Cabrillo College

CISCO SYSTEMS
NETWORKING ACADEMY

CCNP – Advanced Routing

Ch. 4 - OSPF, Single Area – Part 2 of 3

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Format of the presentation

- Instructors: If you find any misinformation or mistakes, or if you have any questions regarding the content, please email me, Rick Graziani, graziani@cabrillo.cc.ca.us - Thanks!
- I added new information for clarity and interest from Alex Zinin's book, Cisco IP Routing
- Combined different sections of McGregor's Ch. 4 on OSPF, to create a single flow of information. (Tried to.)
- Added some information from Jeff Doyle's "Routing TCP/IP Vol. I," John Moy's book on OSPF and RFC 2328, OSPF version 2 (current version).

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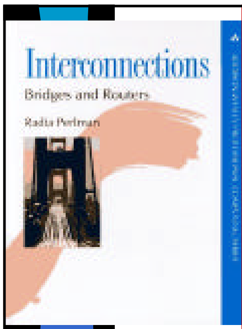

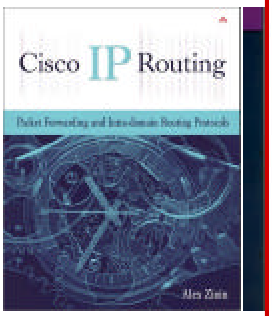

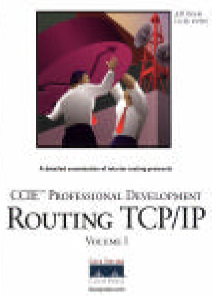

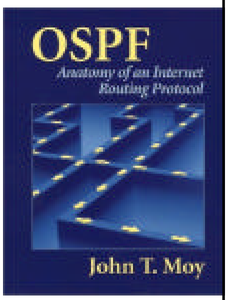

Interconnections : Bridges and Routers by Radia Perlman

Cisco IP Routing: Packet Forwarding & Intra-domain Routing Protocols by Alex Zinin

This book has been especially helpful for information contained in these presentations.

Routing TCP/IP Volume I by Jeff Doyle

OSPF, Anatomy of an Internet Routing Protocol by John Moy (creator of OSPF)

For more information on OSPF, link-state routing protocol, Dijkstra's algorithm and routing in general, check out these sources.

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Steps to OSPF Operation

1. Establishing router adjacencies
2. Electing DR and BDR
3. Discovering Routes
4. Choosing Routes
5. Maintaining Routing Information

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OSPF States

States of the OSPF neighbor FSM (Finite State Machine)

- Every OSPF router represents its communications with other OSPF routers in the form of neighbor data structures.
- Every neighbor can be in one of many states
  - **Down State**
  - **Attempt State**
  - **Init State**
  - **Two-way State**
  - **ExStart State**
  - **Exchange State**
  - **Loading State**
  - **Full Adjacency State**

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Steps to OSPF Operation with OSPF States

1. Establishing router adjacencies ←
   - Down State
   - Init State
   - Two-way State
   - (ExStart State unless DR/BDR election needed)
2. Electing DR and BDR
   - ExStart State with DR and BDR
   - Two-way State with all other routers
3. Discovering Routes
   - ExStart State
   - Exchange State
   - Loading State
   - Full State
4. Choosing Routes
5. Maintaining Routing Information

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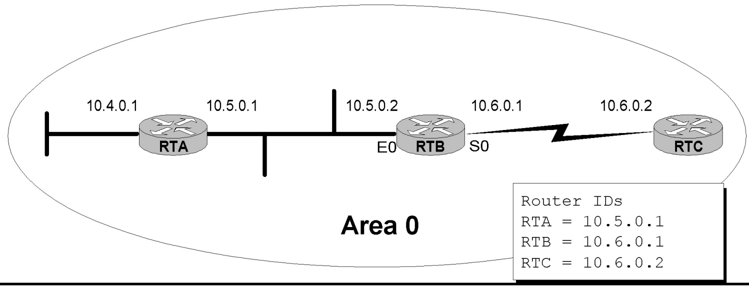
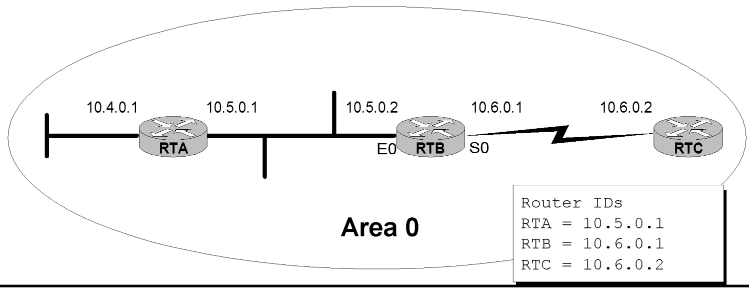
1.Establishing Adjacencies

- Initially, an OSPF router interface is in the **down state.**
- An OSPF interface can transition back to this state if it has not received a Hello packet from a neighbor within the RouterDeadInterval time (40 seconds unless NBMA, 120 seconds).
- In the **down state**, the OSPF process has not exchanged information with any neighbor.
- OSPF is waiting to enter the **init state**.
- An OSPF router tries to form an adjacency with at least one neighbor for each IP network it's connected to.

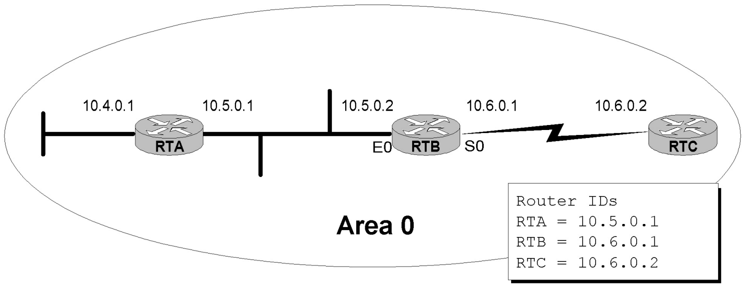


1.Establishing Adjacencies

- The process of establishing adjacencies is asymmetric, meaning the states between two adjacent routers may be different as they both transition to full state.
- RTB perspective and assuming routers are configured correctly.
- Trying to start a relationship and wanting to enter the **init state** or really the **two-way-state**
- RTB begins multicasts **OSPF Hello packets** (224.0.0.5, AllSPFRouters), advertising its own **Router ID**.
  - 224.0.0.5: All OSPF routers should be able to transmit and listen to this address.



