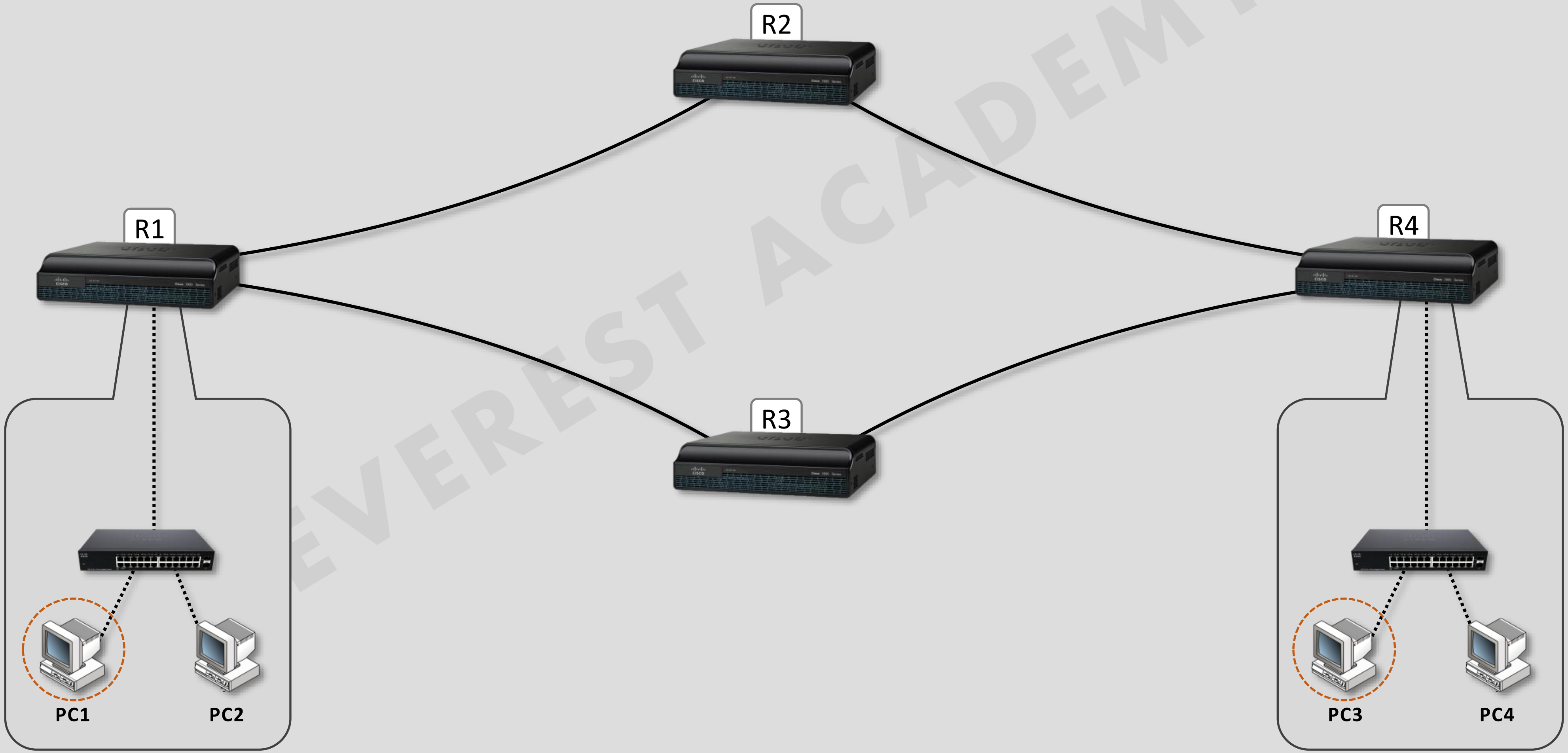
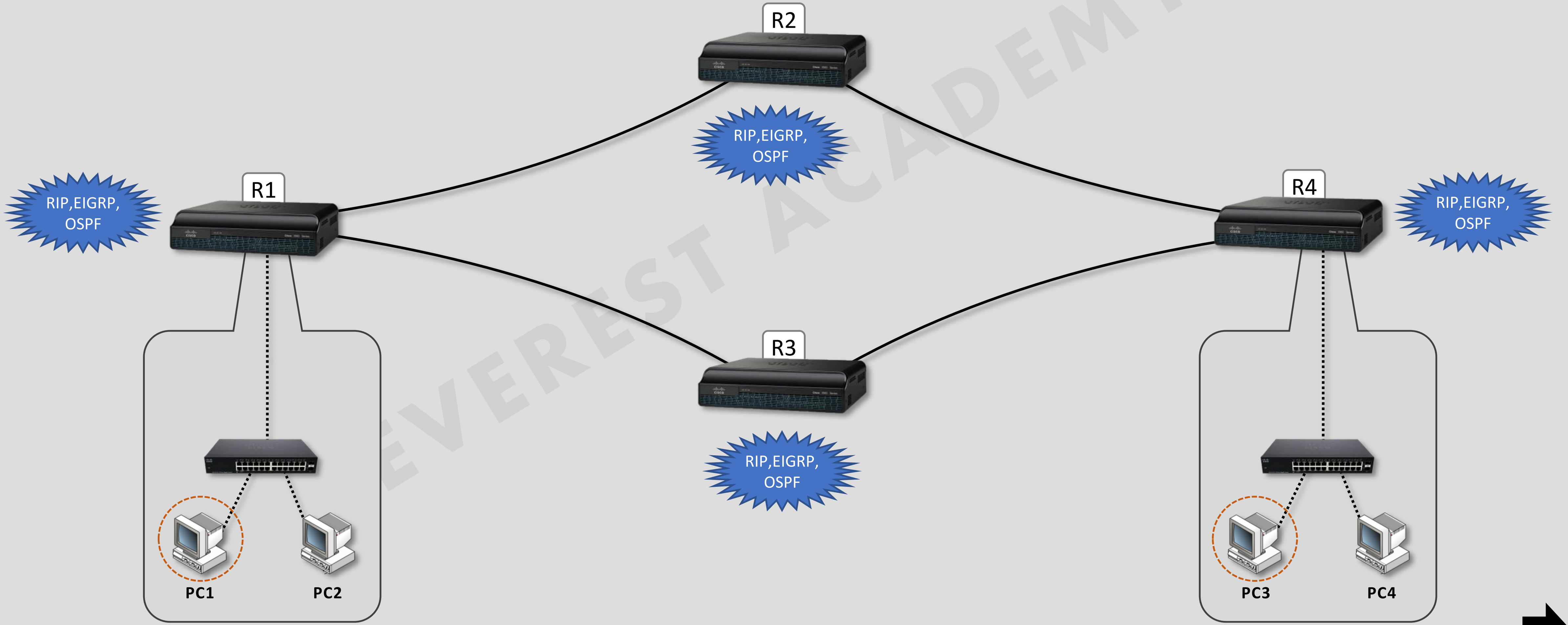
Dynamic Routing

❖ **Dynamic routing** is a process where a router can forward data via a different route.



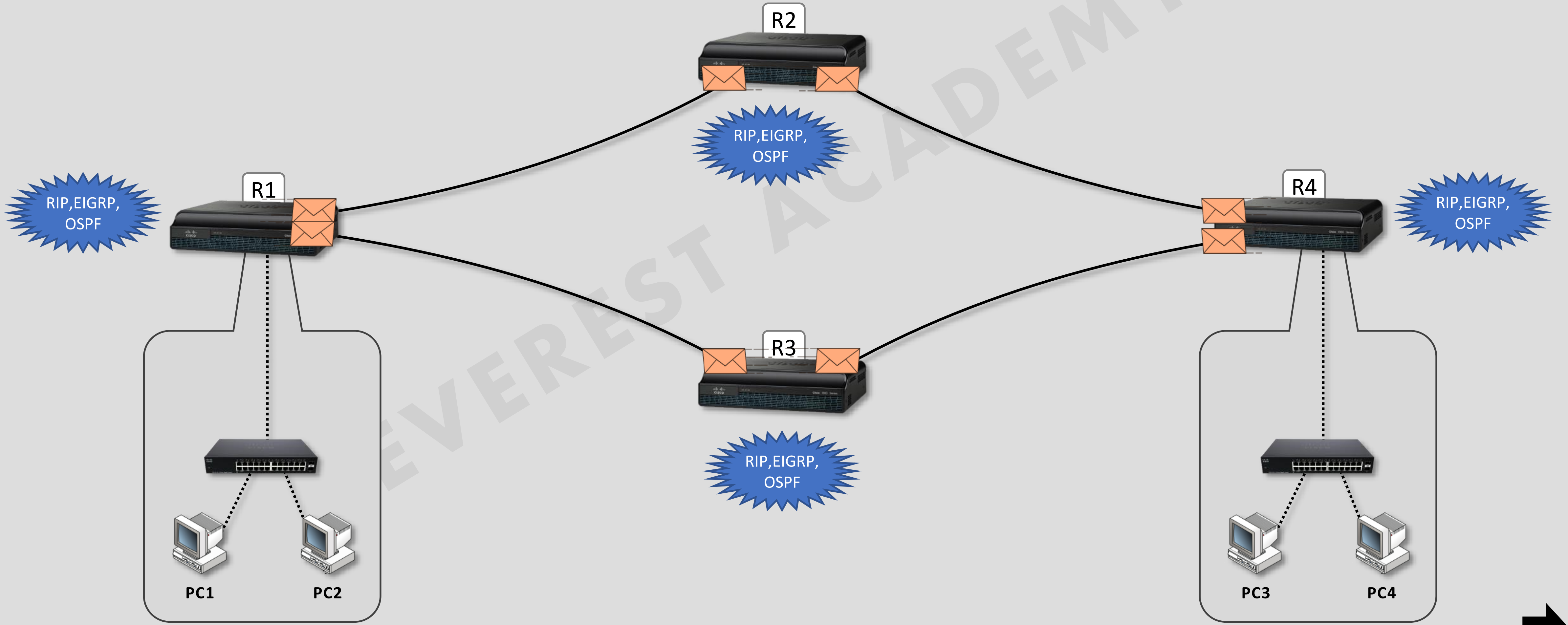
Dynamic Routing

❖ **Dynamic routing** uses algorithms and protocols such as **RIP**, **EIGRP** and **OSPF**.



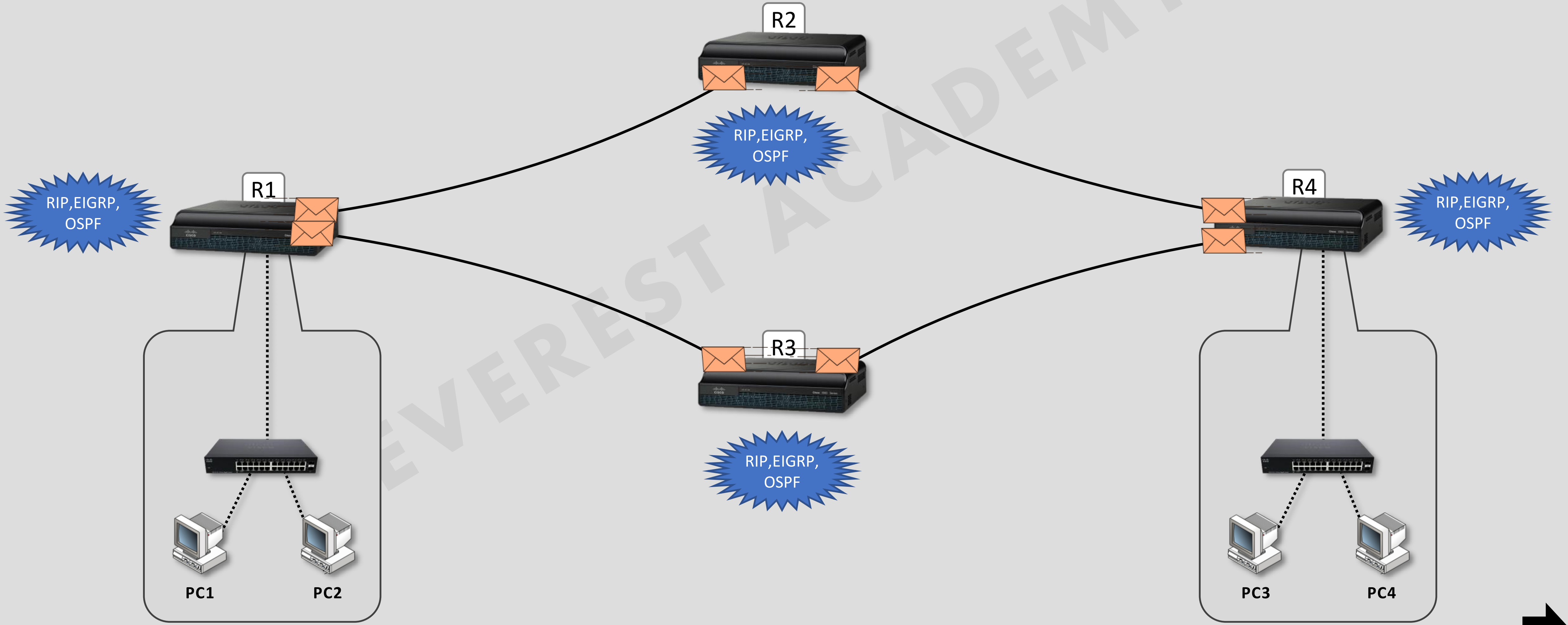
Routing Protocols

❖ **Routing protocol** is a set of messages, rules, and algorithms used by routers for the overall purpose of learning routes.



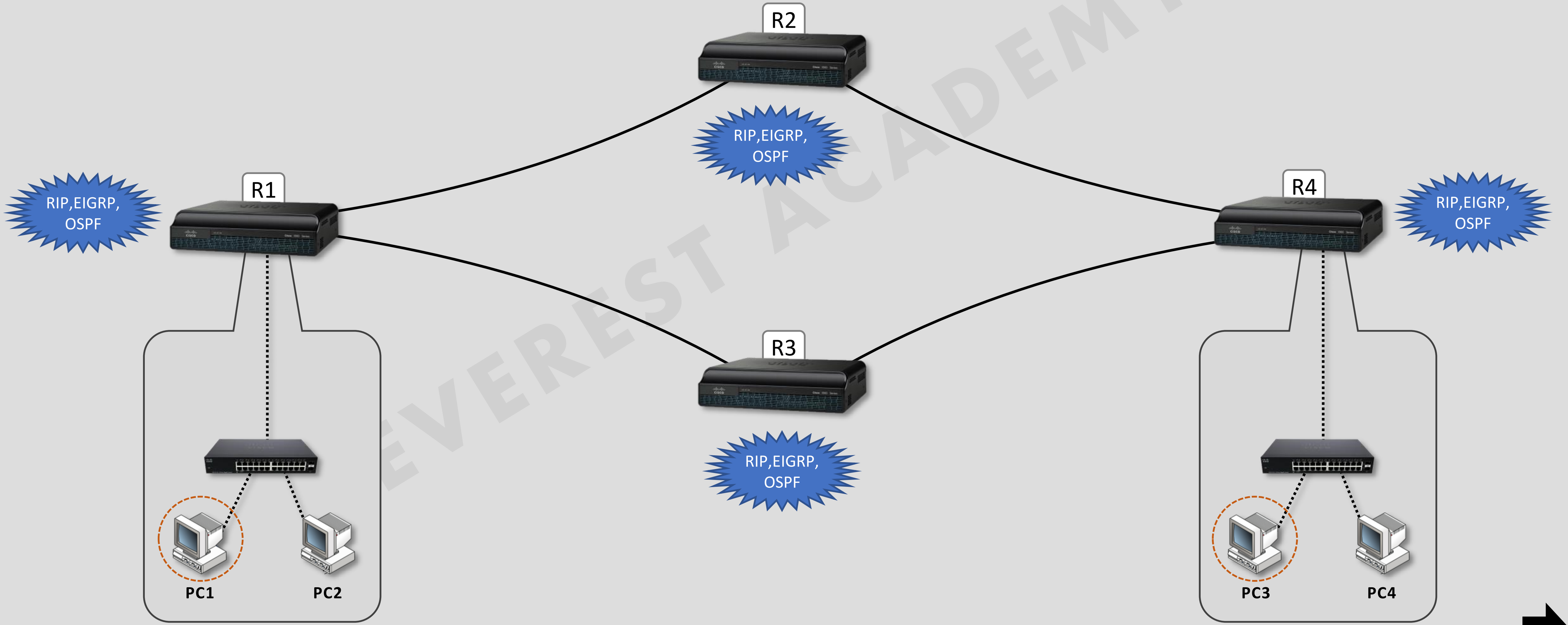
Routing Protocols

❖ **Routing protocols** allow routers to exchange information about networks with other routers to allow them to select the best path to reach a destination.



Best Routes

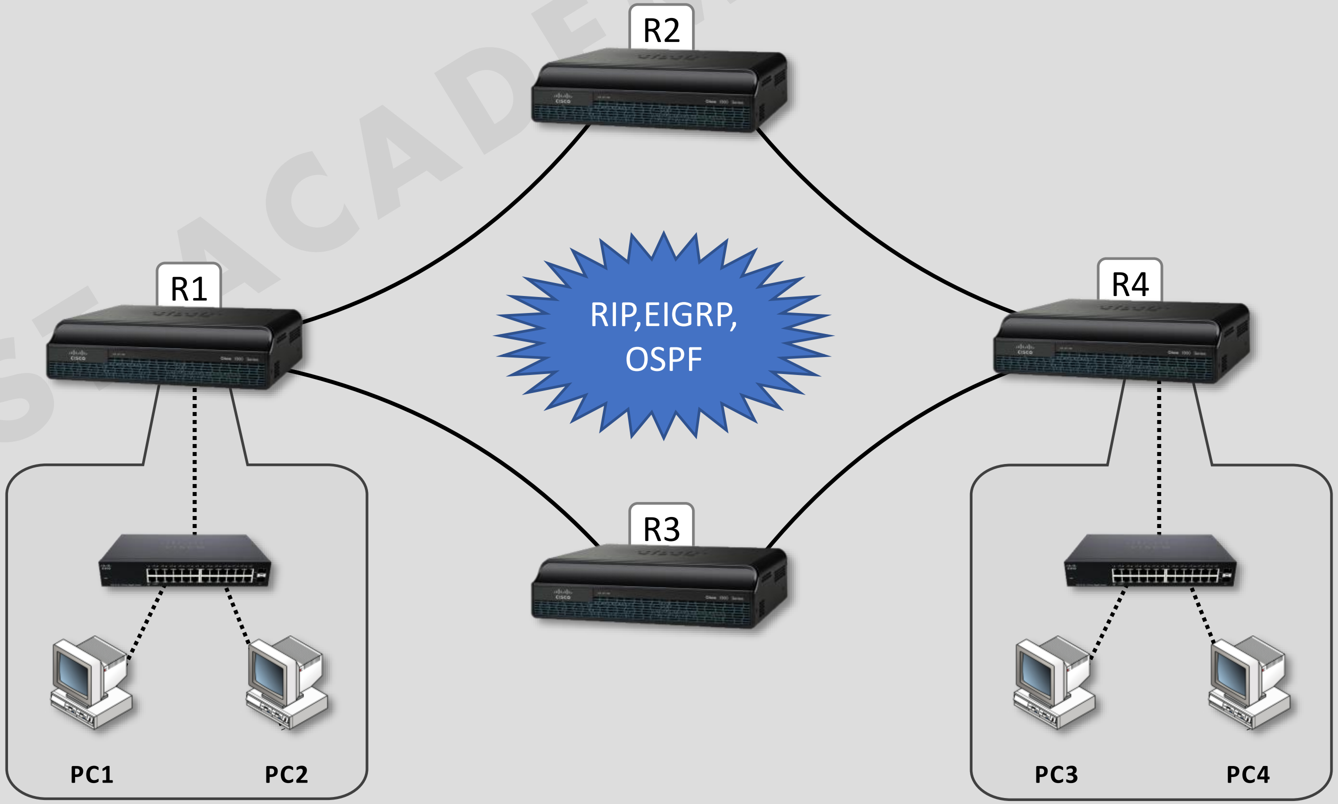
❖ Each router chooses the best route to each subnet and places those best routes in its **IP routing table**.



