Open **S**hortest **P**ath **F**irst (Advanced)

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Before starting this study material, in case if you didn't check, it is recommended to go through the previous version named "OSPF Basic"

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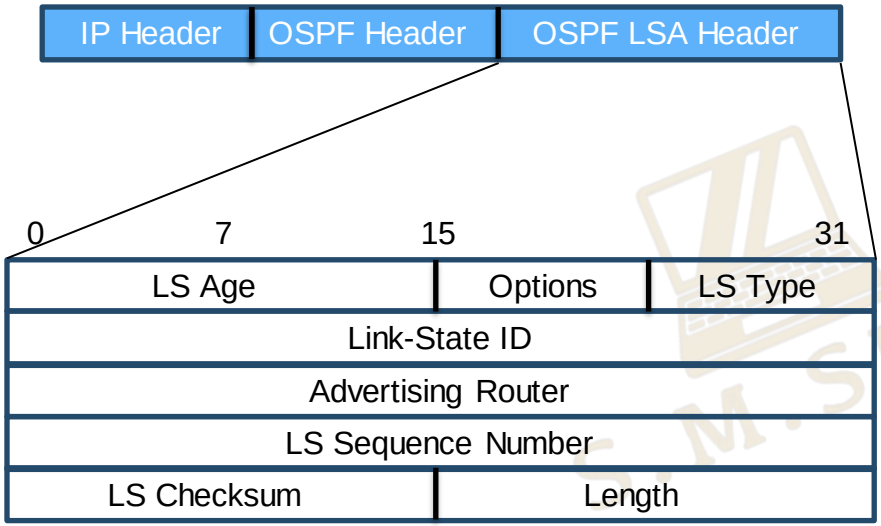
LSA Types

- 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.***

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

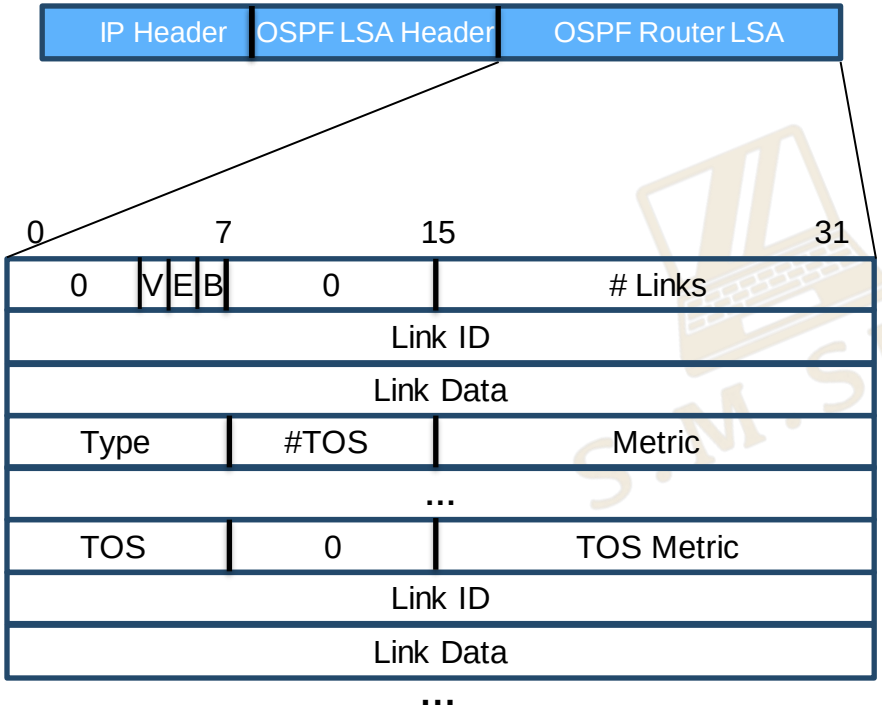
Advertising Router: The router ID of the router that generated the LSA.

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.

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.

