SWINBURNE

CENTRE FOR ADVANCED INTERNET ARCHITECTURES

TNE20002/TNE70003

Topic 5. OSPF

Rev. 1.3

Outline

5.1 OSPF Overview

- Characteristics
- Data Structures & Messages
- Router ID & Hello interval

5.2 OSPF Phases to Convergence

- Establish Neighbor Adjacency Phase
- Synchronise OSPF Database Phase
- Shortest Path First Algorithm Phase

5.3 OSPF Configuration

- OSPF Process id
- OSPF Network command , wildcard mask , area-ID
- Passive Interface , Router ID, Propagate default static route

5.4 Verify OSPF

- Verify OSPF neighbors
- Verify OSPF protocol settings , interface settings
- Setting OSPF Cost

OSPF Characteristics

Open Shortest Path First Algorithm

OSPFv1 -1989 , OSPFv2 – 1991, OSPFv2 Update1998 , OSPFv3 for IPv6 - 1999

Implementation of a Classless Link-State Routing Protocol

Link State Routing Protocols, Link State information from neighbor routers create topology Map.

Use Shortest-Path-First or SPF Algorithm to select least cost path to destination networks.

Features: VLSM

- Administrative Distance 110
- Metric → cumulative bandwidth
- Multicast address 224.0.0.5
- Updates triggered by change in topology.
- Single Area and Multiple Areas
- Authentication

Data Structures:

- Adjacency Database
- Link State Database
- Forwarding Database

Routing Protocol Metrics

Dynamic routing protocols typically use their own rules and metrics to build and update routing tables.

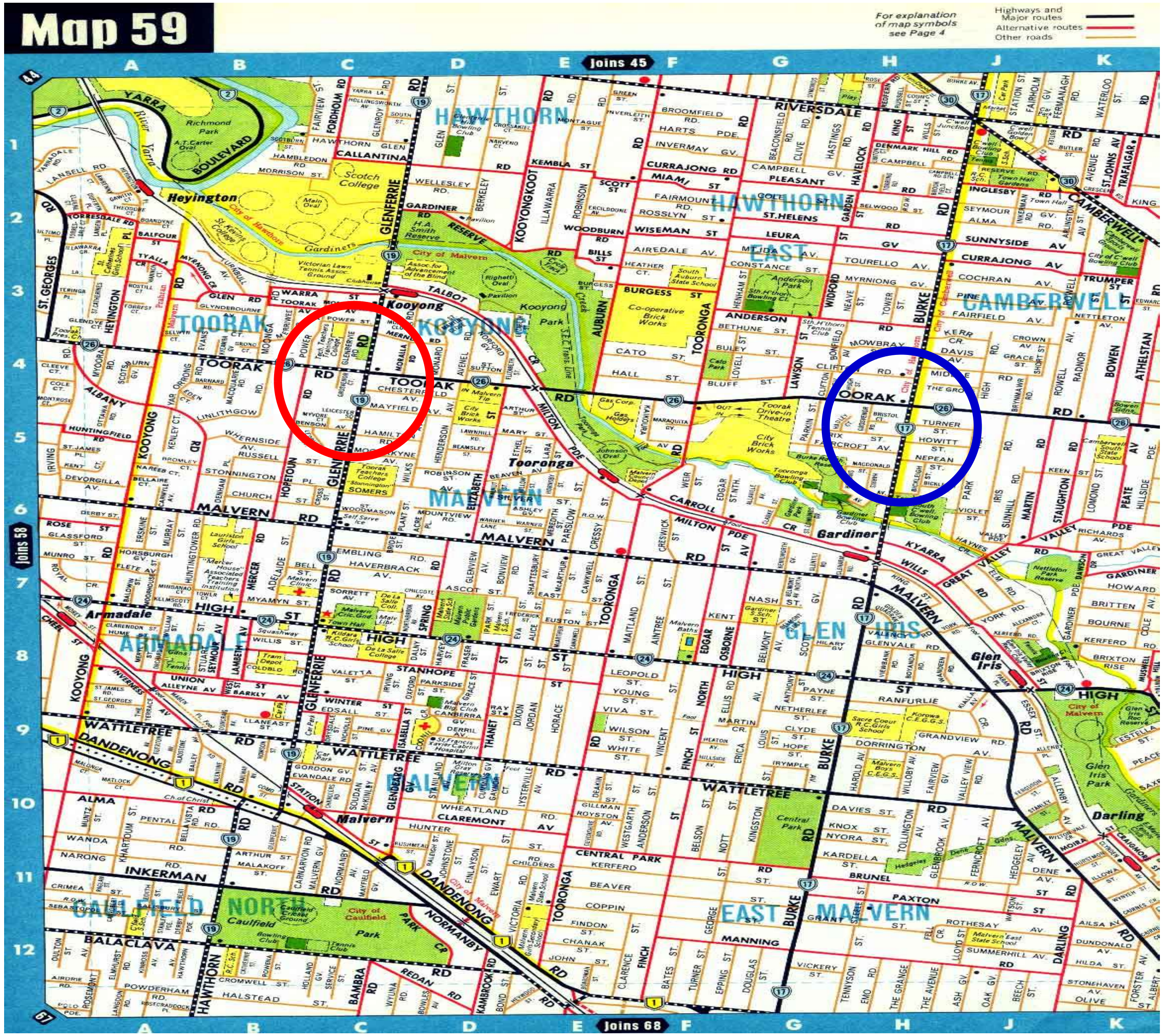
Dynamic Routing Protocol	Metric
•Routing Information Protocol (RIP)	•Metric is “hop count” •Each router along a path adds a hop to the hop count •A maximum of 15 hops
•Enhanced Interior Routing Protocol (EIGRP)	•Metric based on the slowest bandwidth and delay values •Metric calculation could include reliability and load..
•Open Shortest Path First (OSPF)	•Metric is “cost” based on the cumulative bandwidth. •Faster links are assigned lower costs compared to slower links.

Topological Map (Network Area 59)

Like (Melways road map 59)

OSPF
creates a map of the
network area

each router
 uses this map to determine
 the least cost path
to any destination
within
network area



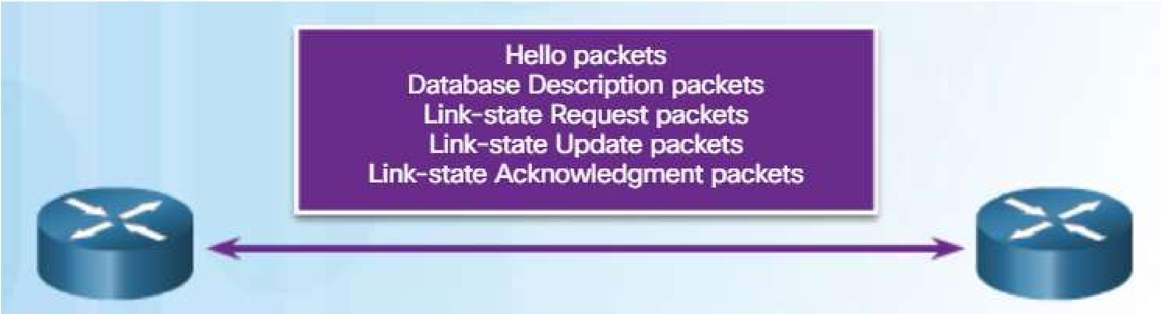
OSPF Data Structures

Data Structures

Database	Table	Description
Adjacency	Neighbor	• Lists all neighbor routers to which a router has established bidirectional communication • Unique for each router • View using the **show ip ospf neighbor** command
Link-state (LSDB)	Topology	• Lists information about all other routers • Represents the network topology • Contains the same LSDB as all other routers in the same area • View using the **show ip ospf database** command
Forwarding	Routing	• Lists routes generated when the SPF algorithm is run on the link-state database. • Unique to each router and contains information on how and where to send packets destined for remote networks • View using the **show ip route** command

OSPF Packet types

OSPF packet types: 1-> hello , 2-> database description , 3-> link-state request , 4-> link-state update, 5-> link-state Acknowledgment



OSPF Databases

Adjacency Database (Neighbor Table)

List of all neighbor routers

Unique for each router

show ip ospf neighbor

Link State Database (Topology Table)

List of information about all other routers in network area

The database shows the network topology

All routers within an network area have identical LSDBs

show ip ospf database

Forwarding Database (Routing Table)

List of least cost routes to other destinations within network area

Unique for each router

show ip route

OSPF Packet Types

OSPF Five Types of Packets

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	Database Description (DBD)	Checks for database synchronization between routers
3	Link-State Request (LSR)	Requests specific link-state records from router to router
4	Link-State Update (LSU)	Sends specifically requested link-state records
5	Link-State Acknowledgement (LSAck)	Acknowledges the other packet types

OSPF Packet Types

Type 4 Link State Packet

called

Link State Update (LSU) that contains one or more LSA Types.