Routed Protocols (IPv4 & IPv6)

❖ **Routed protocols** such as **IPv4** and **IPv6** are used by routers to defines a **packet structure** and **logical addressing**, allowing routers to forward or route the packets.

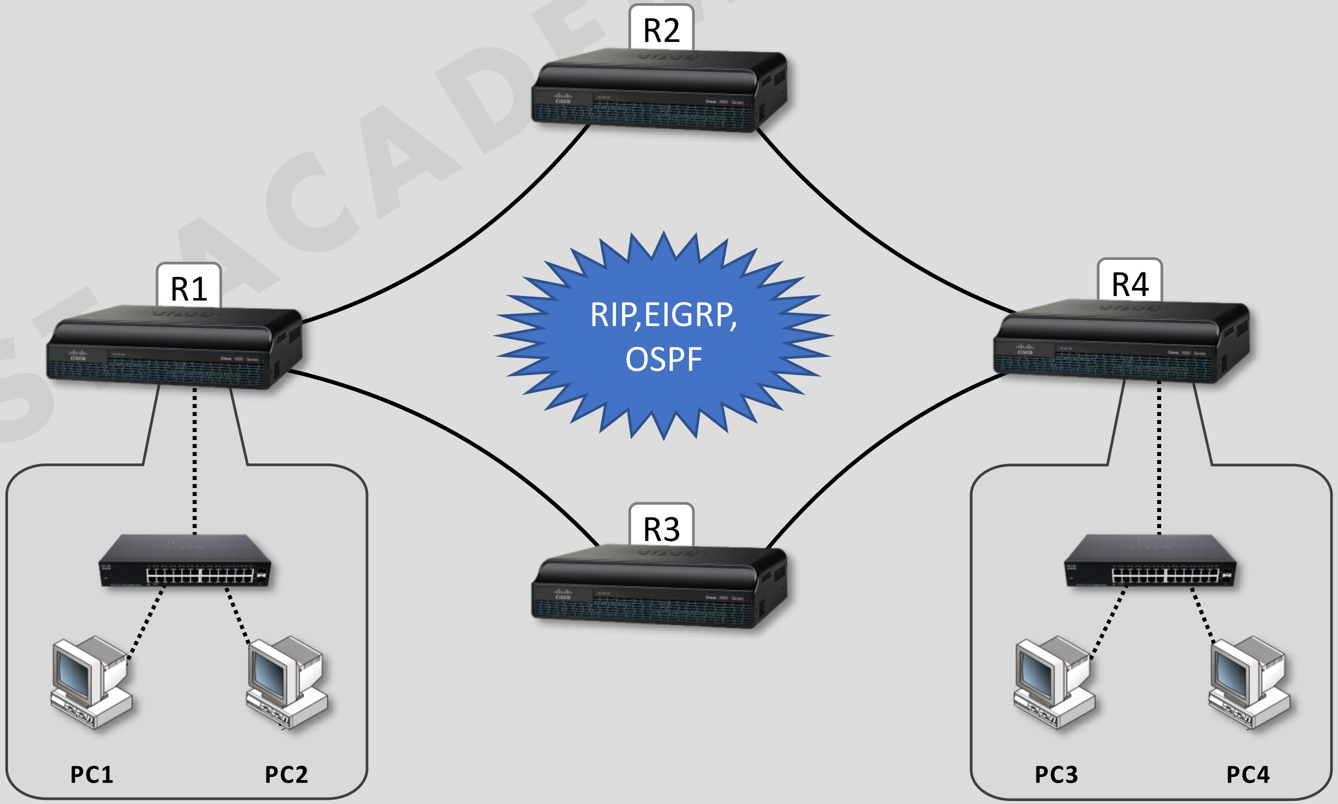
<table>
<tr><th>4</th><th>8</th><th>12</th><th>16</th><th>20</th><th>24</th><th>28</th><th>32</th></tr>
<tr><td>Ver.</td><td>IHL</td><td colspan="2">ToS</td><td colspan="4">Total Length</td></tr>
<tr><td colspan="4">Identification</td><td>Flags</td><td colspan="3">Fragment Offset</td></tr>
<tr><td colspan="2">Time to Live</td><td colspan="2">Protocol</td><td colspan="4">Header Checksum</td></tr>
<tr><td colspan="8">Source Address (4 Bytes)</td></tr>
<tr><td colspan="8">Destination Address (4 Bytes)</td></tr>
<tr><td colspan="6">Options</td><td colspan="2">Padding</td></tr>
<tr><td colspan="8">Data</td></tr>
</table>



Routed Protocols (IPv4 & IPv6)

❖ **Routed protocols** such as **IPv4** and **IPv6** are used by routers to defines a **packet structure** and **logical addressing**, allowing routers to forward or route the packets.

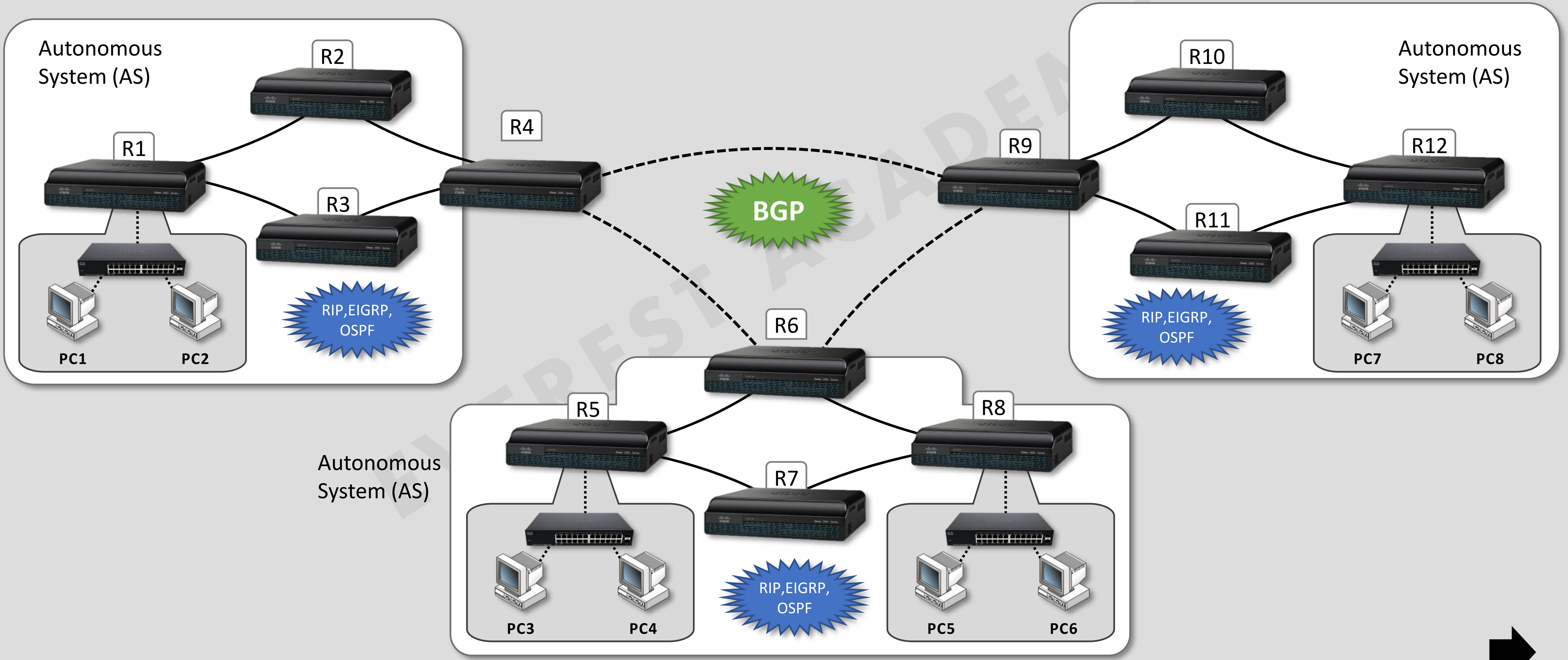
4	8	12	16	20	24	28	32
Ver.	Traffic Class		Flow Label				
Payload length				Next Header		Hop Limit	
Source Address (16 Bytes)							
Destination Address (16 Bytes)							
Extension Header (Optional)							
Data							



Interior and Exterior Routing Protocols

❖ Interior Gateway Protocols (IGP)

❖ Exterior Gateway Protocols (EGP)

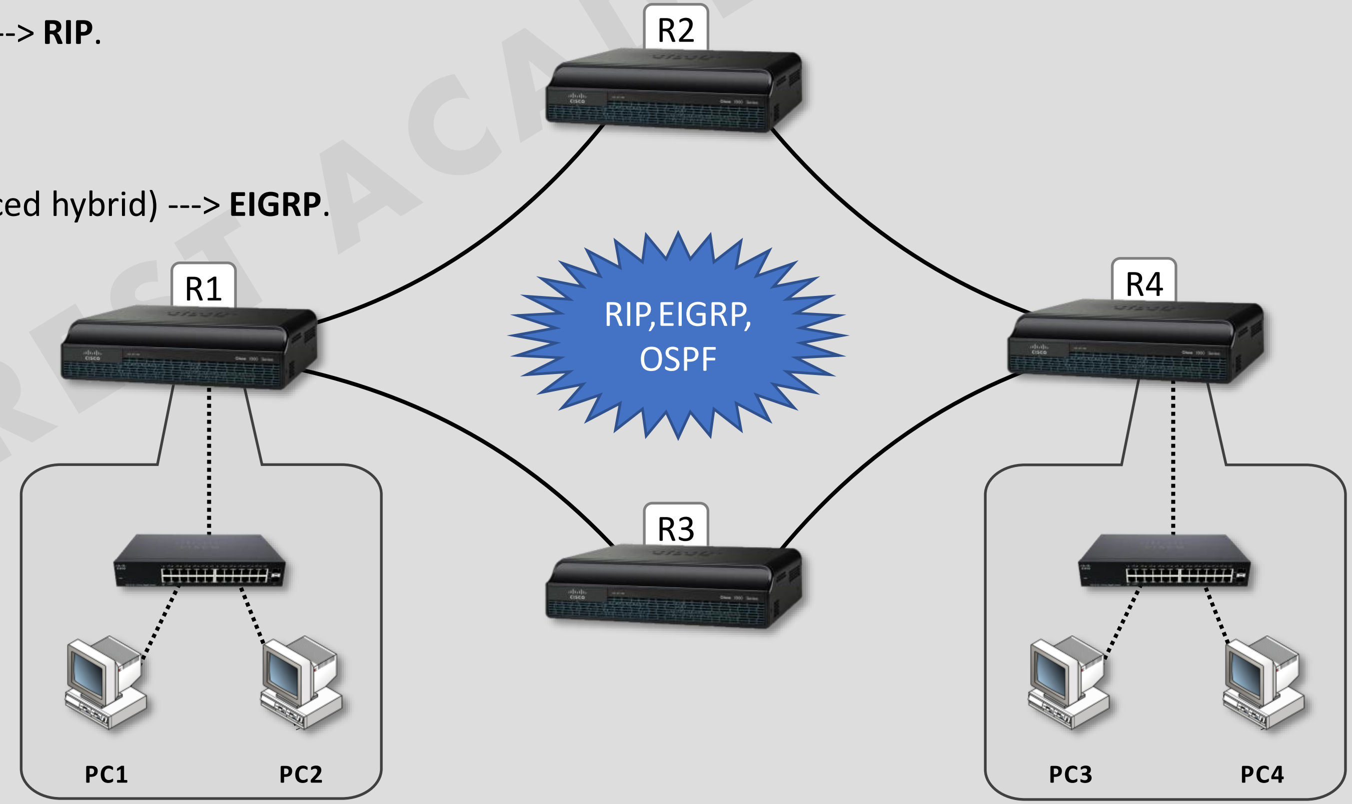


IGP Routing Protocol Algorithms

❖ **The term routing protocol algorithm** refers to the logic and processes used by different routing protocols to solve the problem of **learning** all routes, **choosing** the best route to each subnet, and **converging** in reaction to changes in the internetwork.

There are three types of routing protocol algorithms exist for IGP routing protocols:

- Distance vector (Bellman-Ford) ---> **RIP**.
- Link-state ---> **OSPF**.
- Advanced distance vector (balanced hybrid) ---> **EIGRP**.

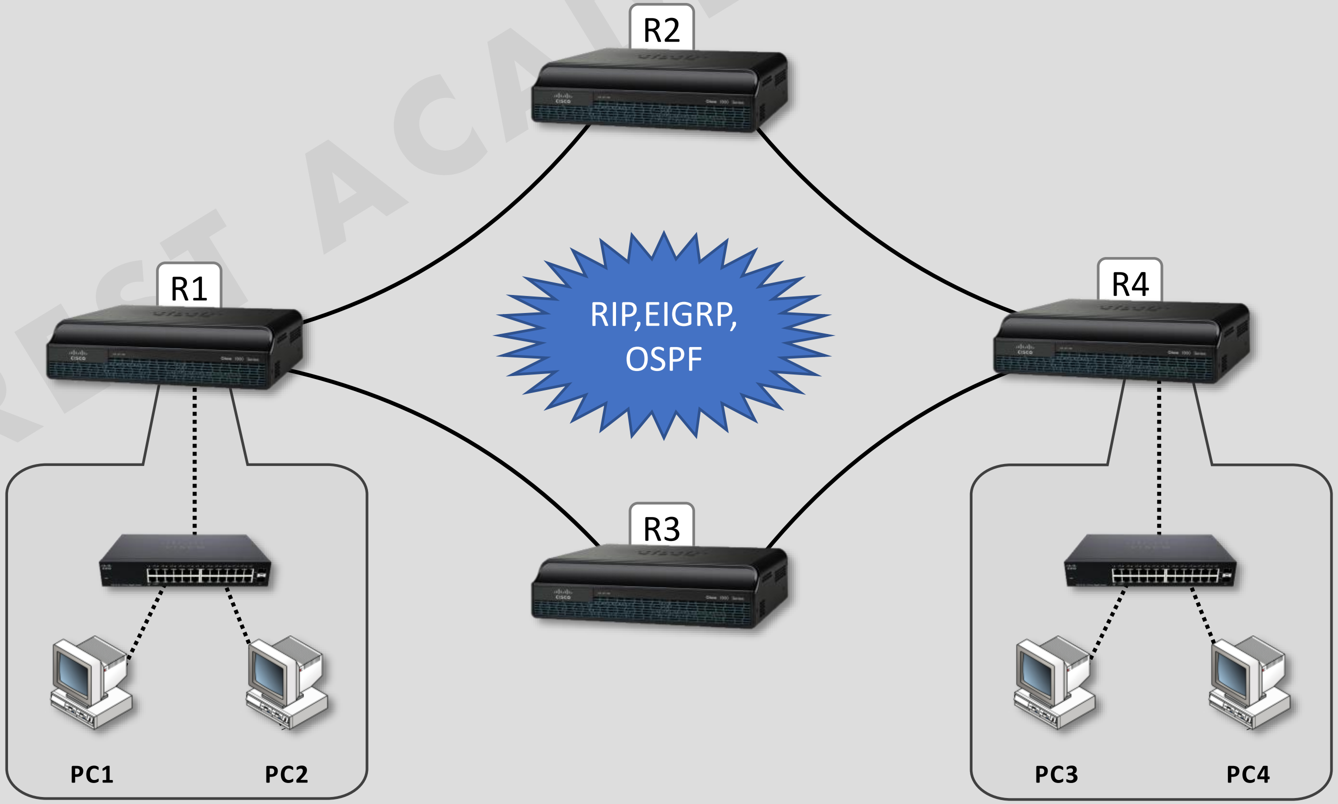


Metrics

❖ **Metrics** is used by the routing protocol to calculate the best path to a given destination, if it learns multiple paths to the same destination.

❖ Each routing protocol uses a different metric.

- RIP ---> **Hop Count**.
- OSPF ---> **Cost**.
- EIGRP ---> **Bandwidth and Delay**.



