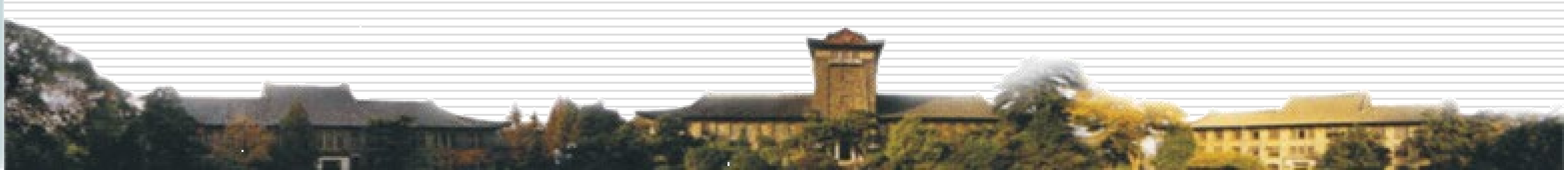
Routing Protocols

RIP and OSPF



Routing and Routers

- RIPv1/RIPv2
  - RIP History
  - Differences Between RIP v1 and RIP v2
  - Configuration of RIP v2
- OSPF(single area)
  - Link-state routing protocol
  - Single-area OSPF concepts
  - Single-area OSPF configuration

RIP History

- RIP v1 is considered an interior gateway protocol that is classful.
  - RIP v1 is a distance vector protocol that broadcasts its entire routing table to each neighbor router at predetermined intervals. The default interval is 30 seconds.
  - RIP uses hop count as a metric, with 15 as the maximum number of hops.
- RIP v1 is capable of load balancing over as many as six equal-cost paths, with four paths as the default
- RIP was originally specified in RFC 1058

RIP History

- RIPv1 has the following limitations:
  - It does not send subnet mask information in its updates.
  - It sends updates as broadcasts on 255.255.255.255 .
  - It does not support authentication.
  - It is not able to support VLSM or Classless Interdomain Routing (CIDR).

RIP Configuration

- The router rip command selects RIP as the routing protocol.
- The network command assigns a NIC-based network address to which a router will be directly connected.

Router(config)#

router rip

- Starts the RIP routing process

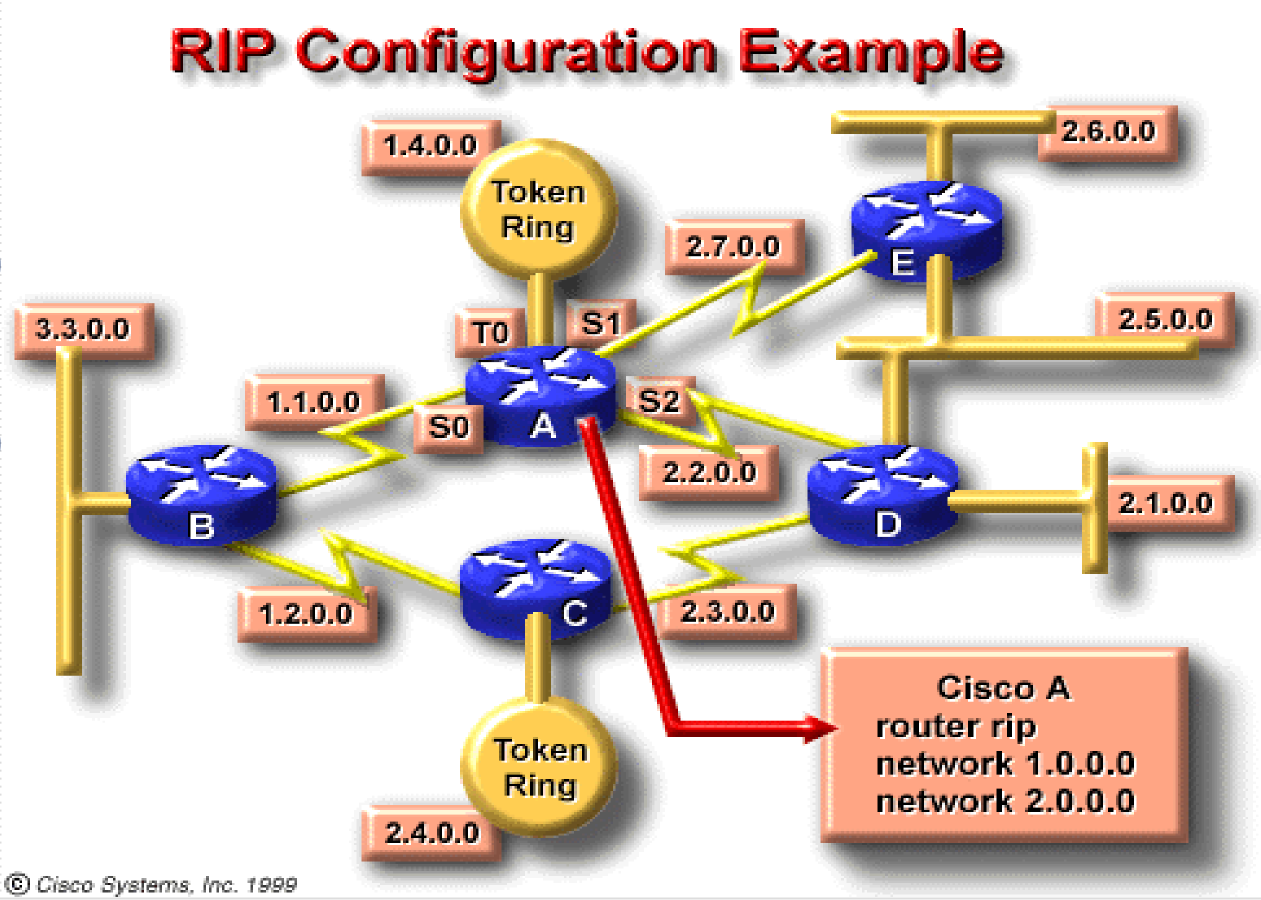
Router(config-router)#

network *network-number*

- Selects participating attached networks

RIP Configuration

- router rip
- network 1.0.0.0
- network 2.0.0.0



RIP v2

- RIP v2 is an improved version of RIP v1 and shares the following features:
  - It is a distance vector protocol that uses a hop count metric.
  - It uses holddown timers to prevent routing loops – default is 180 seconds.
  - It uses split horizon to prevent routing loops.
  - It uses 16 hops as a metric for infinite distance.

Comparing RIPv1 and RIPv2

RIP v1	RIP v2
Easy to configure	Easy to configure
Only supports classful routing protocol	Supports use of classless routing
No subnet information with the routing update	Sends subnet mask information with the routing updates
Does not support prefix routing - all the devices in the same network must use the same subnet mask.	Supports prefix routing - different subnets within the same network can have different subnet masks (VLSM)
No authentication in updates	Provides for authentication in its updates
Broadcasts over 255.255.255.255	Multicasts routing updates over the Class D address 224.0.0.9 - makes it more efficient

RIP v2 Configuration

- The router command starts the routing process.
- The network command causes the implementation of the following three functions:
  - The routing updates are multicast out an interface.
  - The routing updates are processed if they enter that same interface.
  - The subnet that is directly connected to that interface is advertised.

RIP v2 Configuration Example


```
router rip
version 2
network 172.16.0.0
network 10.0.0.0
```

```
router rip
version 2
network 10.0.0.0
network 192.168.1.0
```

```
router rip
version 2
network 10.0.0.0
```

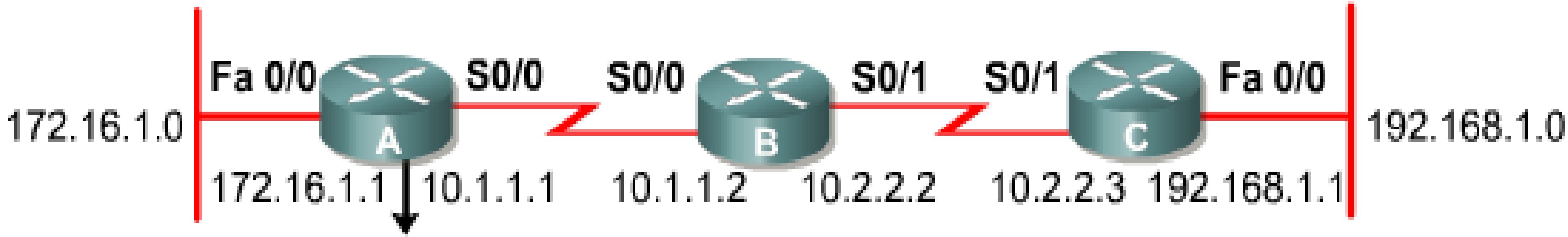
Select a routing protocol

Select rip version 2 as the routing protocol

Mandatory configuration command for each IP routing process

Verifying &Troubleshooting

- Verifying RIP v2
  - Router# show ip protocols
    - Verifying the RIP Configuration
  - Router# show ip route
    - Displaying the IP Routing Table
- Troubleshooting RIP v2
  - Router# debug ip rip
    - display RIP routing updates sent and received.
  - Router# undebug all (/no debug all)
    - Router# turn off all debugging



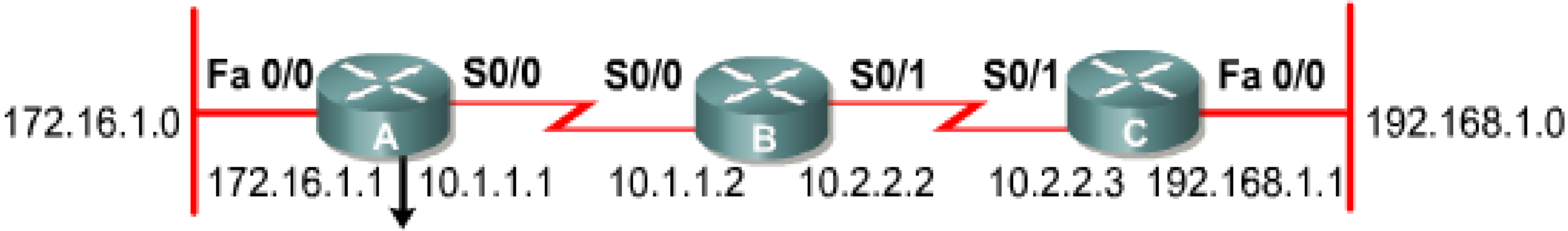

```
RouterA#show ip protocols
Routing Protocol is "rip"
  Sending updates ever 30 seconds, next due in 12 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Outgoing update filter lists for all interfaces is
  Incoming update filter lists for all interfaces is
  Redistributing: rip
  Default version control: send version 1, receive any version
     Interface        send    Recv  Triggered  RIP  Keychain
     Ethernet          1       1 2
    Serial2            1       1 2
Routing for Networks:
   10.0.0.0
   172.16.0.0
Routing Information Sources:
   Gateway          Distance        Last Update
   (this router)    120               0:2:12:15
   10.1.1.2         120               0:1:09:01
Distance: (default is 120)
```

The debug ip rip Command

- The **debug ip rip** command displays RIP routing updates as they are sent and received. In this example, the update is sent by 183.8.128.130.

- It reported on three routers, one of which is inaccessible because its hop count is greater than 15. Updates were then broadcast through 183.8.128.2.

```
Router# debug ip rip
RIP Protocol debugging is on
Router#
RIP: received update from 183.8.128.130 on Serial0
      183.8.0.128 in 1 hops
      183.8.64.128 in 1 hops
      0.0.0.0 in 16 hops (inaccessible)
RIP: received update from 183.8.64.140 on Serial1
      183.8.0.128 in 1 hops
      183.8.128.128 in 1 hops
      0.0.0.0 in 16 hops (inaccessible)
RIP: received update from 183.8.128.130 on Serial0
      183.8.0.128 in 1 hops
      183.8.64.128 in 1 hops
      0.0.0.0 in 16 hops (inaccessible)
RIP: sending update to 255.255.255.255 via Ethernet0 (183.8.128.2)
      subnet 183.8.0.128, metric 16
      subnet 183.8.64.128, metric 1
      subnet 183.8.128.128, metric 1
      default 0.0.0.0, metric 16
      network 144.253.0.0, metric 1
RIP: Sending update to 255.255.255.255 via Ethernet1 (144.253.100.202)
      default 0.0.0.0, metric 16
      network 153.50.0.0, metric 2
      network 183.8.0.0, metric 1
```




```
RouterA#show ip route
Codes:C - connected, S - static, I - IGRP, R - RIP, M - mobile, B -BGP
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
      N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
      N1 - OSPF external type 1, E2 - OSPF external type 2, * -
candidate
default
       U - Per-user static route, 0 = CCR
       T - Traffic engineered route

Gateway of last resort is not set
   172.16.0.0/24 is subnetted, 1 subnets
C      172.16.1.0 is directly connected, Ethernet0
   10.0.0.0/24 is subnetted, 2 subnets
R      10.2.2.0 (120/1) via 10.1.1.2, 00:00:07, Serial 0/0
C      10.1.1.0 is directly connected, Serial 0/0
R    192.168.1.0/24 (120/2) via 10.1.1.2, 00:00:07, Serial 0/0
```

Routing and Routers

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OSPF Overview

- Open Shortest Path First (OSPF) is a link-state routing protocol based on open standards.
- It is described in several standards of the Internet Engineering Task Force (IETF)
  - The most recent description is RFC 2328.
- OSPF is becoming the preferred IGP protocol when compared with RIPv1 and RIPv2 because it is scalable.