Various Types of LSAs contain route information for destination networks

LSA Type	Description
1	Router LSAs
2	Network LSAs
3 or 4	Summary LSAs
5	Autonomous System External LSAs
6	Multicast OSPF LSAs
7	Defined for Not-So-Stubby Areas
8	External Attributes LSA for Border Gateway Protocol (BGP)
9, 10, 11	Opaque LSAs

OSPF – Hello Protocol

Router ID of transmitting router

Router ID identifies router so link states can be organized

How does OSPF select an ID?

OSPF Hello Interval

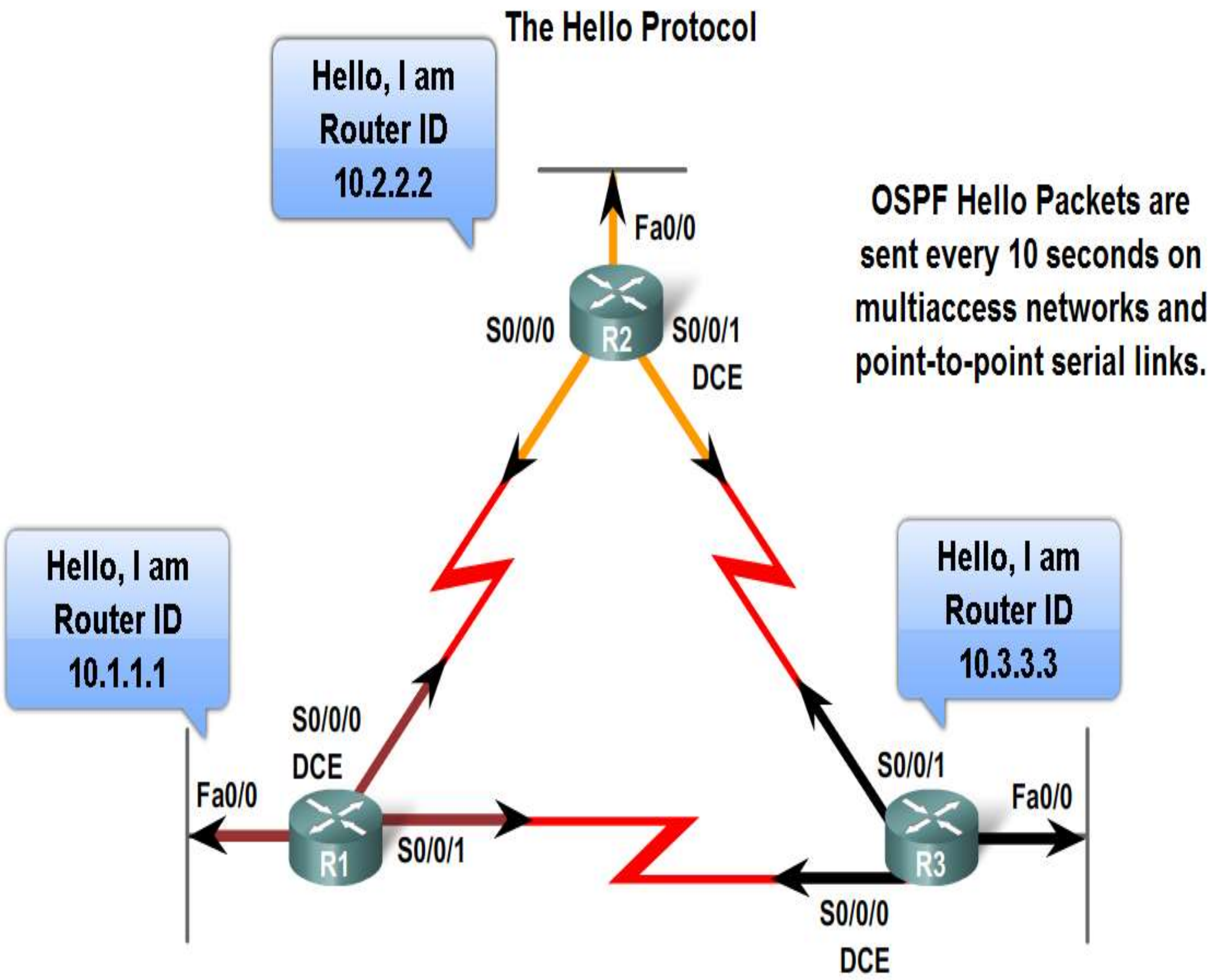
Multicast (224.0.0.5)

10 secs

OSPF Dead Interval

The time that must transpire before the neighbor is considered down

Default is 4 times the hello interval



Matching interface values for two routers to form an adjacency

Hello Interval, Dead Interval, Network Type = Hello Interval, Dead Interval, Network Type

5.2 OSPF Phases to Convergence

- Establish Neighbor Adjacency Phase
- Synchronise OSPF Database Phase
- Shortest Path First Algorithm Phase

Link State Routing

After Routers have formed an adjacency with neighbour routers
& negotiate parameters for two way communication.

Routers exchange link state information with other routers
in the network area.

With this link state information,
each router can create its own topological map
of the network area

then
Each router independently calculate least cost path to every destination
within network area.

Link-State Routing Convergence

Establish Neighbor Adjacency Phase

1) Each router learns about its own directly connected networks
Routers exchange hello packets to meet other directly connected routers, their neighbors, form adjacency

Synchronise OSPF Database Phase

2) Each router builds its own Link State Packet (LSP) which includes information Neighbor ID Link Types , Bandwidth

3) LSP is flooded to all neighbors who in turn store and forward information to their neighbors

4) Once all routers have received all LSPs, router constructs a topological map or LSDB of the network area.

Shortest Path First Algorithm Phase

5) Each router executes SPF algorithm to create an SPF Tree
Each router is the root of its own SPF Tree

6) Each router uses SPF Tree to determine the least cost path to each destination.
The Least cost paths to each remote destination are put in the Routing Table
OSPF route entries indicated by “O”

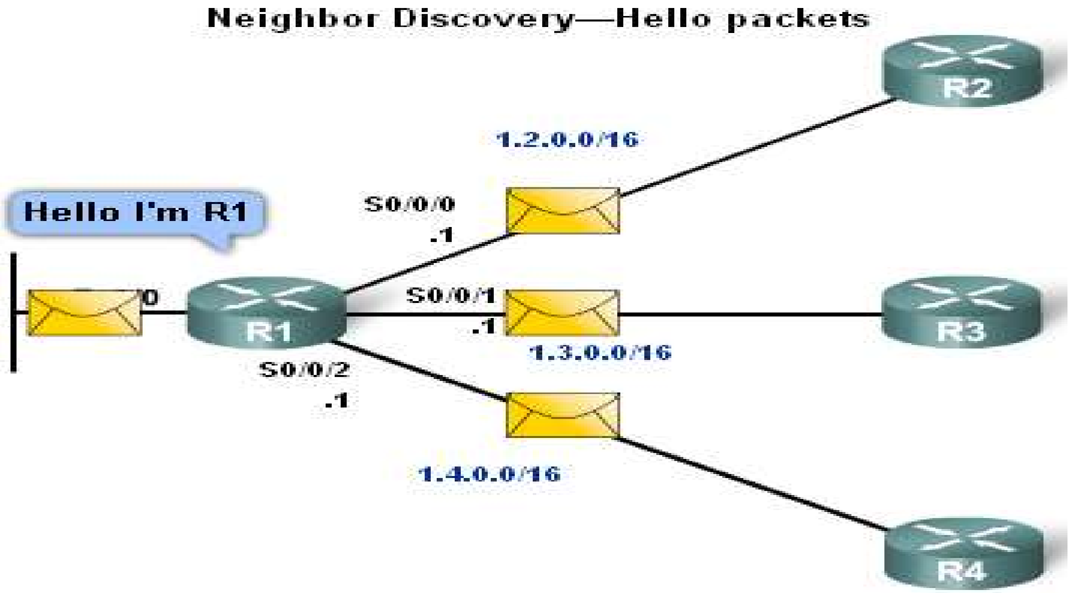
1) Link-State Routing: Discovering the Neighbors

