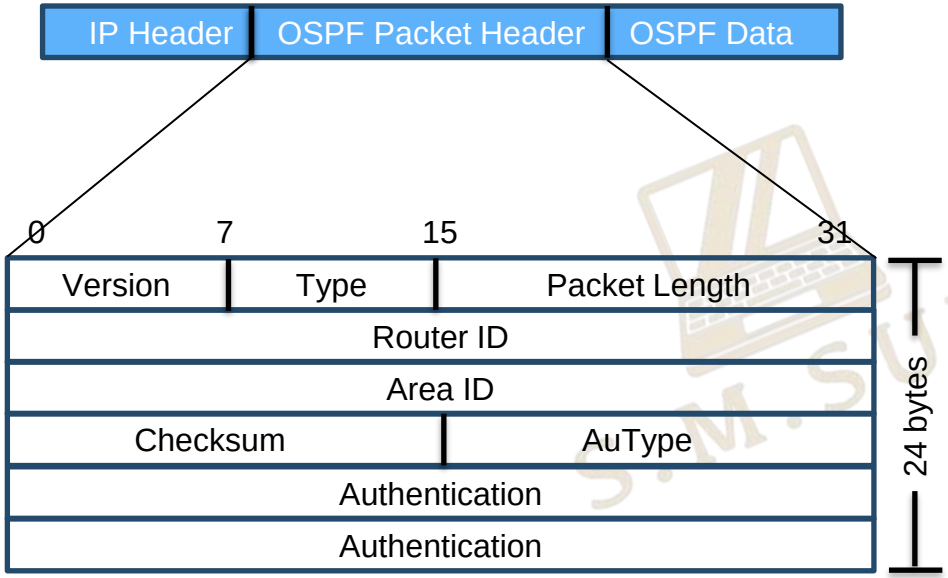
Basic - Introduction

- Open Shortest Path First - uses Dijkstra's Algorithm (SPF).
- **IGP** (Interior Gateway Protocol) - route traffic within a single **AS** (Autonomous System).
- Standard Protocol – Cisco/Non-Cisco devices.
- Link-State Protocol – sent **LSA**s (Link-State Advertisement) periodically.
- Thus, convergence is Fast (**40 seconds**).
- Protocol number **89**.
- AD (Administrative Distance) value **110**.
- Multicast address **224.0.0.5** for normal communication and **224.0.0.6** for update to DR/BDR (Designated Router/Backup Designated Router).
- Supports equal Load balancing.
- No automatic summarization.
- Multiple areas.
- Supports CIDR (Classless Inter-Domain Routing).
- No limit for number of Hops (routers) connected.

Basic – Packet Header Format



Version: OSPFv2 for IPv4.

Type: OSPF packet type from 1 to 5. Such as: Hello, DD, LSR, LSU, LSAck.

Packet Length: Total length of the packet in bytes including header.

Router ID: Advertising router ID.

Area ID: To which the OSPF enabled interface belongs.

Checksum: To perform error checking.

AuType: Authentication type ranging from 0 to 2 respectively non-authentication, simple (plaintext) authentication, and MD5 authentication.

Authentication: Data used for authentication.

Basic – How it works!

OSPF works in three steps mainly:

1. **Becoming Neighbors**: OSPF routers discover and establish neighbor relationships with other OSPF routers on the same network segment by sending ***Hello*** packets.

   To see the neighbor table, type this command in privileged EXEC mode:

   'show ip ospf neighbor'

2. **Exchanging Database:** OSPF routers exchange Link-State Advertisements (LSAs) to create and maintain a synchronized link-state database. LSAs contain information about the routers, links, and subnets within the OSPF area.

   To see the database table, type this command in privileged EXEC mode:

   'show ip ospf database'

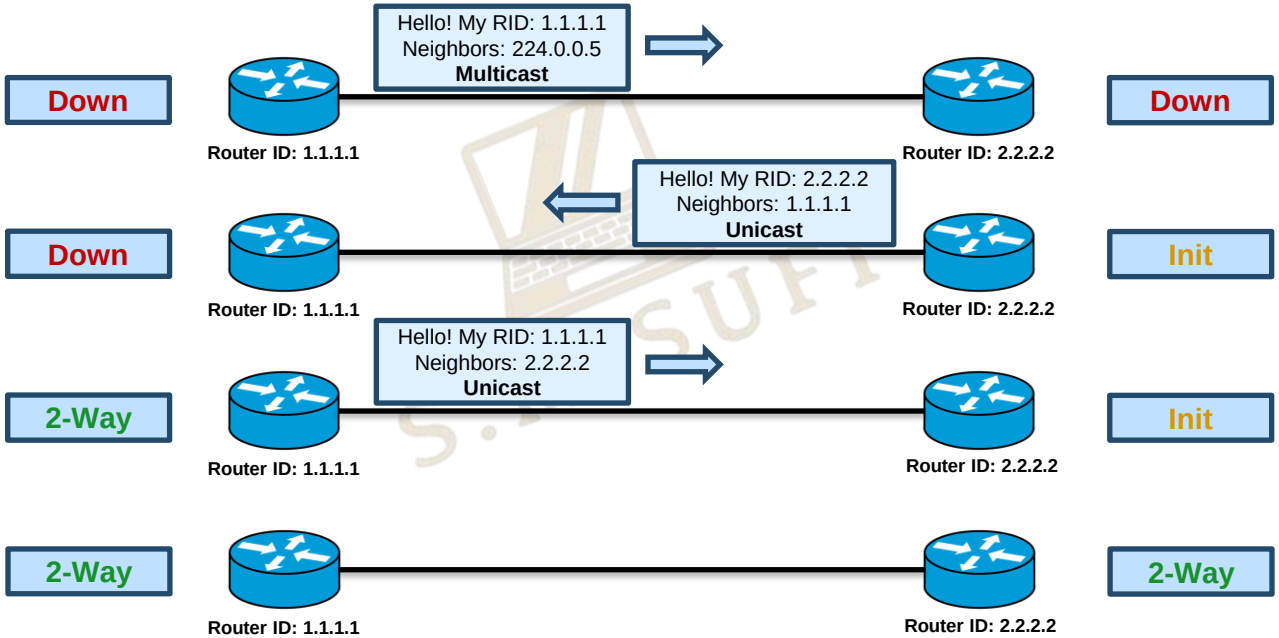
3. **Calculating Best Route:** OSPF use Dijkstra's algorithm to calculate the shortest path tree (SPF tree). The SPF tree represents the best paths to reach all destinations within the OSPF area.

   To see the routing table, type this command in privileged EXEC mode:

   'show ip route'

Basic – Becoming Neighbors

OSPF process stars with a ***Hello*** message. There are 3 states in becoming neighbors:



Basic – Becoming Neighbors

Router ID: A 32 bit unique number. OSPF router is identified using same ID in all directions. It is selected in following cascading selection:

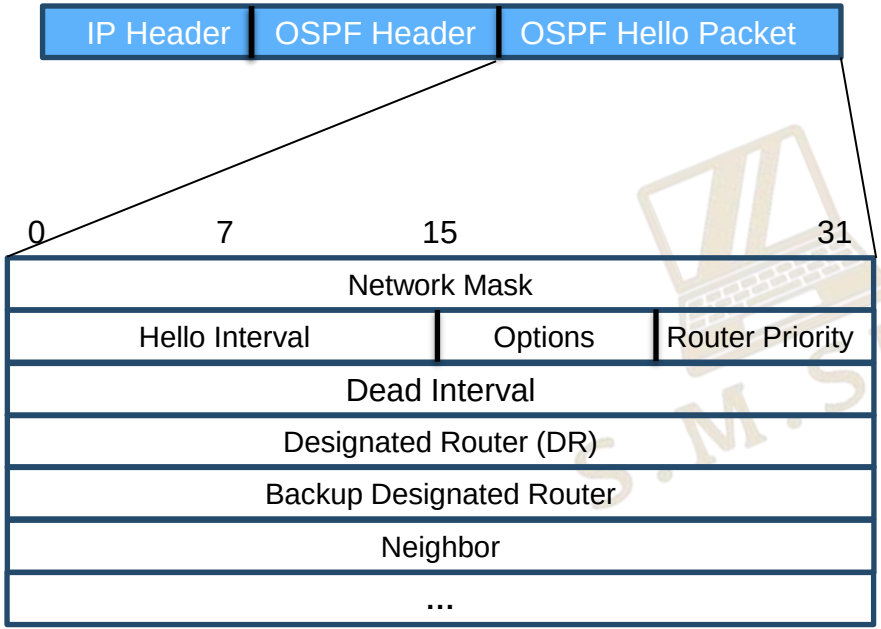
1. Manually assigned.
   'Router(config)# router ospf 1'
   'Router(config-router)# router-id 1.1.1.1'
2. Highest 'up' status loopback interface IP address.
3. Highest 'up' status physical interface IP address.

> To reset the Router ID, use following command in privileged EXEC mode:
> ***'Router# clear ip ospf process'***

Conditions: There are some requirements to match to become neighbors:

1. Hello interval
2. Dead interval
3. OSPF area ID
4. Subnet number
5. Subnet mask
6. Authentication
7. Stub area flag
8. Unique router ID

Basic – Packet Type 1 (Hello)



***Initial DR, BDR & Neighbors are "**0.0.0.0**"

Network Mask: The netmask of the interface.

Hello Interval: The default is 10 seconds for broadcast and point-to point networks and 30 seconds for NBMA (Non-broadcast Multi-access).

Options: Indicating the various OSPF router capability, such as whether stub areas are supported in the Options field.

Router Priority: This is a number from 0 to 255, which defaults to 1. The router with the highest value will become the designated router. If the Priority is set to 0, the router does not participate in the DR/BDR selection.

Dead Interval: Time before declaring a silent router down. It is four times hello interval.

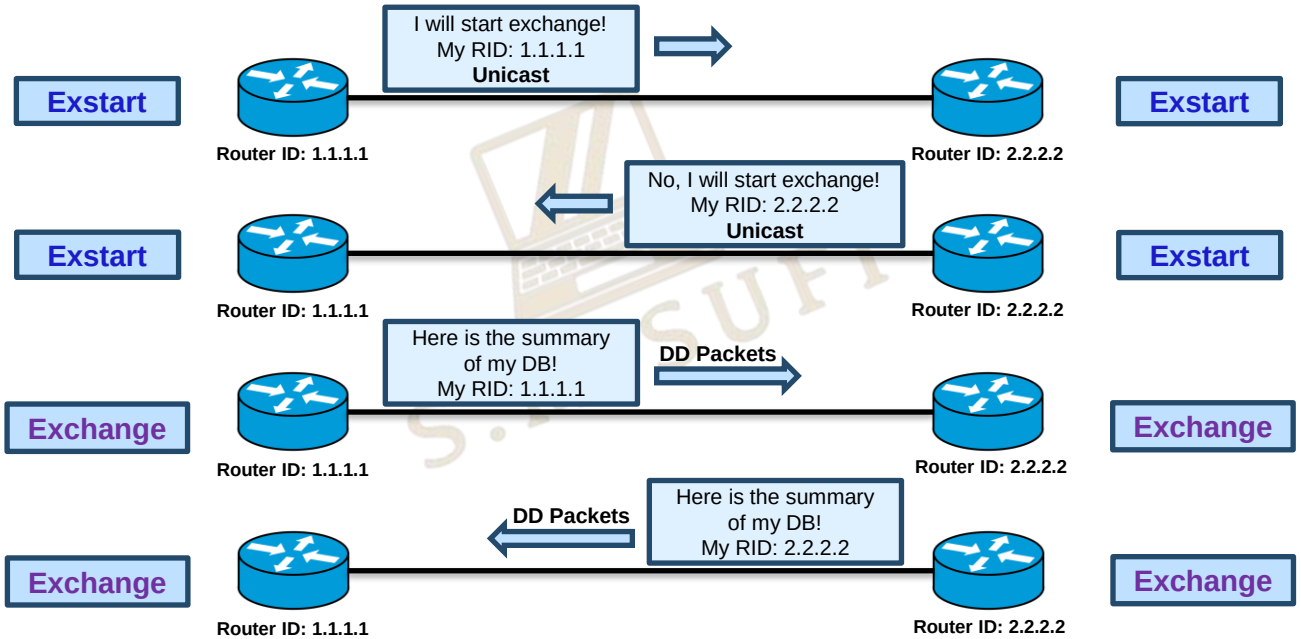
DR: IP address of the Designated Router.

BDR: IP address of the Backup Designated Router.

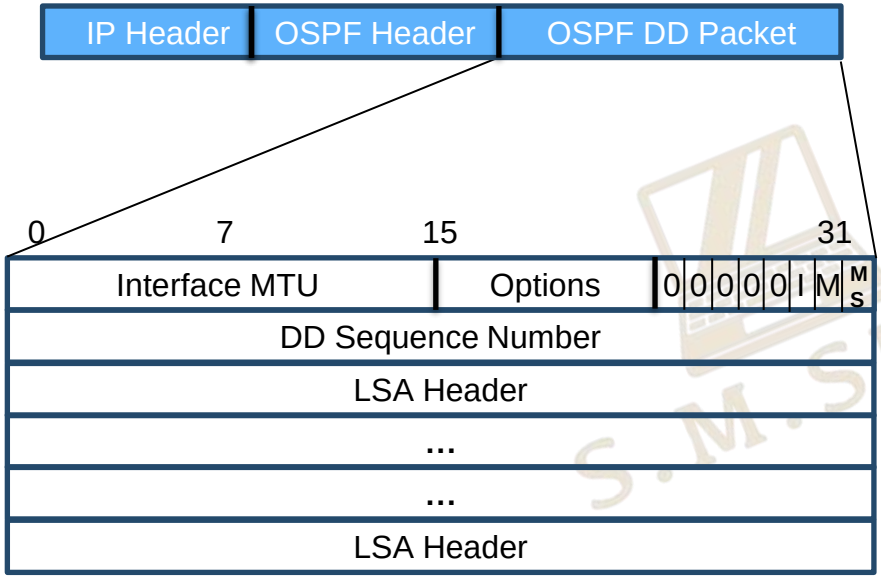
Neighbors: Router ID of the neighbor routers.

Basic – Exchanging Database

After becoming neighbors, routers starts to flood the summary information of LSAs. There are some states to become adjacent router:



Basic – Packet Type 2 (DD-Database Descriptor)



Interface MTU: largest IP datagram in bytes that the interface can send without fragmentation. *If the MTU sizes do not match, the neighbor will get stuck in the ExStart state.*

Options: Indicate the various capabilities of the OSPF router.

5 bits following options are fixed to **"00000"**.

I: The Initial bit, which is set to 1 if the packet is the first DD packet. It is set to 0 if not.

M: The More bit, which is set to 0 if the packet is the last DD packet. It is set to 1 if more DD packets are to follow.

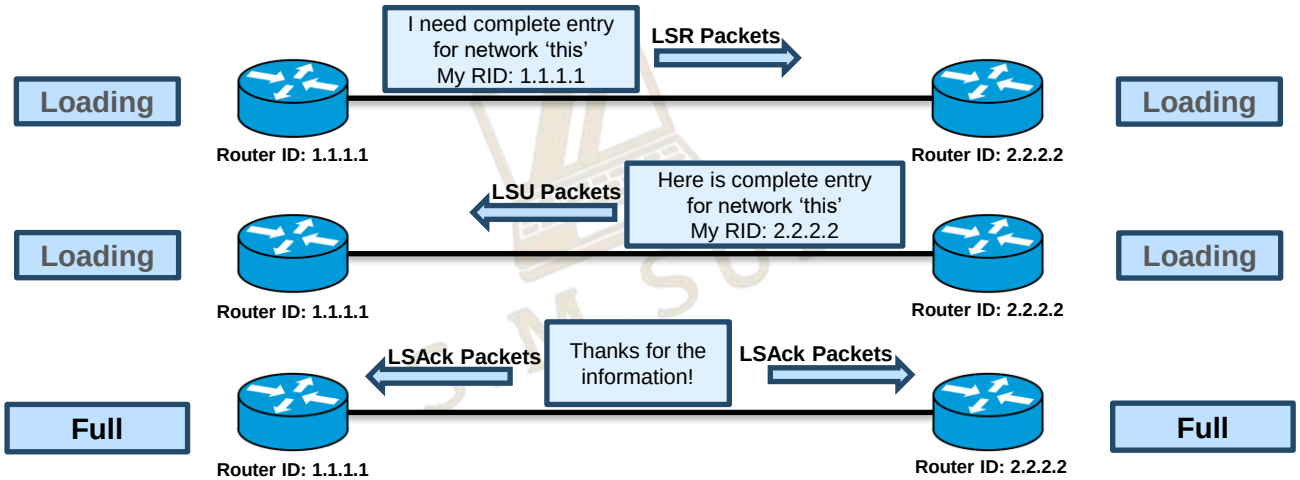
M/S: The master/Slave bit. M/S-bit=1 indicates that the router is the Master router, otherwise the router is the Slave router.

DD Sequence Number: Ensures that DD packets are received; the router that serves as the Master determines a unique initial value and increments the sequence number in subsequent DD packet exchanges.