Routing Information

- The state of the link is a description of an interface and the relationship to its neighboring routers.
- The collection of link-states forms a link-state database, sometimes called a topological database.
- Routers apply the Dijkstra shortest path first (SPF) algorithm to build the SPF tree, with themselves as the root.
- Routers calculate the best paths through SPF tree, then best paths are selected and placed in the routing table.

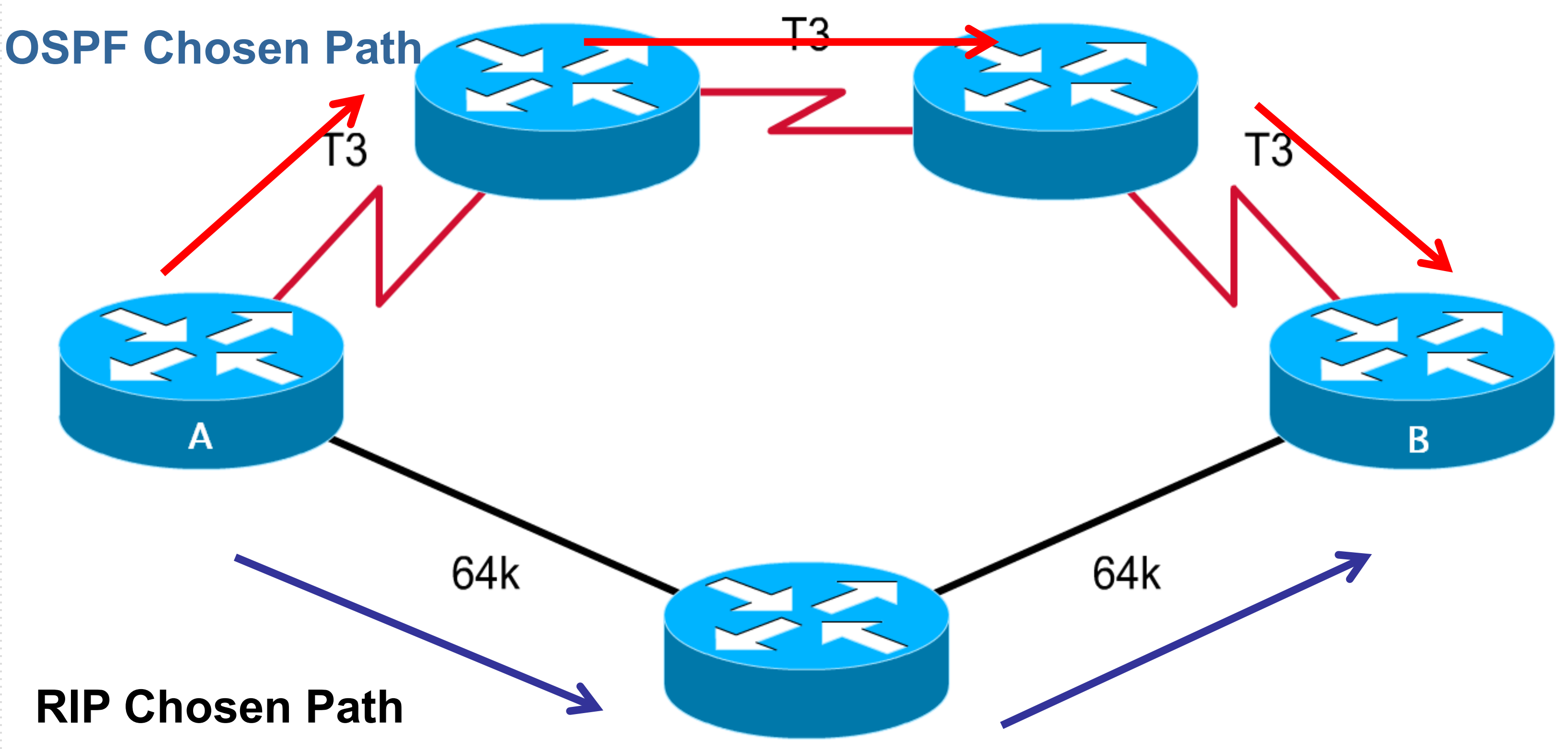
OSPF vs. RIP

OSPF
- Uses Metrics such as Bandwidth
- Appropriate for Large Networks
- Can further subdivide a network into areas
- Supports VLSM
- Fast convergence
- Supports equal-cost multipath

RIP
- Uses Hop Count
- Designed for Small Networks (15 hops)
- Flat hierarchy design
- Non VLSM (for RIP v1)

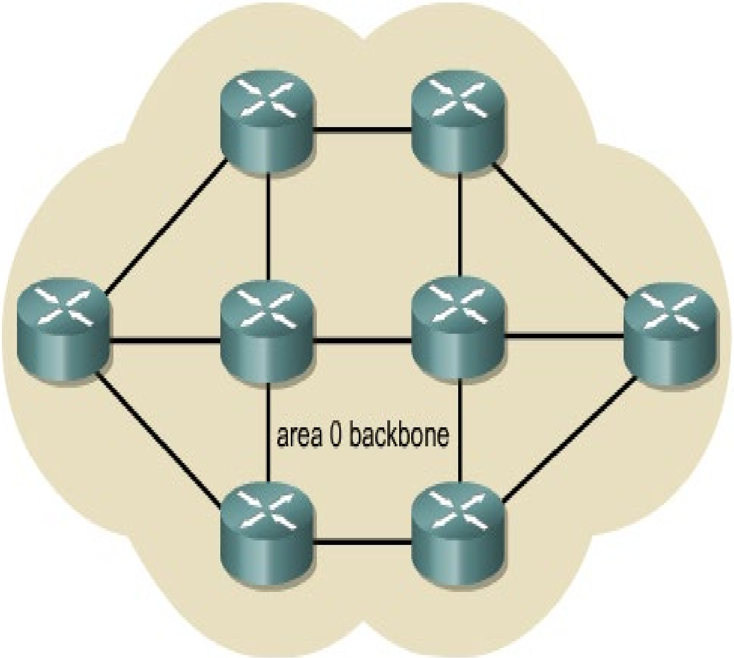
OSPF vs. RIP (cont.)

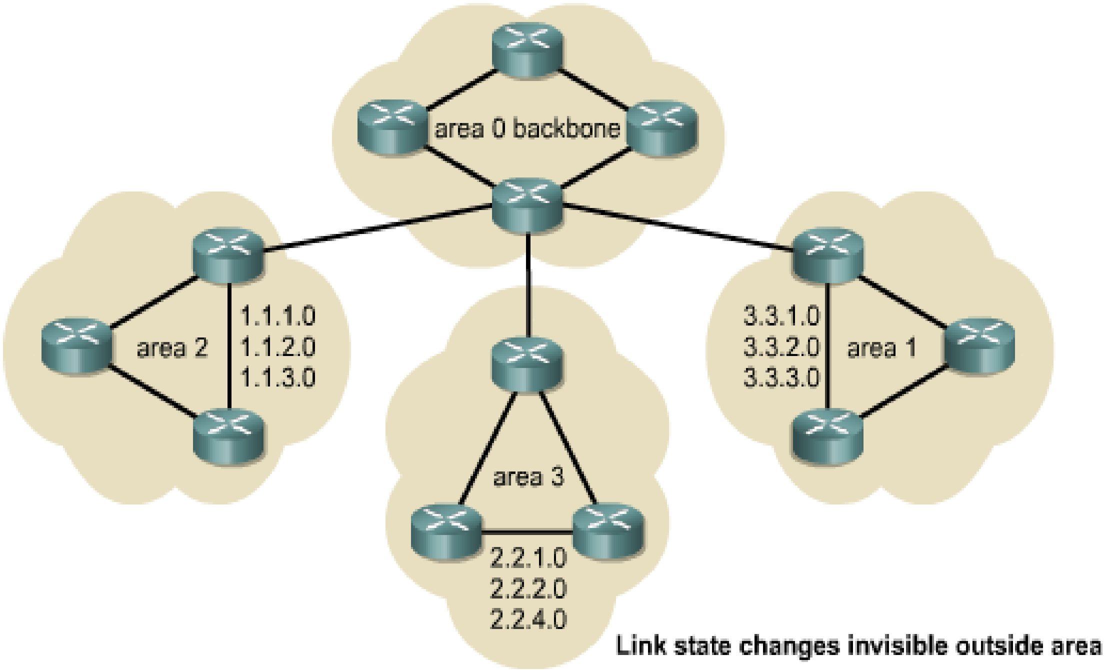
What is the Best Path from A to B?



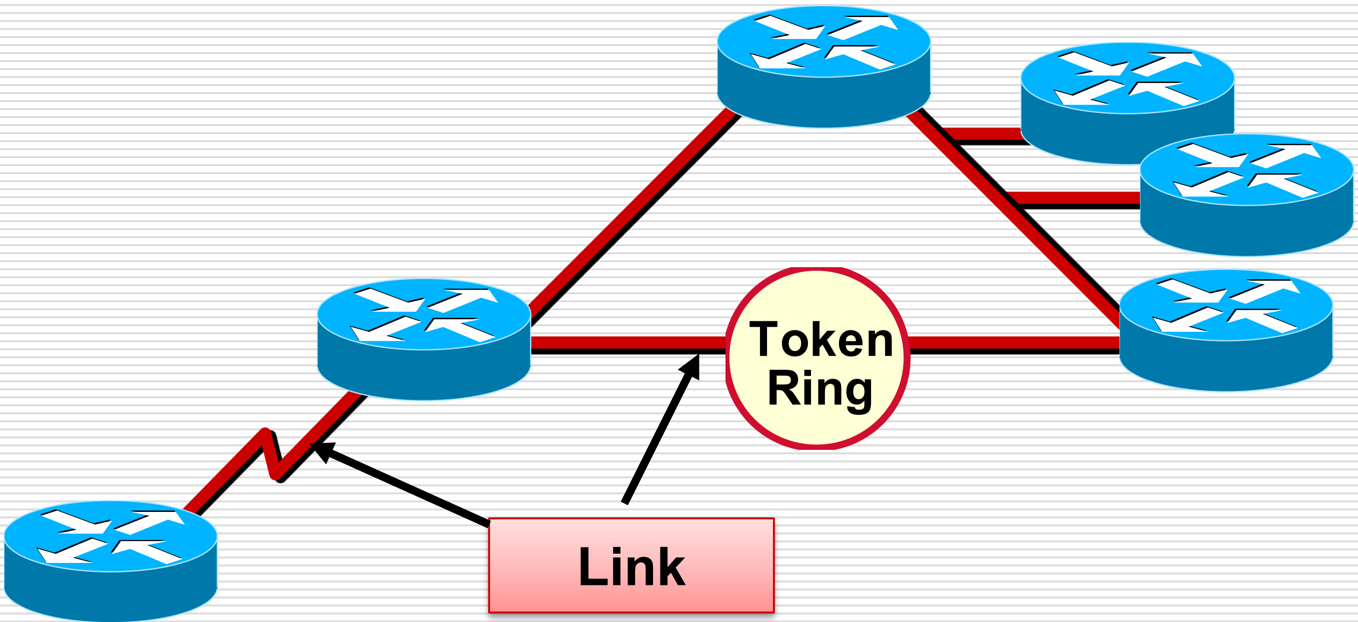
OSPF Feature

- OSPF overcomes these limitations
  - More robust
  - More scalable
- Large OSPF networks use a hierarchical design.