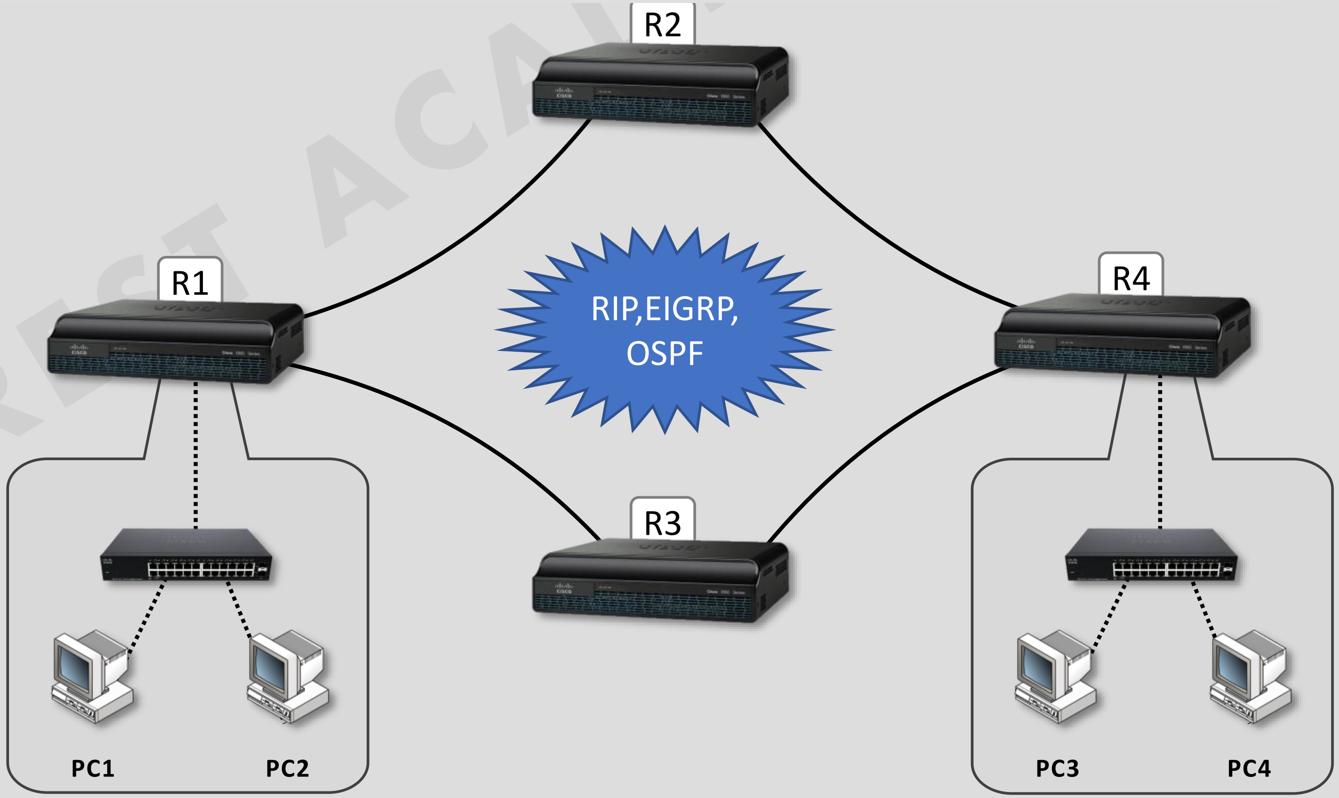
Administrative Distance (AD)

- ❖ **Administrative Distance (AD)** is a value that routers use in order to select the best path when there are **two or more** different routes to the same destination from **two or more** different routing protocols.

- ❖ **Administrative Distance (AD)** is a numeric value which can range from **0 to 255**.

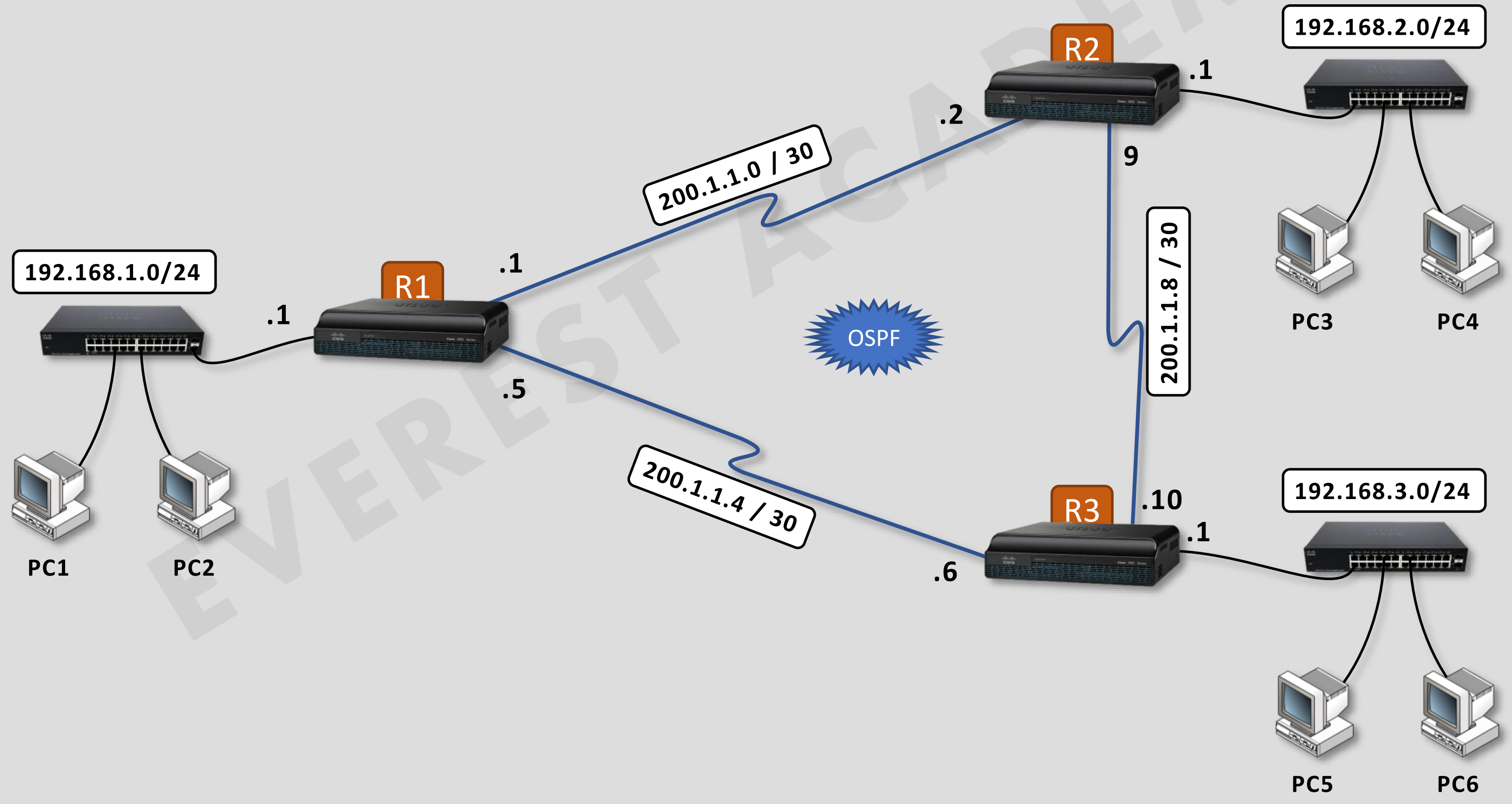
- ❖ **A smaller Administrative Distance (AD)** is more trusted by a router.

AD	Route Type
0	Connected interface
0 or 1	Static Route
90	EIGRP Route
110	OSPF Route
120	RIP Route



Open Shortest Path First (OSPFv2) Protocol

- ❖ **Routing protocols** exchange information between routers so it can learn routes.
- ❖ **The routers** learn information about ***subnets***, ***routes,*** and ***metric information*** about how good each route is compared to others.
- ❖ **The routing protocol** can then choose the ***best route*** to each subnet to build the ***IP routing table***.



Open Shortest Path First (OSPFv2) Protocol

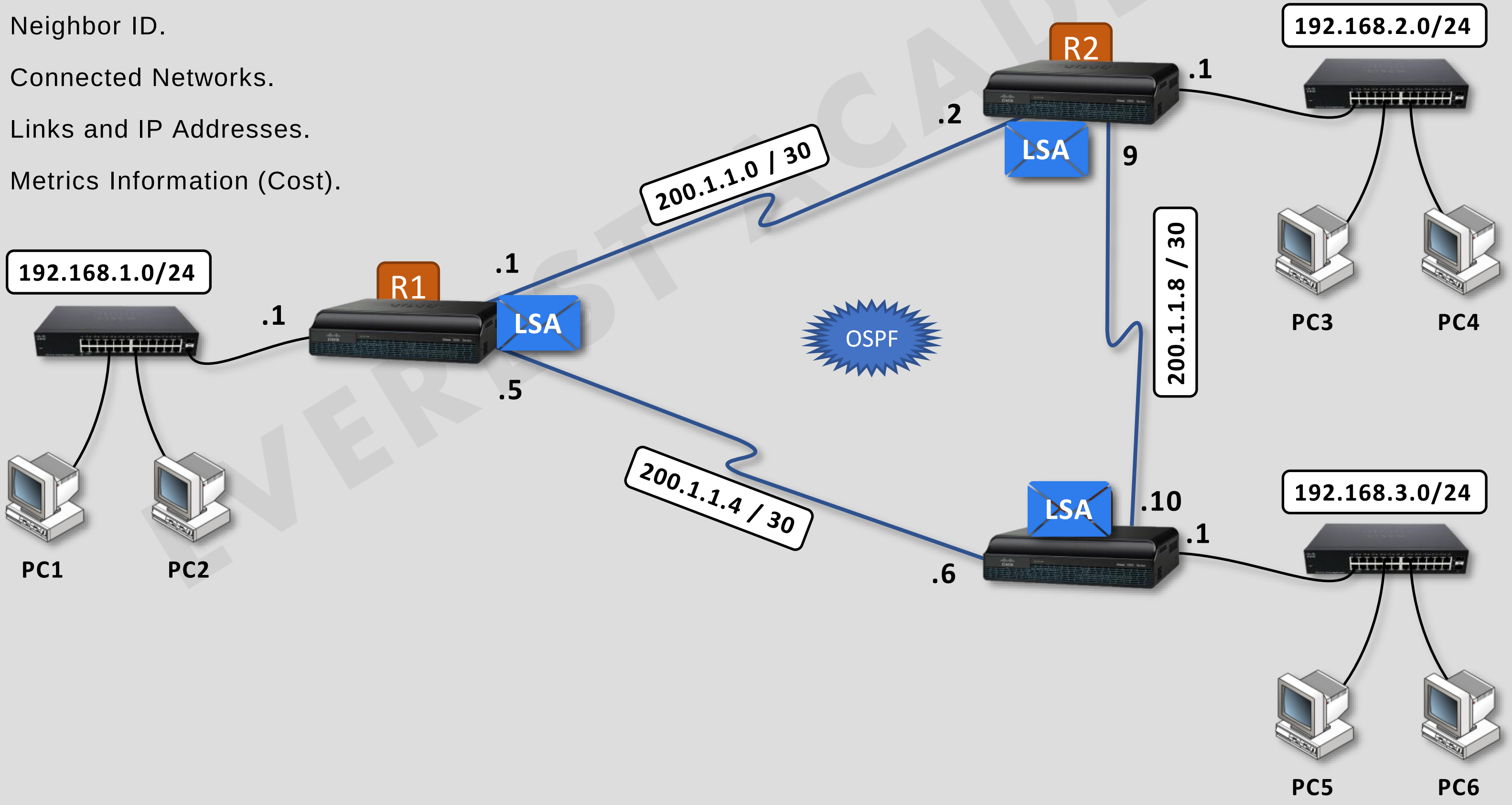
❖ **OSPF Protocol** is a Link-state protocol.

❖ **OSPF Protocol** exchanges data about the networks using ***link-state advertisements (LSA) .***

❖ **Each router** builds a link-state advertisement (LSA) packet and floods it to all other router in the topology.

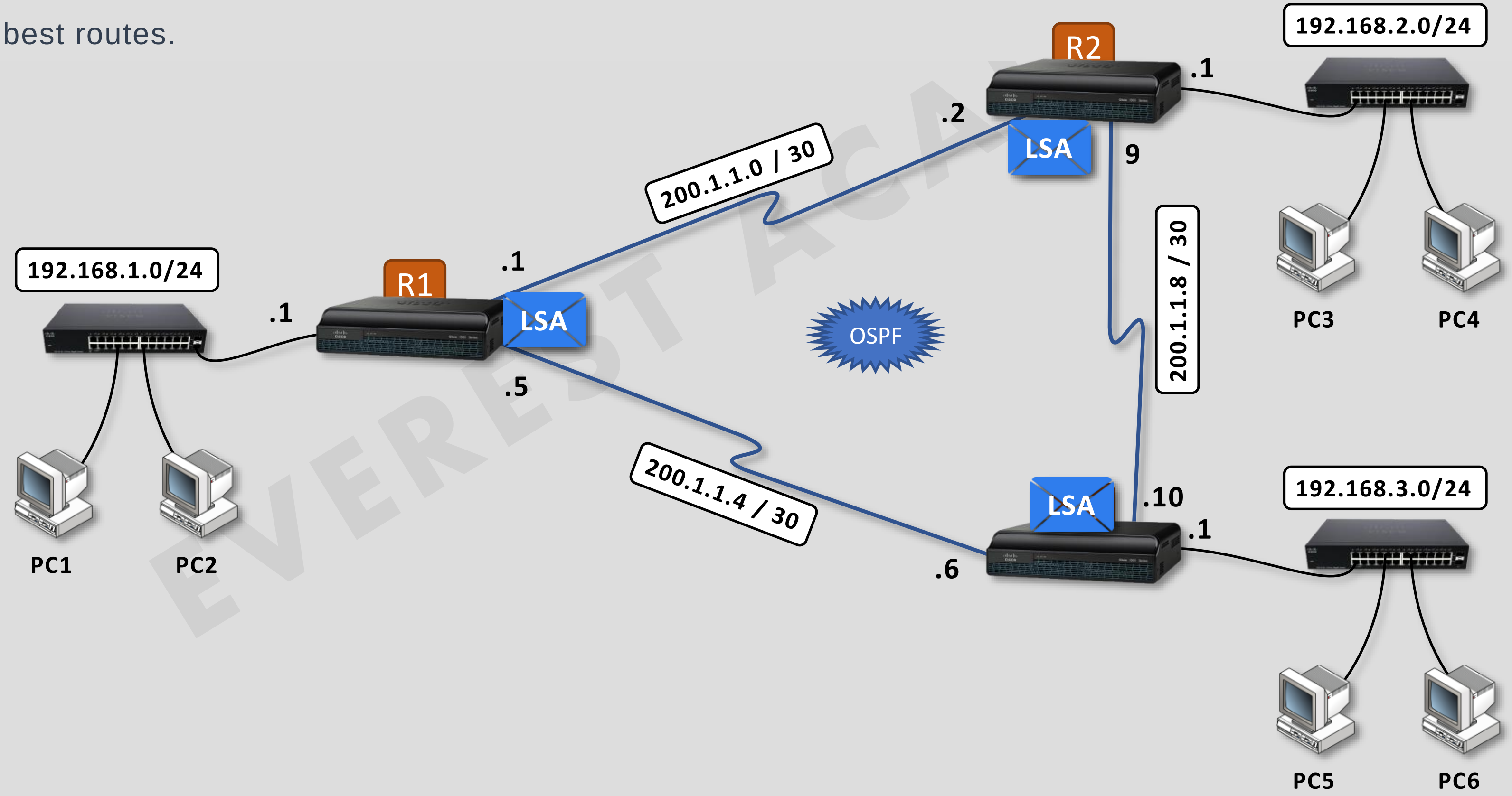
❖ **The link-state advertisement (LSA)** packet contains information such as :

- Router ID.
- Neighbor ID.
- Connected Networks.
- Links and IP Addresses.
- Metrics Information (Cost).



Link-state Database (LSDB).

- **The LSDB (Link State Database)** is the database that OSPF builds and is based on the information that it has found in LSAs (Link State Advertisements).
- **The LSDB** is synchronized between routers within the same area.
- **After LSDBs** are synced between the routers, OSPF uses the shortest path first (SPF) algorithm to calculate the best routes.

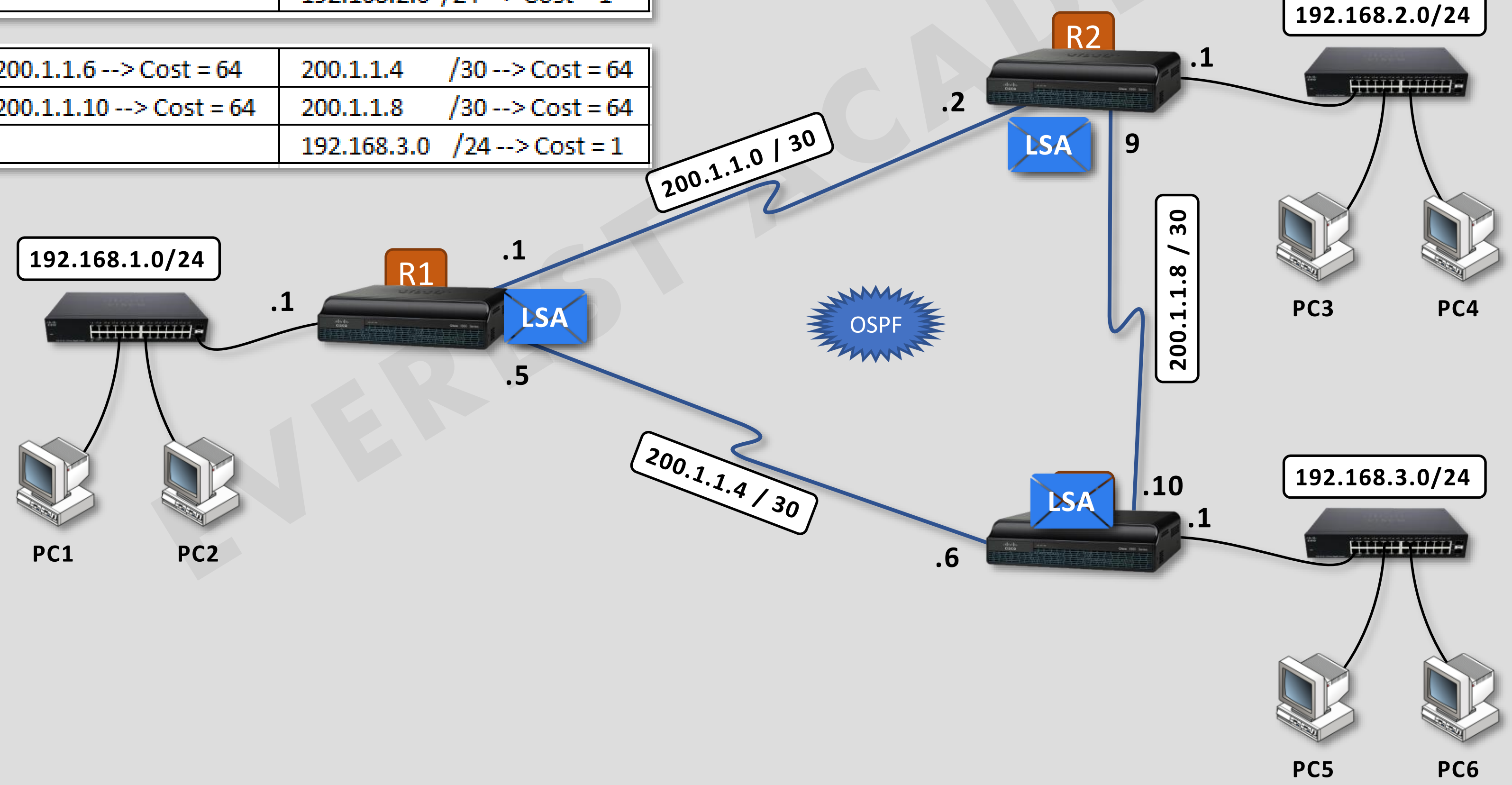


Link-state Database (LSDB).