LSA Header: A list of LSA headers for all LSAs in the LSDB of the router generating the DD packet.

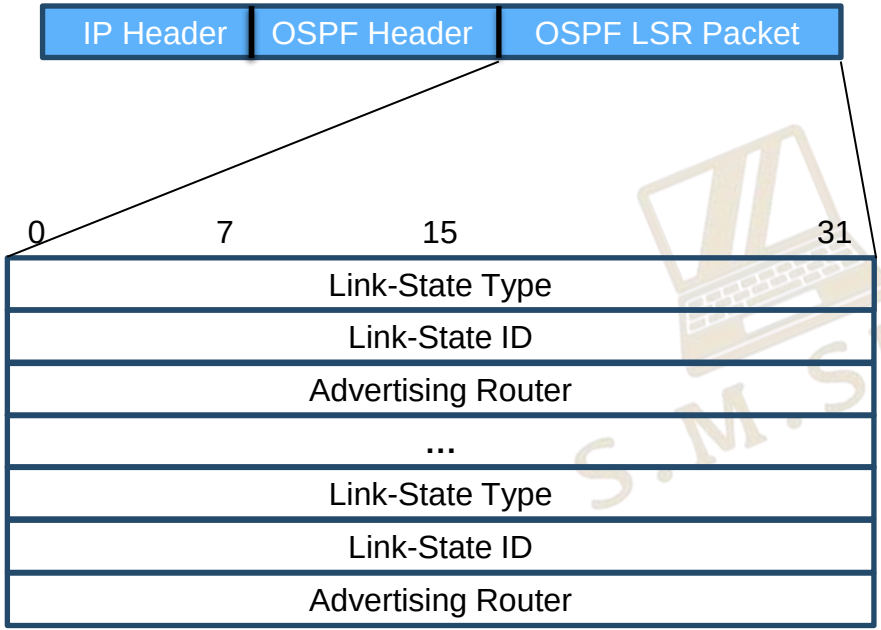
Basic – Calculating Best Route

Each router can check which LSAs it already has and then ask the router for only remaining LSAs. After the link-state databases of the neighbors are fully synchronized, they become full adjacent and apply algorithm analyzing the LSDB.



There is another state named ***"Attempt"*** state. It is only seen in ***NBMA*** (Non-Broadcast Multi Access) links. In NMBA, we have to manually configure the neighbor's IP because it doesn't support multicast. Then, ***hello*** packets are sent ***unicast*** to manually configured neighbor IP.

Basic – Packet Type 3 (LSR-Link State Request)

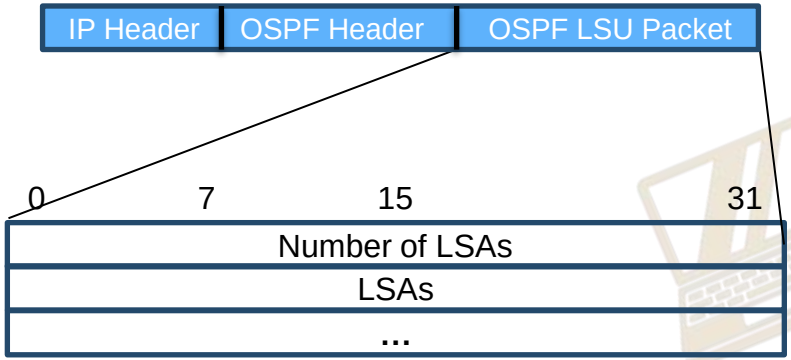


Link-State Type: It is a number (1-7) that indicates the type of LSA.
LSA type code 1 - Router LSA
LSA type code 2 - Network LSA
LSA type code 3 - Network Summary LSA
LSA type code 4 - ASBR Summary LSA
LSA type code 5 - AS External LSA
LSA type code 7 - NSSA External LSA

Link-State ID: The Link State ID is contained in the LSA header, and what the Link State ID contains depends on the type of LSA. For,
LSA type 1 - the router ID that generated the LSA.
LSA type 2 - the IP address of the DR.
LSA type 3 - the network address of another area generated by ABRs (inter-area routes).
LSA type 4 – the network address of another area (routes to ASBRs).
LSA type 5 - the router ID of the ASBR advertising the external routes.
LSA type 7 - the ABR in the NSSA (Not So Stubby Area) translates type 7 LSAs into Type 5 LSAs before sending them to other OSPF areas.

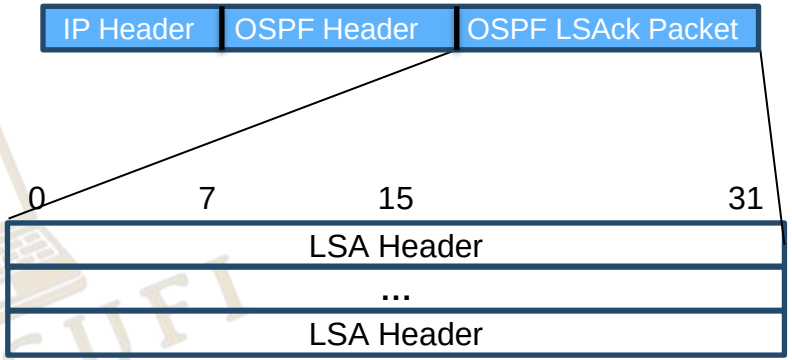
Advertising Router: The router ID of the router that generated the LSA.

Basic – Packet Type 4 (LSU-Link State Update) & Type 5 (LSAck)



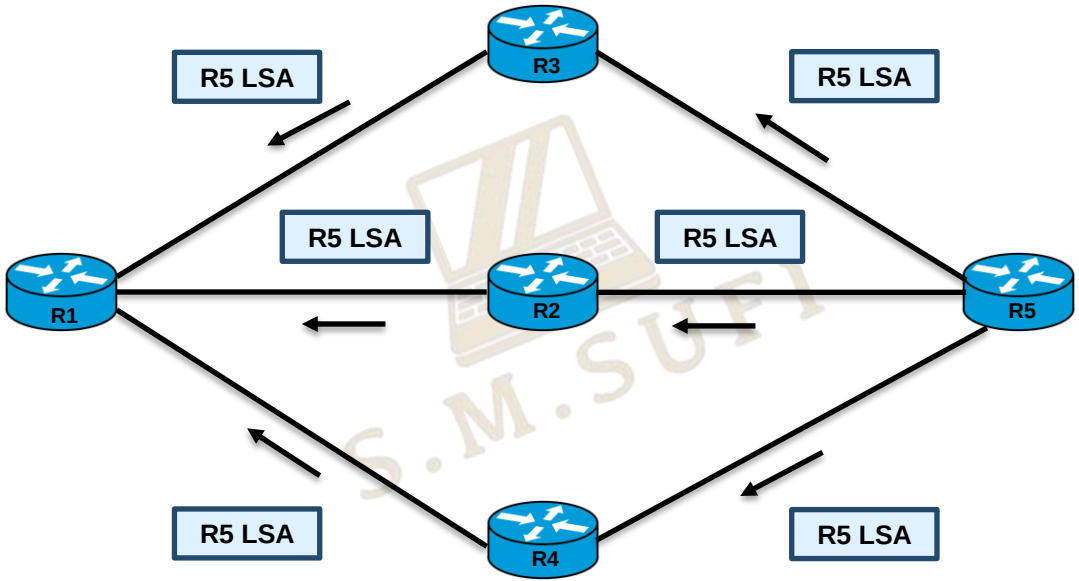
Number of LSAs: the number of LSAs contained in the LSU packet.

LSAs: LSAs to be advertised in LSU packets; multiple LSAs can be included and advertised in a single LSU packet. The LSA consists of LSA header and LSA data.



LSA Header: A list of received LSA headers; a single LSAck packet can contain multiple LSA headers.

Basic – LSA Flooding



Basic – Maintaining Updates

Maintaining Neighbors and the LSDB-

- ***Incremental*** updates (whenever there is a change).
- ***Hello*** packets are sent periodically every ***10 seconds*** and Dead time is ***40 seconds***.
- Convergence rate is fast (***40 seconds***).

Periodic Updates-

- Each router re-flood the LSA every ***30 minutes*** by default even if no changes occur.
- But the network is not overloaded with flooding LSAs. ***Why?***

  Because, each LSA has e ***separate timer***, based on when the LSA was created.

```
Router#sh ip ospf nei

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.2.1       1   2WAY/DROTHER    00:00:30    192.168.1.1     GigabitEthernet0/0/0
192.168.3.2       1   2WAY/DROTHER    00:00:30    192.168.3.2     GigabitEthernet0/0/1
```

```
Router#sh ip ospf nei

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.2.1       1   FULL/BDR        00:00:34    192.168.1.1     GigabitEthernet0/0/0
192.168.3.2       1   FULL/DR         00:00:34    192.168.3.2     GigabitEthernet0/0/1
```

Basic – Configurations

R1(config)# router ospf <process ID>
R1(config-router)# network <network ID> <wildcard mask> area <area ID>

```
R1(config)#router ospf 1
R1(config-router)#network 10.0.0.0 0.0.0.255 area 0
```

```
R2(config)#router ospf 1
R2(config-router)#network 10.0.0.0 0.0.0.255 area 0
R2(config-router)#
00:18:35: %OSPF-5-ADJCHG: Process 1, Nbr 10.0.0.1 on Serial0/1/0 from
LOADING to FULL, Loading Done
```

Process ID: ***32 bit*** Process ID is a number used to identify an OSPF routing process on the router. Multiple OSPF processes can be started on the same router. This process ID is locally significant. Its range is ***0 to 65535***.

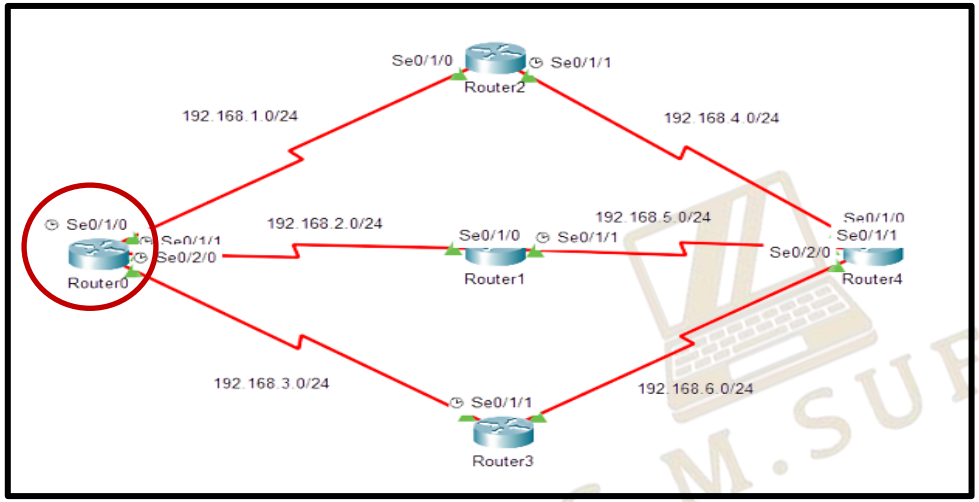
Network ID: Advertising network's IP address.

Wildcard Mask: Tell the IOS which portion of the bits to match or ignore.

- **Decimal 0 (Min):** The router must ***compare*** this octet as normal .
- **Decimal 255 (Max):** The router ***ignores*** this octet, considering it to already match.

Area ID: OSPF area number in which this interface/network will exist.

Basic – Neighbor Table




```
Router#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.4.1       0   FULL/  -        00:00:32    192.168.1.2     Serial0/1/0
192.168.5.1       0   FULL/  -        00:00:39    192.168.2.2     Serial0/1/1
192.168.6.1       0   FULL/  -        00:00:39    192.168.3.2     Serial0/2/0
```

Table-1: Neighbor Table

Neighbor ID: The router ID of the neighbor.

Pri: The priority value is used in the OSPF neighbor election process. It determines the likelihood of a router becoming the Designated Router (DR) or Backup Designated Router (BDR) on a multi-access network segment.

State: The current status of neighborship.

Dead Time: time interval within which OSPF routers expect to receive Hello packets from their neighbors, if not received it will go to down state.

Address: IP address of the neighbor.

Interface: the specific interface through which the OSPF neighbor is reachable.

Basic – Database Table

```
Router#show ip ospf database
            OSPF Router with ID (192.168.3.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.3.1     192.168.3.1     71          0x80000006 0x00aa29 6
192.168.5.1     192.168.5.1     38          0x80000004 0x00911f 4
192.168.4.1     192.168.4.1     35          0x80000004 0x002f87 4
192.168.6.1     192.168.6.1     26          0x80000004 0x00f3b6 4
192.168.6.2     192.168.6.2     26          0x80000006 0x00bbfa 6
```

Table-2: Database Table

Link ID: What the Link State ID contains depends on the type of LSA.

ADV Router: IP address of the OSPF router that originated or advertised the LSA.

Age: indicates how long (in seconds) ago the LSA was originally generated by the advertising router. It helps routers determine the freshness of the routing information.

- **OSPF Database Table is called LSDB.**
- **Each Entry in LSDB is known as LSA.**

Seq#: Each LSA has a sequence number associated with it, which helps routers track the most recent version of the LSA. If a router receives an LSA with a higher sequence number, it indicates a more recent update.

Checksum: A checksum value calculated for the LSA's contents. Routers use this value to verify the integrity of the LSA during transmission.

Link count: The number of individual links or entries within the LSA. The number of links can vary depending on the LS type.

Basic – Route Table

```
Router#show ip route
Codes: L - local, C - connected, S - static, 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
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.1.0/24 is directly connected, Serial0/1/0
L       192.168.1.1/32 is directly connected, Serial0/1/0
     192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.2.0/24 is directly connected, Serial0/1/1
L       192.168.2.1/32 is directly connected, Serial0/1/1
     192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.3.0/24 is directly connected, Serial0/2/0
L       192.168.3.1/32 is directly connected, Serial0/2/0
O    192.168.4.0/24 [110/128] via 192.168.1.2, 00:02:15, Serial0/1/0
O    192.168.5.0/24 [110/128] via 192.168.2.2, 00:01:38, Serial0/1/1
O    192.168.6.0/24 [110/128] via 192.168.3.2, 00:01:04, Serial0/2/0
```

Table-3: Route Table

- **Destination Network IP address with its Subnet Mask (CIDR) value.**
- **Administrative Distance and Cost (Metric) value (lowest).**
- **Next Hop ID Address**
- **Existing Route duration time.**
- **Interface through which traffic should be sent to reach the destination network.**

Basic – OSPF Route Table

```
Router#show ip route ospf
     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/129] via 192.168.1.2, 00:01:33, Serial0/1/0
                [110/129] via 192.168.2.2, 00:01:33, Serial0/1/1
                [110/129] via 192.168.3.2, 00:01:33, Serial0/2/0
O    192.168.4.0 [110/128] via 192.168.1.2, 01:34:20, Serial0/1/0
O    192.168.5.0 [110/128] via 192.168.2.2, 01:33:43, Serial0/1/1
O    192.168.6.0 [110/128] via 192.168.3.2, 01:33:09, Serial0/2/0
```

Table-4: OSPF Route Table

In ***Route Table,*** we only get the best route to get to the destination network. But in ***OSPF Route Table,*** we get every possible route found to get to the destination network by OSPF routing protocol with their Destination IP Address (with CIDR value), Administrative Distance, Cost (Metric), Next Hop IP Address, Existing Route Duration Time and Source Interface IP Address.

Basic – Protocols Table

```
Router#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 192.168.3.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    192.168.1.0 0.0.0.255 area 0
    192.168.2.0 0.0.0.255 area 0
    192.168.3.0 0.0.0.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.3.1           110      00:08:48
    192.168.4.1           110      00:08:16
    192.168.5.1           110      00:08:19
    192.168.6.1           110      00:08:05
    192.168.6.2           110      00:07:59
  Distance: (default is 110)
```

Table-5: Protocols Table

In ***Route Table,*** we only get the best route to get to the destination network. But in ***OSPF Route Table,*** we get every possible route found to get to the destination network by OSPF routing protocol with their Destination IP Address (with CIDR value), Administrative Distance, Cost (Metric), Next Hop IP Address, Existing Route Duration Time and Source Interface IP Address.

Basic – Interfaces

```
Router#show ip ospf interface

Serial0/1/0 is up, line protocol is up
  Internet address is 192.168.1.1/24, Area 0
  Process ID 1, Router ID 192.168.3.1, Network Type POINT-TO-POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:00
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 192.168.4.1
  Suppress hello for 0 neighbor(s)
Serial0/1/1 is up, line protocol is up
  Internet address is 192.168.2.1/24, Area 0
  Process ID 1, Router ID 192.168.3.1, Network Type POINT-TO-POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 192.168.5.1
  Suppress hello for 0 neighbor(s)
```

This command provides details about OSPF-enabled interfaces, including their state, IP addresses, area assignments, hello time, dead time, waiting time, process ID and many more.