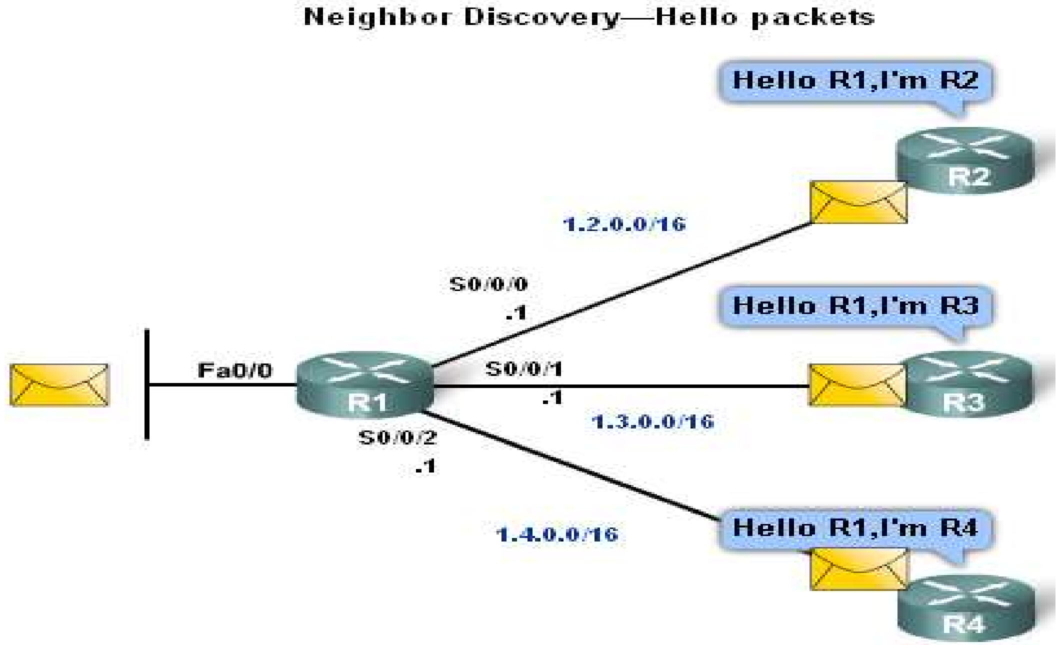
Routers send Hello packets on connected interfaces

When a router learns it has a neighbor

- Neighbors exchange Hello packets
- They form an adjacency

- Hello packets also serve as a "keep alive function"

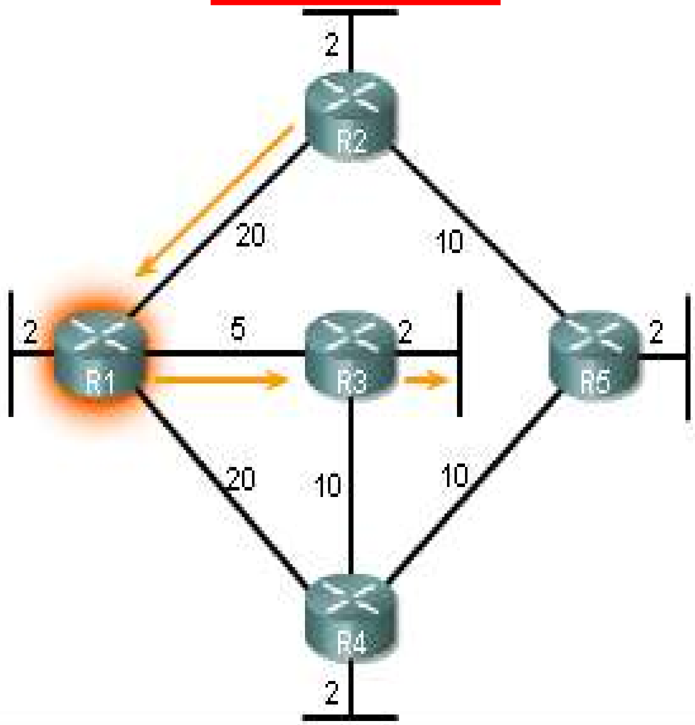




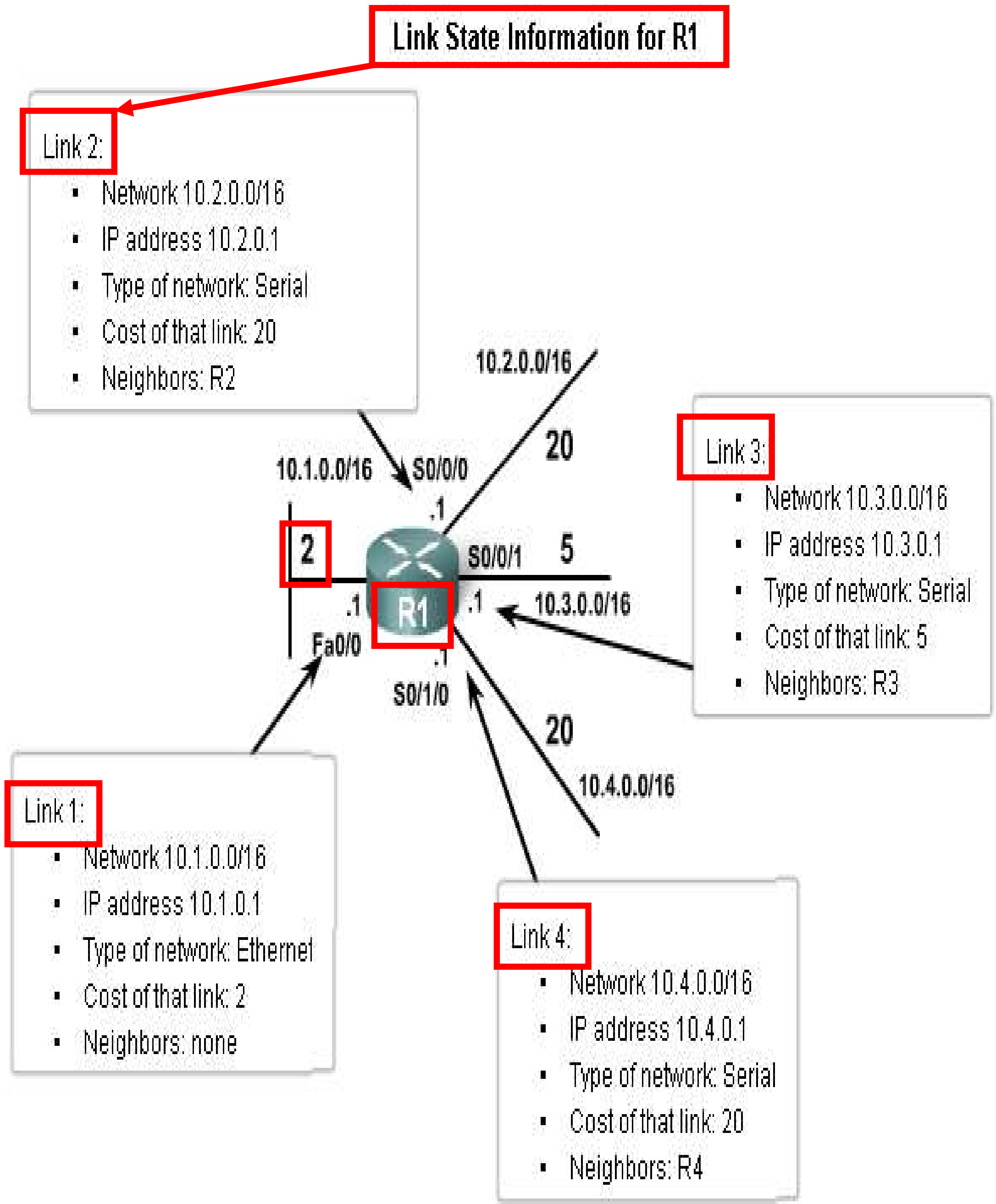
2a) Link-State Routing: R1 Link State Information