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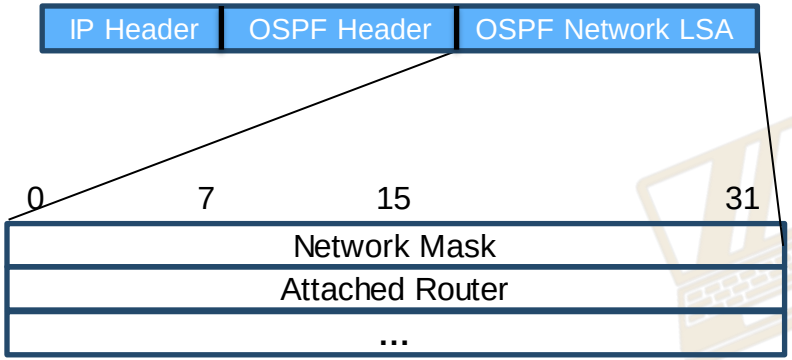
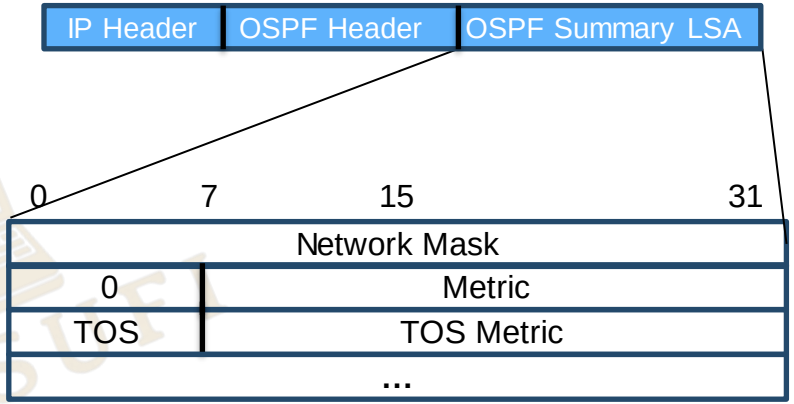
Network LSA Type 2 Format & Summary LSA Type 3 or 4





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

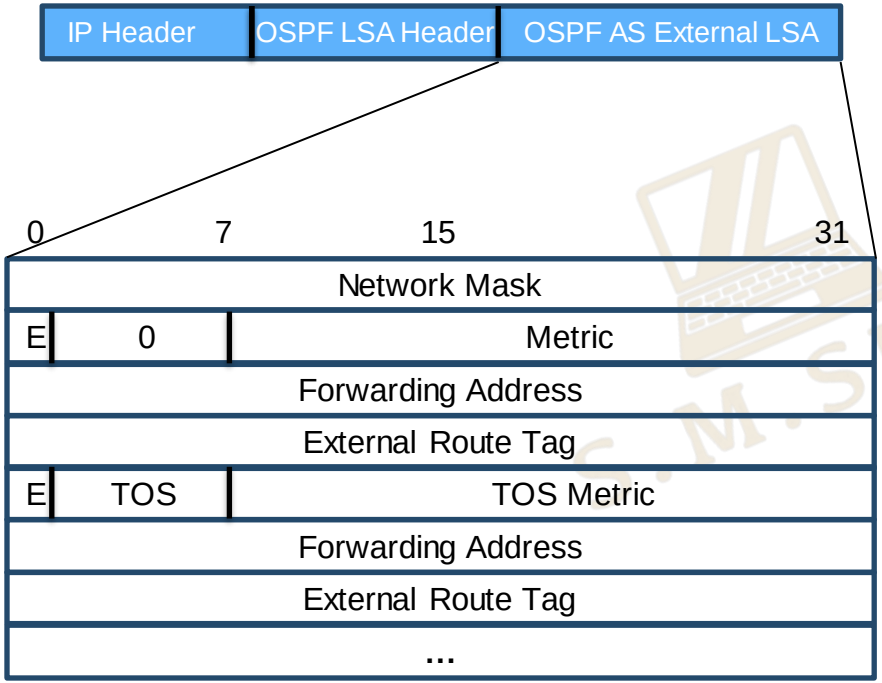
Attached Router: The IDs of the routers, which are adjacent to the DR, including the DR itself.

