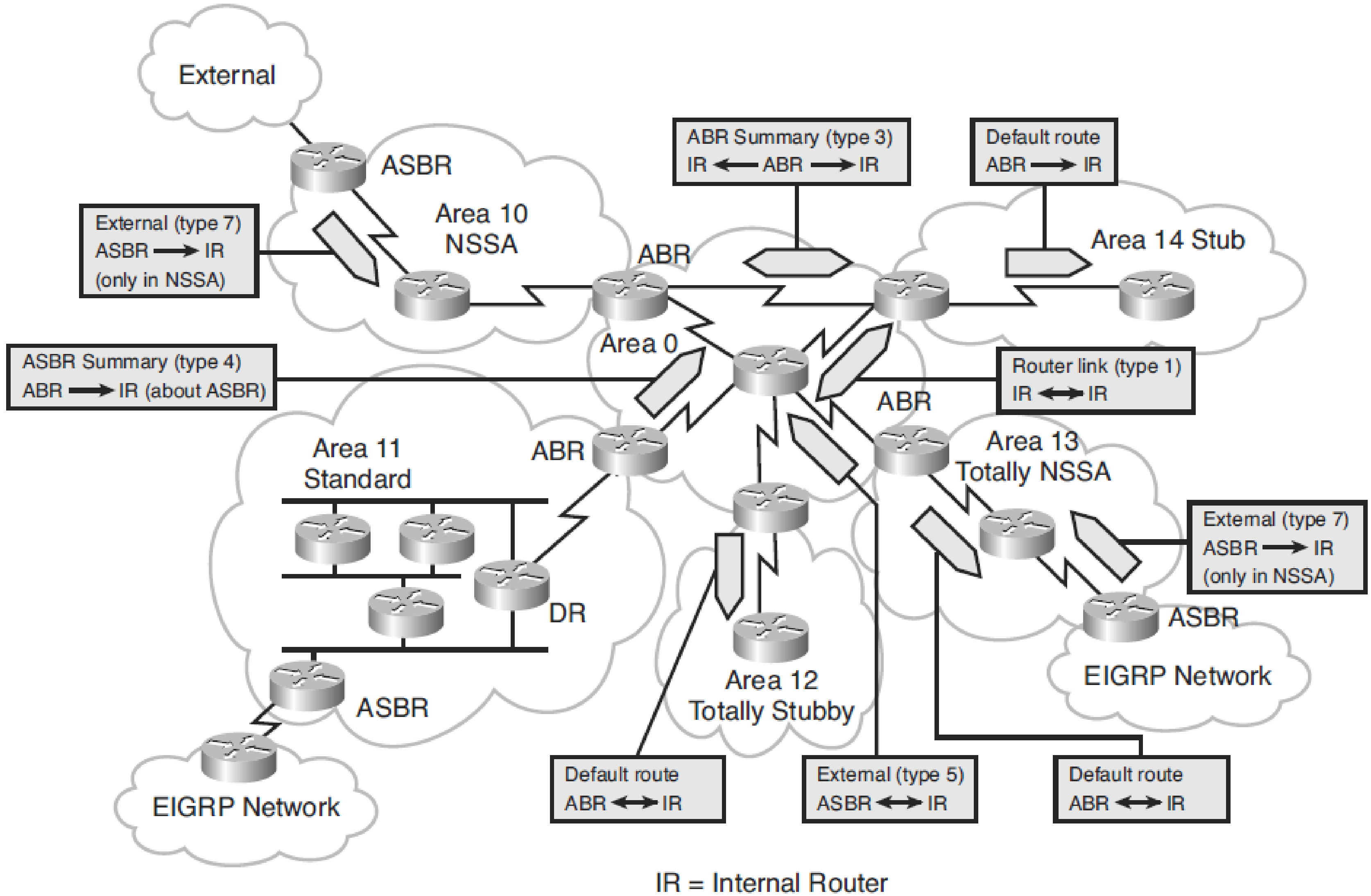
Totally Stubby NSSA

- Cisco proprietary solution to NSSA.
- Area does not accept external AS routes or inter-area routes.
  - Specifically, it does not accept Types 3, 4 and 5 LSAs.
  - It recognizes only intra-area routes and the default route 0.0.0.0.
  - A default route (0.0.0.0) is propagated throughout the area.
- The ABR of a totally stubby NSSA must be configured with the **`no-summary`** keyword to prevent the flooding of summary routes for other areas into the NSSA area.