Introduction to the SPF Algorithm

SPF Tree for R1

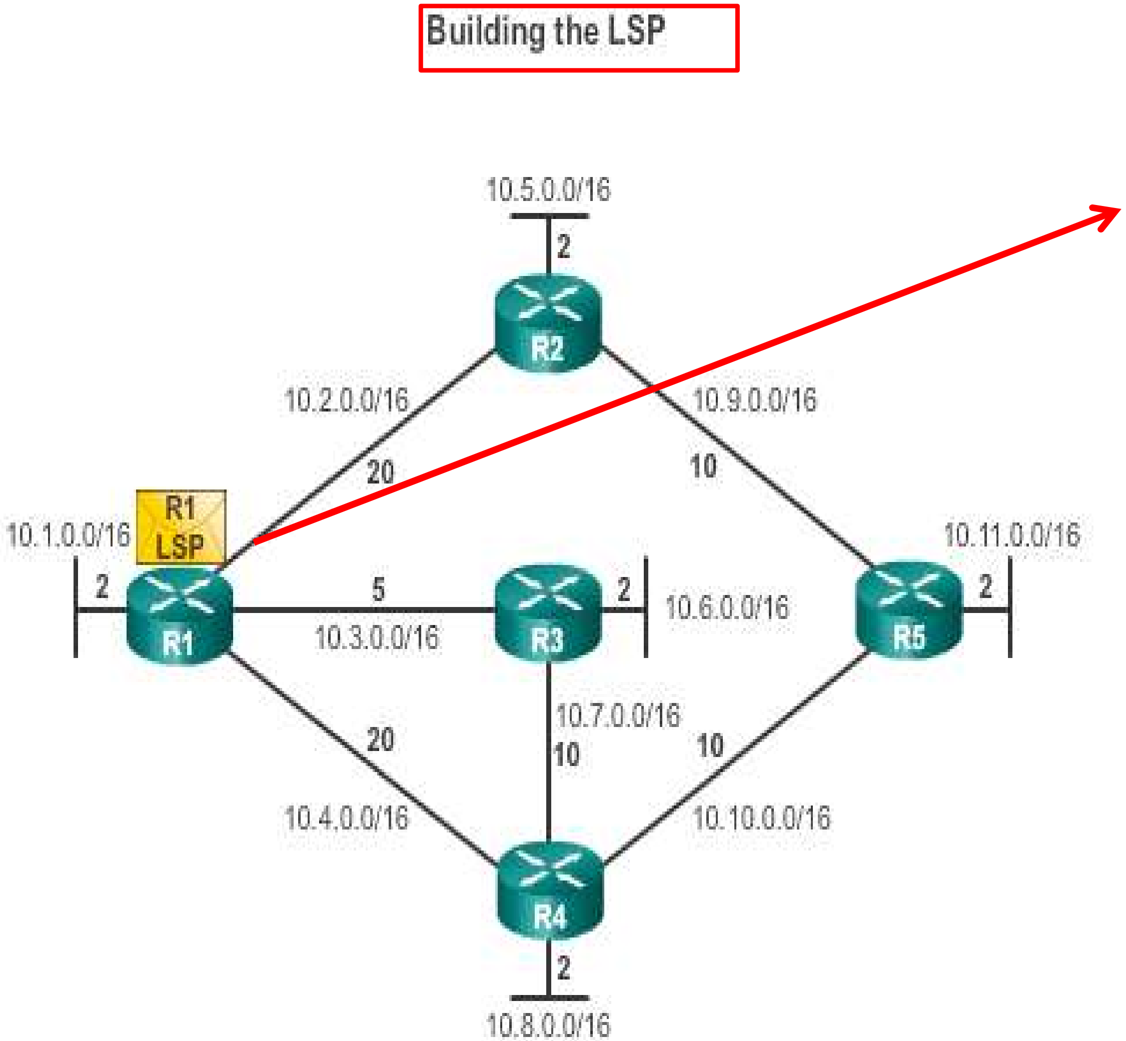


Destination	Shortest Path	Cost
R2 LAN	R1 to R2	22
R3 LAN	R1 to R3	7
R4 LAN	R1 to R3 to R4	17
R5 LAN	R1 to R3 to R4 to R5	27



2b) Link-State Routing: R1 builds an LSP

Each router builds a link-state packet (LSP) containing the state of each directly connected link.



R1's LSP Contains:

1. R1-> Ethernet network: 10.1.0.0/16; Cost 2
2. R1 -> R2: Serial point-to-point network; 10.2.0.0/16; Cost 20
3. R1 -> R3: Serial point-to-point network; 10.3.0.0/16; Cost 5
4. R1 -> R4: Serial point-to-point network; 10.4.0.0/16; Cost 20

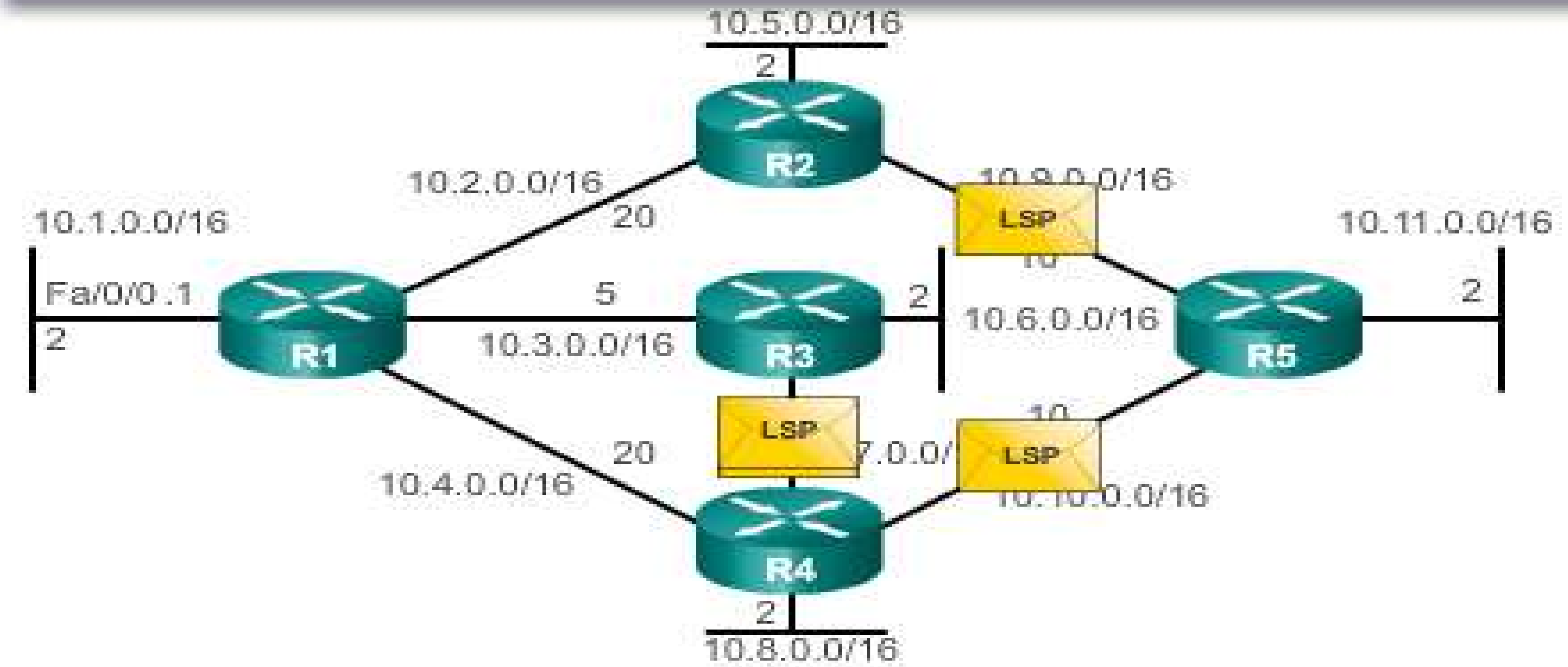
3) Link-State Routing: Flooding the LSPs

Each router floods LSP to all neighbors, who then store all LSPs received in a link statedatabase.

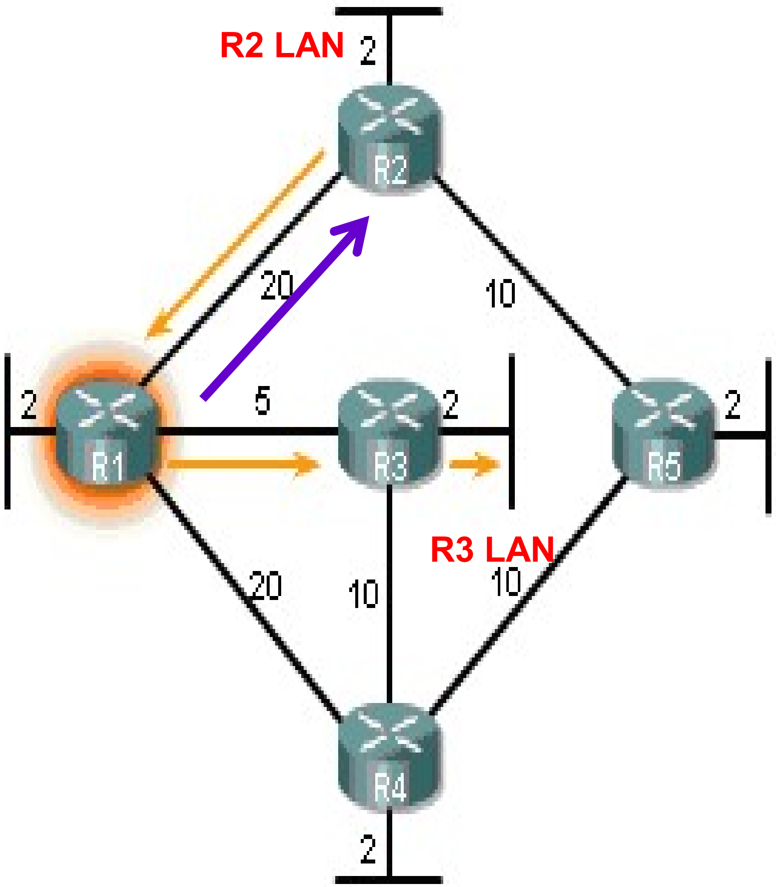
Flooding the LSP

R1 Link State Contents

- R1; Ethernet network; 10.1.0.0/16; Cost 2
- R1 -> R2; Serial point-to-point network; 10.2.0.0/16; Cost 20
- R1 -> R3; Serial point-to-point network; 10.3.0.0/16; Cost 5
- R1 -> R4; Serial point-to-point network; 10.4.0.0/16; Cost 20