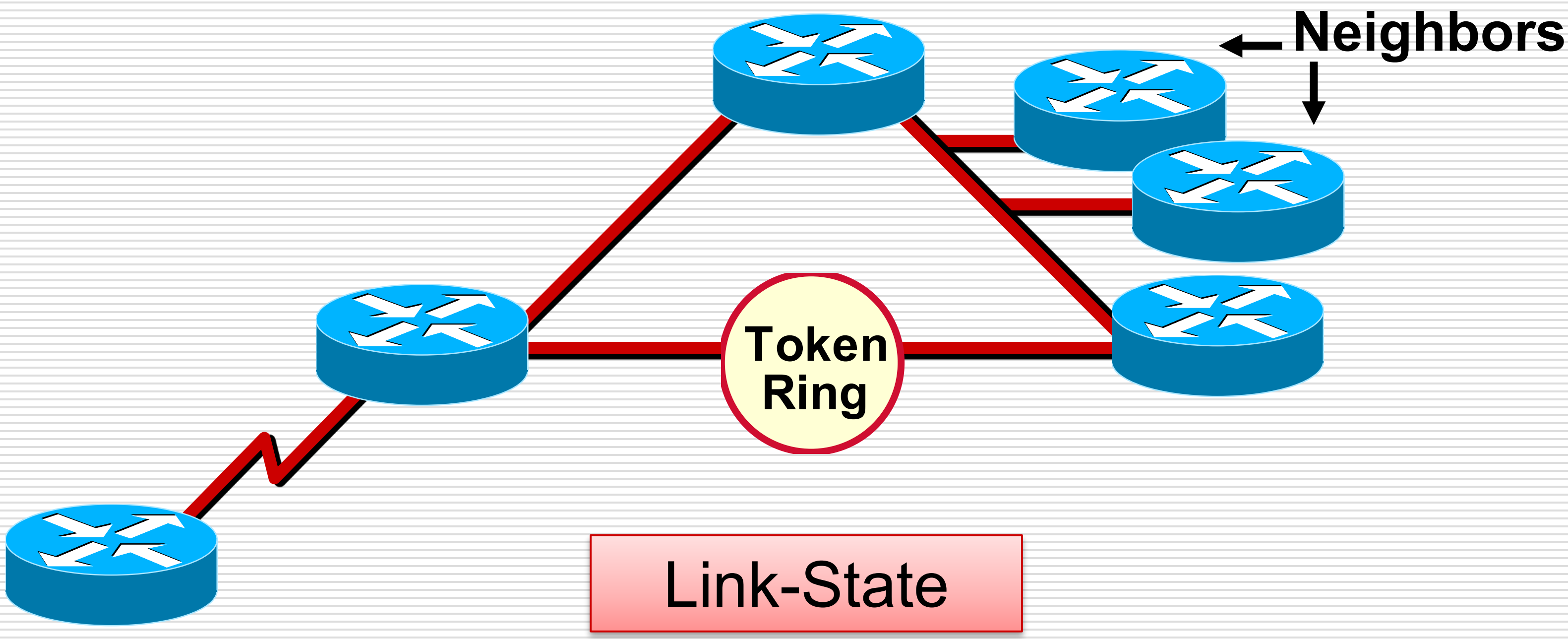


OSPF Terminology



A physical connection between two network devices

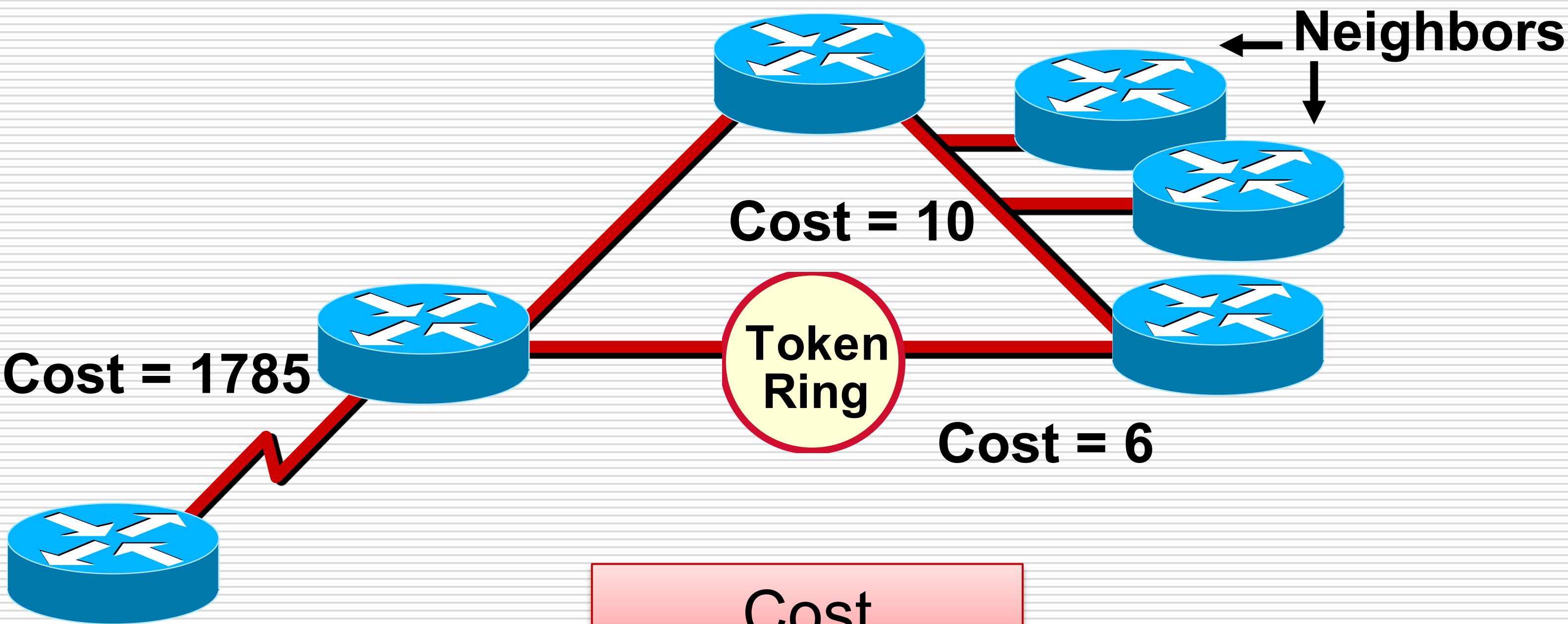
OSPF Terminology



Link-State

The status of a link between two routers, including information about a router's interface and its relationship to neighbouring routers.

OSPF Terminology

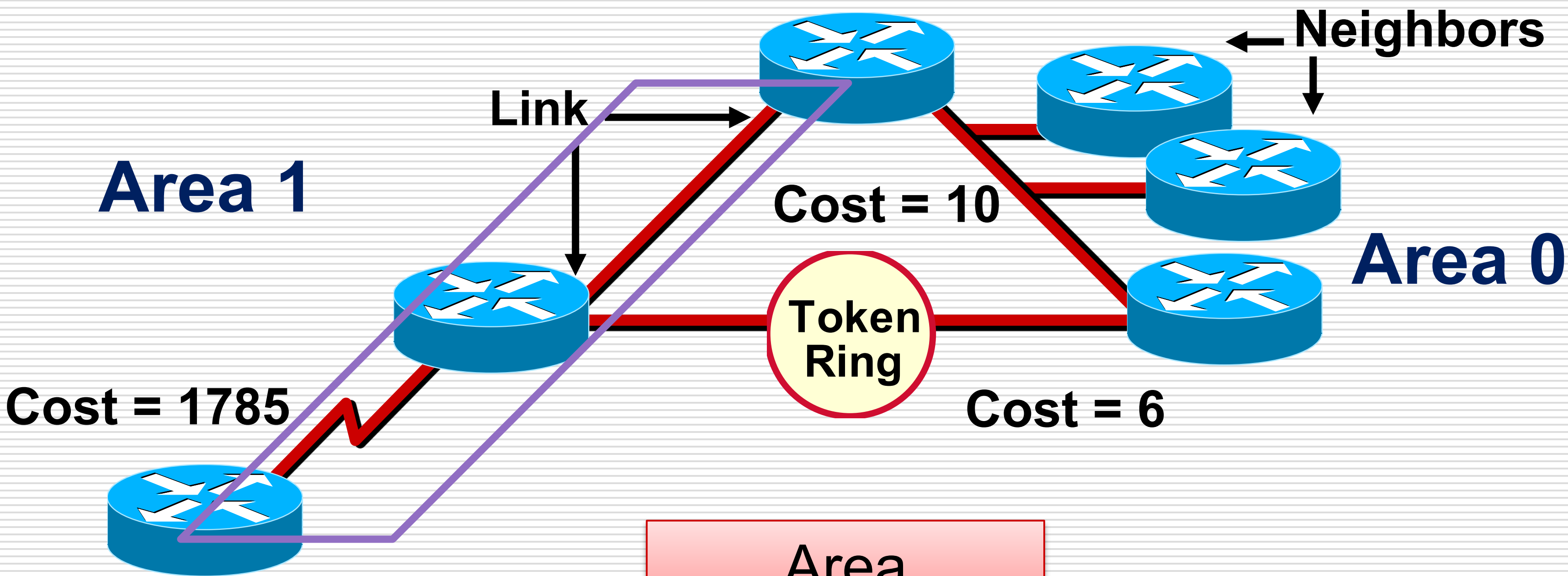


Cost

The value assigned to a link

Rather than hops, link-state protocols assign a cost to a link, which is based on the bandwidth of the link