1. Establishing Adjacencies



- **Router ID** = Highest loopback address else highest active IP address.
- **Loopback address** has the advantage of never going down, thus diminishing the possibility of having to re-establish adjacencies. (more in a moment)
- Use private ip addresses for loopbacks, so you do not inadvertently advertise a route to a real network that does not exist on your router.
- RTA and RTC receive Hello packets from RTB
- RTA and RTC add RTB's **Router ID** to the **Neighbor ID** field of the Hello packet its sends back to RTB, at the same time entering the **init state**.

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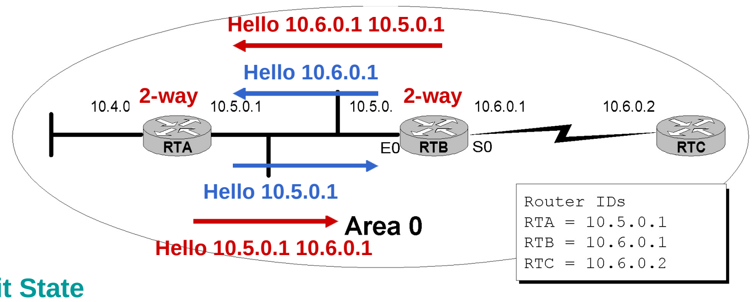
1. Establishing Adjacencies



Init State

- **Init State** - OSPF routers sent Type 1 Hello packets at regular intervals (10 sec.) to establish neighbors.
- When a router receives its first **Hello packet**, it enters the init state, indicating that the Hello packet was received but did not contain the Router ID of the receiving router in the list of neighbors, so two-way communications is not yet ensured.
- As soon as the router sends a Hello packet to the neighbor with its RouterID and the neighbor sends a Hello packet packet back with that Router ID, the router's interface will transition to the two-way state.
- Now, the router is ready to take the relationship to the next level.

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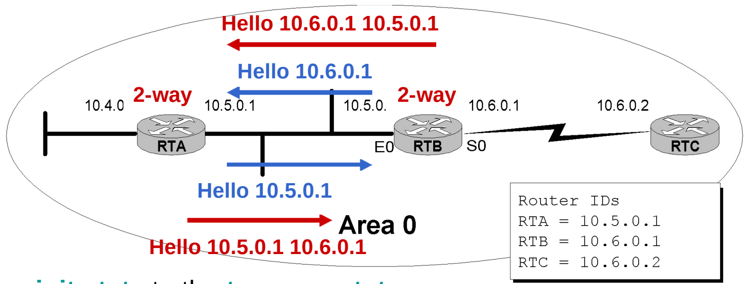
1. Establishing Adjacencies



From **init state** to the **two-way state**

- RTB receives Hello packets from RTA and RTC (its neighbors), and sees its own Router ID (10.6.0.1) in the Neighbor ID field.
- RTB declares takes the relationship to a new level, and declares a **two-way state** between itself and RTA, and itself and RTC.
- As soon as the router sends a **Hello packet** to the neighbor with its RouterID and the neighbor sends a Hello packet packet back with that Router ID, the router's interface will transition to the two-way state.
- Now, the router is ready to take the relationship to the next level.

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1. Establishing Adjacencies

Two-way state (and adjacency)

- Using Type-1 **Hello packets** every OSPF router tries to establish a **two-way** state or bi-directional communication with every neighbor router on the same IP network.
- Among other information, these Hello packets include a list of the sender's known OSPF neighbors.
- A router enters the **two-way state** when it sees itself in a neighbor's Hello packet.
- As we will see later, a router may stay in this state if it is on a broadcast segment and it is neither the DR or the BDR. (later)
- To learn about other routers' link states and eventually build a routing table, every OSPF router must form at least one "adjacency" and involve a series of progressions that will not just rely just on hellos, but the other four kinds of OSPF packets.

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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1. Establishing Adjacencies

Two-way state

- RTB now decides who to establish a "full adjacency" with depending upon the type of network that the particular interfaces resides on.
- **Note**: The term adjacency is used to both describe routers reaching 2-way state and when they reach full-state. Not to go overboard on this, but technically OSPF routers are adjacent when the FSM reaches full-state and IS-IS is considered adjacent when the FSM reaches 2-way state.

Two-way state to ExStart state

- If the interface is on a point-to-point link, the routers becomes adjacent with its sole link partner (aka "soul mates"), and take the relationship to the next level by entering the **ExStart state**. (coming soon)

Remaining in the two-way state

- If the interface is on a multi-access link (Ethernet, Frame Relay, ...) RTB must enter an election process to see who it will establish a full adjacency with, and remains in the **two-way state**. (Next!)

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Steps to OSPF Operation with OSPF States

1. Establishing router adjacencies
   - **Down State** – No Hello received
   - **Init State** – Hello received, but not with this router's Router ID
   - **Two-way State** – Hello received, and with this router's Router ID
   - (ExStart State unless DR/BDR election needed)
2. Electing DR and BDR – Broadcast segments only ←
   - **ExStart State** with DR and BDR
   - **Two-way State** with all other routers
3. Discovering Routes
   - **ExStart State**
   - **Exchange State**
   - **Loading State**
   - **Full State**
4. Calculating the Routing Table
5. Maintaining the LSDB and Routing Table

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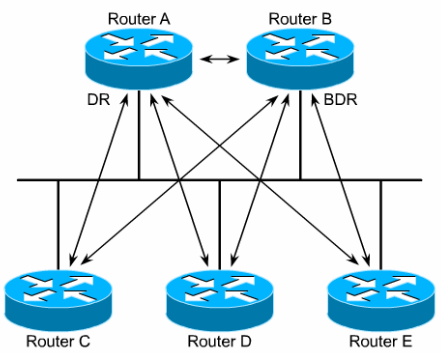
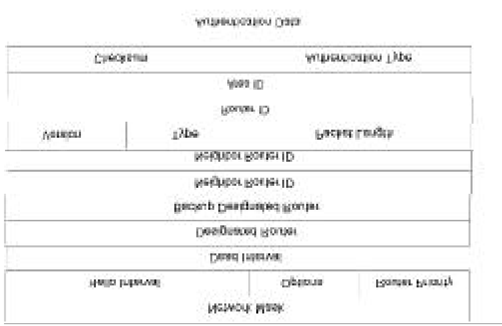
2. Electing a DR and BDR