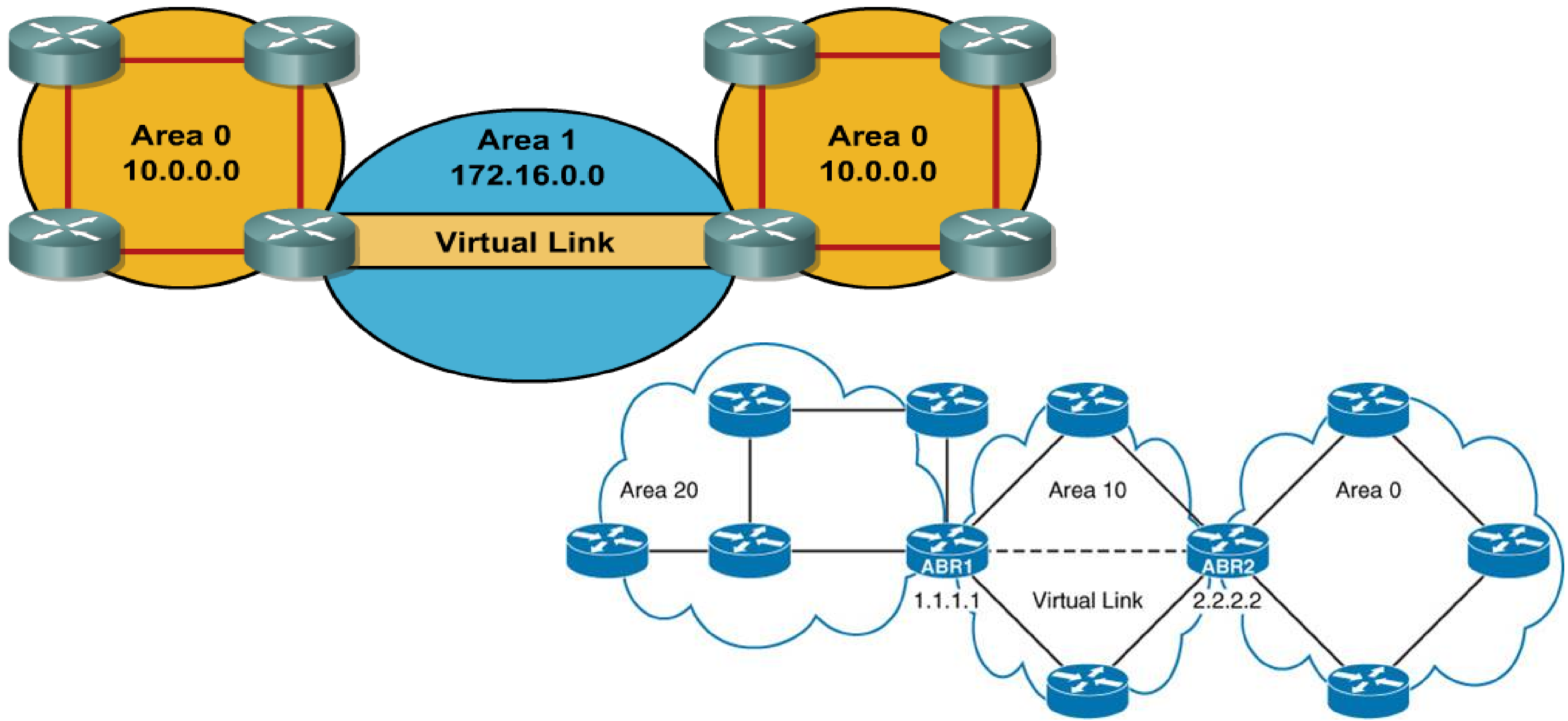
How Does OSPF Generate Default Routes?

- Depends on the type of area.
- In a standard area:
  - Routers do not automatically generate default routes.
  - The **`default-information originate`** command must be used.
- In a stub and totally stubby area:
  - The ABR automatically generates a summary LSA with the link-state ID 0.0.0.0.
  - The **`default-information originate`** command is not required.
  - This is true even if the ABR does not have a default route.
- In an NSSA area:
  - The ABR generates the default route, but not by default.
  - To force the ABR to generate the default route, use the **`area`** *`area-id`* **`nssa default-information-originate`** command.
- In a totally stubby NSSA:
  - The ABR automatically generates a default route.

