Cabrillo College

CCNP – Advanced Routing

Ch. 5 OSPF - Multi-areas (Part I)

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Mar. 4, 2002

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OSPF Multi-Area Part I

- Areas
- LSAs
- show ip ospf database (summary of link state database)
- show ip route
- Stub Areas
- Totally Stubby Areas

OSPF Multi-Area Part II (next week)

- E1 and E2 routes
- Default Routes
- Route Summarization
- NSSA (Not So Stubby Areas)
- Multiple ABR Scenario
- Multiple ASBR Scenario
- Virtual Links
- Load Balancing
- show commands

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Issues with large OSPF nets

- Large link-state table
  - Each router maintains a LSDB for all links in the area
  - The LSDB requires the use of memory
- Frequent SPF calculations
  - A topology change in an area causes each router to re-run SPF to rebuild the SPF tree and the routing table.
  - A flapping link will affect an entire area.
  - SPF re-calculations are done only for changes within that area.
- Large routing table
  - Typically, the larger the area the larger the routing table.
  - A larger routing table requires more memory and takes more time to perform the route look-ups.

Solution: Divide the network into multiple areas

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Rick' s OSPF Scenarios

We will be using the following handout for this presentation:

Rick' s OSPF Handout:

1. OSPF Multi-Area - All Normal Areas
2. OSPF Multi-Area - Stub Area
3. OSPF Multi-Area - Totally Stubby Area

Handouts can be downloaded from (Word doc):

- http://www.cabrillo.cc.ca.us/ciscoacad/curriculum/presentations/semester5/OSPF_Scenario_Handout.doc

Instructors: Draw this network on the white-board as it will be used for discussion throughout these slides

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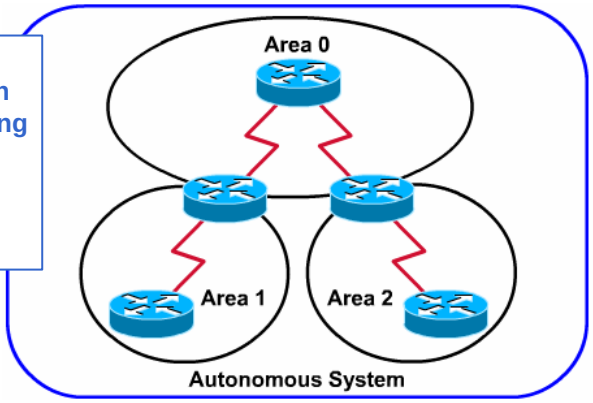
OSPF uses “Areas”

- Hierarchical routing enables you to separate large internetworks (autonomous systems) into smaller internetworks that are called **areas**.
- With this technique, routing still occurs between the areas (called **inter-area routing**), but many of the smaller internal routing operations, such as recalculating the database – re-running the SPF algorithm, are restricted within an area.

Sometimes referred to an “OSPF Routing Domain” instead of an Autonomous System



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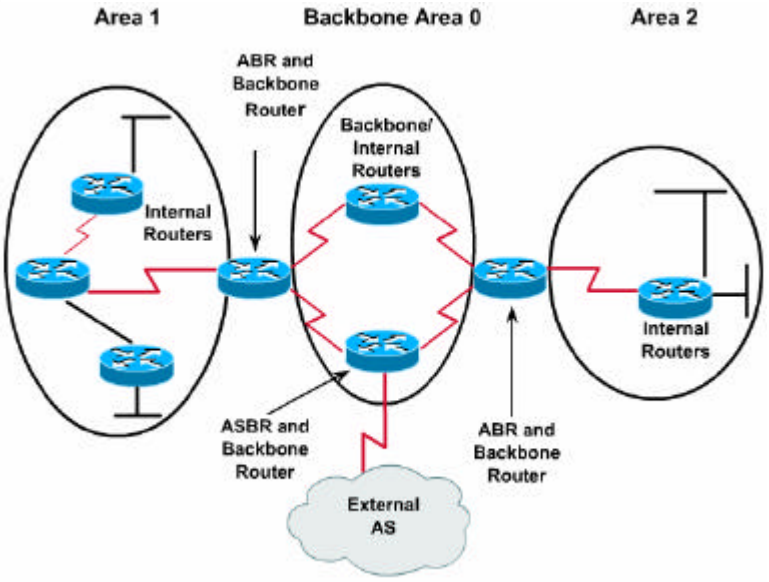
OSPF Router Types



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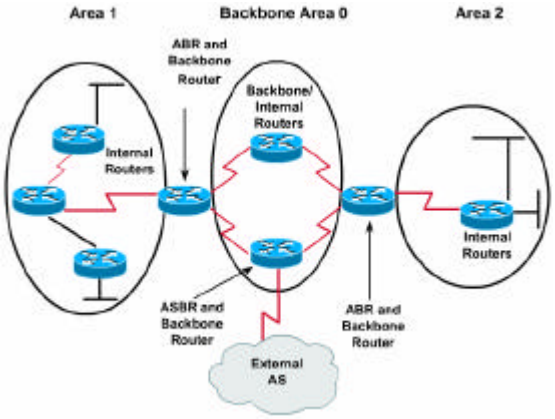
OSPF Router Types

Internal: Routers with all their interfaces within the same area

Backbone: Routers with at least one interface connected to area 0

***ASBR*:** (Autonomous System Boundary Router): Routers that have at least one interface connected to an external internetwork (another autonomous system)

***ABR*:** (Area Border Router): Routers with interfaces attached to multiple areas.



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OSPF Packet Types

- Last week we discussed various OSPF packets, used for:
  - Means for dynamic neighbor discovery
  - Detect unreachable neighbors within a finite period of time
  - Ensure two-way communications between neighbors
  - Ensure correctness of basic interace parameters between neighbors
  - Provide necessary information for the election of the Designated and Backup Designated routers on a LAN segement
  - Request link state information from another router
  - Sharing data base summary and detailed information
  - Acknowledge the receipt of an OSPF packet

OSPF packet types

Type	Description
1	Hello (establishes and maintains adjacency relationships with neighbors)
2	Database description packet (describes the contents of an OSPF router's link-state database)
3	Link-state request (requests specific pieces of a neighbor router's link-state database)
4	Link-state update (transports link-state advertisements (LSAs) to neighbor routers)
5	Link-state acknowledgement (Neighbor routers acknowledge receipt of the LSAs)

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OSPF Type 4 - Link State Advertisements

- This week we will look at OSPF Type 4 packets more closely

OSPF packet types

Type	Description
1	Hello (establishes and maintains adjacency relationships with neighbors)
2	Database description packet (describes the contents of an OSPF router's link-state database)
3	Link-state request (requests specific pieces of a neighbor router's link-state database)
4	Link-state update (transports link-state advertisements (LSAs) to neighbor routers)
5	Link-state acknowledgement (Neighbor routers acknowledge receipt of the LSAs)

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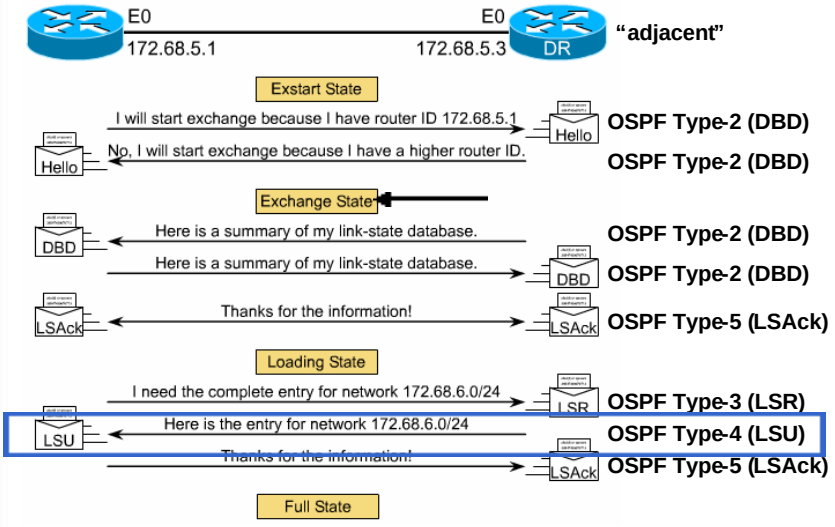
OSPF packet types

Type	Description
1	Hello (establishes and maintains adjacency relationships with neighbors)
2	Database d… router's link-state database)
3	Link-state request (requests link-state database)
4	Link-state update (transport neighbor routers)
5	Link-state acknowledgemen receipt of the LSAs)

OSPF Type-4 packets have 7 LSA packets (later)

LSA Type	Name	Description
1	Router link entry (record) (O-OSPF)	Generated by each router for each area it belongs to. It describes the states of the router's link to the area. These are only flooded within a particular area.The link status and cost are two of the descriptors provided.
2	Network link entry (O-OSPF)	Generated by Designated Router in multiaccess networks. They describe the set of routers attached to a particular network. LSA Type 2 messages are flooded only within the area that contains the network.
3 or 4	Summary link entry (IA-OSPF Inter area)	Originated by ABRs. They describes the links between the ABR and the internal routers of a local area. These entries are flooded throughout the backbone area to the other ABRs. Type-3 message s describe routes to networks within the local area and are sent to the backbone area. Type-4 messages describe reachability to ASBRs. These link entries are not flooded through totally stubby areas.
5	Autonomous system external link entry (E1-OSPF external type-1)	Originated by the ASBR. Describes routes to destinations external to the autonomous system. Flooded throughout an OSPF autonomous system except for stub and totally stubby areas.

LSAs used for discovering routes and reaching Full State, along with Maintain Routes



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LSA Types

LSA Types 1 through 5

- We will look at these in detail as we discuss areas in this chapter.

LSA Type 6 **MOSPF (Multicast OSPF)**

- Not supported by Cisco.
- MOSPF enhances OSPF by letting routers use their link-state databases to build multicast distribution trees for the forwarding of multicast traffic.

LSA Type 7 **NSSA External Link Entry**

- Originated by an ASBR connected to an NSSA.
- Type 7 messages can be flooded throughout NSSAs and translated into LSA Type 5 messages by ABRs.
- Routes learned via Type-7 LSAs are denoted by either a "N1" or and "N2" in the routing table. (Compare to E1 and E2).
- We will discuss this more later when we look at NSSA areas.

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Area Types

- Standard or Normal Areas
  - Backbone
  - Non-Backbone
- Stub
  - Stub Area
  - Totally Stubby Area (TSA)
  - Not-so-stubby-area (NSSA)

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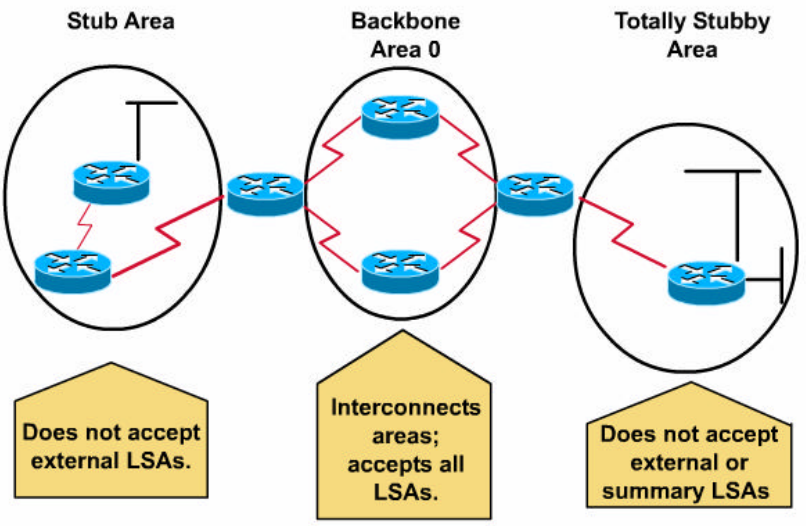
Area Types



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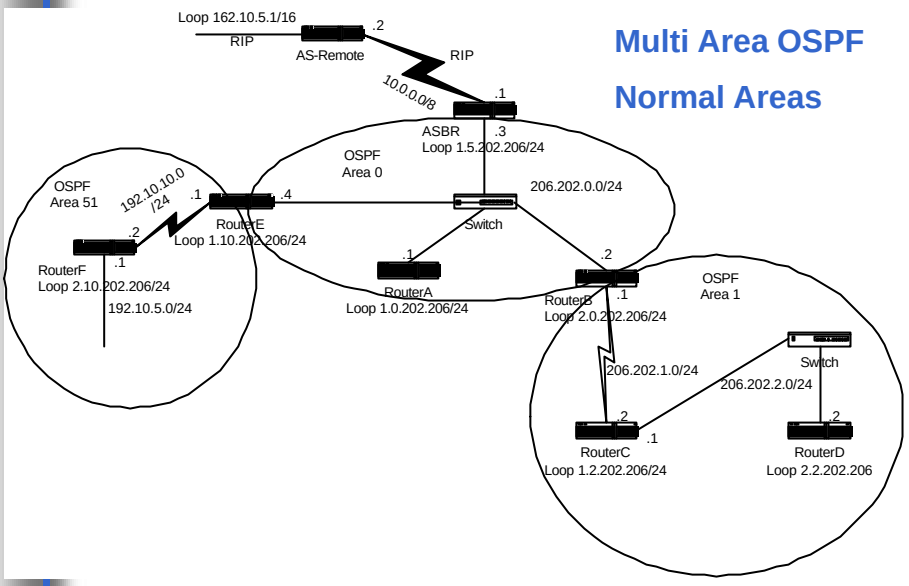
Part I - LSAs in a normal areas



Multi Area OSPF

Normal Areas

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Routes Received on all OSPF Routers

<u>Overview of Normal Areas – This will all be explained!</u>

Receives all routes from within A.S.:

- Within the local area – LSA 1 and LSA 2
- From other areas (Inter-Area) – LSA 3, LSA 4, LSA 5

Receives all routes from External A.S.' s (External AS means routes not from this OSPF routing domain):

- From external AS' s – LSA 5
- As long as routes are being redistributed by the ASBR (more later)

Default Routes

- Received only if **default-information-originate** command was used (later)
- If **default-information-originate** command is <u>not</u> used, then the default route is <u>not</u> received

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Your Turn - In groups, examine running-configs

- Look at the running-configs for "1. OSPF Multi-Areas - All Normal Areas"
- Look at the OSPF network statements!