- On point-to-point links adjacencies (don't get this confused with being "fully adjacent" or the full state) are established with all neighbors, because there is only one neighbor.
- On multi-access networks,OSPF elects a DR and BDR to limit the number of adjacencies using **OSPF Hello packets**.
  – Reduce routing update traffic





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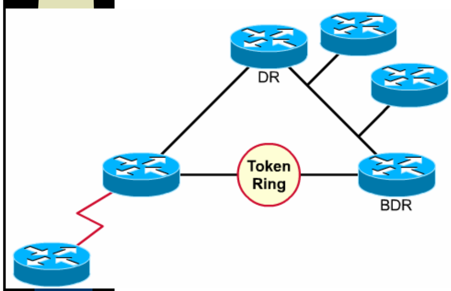
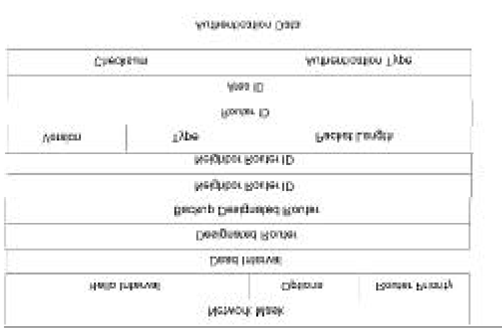
2. Electing a DR and BDR

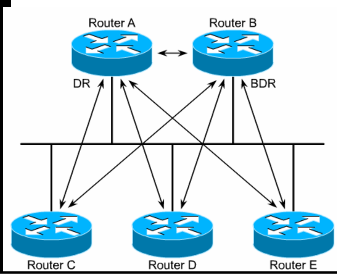
- ***DR*** - Designated Router
- ***BDR*** – Backup Designated Router
- DR's serve as collection points for Link State Advertisements (LSAs)
- A BDR back ups the DR.
- If the IP network is ***multi-access***, the OSPF routers will elect 1 DR and 1 BDR (unless there is only 1 router on the network).



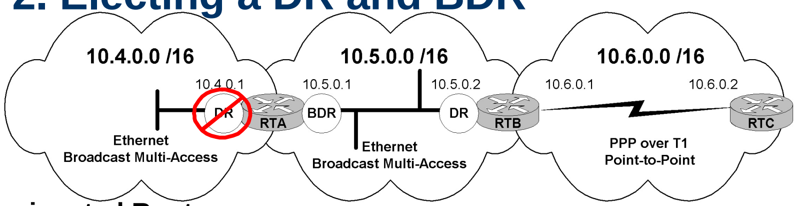


2. Electing a DR and BDR

- The formation of an adjacency between every attached router would create many unncessary LSA (Link State Advertisements), n(n-1)/2 adjacencies.
- Flooding on the network itself would be chaotic.
- A router would flood an LSA to all its adjacent neighbors, which in turn would flood it to all their adjacent neighbors, and so on, creating many copies of the same LSA on the same network.
- To prevent this problem, a Designate Router (DR) is elected on multi-access networks.
- Not knowing any different, at first all routers declare themselves the DR until it learns differently.
- Technical Note: In reality the BDR selection process happens first to ensure the BDR takes over the DR responsibilities when the DR fails.



2. Electing a DR and BDR



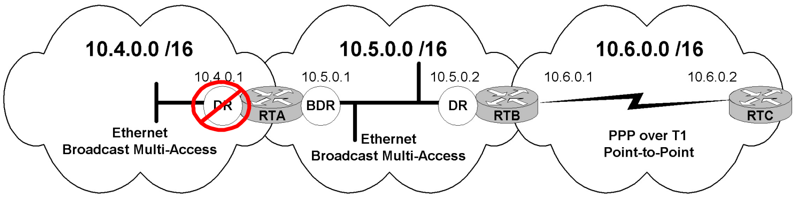
Designated Router

- A DR (Designated Router) and perhaps a BDR (Backup Designated Router) is elected for every multi-access network, using Hello packets as "ballots."
- Router with the **highest Router ID** is elected the DR.
- But like other elections, this one can be rigged.
- The **router's priority field** can be set to either ensure that it becomes the DR or prevent it from being the DR.

  `Rtr(config-if)# ip ospf priority <0-255>`

  – Higher priority becomes DR/BDR
  – Default = 1
  – 0 = Ineligible to become DR/BDR
- The router can be assigned a priority between 0 and 255, with 0 preventing this router from becoming the DR (or BDR) and 255 ensuring at least a tie. (The highest Router ID would break the tie.)

2. Electing a DR and BDR



Backup Designated Router

- BDR (Backup Designated Router) is elected in addition to the DR in case the DR fails.
- The BDR is the router that wins second place in the previous process.
- If a multi-access network only has one router, it will be the DR and there will be no BDR.
- **NOTE**: On an multi-access stub network, there is **no** DR or BDR. I am still investigating this, but the DR does not show in the show ip ospf commands. This may be a function of the output command and not the election process. This will be updated when I find out more information.

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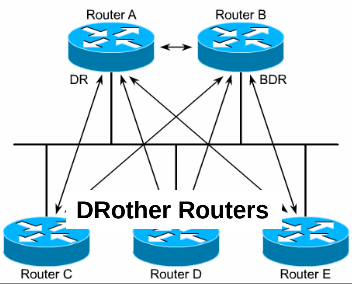
2. Electing a DR and BDR

- All other routers, “DRother”, establish adjacencies with only the DR and BDR.
- DRother routers multicast LSAs to only the DR and BDR
  – (224.0.0.6 - all DR routers)
- DR sends LSA to all adjacent neighbors
  – (224.0.0.5 - all OSPF routers)

Backup Designated Router - BDR

- Listens, but doesn’t act.
- If LSA is sent, BDR sets a timer.
- If timer expires before it sees the reply from the DR, it becomes the DR and takes over the update process.
- The process for a new BDR begins.