Example OSPF Area Types in a Network



Virtual Links

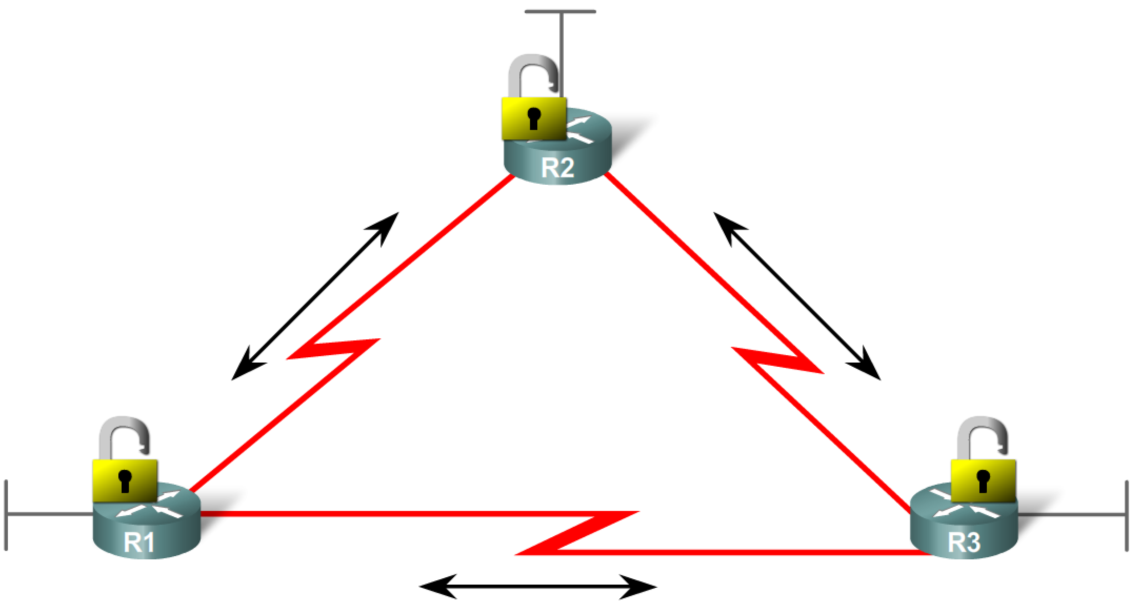


- Virtual links are used to connect a discontiguous area 0 or to connect an area to area 0 through another area.
- A logical connection is built between the ABRs.
- Virtual links are recommended for backup or temporary connections.

OSPF Authentication

- Purpose is to authenticate routing information.
  - This is an interface specific configuration.
  - Routers will only accept routing information from other routers that have been configured with the same authentication information.

Authentication



OSPF Authentication Types

- Router generates and checks each packet and authenticates the source of each update packet it receives
- Requires a pre-defined “key” (password)
  - Note: All participating neighbors must have the same key configured
- OSPF supports 2 types of authentication:
  - Simple password authentication (plain text)
    - Less secure
  - MD5 authentication
    - More secure and recommended

Planning to Deploy OSPF

- Prior to deploying an OSPF routing solution, the following should be considered:
  - IP addressing plan
  - Network topology
  - OSPF areas
- Once the requirements have been assessed, the implementation plan can be created.

Troubleshooting OSPF - Routing Review

- To diagnose and resolve problems related to OSPF, you must be able to do the following:
  - Apply your knowledge of OSPF data structures to plan the gathering of necessary information as part of a structured approach to troubleshooting OSPF routing problems
  - Apply your knowledge of the processes that OSPF uses to exchange network topology information within an area, to interpret and analyze the information that is gathered during an OSPF troubleshooting process
  - Apply your knowledge of the processes that OSPF uses to exchange network topology information between areas, to interpret and analyze the information that is gathered during an OSPF troubleshooting process
  - Use IOS commands to gather information from the OSPF data structures and track the flow of OSPF routing information to troubleshoot OSPF operation

Troubleshooting OSPF - Routing Review

OSPF stores its operational data, configured parameters, and statistics in four main data structures:

- Interface table
  - Lists all interfaces enabled for processing OSPF packets
  - Passive interfaces are stored, but no neighbor relationsships establ.
- Neighbor table
  - To keep track of all active OSPF neighbors
  - Built based on the reception of hello packets
- Link-state database
  - Contains full topology information for the areas that a router connects to, and information about the available paths to reach other areas
- Routing Information Base
  - The results from the SPF calculations
  - Includes best routes with associated costs

Monitoring OSPF with show Commands

To gather information from the OSPF data structures use the following **`show`** commands:

- **`show ip ospf`**:
  - Displays general OSPF information, Router ID, areas, their types, SPF run count and other
- **`show ip ospf interface [brief]`**:
  - Displays the interfaces that have been activated for OSPF.
  - Listing contains interfaces that have an IP address covered by a network statement or configured using the interface configuration mode command: ip ospf process-number area area-number.
- **`show ip ospf neighbor`**:
  - Lists all neighbors of this router on its active OSPF interfaces and shows their current state.
- **`show ip ospf database`**:
  - Displays a summary of the OSPF link-state database content (LSA headers).
  - Using additional command options, specific LSAs can be selected and the actual LSA content can be inspected.
- **`show ip ospf statistics`**:
  - Displays how often and when the SPF algorithm was last executed.
  - This command can be helpful when diagnosing routing instability.