To see summary of OSPF interfaces apply this command-

'Router# show ip ospf interface brief'

Basic – Cost Metric

- OSPF uses ***SPF*** (Shortest Path First) algorithm to calculate the best route.
- The sum of the OSPF interface costs for all outgoing interfaces in the route.
- Router then adds each route to its routing table.
- The ***Formula*** used to calculate the OSPF cost is:
- By default, ***Reference Bandwidth*** is 10^8 in ***bps*** (bit per second)
- Default Cost Metric value is given below:

$$\text{Cost} = \frac{Reference\ Bandwidth}{Interface\ Bandwidth}$$

Interface	Interface Default Bandwidth (Kbps)	Formula (Kbps)	OSPF Cost
Serial	1544	100,000/1544	**64**
Ethernet	10,000	100,000/10,000	**10**
Fast Ethernet	100,000	100,000/100,000	**1**
Gigabit Ethernet	1,000,000	100,000/1,000,000	**1**
10 Gigabit Ethernet	10,000,000	100,000/10,000,000	**1**
100 Gigabit Ethernet	100,000,000	100,000/100,000,000	**1**

Basic – Cost Metric

There are ***three ways*** to change interface cost in cisco routers:

1. **Changing Interface Bandwidth:** It will change the total cost metric of interface by using the interface subcommand- ***'bandwidth <value>'***
2. **Changing Default Reference Bandwidth:** Any interface with an interface bandwidth of 100 Mbps or faster ties with a calculated OSPF cost of 1 which is a limitation. It is probably not the right basis for choosing routes. It can be changed by using this command- ***'auto-cost reference-bandwidth <value>'***
3. **Changing Cost Manually:** Manually setting the cost will replace the calculated cost metric. Thus the calculated best route might also change. We can change the cost manually using the interface subcommand- ***'ip ospf cost <value>'***

```
Router(config)#interface se0/1/0
Router(config-if)#bandwidth ?
  <1-10000000>  Bandwidth in kilobits
Router(config-if)#bandwidth 10000
```

```
Router(config)#router ospf 1
Router(config-router)#auto-cost reference-bandwidth ?
  <1-4294967>  The reference bandwidth in terms of Mbits per second
Router(config-router)#auto-cost reference-bandwidth 10000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
```

```
Router(config)#interface se0/1/0
Router(config-if)#ip ospf cost ?
  <1-65535>  Cost
Router(config-if)#ip ospf cost 5
```

******Cisco recommends making the OSPF reference bandwidth settings the same on all OSPF routers in an Enterprise Network.***

Basic – OSPF Area

Single Area Limitations:

- Larger topology requires ***more memory*** on router.
- Too many LSAs may cause ***network overload***.
- Take more ***CPU time*** & ***resources*** to run SPF algorithm.
- A ***single interface status change*** anywhere forces every router to run SPF again.
- Convergence time becomes ***very slow***.

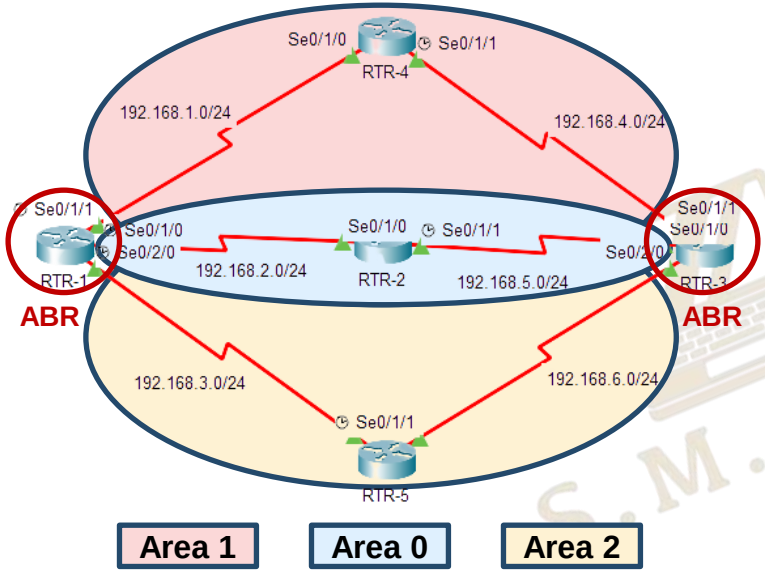
OSPF Multiple Area:

- Multiple area allows to ***logically group*** set of routers in one area.
- It will break one large LSDB into several ***smaller LSDBs***.
- Minimizes the ***CPU & memory*** resources.
- Convergence becomes ***fast***.
- Any changes are ***restricted***, LSA advertised in the ***particular area only***.
- OSPF area range ***0 to 4294967295***.

OSPF Multiple Area Design Rules:

- In each area, recommended number of router is ***less than 30 to 50.***
- Two or more area must have at least one area named '***area 0'*** which is called the ***backbone area***.
- All the ***non-backbone areas*** must connect to area 0. Else it cannot advertise its networks in other areas by default.
- There must be at least ***one ABR*** (Area Border Router) connecting two or more areas.
- Interfaces of both routers facing must be in the ***same area***.

Basic – OSPF Multiple Area Configuration



Router doesn't belong to any area, only router's interfaces belong to specific areas.

```
RTR-1(config)#router ospf 1
RTR-1(config-router)#network 192.168.1.1 0.0.0.0 area 1
RTR-1(config-router)#network 192.168.2.1 0.0.0.0 area 0
RTR-1(config-router)#network 192.168.3.1 0.0.0.0 area 2
```

```
RTR-2(config)#router ospf 1
RTR-2(config-router)#network 192.168.2.2 0.0.0.0 area 0
RTR-2(config-router)#network 192.168.5.1 0.0.0.0 area 0
```

```
RTR-3(config)#router ospf 1
RTR-3(config-router)#network 192.168.4.2 0.0.0.0 area 1
RTR-3(config-router)#network 192.168.5.2 0.0.0.0 area 0
RTR-3(config-router)#network 192.168.6.2 0.0.0.0 area 2
```

```
RTR-4(config)#router ospf 1
RTR-4(config-router)#network 192.168.1.2 0.0.0.0 area 1
RTR-4(config-router)#network 192.168.4.1 0.0.0.0 area 1
```

```
RTR-5(config)#router ospf 1
RTR-5(config-router)#network 192.168.3.2 0.0.0.0 area 2
RTR-5(config-router)#network 192.168.6.1 0.0.0.0 area 2
```

Basic – OSPF Multiple Area Database Tables

1

```
RTR-1#show ip ospf database
            OSPF Router with ID (192.168.3.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.3.1     192.168.3.1     345         0x80000003 0x0001a0 2
192.168.6.2     192.168.6.2     346         0x80000004 0x002d64 2
192.168.5.1     192.168.5.1     346         0x80000006 0x00b4f9 4
```

2

```
                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.3.0     192.168.3.1     350         0x80000005 0x000a37
192.168.1.0     192.168.3.1     335         0x80000006 0x001e24
192.168.4.0     192.168.3.1     335         0x80000007 0x007e7f
192.168.6.0     192.168.3.1     315         0x80000008 0x006694
192.168.4.0     192.168.6.2     341         0x80000005 0x00e358
192.168.1.0     192.168.6.2     341         0x80000006 0x008677
192.168.6.0     192.168.6.2     336         0x80000007 0x00c96e
192.168.3.0     192.168.6.2     336         0x80000008 0x006c8d
```

3

```
                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.3.1     192.168.3.1     344         0x80000003 0x00d5ce 2
192.168.6.2     192.168.6.2     344         0x80000004 0x000292 2
192.168.4.1     192.168.4.1     344         0x80000006 0x005262 4

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.3.0     192.168.3.1     349         0x80000006 0x000838
192.168.2.0     192.168.3.1     334         0x80000007 0x00112f
192.168.5.0     192.168.3.1     324         0x80000008 0x00718a
192.168.6.0     192.168.3.1     314         0x80000009 0x006495
192.168.6.0     192.168.6.2     334         0x80000005 0x00cd6c
192.168.3.0     192.168.6.2     334         0x80000006 0x00708b
192.168.5.0     192.168.6.2     324         0x80000007 0x00d464
192.168.2.0     192.168.6.2     324         0x80000008 0x007783
```

4

```
                Router Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.3.1     192.168.3.1     346         0x80000003 0x002c72 2
192.168.6.1     192.168.6.1     345         0x80000006 0x001791 4
192.168.6.2     192.168.6.2     345         0x80000003 0x005a35 2

                Summary Net Link States (Area 2)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.2.0     192.168.3.1     336         0x80000006 0x00132e
192.168.1.0     192.168.3.1     336         0x80000007 0x001c25
192.168.4.0     192.168.3.1     336         0x80000008 0x007c80
192.168.5.0     192.168.3.1     326         0x80000009 0x006f8b
192.168.4.0     192.168.6.2     341         0x80000005 0x00e358
192.168.1.0     192.168.6.2     341         0x80000006 0x008677
192.168.5.0     192.168.6.2     326         0x80000007 0x00d464
192.168.2.0     192.168.6.2     326         0x80000008 0x007783
```

******OSPF Areas create a 2-Tier Hierarchy:***

- ***Area 0 – Top of Hierarchy – Backbone Area (Assures loop free area topologies, also Hub and Spike design)***
- ***Area # – All other Areas***

Basic – OSPFv2 Interface Subcommands

- We can use ***Interface Subcommands*** instead of using the network command in global config mode to advertise OSPF-

  'Router(config)# interface <interface name>'

  'Router(config-if)# ip ospf <process ID> area <area no>'

- It can also be used in ***sub-interfaces*** using these commands-

  'Router(config)# interface g0/0.1'

  'Router(config-if)# ip ospf 1 area 0'

  'Router(config-if)# interface g0/0.2'

  'Router(config-if)# ip ospf 1 area 0'

  'Router(config-if)# interface g0/0'

  'Router(config-if)# ip ospf 1 area 0'

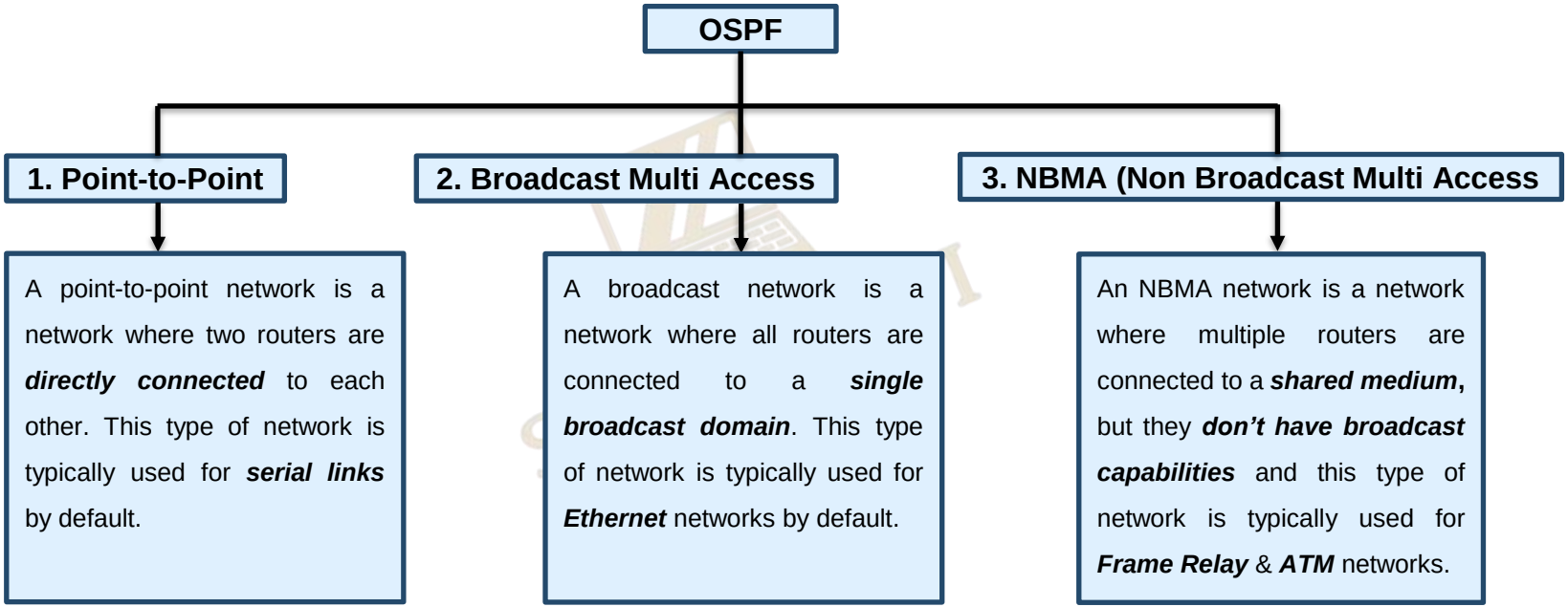
```
RTR-1(config)#interface se0/1/1
RTR-1(config-if)#ip ospf 1 area 1
RTR-1(config-if)#interface se0/1/0
RTR-1(config-if)#ip ospf 1 area 0
RTR-1(config-if)#interface se0/2/0
RTR-1(config-if)#ip ospf 1 area 2
02:02:05: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.4.1 on
Serial0/1/1 from LOADING to FULL, Loading Done

RTR-1(config-if)#
02:02:08: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.5.1 on
Serial0/1/0 from LOADING to FULL, Loading Done

02:02:16: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.6.1 on
Serial0/2/0 from LOADING to FULL, Loading Done
```

Basic – Types of Routers

- **IR (Internal Router):** IRs are routers that have ***all their interfaces*** in the ***same OSPF area***. They don't have interfaces in multiple OSPF areas. They maintain the OSPF Database for their area and participate in the calculation of the best routes within the area.
- **ABR (Area Border Router):** An ABR is a router that is ***connected to two or more OSPF areas***. They maintain an LSDB for each area and serve as a gateway, thus ***summarize routes*** from one area to another, reducing the size of the OSPF database in each area.
- **ASBR (Autonomous System Border Router):** ***Connect*** the OSPF routing domain ***to external networks*** or other routing domains, such as those using different routing protocols. ASBRs ***redistribute external routes*** into the OSPF routing domain and vice versa.
- **BR (Backbone Router):** Backbone Routers are routers that have ***at least one interface*** in the OSPF ***backbone area*** (Area 0). Backbone Routers are crucial for ***interconnecting*** OSPF areas.
- **DR (Designated Router):** Elected on ***multi-access network*** segments (Ethernet) to ***reduce OSPF traffic and adjacencies***. The DR is responsible for generating network-specific LSAs (Type 2 LSAs) & forwarding OSPF updates to other routers on the same segment.
- **BDR (Backup Designated Router):** The BDR ***monitors the DR*** and ***quickly assumes the DR role*** if the DR becomes unavailable. This ensures redundancy and stability on multi-access segments.
- **VLR (Virtual Link Router):** Virtual Routers are routers that ***establish virtual links*** to connect OSPF areas when physical connectivity to the backbone area (Area 0) is not possible. They allow routers in non-backbone areas to reach the backbone area ***indirectly***.
- **SR (Stub Router):** A stub router is a router that is ***connected to only one OSPF area*** and does ***not exchange*** routing information with other areas. Stub routers are typically used in small networks.

Basic – Network Types

There are mainly ***three*** types of OSPF network-



Basic – Point-to-Point Network

- A single point-to-point link is a ***single pair*** of router.
- Does not support the ability to add a third router to the link.
- Usually a serial interface running either ***PPP*** or ***HDLC***.
- May also be a point-to-point ***sub-interface*** running ***Frame Relay*** or ***ATM***.
- ***No election*** of DR or BDR is required.
- OSPF packets are sent using ***multicast 224.0.0.5***.
- OSPF ***auto-detects*** this interface type.

Point-to-Point over Ethernet Links:

Most of the WAN Ethernet connections can be P2P. Like- Ethernet Private Wire Service, Ethernet Line, etc. In this scenario, Ethernet DR/BDR adds a extra convergence time. P2P over ethernet links can be done using the commands-

'R1(config)# interface se0/1/0'

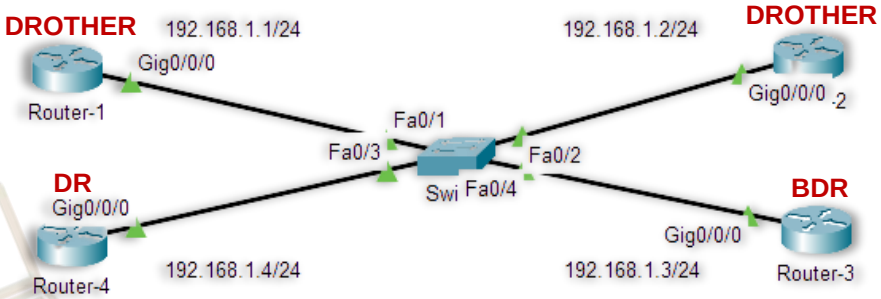
'R1(config-if)# ip ospf network point-to-point'


```
R1#show ip ospf interface se0/1/0

Serial0/1/0 is up, line protocol is up
  Internet address is 10.0.0.1/24, Area 0
  Process ID 1, Router ID 10.0.0.1, Network Type POINT-TO-POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 10.0.0.2
  Suppress hello for 0 neighbor(s)
```

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.0.0.2          0   FULL/  -        00:00:34    10.0.0.2        Serial0/1/0
```

Basic – Broadcast Network

- OSPF by default uses ***Broadcast network type*** on all types of ***Ethernet interfaces***.
- In broadcast multi-access networks there is two challenges-
- ***Multiple adjacencies.***
- ***Flooding of LSAs.***
- These challenges are solved by electing ***DR*** and ***BDR***.
- All neighbor routers form ***full adjacencies*** with the DR and BDR only.
- The ***DROTHER*** routers will ***never update*** other routers in the network.
- DROTHER ➡ DR, use multicast ***224.0.0.6***
  DR ➡ DROTHER, use multicast ***224.0.0.5***.