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1. OSPF Multi-Areas - All Normal Areas

Remote-AS

```
router rip
  network 10.0.0.0
  network 162.10.0.0
```

ASBR

```
router ospf 1
  redistribute rip metric 500
  network 206.202.0.0 0.0.0.255 area 0
ip route 0.0.0.0 0.0.0.0 10.0.0.2
```

RouterA

```
router ospf 1
  network 206.202.0.0 0.0.0.255 area 0
```

RouterB

```
router ospf 1
  network 206.202.0.0 0.0.0.255 area 0
  network 206.202.1.0 0.0.0.255 area 1
```

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1. OSPF Multi-Areas - All Normal Areas

RouterC

```
router ospf 1
  network 206.202.1.0 0.0.0.255 area 1
  network 206.202.2.0 0.0.0.255 area 1
```

RouterD

```
router ospf 1
  network 206.202.2.0 0.0.0.255 area 1
```

RouterE

```
router ospf 1
  network 192.10.10.0 0.0.0.255 area 51
  network 206.202.0.0 0.0.0.255 area 0
```

RouterF

```
router ospf 1
  network 192.10.5.0 0.0.0.255 area 51
  network 192.10.10.0 0.0.0.255 area 51
```

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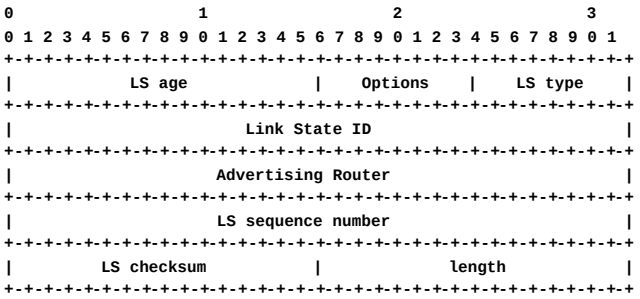
Understanding LSAs

- **show ip ospf database**
  - This is <u>not</u> the link state database, only a summary.
  - It is a tool to help determine what routes are included in the routing table.
  - We will look at this output to learn the tool as well as become familiar with the different types of LSAs.
  - To view the link state database use: **show ip ospf database [router|network| ..]**

LSA Header



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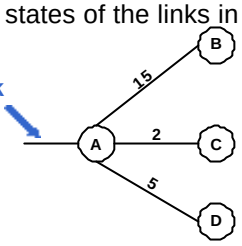
LSA 1 - Router Link States

- LSA 1 – Router LSA
- Generated by each router for each area it belongs to.
- Describes the states of the links in the area to which this router belongs.

"Leaf" network



Last week's Router A's LSA 1s which are flooded to all other routers in this area.

- Tells the other routers in the area about itself and its links to adjacent OSPF routers, and "leaf networks."
- Flooded only within the area.
- Denoted by just an "O" in the routing table or "C" if the network is directly connected.
- ABR will include a set of LSA 1's for each area it belongs to.

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LSA 1 – Router LSA

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            LS age            |     Options   |       1       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link State ID                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Advertising Router                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     LS sequence number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         LS checksum           |             length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    0    |V|E|B|        0      |            # links            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link ID                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link Data                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     # TOS     |            metric             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              ...                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      TOS      |       0       |          TOS  metric          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link ID                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link Data                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              ...                              |
```

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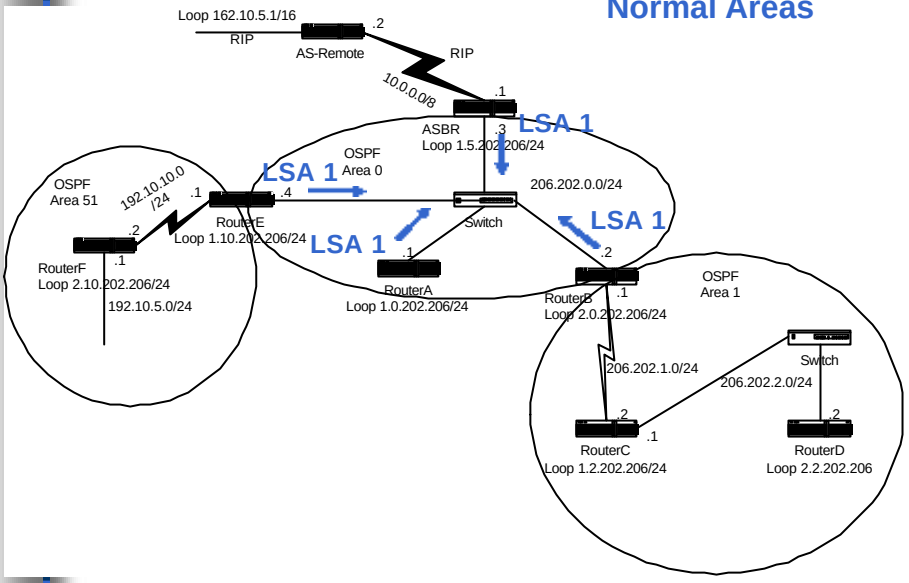
LSA 1's being sent within Area 0

Multi Area OSPF

Normal Areas



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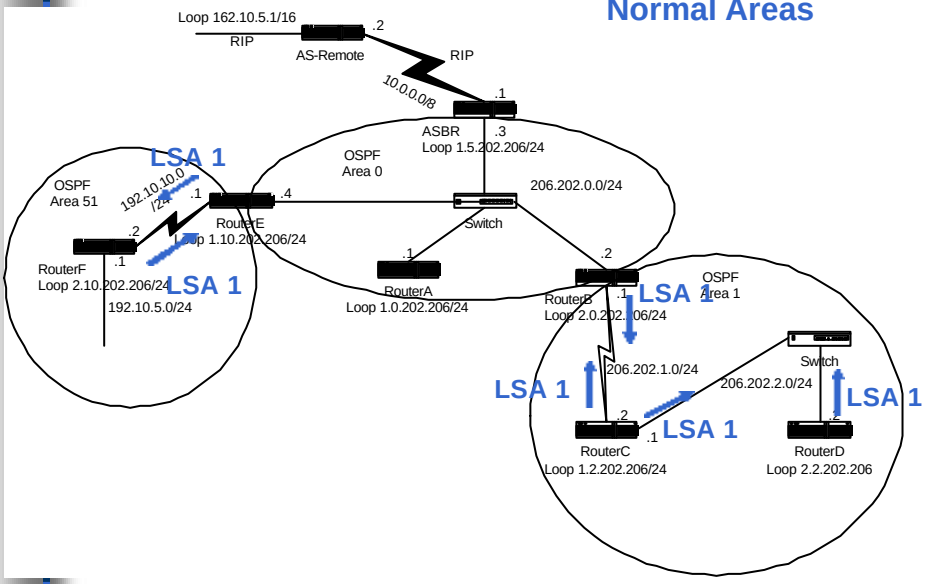
LSA 1's being sent within other areas

Multi Area OSPF

Normal Areas



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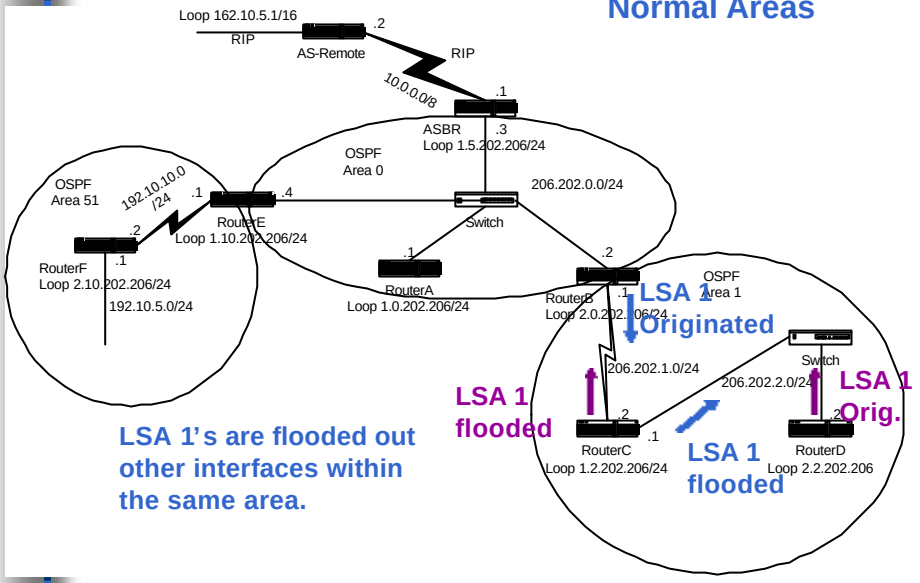
Multi Area OSPF

Normal Areas



LSA 1's are flooded out other interfaces within the same area.

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LSA 1 - Router Link States

- For Router Links, the **Link State ID** is always the same as the **Advertising Router**
- **Advertising Router** is the Router ID of the router that created this LSA 1
- Link Count - Ignore

```
RouterA#show ip ospf database
       OSPF Router with ID (1.0.202.206) (Process ID 1)
                Router Link States (Area 0) <- Note the Area!
```

(LSA 1 - Links in the area to which this router belongs.)

```
Link ID         ADV Router      Age     Seq#       Checksum  Lkcnt
1.0.202.206     1.0.202.206     69      0x80000005 0xA733    1
1.5.202.206     1.5.202.206     357     0x80000005 0x8329    1
1.10.202.206    1.10.202.206    1671    0x80000004 0x2C77    1
2.0.202.206     2.0.202.206     92      0x80000006 0xA035    1
```

- **Bottom line: Router Link States (LSA1's) should display all the RouterIDs of routers in that area, including its own.**
- **Rick's reminder: LSA 1 -> "my one area"**

LSA 1 - Router Link States

Routing Table Results

- Denoted by just an "O" in the routing table, or a "C"

RouterD - show ip route