	Connected to another Router	Connected to Network
R1	R3 (Point-To-Point) / 200.1.1.5 --> Cost = 64	200.1.1.4 /30 --> Cost = 64
	R2 (Point-To-Point) / 200.1.1.1 --> Cost = 64	200.1.1.0 /30 --> Cost = 64
		192.168.1.0 /24 --> Cost = 1

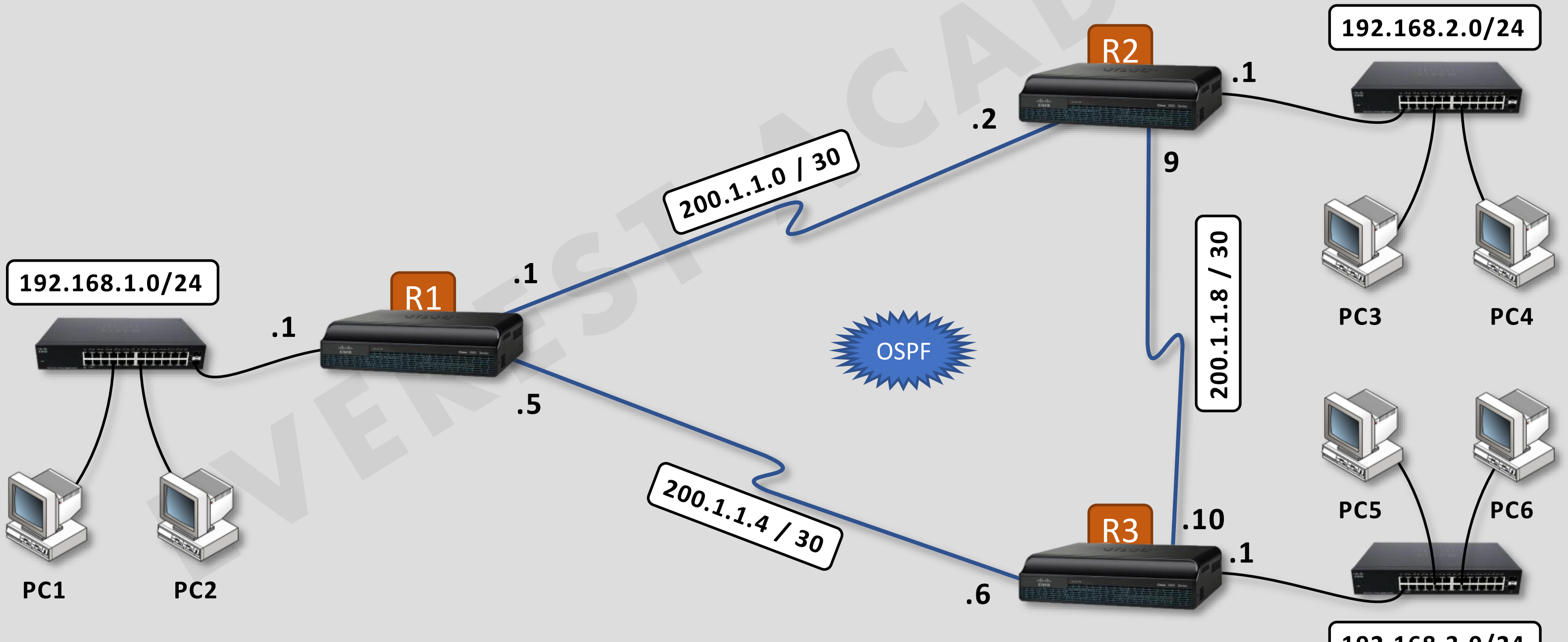
R2	R1 (Point-To-Point) / 200.1.1.2 --> Cost = 64	200.1.1.8 /30 --> Cost = 64
	R3 (Point-To-Point) / 200.1.1.9 --> Cost = 64	200.1.1.0 /30 --> Cost = 64
		192.168.2.0 /24 --> Cost = 1

R3	R1 (Point-To-Point) / 200.1.1.6 --> Cost = 64	200.1.1.4 /30 --> Cost = 64
	R2 (Point-To-Point) / 200.1.1.10 --> Cost = 64	200.1.1.8 /30 --> Cost = 64
		192.168.3.0 /24 --> Cost = 1



Dijkstra SPF Algorithm

- ❖ **link-state protocols** use Dijkstra Shortest Path First (SPF) algorithm, to process the LSDB.
- ❖ **SPF algorithm** analyzes the LSDB and builds the routes that the local router should add to the IP routing table.
- ❖ **Each route** represented by a subnet number and mask, an outgoing interface, and a next-hop router IP address.



Dijkstra SPF Algorithm

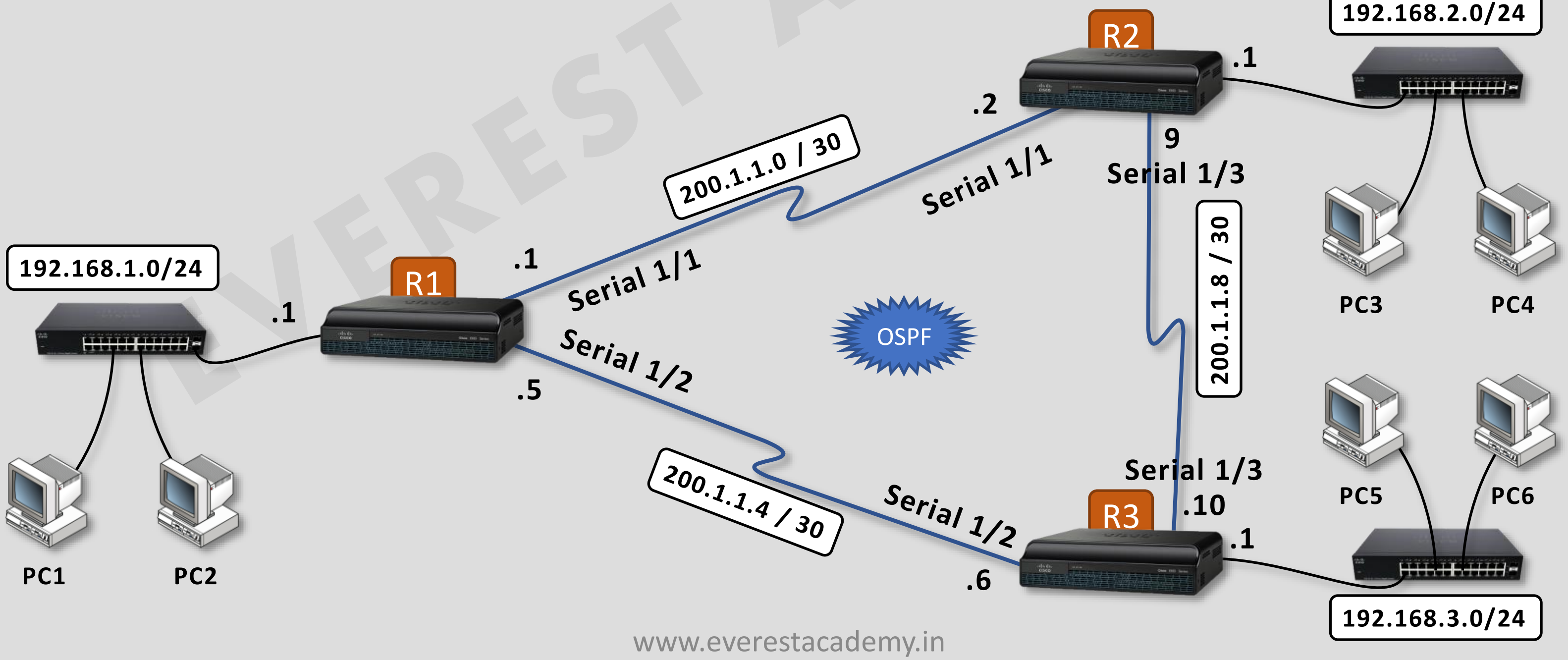
	Connected to another Router	Connected to Network
R1	R3 (Point-To-Point) / 200.1.1.5 --> Cost = 64	200.1.1.4 /30 --> Cost = 64
	R2 (Point-To-Point) / 200.1.1.1 --> Cost = 64	200.1.1.0 /30 --> Cost = 64
		192.168.1.0 /24 --> Cost = 1
R2	R1 (Point-To-Point) / 200.1.1.2 --> Cost = 64	200.1.1.8 /30 --> Cost = 64
	R3 (Point-To-Point) / 200.1.1.9 --> Cost = 64	200.1.1.0 /30 --> Cost = 64
		192.168.2.0 /24 --> Cost = 1
R3	R1 (Point-To-Point) / 200.1.1.6 --> Cost = 64	200.1.1.4 /30 --> Cost = 64
	R2 (Point-To-Point) / 200.1.1.10 --> Cost = 64	200.1.1.8 /30 --> Cost = 64
		192.168.3.0 /24 --> Cost = 1

SPF Algorithm

R1
```
O    192.168.2.0/24 [110/65] via 200.1.1.2 , Serial 1/1
O    192.168.3.0/24 [110/65] via 200.1.1.6, Serial 1/2
O       200.1.1.8/30 [110/128] via 200.1.1.6, Serial 1/2
                     [110/128] via 200.1.1.2, Serial 1/1
```

R2
```
O    192.168.1.0/24 [110/65] via 200.1.1.1 , Serial 1/1
O    192.168.3.0/24 [110/65] via 200.1.1.10 , Serial 1/3
O       200.1.1.4/30 [110/128] via 200.1.1.10 , Serial 1/3
                     [110/128] via 200.1.1.1 , Serial 1/1
```

R3
```
O    192.168.1.0/24 [110/65] via 200.1.1.5 , Serial 1/2
O    192.168.2.0/24 [110/65] via 200.1.1.9 , Serial 1/3
O       200.1.1.0/30 [110/128] via 200.1.1.9 , Serial 1/3
                     [110/128] via 200.1.1.5 , Serial 1/2
```



رابط دورة المدخل الى شبكات سيسكو CCNA 200-301 على موقع يودمي , هذه الدورة من إعداد المدرب عبد الرحمن العلوش

OSPFv2

	Connected to another Router	Connected to Network
R1	R3 (Point-To-Point) / 200.1.1.5 --> Cost = 64	200.1.1.4 /30 --> Cost = 64
	R2 (Point-To-Point) / 200.1.1.1 --> Cost = 64	200.1.1.0 /30 --> Cost = 64
		192.168.1.0 /24 --> Cost = 1
R2	R1 (Point-To-Point) / 200.1.1.2 --> Cost = 64	200.1.1.8 /30 --> Cost = 64
	R3 (Point-To-Point) / 200.1.1.9 --> Cost = 64	200.1.1.0 /30 --> Cost = 64
		192.168.2.0 /24 --> Cost = 1
R3	R1 (Point-To-Point) / 200.1.1.6 --> Cost = 64	200.1.1.4 /30 --> Cost = 64
	R2 (Point-To-Point) / 200.1.1.10 --> Cost = 64	200.1.1.8 /30 --> Cost = 64
		192.168.3.0 /24 --> Cost = 1

Link-state Database (LSDB)

SPF Algorithm

R1

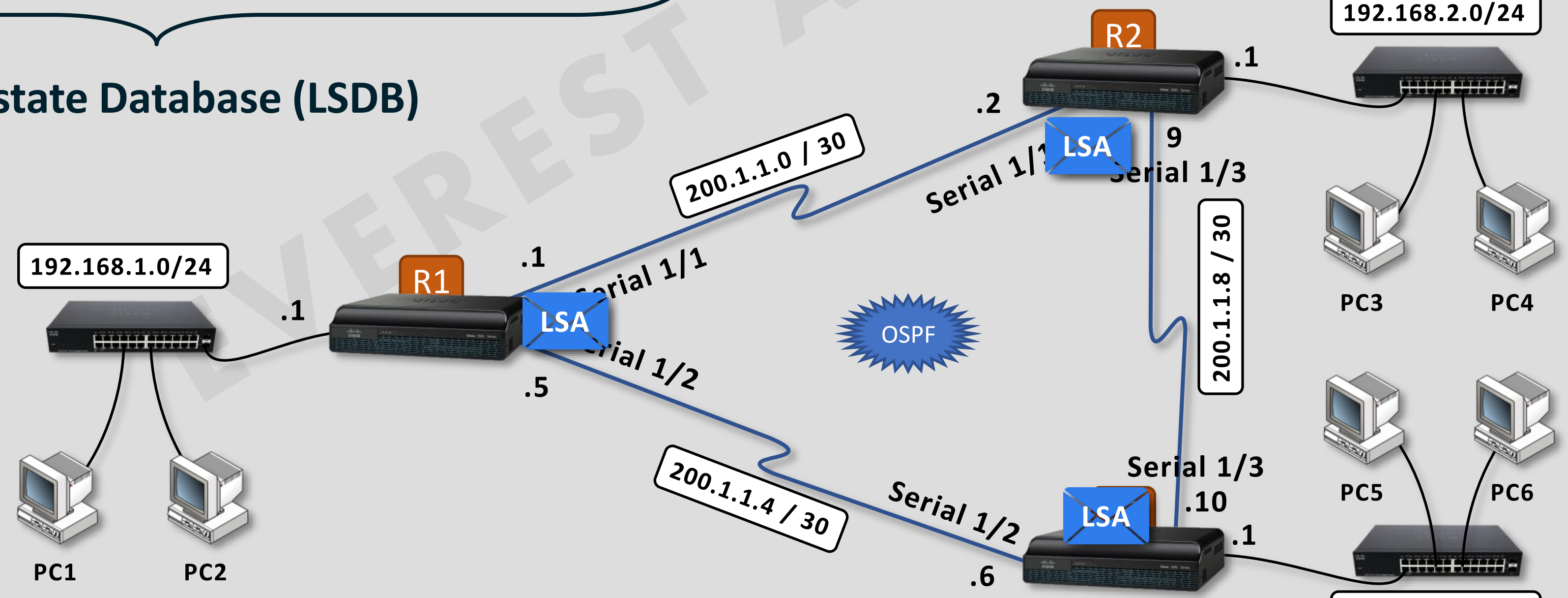
O 192.168.2.0/24 [110/65] via 200.1.1.2 , Serial 1/1
O 192.168.3.0/24 [110/65] via 200.1.1.6, Serial 1/2
O 200.1.1.8/30 [110/128] via 200.1.1.6, Serial 1/2
[110/128] via 200.1.1.2, Serial 1/1

R2

O 192.168.1.0/24 [110/65] via 200.1.1.1 , Serial 1/1
O 192.168.3.0/24 [110/65] via 200.1.1.10 , Serial 1/3
O 200.1.1.4/30 [110/128] via 200.1.1.10 , Serial 1/3
[110/128] via 200.1.1.1 , Serial 1/1

R3

O 192.168.1.0/24 [110/65] via 200.1.1.5 , Serial 1/2
O 192.168.2.0/24 [110/65] via 200.1.1.9 , Serial 1/3
O 200.1.1.0/30 [110/128] via 200.1.1.9 , Serial 1/3
[110/128] via 200.1.1.5 , Serial 1/2



OSPF Neighbor Relationship and Adjacency

OSPF Router ID (RID) :

❖ **A Router ID** is 32-bit number assigned to each router running the OSPF protocol. This number uniquely identifies the router within an Autonomous System (AS).

---------- . ---------- . ---------- . ----------

8 bits 8 bits 8 bits 8 bits

32 bits

❖ **OSPF** uses the following criteria to select the router ID:

1. Manually configured OSPF Router ID using **router-id command**.
2. Highest IP address on any of the router's **loopback interfaces**.
3. Highest IP address on any of the router's **active interfaces**.

- **Router-id 1.1.1.1**
- **Fastethernet 0/0 : 192.168.1.1 --> up/up**
- **Serial 1/1 : 200.1.1.1 --> up/up**
- **Loopback 1 : 10.0.0.1**
- **Loopback 2 : 172.16.0.1**

OSPF process failed to allocate unique router-id and cannot start

OSPF Neighbor Relationship and Adjacency

OSPF Hello Message :

❖ **Hello messages** are used to discover, build, and maintain OSPF ***neighbor relationship***.

❖ **An OSPF router** generates a Hello message every ***10 seconds*** for Peer-to-Peer (P2P) networks and ***30 seconds*** for Non-Broadcast-Multiple-Access (NBMA) networks by default.

❖ **An OSPF router** sends Hello message through multicast address ***224.0.0.5*** to all routers connected to its interfaces.

❖ **The Hello message** contains a list of information needed to form an OSPF neighbor relationship between two routers.

❖ **To establish neighbor relationship**, OSPF routers at both sides of the link must agree on some parameters contained in the Hello message to become OSPF neighbors.

- They must have the same IP network/subnet.
- The Hello and Dead Interval timers must be identical.
- Router interfaces connecting two routers must have the same Area ID.
- Type of area must be identical (normal or stub area).
- Authentication password (if used) must be identical.