```
Router-3#show ip ospf interface g0/0/0

GigabitEthernet0/0/0 is up, line protocol is up
  Internet address is 192.168.1.3/24, Area 0
  Process ID 1, Router ID 192.168.1.3, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 192.168.1.3, Interface address 192.168.1.4
  Backup Designated Router (ID) 192.168.1.3, Interface address 192.168.1.3
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:09
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 3, Adjacent neighbor count is 3
    Adjacent with neighbor 192.168.1.3  (Designated Router)
    Adjacent with neighbor 192.168.1.2
    Adjacent with neighbor 192.168.1.1
  Suppress hello for 0 neighbor(s)
```

Basic – DR and BDR Election

- The router having ***highest priority*** will become ***DR***.
- The router with ***second-highest priority*** is ***BDR***.
- The default ***priority*** value is ***1***.
- The ***range*** of priority value is ***0-255***.
- In case of a ***tie***,
  - Router with ***highest router ID*** is DR.
  - ***Second highest router ID*** becomes BDR.
- This DR/BDR election occurs during OSPF ***neighborship***, specifically during the ***last phase*** of ***2-Way*** neighbor state and ***just before*** the ***Exstart*** state.
- If router ***priority is 0***, it cannot become DR/BDR.
- DR/BDR election is ***not preemtive***.
  - If a new router is added within the topology with a better priority value after DR/BDR election, it does not preempt the existing DR and BDR ***until the current DR and BDR fail***.

```
Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.2       1   2WAY/DROTHER    00:00:37    192.168.1.2     GigabitEthernet0/0/0
Router#show ip ospf nei


Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.2       1   EXSTART/DR      00:00:33    192.168.1.2     GigabitEthernet0/0/0
```

```
Router-1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.2       1   2WAY/DROTHER    00:00:36    192.168.1.2     GigabitEthernet0/0/0
192.168.1.3       1   FULL/BDR        00:00:30    192.168.1.3     GigabitEthernet0/0/0
192.168.1.3       1   FULL/DR         00:00:36    192.168.1.4     GigabitEthernet0/0/0
```

```
Router-3#sh ip ospf nei

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.3       1   EXSTART/DR      00:00:39    192.168.1.4     GigabitEthernet0/0/0
192.168.1.2       1   FULL/DROTHER    00:00:39    192.168.1.2     GigabitEthernet0/0/0
192.168.1.1       1   FULL/DROTHER    00:00:35    192.168.1.1     GigabitEthernet0/0/0
```

- DR ⟷ BDR – ***EXSTART***

  DR/BDR ⟷ DROTHER – ***FULL***

  DROTHER ⟷ DROTHER – ***2-WAY***
- To change the priority value ***manually*** using the command-

  'Router(config)# interface g0/0/0'

  'Router(config-if)# ip ospf priority <priority value>'

Basic – DR/BDR/DROTHER & OSPF Show Commands

- When DR has Routing Update:
  - DR sends LSU to 224.0.0.5
  - BDR sends LSAck to 224.0.0.5
  - DROTHER send LSAck to 224.0.0.6
- When BDR has Routing Update:
  - BDR sends LSU to 224.0.0.5
  - DR sends LSAck to 224.0.0.5
  - DROTHER send LSAck to 224.0.0.6
- When DROTHER has Routing Update:
  - DROTHER sends LSU to 224.0.0.6
  - DR sends LSU to 224.0.0.5
  - BDR sends LSAck to 224.0.0.5
  - Remaining DROTHER send LSAck to 224.0.0.6

- ***'show ip protocols'***
- ***'show ip ospf interface'***
- ***Show ip ospf interface ?'***
- ***'show ip ospf interface brief'***
- ***'show ip neighbors'***
- ***'show ip ospf rib'***
- ***'show ip route'***
- ***'show ip route ospf'***
- ***'show ip ospf'***
- ***'show ip ospf database'***
- ***'show ip ospf database router (routerID)'***
- ***'show ip ospf database network (networkID)'***
- ***'show ip ospf database ?'***
- ***'debug ip ospf ?'***

Basic – OSPF Passive Interface

- Passive Interface is used to ***prevent*** OSPF interfaces ***from sending OSPF Hello packets***.
- Thus, the passive interface ***does not participate*** in OSPF ***neighborship***.
- Instead, these interfaces ***only listen to OSPF updates*** and do not actively advertise OSPF routing information.
- It can be used in ***Stub areas*** where no further OSPF routing information is needed.
- It can be used on interfaces connected to ***external networks***, such as the internet or ***untrusted networks***.
- It can be used to ***minimize OSPF traffic*** on specific links without affecting overall network functionality.
- To make one or few interfaces as passive interface use these commands-

  'Router(config)# router ospf <process ID>'

  'Router(config-router)# passive-interface <interface name>'
- In scenarios where multiple interfaces are need to make as passive interfaces excluding few interfaces, use these commands-

  'Router(config)# router ospf <process ID>'

  'Router(config-router)# passive-interface default'

  'Router(config-router)# no passive-interface <excluded interface name>'

The ***'passive-interface default'*** command make all the interfaces as passive interface.

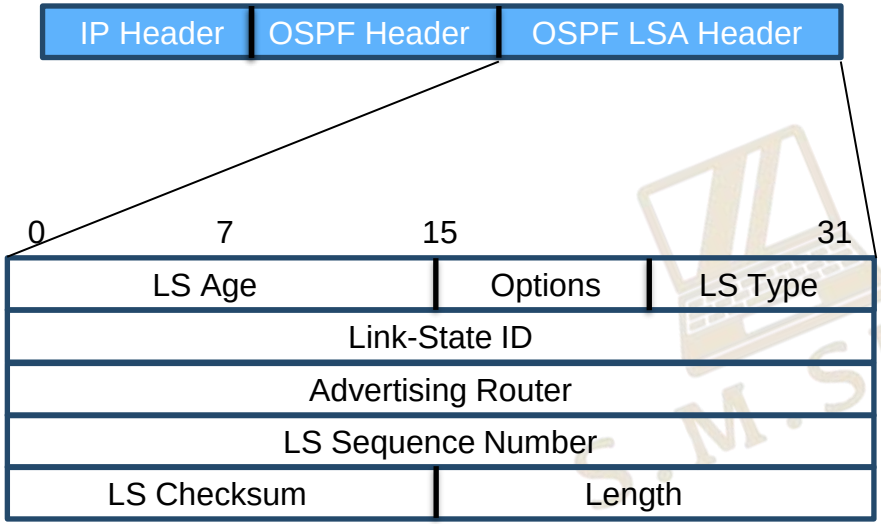
Advanced – LSA Types

- LSA stands for Link State Advertisements. They are used to exchange information about the network's topology.
- There are total 11 types of LSAs-

1. **Type 1 Router LSA:** Advertises the router itself, directly connected interface addresses, link states & costs, and neighbor routers.
2. **Type 2 Network LSA:** Advertises the networks that the router is connected to, as well as the routers that are connected to those networks. Network LSA is generated by DR on multi-access networks, and the LSA which DR get from DROTHERs area LSA type 1.
3. **Type 3 Summary LSA:** Advertises a summary of the routes in an area to other areas, generated by ABRs.
4. **Type 4 ASBR Summary LSA:** Advertises a summary of the routes to external ASs to other areas, generated by ABRs.
5. **Type 5 AS External LSA:** Advertises routes to external ASs, generated by ASBRs.
6. **Type 6 Multicast OSPFv3 LSA:** Advertises the multicast groups that the router is a member of, used in OSPFv3 (IPv6 networks).
7. **Type 7 NSSA External LSA:** Advertises routes to external networks in an NSSA.
8. **Type 8 External Attributes LSA:** Advertises additional information about external routes, such as the next hop address and the metric.
9. **Type 9 Opaque LSA:** Advertises prefixes within an OSPFv3 area, used for future extensions or proprietary information.
10. **Type 10 Opaque LSA:** Similar purposes as Type 9, but they serve as a distinct type for differentiating information.
11. **Type 11 Opaque LSA:** Similar purposes as Type 9 and type 10, used for additional custom extensions or proprietary data.

******Type 1 & 2 are used for same area (O), type 3 for different area (OIA), type 4 & 5 for external area (E1/E2) and type 7 for nssa area.***
******Type 6 is not used and type 8-11 are advanced analysis which are commonly used with PGP and MPLS OSPF integration for traffic engineering.***

Advanced – LSA Header



All LSAs have the same header

Link-State Age: Time, in seconds, elapsed since the LSA was originated. An LSA ages in the LSDB (added by 1 per second), but does not age during transmission.

Link-State Type: It is a number (1-7) that indicates the type of LSA.

Link-State ID: What the Link State ID contains depends on the type of LSA

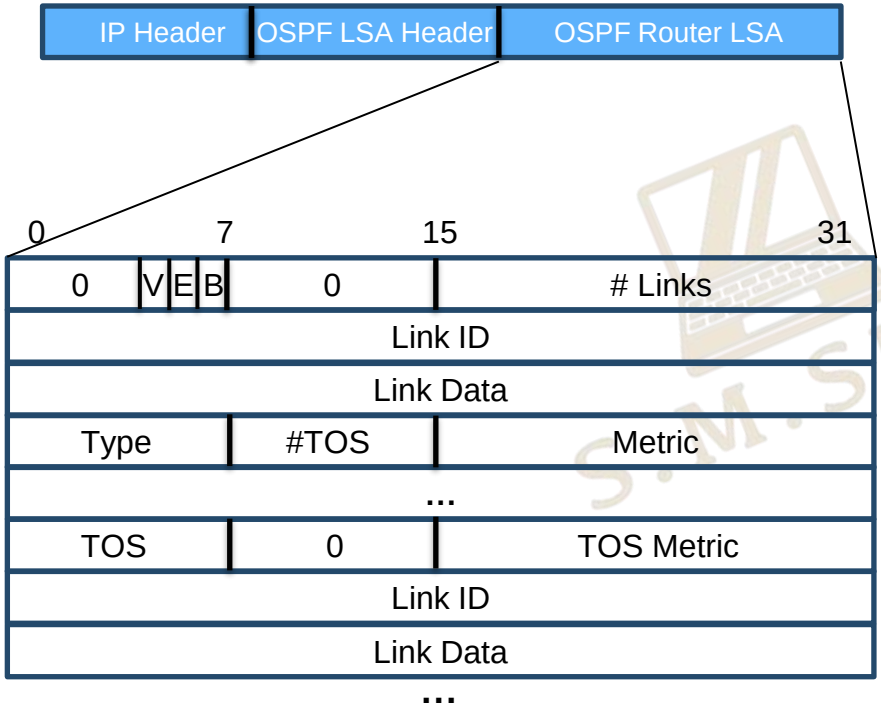
Advertising Router: The router ID of the router that generated the LSA.

LS Sequence Number: Used by other routers to judge new and old LSAs.

LS Checksum: Checksum of the LSA except the LS age field.

Length: Length in bytes of the LSA, including the LSA header.

Advanced – Router LSA Type 1 Format



V (Virtual Link): V=1 if the router that originated the LSA is a virtual link endpoint.

E (External): E=1 if the router that originated the LSA is an ASBR.

B (Border): B=1 if the router that originated the LSA is an ABR.

 # Links: Number of the router links (interfaces) to the area.

Link ID: Determined by link type.

Link Data: Determined by link type.

Type: Link type. A value of-
1 indicates a point-to-point link to a remote router
2 indicates a link to a transit network
3 indicates a link to a stub network
4 indicates a virtual link.

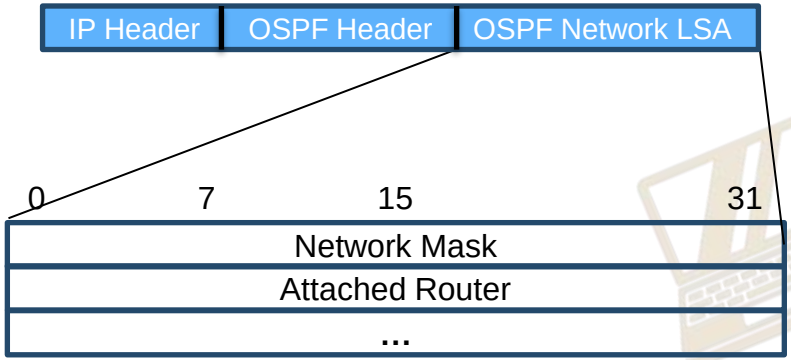
#TOS: Number of different TOS metrics given for this link. If no TOS metric is given for the link, this field is set to 0. TOS is not supported in RFC 2328. The #TOS field is reserved for early versions of OSPF.

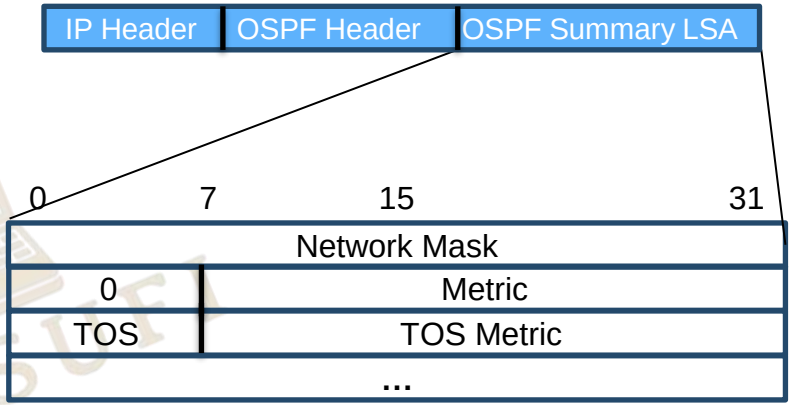
Metric: Cost of using this router link.

TOS: IP type of service that this metric refers to.

TOS Metric: TOS-specific metric information.

Advanced – Network LSA Type 2 Format & Summary LSA Type 3 or 4





Network Mask: The mask of the network (a broadcast or NMBA network).

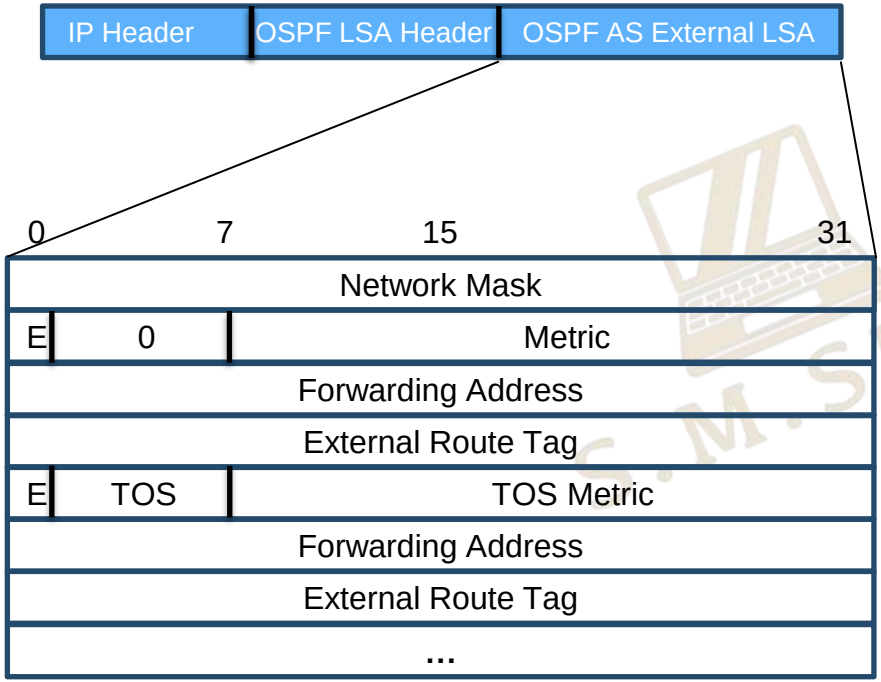
Attached Router: The IDs of the routers, which are adjacent to the DR, including the DR itself.

Link State ID: For a type 3 LSA, it is an IP address outside the area. For a type 4 LSA, it is the router ID of an ASBR outside the area.

Network Mask: The network for the type 3 LSA. It is set to 0.0.0.0 for the type 4 LSA.

Metric: The metric to the destination.

Advanced – AS External LSA Type 5 Format



Link State ID: The IP address of another AS to be advertised. When describing a default route, the link state ID is always set to default destination (0.0.0.0) and the network mask is set to 0.0.0.0.

Network Mask: The IP address mask for the advertised destination.

E (External Metric): The type of the external metric value, which is set to 1 for type 2 external routes, and set to 0 for type 1 external routes.

Metric: The metric to the destination.

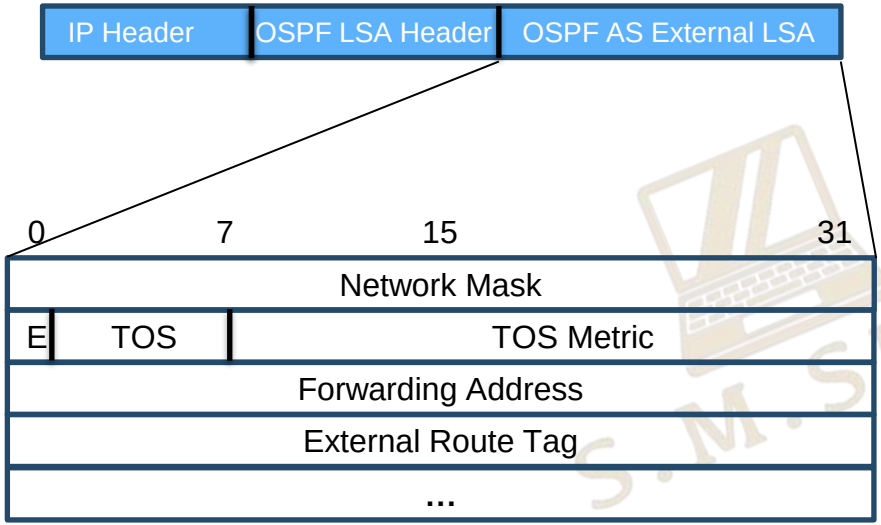
Forwarding Address: Data traffic for the advertised destination is forwarded to this address.

External Route Tag: A tag attached to each external route. This is not used by the OSPF protocol. It may used to manage external routes.

TOS: IP type of service that this metric refers to.

TOS Metric: TOS-specific metric information.

Advanced – NSSA External LSA Type 7 Format



Link State ID: The IP address of another AS to be advertised. When describing a default route, the link state ID is always set to default destination (0.0.0.0) and the network mask is set to 0.0.0.0.

Network Mask: The IP address mask for the advertised destination.

E (External Metric): The type of the external metric value, which is set to 1 for type 2 external routes, and set to 0 for type 1 external routes.

Metric: The metric to the destination.

Forwarding Address: Data traffic for the advertised destination is forwarded to this address.

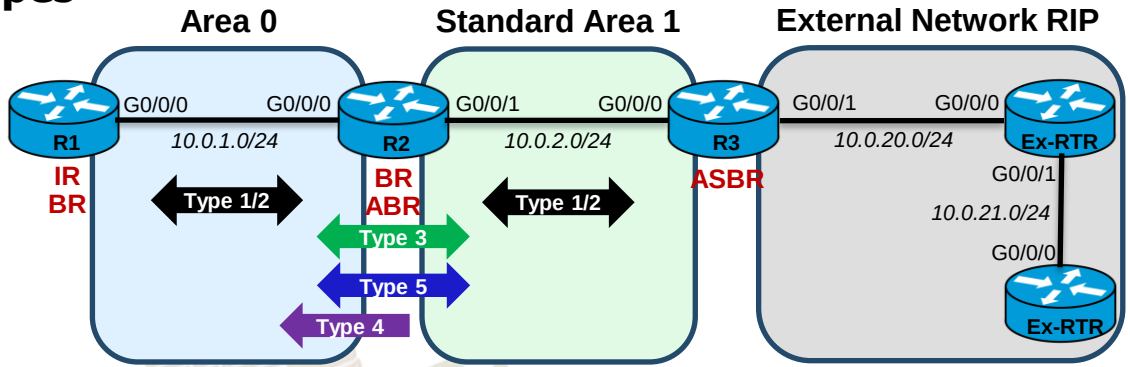
External Route Tag: A tag attached to each external route. This is not used by the OSPF protocol. It may used to manage external routes.

TOS: IP type of service that this metric refers to.

Advanced – OSPF Area Types

- There are ***five types*** of OSPF area-

1.Backbone Area: The backbone area is ***area 0***. It plays the role of the ***central node*** in the OSPF network and the link information of other areas is ***transmitted through area 0***. This also means that all other areas ***must be connected*** to area 0. This area supports type ***1, 2, 3, 4,*** and ***5*** LSAs.