4) Build Link State Database: Cost R1 to R2 LAN, R1 to R3 LAN



R1 Link-State Database

R1s Link-State DatabaseLSPs from R2:

- Connected to neighbor R1 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R5 on network 10.9.0.0/16, cost of 10
- Has a network 10.5.0.0/16, cost of 2

LSPs from R3:

- Connected to neighbor R1 on network 10.3.0.0/16, cost of 5
- Connected to neighbor R4 on network 10.7.0.0/16, cost of 10
- Has a network 10.6.0.0/16, cost of 2

LSPs from R4:

- Connected to neighbor R1 on network 10.4.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.7.0.0/16, cost of 10
- Connected to neighbor R5 on network 10.10.0.0/16, cost of 10
- Has a network 10.8.0.0/16, cost of 2

LSPs from R5:

- Connected to neighbor R2 on network 10.9.0.0/16, cost of 10
- Connected to neighbor R4 on network 10.10.0.0/16, cost of 10
- Has a network 10.11.0.0/16, cost of 2

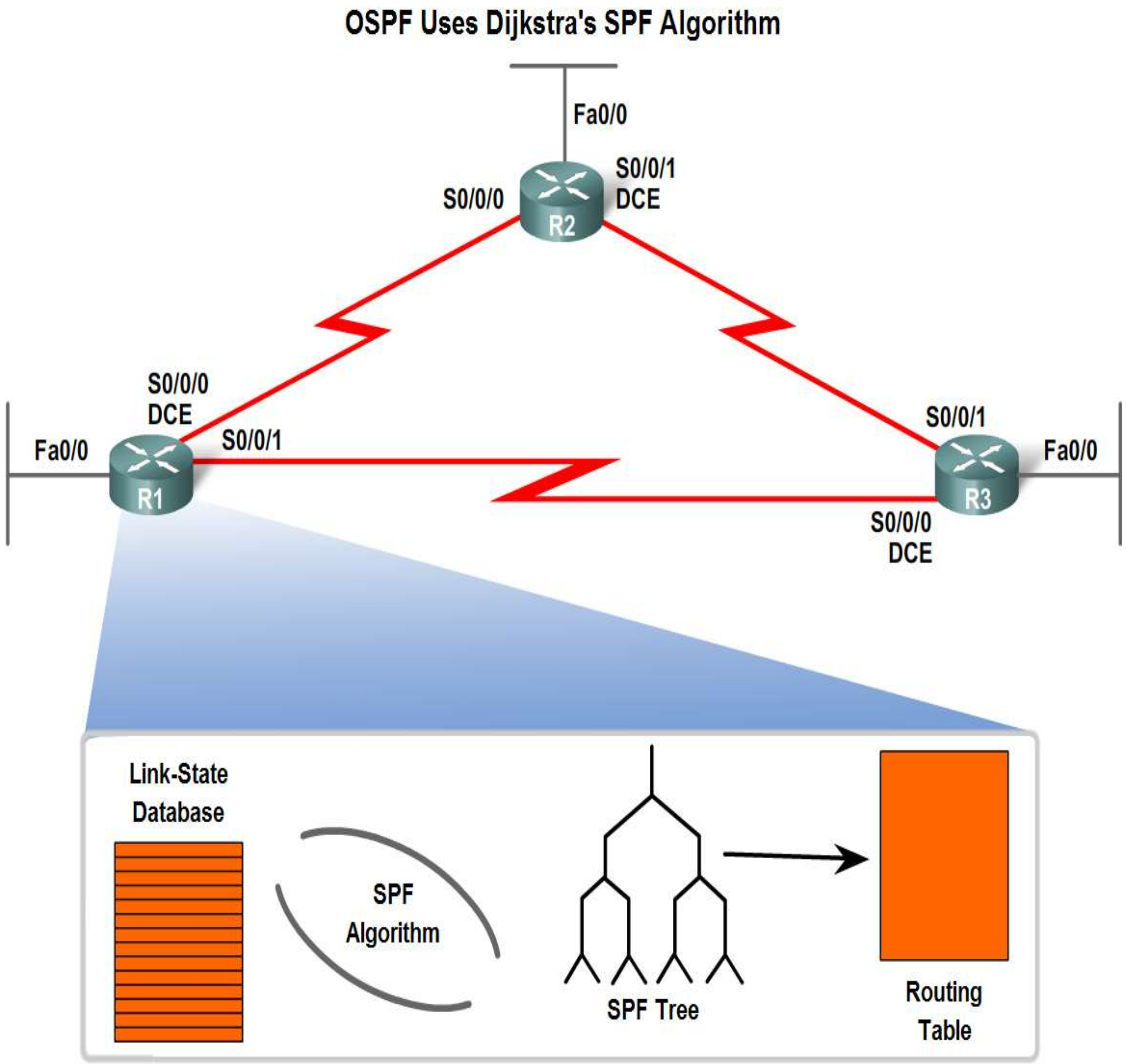
R1 Link-states:

- Connected to neighbor R2 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.3.0.0/16, cost of 5
- Connected to neighbor R4 on network 10.4.0.0/16, cost of 20

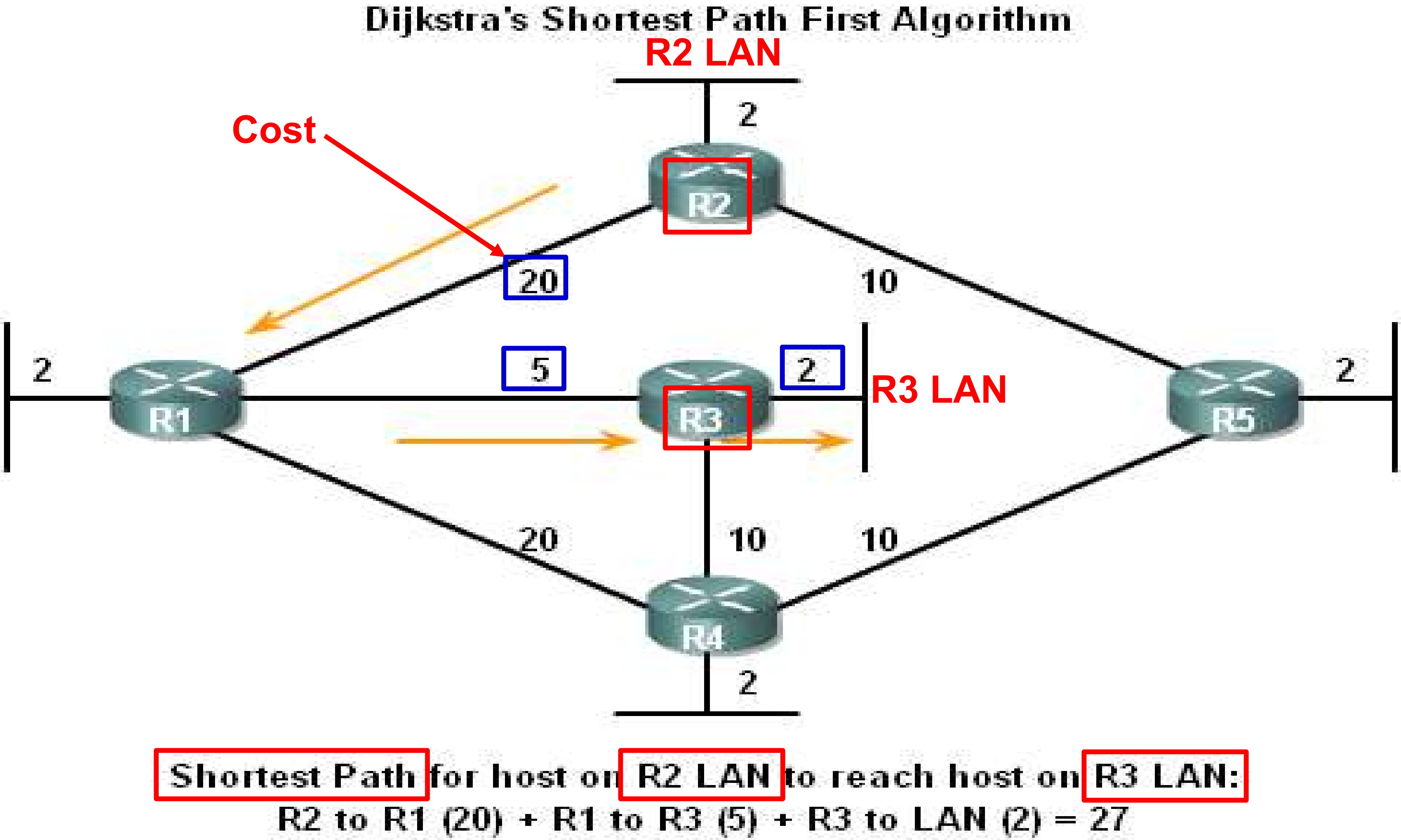
5) Link State Routing: SPF (Shortest Path First) Algorithm

This information is utilized on execution of Dijkstra SPF algorithm to create a SPF tree

SPF tree used to populate the routing table. Only the least cost (best) routes are put in the routing table



Link-State Routing: Cost R2 LAN to R3 LAN



6) The least cost paths are put in the Routing Table

OSPF Cost

The “OSPF Cost” for a destination network is an accumulation of all Cost values from source to destination.