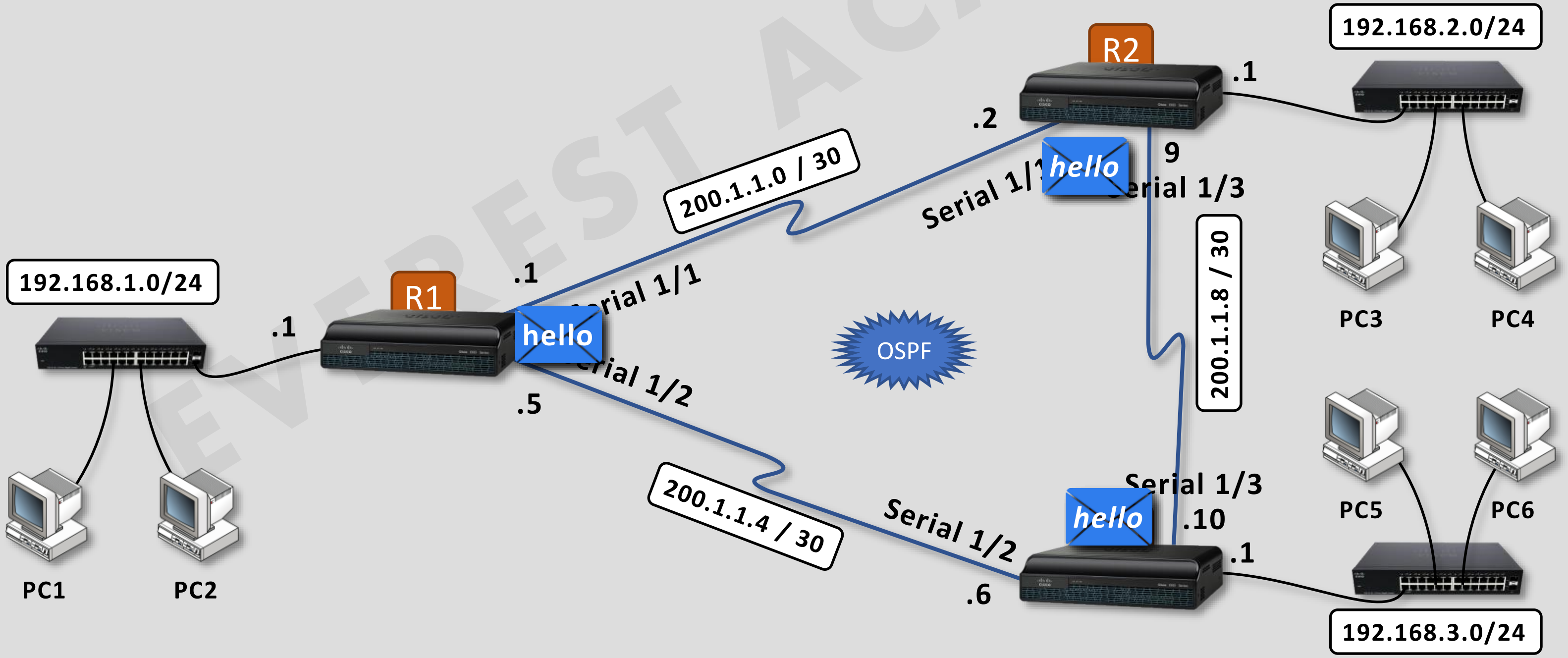
```
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: Hello Packet (1)
      Packet Length: 44
      Source OSPF Router: 1.1.1.1
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0xe9a0 [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  v OSPF Hello Packet
      Network Mask: 255.255.255.252
      Hello Interval [sec]: 10
    > Options: 0x12, (L) LLS Data block,
      Router Priority: 1
      Router Dead Interval [sec]: 40
      Designated Router: 0.0.0.0
```

OSPF Neighbor Relationship and Adjacency

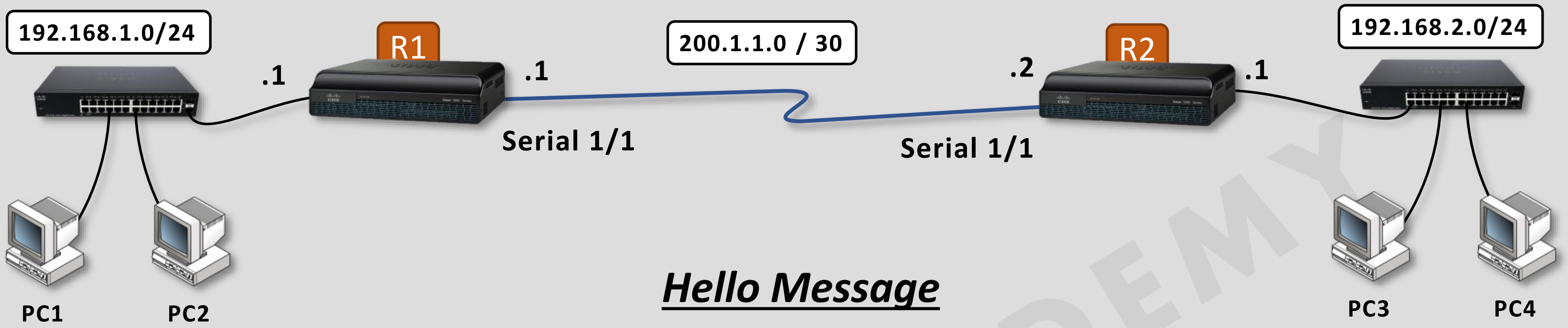
❖ **Neighbor Table** Contains all discovered OSPF neighbors with whom routing information will be exchanged.

```
R3#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2           0   FULL/  -        00:00:31    200.1.1.9       Serial1/3
1.1.1.1           0   FULL/  -        00:00:31    200.1.1.5       Serial1/2
```



OSPF Neighbor Relationship and Adjacency

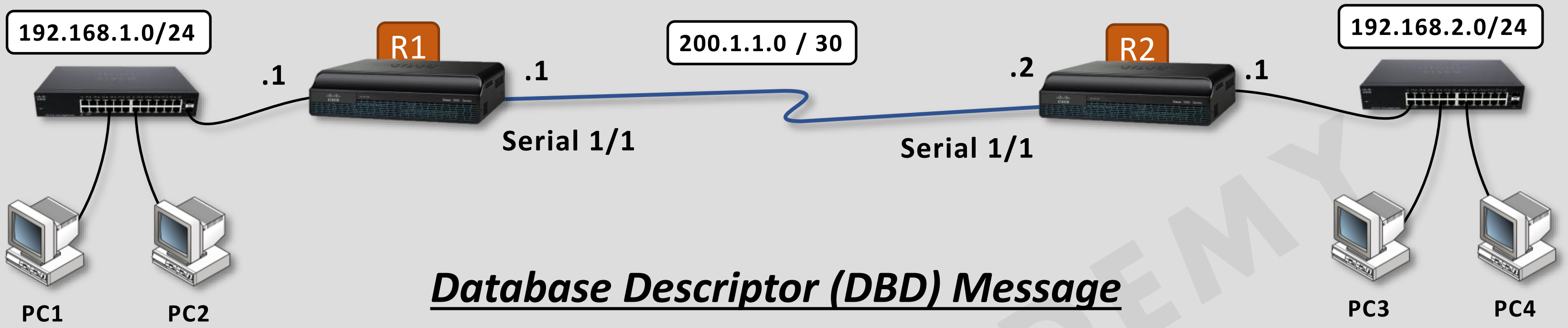


Hello Message

```
> Frame 5: 84 bytes on wire (672 bits), 84 bytes captured (672 bi
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.1, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: Hello Packet (1)
      Packet Length: 48
      Source OSPF Router: 1.1.1.1
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0xe598 [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  v OSPF Hello Packet
      Network Mask: 255.255.255.252
      Hello Interval [sec]: 10
    > Options: 0x12, (L) LLS Data block, (E) External Routing
      Router Priority: 1
      Router Dead Interval [sec]: 40
      Designated Router: 0.0.0.0
      Backup Designated Router: 0.0.0.0
      Active Neighbor: 2.2.2.2
  > OSPF LLS Data Block
```

```
> Frame 7: 84 bytes on wire (672 bits), 84 bytes captured (672 b
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.2, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: Hello Packet (1)
      Packet Length: 48
      Source OSPF Router: 2.2.2.2
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0xe598 [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  v OSPF Hello Packet
      Network Mask: 255.255.255.252
      Hello Interval [sec]: 10
    > Options: 0x12, (L) LLS Data block, (E) External Routing
      Router Priority: 1
      Router Dead Interval [sec]: 40
      Designated Router: 0.0.0.0
      Backup Designated Router: 0.0.0.0
      Active Neighbor: 1.1.1.1
  > OSPF LLS Data Block
```

OSPF Neighbor Relationship and Adjacency

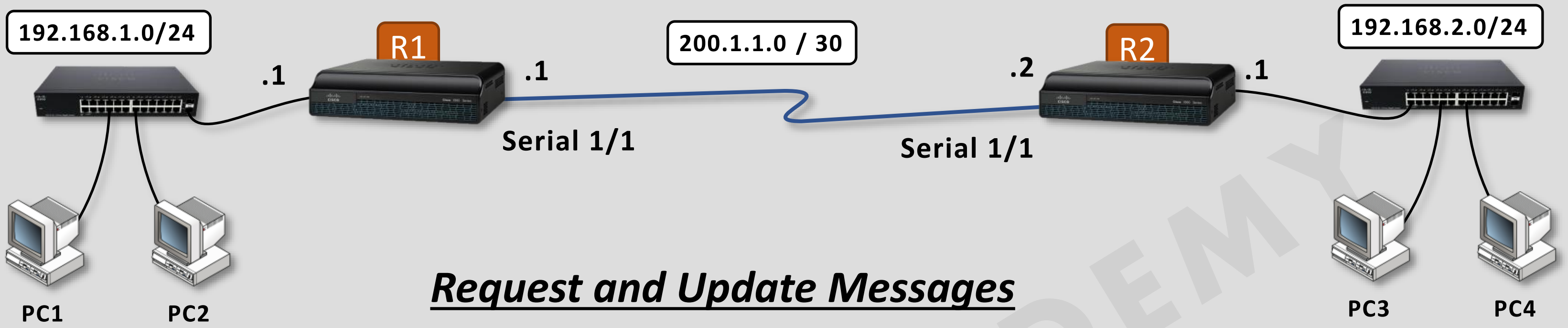


Database Descriptor (DBD) Message

```
> Frame 9: 108 bytes on wire (864 bits), 108 bytes captured (86
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.1, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: DB Description (2)
      Packet Length: 72
      Source OSPF Router: 1.1.1.1
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0x0889 [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  v OSPF DB Description
      Interface MTU: 1500
    > Options: 0x52, O, (L) LLS Data block, (E) External Routi
    v DB Description: 0x02, (M) More
        .... 0... = (R) OOBResync: Not set
        .... .0.. = (I) Init: Not set
        .... ..1. = (M) More: Set
        .... ...0 = (MS) Master: No
      DD Sequence: 657
  > LSA-type 1 (Router-LSA), len 48
  > LSA-type 1 (Router-LSA), len 60
```

```
> Frame 10: 108 bytes on wire (864 bits), 108 bytes captured (8
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.2, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: DB Description (2)
      Packet Length: 72
      Source OSPF Router: 2.2.2.2
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0x6bf3 [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  v OSPF DB Description
      Interface MTU: 1500
    > Options: 0x52, O, (L) LLS Data block, (E) External Routi
    v DB Description: 0x01, (MS) Master
        .... 0... = (R) OOBResync: Not set
        .... .0.. = (I) Init: Not set
        .... ..0. = (M) More: Not set
        .... ...1 = (MS) Master: Yes
      DD Sequence: 658
  > LSA-type 1 (Router-LSA), len 60
  > LSA-type 1 (Router-LSA), len 36
```

OSPF Neighbor Relationship and Adjacency

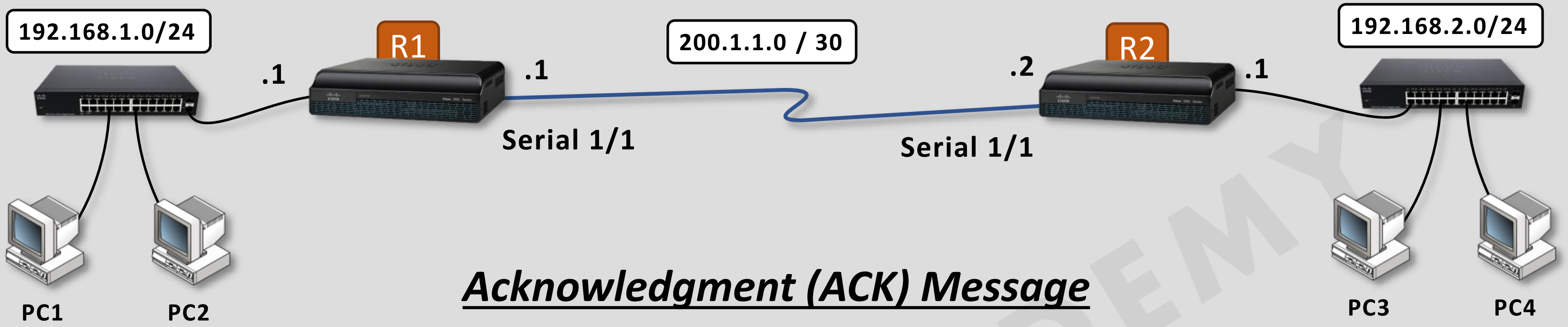


Request and Update Messages

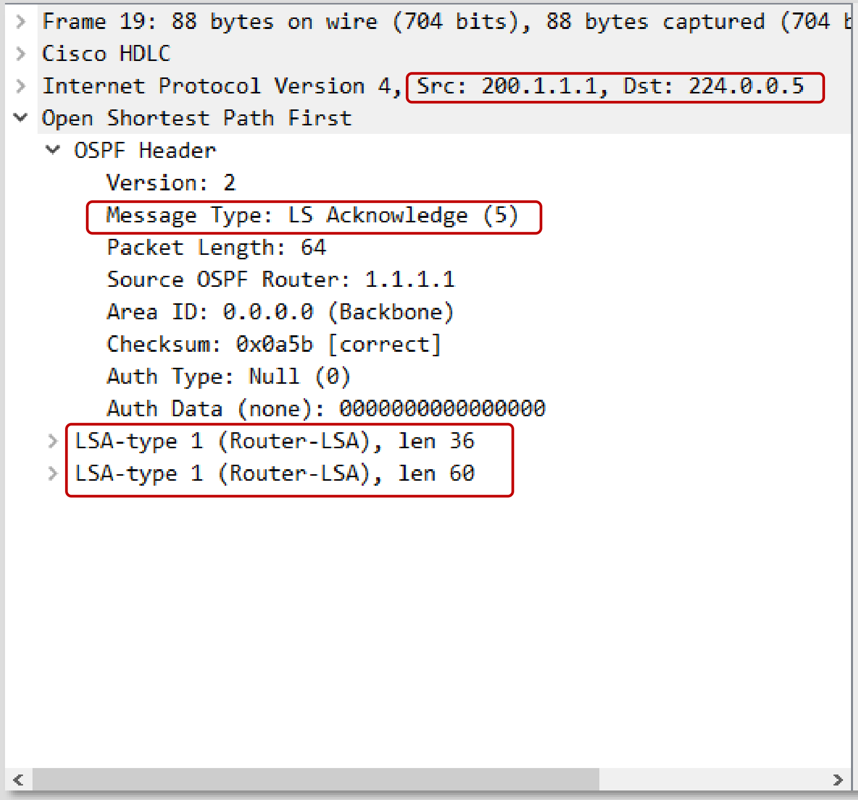
```
> Frame 11: 60 bytes on wire (480 bits), 60 bytes captured (480 b
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.1, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: LS Request (3)
      Packet Length: 36
      Source OSPF Router: 1.1.1.1
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0xf3cd [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  v Link State Request
      LS Type: Router-LSA (1)
      Link State ID: 2.2.2.2
      Advertising Router: 2.2.2.2
```

```
> Frame 13: 88 bytes on wire (704 bits), 88 bytes captured (704 b
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.2, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: LS Update (4)
      Packet Length: 64
      Source OSPF Router: 2.2.2.2
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0xa5bc [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  v LS Update Packet
      Number of LSAs: 1
    > LSA-type 1 (Router-LSA), len 36
```

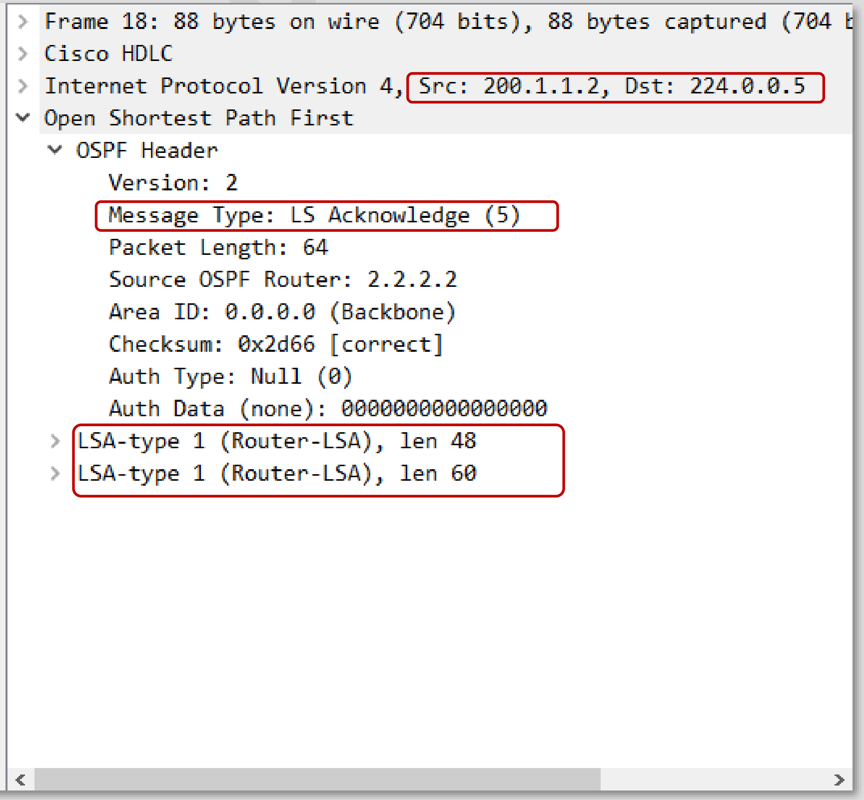
OSPF Neighbor Relationship and Adjacency