2. Electing a DR and BDR

A new router enters the network

- Once a DR is established, a new router that enters the network with a higher priority or router id will NOT become the DR or BDR. (Bug in early IOS 12.0)
- There is a valid condition where this may arise, but it is unlikely. (If a router enters a network and does not hear a hello from routers already on the network.)
- If DR fails, BDR takes over as DR and selection process for new BDR begins.
- State of the relationship
  - **DROthers** enter ExStart state with DR and BDR and two-way state with all other routers
  - **DR** and **BDR** enter ExStart state with all routers

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2. Electing a DR and BDR

DR - Summary

DR Election

- Router with the highest interface priority (0 = cannot become DR or BDR)
- Router with the highest router ID.
  - Loopback address used first
  - IP Address on active interface used second
- BDR is the second highest

Adjacencies and multicasting

- All other routers, DRother, establish adjacencies with only the DR and BDR.
- All routers continue to multicast Hello packets to AllSPFRouters (224.0.0.5) so they can track neighbors.
- But updates (LSAs) are multicast to DR and BDR only (224.0.0.6 - AllDRrouters) and in turn
- DR floods updates (LSAs) to all adjacent neighbors (224.0.0.5 - AllSPFRouters)

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2. Electing a DR and BDR

BDR

- Listens, but doesn' t act.
- If LSA is sent, BDR sets a timer.
- If timer expires before it sees the reply from the DR, it becomes the DR and takes over the update process and the process for a new BDR begins.

Network Type	Determined Characteristics	DR Election?
Broadcast multiaccess	Ethernet, Token Ring, or FDDI	Yes
Nonbroadcast multiaccess	Frame Relay, X.25, SMDS	Yes
Point-to-point	PPP, HDLC	No
Point-to-multipoint	Configured by an administrator	No

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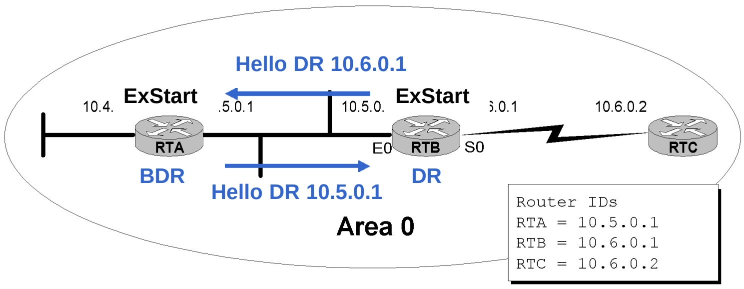
2. Electing a DR and BDR



DR and BDR get elected and FSM interface transitions from **two-way state** to the **ExStart state**

Note: Any DROther routers remain in **two-way state** with each other, but **ExStart state** with DR and BDR.

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Steps to OSPF Operation with OSPF States

1. Establishing router adjacencies
   - **Down State** – No Hello received
   - **Init State** – Hello received, but not with this router' s Router ID
   - **Two-way State** – Hello received, and with this router' s Router ID
   - (ExStart State unless DR/BDR election needed)
2. Electing DR and BDR – Broadcast segments only
   - **ExStart State** – Router interfaces with DR and BDR
   - **Two-way State** – Router interfaces with all other routers
3. Discovering Routes ←
   - **ExStart State** –Starts LSDB synchronization process between neighbors. Decide on Master/Slave.
   - **Exchange State** – Routers exchange DBD packets and determines if there is anything in its Link State Request list.
   - **Loading State** – If entries in LSR list, exchange LSUs.
   - **Full State** – Once LSDBs are synchronized.
4. Calculating the Routing Table
5. Maintaining the LSDB and Routing Table

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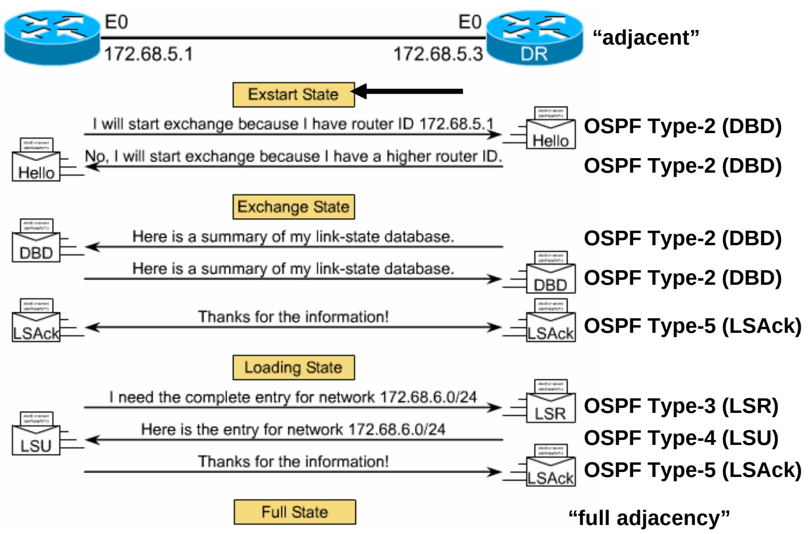
3. Discovering Routes and reaching Full State



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3. Discovering Routes and reaching Full State

ExStart State

- This state starts the LSDB (Link State Data Base) synchronization process.
- This will prepare for initial database exchange.
- Routers are now ready to exchange routing information.
  - Between routers on a point-to-point network
  - On a multi-access network between the DRothers and the DR and BDR.
- Formally, routers in **ExStart state** are characterized as adjacent, but have not yet become "fully adjacent" as they have not exchanged data base information.

But who goes first in the exchange?

- **ExStart** is established by exchanging OSPF Type-2 DBD (Database Description) packets (I believe the curriculum says LSA type 2 which is something else).
- Purpose of **ExStart** is to establish a master/slave relationship between the two routers decided by the **higher router id**.
- Once the roles are established they enter the **Exchange state**.