OSPF Cost - - > Interface bandwidth
OSPF uses metric “Cost” to determine the best path to remote destination
(“Cost” = reference bandwidth / interface bandwidth)
Interface bandwidth influences “Cost”
eg . Lower bandwidth - - > Higher cost

```
R1# show ip route | include 172.16.2.0
O        172.16.2.0/24 [110/65] via 172.16.3.2, 03:39:07,
         Serial0/0/0
R1#
R1# show ip route 172.16.2.0
Routing entry for 172.16.2.0/24
  Known via "ospf 10", distance 110, metric 65, type intra
  area
  Last update from 172.16.3.2 on Serial0/0/0, 03:39:15 ago
  Routing Descriptor Blocks:
  * 172.16.3.2, from 2.2.2.2, 03:39:15 ago, via Serial0/0/0
      Route metric is 65, traffic share count is 1
```

6) The least cost paths are put in the Routing Table

R1 Routing Table

Destination	Shortest Path	Cost
R2 LAN	R1 to R2	22
R3 LAN	R1 to R3	7
R4 LAN	R1 to R3 to R4	17
R5 LAN	R1 to R3 to R4 to R5	27

5.3 OSPF Configuration

- OSPF Process id
- OSPF Network command , wildcard mask , area-ID
- Passive Interface , Router ID, Propagate default static route

Configuring OSPF

OSPF process-id command

OSPFv2 configuration uses the router ospf configuration mode

To enable OSPF on a router

use router ospf *process-id* command.

process id between **1** and **65535**

OSPF Routers

R1(config)# router ospf **1**

R2(config)# router ospf **1**

R3(config)# router ospf **1**

Configuring OSPF

OSPF **network** command

Use the **network** command to specify which interface(s) participate in the OSPFv2 area.

(config-router)# **network** *x.x.x.x wildcard_mask* **area** *area-id*

network address   wildcard mask - the inverse of the subnet mask

area-id - area-id refers to the OSPF area.

OSPF area is a group of routers that share link state information

```
R1(config)#router ospf 1
R1(config-router)#network 172.16.1.16 0.0.0.15 area 0
R1(config-router)#network 192.168.10.0 0.0.0.3 area 0
R1(config-router)#network 192.168.10.4 0.0.0.3 area 0
```

```
R2(config)#router ospf 1
R2(config-router)#network 10.10.10.0 0.0.0.255 area 0
R2(config-router)#network 192.168.10.0 0.0.0.3 area 0
R2(config-router)#network 192.168.10.8 0.0.0.3 area 0
```

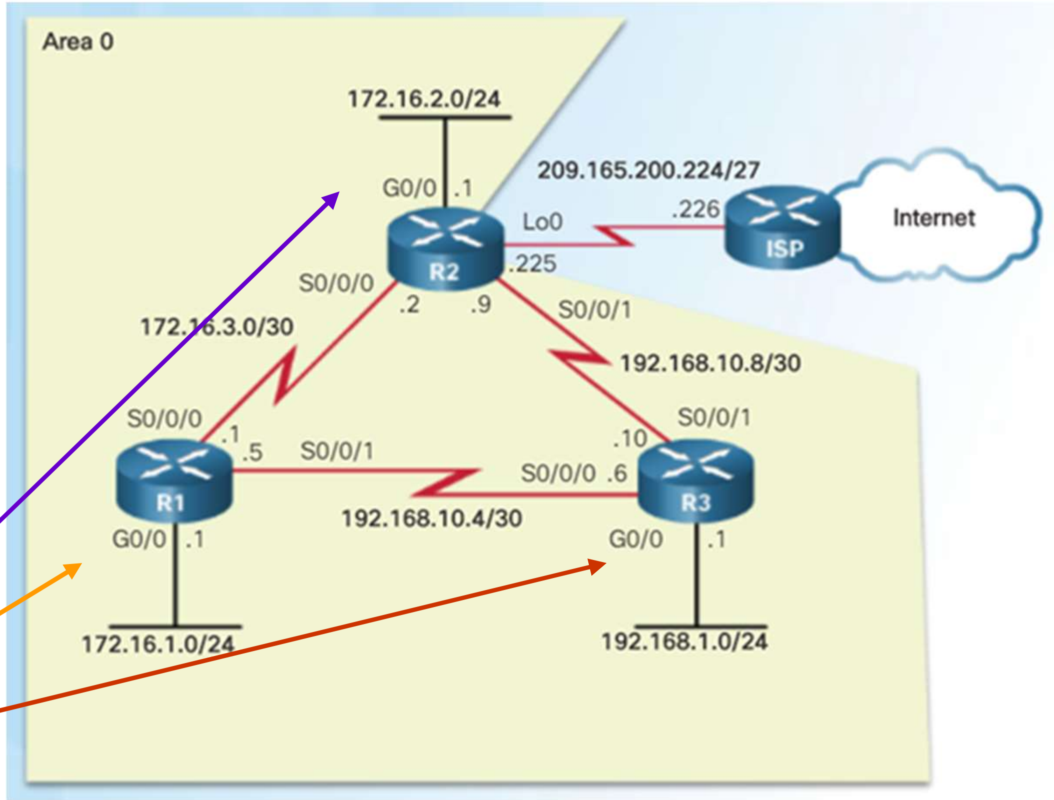
Configuring OSPF

Passive Interface command

Use passive interface command to specify interface(s) that DO NOT SEND OSPF messages.

(config-router)# **passive-interface** *type number*

```
R1(config)# router ospf 10
R1(config-router)# passive-interface GigabitEthernet 0/0
```



Configure these interfaces as a Passive interface

OSPF Propagate Default Static Route

Propagate Default Static Route in OSPFv2

To propagate a default route, the edge router must be configured with the following:

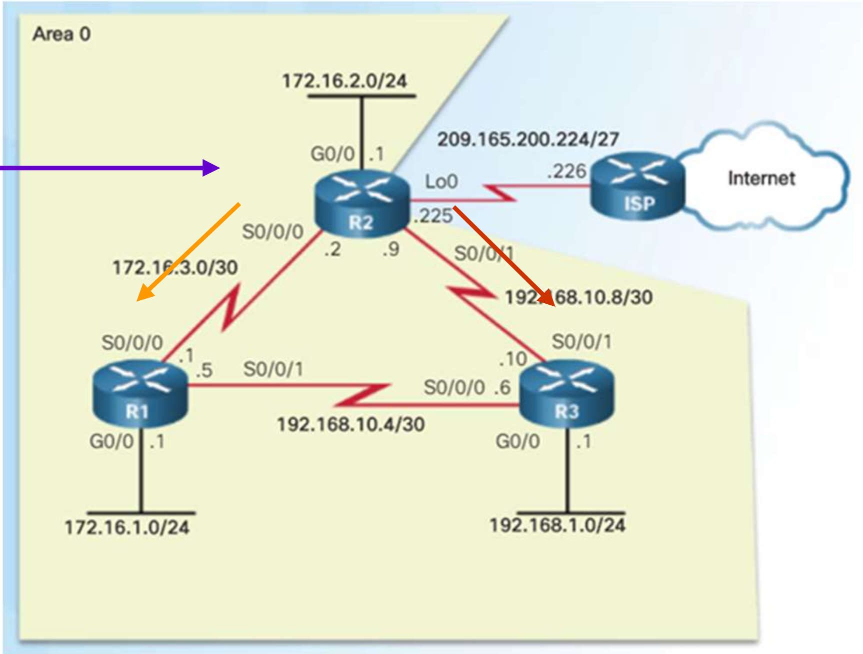
A default static route using the ip route 0.0.0.0 0.0.0.0 [next-hop-address | exit-intf] command.

The default-information originate router configuration command instructs R2 to be the source of the default route information and propagate the default static route in OSPF updates

```
R2(config)# interface lo0
R2(config-if)# ip address 209.165.200.225 255.255.255.224
R2(config-if)# exit
R2(config)# ip route 0.0.0.0 0.0.0.0 loopback 0
%Default route without gateway, if not a point-to-point interface, may impact performance
R2(config)# router ospf 10
R2(config-router)# default-information originate
R2(config-router)# end
R2#
```

R2 is the source of Default route information in OSPF updates to R1 & R3

Verify using Show ip route



OSPF – Determining Router ID

Router ID

To use OSPF a Router must have a

Router ID are 32bits long uniquely identify router within the OSPF network area.