Acknowledgment (ACK) Message

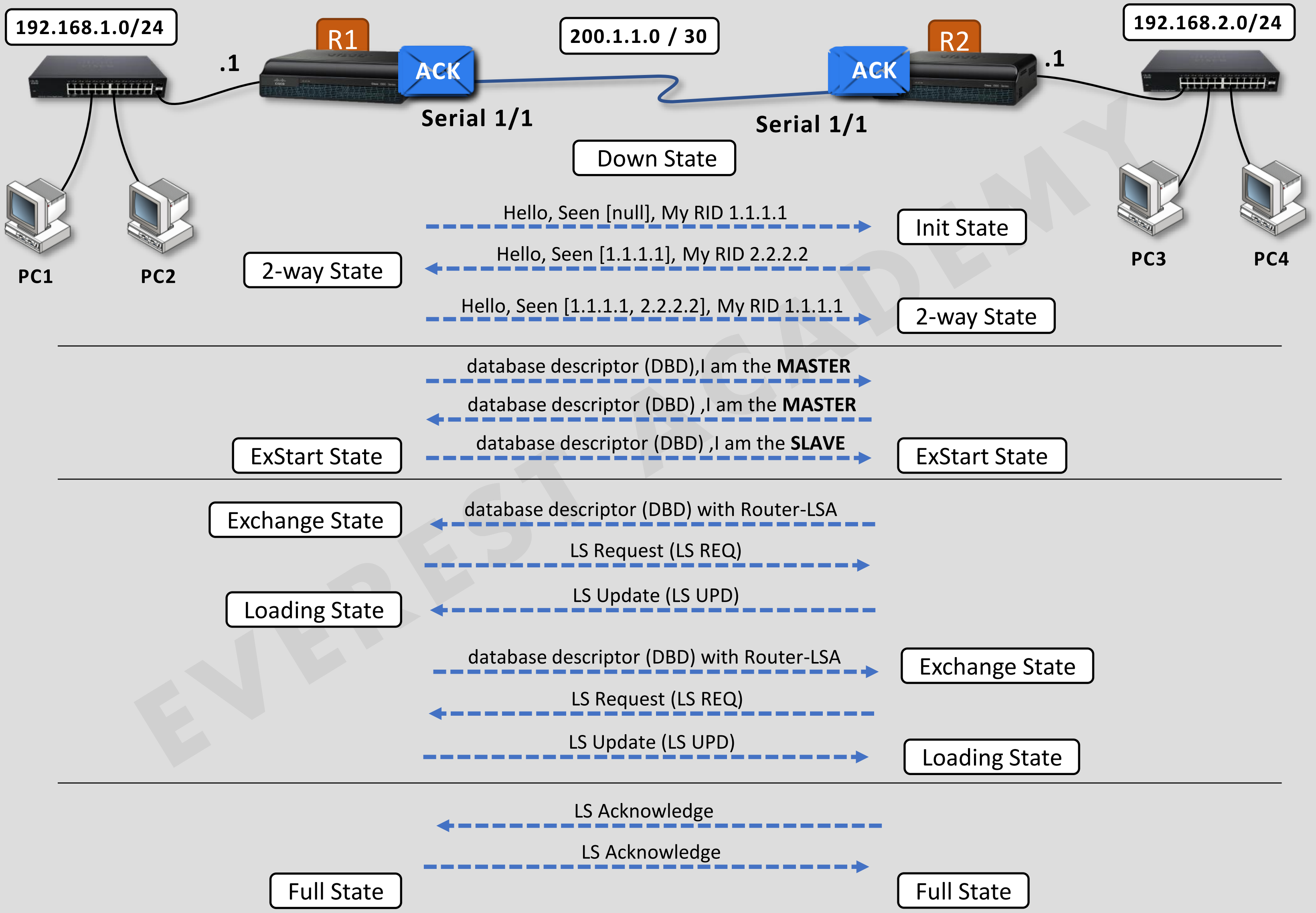


```
> Frame 19: 88 bytes on wire (704 bits), 88 bytes captured (704 b
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.1, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: LS Acknowledge (5)
      Packet Length: 64
      Source OSPF Router: 1.1.1.1
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0x0a5b [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  > LSA-type 1 (Router-LSA), len 36
  > LSA-type 1 (Router-LSA), len 60
```

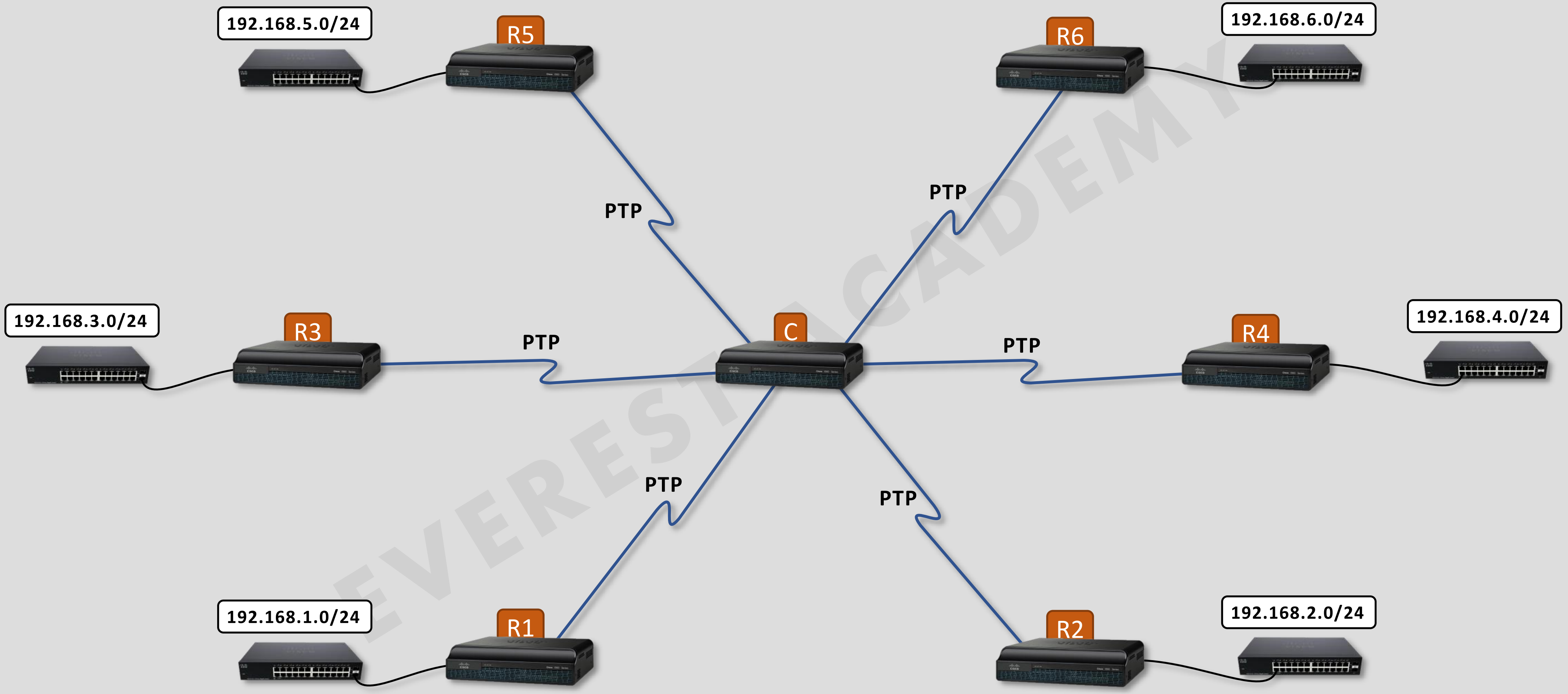


```
> Frame 18: 88 bytes on wire (704 bits), 88 bytes captured (704 b
> Cisco HDLC
> Internet Protocol Version 4, Src: 200.1.1.2, Dst: 224.0.0.5
v Open Shortest Path First
  v OSPF Header
      Version: 2
      Message Type: LS Acknowledge (5)
      Packet Length: 64
      Source OSPF Router: 2.2.2.2
      Area ID: 0.0.0.0 (Backbone)
      Checksum: 0x2d66 [correct]
      Auth Type: Null (0)
      Auth Data (none): 0000000000000000
  > LSA-type 1 (Router-LSA), len 48
  > LSA-type 1 (Router-LSA), len 60
```

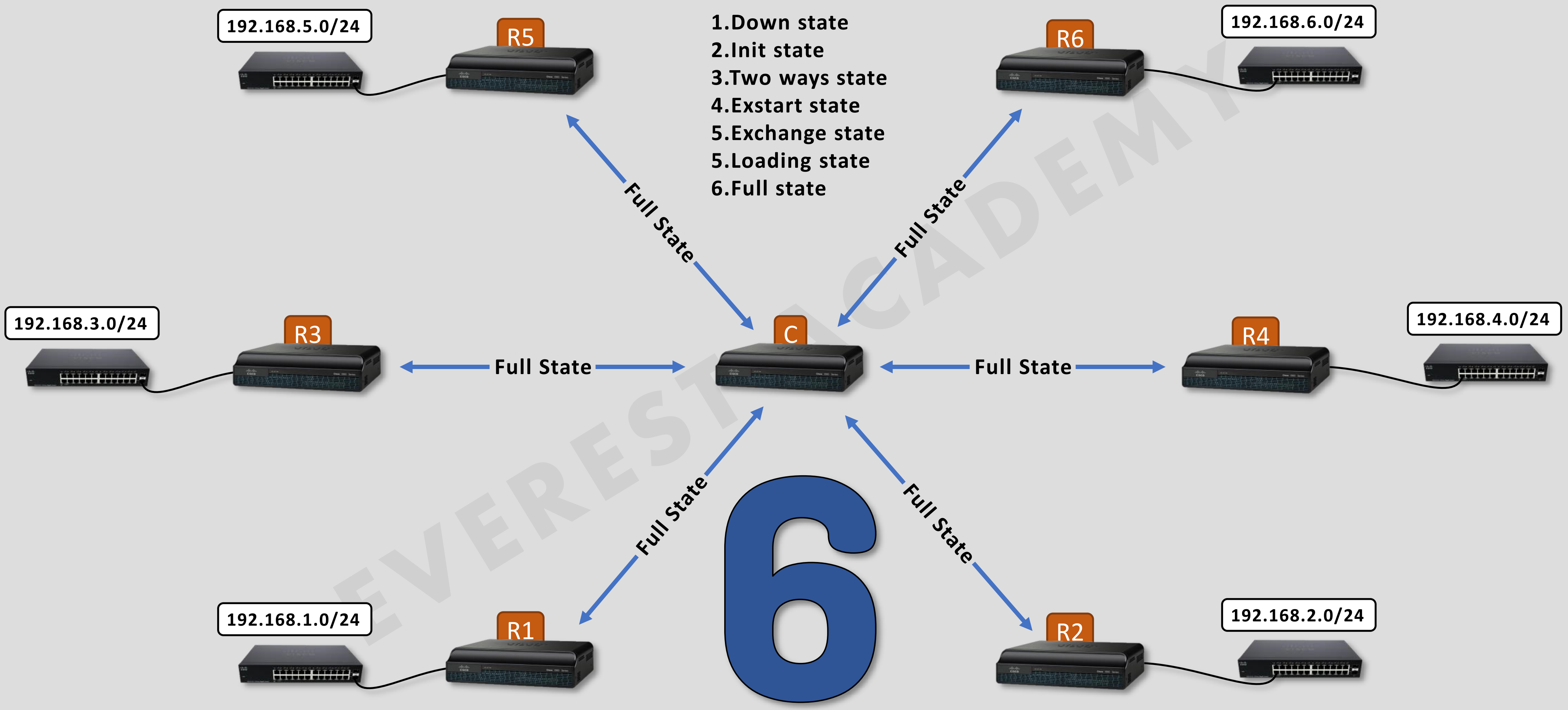
OSPF Neighbor Relationship and Adjacency



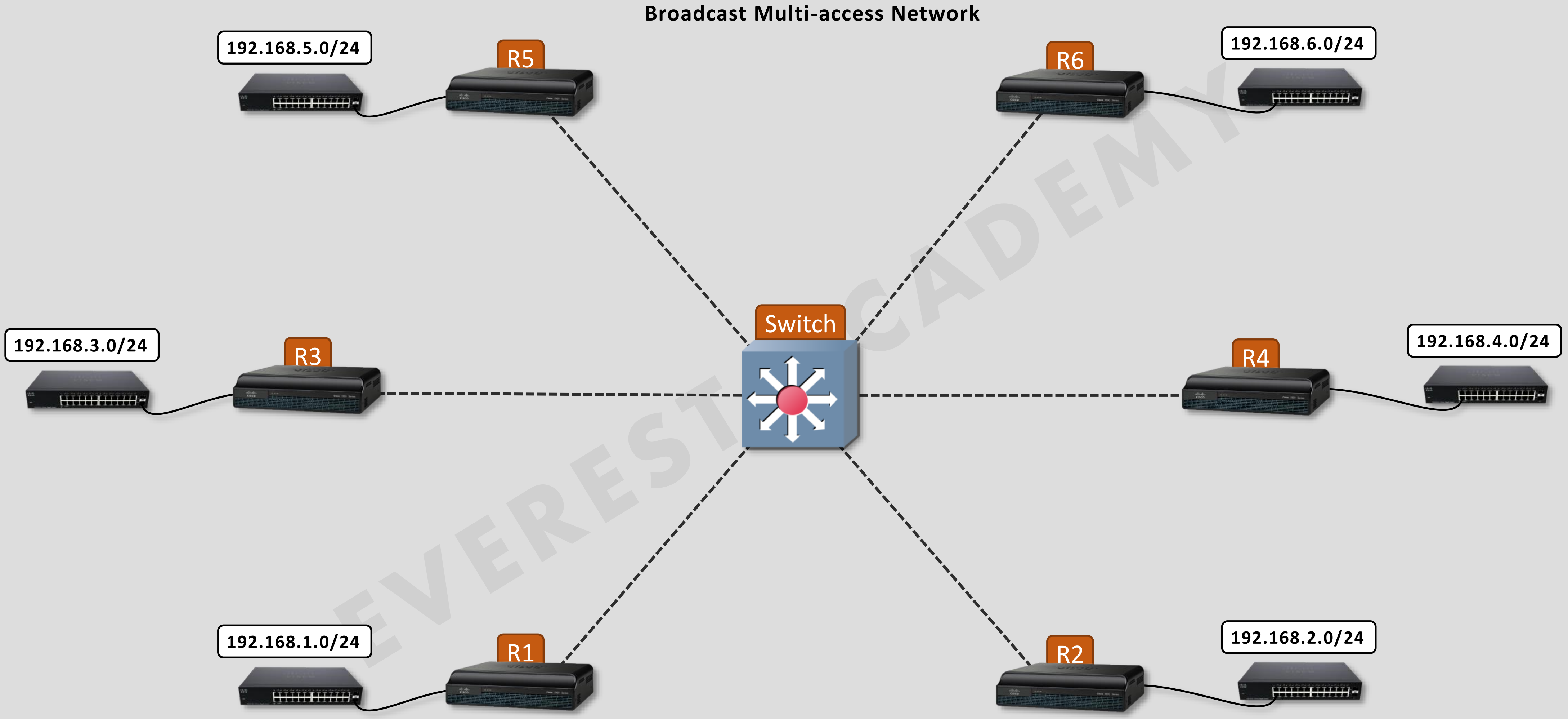
OSPF Designated Router (DR)



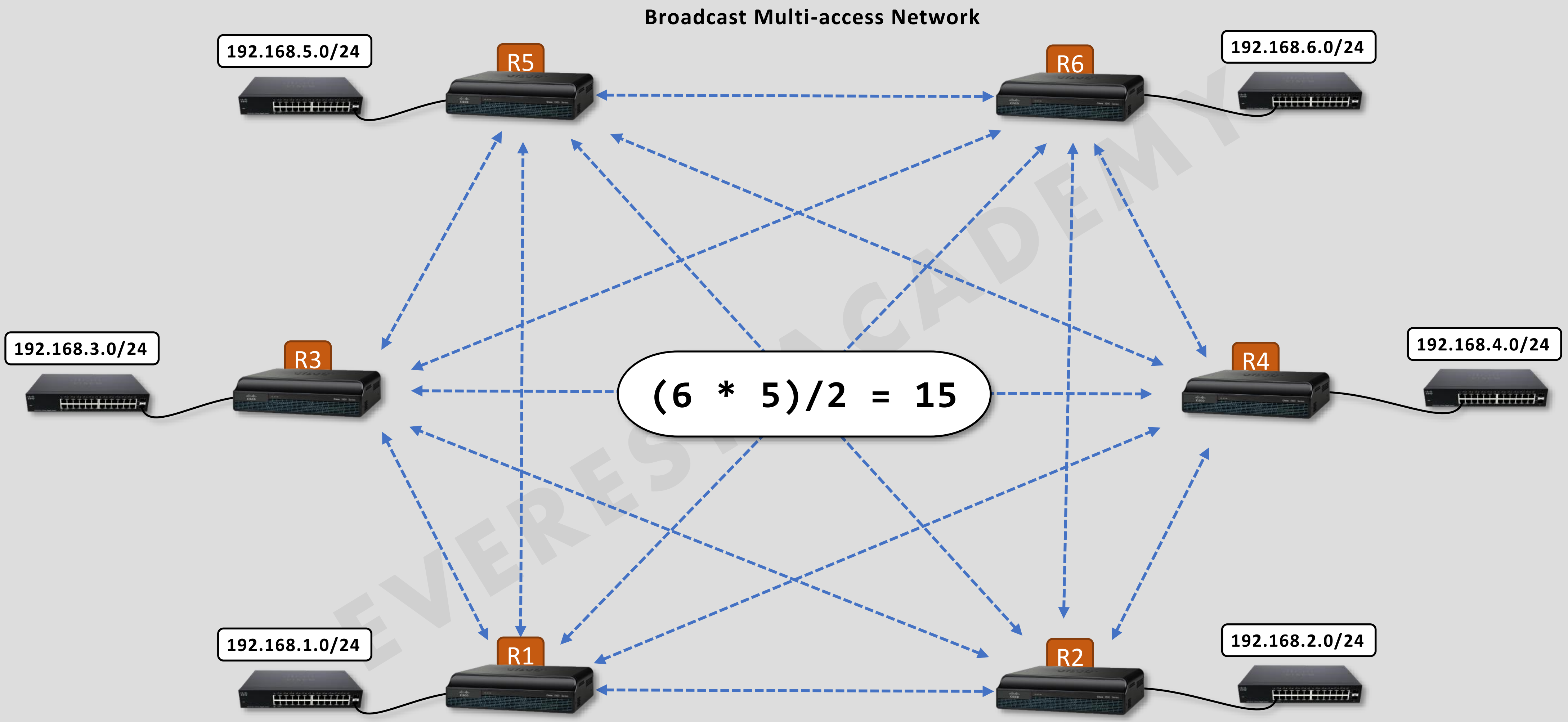
OSPF Designated Router (DR)