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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) **OSPF Type-2 (DBD)**
3	Link-state request (requests specific pieces of a neighbor router's link-state database) **OSPF Type-3 (LSR)**
4	Link-state update (transports link-state advertisements (LSAs) to neighbor routers) **OSPF Type-4 (LSU)**
5	Link-state acknowledgement (Neighbor routers acknowledge receipt of the LSAs) **OSPF Type-5 (LSAck)**

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OSPF DBD packet format

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       2       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuthType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Interface MTU         |    Options    |0|0|0|0|R|I|M|MS
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     DD sequence number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-                                                             -+
|                                                               |
+-                      An LSA Header                          -+
|                                                               |
+-                                                             -+
|                                                               |
+-                                                             -+
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              ...                              |
```

(LSA descriptions)

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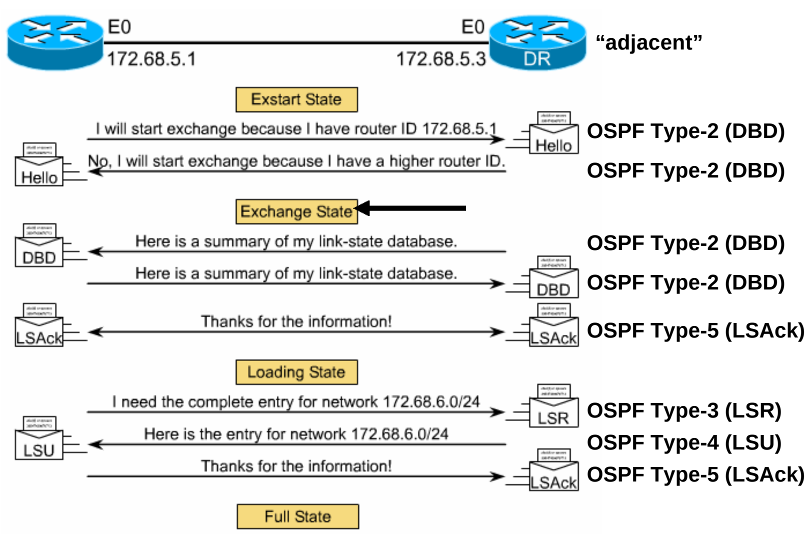
3. Discovering Routes and reaching Full State



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3. Discovering Routes and reaching Full State

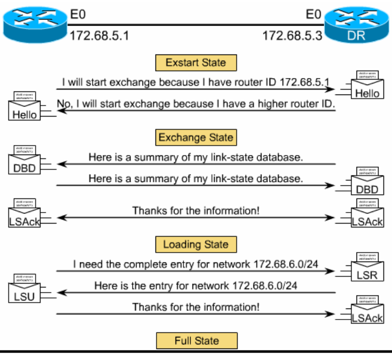
Exchange State

- **Exchange state** - Routers exchange one or more Type-2 DBDs (Database Description) packets, which is a **summary of the link-state database**
  - send LSAcks to verify
- Routers compare these DBDs with information in its own database.
- When a DBD packet is received the router looks through the LSA (Link State Advertisement) headers and identifies LSAs that are not in the router' s LSDB or are a different version from its LSDB version (older or newer).
- If the LSA is not in its LSDB or the LSA is a more recent version, the router adds an entry to its **Link State Request list**.
- This process ends when both routers stop have sent and received acknowledgements for all their DBD packets – that is they have successfully sent all their DBD packets to each other.

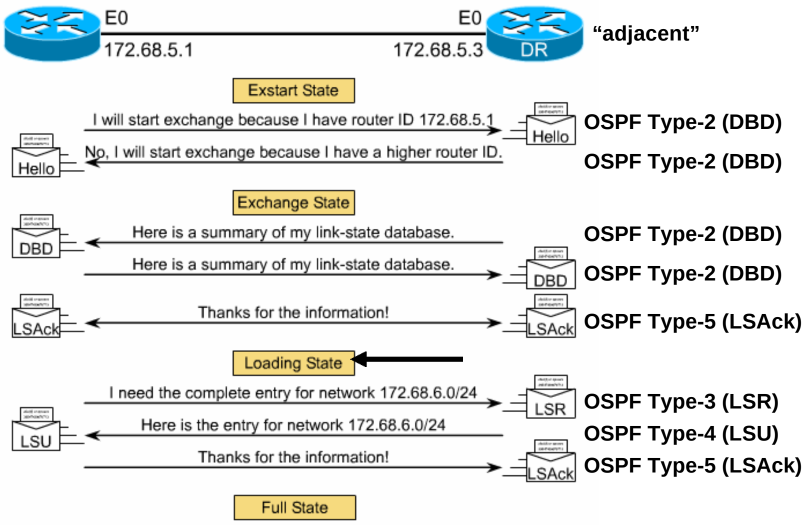
3. Discovering Routes and reaching Full State

Exchange State

- If a router has entries in its **Link State Request list**, meaning that it needs additional information from the other router for routes that are not in its LSDB or has more recent versions, then it enters the **loading state.**
- If there are <u>no</u> entries in its **Link State Request list**, than the router' s interface can transition directly to **full state**.
- Complete routing information is exchanged in the **loading state**, discussed next.



3. Discovering Routes and reaching Full State



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3. Discovering Routes and reaching Full State

Loading State

- If a router has entries in its **Link State Request list**, meaning that it needs additional information from the other router for routes that are not in its LSDB or has more recent versions, then it enters the **loading state.**
- The router needing additional information sends **LSR (Link State Request) packets** using LSA information from its LSR list.

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)	OSPF Type-2 (DBD)
3	Link-state request (requests specific pieces of a neighbor router's link-state database)	OSPF Type-3 (LSR)
4	Link-state update (transports link-state advertisements (LSAs) to neighbor routers)	OSPF Type-4 (LSU)
5	Link-state acknowledgement (Neighbor routers acknowledge receipt of the LSAs)	OSPF Type-5 (LSAck)

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OSPF LSR packet format

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       3       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          LS type                              |  \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+   |
|                       Link State ID                           |   > LSR
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+   |
|                     Advertising Router                        |  /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            ...                                 |
```

(LSRs)

3. Discovering Routes and reaching Full State

Loading State

- The other routers replies by sending the requested LSAs in the **Link State Update (LSU) packet.**
- The receiving router sends **LSAck** to acknowledge receipt.
- When all LSAs on the neighbors **Link State Request list** have been received, the "neighbor FSM" transitions this interface to **Full state.**