```
    2.0.0.0/8 is subnetted, 1 subnets
C       2.2.202.0 is directly connected, Loopback0
O IA 206.202.0.0/24 [110/84] via 206.202.2.1, 00:10:45, Ethernet0
O    206.202.1.0/24 [110/74] via 206.202.2.1, 00:10:46, Ethernet0
C    206.202.2.0/24 is directly connected, Ethernet0
O E2 10.0.0.0/8 [110/500] via 206.202.2.1, 00:10:46, Ethernet0
O E2 162.10.0.0/16 [110/500] via 206.202.2.1, 00:10:46, Ethernet0
O IA 192.10.10.0/24 [110/148] via 206.202.2.1, 00:10:46,Ethernet0
O IA 192.10.5.0/24 [110/158] via 206.202.2.1, 00:10:46, Ethernet0
```

- Why is there only just an" O" for this network and not the other networks?
  - Directly connected or via another area.

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Your Turn -Discuss in groups (LSA 1s)

- Using the Handout: "1. OSPF Multi-Areas - All Normal Areas" verify these results.
- Look at the link state database summary (show ip ospf database) commands and the Router Links States (LSA1s) for each router.
- Look at the routing tables (show ip route) and notice the routes within that router' s area.
- *Why do some routers have more than one set of Router Links States?*
- *Where does "show ip ospf database" tell you the RouterID.*
- *Where does "show ip ospf database" tell you the Area.*

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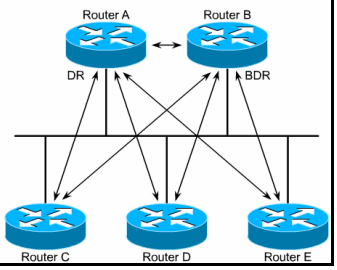
LSA 2 - Net Link States

- LSA 2 – Network LSA
- LSA 2 - Generated by the DR on every multi-access network
- Denoted by just an "O" in the routing table or "C" if the network is directly connected.
- Network LSAs (LSA 2) are flooded only within the originating area.
- In link state database for **all** routers within area, even those routers on not on multi-access networks or DRs on other multi-access networks in the same area.
- ABR will include a set of LSA 2s for each area it belongs to.

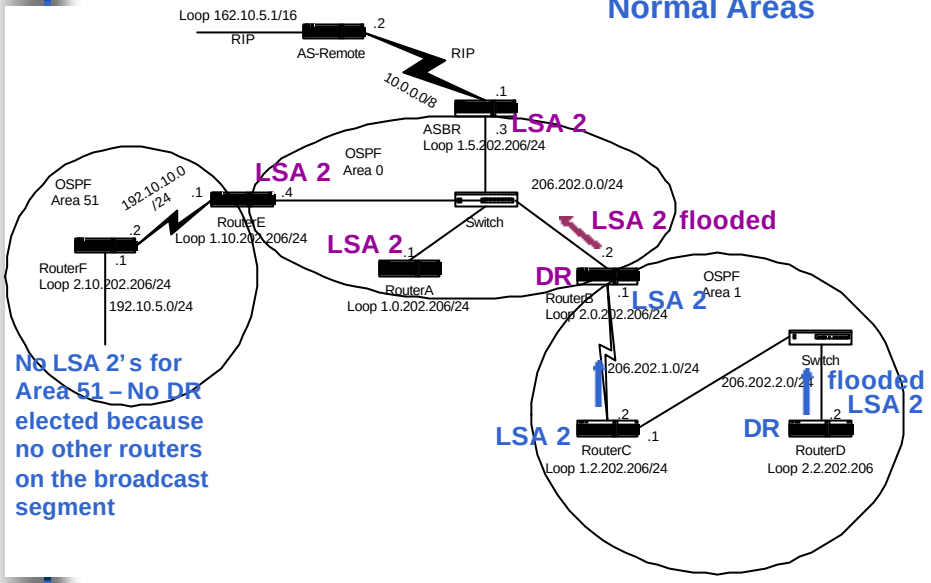


LSA 2 – Network LSA

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            LS age            |      Options  |      2        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link State ID                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Advertising Router                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     LS sequence number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         LS checksum           |             length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Network Mask                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Attached Router                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              ...                              |
```

Multi Area OSPF

Normal Areas



No LSA 2's for Area 51 – No DR elected because no other routers on the broadcast segment

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LSA 2 - Net Link States

Router A

```
RouterA# show ip ospf database
                Net Link States (Area 0)
                (LSA 2 - Generated by the DR)

Link ID         ADV Router      Age     Seq#       Checksum
206.202.0.2     2.0.202.206     92      0x80000006 0x4E4D
```

- **Link ID** 206.202.0.2 = IP address of DR on MultiAccess Network
- **ADV Router** 2.0.202.206 = Router ID of DR
- **Bottom line:** Net Link States (LSA2 s) should display the RouterIDs of the DRs on all multi-access networks in the area and their IP addresses.
- **Rick's reminder: LSA 2 -> "Ethernet = Layer 2 = D R"**
  1 2

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Your Turn -Discuss in groups (LSA 2s)

- Using the Handout: "1. OSPF Multi-Areas - All Normal Areas" verify these results.
- Look at the link state database summary (show ip ospf database) commands and the Net Links States (LSA2s) for each router.
- Look at the routing tables (show ip route) and notice the multi-access routes within that router's area.
- *Could a router have more than one entry in its listing of Net Links States?*
- *Could an area with a broadcast segment, still have no LSA 2's?*
- *Why doesn't Router F have any LSA 2's? Take a look at the "show ip ospf neighbor" for RouterF. There is no DR or BDR on an multi-access stub network.*

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LSA 3 - Summary Net Link States

- LSA 3 – Summary LSA
- Originated by the **ABR**.
- Describes links between **ABR** and **Internal Routers** of the Local Area
- ABR will include a set of LSA 3 s for each area it belongs to.
- LSA 3s are flooded throughout the backbone (Area 0) and to other ABRs.
- Routes learned via LSA type 3s are denoted by an "IA" (Inter-area) in the routing table.