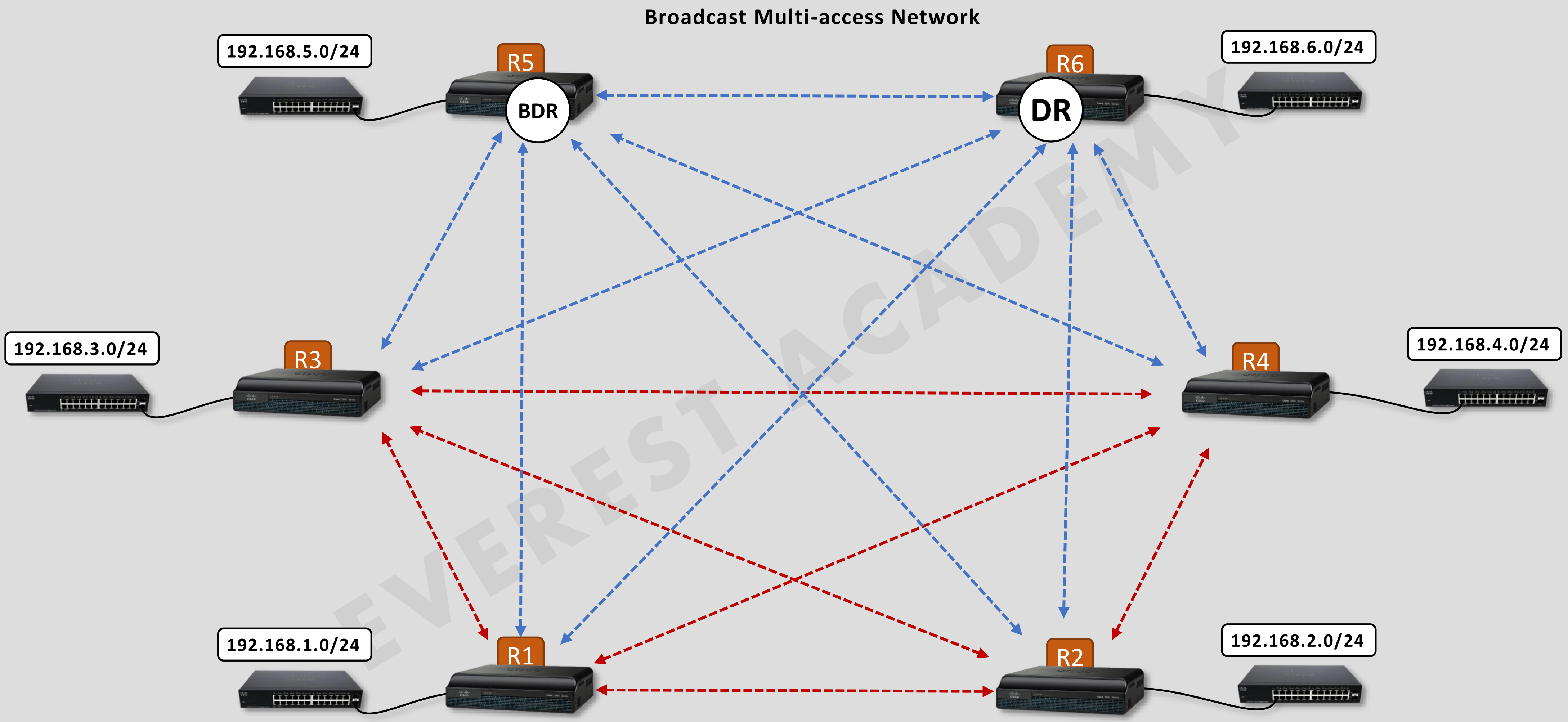
OSPF Designated Router (DR)



OSPF Designated Router (DR)



OSPF Designated Router (DR)

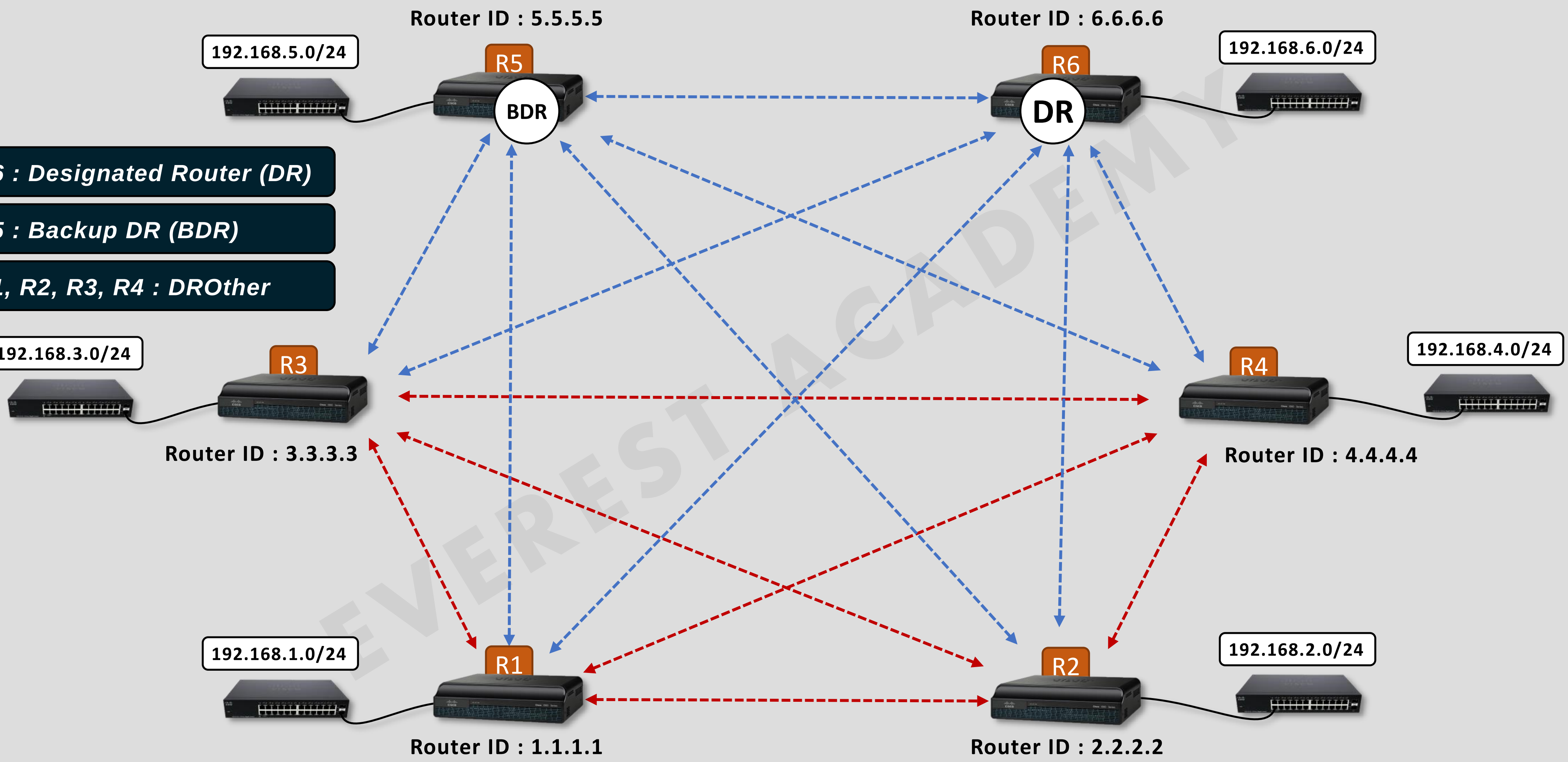


Electing The DR and BDR

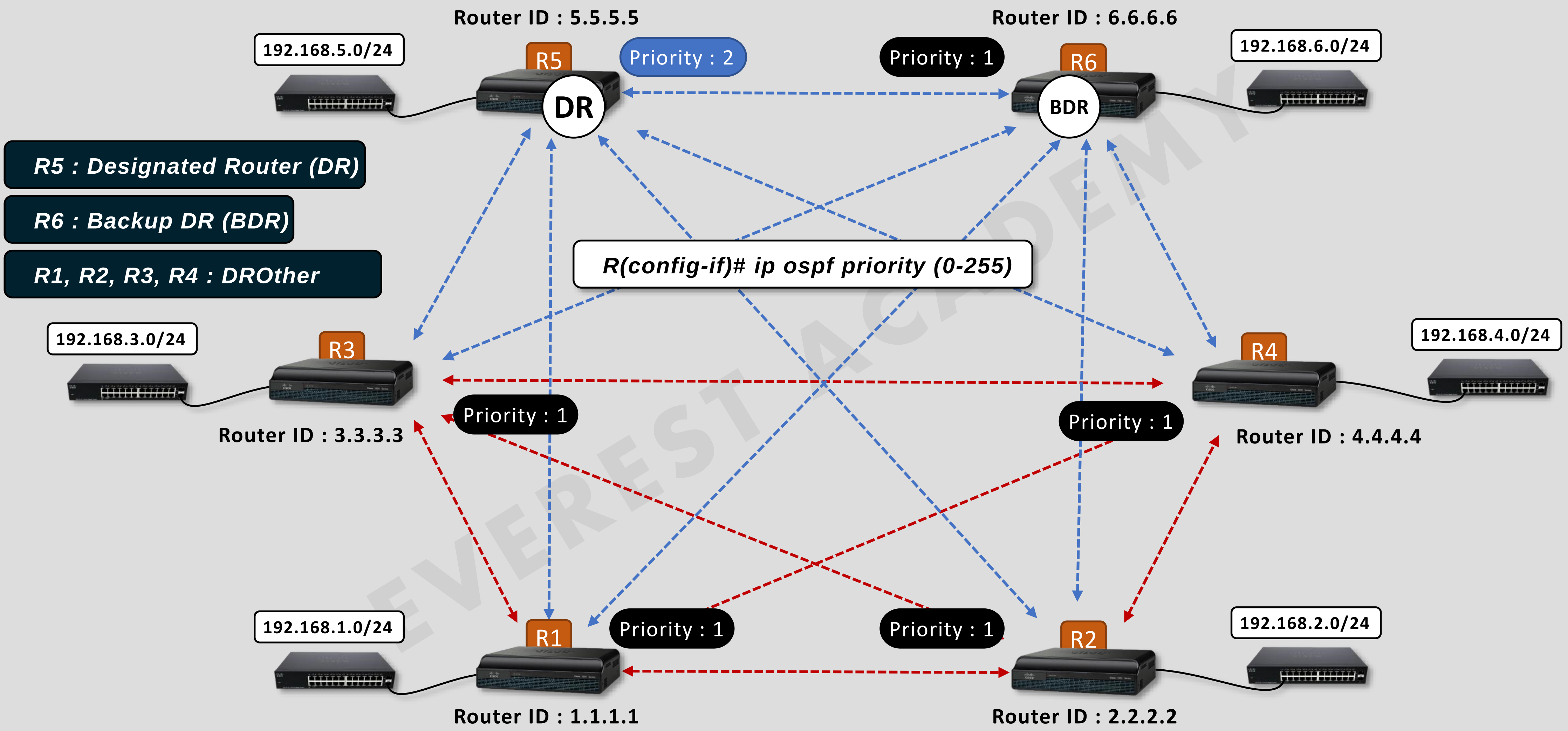
R6 : Designated Router (DR)

R5 : Backup DR (BDR)

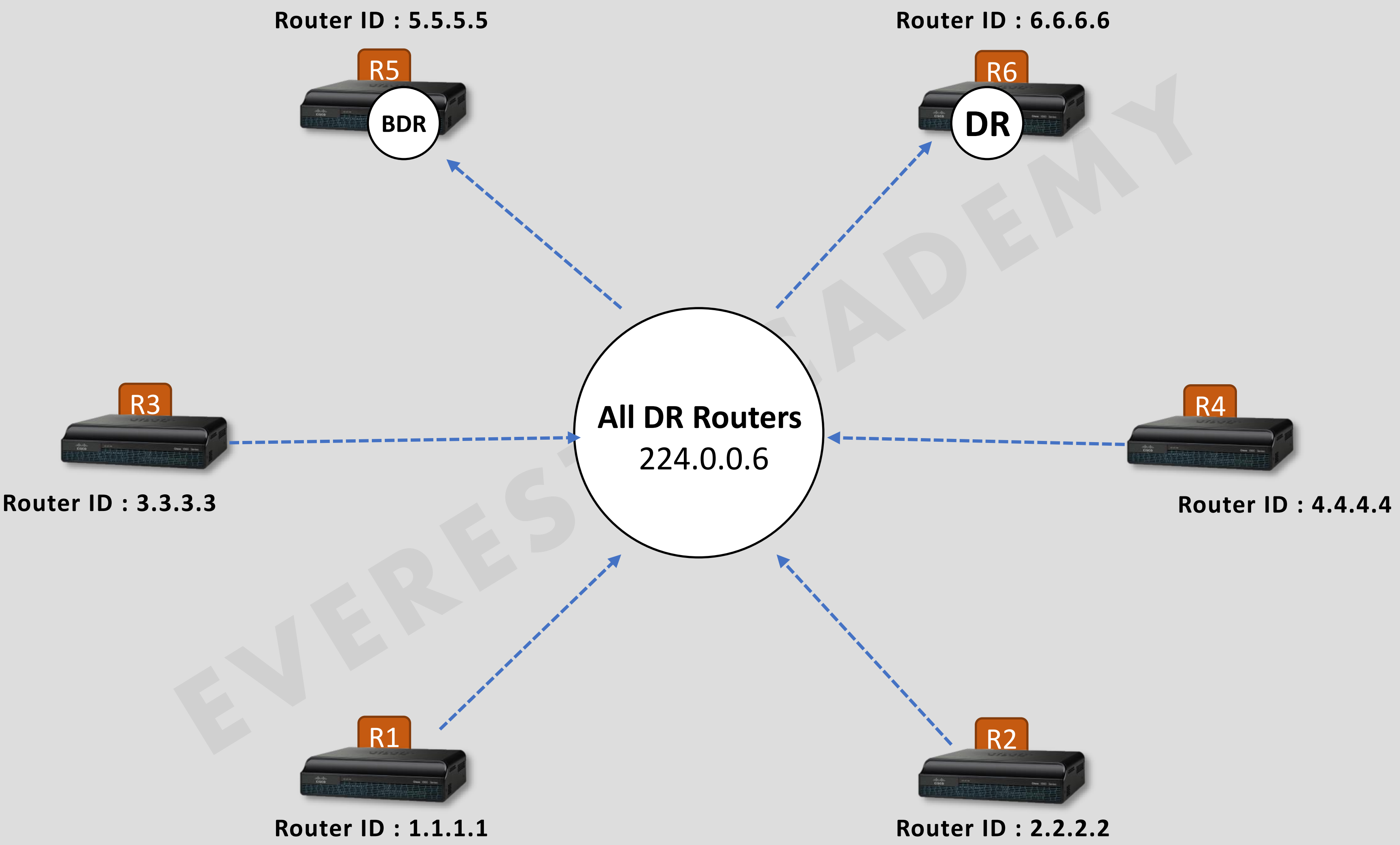
R1, R2, R3, R4 : DROther



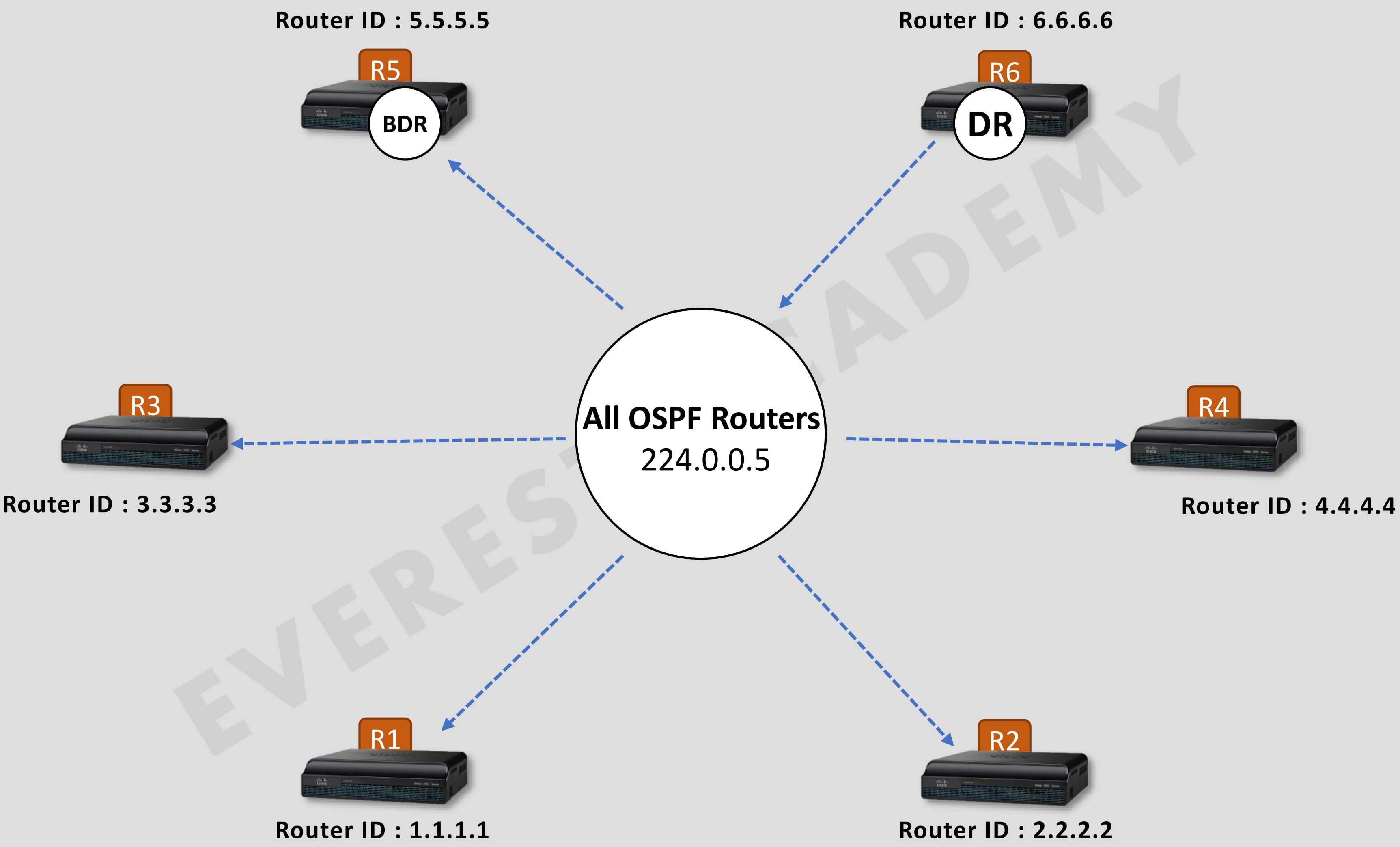
OSPF Priority



All DR Routers (224.0.0.6) and All OSPF Routers (224.0.0.5) Multicast Addresses



All DR Routers (224.0.0.6) and All OSPF Routers (224.0.0.5) Multicast Addresses



OSPF Metric (Cost)

- **In OSPF, the metric** that is used to determine the best path to a destination network is the **cost**.

- **OPSP Protocol** uses a special formula to calculate the cost of an interface :

Cisco Default Value = **100** Mbps

$$Cost = \frac{Reference\ bandwidth}{Interface\ bandwidth\ (bps)}$$

$$Cost = \frac{10^8}{Interface\ bandwidth\ (bps)}$$

```
R1#show interface fastethernet 0/0
FastEthernet0/0 is up, line protocol is up (connected)
  Hardware is Lance, address is 0060.3e31.b901 (bia 0060.3e31.b901)
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 100000 Kbit, DLY 100 usec,
     reliability 255/255, txload 1/255, rxload 1/255
```

```
R1#show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up (connected)
  Hardware is HD64570
  Internet address is 200.1.1.1/30
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
```

OSPF Metric (Cost)

❖ **In OSPF, the metric** that is used to determine the best path to a destination network is the **cost**.