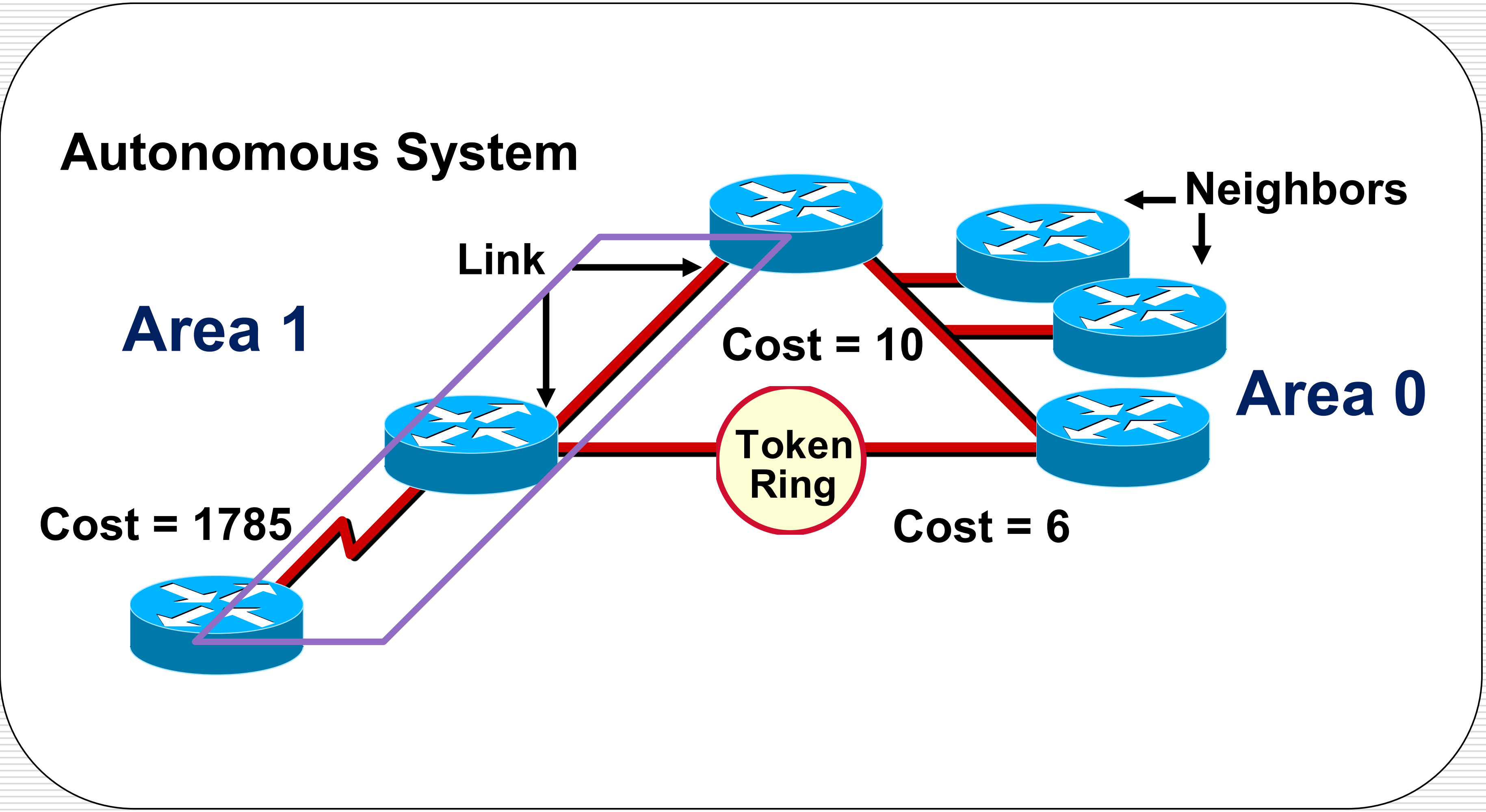
OSPF Terminology



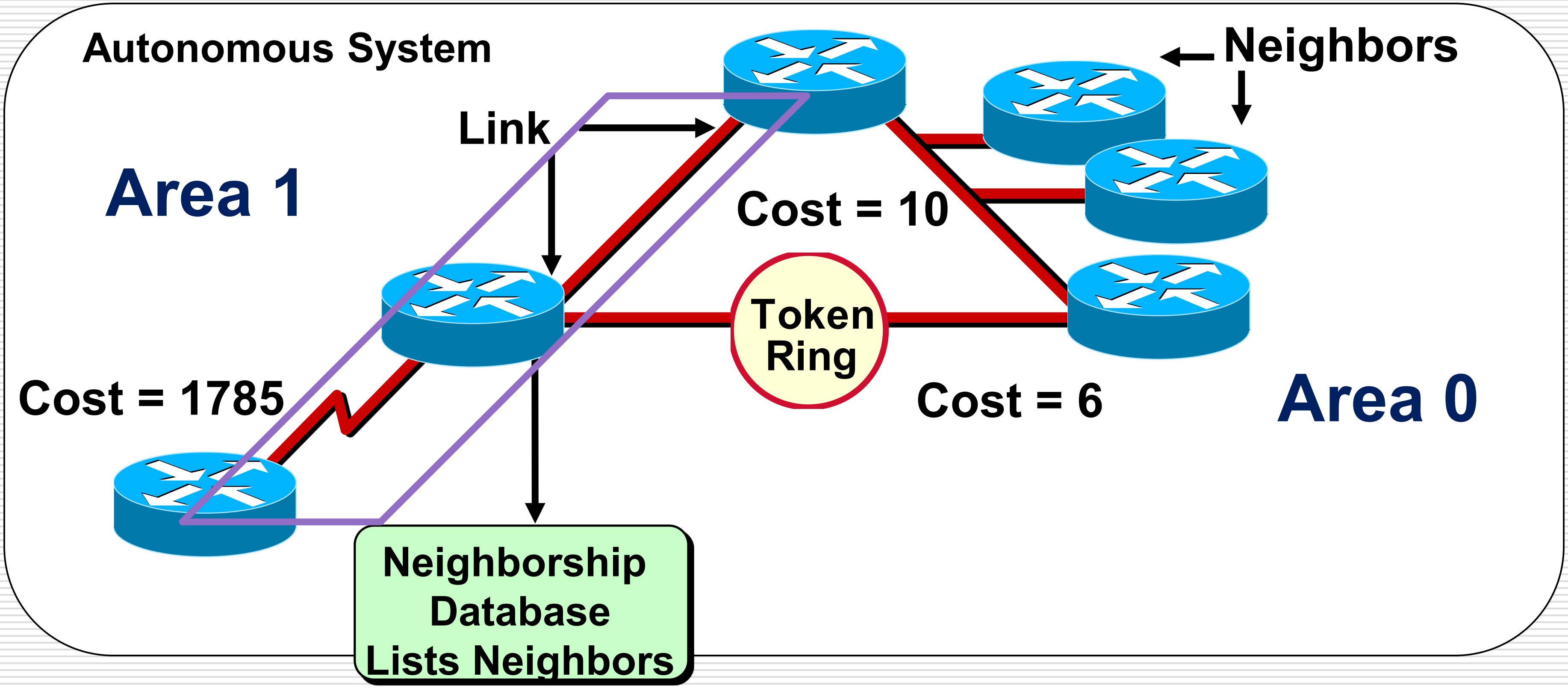
Area

A collection of networks/routers having the same area ID
Each router within an area has the same link-state information

OSPF Terminology

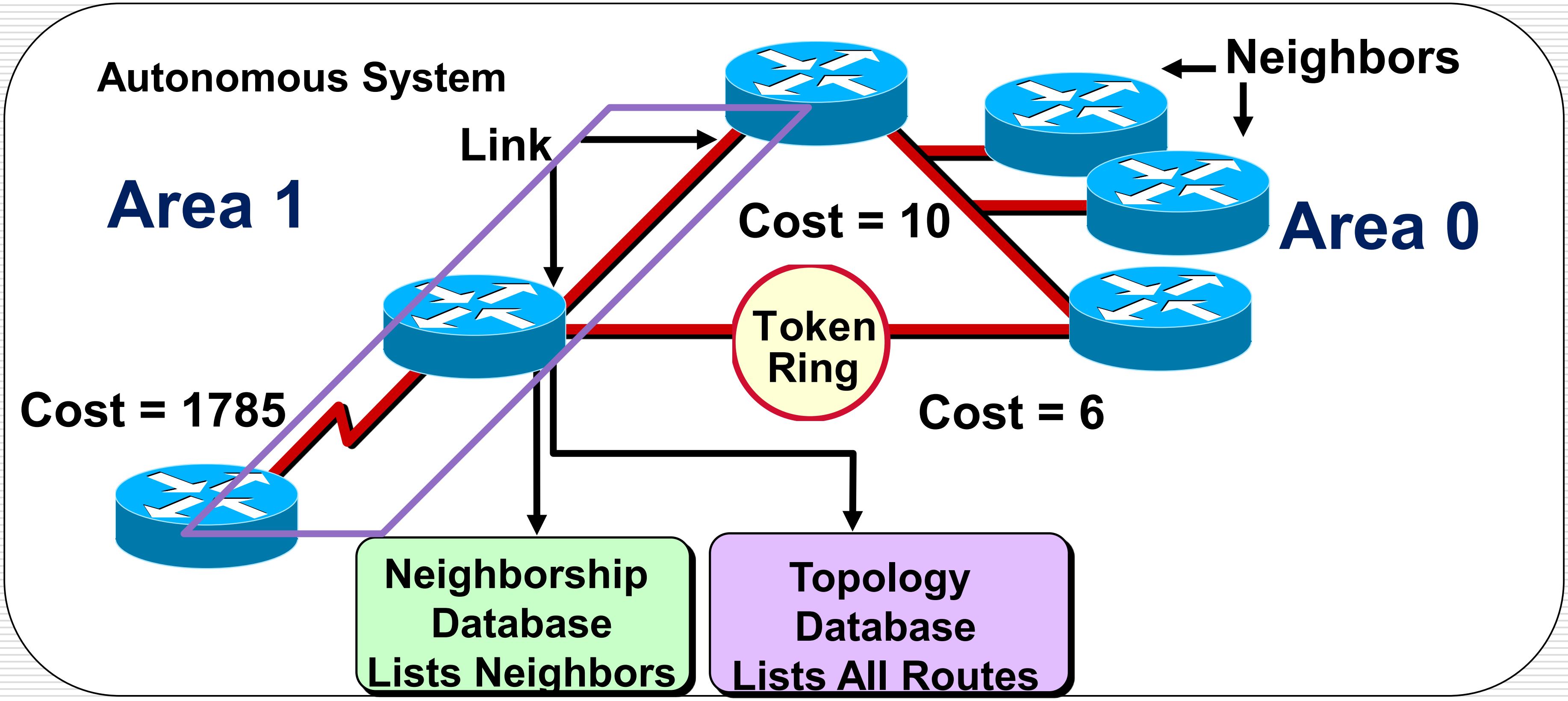


OSPF Terminology



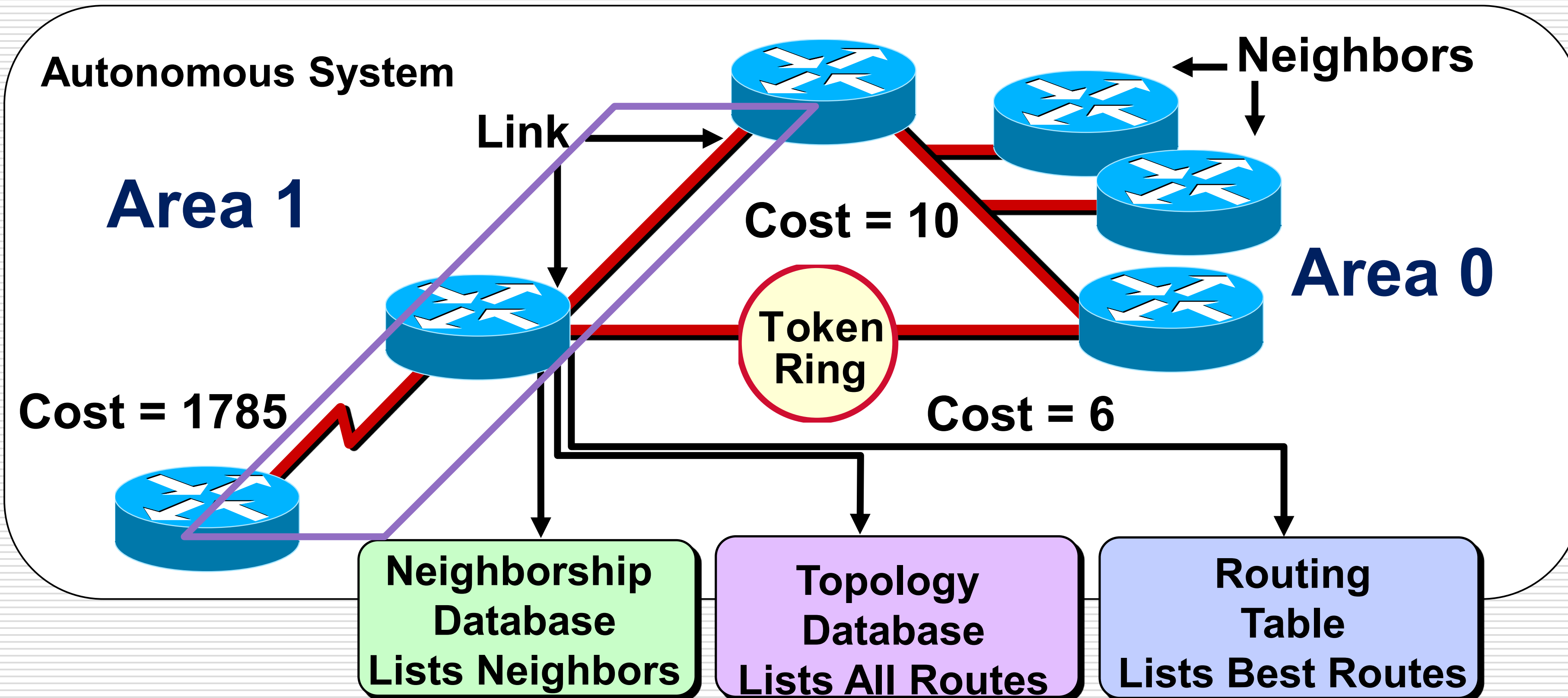
A listing of all the neighbors to which a router has established a bi-directional communication.

OSPF Terminology



A list of information about all other routers in the internetwork. It shows the internetwork topology.

OSPF Terminology



Sometimes known as the forwarding database
The routing table for each router is unique.