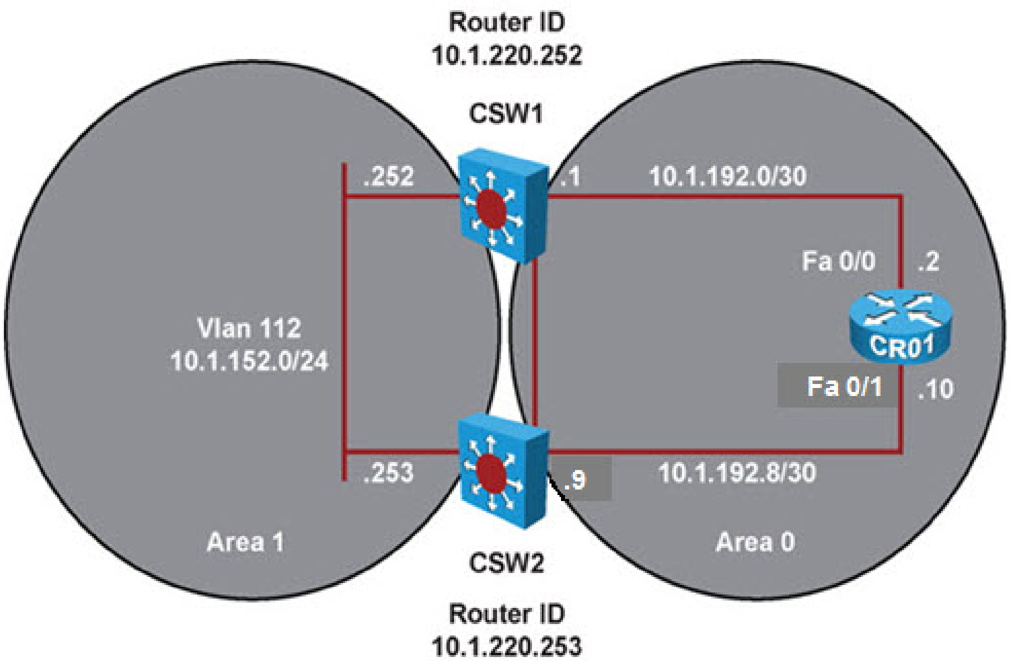
Monitoring OSPF with debug Commands

To observe the real-time OSPF information exchange use the following **`debug`** commands:

- **`debug ip routing`**:
  - Command is not specific to the OSPF protocol.
  - Displays any changes that are made to the routing table, such as installation or removal of routes.
  - Can be useful in diagnosing routing protocol instabilities.
- **`debug ip ospf packet`**:
  - Displays the transmission and reception of OSPF packets.
  - Only the packet headers are displayed, not the content of the packets.
  - Can be useful to verify if Hellos are sent and received as expected.
- **`debug ip ospf events`**:
  - This command displays OSPF events such as reception and transmission of Hellos.
  - Output also includes the establishment of neighbor relationships and the reception or transmission of LSAs.
  - Can provide clues as to why neighbor Hellos might be ignored (mismatched parameters such as timers, area number, etc.).