❖ **OPSP Protocol** uses a special formula to calculate the cost of an interface :

Cisco Default Value = **100** Mbps

$$Cost = \frac{Reference\ bandwidth}{Interface\ bandwidth\ (bps)}$$

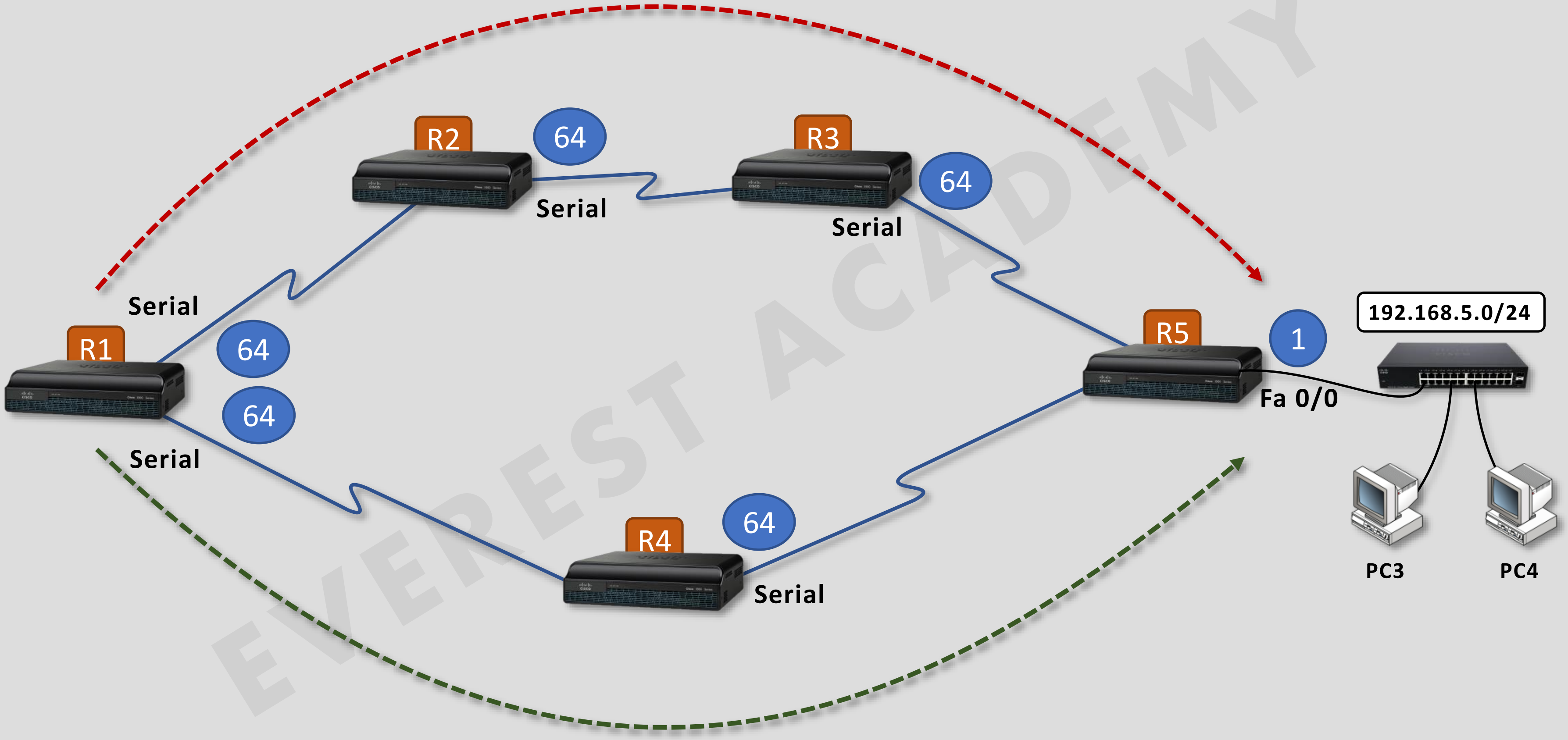
$$Cost = \frac{10^8}{Interface\ bandwidth\ (bps)}$$

Interface Type	Bandwidth	Metric Calculation	Cost
Ethernet	10 Mbps	**100** 000 000 / 10 000 000 = 10	10
FastEthernet	100 Mbps	**100** 000 000 / 100 000 000 = 1	1
GigabitEthernet	1000 Mbps	**100** 000 000 / 1000 000 000 = 0.1	1
Serial	1544 Kbps	**100** 000 000 / 1544 000 = 64.76	64

```
Router > enable
Router # configure terminal
Router (config)# router ospf 1
Router (config-router)# auto-cost reference-bandwidth 100
```

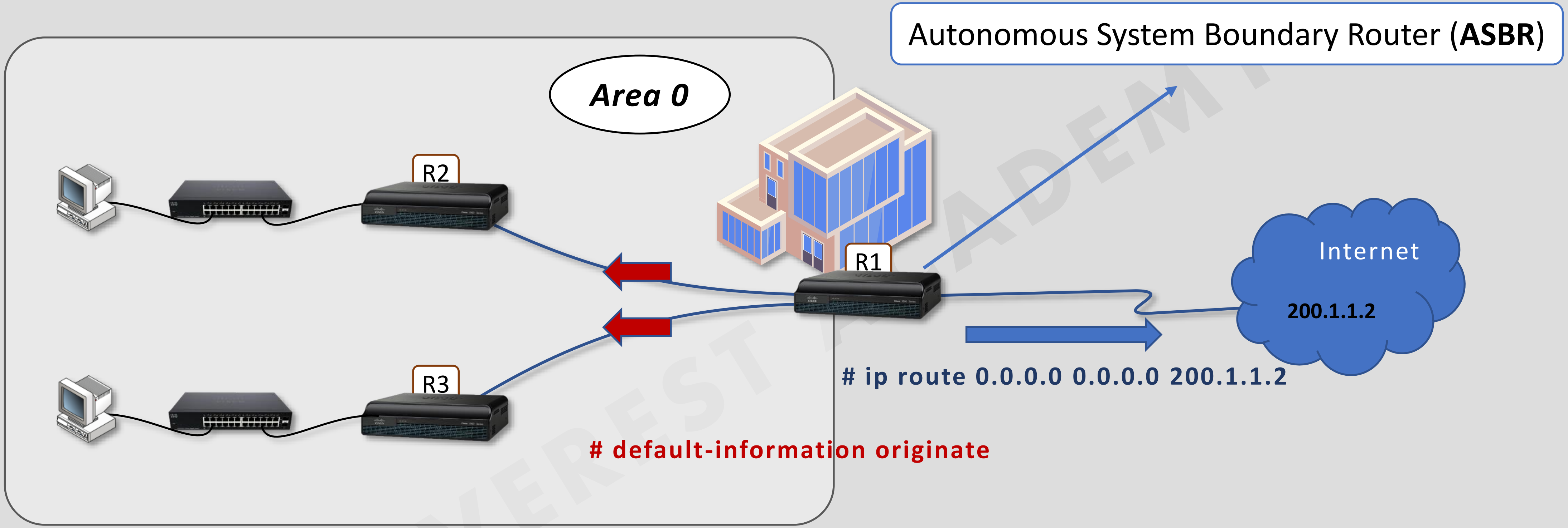
Cumulative Cost

Cumulative Cost = 64 + 64 + 64 + 1 = 193



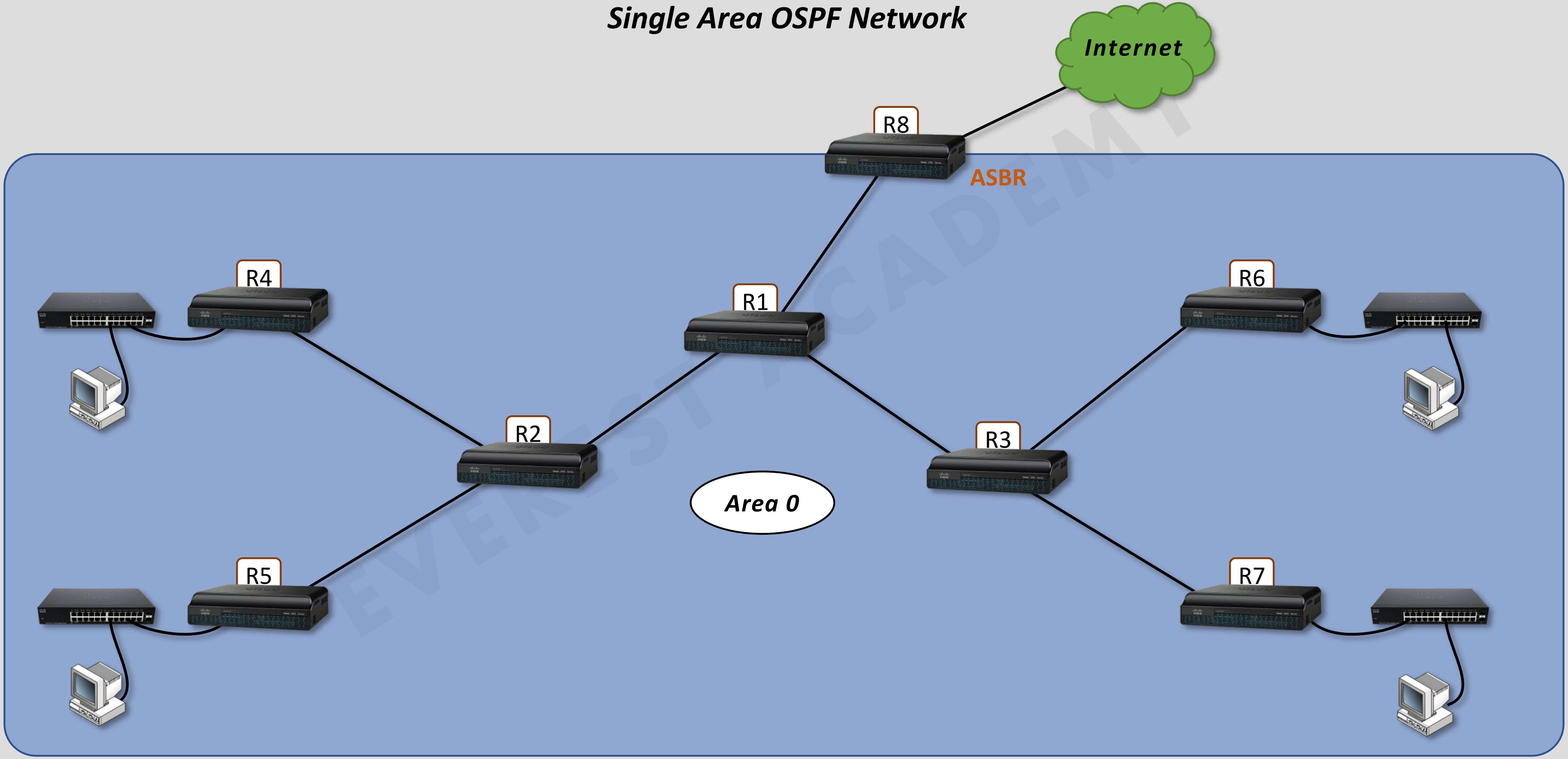
Cumulative Cost = 64 + 64 + 1 = 129

OSPF Default Route



OSPF Hierarchical Network Design

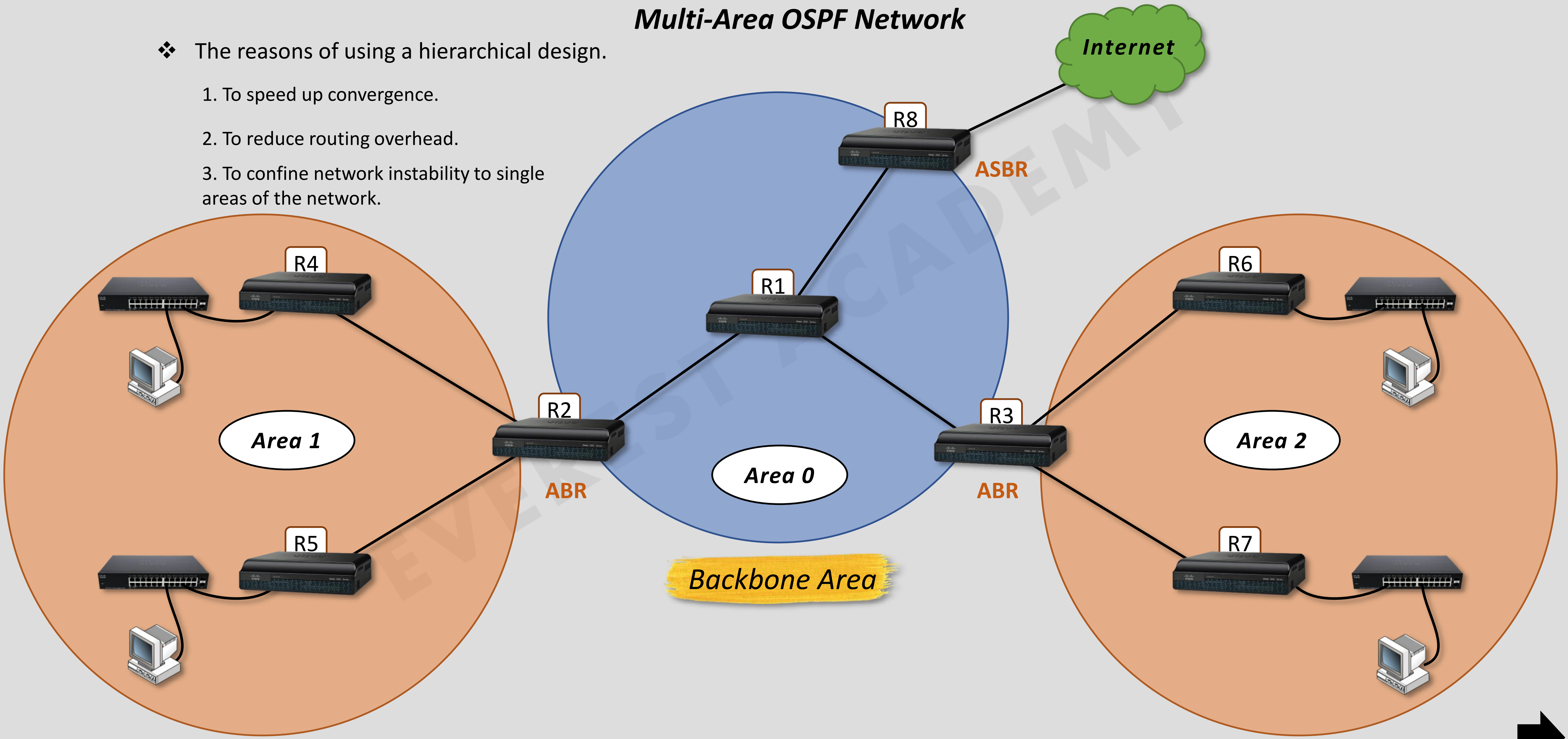
Single Area OSPF Network



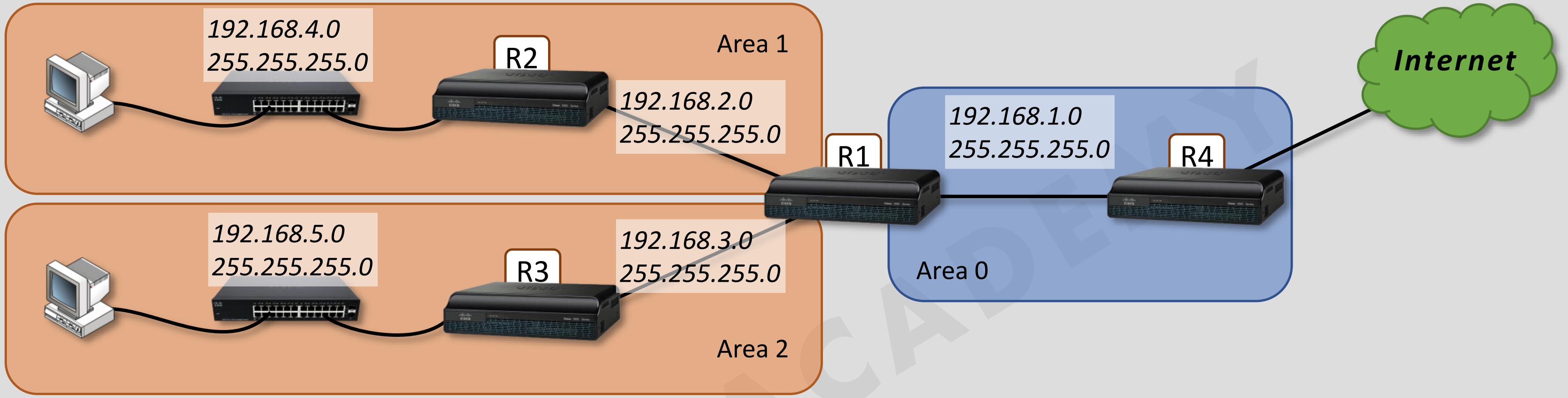
OSPF Hierarchical Network Design

Multi-Area OSPF Network

- The reasons of using a hierarchical design.
  1. To speed up convergence.
  2. To reduce routing overhead.
  3. To confine network instability to single areas of the network.



OSPF Hierarchical Network Design



R1> enable
R1# configure terminal
R1(config)# router ospf 1
R1(config-router)# router-id 1.1.1.1
R1(config-router)# network 192.168.1.0 0.0.0.255 **area 0**
R1(config-router)# network 192.168.2.0 0.0.0.255 **area 1**
R1(config-router)# network 192.168.3.0 0.0.0.255 **area 2**
R1(config-router)# end

R3> enable
R3# configure terminal
R3(config)# router ospf 1
R3(config-router)# router-id 3.3.3.3
R3(config-router)# network 192.168.3.0 0.0.0.255 **area 2**
R3(config-router)# network 192.168.5.0 0.0.0.255 **area 2**
R3(config-router)# end

R4> enable
R4# configure terminal
R4(config)# router ospf 1
R4(config-router)# router-id 4.4.4.4
R4(config-router)# network 192.168.1.0 0.0.0.255 **area 0**
R4(config-router)# end

R2> enable
R2# configure terminal
R2(config)# router ospf 1
R2(config-router)# router-id 2.2.2.2
R2(config-router)# network 192.168.2.0 0.0.0.255 **area 1**
R2(config-router)# network 192.168.4.0 0.0.0.255 **area 1**
R2(config-router)# end