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LSA 3 – Summary LSA

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            LS age            |     Options   |    3 or 4     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link State ID                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Advertising Router                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     LS sequence number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         LS checksum           |             length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Network Mask                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      0        |                  metric                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     TOS       |               TOS  metric                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              ...                              |
```

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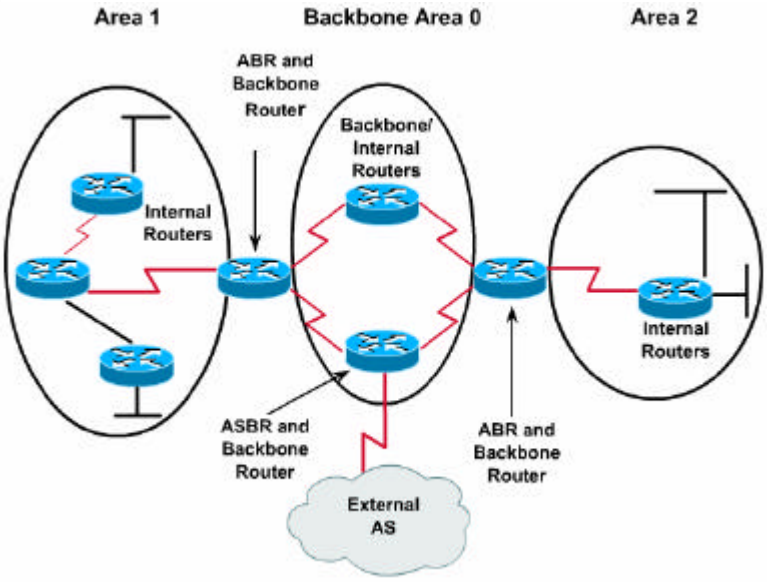
OSPF Router Types



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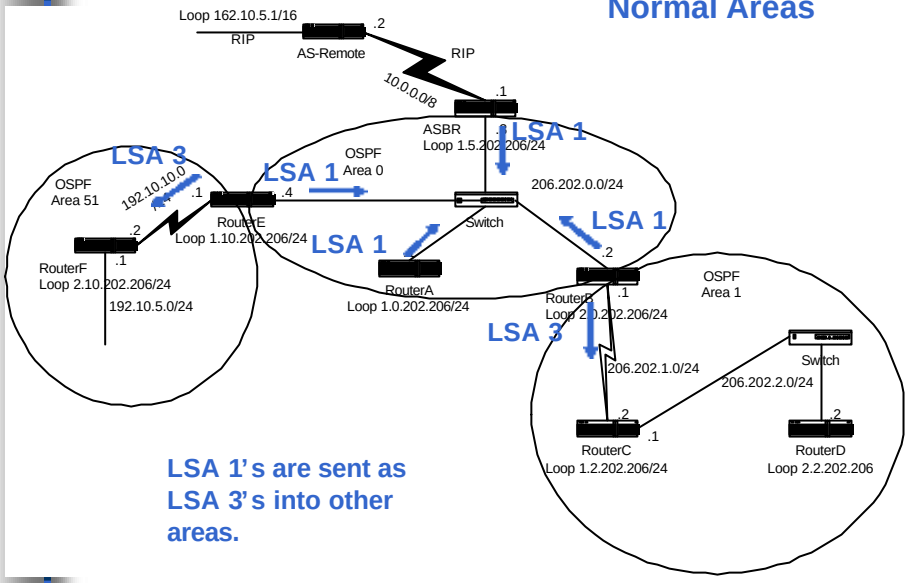
Multi Area OSPF

Normal Areas



LSA 1's are sent as LSA 3's into other areas.

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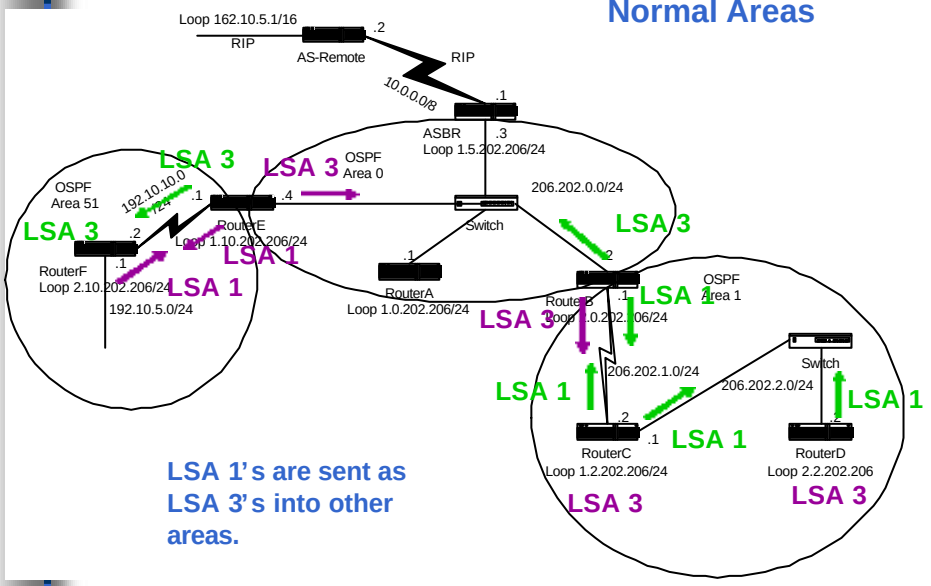
Multi Area OSPF

Normal Areas



LSA 1's are sent as LSA 3's into other areas.

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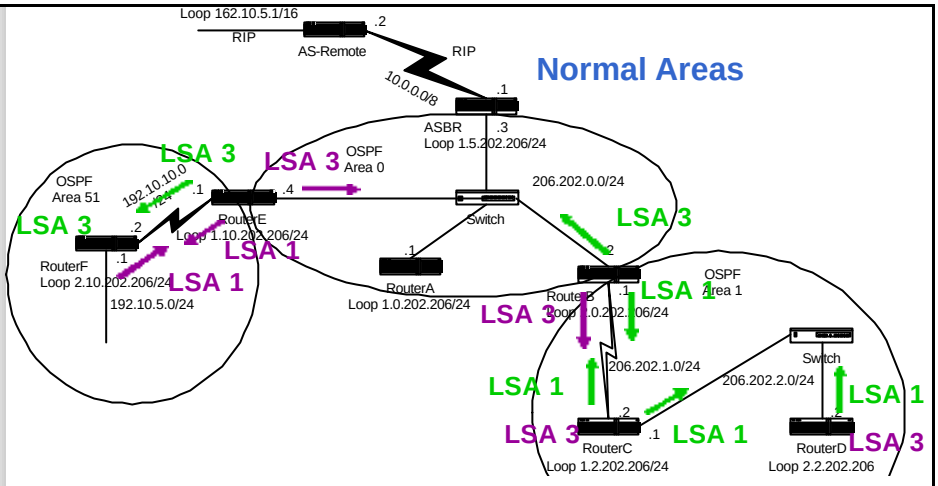
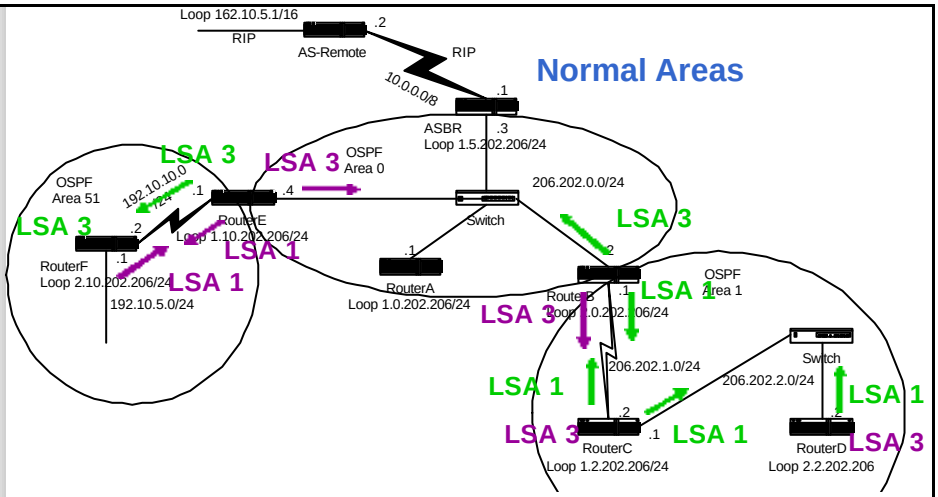


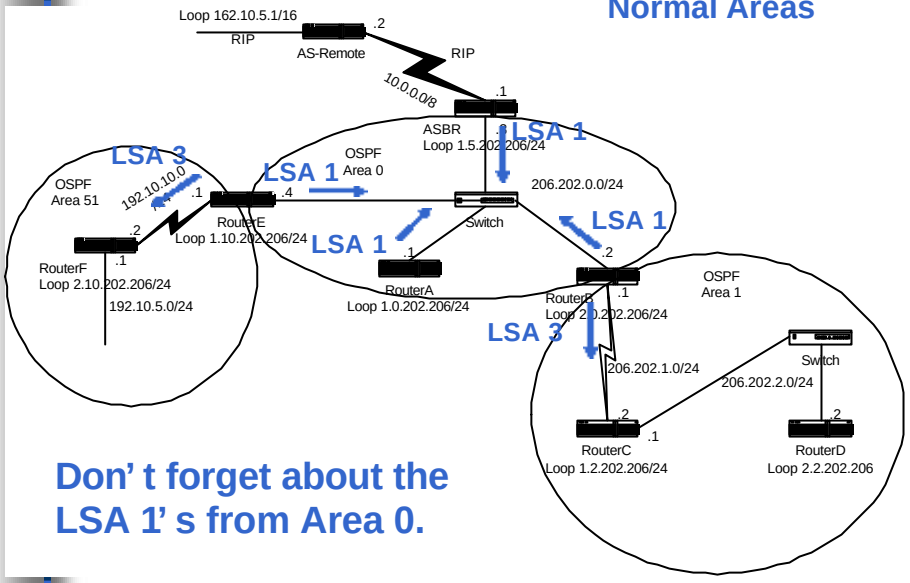
- Routers only see the topology of the area they belong to.
- When a link in one area changes, the adjacent routers originate in LSA 1's and flood them within the area, causing intra-area (internal) routers to re-run the SPF and recalculating the routing table.
- ABRs do not announce topological information between areas.
- ABRs only inject routing information into other areas, which is basically a distance-vector technique.



- ABRs calculate intra-area routes for directly attached areas and announce them to all other areas as inter-area routes, using LSA 3's.
- OSPF ABRs will only announce inter-area routes that were learned from the backbone area, area 0.
- The backbone area serves as a repository for inter-area routes.
- This keeps OSPF safe from routing loops.

Multi Area OSPF

Normal Areas



Don' t forget about the LSA 1' s from Area 0.

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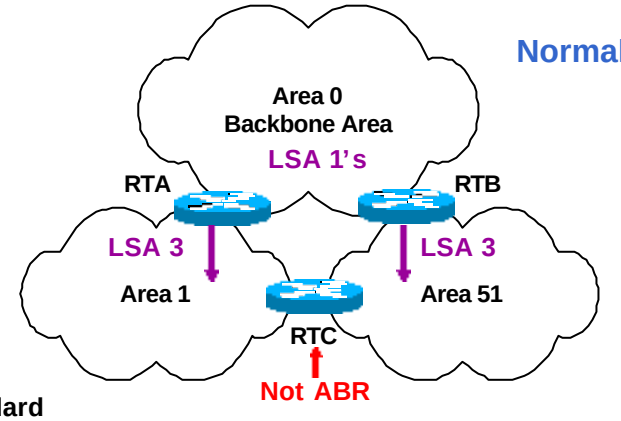
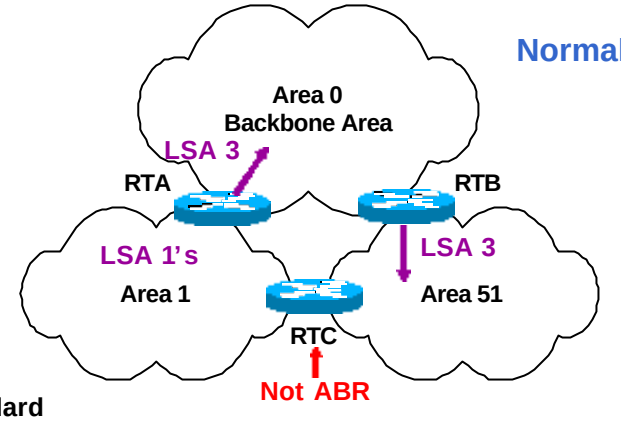
Normal Areas



OSPF standard

- ABRs calculate intra-area routes for directly attached areas and announce them to all other areas as inter-area routes, using LSA 3' s.
- In normal operation, OSPF ABRs will only announce inter-area routes that were learned from the backbone area, area 0.
- RTC does not forward LSA 3' s from Area 1 to Area 51, and does not forward LSA 3 s from Area 51 to Area 1.
- The backbone area serves as a repository for inter-area routes.
- This keeps OSPF safe from routing loops.

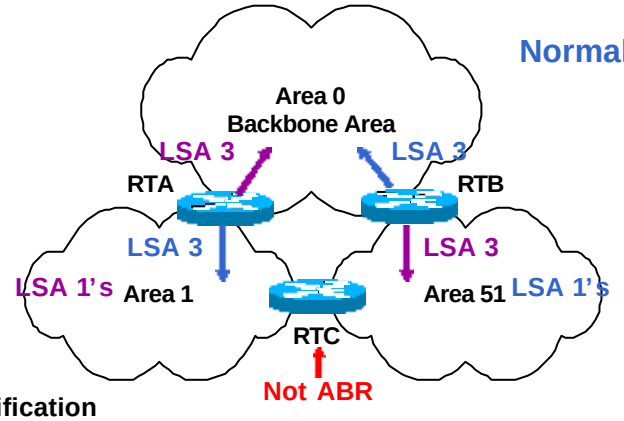
Normal Areas



OSPF standard

- Example of LSA 1 originated in Area 1, sent to Area 0 as an LSA 3, and the sent to Area 51 as an LSA 3.
- RTC does not forward the LSA 3's back into Area 1, or routing loops may develop.
- Again, in normal operations, OSPF ABRs will only announce inter-area routes that were learned from the backbone area, area 0.
- Note: RTC will create LSA 1's and flood them within the appropriate area.

Normal Areas

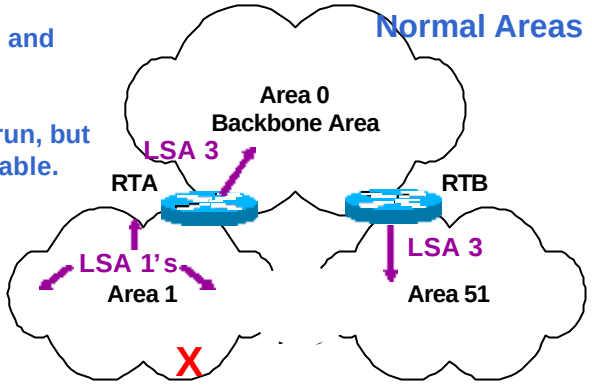


OSPF specification

- RTC does not forward LSA 1's from Area 1 as LSA 3's into Area 51.
- RTC does not forward LSA 1's from Area 51 as LSA 3's into Area 1.
- The LSA 3's from RTC are not forwarded into Area 0 by RTA or RTB.
- OSPF specification states that ABRs are restricted to considering LSA 3's only from the backbone area to avoid routing information loops.

Update is sent to Area 0 and Area 51 routers using a "distance vector update technique." SPF not re-run, but routers update routing table.

Area 1 routers re-run SPF, creates new SPF tree and updates routing table.

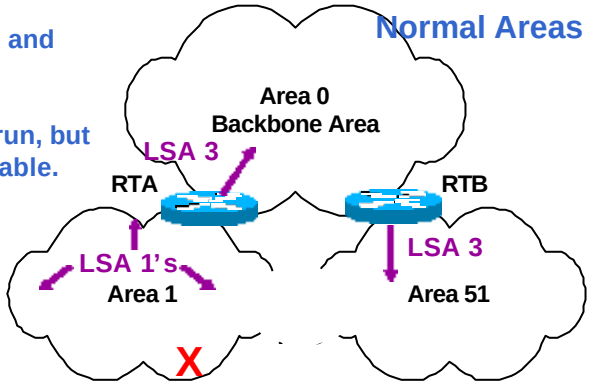


Topology Change: Down Link

- When a router detects a topology change it immediately sends out LSA 1's (Router LSAs) with the change.
- In the case of a down link, the age of the LSA is set to MaxAge (3,600 seconds) – Routers that receive LSAs with the age equal to MaxAge remove this entry from their LSDB (Link State Data Base).
- Routers that receive the LSA 1's, within the area of the change, re-run their SPF algorithm, to build a new SPF tree and then make the changes to their IP routing tables. (*Continued next slide*)

Update is sent to Area 0 and Area 51 routers using a "distance vector update technique." SPF not re-run, but routers update routing table.

Area 1 routers re-run SPF, creates new SPF tree and updates routing table.



Topology Change: Down Link

- ABR RTA receives the LSA 1 and recalculate their SPF for that area, Area 1.
- RTA floods the change as a LSA 3 within its other area, Area 0.
- RTB receives the LSA 3 and floods it within Area 51.
- Area 0 and Area 51 routers do not recalculate their SPFs, but inject the change into their routing tables.
- **Note:** LSA 3's (and other Inter-Area routes) are viewed as "leaf nodes" in the SPF tree.

LSA 3 - Summary Net Link States

Router A

```
RouterA# show ip ospf database
            Summary Net Link States (Area 0)
Link ID         ADV Router      Age     Seq#       Checksum
(Area 51 networks - ADV Router E ABR)
192.10.5.0      1.10.202.206    417     0x80000001 0x3945
192.10.10.0     1.10.202.206    1671    0x80000002 0x9BE6
(Area 1 networks - ADV Router B ABR)
206.202.1.0     2.0.202.206     92      0x80000017 0xC0CF
206.202.2.0     2.0.202.206     92      0x80000002 0xC119
```

- **Link ID** 192.10.5.0 = Network IP addresses of networks in other areas
- **ADV Router** 1.10.202.206 = Router ID ABR
- Divided by ABR
- **Bottom line:** Should see networks in other areas and the ABR advertising that route.
- **Rick's reminder: LSA 3 -> "networks sent by the A B R"**
  1 2 3

LSA 3 - Summary Net Link States

Router A

```
RouterA# show ip route
     1.0.0.0/8 is subnetted, 1 subnets
C       1.0.202.0 is directly connected, Loopback0
C    206.202.0.0/24 is directly connected, Ethernet0
O IA 206.202.1.0/24 [110/138] via 206.202.0.2, 00:06:14, Ethernet0
O IA 206.202.2.0/24 [110/84] via 206.202.0.2, 00:06:19, Ethernet0
O E2 10.0.0.0/8 [110/500] via 206.202.0.3, 00:35:15, Ethernet0
O E2 162.10.0.0/16 [110/500] via 206.202.0.3, 00:33:56, Ethernet0
O IA 192.10.10.0/24 [110/74] via 206.202.0.4, 00:37:56, Ethernet0
O IA 192.10.5.0/24 [110/84] via 206.202.0.4, 00:06:49, Ethernet0
```

- Routes learned via LSA type 3s are denoted by an " IA" (Inter-Area Routes) in the routing table.

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```
                Summary Net Link States (Area 1)
```

LSA 3 - Generated by the ABR. Describes links between ABR and Internal Routers of the Local Area

```
Link ID         ADV Router      Age     Seq#       Checksum
Area 51 networks - ADV Router B ABR
192.10.5.0      2.0.202.206     281     0x80000002 0xC4D7
192.10.10.0     2.0.202.206     282     0x80000003 0x2779
Area 0 networks - ADV Router B ABR
206.202.0.0     2.0.202.206     282     0x80000006 0x4DCB
```

```
    1.0.0.0/8 is subnetted, 1 subnets
C       1.2.202.0 is directly connected, Loopback0
O IA 206.202.0.0/24 [110/74] via 206.202.1.1, 00:09:31, Serial0
C    206.202.1.0/24 is directly connected, Serial0
C    206.202.2.0/24 is directly connected, Ethernet0
O E2 10.0.0.0/8 [110/500] via 206.202.1.1, 00:09:31, Serial0
O E2 162.10.0.0/16 [110/500] via 206.202.1.1, 00:09:31, Serial0
O IA 192.10.10.0/24 [110/138] via 206.202.1.1, 00:09:31, Serial0
O IA 192.10.5.0/24 [110/148] via 206.202.1.1, 00:09:31, Serial0
```

- **Another example: non-area 0 router, RouterC**

Your Turn -Discuss in groups (LSA 3s)

- Using the Handout: “1. OSPF Multi-Areas - All Normal Areas” verify these results.
- Look at the link state database summary (show ip ospf database) commands and the Summary Net Links States (LSA3s) for each router.
- Look at the routing tables (show ip route) and notice the Interarea (IA) routes.
- *Why do some routers have more than one set of Summary Net Links States?*