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)	**OSPF Type-2 (DBD)**
3	Link-state request (requests specific pieces of a neighbor router's link-state database)	**OSPF Type-3 (LSR)**
4	Link-state update (transports link-state advertisements (LSAs) to neighbor routers)	**OSPF Type-4 (LSU)**
5	Link-state acknowledgement (Neighbor routers acknowledge receipt of the LSAs)	**OSPF Type-5 (LSAck)**

OSPF LSU packet format

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       4       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            # LSAs                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-                                                            +-+
|                             LSAs                              |
+-                                                            +-+
|                              ...                              |
```

LSAs

LSAs: Types 1, 2, 3, 4, or 5

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OSPF packet types – More later

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.

3. Discovering Routes and reaching Full State

Full State

- **Full state** - after all LSRs have been updated.
- At this point the routers should have identical LSDBs (link-state databases).

Flooding LSAs

- Once this interface transitions to or from **Full state** the router originates a new version of a **Router LSA** (LSA Type –1, coming) and floods it to its neighbors, distributing the new topological information – out all OSPF enabled interfaces.
- Broadcast networks:
  - DR: If the LSA was received on this interface, send it out this interface so DROthers receive it (224.0.0.5 - all OSPF routers)
  - BDR/DROther: If the LSA was received on this interface, do not send out this interface (received from DR).

Calculating Routing Table

- The router still must calculate its routing table – ***Next!***

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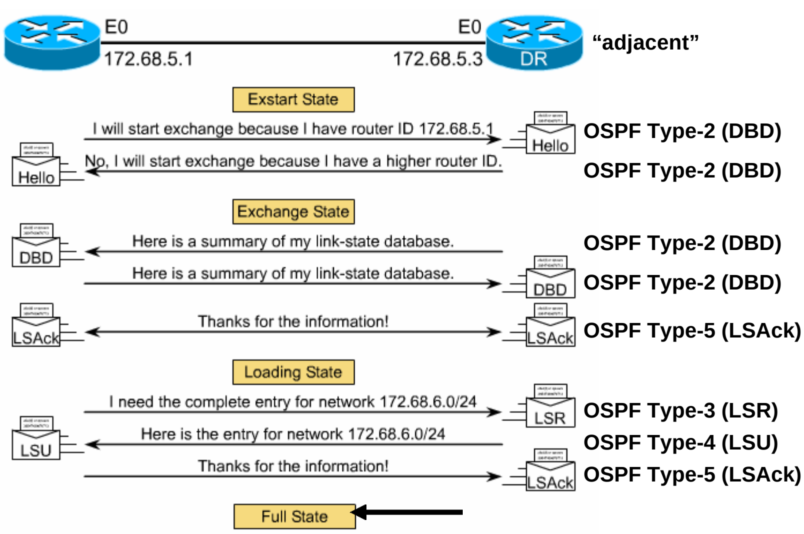
3. Discovering Routes and reaching Full State



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Steps to OSPF Operation with OSPF States

1. Establishing router adjacencies
   - **Down State** – No Hello received
   - **Init State** – Hello received, but not with this router's Router ID
   - **Two-way State** – Hello received, and with this router's Router ID
   - (ExStart State unless DR/BDR election needed)
2. Electing DR and BDR – Broadcast segments only
   - **ExStart State** – Router interfaces with DR and BDR
   - **Two-way State** – Router interfaces with all other routers
3. Discovering Routes
   - **ExStart State**
   - **Exchange State**
   - **Loading State**
   - **Full State**
4. Calculating the Routing Table ←
5. Maintaining the LSDB and Routing Table

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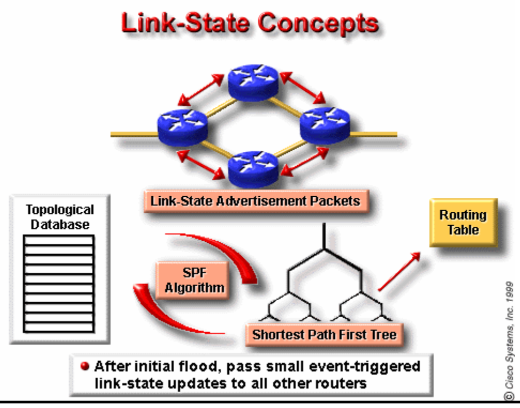
4. Calculating the Routing Table

- The router now has a complete link-state database
- Now the router is ready to create a routing table, but first needs to run the Shortest Path First Algorithm on the link state database, which will create the SPF tree.
- **Dijkstra's algorithm** is used to calculate the Shortest Path Tree from the LSAs in the link state database.
- SPF, Shortest Path First calculations places itself as the root and creating a "tree diagram" of the network.



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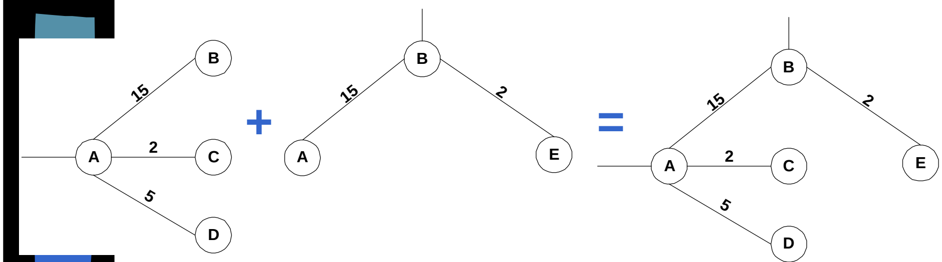
4. Calculating the Routing Table

- The LSAs that build the database contain three important pieces of generic information: **RouterID** of the sender of the LSA, the **NeighborID**, and **cost** of the link between the Router and the neighbor (I.e the state of the link or link-state).
- We will not go into the details here, but the books mentioned earlier all some excellent examples on this process.
- Also, remember the link-state exercise we did earlier!

Exercise: From link-state flooding to routing tables



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4. Calculating the Routing Table

Cost = 10^8/BW

- OSPF basis routing metrics on cost.
- Cisco routers, cost = 10^8/BW
- **Note for both IGRP and EIGRP it is 10^7, whereas OSPF is 10^8**
- BW is the configured bandwidth for an interface (See CCNA IGRP information)
- Cisco uses a default cost of 10^8/BW, where BW is the configured bandwidth (bandwidth command) of the interface and 10^8 (100,000,000) as the reference bandwidth.
- Example: A serial link with a configured bandwidth of 128K would have a cost of: 100,000,000/128,000 = **781**
- **The cost of a route is the sum of the costs of all the outgoing interfaces to a destination.**
- In general, cost decreases as the speed of the link increases.
- RTB's 10 Mbps Ethernet interface has a lower cost than its T-1, 1.544 Mbps interface.

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4. Calculating the Routing Table

Cisco default interface costs:

- 56-kbps serial link —Default cost is 1785
- 64-kbps serial link —Default cost is 1562
- T1 (1.544-Mbps serial link) —Default cost is 65
- E1 (2.048-Mbps serial link) —Default cost is 48
- 4-Mbps Token Ring —Default cost is 25
- Ethernet —Default cost is 10
- 16-Mbps Token Ring —Default cost is 6
- FDDI —Default cost is 1

Notes:

- Cisco routers default to T1 (1.544 Mbps) on all serial interfaces and require manual modification with the bandwidth command.
- **ospf auto-cost reference-bandwidth** *ref-bw* can be used to modify the reference-bandwidth for higher speed interfaces

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4. Calculating the Routing Table

Modifying the cost

- **bandwidth** command can be used to change the bandwidth metric on an interface and used in the 10^8/BW calculation:

```
RTB(config)# inter s 0
RTB(config-if)# bandwidth 56   (in Kbps)
```

Note: The metric for this interface is now 1785.

- **ip ospf cost** is used when converting the metric between routers from different vendors. It overrides the default cost and becomes the metric for that interface. Bay Networks and some other vendors use a default cost of 1 on all interfaces, essentially making the OSPF cost reflect hop counts.

```
RTB(config)# inter s 0
RTB(config-if)# ip ospf cost 1000
```

Note: The metric for this interface is now 1000.

Note: For the Cisco IOS cost formula to be accurate it is important to have appropriate costs on both sides of a link.

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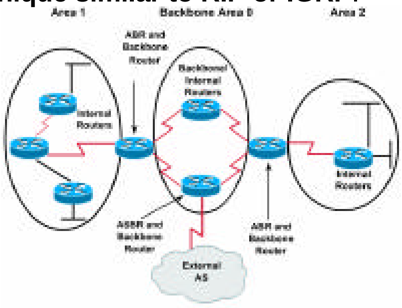
4. Calculating the Routing Table

- In the next chapter we will discuss OSPF and multiple areas.
- Here is some information regarding the routing table calculation that we will discuss again in the chapter on OSPF multiple areas:
- OSPF areas are designed to keep issues like flapping links within an area.
- SPF is not recalculated if the topology change is in another area.
- The interesting thing is that OSPF distributes inter-area (between areas) topology information using a distance-vector method.
- **OSPF uses link-state principles only within an area**.
- **ABRs relay routing information between areas via distance vector technique similar to RIP or IGRP**.



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4. Calculating the Routing Table

FYI: The rest of the story, which will be discussed in OSPF multiple areas.

OSPF areas are designed to keep issues like flapping links within an area. SPF is not recalculated if the topology change is in another area. The interesting thing is that OSPF distributes inter-area (between areas) topology information using a distance-vector method. OSPF uses link-state principles only within an area. ABRs do not announce topological information between areas, instead, only routing information is injected into other areas. ABRs relay routing information between areas via distance vector technique similar to RIP or IGRP. This is why show ip ospf does not show a change in the number of times SPF has been executed when the topology change is in another area.

Note: It is still a good idea to perform route summarization between areas, announcing multiple routes as a single inter-area route. This will hide any changes in one area from affecting routing tables in other areas.

For more information, look at Cisco IP Routing by Alex Zinin.

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4. Calculating the Routing Table

SPF Holdtime

- SPF algorithm is CPU intensive and takes some time depending upon the size of the area (coming next week), the number of routers, the size of the link state database.
- A flapping link can cause an OSPF router to keep on recomputing a new routing table, and never converge.
- To minimize this problem:
  - SPF calculations are **delayed by** 5 seconds after **receiving an LSU** (Link State Update)
  - **Delay between consecutive SPF calculations** is **10 seconds**
- You can configure the delay time between when OSPF receives a topology change and when it starts a shortest path first (SPF) calculation (*spf-delay*).
- You can also configure the hold time between two consecutive SPF calculations (*spf-holdtime*).

```
Router(config-router)#timers spf spf-delay spf-
  holdtime
```


4. Calculating the Routing Table

```
RTB#show ip ospf 1
Routing Process "ospf 1" with ID 10.6.0.1
<OUTPUT OMITTED>
    Area BACKBONE(0)
        Number of interfaces in this area is 2
        Area has no authentication
        SPF algorithm executed 5 times
        Area ranges are
        Number of LSA 4. Checksum Sum 0x1D81A
        Number of opaque link LSA 0. Checksum Sum 0x0
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
```

5.Maintaining the LSDB and the Routing Table

Routes are kept in the IP routing table (show ip route)

- **Note**: There is a routing table which is internal to the OSPF process. This internal routing table contains information used as an intermediate result for inter-area and external route calculations and contains routes to ABRs and ASBRs. (Just a technical note and fyi.)