```
R1(config)#router ospf 10
R1(config-router)#network 10.0.1.0 0.0.0.255 area 0
R2(config)#router ospf 10
R2(config-router)#network 10.0.1.0 0.0.0.255 area 0
R2(config-router)#network 10.0.2.0 0.0.0.255 area 1
R3(config)#router ospf 10
R3(config-router)#network 10.0.2.0 0.0.0.255 area 1
R3(config-router)#redistribute rip subnets
```

2.Standard Area: A standard area is a ***non-backbone area***. Standard areas can communicate with each other through the backbone area. A Standard Area has ***no specific characteristics***. It help in ***optimizing routing*** as the information about all routes is with all routers. This area supports type ***1, 2, 3, 4,*** and ***5*** LSAs.

Advanced – OSPF Area Types

The following commands on the ***ASBRs*** of OSPF standard area-

'Router(config)# router ospf <process ID>'

'Router(config-router)# network <network IP> <wildcard mask> area <non zero area ID>'

'Router(config-router)# redistribute <external routing protocols> subnets'

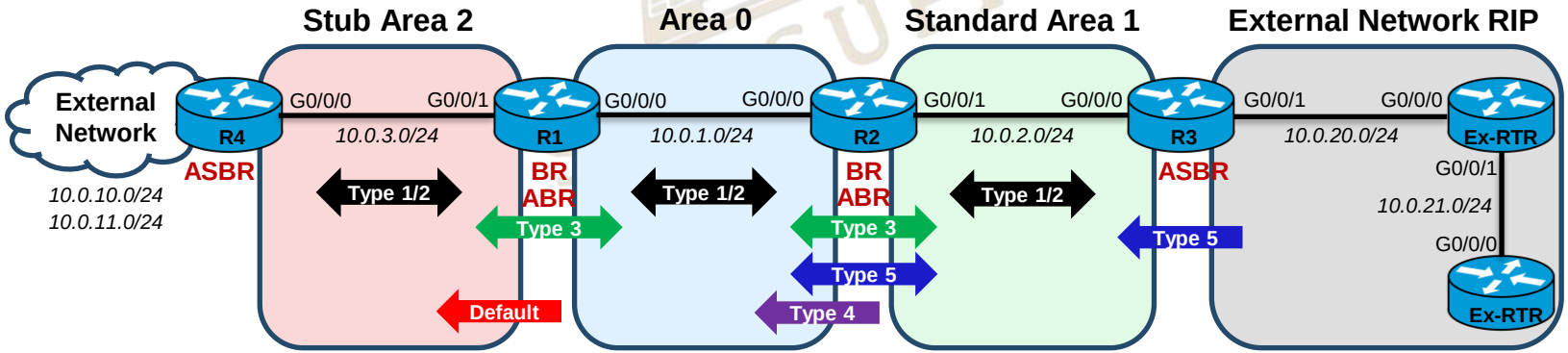
```
R3#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
O IA     10.0.1.0/24 [110/2] via 10.0.2.1, 00:10:26, GigabitEthernet0/0/0
C        10.0.2.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.2.2/32 is directly connected, GigabitEthernet0/0/0
C        10.0.20.0/24 is directly connected, GigabitEthernet0/0/1
L        10.0.20.1/32 is directly connected, GigabitEthernet0/0/1
R        10.0.21.0/24 [120/1] via 10.0.20.2, 00:00:21, GigabitEthernet0/0/1
```

```
R1#show ip route
Codes: L - local, C - connected, S - static, 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
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
C        10.0.1.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.1.1/32 is directly connected, GigabitEthernet0/0/0
O IA     10.0.2.0/24 [110/2] via 10.0.1.2, 00:41:58, GigabitEthernet0/0/0
C        10.0.5.0/24 is directly connected, GigabitEthernet0/0/1
L        10.0.5.1/32 is directly connected, GigabitEthernet0/0/1
O E2     10.0.20.0/24 [110/20] via 10.0.1.2, 00:09:22, GigabitEthernet0/0/0
O E2     10.0.21.0/24 [110/20] via 10.0.1.2, 00:09:22, GigabitEthernet0/0/0
```

Advanced – OSPF Area Types

3.Stub Area: A stub area is a ***non-backbone area*** that ***only receives LSAs from the backbone area***. Its is an ***optimization*** of standard area. Stub areas ***do not send LSAs*** to other areas and ***does not accept any external routes*** of non-OSPF network, if it wants to reach those external routes, only Need to send it through the ***default route***. This area supports type ***1, 2,*** and ***3*** LSAs. Stub area does not accept external routes(Type 5), it is replaced by default route.

```
R4(config-router)#redistribute rip subnets
R4(config-router)#%OSPF-4-ASBR_WITHOUT_VALID_AREA: Router is currently an ASBR while having only one area which is a stub area
```



Advanced – OSPF Area Types

The following commands on routers of OSPF stub area-

'Router(config)# router ospf <process ID>'

'Router(config-router)# network <network IP> <wildcard mask> area <non zero area ID>'

'Router(config-router)# area <non zero area ID> stub'

```
R1(config)#router ospf 10
R1(config-router)#network 10.0.3.0 0.0.0.255 area 2
R1(config-router)#area 2 stub
```

```
R4(config)#router ospf 10
R4(config-router)#network 10.0.3.0 0.0.0.255 area 2
R4(config-router)#area 2 stub
```

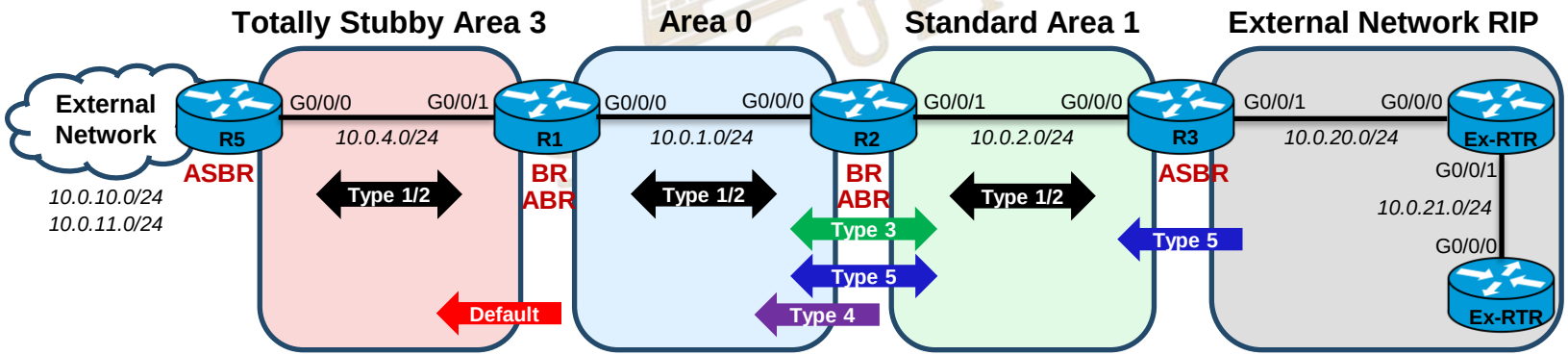
```
R4#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 10.0.3.1 to network 0.0.0.0

     10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
O IA     10.0.1.0/24 [110/2] via 10.0.3.1, 00:00:28, GigabitEthernet0/0/0
O IA     10.0.2.0/24 [110/3] via 10.0.3.1, 00:00:28, GigabitEthernet0/0/0
C        10.0.3.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.3.2/32 is directly connected, GigabitEthernet0/0/0
C        10.0.10.0/24 is directly connected, GigabitEthernet0/0/1
L        10.0.10.1/32 is directly connected, GigabitEthernet0/0/1
O*IA 0.0.0.0/0 [110/2] via 10.0.3.1, 00:00:28, GigabitEthernet0/0/0
```

```
R1#show ip route
Codes: L - local, C - connected, S - static, 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
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
C        10.0.1.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.1.1/32 is directly connected, GigabitEthernet0/0/0
O IA     10.0.2.0/24 [110/2] via 10.0.1.2, 00:14:03, GigabitEthernet0/0/0
C        10.0.3.0/24 is directly connected, GigabitEthernet0/0/1
L        10.0.3.1/32 is directly connected, GigabitEthernet0/0/1
O E2     10.0.20.0/24 [110/20] via 10.0.1.2, 00:14:03, GigabitEthernet0/0/0
O E2     10.0.21.0/24 [110/20] via 10.0.1.2, 00:14:03, GigabitEthernet0/0/0
```

Advanced – OSPF Area Types

4.Totally Stubby Area: It is one step ***more strict*** Area than Stub Area. It means that the area ***does not accept external routes*** and does not accept the link information of ***other areas outside of their own area***. This is a ***Cisco Proprietary*** OSPF Area. If it wants to reach the target network outside the area, it will send out the message through the ***default route*** just like the stub area. This area supports type ***1, 2*** and ***3*** LSAs with default routes.

```
R5(config)#router ospf 10
R5(config-router)#redistribute rip subnets
R5(config-router)#%OSPF-4-ASBR_WITHOUT_VALID_AREA: Router is currently an ASBR while having only one area which is a stub area
```



Advanced – OSPF Area Types

The following commands on the ***ABR*** of OSPF totally stubby area-

'Router(config)# router ospf <process ID>'

'Router(config-router)# network <network IP> <wildcard mask> area <non zero area ID>'

'Router(config-router)# area <area no> stub no-summary'

And on ***other routers***-

'Router(config-router)# area <area no> stub'

```
R1(config)#router ospf 10
R1(config-router)#network 10.0.4.0 0.0.0.255 area 3
R1(config-router)#area 3 stub no-summary
```

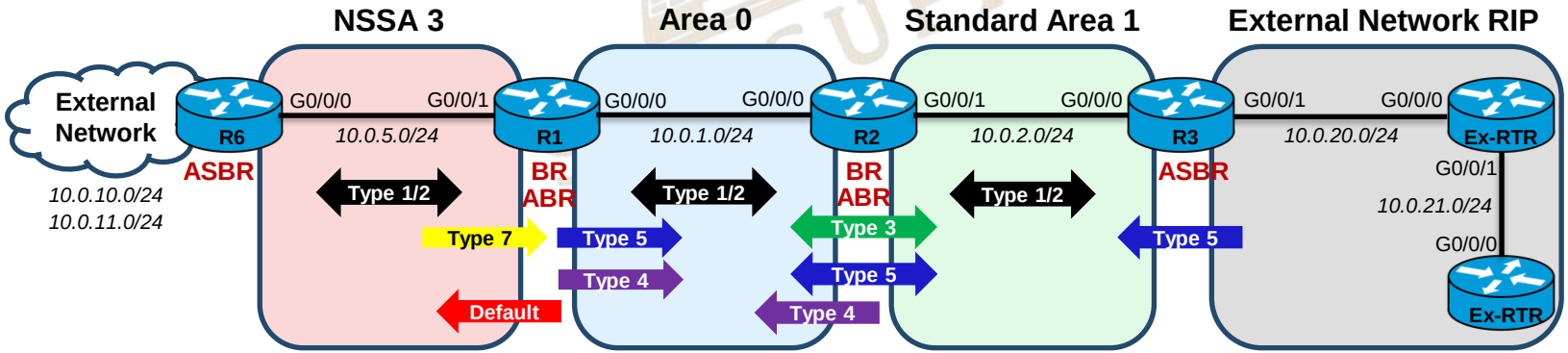
```
R5(config)#router ospf 10
R5(config-router)#network 10.0.4.0 0.0.0.255 area 3
R5(config-router)#area 3 stub
```

```
R5#show ip route
Codes: L - local, C - connected, S - static, 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
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 10.0.4.1 to network 0.0.0.0

     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C       10.0.4.0/24 is directly connected, GigabitEthernet0/0/0
L       10.0.4.2/32 is directly connected, GigabitEthernet0/0/0
C       10.0.10.0/24 is directly connected, GigabitEthernet0/0/1
L       10.0.10.1/32 is directly connected, GigabitEthernet0/0/1
O*IA 0.0.0.0/0 [110/2] via 10.0.4.1, 00:00:07, GigabitEthernet0/0/0
```