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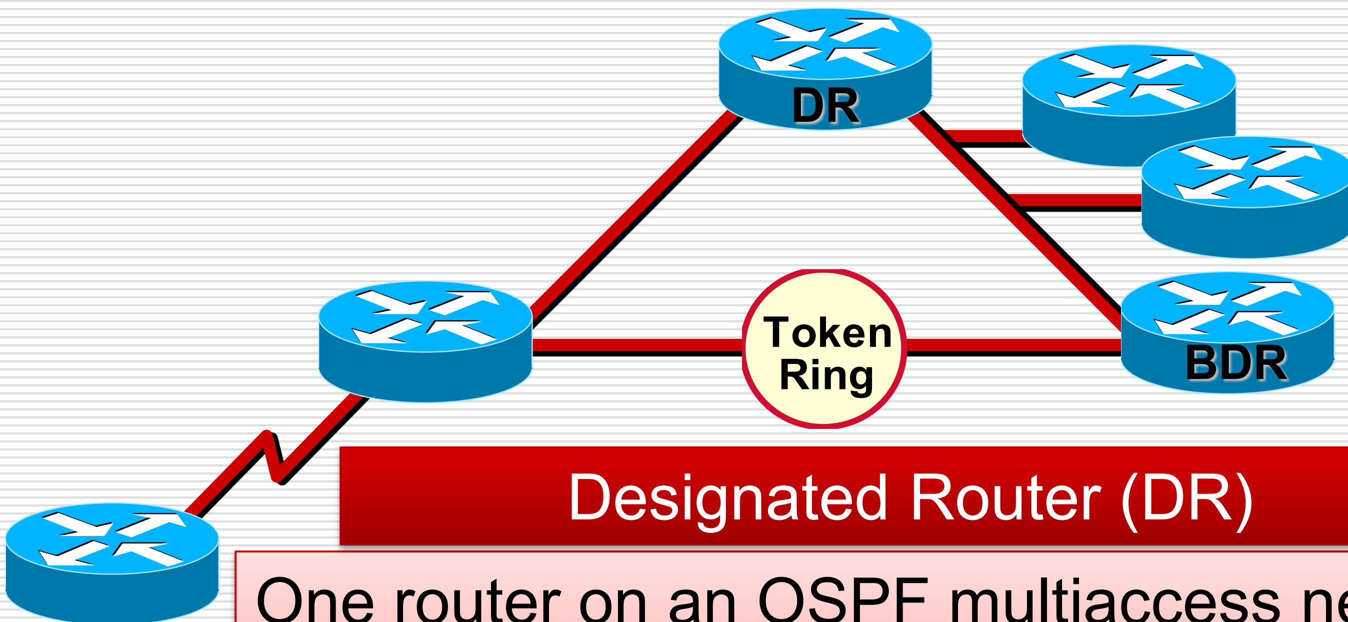
OSPF Terminology



Designated Router (DR)

One router on an OSPF multiaccess network that is elected to represent all the routers in that network

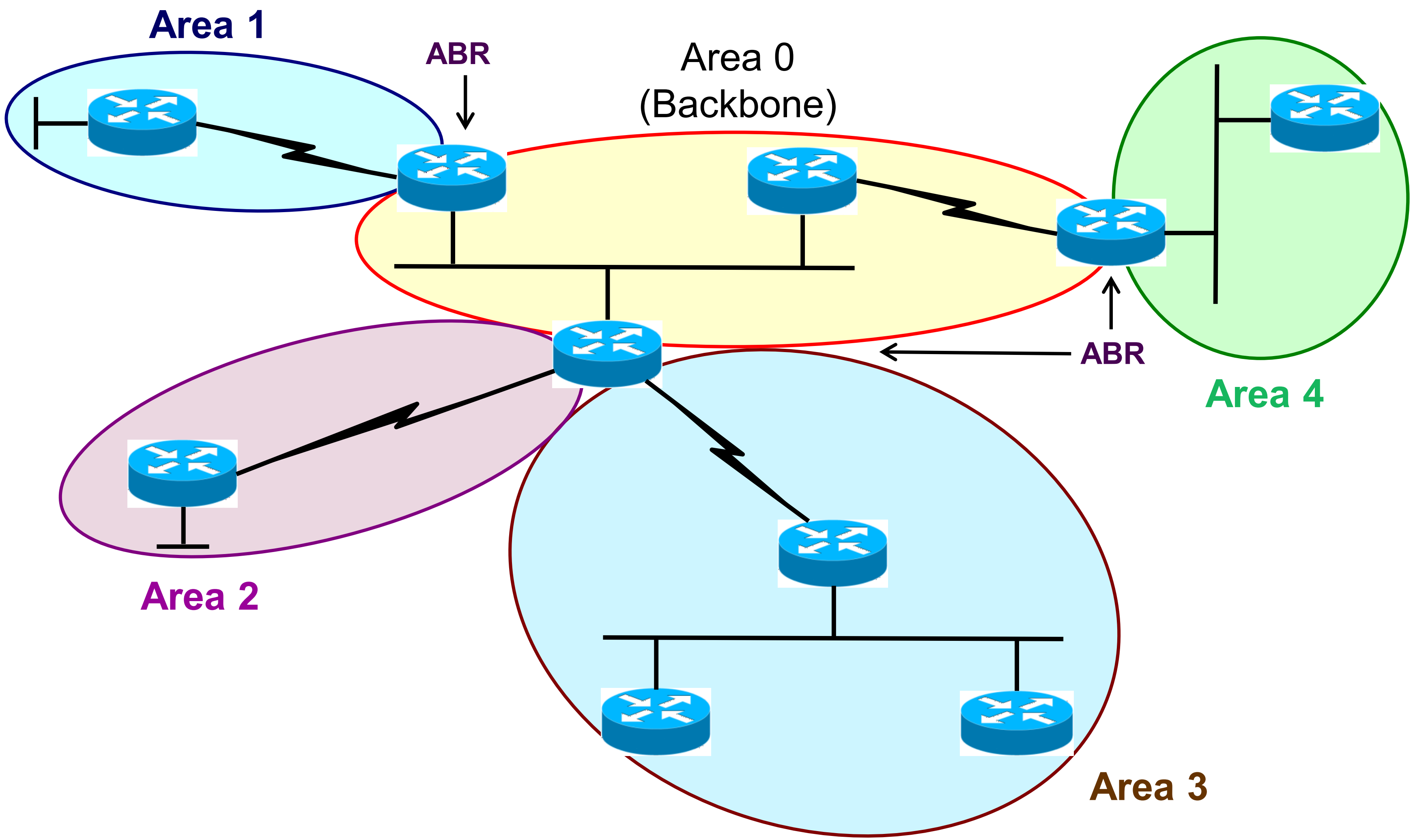
Backup Designated Router (BDR)

A standby router that becomes the DR, if the original DR fails.

OSPF Areas

- Areas are defined with a 32 bits number
  - Can be either in IP format or single decimal value
  - Area 0 or Area 0.0.0.0
- Area 0: A single area whose area number is 0
- OSPF uses a 2 level hierarchical model
- In multi-area OSPF networks, all areas are required to connect to area 0(backbone)

OSPF Areas Example

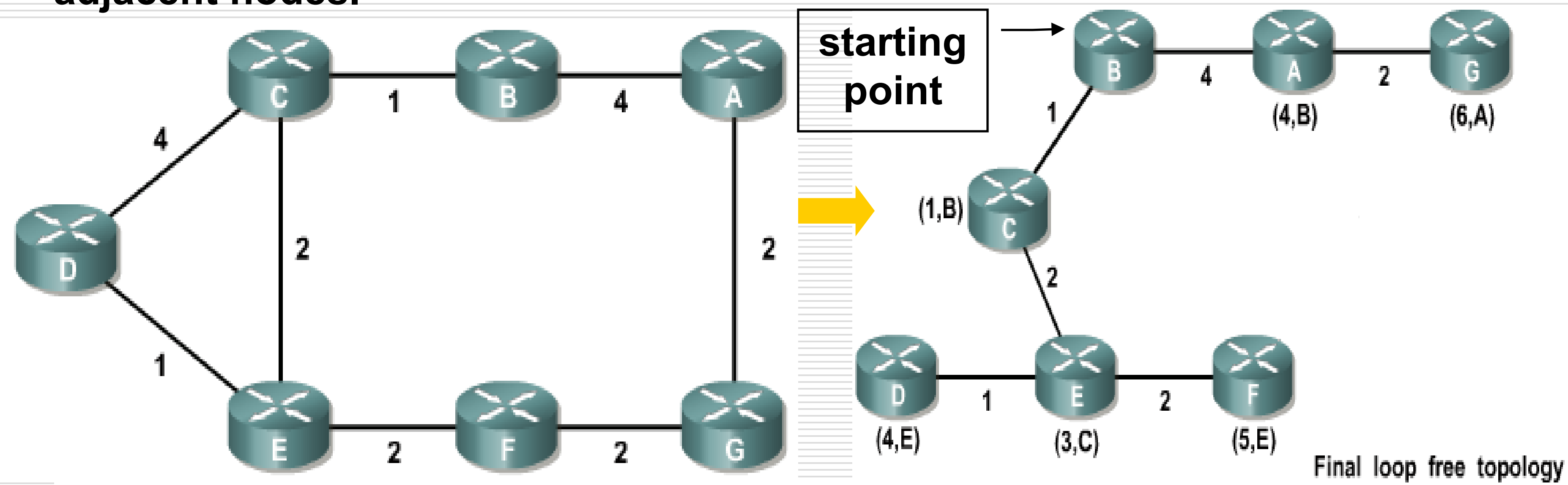


OSPF Operations

- OSPF uses neighbor adjacencies to gain full knowledge of the network.
- OSPF operation include five steps:
  - Step1: Set up the adjacency relationships
  - Step2: Elect DR and BDR (if needed)
  - Step3: Discover the routes
  - Step4: Choose appropriate routes
  - Step5: Maintain the route information
- OSPF has seven states. Briefly, they are:
  - Init, 2Way, Ex Start, Exchange, Loading, Full

The shortest path algorithm

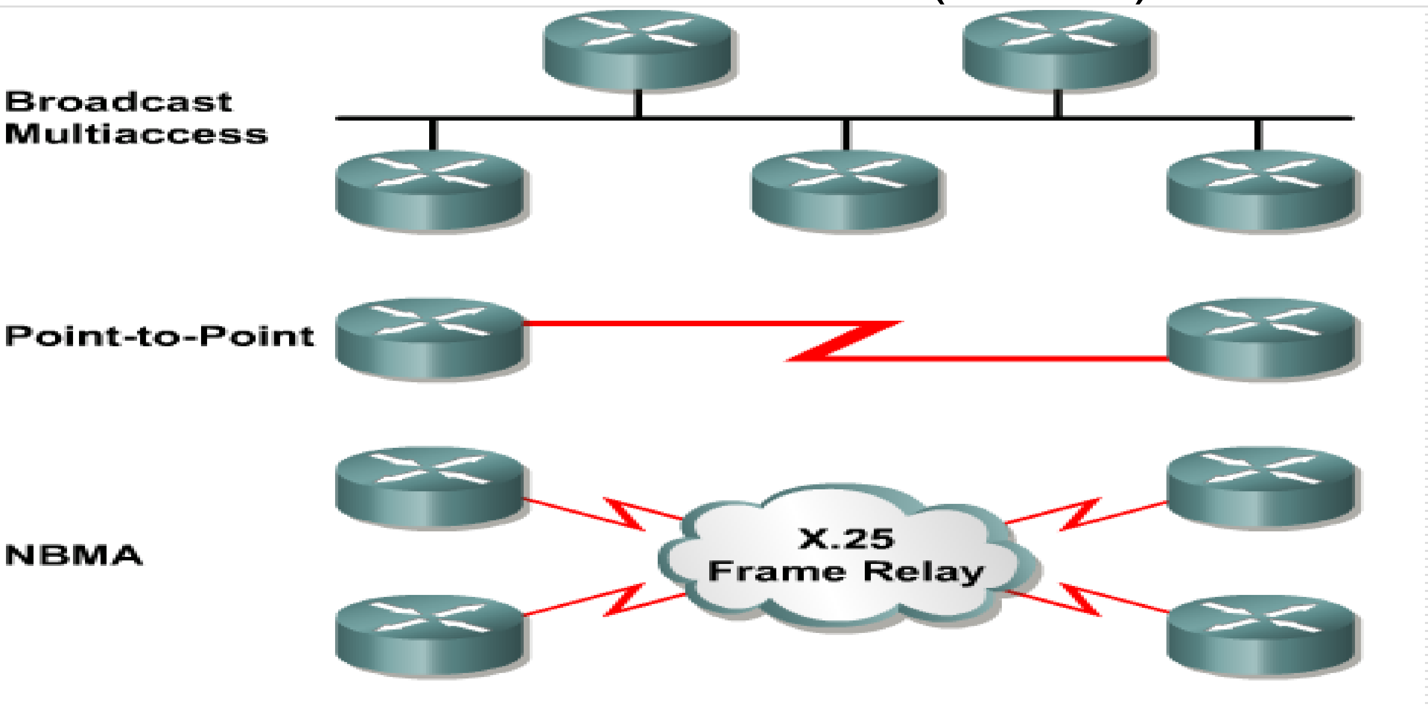
The shortest path algorithm calculates a loop-free topology using the node as the starting point and examining in turn information it has about adjacent nodes.