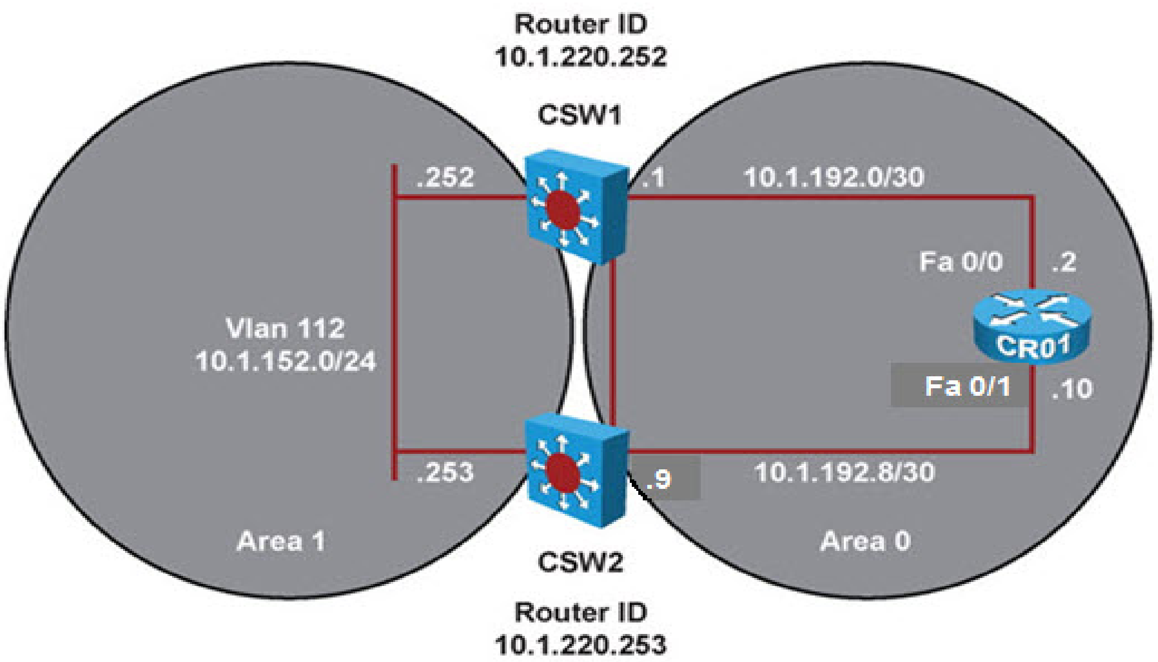
OSPF Troubleshooting Example

Only one equal-cost OSPF path used by CR01




```
CRO1# show ip route 10.1.152.0 255.255.255.0
Routing entry for 10.1.152.0/24
  Known via "ospf 100", distance 110, metric 2, type inter area
  Last update from 10.1.192.1 on FastEthernet0/0, 00:00:11 ago
  Routing Descriptor Blocks:
  * 10.1.192.1, from 10.1.220.252, 00:00:11 ago, via FastEthernet0/0
      Route metric is 2, traffic share count is 1
```

OSPF Troubleshooting Example - Cont.



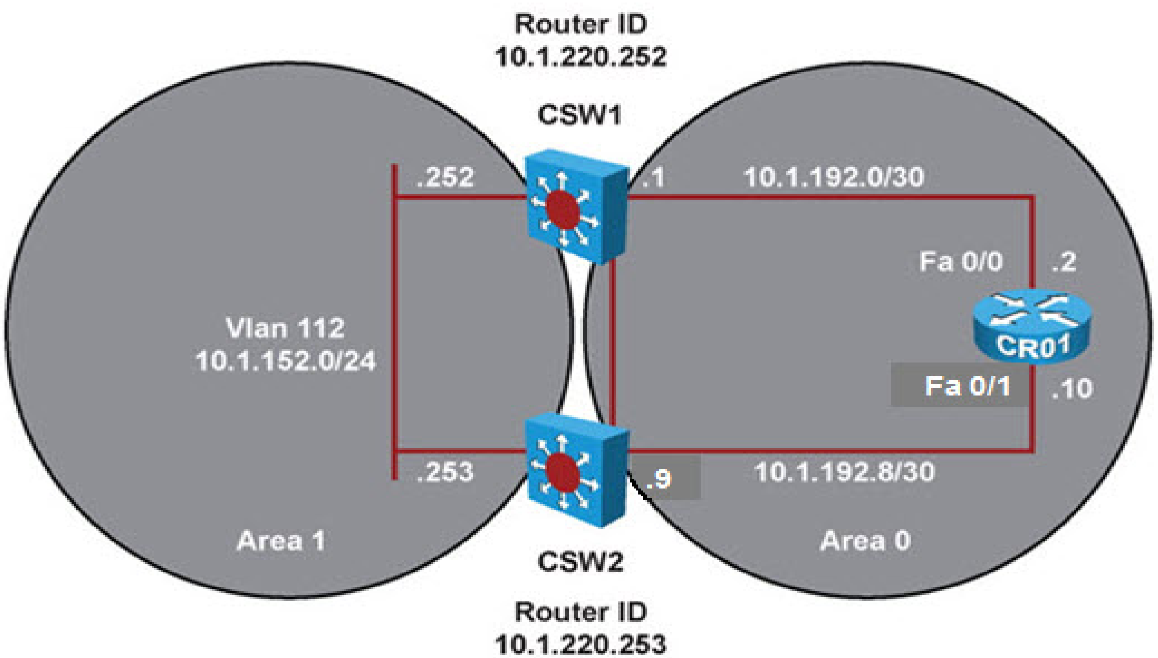

```
CRO1# ping 10.1.192.9

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.192.9, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
```

OSPF Troubleshooting Example - Cont.