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.

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.

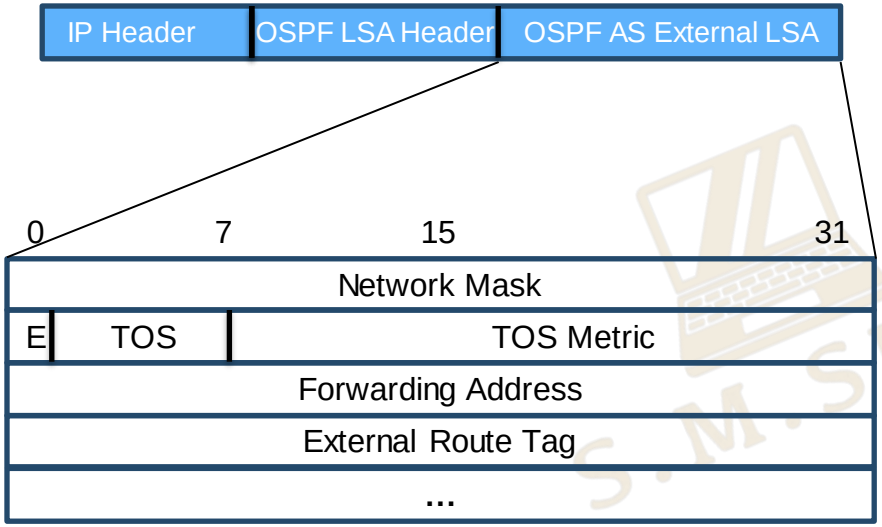
Forwarding Address: Data traffic for the advertised destination is forwarded to this address.

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.

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.

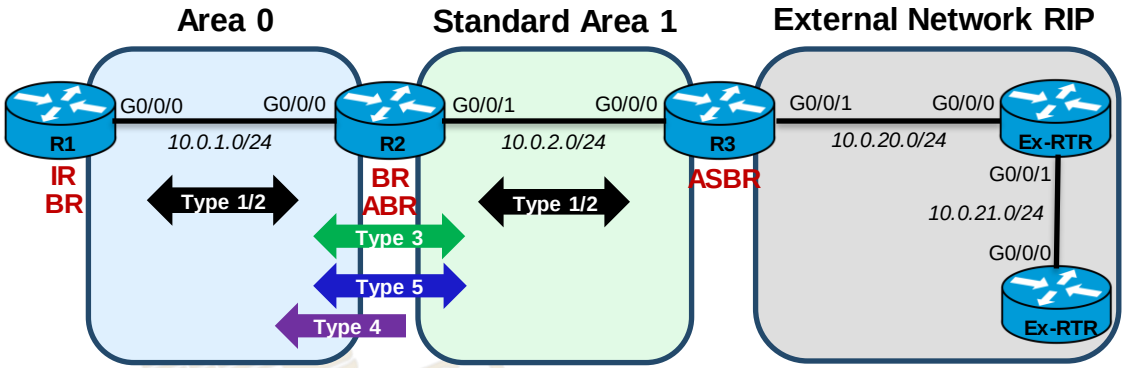
External Route Tag: A tag attached to each external route. This is not used by the OSPF protocol. It may used to manage external routes.

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

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.