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LSA 4 – ASBR Summary Link States

- LSA 4 – ASBR Summary LSA
- Originated by the ABR.
- Flooded throughout the backbone area to the other ABRs.
- Describes the **reachability to the ASBRs**
- Advertises an ASBR (Router ID) not a network
- Included in routing table as an "IA" route.
- Same format as a LSA 3 - Summary LSA, except LSA 4 ASBR Summary LSA the Network Mask field is always 0

Exceptions

- **Not** flooded to Stub and Totally Stubby networks.
- More on this later

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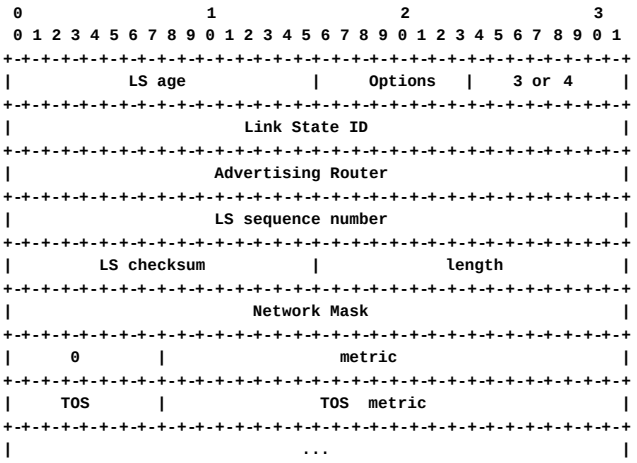
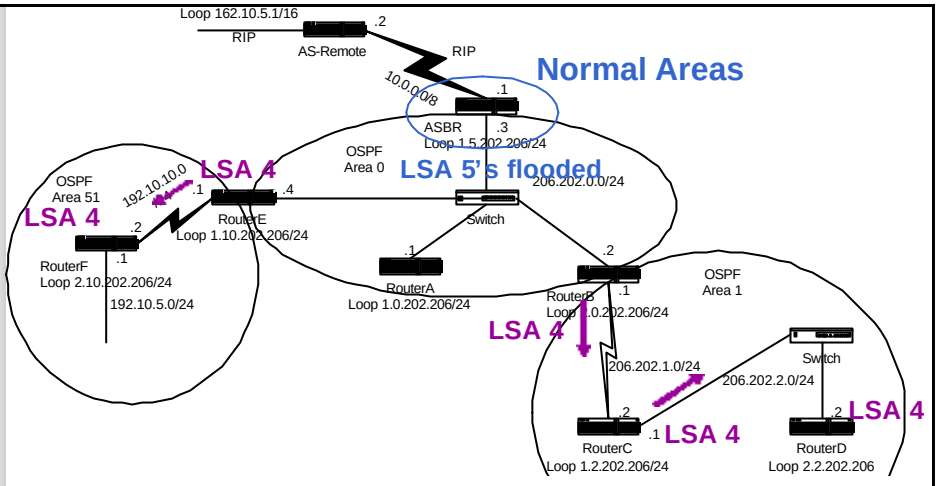
LSA 4 – ASBR Summary LSA



52



- Flooded throughout the backbone area to the other ABRs.
- Describes the **reachability to the ASBRs**
- How do the ABRs know about the ASBR? I am still researching this, but I believe when routers receive an LSA 5 (AS External LSA) with external route information, the routers denote the Router ID being the ASBR.

LSA 4 – ASBR Summary Link States

Router C

RouterC# show ip ospf database

Summary ASB Link States (Area 1)

LSA 4 - Reachability to ASBR.

Not flooded to Stub and Totally Stubby networks.

Link ID	ADV Router	Age	Seq#	Checksum
1.5.202.206	2.0.202.206	282	0x80000003	0x33E1

- **Link ID** 1.5.202.206 = Router ID of ASBR
- **ADV Router** 2.0.202.206 = Router ID ABR advertising route

- **Bottom line: Routers in non-area 0, should see Router ID of ASBR and its ABR to get there .**
- **Rick's reminder: LSA 4 -> "Reachability to the A S B R"**
  1 2 3 4

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LSA 4 – ASBR Summary Link States

Router B

```
RouterB# show ip ospf database
             Summary ASB Link States (Area 1)
               LSA 4 - Reachability to ASBR.
                       Not flooded to Stub and Totally Stubby
   networks.

Link ID         ADV Router      Age     Seq#       Checksum
1.5.202.206     2.0.202.206     184     0x80000003 0x33E1
```

- No LSA 4s for Area 0 on Router B
- Note: RouterE (Area 51) and RouterF (Area 51) include an extra entry of RouterE for the Link ID and ADV Router. - Don't know why.

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Your Turn -Discuss in groups (LSA 4s)

- Using the Handout: "1. OSPF Multi-Areas - All Normal Areas" verify these results.
- Look at the link state database summary (show ip ospf database) commands and the Summary Net Links States (LSA4s) for each router.

- *Why do some routers have more than one set of Summary ASB Links States and others may not (like RouterA and ASBR)?*
- *Which Area 0 routers have LSA 4's in their LSDB?*
- *Why don't some Area 0 routers have LSA 4's in their LSDB?*

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LSA 5 - AS External Link States

- LSA 5 – AS External LSA
- **Originated by the ASBR**.
- Describes destination **networks external to the Autonomous System (This OSPF Routing Domain)**
- Flooded throughout the OSPF AS except to stub and totally stubby areas
- Denoted in routing table as E1 or E2 (default) route (soon)
- We will discuss default routes later.
- **ASBR** – Router which “ redistributes” routes into the OSPF domain.

Exceptions

- **Not** flooded to Stub and Totally Stubby networks.
- More on this later

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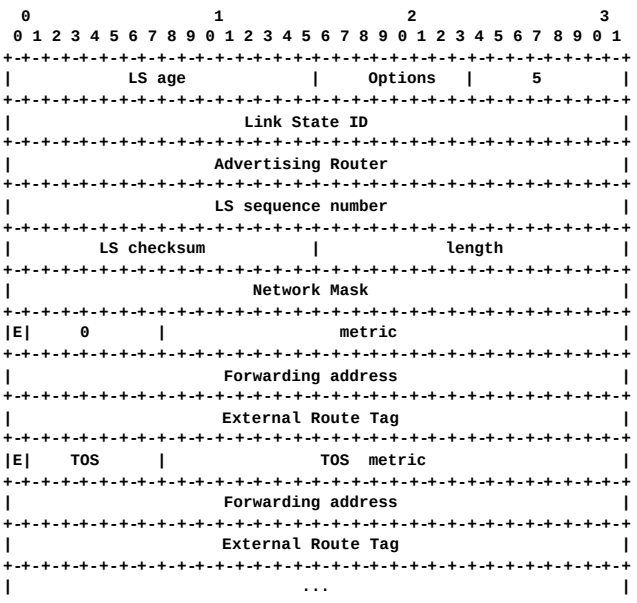
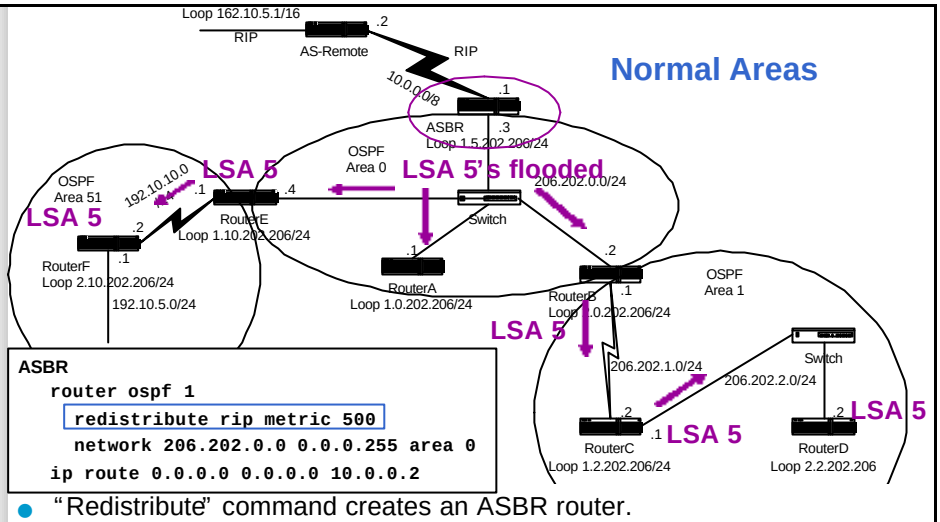
LSA 5 – AS External LSA



58



- "Redistribute" command creates an ASBR router.
- Originated by the ASBR.
- Describes destination networks external to the OSPF Routing Domain
- Flooded throughout the OSPF AS except to stub and totally stubby areas

LSA 5 - AS External Link States

Router A

```
RouterA# show ip ospf database
                AS External Link States
```

LSA 5 - External Networks originated by the ASBR,
Flooded throughout A.S. except to Stub and Totally Stubby

```
Link ID         ADV Router      Age     Seq#       Checksum Tag
10.0.0.0        1.5.202.206     98      0x80000002 0x9F74   0
162.10.0.0      1.5.202.206     98      0x80000002 0x670A   0
```

- **Link ID** 162.10.0.0 = External Network
- **ADV Router** 1.5.202.206 = Router ID ASBR

- **Bottom line:** All Routers should see External networks and the Router ID of ASBR to get there .
- **Rick's reminder: LSA 5 -> Five fingers waving hello to external routes.** (*Okay, so this one is lagging* ☺)

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LSA 5 - AS External Link States

Router A

```
RouterA# show ip route
 1.0.0.0/8 is subnetted, 1 subnets
C       1.0.202.0 is directly connected, Loopback0
C    206.202.0.0/24 is directly connected, Ethernet0
O IA 206.202.1.0/24 [110/138] via 206.202.0.2, 00:06:14, Ethernet0
O IA 206.202.2.0/24 [110/84] via 206.202.0.2, 00:06:19, Ethernet0
O E2 10.0.0.0/8 [110/500] via 206.202.0.3, 00:35:15, Ethernet0
O E2 162.10.0.0/16 [110/500] via 206.202.0.3, 00:33:56, Ethernet0
O IA 192.10.10.0/24 [110/74] via 206.202.0.4, 00:37:56, Ethernet0
O IA 192.10.5.0/24 [110/84] via 206.202.0.4, 00:06:49, Ethernet0
```

- Notice that the cost is 500 for both routes.
- We will see why later, but it has to do with E2 routes and :

ASBR:

```
router ospf 1
   redistribute rip metric 500
   network 206.202.0.0 0.0.0.255 area 0
```

LSA 5 - AS External Link States

Another look (internal non-area 0 router)

Router C

```
RouterC# show ip ospf database
```

Type-5 AS External Link States **<- Note, NO Area!**

LSA 5 - External Networks originated by the ASBR,
Flooded throughout A.S. except to Stub and Totally Stubby

Link ID	ADV Router	Age	Seq#	Checksum	Tag
10.0.0.0	1.5.202.206	289	0x80000002	0x9F74	0
162.10.0.0	1.5.202.206	289	0x80000002	0x670A	0

- **Note**: For ABRs: There is only one set of "AS External Link States" in database summary. In other words, an ABR router will only show one set of "AS External Link States," not one per area.

LSA 5 - AS External Link States

Router C

```
RouterC# show ip route
     1.0.0.0/8 is subnetted, 1 subnets
C       1.2.202.0 is directly connected, Loopback0
O IA 206.202.0.0/24 [110/74] via 206.202.1.1, 00:09:31, Serial0
C    206.202.1.0/24 is directly connected, Serial0
C    206.202.2.0/24 is directly connected, Ethernet0
O E2 10.0.0.0/8 [110/500] via 206.202.1.1, 00:09:31, Serial0
O E2 162.10.0.0/16 [110/500] via 206.202.1.1, 00:09:31, Serial0
O IA 192.10.10.0/24 [110/138] via 206.202.1.1, 00:09:31, Serial0
O IA 192.10.5.0/24 [110/148] via 206.202.1.1, 00:09:31, Serial0
```

- Again, notice that the cost is 500 for both routes, same as Router A.
- Again, we will see why later, but it has to do with E2 routes and:

ASBR:

```
router ospf 1
  redistribute rip metric 500
  network 206.202.0.0 0.0.0.255 area 0
```

Quick Note (more next week)

E1 vs. E2 External Routes

- External routes fall under two categories, external type 1 and the **default** external type 2.
- The difference between the two is in the way the cost (metric) of the route is being calculated.
- The cost of a **type 2** route is always the external cost, irrespective of the interior cost to reach that route.
- A **type 1** cost is the addition of the external cost and the internal cost used to reach that route.
- A type 1 route is always preferred over a type 2 route for the same destination.