```
R1#show ip route
Codes: L - local, C - connected, S - static, 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
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
C       10.0.1.0/24 is directly connected, GigabitEthernet0/0/0
L       10.0.1.1/32 is directly connected, GigabitEthernet0/0/0
O IA    10.0.2.0/24 [110/2] via 10.0.1.2, 00:00:55, GigabitEthernet0/0/0
C       10.0.4.0/24 is directly connected, GigabitEthernet0/0/1
L       10.0.4.1/32 is directly connected, GigabitEthernet0/0/1
O E2    10.0.20.0/24 [110/20] via 10.0.1.2, 00:00:55, GigabitEthernet0/0/0
O E2    10.0.21.0/24 [110/20] via 10.0.1.2, 00:00:55, GigabitEthernet0/0/0
```

Advanced – OSPF Area Types

5.Not So Stubby Area (NSSA): An NSSA is a ***non-backbone area*** that receives ***LSAs from the backbone area*** and from ***external networks***. NSSAs ***do not send LSAs to other areas***, but they ***can send LSAs to external networks***. NSSAs are used when external routes need to be imported into OSPF while maintaining some area boundary restrictions. This area supports type ***1, 2, 3,*** and ***7*** LSAs. Here ***type 7 LSAs*** are used which are ***similar to the type 5 LSA***. Here the external links are advertised by the ASBR towards the ABR, which in turn will ***convert*** the ***LSA type 7 to LSA Type 5*** and then flood it to the rest of OSPF network. Similar to other areas, type 1 and type 2 LSAs are used to build the topology tables. The type 3 LSAs are accepted by the NSSA thus can be used to reach other networks of other areas.



Advanced – OSPF Area Types

The following commands on routers of OSPF stub area-

'Router(config)# router ospf <process ID>'

'Router(config-router)# network <network IP> <wildcard mask> area <non zero area ID>'

'Router(config-router)# area <non zero area ID> nssa'

```
R1(config)#router ospf 1
R1(config-router)#network 10.0.5.0 0.0.0.255 area 4
R1(config-router)#area 4 nssa
```

```
R6(config)#router ospf 10
R6(config-router)#network 10.0.5.0 0.0.0.255 area 4
R6(config-router)#area 4 nssa
```

```
R6#show ip route
Codes: L - local, C - connected, S - static, 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
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
O IA     10.0.1.0/24 [110/2] via 10.0.5.1, 00:01:01, GigabitEthernet0/0/0
O IA     10.0.2.0/24 [110/3] via 10.0.5.1, 00:01:01, GigabitEthernet0/0/0
C        10.0.5.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.5.2/32 is directly connected, GigabitEthernet0/0/0
C        10.0.10.0/24 is directly connected, GigabitEthernet0/0/1
L        10.0.10.1/32 is directly connected, GigabitEthernet0/0/1
```

```
R1#show ip route
Codes: L - local, C - connected, S - static, 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
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
C        10.0.1.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.1.1/32 is directly connected, GigabitEthernet0/0/0
O IA     10.0.2.0/24 [110/2] via 10.0.1.2, 00:16:28, GigabitEthernet0/0/0
C        10.0.5.0/24 is directly connected, GigabitEthernet0/0/1
L        10.0.5.1/32 is directly connected, GigabitEthernet0/0/1
O E2     10.0.20.0/24 [110/20] via 10.0.1.2, 00:16:28, GigabitEthernet0/0/0
O E2     10.0.21.0/24 [110/20] via 10.0.1.2, 00:16:28, GigabitEthernet0/0/0
```

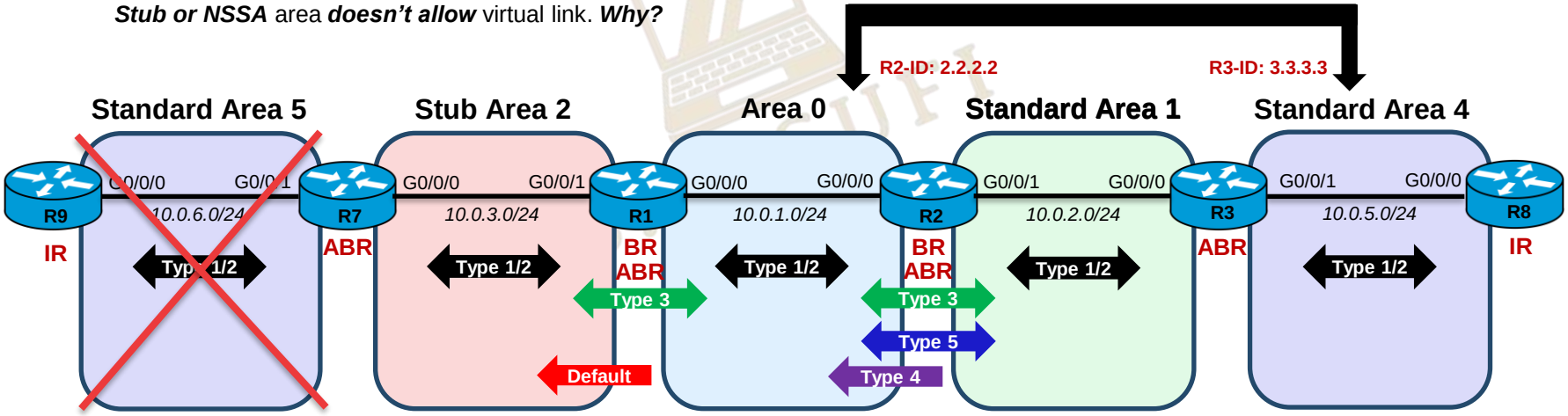
Advanced – OSPF Virtual Link

- Virtual links are used to connect a ***dis-contiguous area to area 0***.
- It is a ***logical connection*** built between routers.
- To configure virtual link, firstly, ***identify the virtual area*** (standard area 1 in the following figure).

  Secondly, ***Identify the ABRs*** of virtual areas (R2 and R1 in the following figure).

  Thirdly, ***identify the router*** IDs of those ABRs.

  Stub or NSSA area ***doesn't allow*** virtual link. ***Why?***



Advanced – OSPF Virtual Link

Commands of virtual link on the ABRs-

'Router(config)# router ospf <process ID>'

'Router(config-router)# area <virtual area ID> virtual-link <ABR ID>'

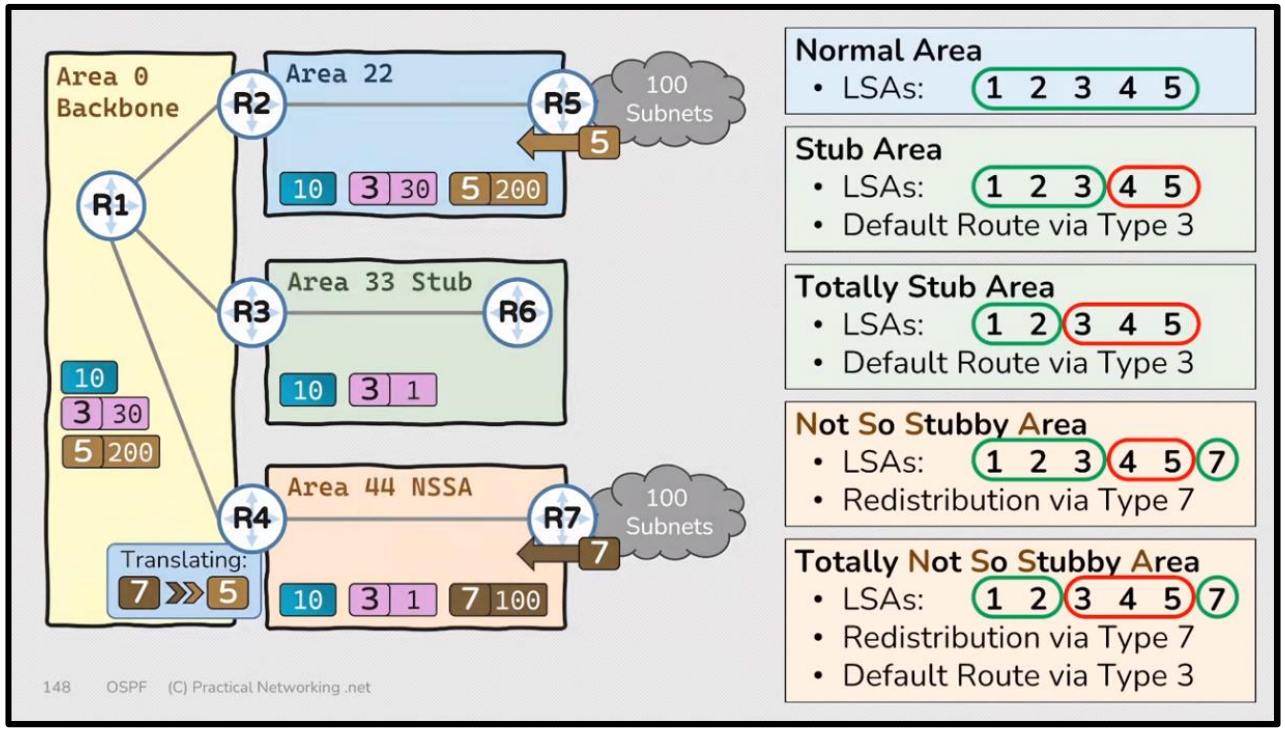
```
R7(config)#router ospf 10
R7(config-router)#area 2 virtual-link 10.0.3.1
R7(config-router)#% OSPF: Area 0.0.0.2 is a stub or nssa so virtual links are not allowed
```

```
R3(config)#router ospf 10
R3(config-router)#area 1 virtual-link 2.2.2.2
```

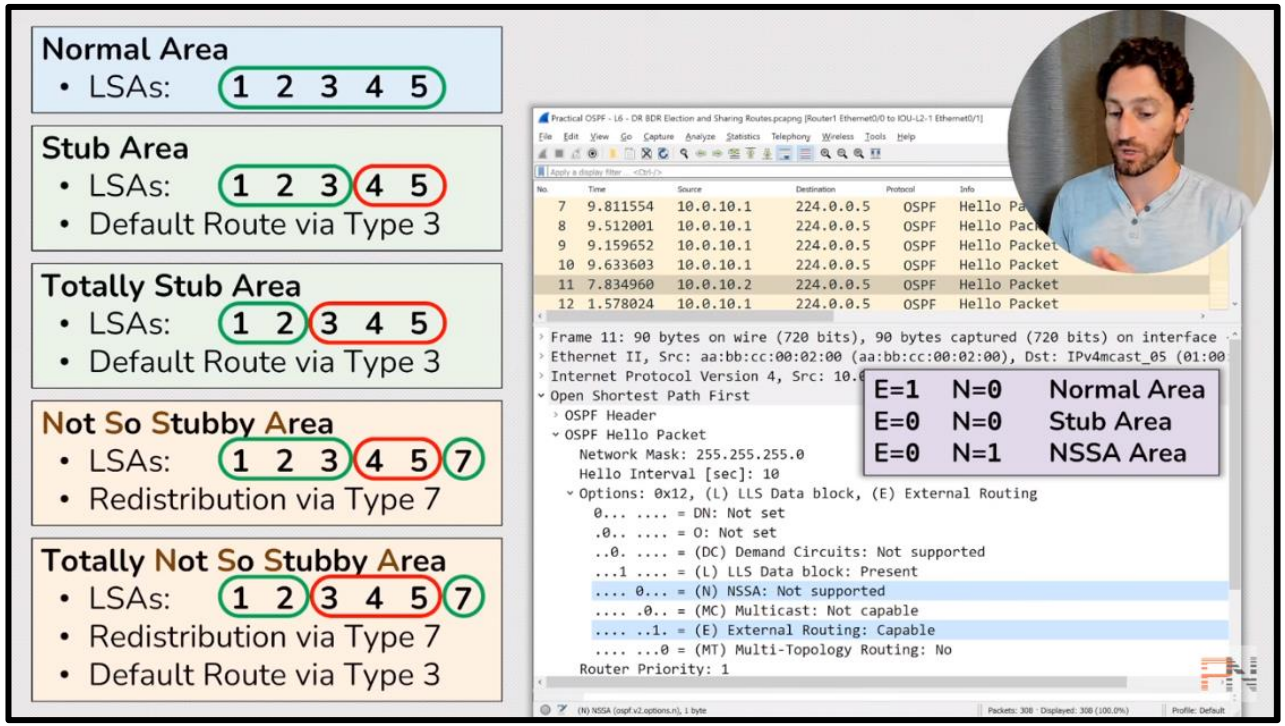
```
R2(config)#
00:59:46: %OSPF-4-ERRRCV: Received invalid packet: mismatch area ID, from backbone
area must be virtual-link but not found from 10.0.2.1, GigabitEthernet0/0/1

R2(config)#router ospf 10
R2(config-router)#area 1 virtual-link 3.3.3.3
R2(config-router)#
00:59:56: %OSPF-5-ADJCHG: Process 10, Nbr 3.3.3.3 on OSPF_VL5 from LOADING to FULL,
Loading Done
```

```
Neighbor ID     Pri   State           Dead Time   Address         Interface
3.3.3.3           0   FULL/  -        00:00:37    10.0.2.2        OSPF_VL5
10.0.3.1          1   FULL/DR         00:00:39    10.0.1.1        GigabitEthernet0/0/0
3.3.3.3           1   FULL/DR         00:00:36    10.0.2.2        GigabitEthernet0/0/1
R2#
```

Advanced – OSPF Area (Network Engineer Pro)



Advanced – OSPF Area (Network Engineer Pro)



Advanced – LSDB Table

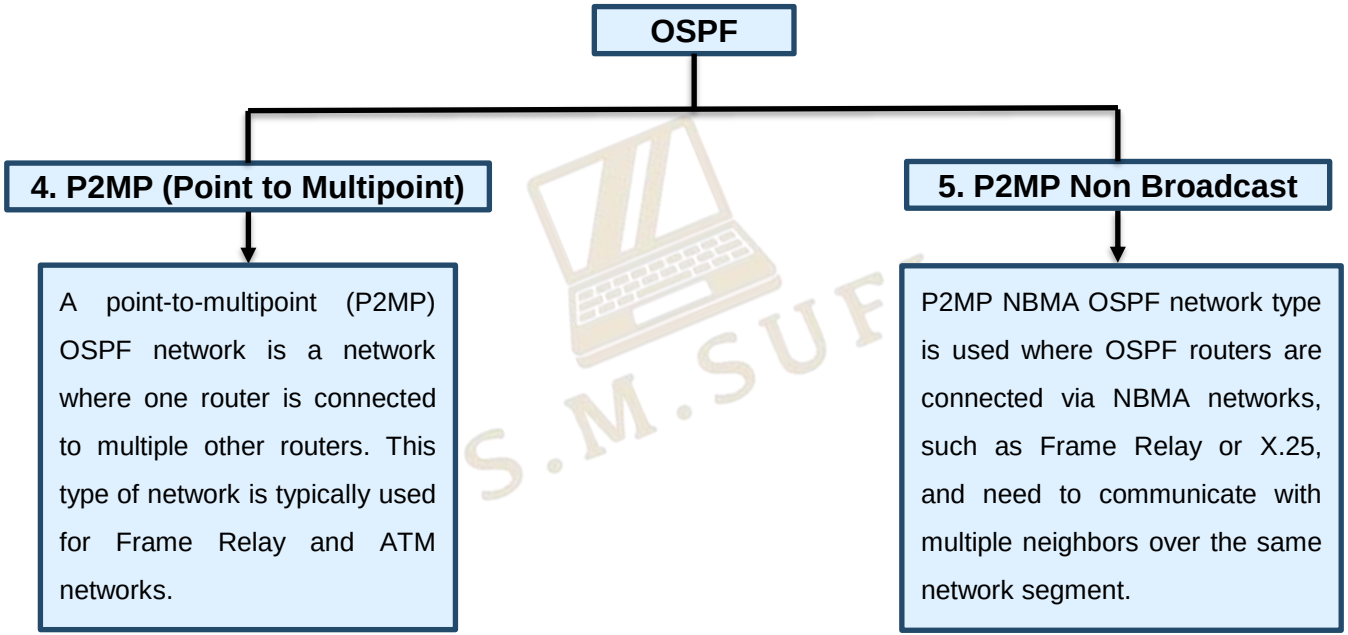
```
R1#sh ip ospf data
            OSPF Router with ID (10.0.5.1) (Process ID 10)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.5.1        10.0.5.1        101         0x80000002 0x008892 1
10.0.2.1        10.0.2.1        101         0x80000003 0x00ca54 1

                Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
10.0.1.1        10.0.5.1        101         0x80000001 0x002d8b

                Summary Net Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
10.0.2.0        10.0.2.1        101         0x80000001 0x008cb8
10.0.5.0        10.0.5.1        96          0x80000001 0x0056e8

                Summary ASB Link States (Area 0)
Link ID         ADV Router      Age         Seq#       Checksum
10.0.20.1       10.0.2.1        101         0x80000002 0x00ab84
10.0.5.1        10.0.5.1        91          0x80000002 0x003cff
```

```
                Router Link States (Area 4)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.0.5.1        10.0.5.1        101         0x80000003 0x00e828 1
10.0.10.1       10.0.10.1       101         0x80000003 0x009f65 1

                Net Link States (Area 4)
Link ID         ADV Router      Age         Seq#       Checksum
10.0.5.2        10.0.10.1       101         0x80000001 0x004f52

                Summary Net Link States (Area 4)
Link ID         ADV Router      Age         Seq#       Checksum
10.0.1.0        10.0.5.1        96          0x80000001 0x0082c0
10.0.2.0        10.0.5.1        96          0x80000002 0x007fc0