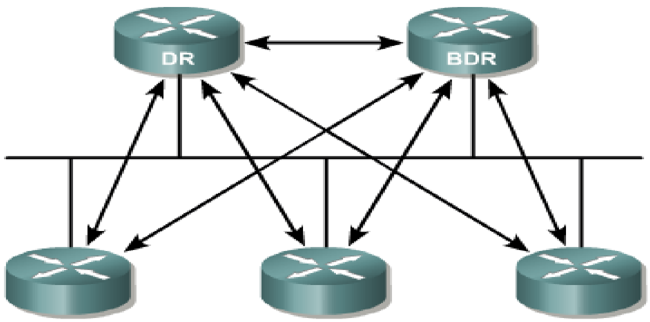
A	B	C	D	E	F	G
B/4	A/4	B/1	C/4	C/2	E/2	A/2
G/2	C/1	D/4	E/1	D/1	G/2	F/2
		E/2		F/2		

Elect DR and BDR

- **OSPF Network Types**
  - Broadcast multi-access, such as Ethernet
  - Point-to-point networks
  - Nonbroadcast multi-access (NBMA)



DR & BDR

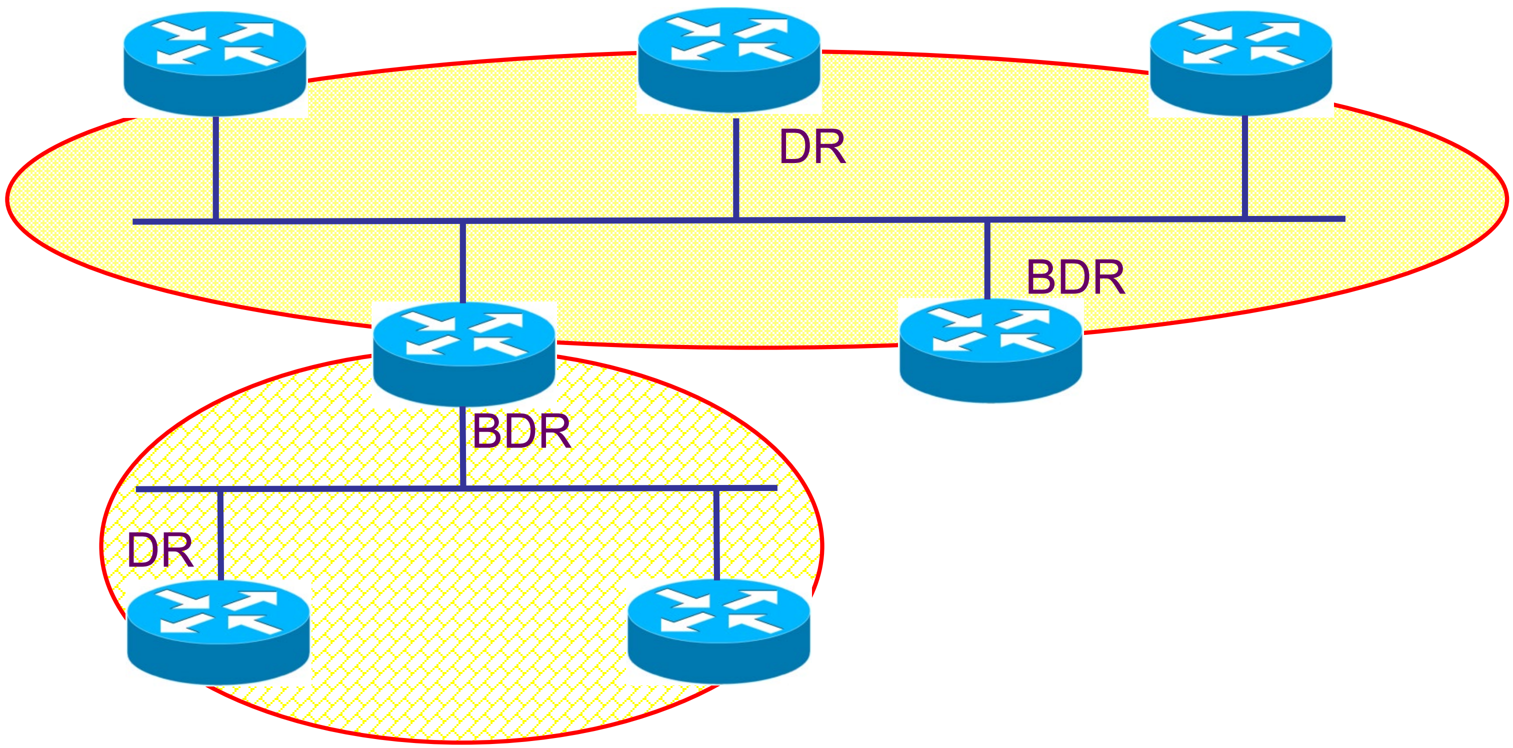


Network Type	Characteristics	DR Election?
Broadcast multiaccess	Ethernet, Token Ring, or FDDI	Yes
Nonbroadcast multiaccess	Frame Relay, X.25, SMDS	Yes
Point-to-point	PPP, HDLC	No
Point-to-multipoint	Configured by an administrator	No

- **Each router then forms adjacency with DR and BDR**
- **The DR sends link-state information to all other routers on the segment using the multicast address of 224.0.0.5 for all OSPF routers.**
- **To ensure that DR/BDR see the link states all routers send on the segment, the multicast address for all DR/BDRs, 224.0.0.6, is used.**

OSPF in Multi-Access media

- Giga/Fast/Ethernet, FDDI, Token Ring



OSPF Packets

- There are 5 types of OSPF routing protocol packets

Function	*Name*
Hello	Hello
Database Description	DBD
Link-State Request	LSR
Link-State Update	LSU
Link-State Acknowledgement	LSAck

OSPF Hello Protocol

- When a router starts an OSPF routing process on an interface, it sends a hello packet and continues to send hellos at regular intervals.
- The rules that govern the exchange of OSPF hello packets are called the Hello protocol.
- Hello packets are addressed to 224.0.0.5.
- Hellos are sent every 10 seconds by default on broadcast multi-access and point-to-point networks.
- On interfaces that connect to NBMA networks, such as Frame Relay, the default time is 30 seconds.

OSPF Packet Header

For the hello packet the type field is set to 1.

Version	Type	Packet Length	
Router ID			
Area ID			
Checksum		Authentication Type	
Authentication Data			

OSPF Hello Protocol

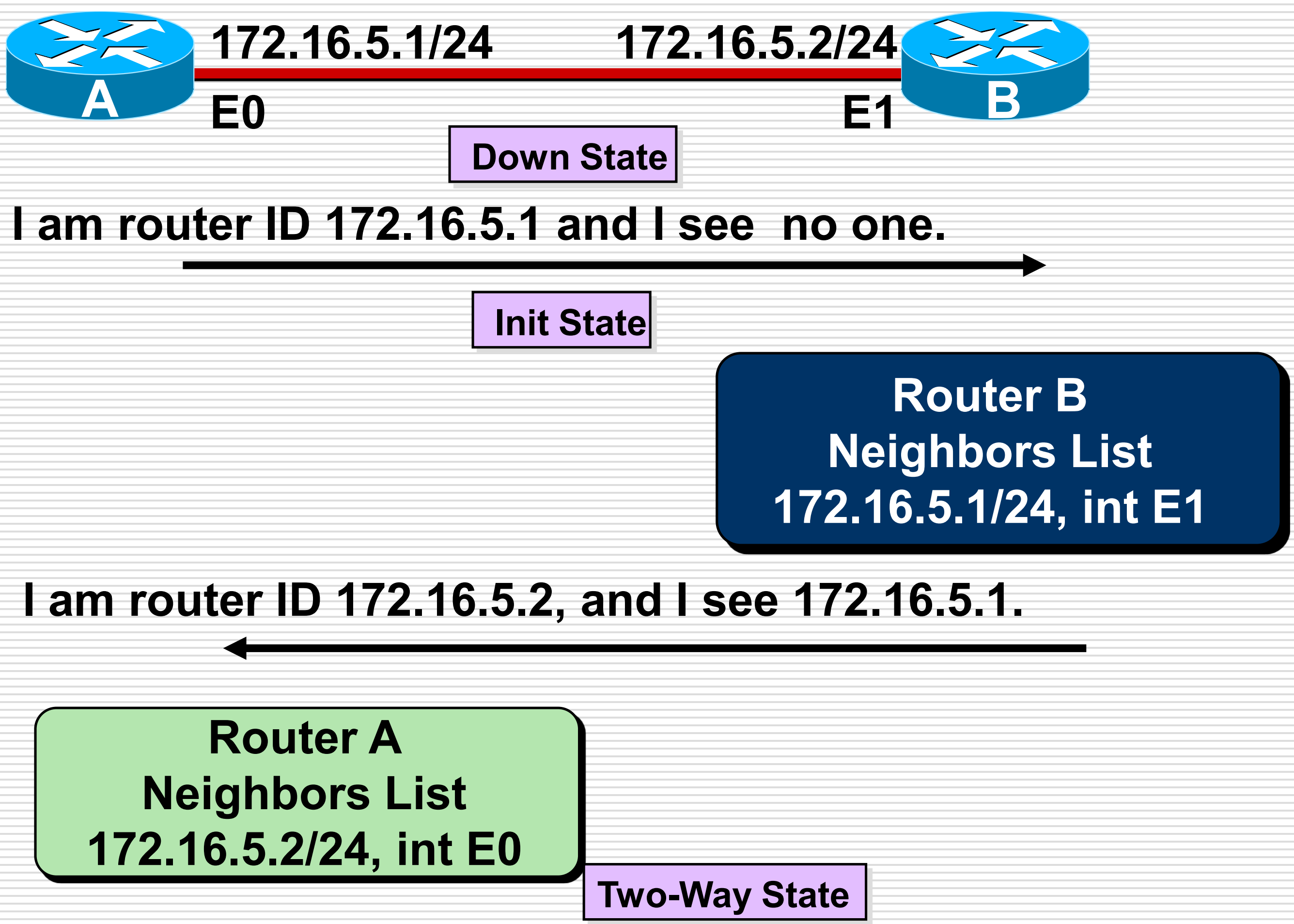
Network Mask		
Hello Interval	Options	Router Priority
Dead Interval		
Designated Router		
Backup Designated Router		
Neighbor Router ID		
Neighbor Router ID		
(additional Neighbor Router ID fields can be added to the end of the header, if necessary)		

OSPF Hello Packet Header

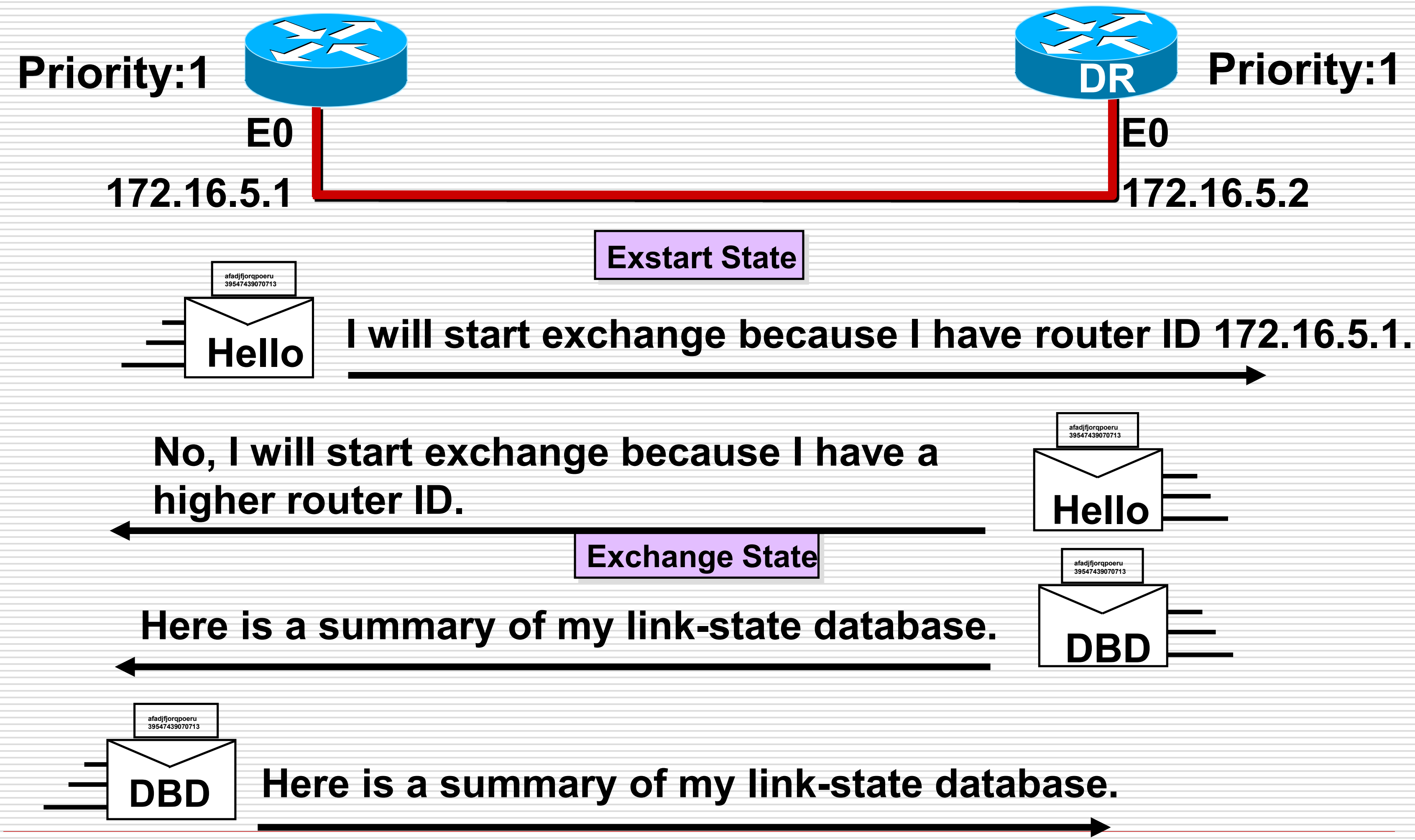
Which Router will be DR?