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Your Turn -Discuss in groups (LSA 5s)

- Using the Handout: "1. OSPF Multi-Areas - All Normal Areas" verify these results.
- Look at the link state database summary (show ip ospf database) commands and the AS External Links States (LSA5s) for each router.
- Also, look at the routing tables for each router.

- *How many sets of LSA 5s does the ABRs have in their link state summary database? Notice the ASBRs entries.*

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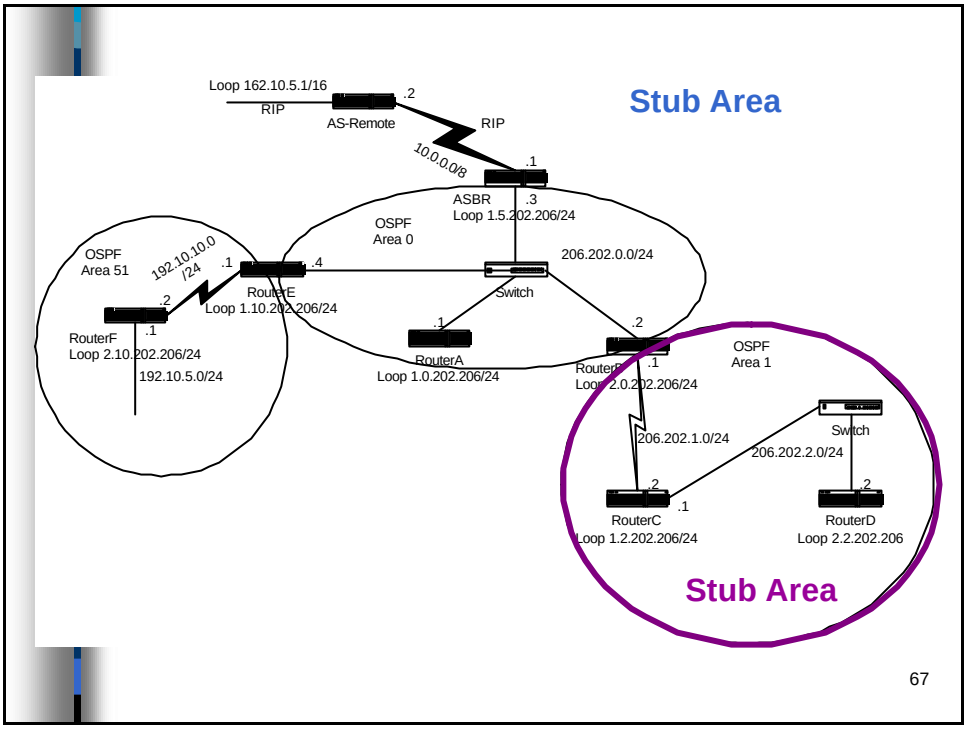
Part II - Stub Areas

Considerations for both Stub and Totally Stubby Areas

- An area could be qualified a stub when there is a single exit point (a single ABR) from that area or if routing to outside of the area does not have to take an optimal path.
- The area is not needed as a transit area for virtual links (later).
- The ASBR is not within the stub area
- The area is not the backbone area (area 0)
- Stub areas will result in memory and processing savings depending upon the size of the network.

66



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Stub Areas

Receives all routes from within A.S.:

- Within the local area - LSA 1s and LSA 2s (if appropriate)
- From other areas (Inter-Area) - LSA 3s

Does **not** receive routes from External A.S. (External Routes).

ABR:

- ABR blocks all LSA 4s and LSA 5s.
- 'If LSA 5s are not known inside an area, LSA 4s are not necessary.'
- LSA 3s are propagated by the ABR.

Note: Default route is automatically injected into stub area by **ABR**

  - External Routes: Once the ABR gets a packet headed to a default route, it must have a default route, either static or propagated by the ASBR via default information originate (coming!)

Configuration:

- All routers in the area must be configured as "stub"

All routers in the area must be configured as "stub" including the ABR

RouterB

```
router ospf 1
 network 206.202.0.0 0.0.0.255 area 0
 network 206.202.1.0 0.0.0.255 area 1
 area 1 stub
```

<< Command: **area** *area* **stub**

RouterC

```
router ospf 1
 network 206.202.1.0 0.0.0.255 area 1
 network 206.202.2.0 0.0.0.255 area 1
 area 1 stub
```

RouterD

```
router ospf 1
 network 206.202.2.0 0.0.0.255 area 1
 area 1 stub
```

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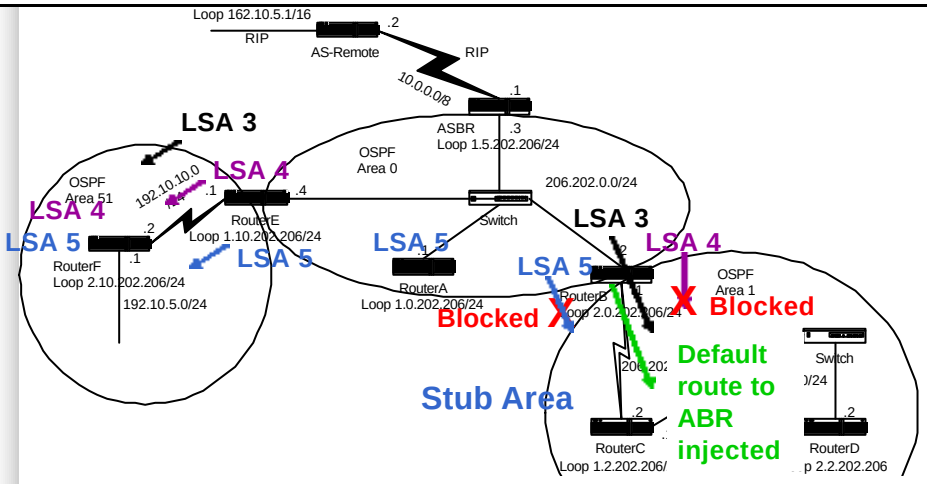
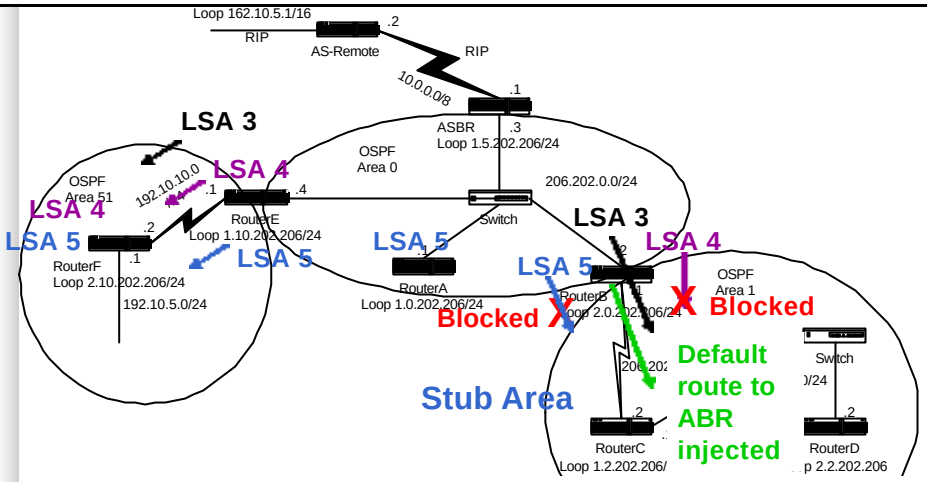


- LSA 3s (Inter-Area routes) are propagated by the ABR.
- ABR blocks all LSA 4s (reachabilitly to ASBR) and LSA 5s (External routes)
- The ABR injects a default route into the stub area, pointing to the ABR. (This does not mean the ABR has a default route of its own.)
- Essentially, internal routers in a Stub Area only see Inter-Area OSPF routes and the default route to the ABR – No External routes.



- Changes in External routes no longer affect Stub Area routing tables.

Stub Areas

RouterC

```
RouterC# show ip ospf database
                Summary Net Link States (Area 1)
```

LSA 3 - Generated by the ABR. Describes links between ABR and Internal Routers of the Local Area

```
Link ID         ADV Router      Age         Seq#       Checksum
Default Route - ADV Router B ABR
0.0.0.0         2.0.202.206     644         0x80000001 0x3B67
Area 51 networks - ADV Router B ABR
192.10.5.0      2.0.202.206     580         0x80000001 0x37C
192.10.10.0     2.0.202.206     580         0x80000001 0x671D
Area 0 networks - ADV Router B ABR
206.202.0.0     2.0.202.206     594         0x80000003 0x8F6E
```

Default Route injected by ABR (LSA 3)

- Notice that there are no LSA 4s or LSA 5s for stub area routers.

Stub Areas

Router C

```
RouterC# show ip route
Gateway of last resort is 206.202.1.1 to network 0.0.0.0

C    206.202.2.0/24 is directly connected, Ethernet0
     1.0.0.0/24 is subnetted, 1 subnets
C       1.2.202.0 is directly connected, Loopback0
O IA 206.202.0.0/24 [110/74] via 206.202.1.1, 00:09:29, Serial0
C    206.202.1.0/24 is directly connected, Serial0
O IA 192.10.10.0/24 [110/138] via 206.202.1.1, 00:09:19, Serial0
O IA 192.10.5.0/24 [110/148] via 206.202.1.1, 00:09:19, Serial0
O*IA 0.0.0.0/0 [110/65] via 206.202.1.1, 00:09:30, Serial0
```

NOTE on default route:

- ABR will advertise a default route with a cost of 1
- cost of 65 = 1 + 64 (serial link)

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Stub Areas

Router B - The ABR

```
RouterB# show ip route
Gateway of last resort is not set

O    206.202.2.0/24 [110/74] via 206.202.1.2, 00:08:04, Serial0
     2.0.0.0/24 is subnetted, 1 subnets
C       2.0.202.0 is directly connected, Loopback0
C    206.202.0.0/24 is directly connected, Ethernet0
C    206.202.1.0/24 is directly connected, Serial0
O IA 192.10.10.0/24 [110/74] via 206.202.0.4, 00:07:55, Ethernet0
O E2 162.10.0.0/16 [110/500] via 206.202.0.3, 00:02:14, Ethernet0
O IA 192.10.5.0/24 [110/84] via 206.202.0.4, 00:07:55, Ethernet0
O E2 10.0.0.0/8 [110/500] via 206.202.0.3, 00:02:24, Ethernet0
```

- Notice, there is no default route here.
- Default route is **NOT** Received from ASBR:
- ASBR's default route (need default-information-originate) – later

ASBR

```
router ospf 1
  redistribute rip metric 500
  network 206.202.0.0 0.0.0.255 area 0
ip route 0.0.0.0 0.0.0.0 10.0.0.2
```

Your Turn -Discuss in groups (Stub)

- Using the Handout: "2. OSPF Multi-Areas - Stub Area" verify these results.
- Look at the link state database summary (show ip ospf database) commands and the Summary Net Links States (LSA 3s) for RouterD.
- Also, look at the routing table for RouterD.

Note: A Stub area may have more than one ABR, but because of the default route, the internal routers will not be able to determine which router is the optimal gateway outside the AS and end up load balancing between the multiple ABRs.

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Part III - Totally Stubby Areas

Cisco proprietary

Same considerations as with Stub areas:

- An area could be qualified a stub when there is a single exit point (a single ABR) from that area or if routing to outside of the area does not have to take an optimal path.
- The area is not needed as a transit area for virtual links (later).
- The ASBR is not within the stub area
- The area is not the backbone area (area 0)
- Stub areas will result in memory and processing savings depending upon the size of the network. - This is even more true with Totally Stubby areas

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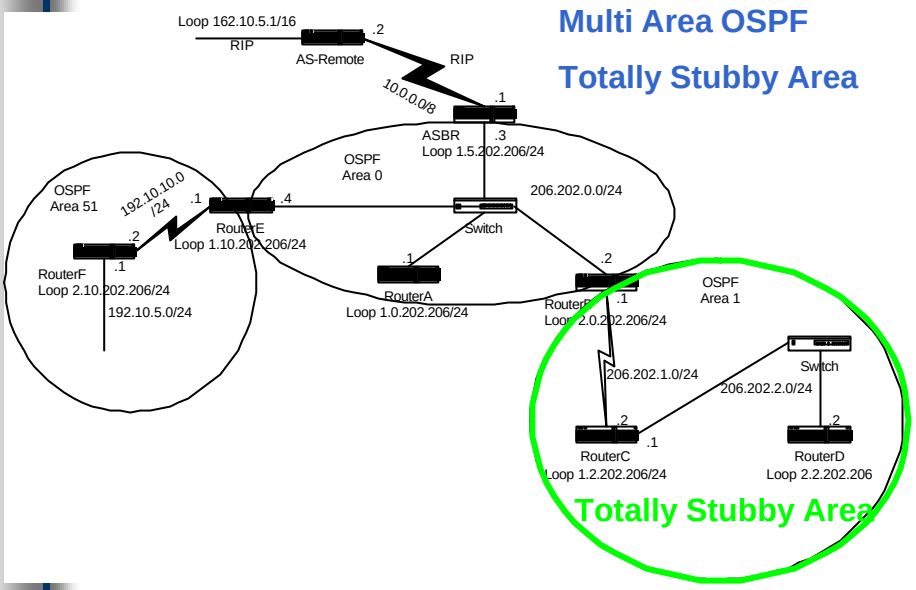

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Totally Stubby Areas

Receives routes from within A.S.:

- Only from within the local area - LSA 1s and LSA 2s (if appropriate)
- Does **not** receive routes from other areas (Inter-Area) - LSA 3s

Does **not** receive routes from External A.S. (External Routes)

ABR:

- ABR blocks all LSA 4s and LSA 5s.
- ABR blocks all LSA 3s, except propagating a default route.
- Default route is injected into totally stubby area by ABR.