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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
```

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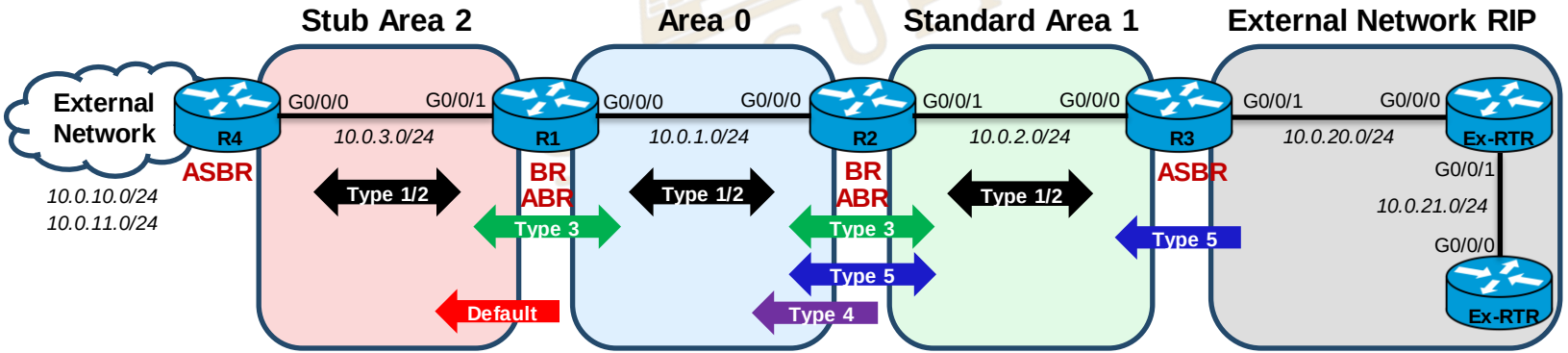
Area Types

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
```



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
```

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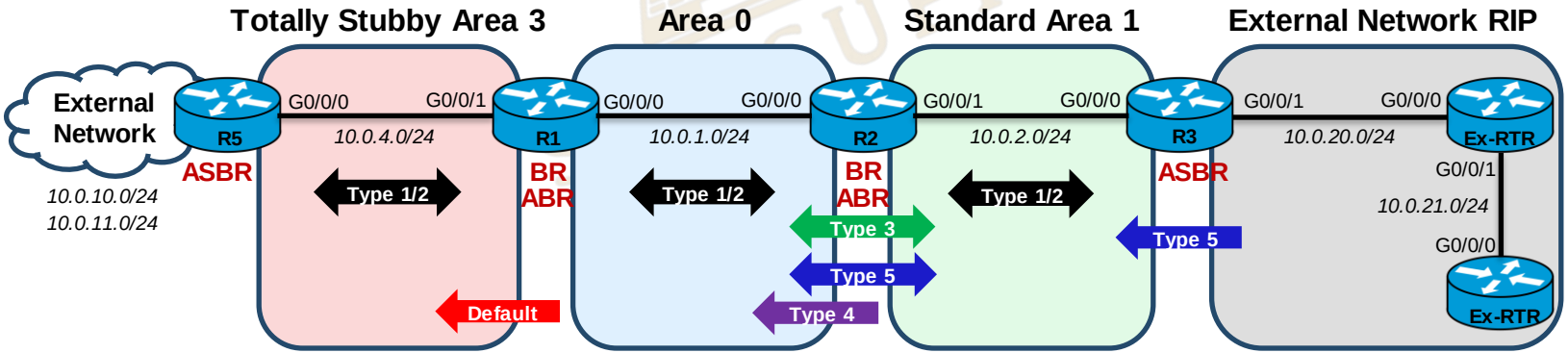
Area Types

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
```



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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
```

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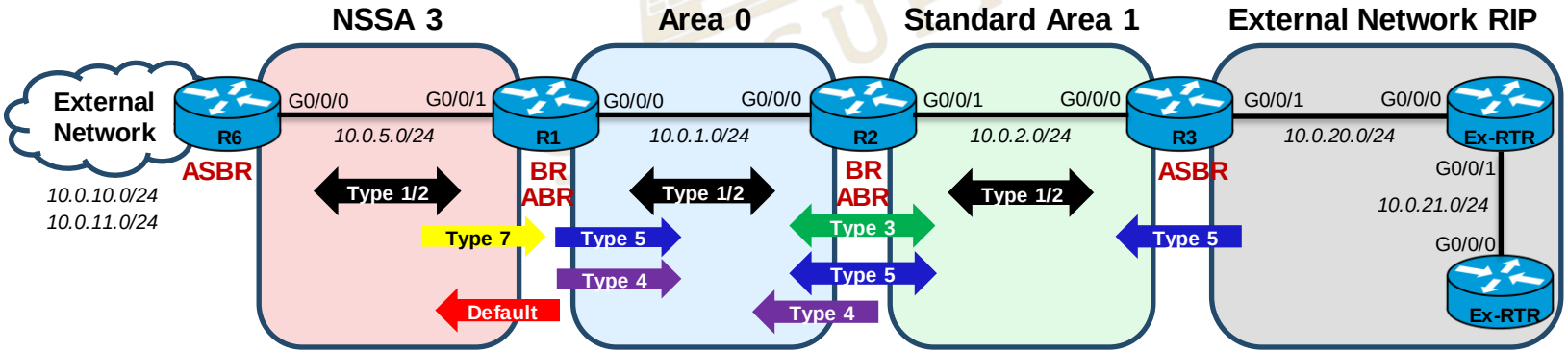
Area Types

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.



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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
```