- Priority + Router ID, the biggest is DR, the second biggest is BDR.
- Priority: 1-255 Default=1
- Router ID
  - A loopback IP address
  - If the absence of loopback IP address, the highest-value address interface IP
  - If the interface goes down, the router must re-establishing adjacency and readvertising LSA

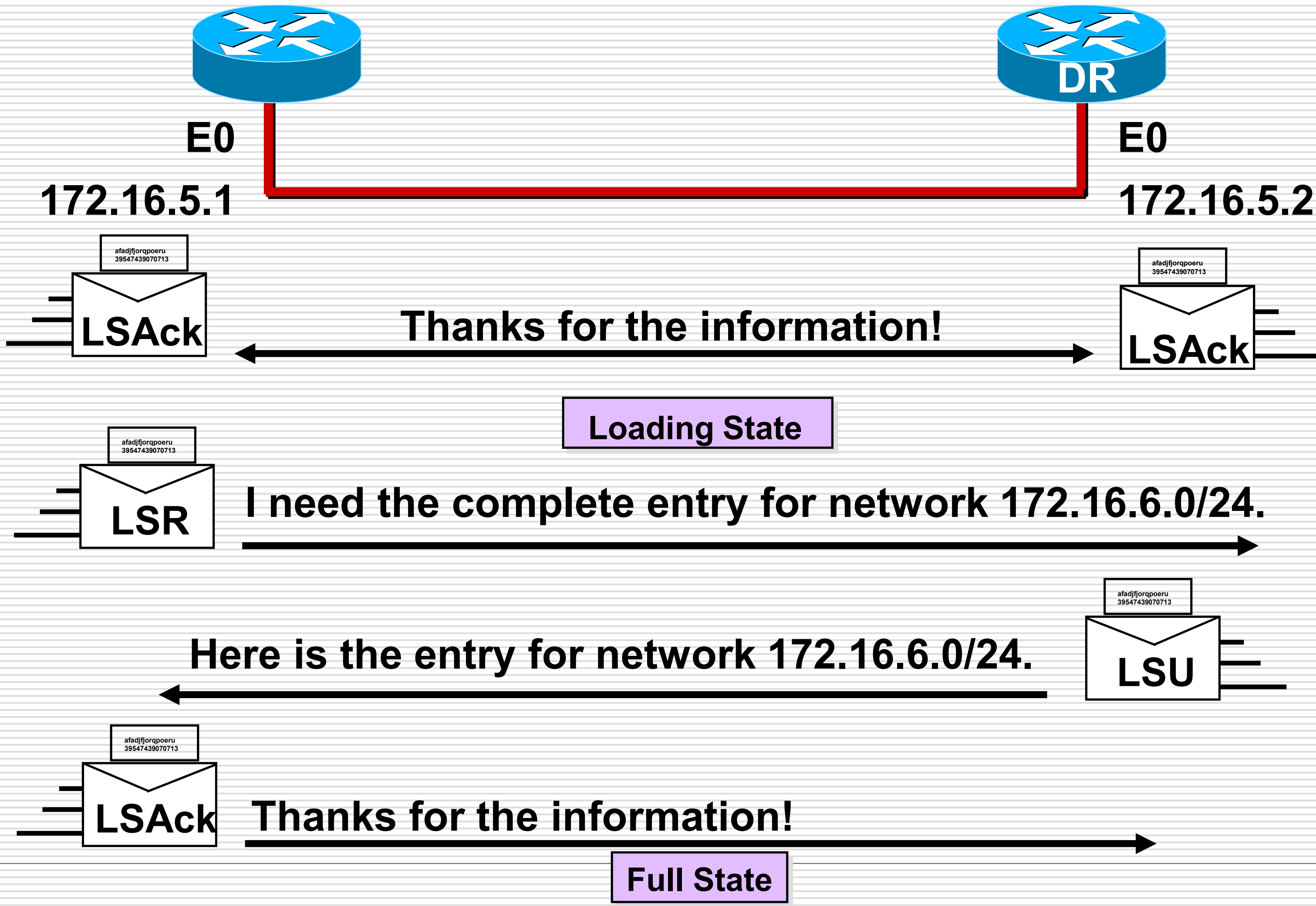
Steps in the Operation of OSPF



Steps in the Operation of OSPF



Steps in the Operation of OSPF



Review: OSPF Operation

- Step1: Set up the adjacency relationships
- Step2: Elect DR and BDR (if needed)
- Step3: Discover the routes
- Step4: Choose appropriate routes
- Step5: Maintain the route information

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Step 1: Establish Router Adjacencies

- Routers send hello packet at an interval
- If a neighbor founded:
  - Add the neighbor to the neighborship database
- Discover the network type
  - If a multi-access network, enter the DR/BDR election process and enter Step 2.
  - If point-to-point or point-to-multipoint, no DR/BDR is elected and skip Step 2.
  - If the DR/BDR fields in the hello packet's header is already occupied (i.e. a DR/BDR pair already exists), no DR/BDR election occurs and skip Step 2.

Step 2: Elect a DR and a BDR

- If no other router online, the router becomes the DR. The next router to "come up" will be the BDR.
- If multiple routers (two or more) come online simultaneously, then…
  - The router with the highest priority becomes DR
    - Priority of zero means "never DR"
  - If there is a tie, then the router with the highest router ID becomes DR
    - Router ID is the highest loopback or interface IP address
  - Router with second highest priority or router ID becomes the BDR

Step 2: Elect a DR and a BDR

- BDR becomes DR if the DR fails.
- However…
  - If a new OSPF router joins the network with a higher priority or router ID, the current DR and BDR **do not change**.
    - It would become the new BDR only if the current DR failed or the new DR only if the current DR and BDR failed.

Step 3: Discover Routes

- Previously explained in the ExStart to Full State
  - Routers determine "master/slave" relationship
  - DR/BDR in multiaccess networks exchange LSAs and all DRothers send the DR/BDR their Type 2 DBDs.
  - If necessary, a router may enter the loading state by sending a LSR requesting more information
    - All routers must wait in Loading State until the requesting router is fully updated.
  - Routers now enter the Full State

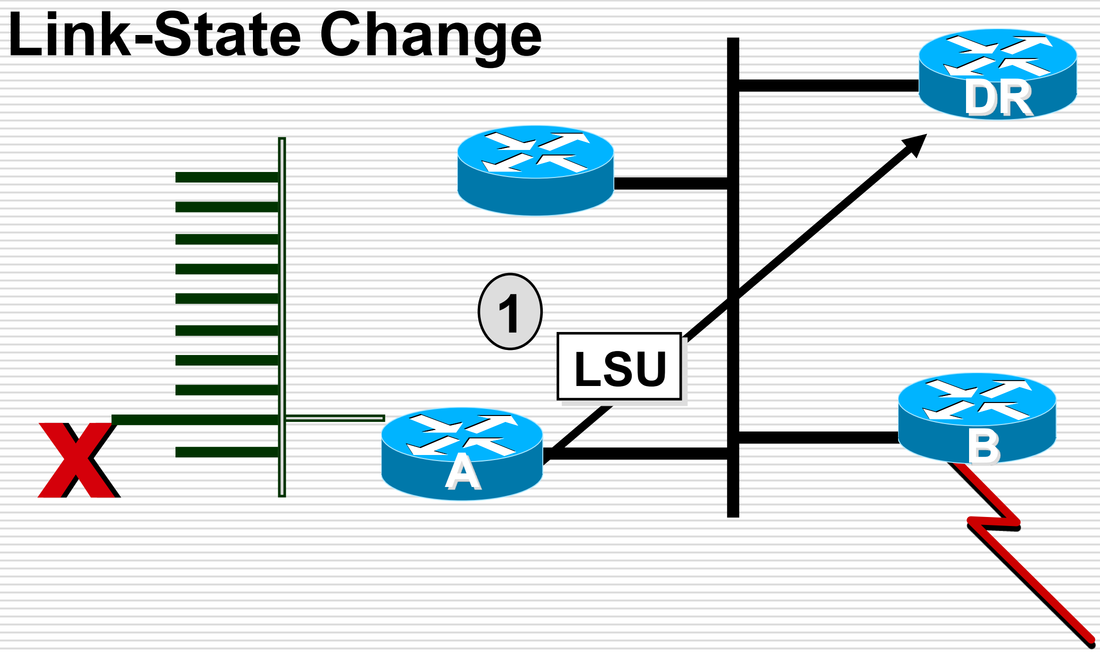
4. Select Appropriate Routes

- The SPF Algorithm is now calculated in parallel with every other router on the network.
  - Remember: All routers must have identical link-state databases before this can occur.
  - The SPF uses cost as its metric
  - SPF adds up the cost for each path from itself to the destination, builds a tree with the router as the root
  - OSPF then installs the least cost path in the routing table
    - Up to 4 equal cost paths will be installed for load sharing

5. Maintain Routing Information

- The regular exchange of Hellos is the mechanism OSPF uses to detect a new neighbor or a downed neighbor.
  - Hello packets are sent at different default intervals depending on the type of network.
    - For links with speeds T1 (1.544 Mbps) or greater, every 10 second: *broadcast multiaccess and point-to-point links*
    - For links with less than a T1, every 30 seconds: *nonbroadcast multiaccess links*
    - The “dead interval” is four times the hello interval.

Maintaining Routing Information



- Router A tells all OSPF DRs on 224.0.0.6

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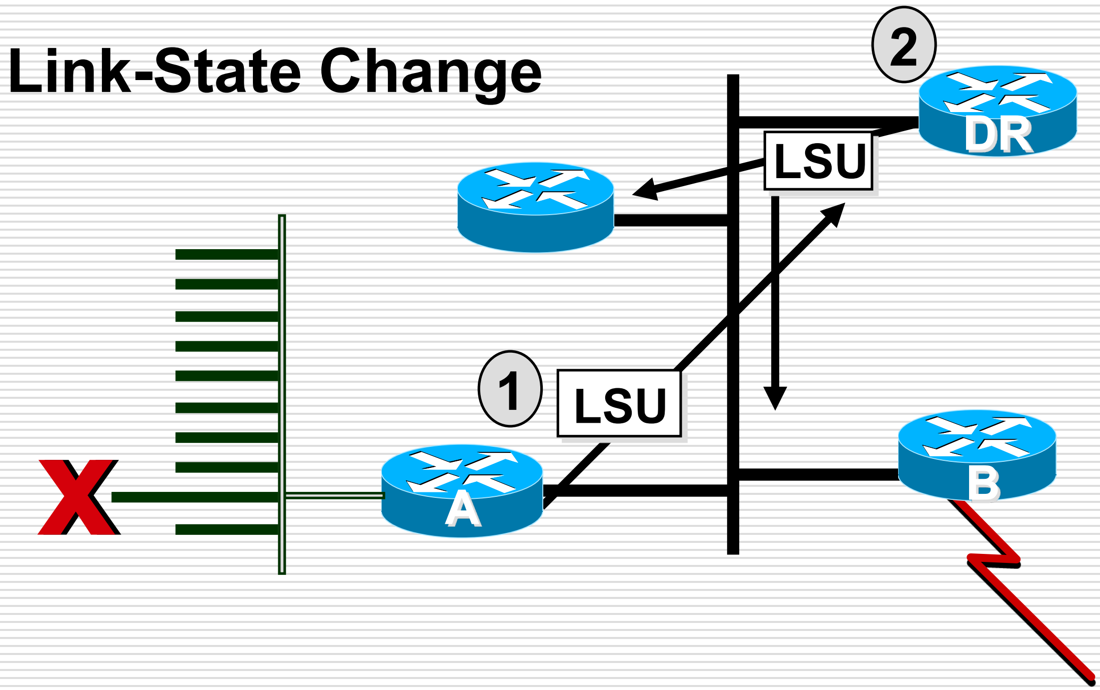
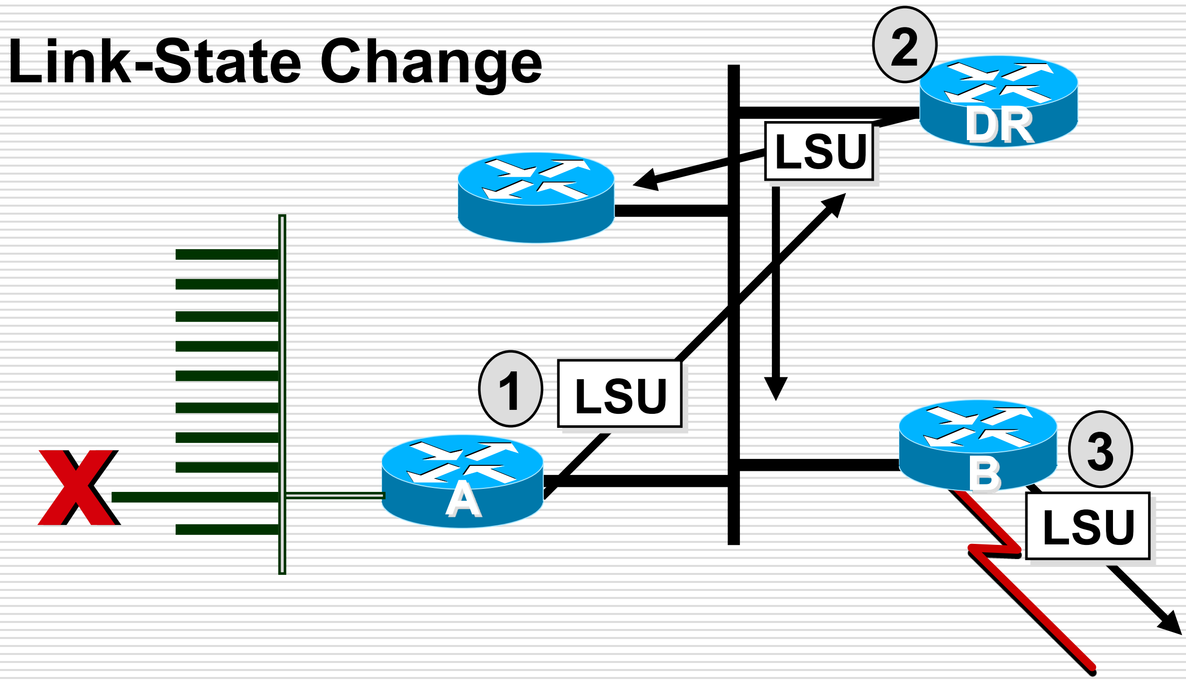
Maintaining Routing Information