Configuring:

- All routers must be configured as "stub"
- ABR must be configured as "stub no-summary"

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RouterB (ABR)

```
router ospf 1
 network 206.202.0.0 0.0.0.255 area 0
 network 206.202.1.0 0.0.0.255 area 1
 area 1 stub no-summary
```

^^ Command: **area** *area* **stub no-summary**

RouterC

```
router ospf 1
 network 206.202.1.0 0.0.0.255 area 1
 network 206.202.2.0 0.0.0.255 area 1
 area 1 stub
```

^^ Command: **area** *area* **stub**

RouterD

```
router ospf 1
 network 206.202.2.0 0.0.0.255 area 1
 area 1 stub
```

^^ Command: **area** *area* **stub**

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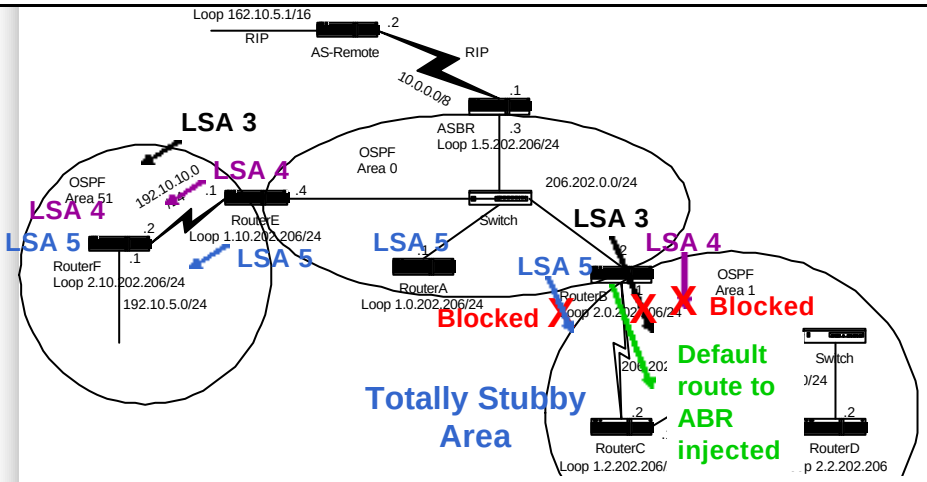
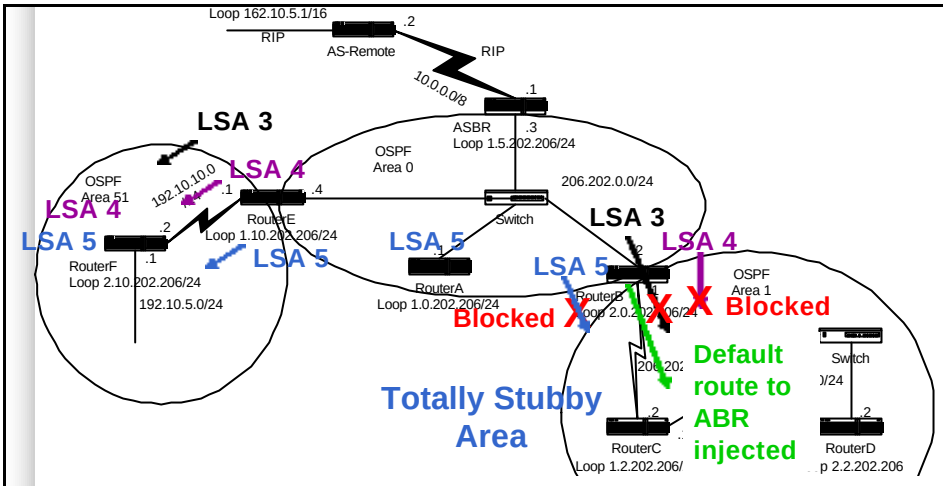


- LSA 3s (Inter-Area routes) are blocked by the ABR.
- ABR blocks all LSA 4s (reachability to ASBR) and LSA 5s (External routes)
- The ABR injects a default route (LSA 3) into the stub area, pointing to the ABR. (This does not mean the ABR has a default route of its own.)
- Essentially, internal routers in a Totally Stubby Area only see the default route to the ABR.



- Changes in any networks outside the Totally Stubby Area no longer affects the Totally Stubby routing tables.

Totally Stubby Areas

RouterC

```
RouterC# show ip ospf database
                Summary Net Link States (Area 1)
```

LSA 3 - Generated by the ABR. Describes links between ABR and Internal Routers of the Local Area

```
Link ID         ADV Router      Age         Seq#       Checksum
Default Route - ADV Router B ABR
0.0.0.0         2.0.202.206     852         0x80000001 0x3B67
```

Default Route injected by ABR (LSA 3)

- Default route is injected into totally stubby area by ABR for all other networks (inter-area and external routes)
- Does **not** receive routes from other areas (Inter-Area)
- Does **not** receive routes from External A.S. (External Routes)

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Totally Stubby Areas

Router C

```
RouterC# show ip route
Gateway of last resort is 206.202.1.1 to network 0.0.0.0

C    206.202.2.0/24 is directly connected, Ethernet0
     1.0.0.0/24 is subnetted, 1 subnets
C       1.2.202.0 is directly connected, Loopback0
C    206.202.1.0/24 is directly connected, Serial0
O*IA 0.0.0.0/0 [110/65] via 206.202.1.1, 00:13:11, Serial0
```

- Default route is injected into totally stubby area by ABR for all other networks (inter-area and external routes)
- Does **not** receive routes from other areas (Inter-Area)
- Does **not** receive routes from External A.S. (External Routes)

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Totally Stubby Areas

Router B - The ABR

```
RouterB# show ip route
Gateway of last resort is not set

O    206.202.2.0/24 [110/74] via 206.202.1.2, 00:11:23, Serial0
     2.0.0.0/24 is subnetted, 1 subnets
C       2.0.202.0 is directly connected, Loopback0
C    206.202.0.0/24 is directly connected, Ethernet0
C    206.202.1.0/24 is directly connected, Serial0
O IA 192.10.10.0/24 [110/74] via 206.202.0.4, 00:11:13, Ethernet0
O E2 162.10.0.0/16 [110/500] via 206.202.0.3, 00:01:39, Ethernet0
O IA 192.10.5.0/24 [110/84] via 206.202.0.4, 00:11:13, Ethernet0
O E2 10.0.0.0/8 [110/500] via 206.202.0.3, 00:02:48, Ethernet0
```

- ABR will forward Intra-Area routes (to other areas within AS)
- Notice, there is no default route here.
- Default route is **NOT** Received from ASBR:
- ASBR's default route (need default-information-originate) - later

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OSPF design considerations

OSPF Design Tips

- Different people have different approaches to designing OSPF networks.
- The important thing to remember is that any protocol can fail under pressure.
- "The idea is not to challenge the protocol but rather to work with it in order to get the best behavior." CCO

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Number of Routers per Area

The maximum number of routers per area depends on several factors, including the following:

- What kind of area do you have?
- What kind of CPU power do you have in that area?
- What kind of media?
- Will you be running OSPF in NBMA mode?
- Is your NBMA network meshed?
- Do you have a lot of external LSAs in the network?
- Are other areas well summarized?

For this reason, it's difficult to specify a maximum number of routers per area.

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Stub and Totally Stubby Areas:

- An area could be qualified a stub when there is a single exit point (a single ABR) from that area or if routing to outside of the area does not have to take an optimal path.
- The area is not needed as a transit area for virtual links (later).
- The ASBR is not within the stub area
- The area is not the backbone area (area 0)
- Stub areas will result in memory and processing savings depending upon the size of the network. - This is even more true with Totally Stubby areas
- Totally Stubby areas is a Cisco enhancement.

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Quick Review

- Areas
- LSAs
- Stub Area
- Totally Stubby Area

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Area Types

- Standard or Normal Areas
  - Backbone
  - Non-Backbone
- Stub
  - Stub Area
  - Totally Stubby Area (TSA)
  - Not-so-stubby-area (NSSA)

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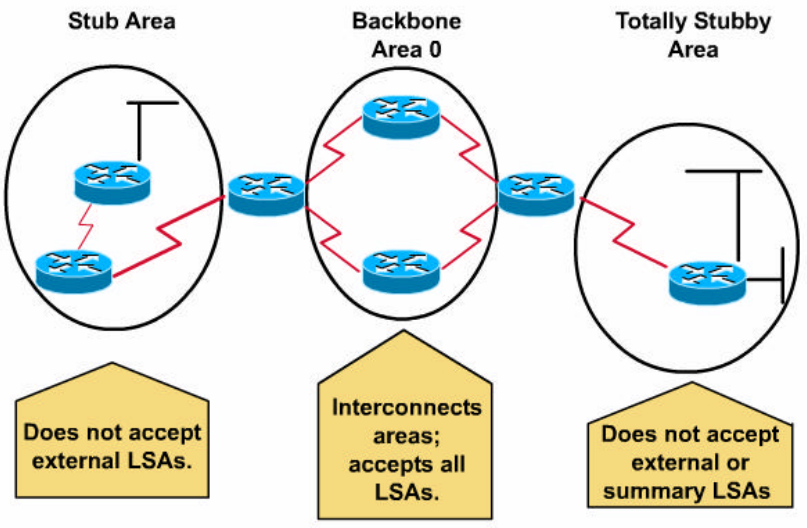
Area Types



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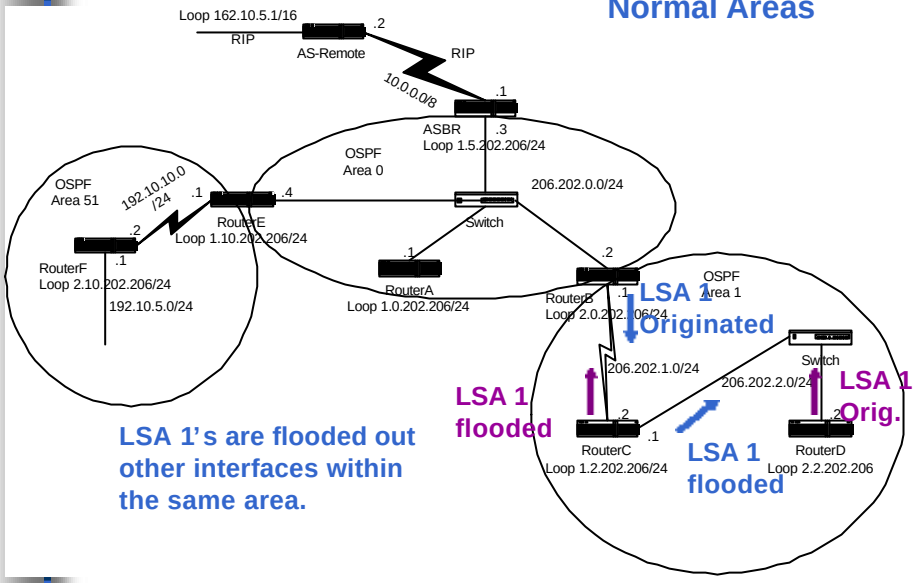
LSA 1 Router LSA

Multi Area OSPF

Normal Areas



LSA 1's are flooded out other interfaces within the same area.