The CR01 link-state database shows two Area 0 Type-3 summary LSAs for network 10.1.152.0, one from CSW1 and one From CSW2.

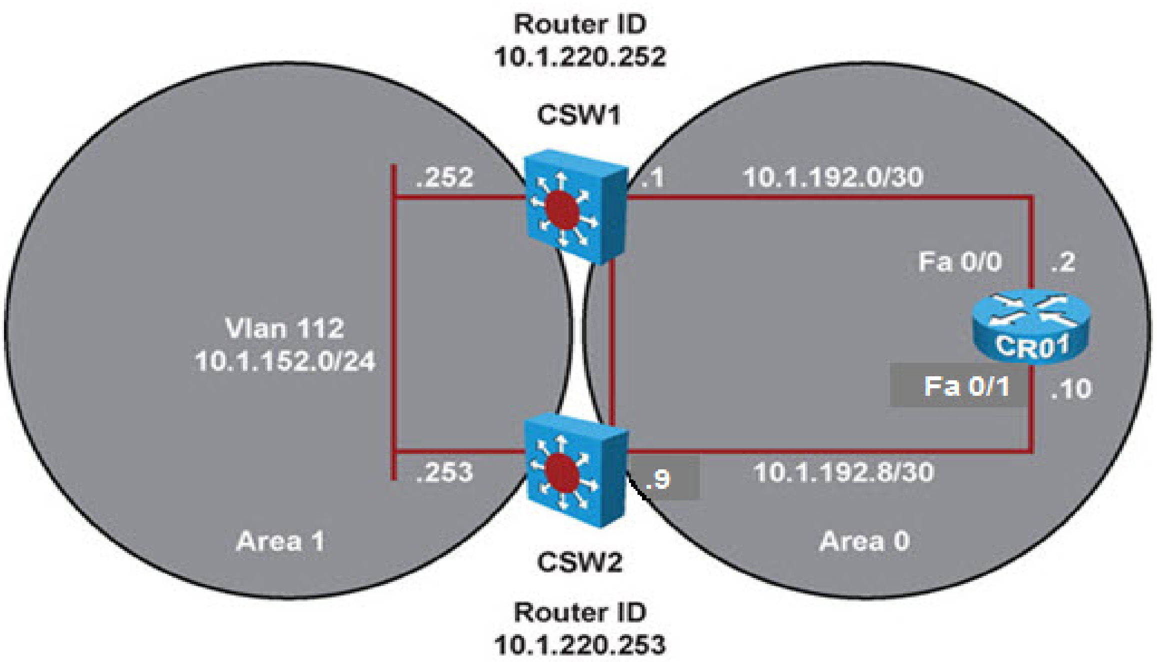
```
CRO1# show ip ospf database summary 10.1.152.0
            OSPF Router with ID (10.1.220.1) (Process ID 100)
            Summary Net Link States (Area 0)
Routing Bit Set on this LSA
  LS age: 201
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.1.152.0 (summary Network Number)
  Advertising Router: 10.1.220.252
  LS Seq Number: 80000001
  Checksum: 0x1C97
  Length: 28
  Network Mask: /24
  TOS: 0     Metric: 1

  LS age: 136
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.1.152.0 (summary Network Number)
  Advertising Router: 10.1.220.253
  LS Seq Number: 80000001
  Checksum: 0x169C
  Length: 28
  Network Mask: /24
```

OSPF Troubleshooting Example - Cont.