- Router A tells all OSPF DRs on 224.0.0.6
- DR tells others on 224.0.0.5

Maintaining Routing Information



- Router A tells all OSPF DRs on 224.0.0.6
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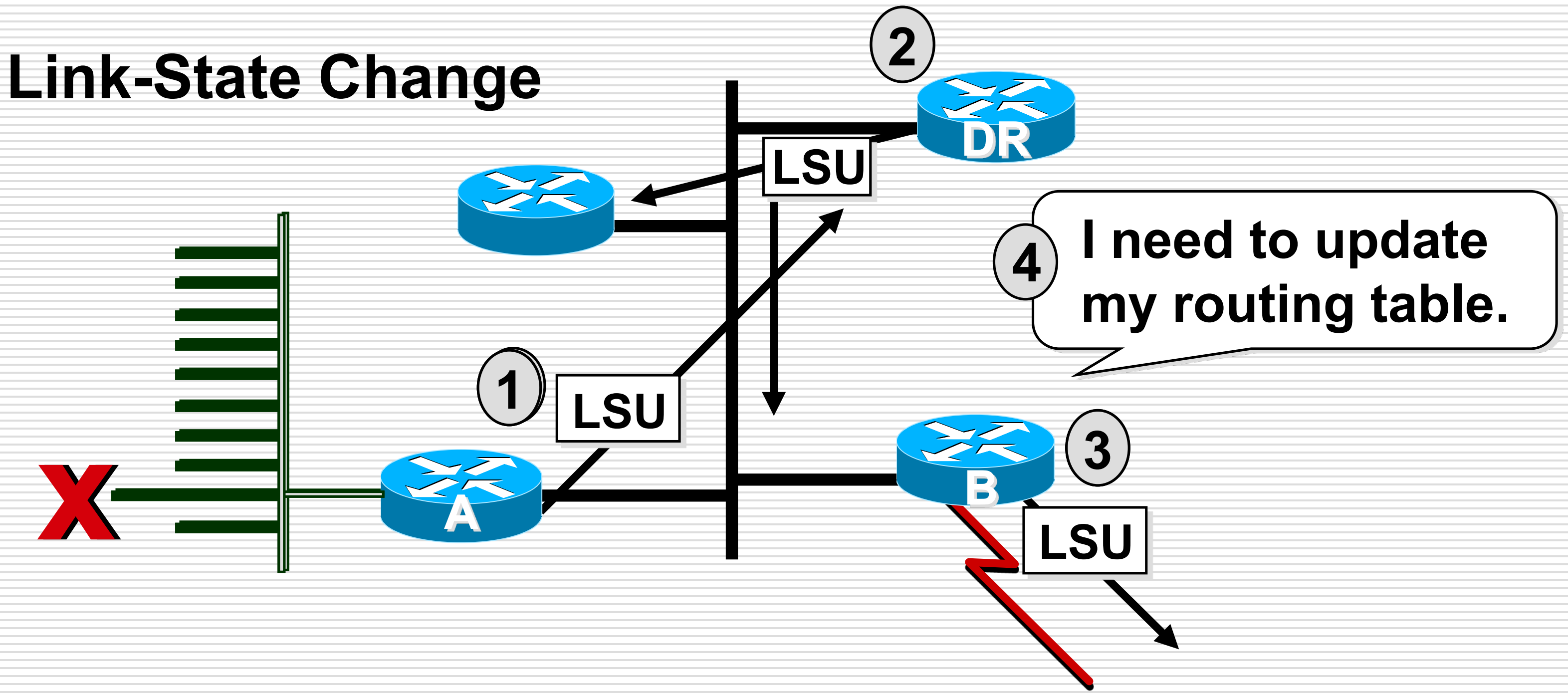
Maintaining Routing Information



- Router A tells all OSPF DRs on 224.0.0.6
- DR tells others on 224.0.0.5

Basic OSPF Configuration

- Enable OSPF on the router

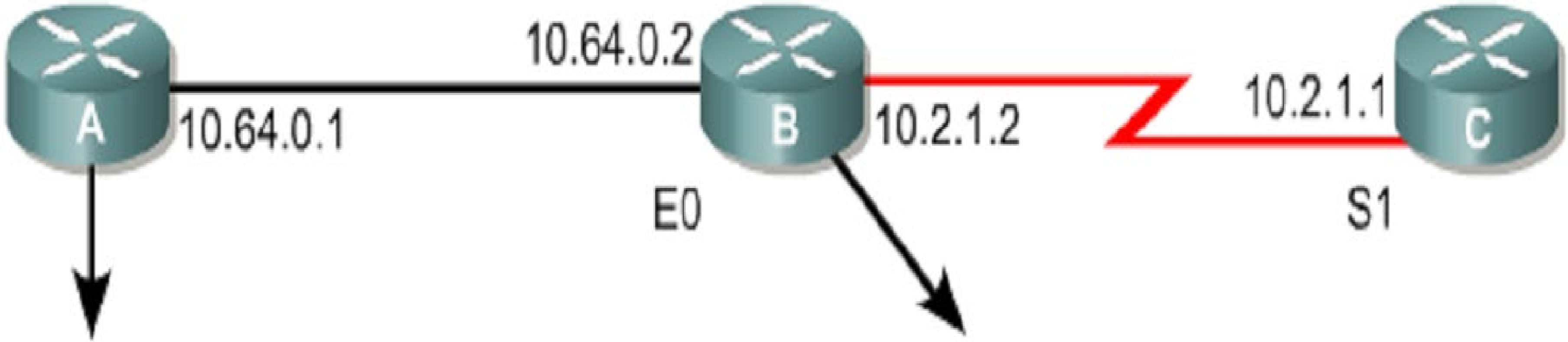
Router (config) # router ospf *process-id*

  - ***process-id***
    - Value: 1 ~ 65535
    - Identify multiple OSPF processes on one router
    - Usually keep the same process ID throughout the entire AS

- Identify IP networks on the router

Router (config-router) # network *address wildcard-mask* **area** *area-id*

The network address can be a whole network, a subnet, or the address of the interface.




```
<Output Omitted>
interface Ethernet0
ip address 10.64.0.1 255.255.255.0
!
<Output Omitted>
router ospf 1
network 10.64.0.0 0.0.0.255 area 0
```

```
<Output Omitted>
interface Ethernet0
ip address 10.64.0.2 255.255.255.0
!
interface Serial0
ip address 10.2.1.2 255.255.255.0
<Output Omitted>
router ospf 1
network 10.2.1.2 0.0.0.255 area 0
network 10.64.0.2 0.0.0.255 area 0
```

Configuring a Loopback Address

To add stability to OSPF router ID

Router (config) # interface loopback ***number***
Router (config-if) # ip address ***address subnet-mask***

- The loopback interface must be configured before the OSPF process starts
- When configuring loopbacks, use a /32 mask to avoid potential routing problems
- It is recommended that you use the loopback address (private or public address) on all key routers in your OSPF based network.

Note: *no shutdown* **command is not needed.**

Configuring a Loopback Address Example

```
! Create the loopback 0 interface
Sydney3(config)#interface loopback 0
Sydney3(config-if)#ip address 192.168.31.33
255.255.255.255
Sydney3(config-if)#exit
! Remove loopback 0 interface
Sydney3(config)#no interface loopback 0
Sydney3(config)#
01:47:27: %LINK-5-CHANGED: Interface Loopback0, changed
state to administratively down
```

A loopback is a software only interface. To remove a loopback interface enter **no interface loopback**.

Modifying OSPF Interface Priority

- To manipulate DR/BDR elections

Router (config-if) # ip ospf priority ***number***

  - ***number***
    - Value: 0 ~ 255, default is 1
    - A priority of 0 indicates an interface cannot be elected as DR or BDR

- Monitoring OSPF interface priority

Router # show ip ospf [interface ***type number*****]**

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Setting OSPF Priority Example

```
Sydney1(config)#interface fastethernet 0/0
Sydney1(config-if)#ip ospf priority 50
Sydney1(config-if)#end
Sydney1#
00:21:57: %SYS-5-CONFIG_I: Configured from console
by console
```

A router with the highest OSPF priority will win the election for DR.

The Hello packet sent on the fastethernet interface will have the Router Priority Field set to 50.

OSPF Cost = Metric

- Cost is applied on all router link paths
- 16 bits number (1 – 65,535)
- Lower metric = more desirable
- Route decision is made on total cost of the path.
- Metric is derived from Bandwidth

Formula $$\text{COST} = \frac{100{,}000{,}000}{\text{Bandwidth}}$$

OSPF Cost for T1 = 100,000,000 / 1,544,000 = 64

OSPF Path Cost

- All interfaces connected to the same link must agree on the cost of that link. Otherwise, the link will be considered down
  - A Cisco router's default cost for a serial link is 1784（56Kbps bandwidth）

1 ~ 65535

Router (config-if) # ip ospf cost ***number***

  - If the line is a slower speed, you must specify the real link speed

Kbps

Router (config-if) # bandwidth ***number***

Modifying OSPF Cost Metric Example

Medium	Cost
56 kbps serial link	1785
T1 (1.544 Mbps serial link)	64
E1 (2.048 Mbps serial link)	48
4 Mbps Token Ring	25
Ethernet	10
16 Mbps Token Ring	6
100 Mbps Fast Ethernet, FDDI	1

```
Sydney2(config-if)#ip ospf cost ?
  <1-65535>   Cost
Sydney2(config-if)#ip ospf cost 1
```

- **A common situation requiring a cost change is in a multi-vendor routing environment. A cost change would ensure that one vendor's cost value would match another vendor's cost value.**
- **Another situation is when Gigabit Ethernet is being used. The default cost assigns the lowest cost value of 1 to a 100 Mbps link.**

Configuring OSPF Timers

- All routers in an OSPF area must agree on the same hello interval and the same dead intervals , default:
  - 10 seconds for links with T1 or greater (broadcast)
  - 30 seconds for links with less than T1 (non-broadcast)
  - Dead interval = 4 * hello interval
- Changing the hello interval

Router(config-if)# ip ospf hello-interval *seconds*
Router(config-if)# ip ospf dead-interval *seconds*

Note: The dead interval will automatically adjust to four times the new hello interval.

Configuring OSPF Timers Example

Cisco

```
Sydney1(config-if)#ip ospf hello-interval 5
Sydney1(config-if)#ip ospf dead-interval 20
```

OSPF timers are configured on the interface.

谢 谢！