Router ID used in OSPF packet Header to identify router within OSPF network

Routers have multiple IP addresses, which one should be used?

Router ID is derived based on **3 criteria** in order of precedence.

Criteria 1

Configure using OSPF ***router-id*** command

or

Criteria 2

If router-id command not used,

router chooses **highest** IP address of any **loopback** interfaces.

or

Criteria 3

If no loopback interfaces are configured, the **highest** IP address on any **active** interface is used

OSPF – Router Identification

Criteria 1

Configured Router ID

ID always the same

Not a reachable address

Criteria 2

Loopback Address

Loopback interface cannot fail, this improves OSPF stability

Criteria 3

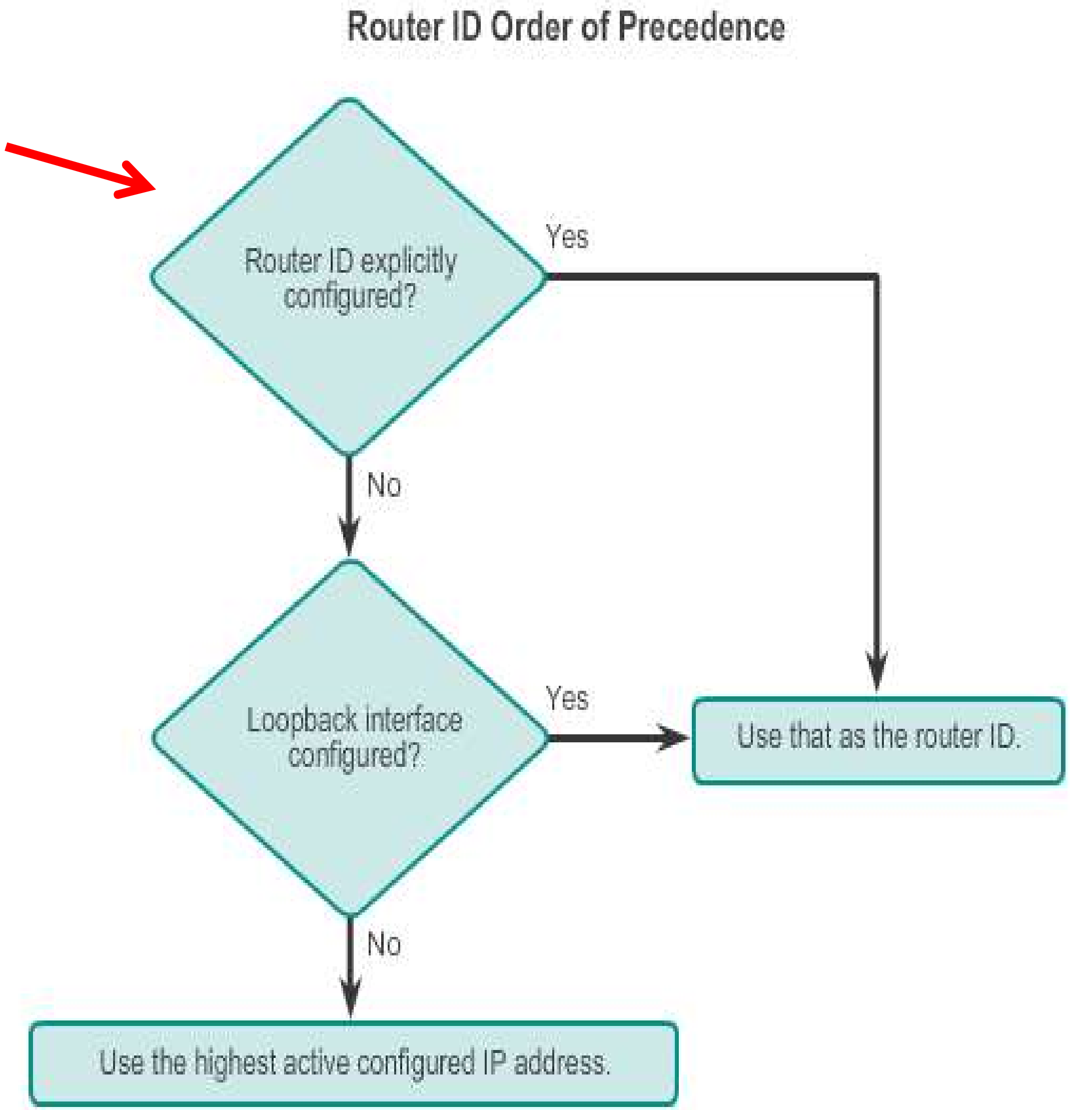
Highest Active Interface

Default option

Has problems – eg when interface goes down, OSPF process crashes

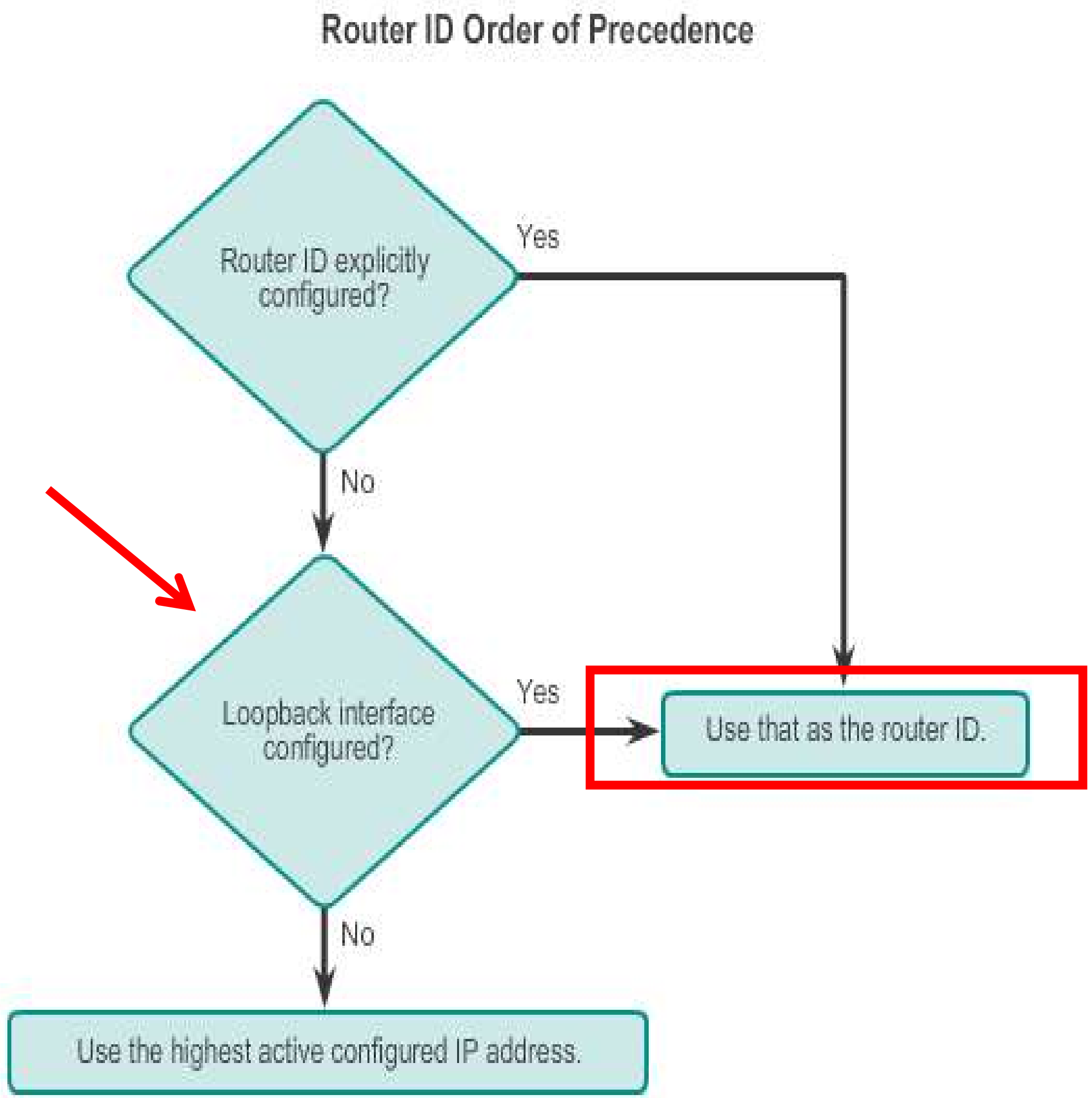
OSPF Router ID Explicitly Configured

```
R1(config)# router ospf 10
R1(config-router)# router-id 1.1.1.1
% OSPF: Reload or use "clear ip ospf process" command, for
this to take effect
R1(config-router)# end
R1#
*Mar 25 19:46:09.711: %SYS-5-CONFIG_I: Configured from
console by console
```



OSPF Router ID is Loopback Address

```
R1(config)# interface loopback 0
R1(config-if)# ip address 1.1.1.1 255.255.255.255
R1(config-if)# end
R1#
```



OSPF – Identification highest Active

Do the Router IDs chosen satisfy the criteria ?