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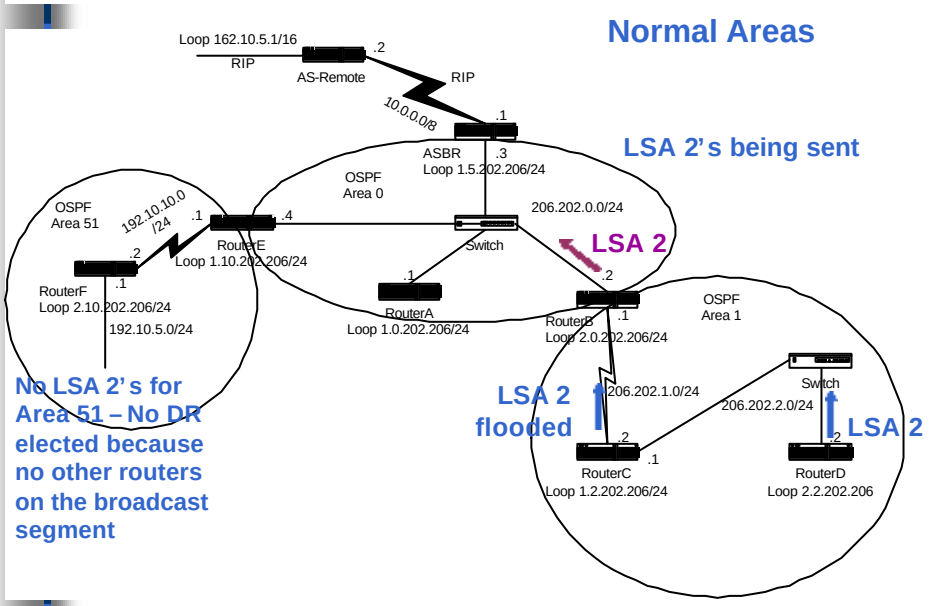
LSA 2 Network LSA

Multi Area OSPF

Normal Areas



No LSA 2's for Area 51 – No DR elected because no other routers on the broadcast segment

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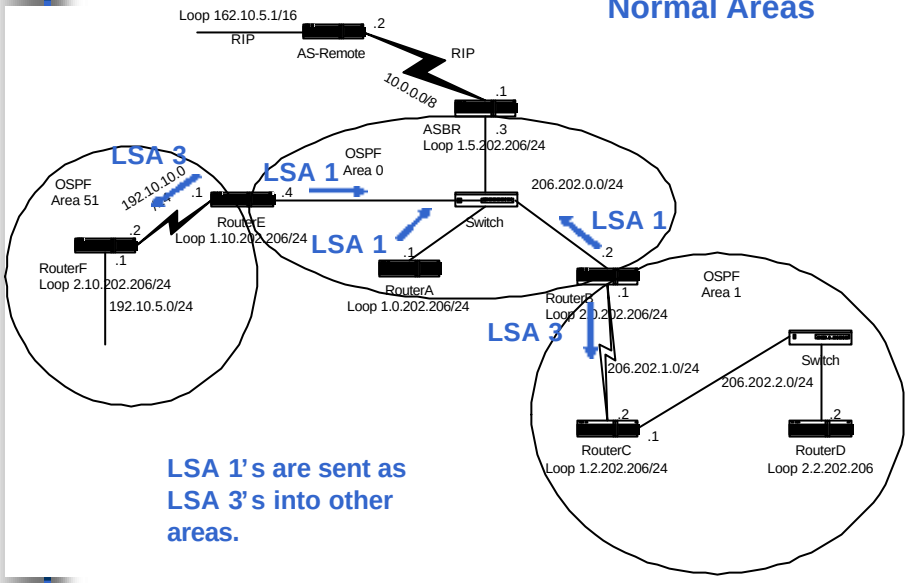
LSA 3 Summary LSA

Multi Area OSPF

Normal Areas

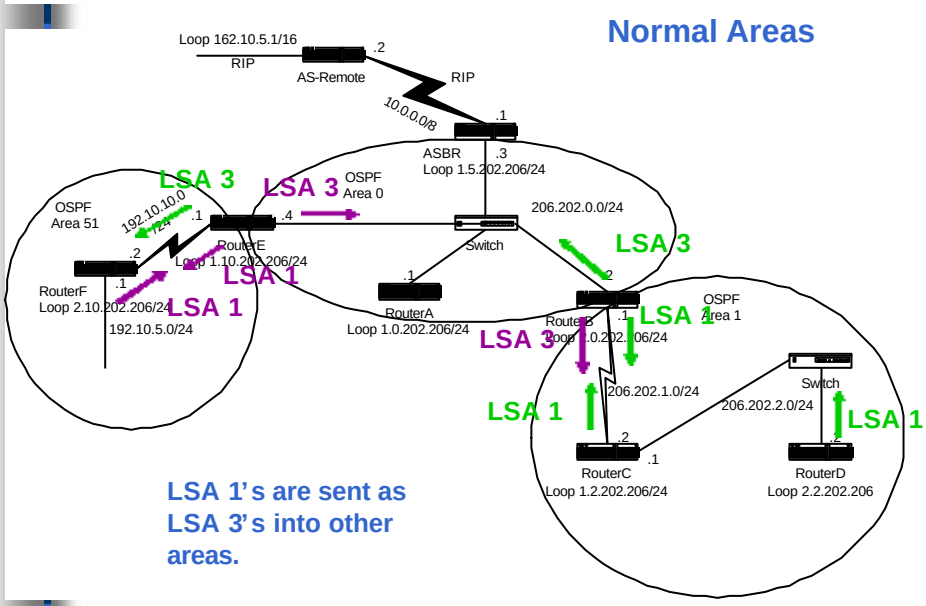


LSA 1's are sent as LSA 3's into other areas.

LSA 3 Summary LSA

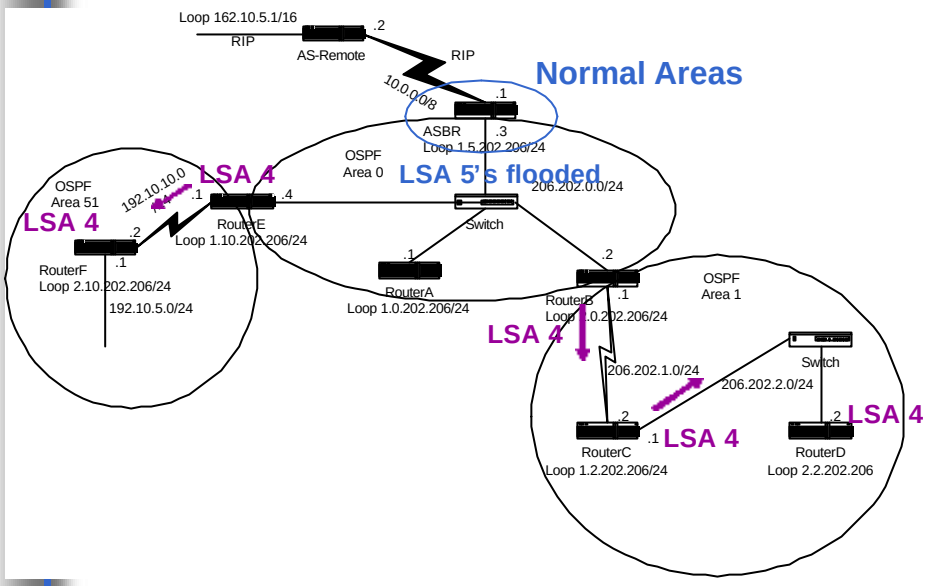
Multi Area OSPF

Normal Areas



LSA 1's are sent as LSA 3's into other areas.

LSA 4 ASBR Summary LSA



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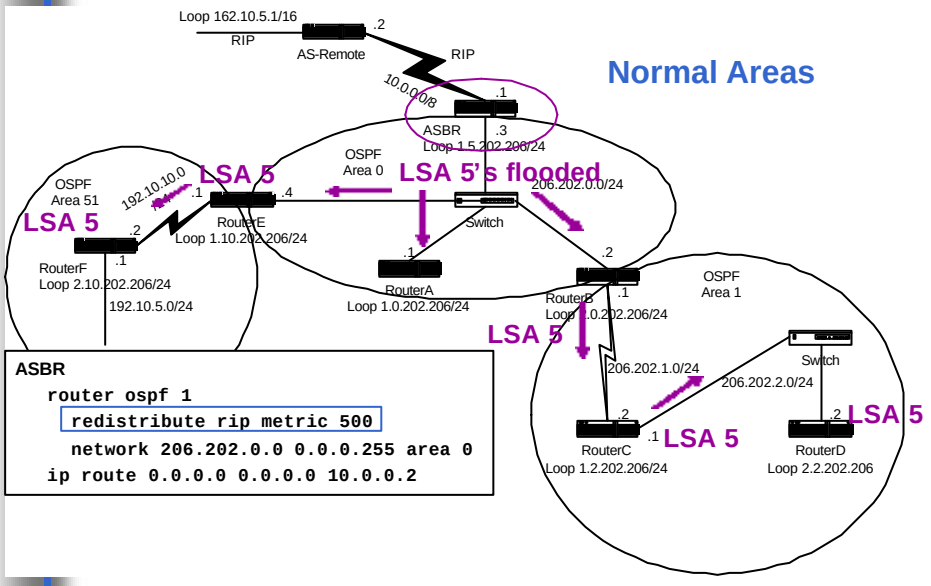
LSA 5 AS External LSA



ASBR

```
router ospf 1
  redistribute rip metric 500
  network 206.202.0.0 0.0.0.255 area 0
ip route 0.0.0.0 0.0.0.0 10.0.0.2
```

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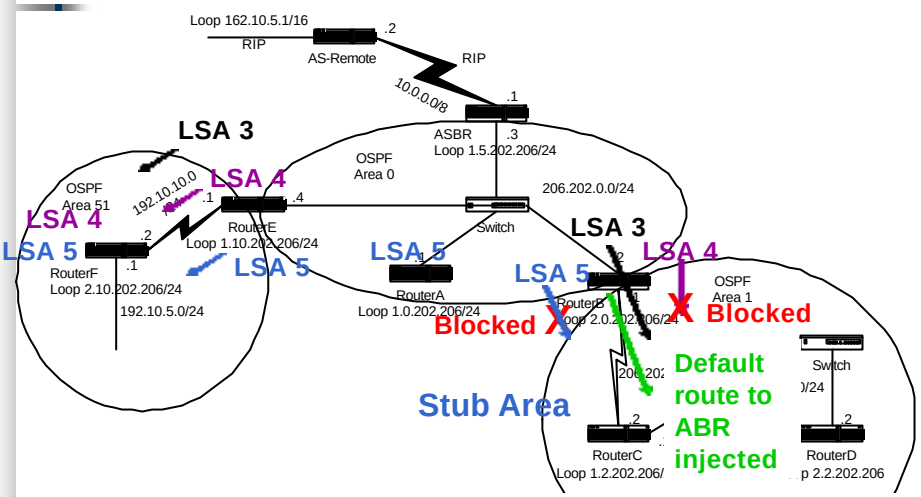
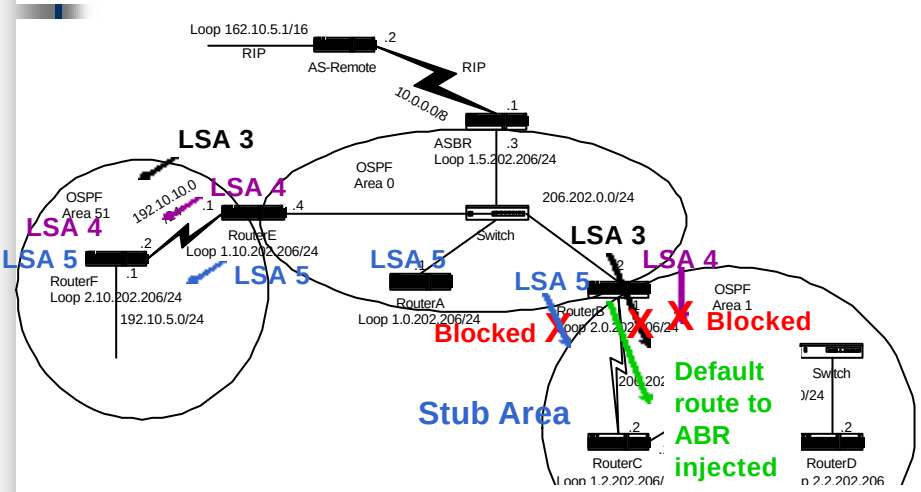
Stub Areas



- All routers in the area must be configured as "stub" including the ABR:

```
router ospf 1
   network 206.202.0.0 0.0.0.255 area 0
   network 206.202.1.0 0.0.0.255 area 1
   area 1 stub
```

Totally Stubby Areas



- All routers in the area must be configured as "stub" except the ABR "stub no summary":

```
router ospf 1
   network 206.202.0.0 0.0.0.255 area 0
   network 206.202.1.0 0.0.0.255 area 1
   area 1 stub no-summary
```

Next Week

OSPF – Multi Area Part II

- E1 and E2 routes
- Default Routes
- Route Summarization
- NSSA (Not So Stubby Areas)
- Multiple ABR Scenario
- Multiple ASBR Scenario
- Virtual Links
- Load Balancing
- show commands

And more PowerPoint animations ☺

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Cabrillo College

CCNP – Advanced Routing

Ch. 5 OSPF - Multi-areas (Part I)

Rick Graziani, Instructor

Mar. 6, 2002

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