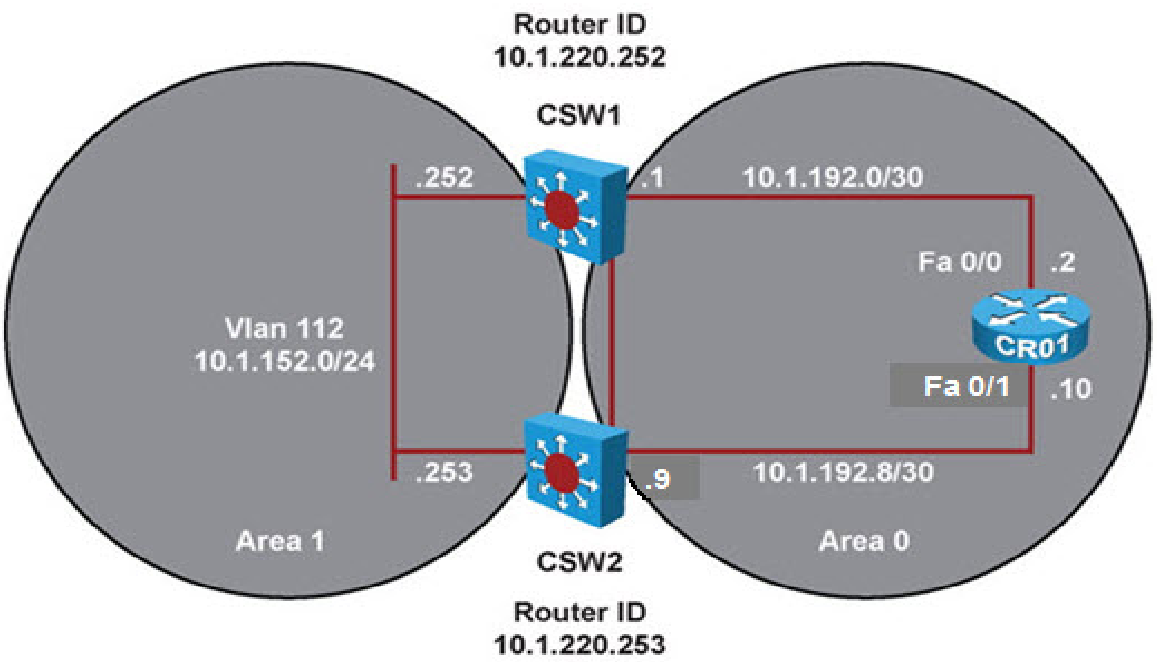

```
CRO1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.220.252      1   FULL/DR         00:00:33    10.1.192.1      FastEthernet0/0
```

OSPF Troubleshooting Example - Cont.




```
CRO1# show ip ospf interface brief
Interface      PID    Area              IP Address/Mask     Cost   State Nbrs F/C
Lo0            100    0                 10.1.220.1/32       1      LOOP  0/0
Fa0/0          100    0                 10.1.192.2/30       1      BDR   1/1
```

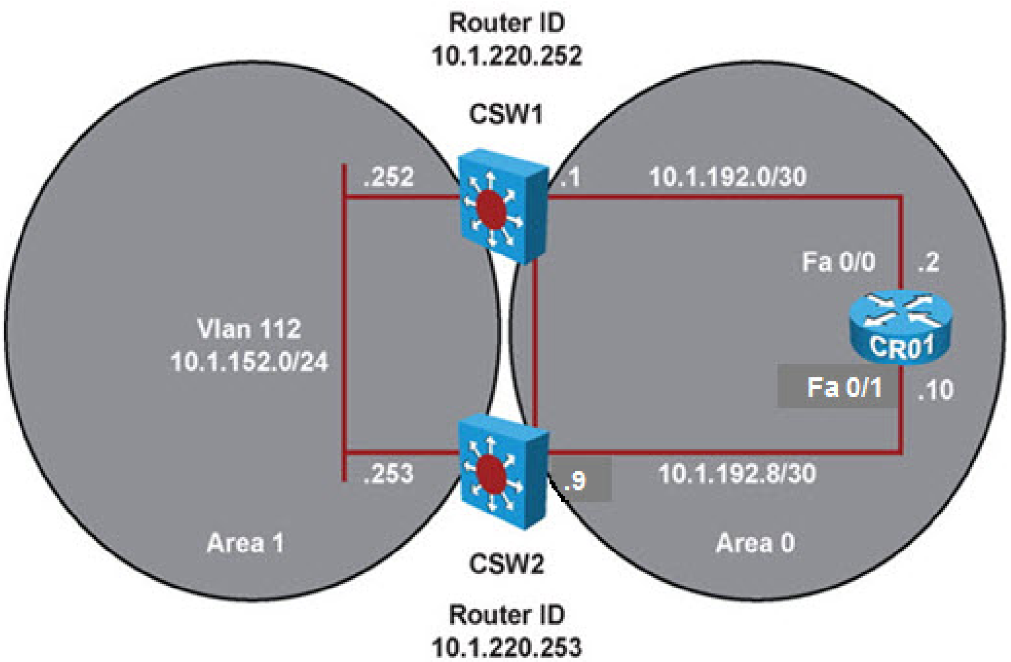
OSPF Troubleshooting Example - Cont.




```
CRO1# show running-config | section router ospf
router ospf 100
 log-adjacency-changes
 network 10.1.192.0 0.0.0.3 area 0
 network 10.1.220.1 0.0.0.0 area 0
```