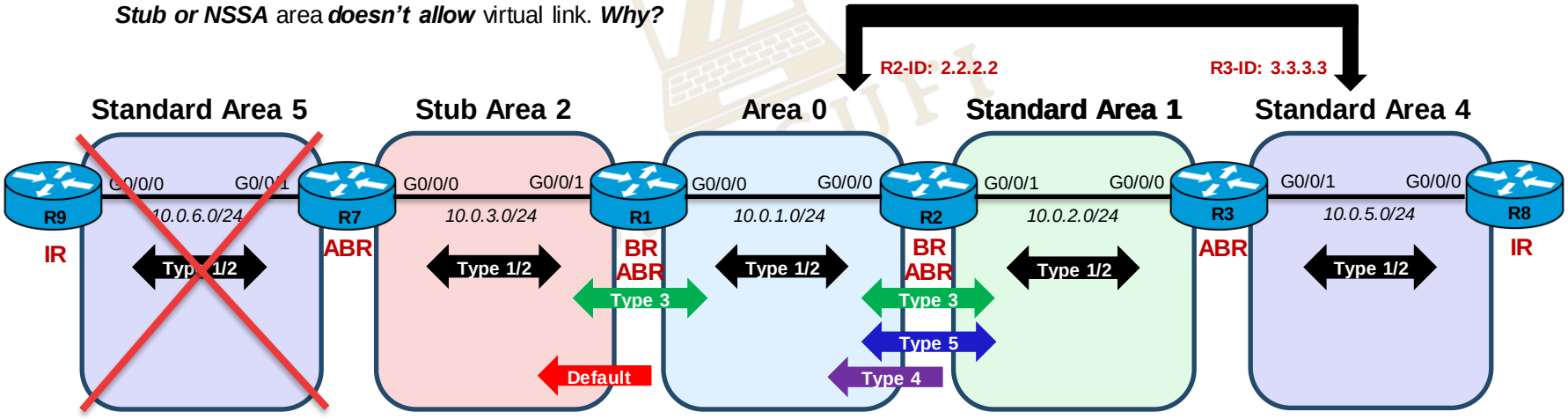
Virtual Link

- 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?***



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#
```

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LSDB (Link State Database) 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
```