```
RouterA#show ip route
Codes: I - IGRP derived, R - RIP derived, O - OSPF derived, C -
   connected, S - static, E - EGP derived, B - BGP derived, * -
   candidate default route, IA - OSPF inter area route, i - IS-IS
   derived, U - per-user static route, o - on-demand routing, D -
   EIGRP, EX - EIGRP external, E1 - OSPF external type 1 route, E2 -
   OSPF external type 2 route, N1 - OSPF NSSA external type 1 route, N2
   - OSPF NSSA external type 2 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
```

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5.Maintaining the LSDB and the Routing Table

Convergence

OSPF convergence time for **intra-area** routing is determined by the amount of time routers spend on:

- Link-failure or neighbor unreachability detection
- Origination of the new LSA
- Flooding the new version of the LSA to all routers
- SPF calculation on all routers

When **inter-area** routing is considered, installation or removal of a route in the routing table may trigger the need to send LSAs to other areas.

- New inter-area routes may need to be calculated in the other areas.
- Remember, OSPF distributes inter-area (between areas) topology information using a distance-vector method.
- OSPF uses link-state principles only within an area, so changes in other areas to <u>not</u> cause the router to re-run the SPF algorithm.

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5.Maintaining the LSDB and the Routing Table

Convergence

Link-failure or neighbor unreachability detection

- In OSPF, link failure can be determined by:
  - Physical layer or data link layer – directly reporting a state change on a directly connected interface.
  - The Hello subprotocol – The router's interface has not received a Hello packet from an adjacent neighbor within the OSPF **RouterDeadInterval** time (40 seconds or 120 seconds on NBMA links).

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5.Maintaining the LSDB and the Routing Table

Convergence

Origination of the new LSA

- Creating the new LSA (Router LSA – Type 1) is quick and simple.
- The LSA (Router LSA - Type 1) is sent in an LSU (OSPF Type 4).
- More in the next chapter on LSA types.

LSU packet

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       4       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            # LSAs                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-                                                            +-+
|                             LSAs                              |
+-                                                            +-+
|                              ...                              |
```

Router LSA

```
 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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OSPF packet types – More later

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.

5.Maintaining the LSDB and the Routing Table

onvergence

rigination of the new LSA (continued)

- FYI: LSAs are not originated any faster than every 5 seconds (MinLSInterval) to prevent flooding storms in unstable networks.
- When the router wants to report a down link, it sets the LS Age field to the MaxAge value (3,600 seconds), which tells routers to flush this entry from their LSDB.

LSU packet

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       4       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            # LSAs                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-                                                            +-+
|                            LSAs                                |
+-                                                            +-+
|                             ...                               |
```

Router LSA

```
 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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5.Maintaining the LSDB and the Routing Table

Convergence

Flooding the new version of the LSA to all routers

- The router detecting the link failure floods the LSA (Router LSA type-1) using the LSU (OSPF type 4) as previously discussed (and will be discussed again next chapter).
- Note: OSPF represents intra-area network topology using a type-1 Router LSA or type-2 Network LSA (next chapter).
- The time it takes to flood an LSA depends on:
  - Complexity of the network topology
  - Bandwidth of the links
  - CPU power of the router
- OSPF relies on hop-by-hop flooding - it does not try to send LSAs directly to all routers in the OSPF domain.
- This means that any router receiving an LSA will flood them out all other OSPF interfaces (not out the interface it was received) - so that LSAs are not flooded back to the sending neighbors.
- The age field is incremented by 1.

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5.Maintaining the LSDB and the Routing Table

Convergence

Flooding the new version of the LSA to all routers

- The LSA (Router LSA type-1) containing the new link-state information using the LSU (OSPF type 4) and sends it to:
  - **Point-to-point links** (No DR/BDR): LSU sent to 224.0.0.5 AllSPFRouters
  - **Multi-access networks**: LSU sent to 224.0.0.6 AllDRrouters (DR/BDR)
    - When DR receives and acknowledges LSU, it floods the LSU to 224.0.0.5 AllSPFRouters.
    - Each router acknowledges the receipt of the of the LSU with a LSAck back to the DR.

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5.Maintaining the LSDB and the Routing Table

Convergence

Flooding the new version of the LSA to all routers

Receiving Router: LSA Installation and SPF Scheduling

Upon receiving an LSU with new information, the OSPF router:

- Sends an LSAck (LSA Acknowledgement) packet to the sender.
- Determines if the it has this information in its LSDB. (This happens if the LSA is received or originated by the router.)
  - For Intra-area routes: (Type 1, Router and Type 2, Network LSAs)
    - If the LSA does not exist in the LSDB or is a newer version, the router schedules the SPF calculation.
  - For Inter-area routes: (Type 3, 4, 5 LSAs - later)
    - Inter-area routes (announced by the ABR – later) are distributed using a distance vector technique. What is important here is that this does not cause the router to schedule the SPF calculation.

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5.Maintaining the LSDB and the Routing Table

OSPF Type 5 – Link State Acknowledgement Packet

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Version #   |       5       |         Packet length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Area ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |             AuType            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Authentication                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                                                |
                                                               -+
                                                                |
                                    An LSA Header              -+
                                                                |
                                                               -+
                                                                |
                                                               -+
                                                                |
              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                 ...                                            |
```

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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5.Maintaining the LSDB and the Routing Table

Receiving Router: LSA Installation and SPF Scheduling (cont.)

- After SPF hold timer expires (5 seconds), router runs SPF algorithm and creates a new routing table
- Router uses new routing table

Periodic updates

- Each LSA entry in the link-state database has its own age timer, with a default of **60 minutes** (3,600 seconds). – this is known as the **MaxAge** value of the LSA entry.
- When an LSA reaches MaxAge, it is flushed from the LSDB.
- Before this happens the LSA has a **Link State Refresh Time (LSRefreshTimer)**, **30 minutes**, (1,800 seconds) and when this time expires the router floods a new LSA to all its neighbors, who will reset the age of the LSA in its LSDB.
- This is also known as the "**paranoid update**." or "**periodic update**."
- These updates do not trigger recalculation of the routing table.

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States of the OSPF neighbor FSM (Finite State Machine)

- Every OSPF router represents its communications with other OSPF routers in the form of neighbor data structures.
- Every neighbor can be in one of many states

. Establishing router adjacencies
  - **Down State** – No Hello received
  - **Init State** – Hello received, but not with this router's Router ID
  - **Two-way State** – Hello received, and with this router's Router ID
  - (ExStart State unless DR/BDR election needed)

. Electing DR and BDR – Broadcast segments only
  - **ExStart State** – Router interfaces with DR and BDR
  - **Two-way State** – Router interfaces with all other routers

. Discovering Routes
  - **ExStart State** –Starts LSDB synchronization process between neighbors. Decide on Master/Slave.
  - **Exchange State** – Routers exchange DBD packets and determines if there is anything in its Link State Request list.
  - **Loading State** – If entries in LSR list, exchange LSUs.
  - **Full State** – Once LSDBs are synchronized.

. Calculating the Routing Table

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. Maintaining the LSDB and Routing Table

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