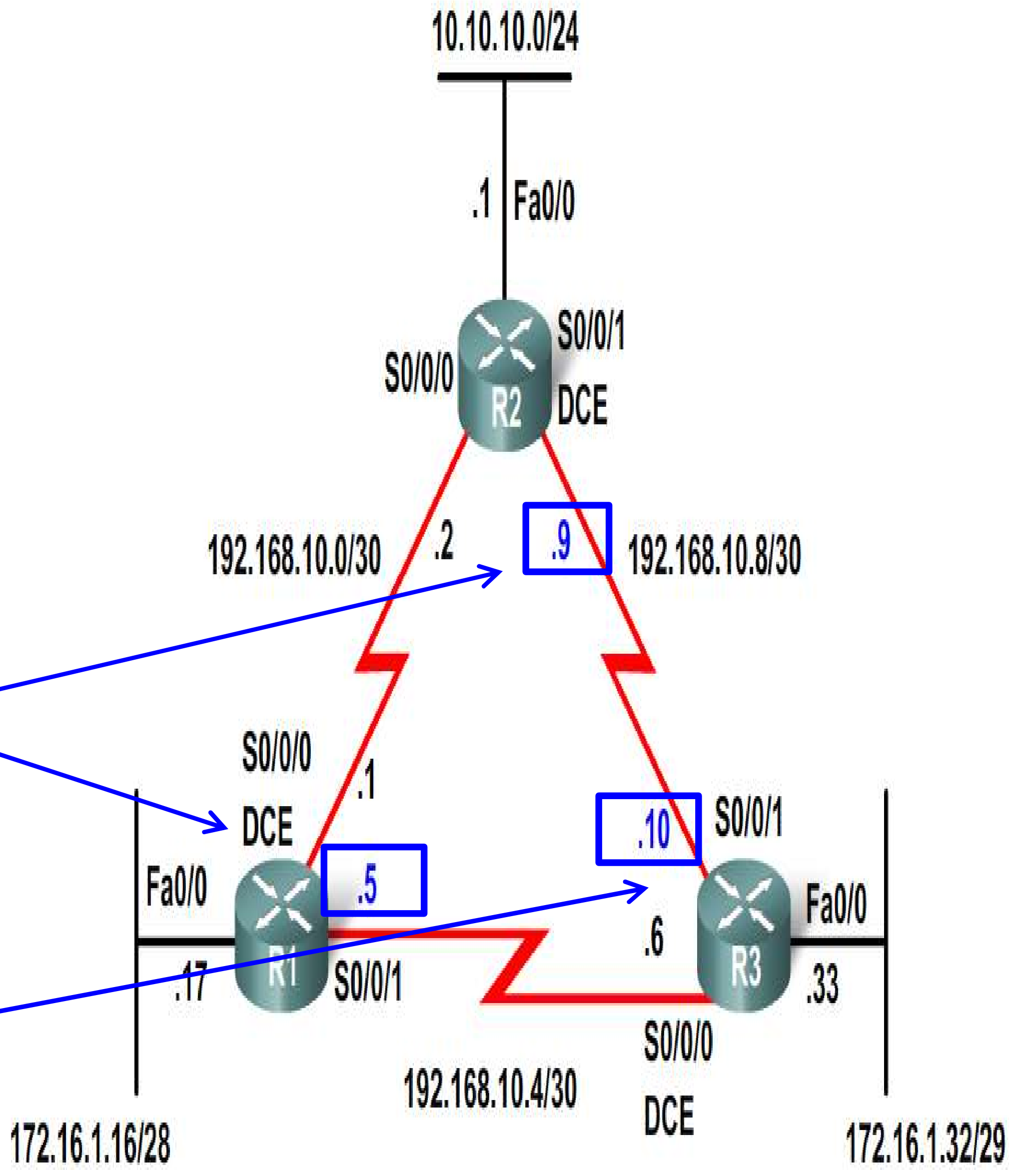
To inspect Router ID use

- show ip protocols
- show ip ospf
- show ip ospf interface

```
R1#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.5
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R2#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.9
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

```
R3#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.10
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```



5.4 Verify OSPF

- Verify OSPF neighbors
- Verify OSPF protocol settings , interface settings
- Setting OSPF Cost

OSPF – Verification

Verify OSPF Neighbors

Use show ip ospf neighbor command, displays Neighbor Adjacency:

- No adjacency indicated by:
  - Neighboring router's Router ID is not displayed
  - A state of **FULL** is not displayed

Consequence of no adjacency:

- No link state information exchanged
- Inaccurate SPF trees and routing tables

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.3.3.3          1   FULL/  -        00:00:30    192.168.10.6    Serial0/0/1
10.2.2.2          1   FULL/  -        00:00:33    192.168.10.2    Serial0/0/0
```

OSPF – Verification

Command	Description
show ip protocols	Displays OSPF process ID, router ID, networks router is advertising & administrative distance
show ip ospf	Displays OSPF process ID, router ID, OSPF area information & the last time SPF algorithm calculated
show ip ospf interface	Displays hello interval and dead interval

OSPF – Verification

Verify OSPF Protocol settings

Use show ip ospf protocol command to verify:
OSPFv2 process ID,
Router ID,
networks being advertised by the router,
neighbors that are sending OSPF updates,
administrative distance (110 by default).

```
R1# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 10"
  Outgoing update filter list for all interfaces is not
  set
  Incoming update filter list for all interfaces is not
  set
  Router ID 1.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0
  nssa
  Maximum path: 4
  Routing for Networks:
    172.16.1.0 0.0.0.255 area 0
    172.16.3.0 0.0.0.3 area 0
    192.168.10.4 0.0.0.3 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    2.2.2.2              110      00:17:18
    3.3.3.3              110      00:14:49
  Distance: (default is 110)
```

or

Use show ip ospf command

Use show ip ospf interface brief
for information about OSPF
enabled interfaces

```
R1# show ip ospf interface brief
Interface  PID  Area  IP Address/Mask   Cost  State  Nbrs F/C
Se0/0/1    10   0     192.168.10.5/30   15625 P2P    1/1
Se0/0/0    10   0     172.16.3.1/30     647   P2P    1/1
Gi0/0      10   0     172.16.1.1/24     1     DR     0/0
```

OSPF Cost

OSPF uses metric "Cost" to determine the best path to remote destination

("Cost" = reference bandwidth / interface bandwidth)

Interface bandwidth influences "Cost"

eg.

Cost is calculated using metric, bandwidth, of an interface

Cost is calculated using the formula $\boxed{10^8 \text{ / bandwidth}}$

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

OSPF – Modifying the Cost

Both sides of a serial link should be configured with the same bandwidth

Two commands used to modify bandwidth value:

- bandwidth – link cost must be calculated
- ip ospf cost – allows you to directly specify interface cost

```
R1(config)#inter serial 0/0/0
R1(config-if)#bandwidth 64
R1(config-if)#inter serial 0/0/1
R1(config-if)#bandwidth 256
R1(config-if)#end
R1#show ip ospf interface serial 0/0/0
Serial0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 1562
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  <output omitted>
```

Calculation $10^8/64{,}000 \text{ bps} = 1562$

```
R1(config)#inter serial 0/0/0
R1(config-if)#ip ospf cost 1562
R1(config-if)#end
R1#show ip ospf interface serial 0/0/0
Serial0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 1562
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  <output omitted>
```

No Calculation Needed

OSPF – Modifying the Cost

bandwidth and ip ospf cost command

Equivalent Commands

bandwidth Commands		ip ospf cost Commands
Router R1 R1(config)#**interface serial 0/0/0** R1(config-if)#**bandwidth 64**	=	**Router R1** R1(config)#**interface serial 0/0/0** R1(config-if)#**ip ospf cost 1562**
R1(config)#**interface serial 0/0/1** R1(config-if)#**bandwidth 256**	=	R1(config)#**interface serial 0/0/1** R1(config-if)#**ip ospf cost 390**
Router R2 R2(config)#**interface serial 0/0/0** R2(config-if)#**bandwidth 64**	=	**Router R2** R2(config)#**interface serial 0/0/0** R2(config-if)#**ip ospf cost 1562**
R2(config)#**interface serial 0/0/1** R2(config-if)#**bandwidth 128**	=	R2(config)#**interface serial 0/0/1** R2(config-if)#**ip ospf cost 781**
Router R3 R3(config)#**interface serial 0/0/0** R3(config-if)#**bandwidth 256**	=	**Router R3** R3(config)#**interface serial 0/0/0** R3(config-if)#**ip ospf cost 390**
R3(config)#**interface serial 0/0/1** R3(config-if)#**bandwidth 128**	=	R3(config)#**interface serial 0/0/0** R3(config-if)#**ip ospf cost 781**