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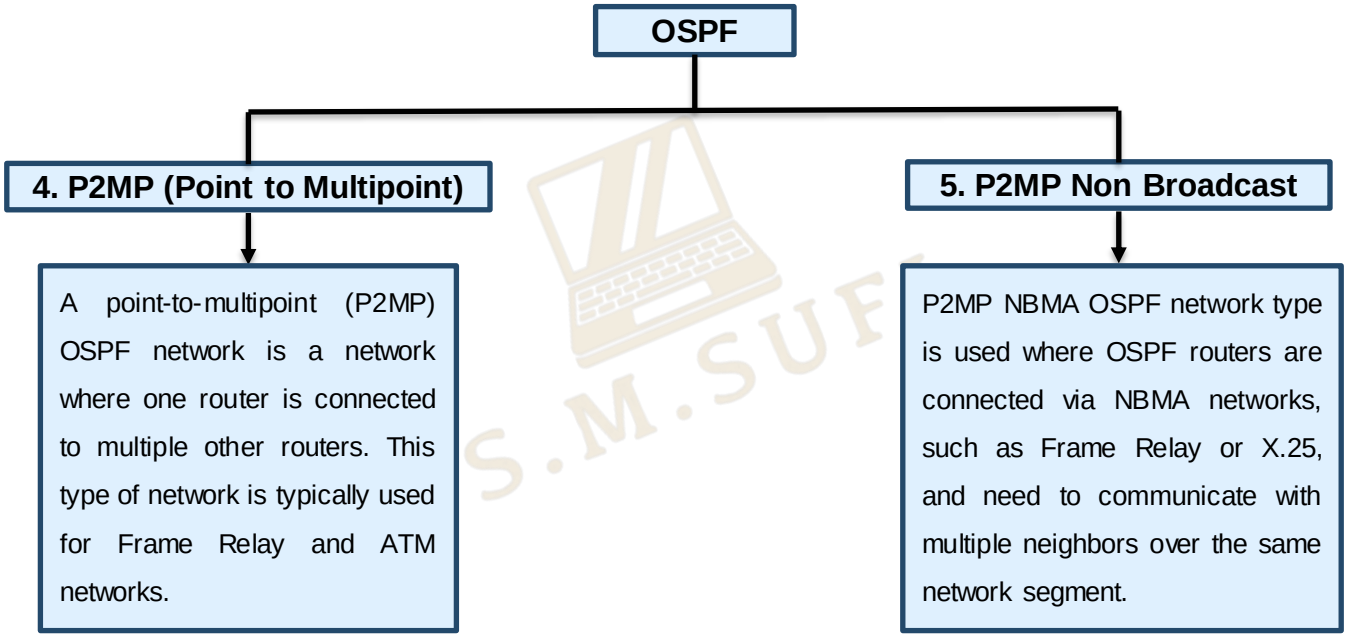
Network Types

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



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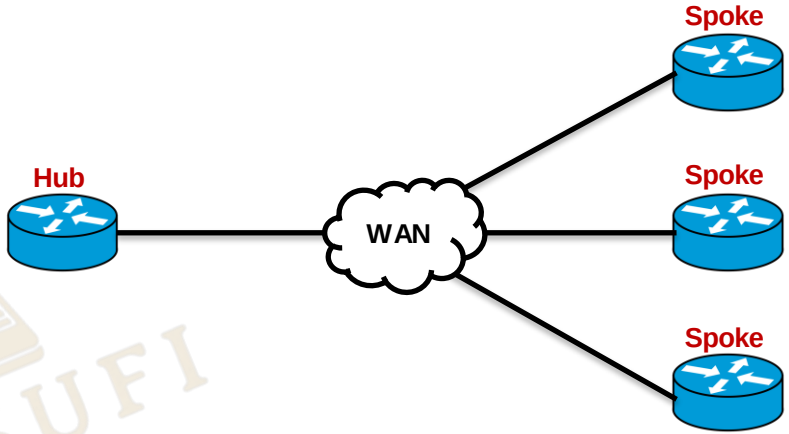
Point-to-Multipoint Network

- 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.

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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

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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.

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#
```

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#
```

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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'

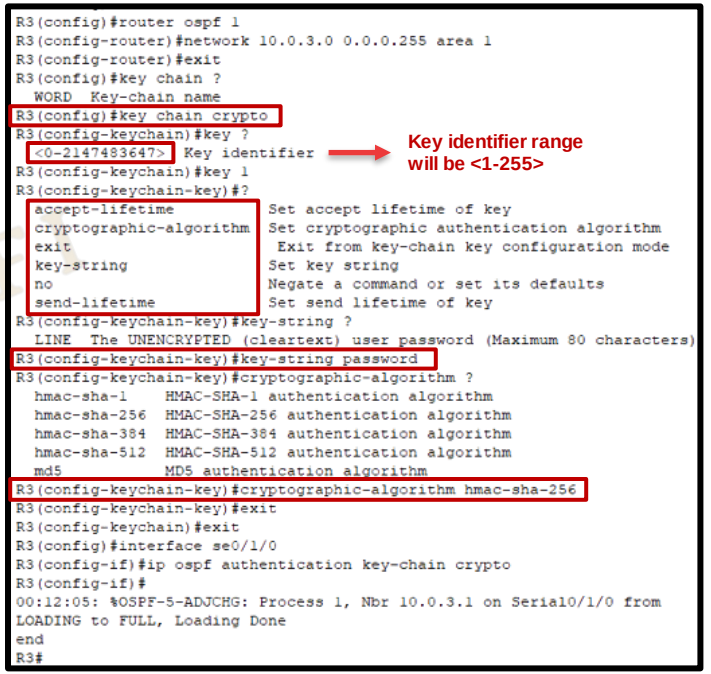
  'Router(config-keychain-key)# exit'