                Type-5 AS External Link States
Link ID         ADV Router      Age         Seq#       Checksum Tag
10.0.20.0       10.0.20.1       145         0x80000001 0x007d06 0
10.0.21.0       10.0.20.1       145         0x80000001 0x007210 0
```

```
R1#show ip ospf interface brief
Interface      PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Gig0/0/0       10    0               10.0.1.1/255.255.255.0    1     DR  0/0
Gig0/0/1       10    4               10.0.5.1/255.255.255.0    1     BDR 0/0
```

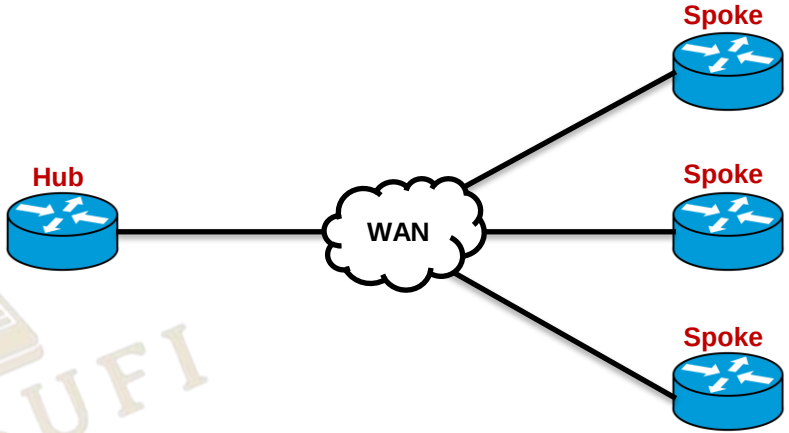
Advanced – OSPF Network Types

There are ***two*** more types of OSPF network-



Advanced – Point-to-Multipoint Network

- P2MP networks are similar to P2P networks, but they support multiple remote routers connecting to a central router. The remote routers are not directly connected to each other.
- Typically used in wireless or hub-and-spoke topologies.
- The hub router maintains a separate OSPF adjacency with each of the remote routers.
- Spoke routers establish OSPF adjacencies with the hub router but do not establish adjacencies with each other.
- Adjacencies are established between all neighboring routers. There is no DR/BDR concept.
- These type of network are not seen in LAN networks. They are commonly used in WAN scenarios such as: Remote site connectivity, branch office connectivity, wireless mesh networks and many more.



- Full mesh WAN deployment are rare and generally not recommended.
- Interfaces connecting Hub and Spoke will be in same subnet just like a OSPF broadcast network connected with a switch.

Advanced – OSPF Network Type Differences

Network Type	P2P	Broadcast	NBMA	P2MP	P2MP NB
Max Routers per Link	2	∞	∞	∞	∞
Full Mesh Connectivity Assumed	Yes	Yes	Yes	No	No
DR/BDR Election	No	Yes	Yes	No	No
Hello/Dead Timer (Cisco Default)	10 / 40	10 / 40	30 / 120	30 / 120	30 / 120
Automatic Neighbor Discovery	Yes	Yes	No	Yes	No
Discovery & Periodic Hello sent to	224.0.0.5	224.0.0.5	Neighbor IP	224.0.0.5	Neighbor IP
Neighbor Communication sent to	224.0.0.5	Unicast	Unicast	Unicast	Unicast
LSA(s) sent to	224.0.0.5	Multicast DR/BDR	Unicast DR/BDR	Unicast	Unicast
Next-Hot IP	Peer	Originated Router	Originated Router	Hub	Hub

Advanced – OSPFv2 Authentication

- Authentication is used to prevent unauthorized or invalid routing updates in the network.
- According to ***RFC 2328*** (Arpril, 1998), there are ***three*** different types of authentication available for OSPF version 2: **Type 0 - Null authentication**: Null authentication means that there is ***no authentication***, which is the default on Cisco routers. **Type 1 - Clear text authentication**: In this method of authentication, ***passwords*** are exchanged in ***clear text*** on the network **Type 2 - Cryptographic authentication**: The cryptographic method uses the open standard ***MD5*** (Message Digest type 5) encryption.
- The authentication type can be configured ***at the area level*** or ***at the interface level***.
- In either case, the ***password must*** still be configured ***at the interface level***.
- If both are configured, interface level configuration ***overrides*** area level configuration.
- Clear Text (***maximum 8 characters***) Authentication is configured when devices within an area cannot support MD5 Authentication. It leaves the internetwork vulnerable to a "***sniffer attack***" — where packets are captured by a protocol analyzer and the passwords can be identified.
- MD5 authentication provides higher security. This method uses the MD5 algorithm to ***compute a hash value*** from the contents of the OSPF packet and ***a password (or key)***. The hash value is transmitted in the packet, along with ***a key ID and a non-decreasing sequence number***. The receiver, which knows the same password, calculates its own hash value. If nothing in the message changes, the hash value of the ***receiver should match the hash value*** of the sender which is transmitted with the message. The key ID allows the routers to reference multiple passwords. This makes password migration easier and more secure.

Advanced – OSPFv2 Authentication Type 1 (Clear Text)

- Area based clear text authentication commands-

  'Router(config)# interface <interface name>'

  'Router(config-if)# ip ospf authentication-key <key value>'

  'Router(config-if)# exit'

  'Router(config)# router ospf <process ID>'

  'Router(config-router)# area <area ID> authentication'

  'Router(config-if)# exit'

- Interface based clear text authentication commands-

  'Router(config)# interface <interface name>'

  'Router(config-if)# ip ospf authentication'

  'Router(config-if)# ip ospf authentication-key <key value>'

  'Router(config-if)# exit'

```
R2(config)#router ospf 1
R2(config-router)#network 10.0.1.0 0.0.0.255 area 0
R2(config-router)#exit
R2(config)#interface se0/1/0
R2(config-if)#ip ospf authentication ?
  key-chain       Use a key-chain for cryptographic authentication keys
  message-digest  Use message-digest authentication
  null            Use no authentication
  <cr>
R2(config-if)#ip ospf authentication
R2(config-if)#ip ospf authentication-key ?
  <0-7>  Encryption type (0 for not yet encrypted, 7 for proprietary)
  WORD   The OSPF password (key) (maximum 8 characters)
R2(config-if)#ip ospf authentication-key cisco
R2(config-if)#
00:21:27: %OSPF-5-ADJCHG: Process 1, Nbr 10.0.1.1 on Serial0/1/0 from LOADING to FULL,
Loading Done
exit
R2(config)#exit
R2#
%SYS-5-CONFIG_I: Configured from console by console

R2#show ip ospf interface se0/1/0

Serial0/1/0 is up, line protocol is up
  Internet address is 10.0.1.2/24, Area 0
  Process ID 1, Router ID 10.0.2.1, Network Type POINT-TO-POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 10.0.1.1
  Suppress hello for 0 neighbor(s)
  Simple password authentication enabled
R2#
```

Advanced – OSPFv2 Authentication Type 2 (Cryptographic – MD5)

- Area based cryptographic MD5 authentication commands-

  'Router(config)# interface <interface name>'

  'Router(config-if)# ip ospf message-digest-key <key num>
  md5 <key value>'

  'Router(config-if)# exit'

  'Router(config)# router ospf <process ID>'

  'Router(config-router)# area <area ID> authentication
  message-digest'

  'Router(config-if)# exit'

- Interface based cryptographic MD5 authentication commands-

  'Router(config)# interface <interface name>'

  'Router(config-if)# ip ospf authentication message-digest'

  'Router(config-if)# ip ospf message-digest-key <key num>
  md5 <key value>'

  'Router(config-if)# exit'

```
R2(config)#router ospf 1
R2(config-router)#network 10.0.2.0 0.0.0.255 area 1
R2(config-router)#exit
R2(config)#interface se0/1/1
R2(config-if)#ip ospf ?
  <1-65535>              Process ID
  authentication         Enable authentication
  authentication-key     Authentication password (key)
  cost                   Interface cost
  dead-interval          Interval after which a neighbor is declared dead
  hello-interval         Time between HELLO packets
  message-digest-key     Message digest authentication password (key)
  network                Network type
  priority               Router priority
R2(config-if)#ip ospf authentication message-digest
R2(config-if)#ip ospf message-digest-key ?
  <1-255>  Key ID
R2(config-if)#ip ospf message-digest-key 100 ?
  md5  Use MD5 algorithm
R2(config-if)#ip ospf message-digest-key 100 md5 ?
  LINE  The OSPF password (key) (maximum 16 characters)
R2(config-if)#ip ospf message-digest-key 100 md5 ciscopro
R2(config-if)#
00:30:22: %OSPF-5-ADJCHG: Process 1, Nbr 10.0.2.2 on Serial0/1/1 from LOADING to FULL,
Loading Done
end
R2#
%SYS-5-CONFIG_I: Configured from console by console
show ip ospf interface se0/1/1

Serial0/1/1 is up, line protocol is up
  Internet address is 10.0.2.1/24, Area 1
  Process ID 1, Router ID 10.0.2.1, Network Type POINT-TO-POINT, Cost: 64
  Transmit Delay is    sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:03
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 10.0.2.2
  Suppress hello for 0 neighbor(s)
  Message digest authentication enabled
    Youngest key id is 100
R2#
```

Advanced – OSPFv2 Authentication Type 3 (Cryptographic – SHA)

- After being compromised, ***RFC 5709*** *(October, 2009)* allows OSPF to use ***HMAC-SHA*** algorithms for cryptographic authentication.
- With the addition of SHA to type 2 authentication, it is now called cryptographic authentication for both MD5 and SHA.
- It is ***similar to MD5 but more secure***.
- This is only available at the ***interface level*** & it uses ***key chains***
- Interface based cryptographic SHA authentication commands-

  'Router(config)# key chain <chain name>'

  'Router(config-keychain)# key <key num>'

  'Router(config-keychain-key)# key-string <string>'

  'Router(config-keychain-key)# cryptographic-algorithm hmac-sha-256'

  'Router(config-keychain-key)# exit'

  'Router(config-keychain)# exit'

  'Router(config)# interface <interface name>'

  'Router(config-if)# ip ospf authentication key-chain <chain name>'

  'Router(config-if)# exit'

```
R3(config)#router ospf 1
R3(config-router)#network 10.0.3.0 0.0.0.255 area 1
R3(config-router)#exit
R3(config)#key chain ?
  WORD  Key-chain name
R3(config)#key chain crypto
R3(config-keychain)#key ?
  <0-2147483647>  Key identifier
R3(config-keychain)#key 1
R3(config-keychain-key)#?
  accept-lifetime       Set accept lifetime of key
  cryptographic-algorithm Set cryptographic authentication algorithm
  exit                   Exit from key-chain key configuration mode
  key-string            Set key string
  no                    Negate a command or set its defaults
  send-lifetime         Set send lifetime of key
R3(config-keychain-key)#key-string ?
  LINE  The UNENCRYPTED (cleartext) user password (Maximum 80 characters)
R3(config-keychain-key)#key-string password
R3(config-keychain-key)#cryptographic-algorithm ?
  hmac-sha-1    HMAC-SHA-1 authentication algorithm
  hmac-sha-256  HMAC-SHA-256 authentication algorithm
  hmac-sha-384  HMAC-SHA-384 authentication algorithm
  hmac-sha-512  HMAC-SHA-512 authentication algorithm
  md5           MD5 authentication algorithm
R3(config-keychain-key)#cryptographic-algorithm hmac-sha-256
R3(config-keychain-key)#exit
R3(config-keychain)#exit
R3(config)#interface se0/1/0
R3(config-if)#ip ospf authentication key-chain crypto
R3(config-if)#
00:12:05: %OSPF-5-ADJCHG: Process 1, Nbr 10.0.3.1 on Serial0/1/0 from
LOADING to FULL, Loading Done
end
R3#
```

Key identifier range will be <1-255>

Advanced – OSPFv2 Authentication Type 3 (Cryptographic – SHA)

```
R3#show ip ospf interface se0/1/0

Serial0/1/0 is up, line protocol is up
  Internet address is 10.0.3.2/24, Area 1
  Process ID 1, Router ID 10.0.3.2, Network Type POINT-TO-POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT-TO-POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1 , Adjacent neighbor count is 1
    Adjacent with neighbor 10.0.3.1
  Suppress hello for 0 neighbor(s)
  Cryptographic authentication enabled
    Sending SA: Key 1, Algorithm HMAC-SHA-256 - key chain crypto
R3#show running-config | begin key
key chain crypto
 key 1
  key-string password
  cryptographic-algorithm hmac-sha-256
!
```

- **Sending SA:** Status of sending Security Association. Key, Cryptographic Algorithm and Key Chain used.

The currently valid algorithms for OSFv2 Cryptographic Authentication include:

- ***Keyed-MD5*** (defined in RFC 2328)
- ***HMAC-SHA-1*** (defined in RFC 5709)
- ***HMAC-SHA-256*** (defined in RFC 5709)
- ***HMAC-SHA-384*** (defined in RFC 5709)
- ***HMAC-SHA-512*** (defined in RFC 5709)

HMAC stands for ***Hashed Message Authentication Code***.

SHA stands for ***Secure Hash Algorithm.***

Advanced – OSPFv3 Basic

- OSPFv3 is based on ***OSPFv2 with enhancement***.
- It distributes IPv6 prefixes and runs directly over IPv6.
- It adds IPv6 specific attributes like-
  - ***128 bit addresses***.
  - ***Link-local address***.
  - ***Multiple addresses and instances per interface***.
  - Authentication (now uses ***IPsec***).
  - OSPFv3 ***runs over a link***, rather than a subnet.
- ***IPv6 routing*** has to be ***enabled*** before using any routing process as by default IPV6 routing is disabled.
- ***Router-ID*** in OSPFv3 ***must be in IPv4 format***. If any loopback or physical interfaces in the router doesn't have any IPv4 address, OSPFv3 cannot be configured without manually configuring its Router-ID ***manually*** in IPv4 format.

Commands for OSPFv3-

'Router(config)# ipv6 unicast-routing'

'Router(config)# ipv6 router ospf <process ID>'

'Router(config-rtr)# router-id <router ID>'

'Router(config-rtr)# exit'

'Router(config)# interface <interface name>'

'Router(config-if)# ipv6 enable'

'Router(config-if)# ipv6 router <process ID> area <area ID>'

'Router(config-if)# end'

'Router# show ipv6 protocols'

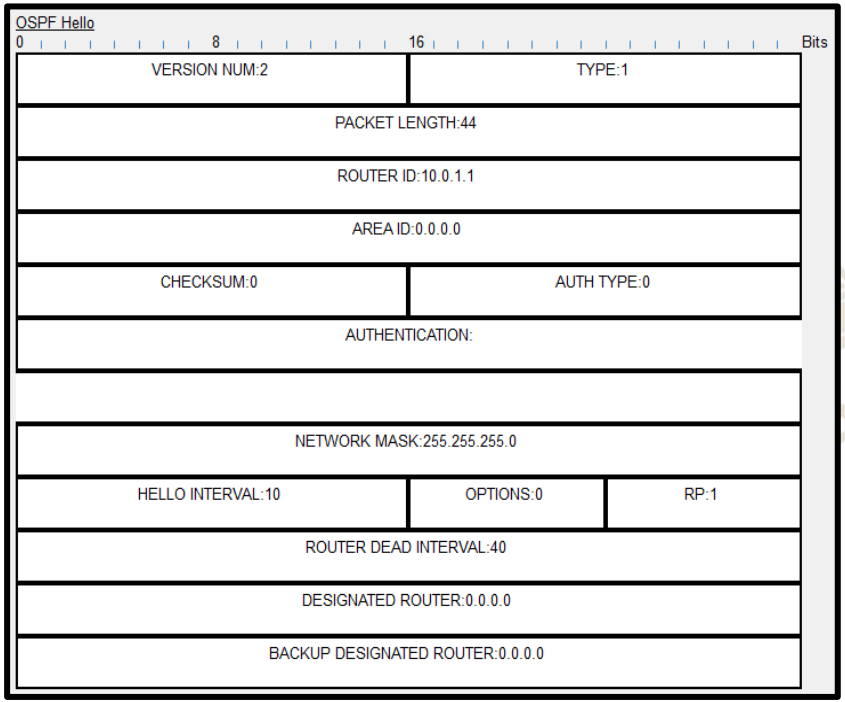
'Router# show ipv6 ospf neighbor'

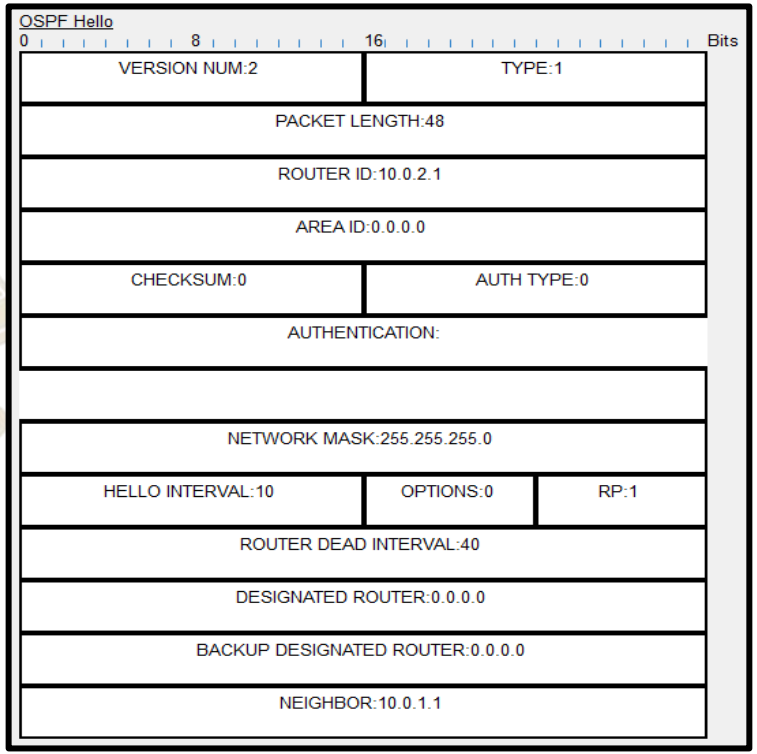
Advanced – OSPFv3 Basic