OSPF Troubleshooting Example:

Correcting the network statement



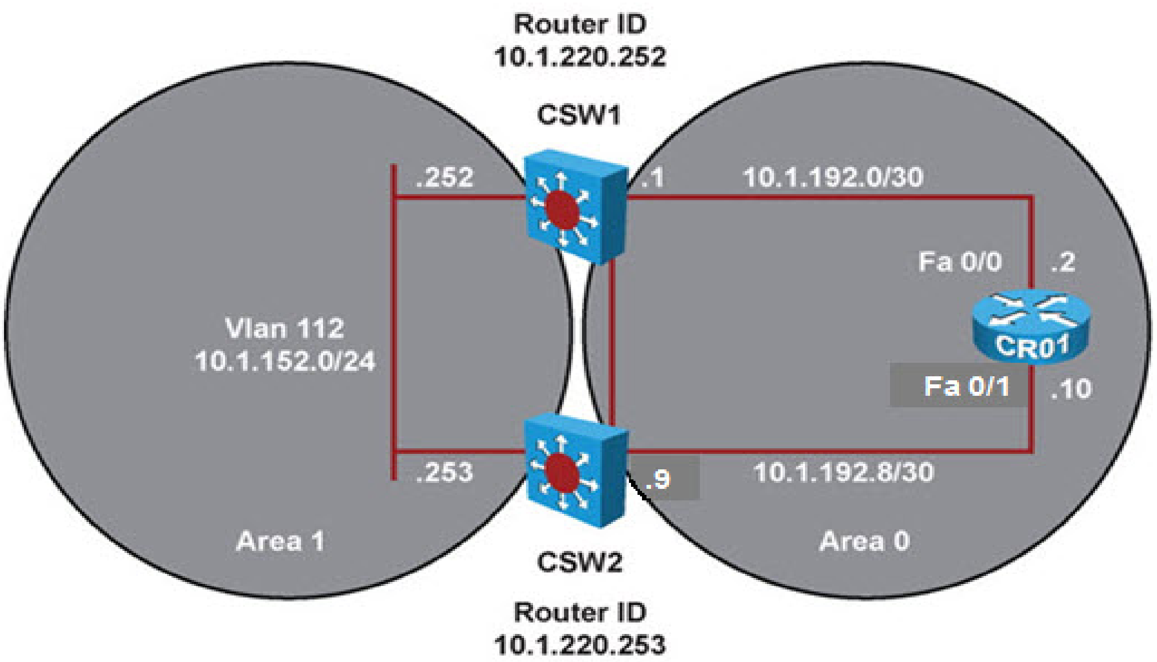

```
CRO1(config)# router ospf 100
CRO1(config-router)# network 10.1.192.8 0.0.0.3 area 0
```

OSPF Troubleshooting Example - Cont.

Results of **show** commands after correcting the OSPF network statement:

```
CRO1# show ip ospf interface brief
Interface     PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Lo0           100   0               10.1.220.1/32      1     LOOP  0/0
Fa0/1         100   0               10.1.192.10/30     1     BDR   1/1
Fa0/0         100   0               10.1.192.2/30      1     BDR   1/1


CRO1# show ip ospf neighbor
Neighbor ID     Pri   State       Dead Time   Address        Interface
10.1.220.253      1   FULL/DR     00:00:39    10.1.192.9     FastEthernet0/1
10.1.220.252      1   FULL/DR     00:00:31    10.1.192.1     FastEthernet0/0
```

OSPF Troubleshooting Example - Cont.




```
CRO1# show ip route 10.1.152.0 255.255.255.0
Routing entry for 10.1.152.0/24
  Known via "ospf 100", distance 110, metric 2, type inter area
  Last update from 10.1.192.9 on FastEthernet0/1, 00:00:29 ago
  Routing Descriptor Blocks:
    10.1.192.9, from 10.1.220.253, 00:00:29 ago, via FastEthernet0/1
      Route metric is 2, traffic share count is 1
  * 10.1.192.1, from 10.1.220.252, 00:00:29 ago, via FastEthernet0/0
      Route metric is 2, traffic share count is 1
```

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