```
R1(config)#interface g0/0/0
R1(config-if)#ipv6 ospf 1 area 0
% IPv6 routing not enabled
R1(config-if)#exit
R1(config)#ipv6 unicast-routing
R1(config)#interface g0/0/0
R1(config-if)#ipv6 ospf 1 area 0
OSPFv3: No IPV6 enabled on this interface
R1(config-if)#ipv6 enable
R1(config-if)#ipv6 ospf 1 area 0
%OSPFv3-4-NORTRID: OSPFv3 process 1 could not pick a router-id,please configure manually
R1(config-if)#exit
R1(config)#ipv6 router ospf 1
R1(config-rtr)#router-id 1.1.1.1
R1(config-rtr)#exit
R1(config)#interface g0/0/0
R1(config-if)#ipv6 ospf 1 area 0
R1(config-if)#
R1(config-if)#end
R1#
%SYS-5-CONFIG_I: Configured from console by console

R1#show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 1"
  Interfaces (Area 0)
  Redistribution:
    None

R1#
```

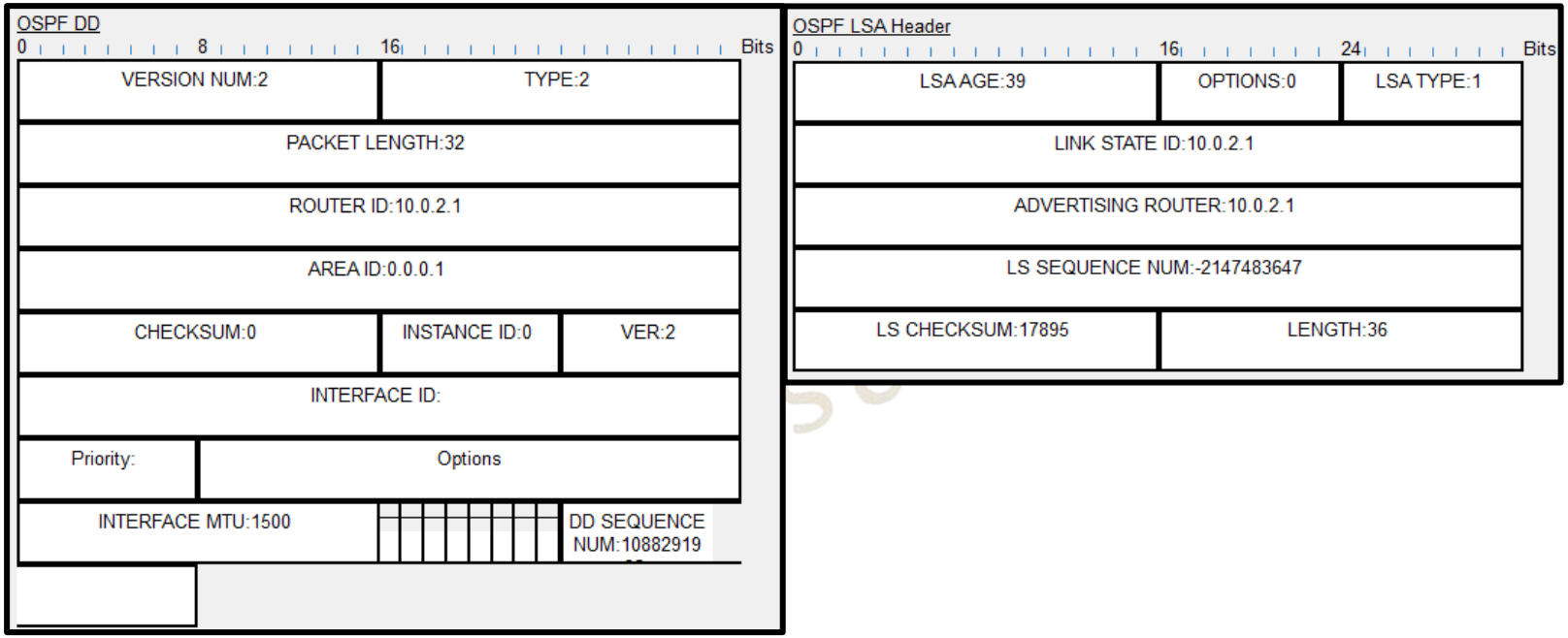
```
R2#show ipv6 ospf neighbor

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
1.1.1.1           1   2WAY/DROTHER    00:00:30    1               GigabitEthernet0/0/0
R2#
00:02:49: %OSPFv3-5-ADJCHG: Process 1, Nbr 1.1.1.1 on GigabitEthernet0/0/0 from LOADING to FULL,
Loading Done
show ipv6 ospf neighbor

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
1.1.1.1           1   FULL/BDR        00:00:38    1               GigabitEthernet0/0/0
R2#
```

PDU – Packet Type 1 (Hello)

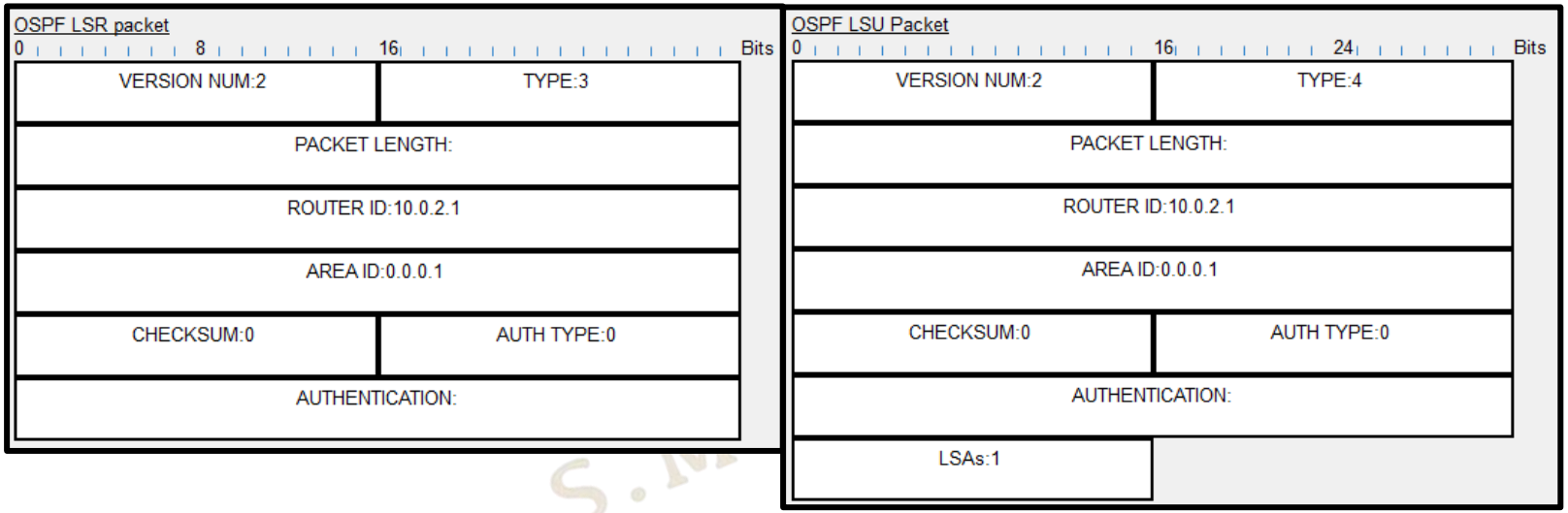




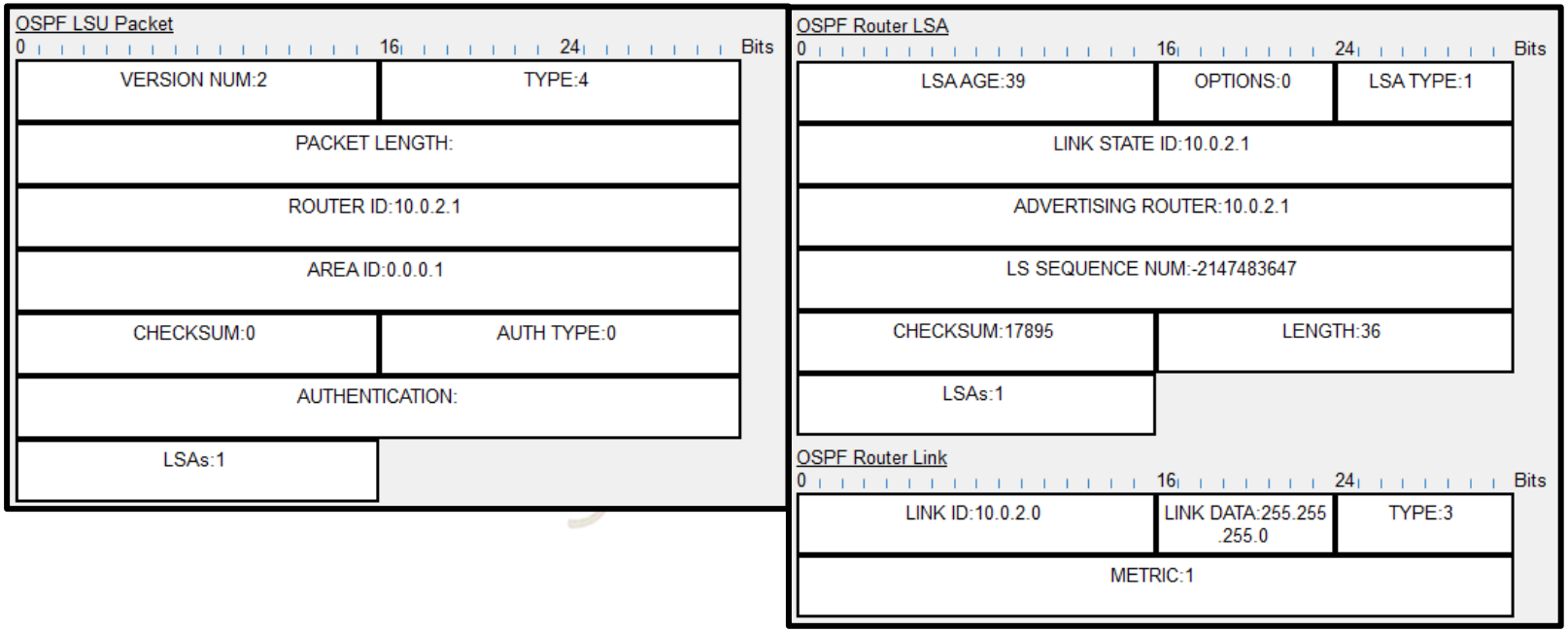
PDU – Packet Type 2 (DD)



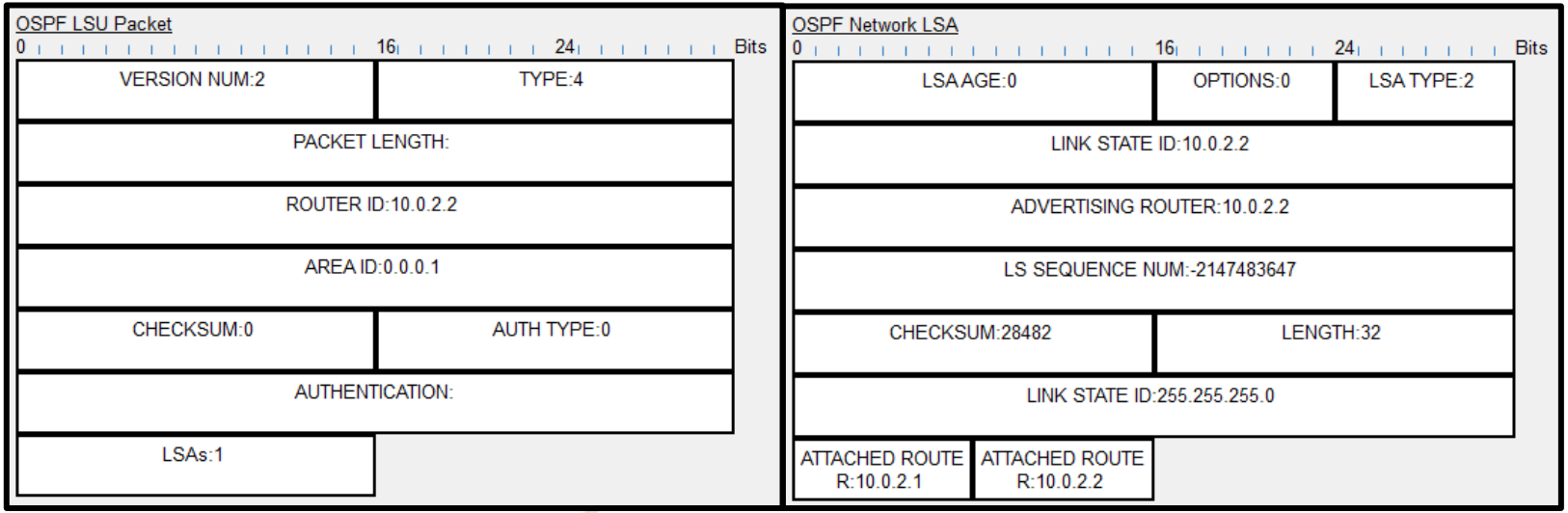
PDU – Packet Type 3 (LSR) & Type 4 (LSU)



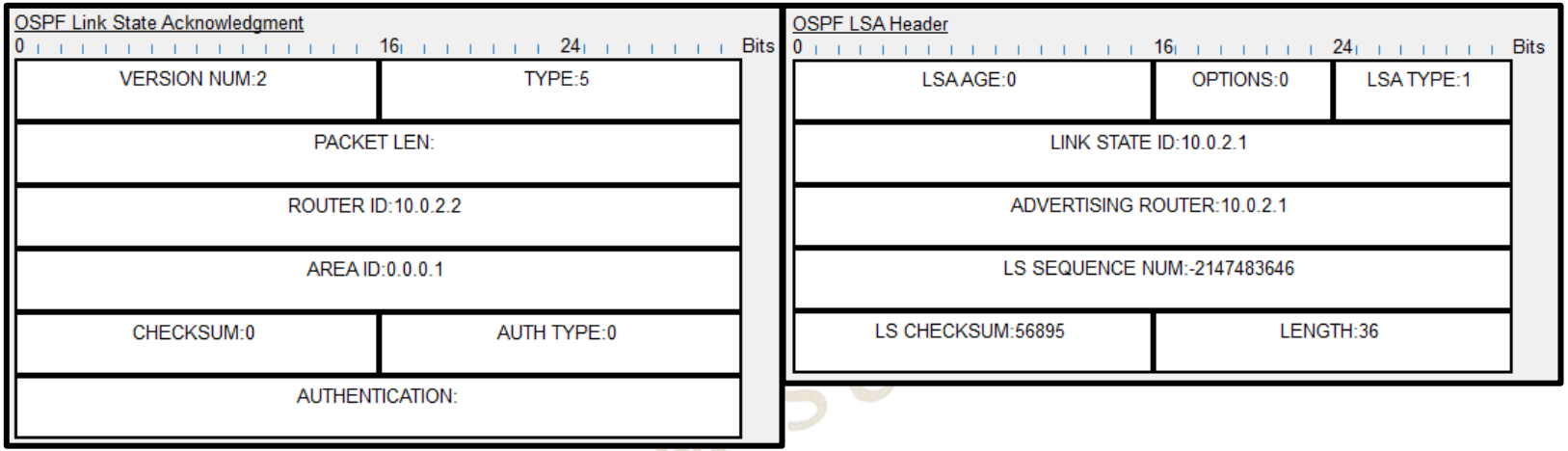
PDU – OSPF Router LSA



PDU – OSPF Network LSA



PDU – Packet Type 5 (LSAck)



Thank You

Feel free to reach out to me for any **suggestions** or **feedback** via **LinkedIn** or **Mail**

 www.github.com/smsufi

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