  'Router(config-keychain)# exit'

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

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

  'Router(config-if)# exit'



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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.***

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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'

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#
```

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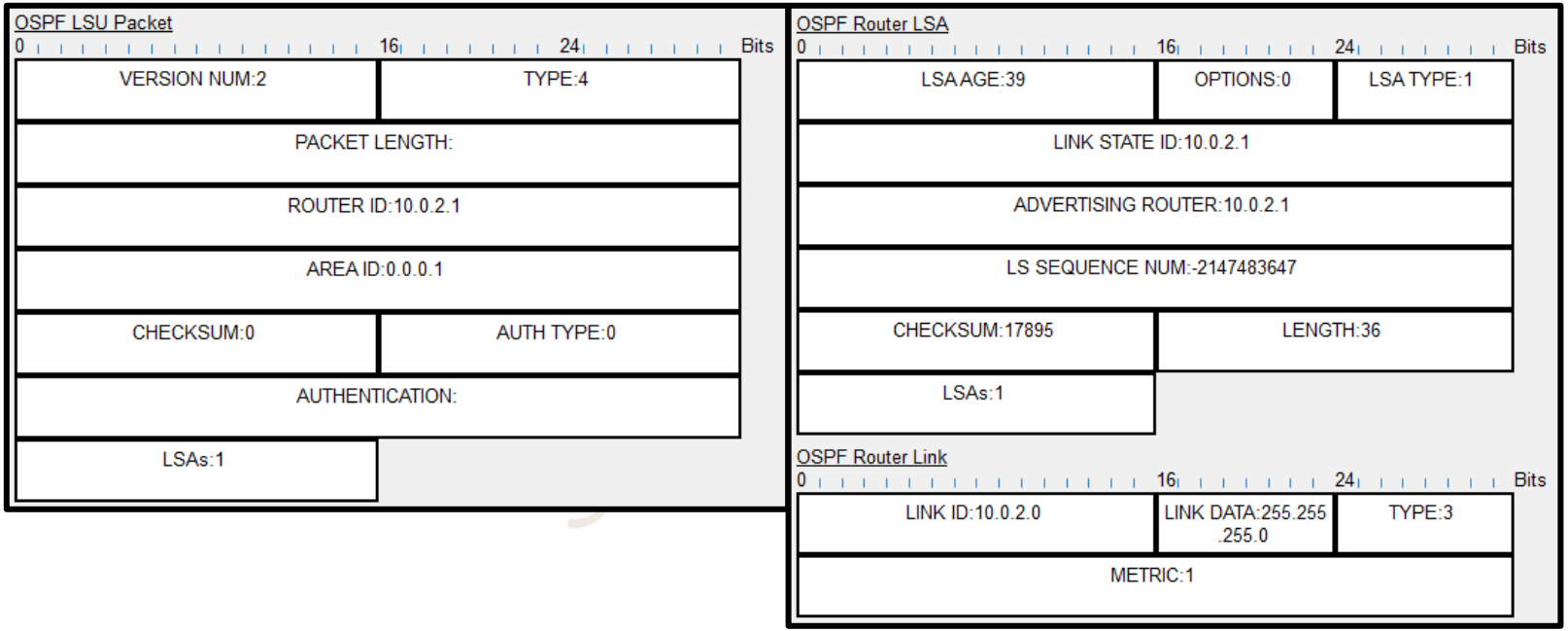
PDU – Router LSA



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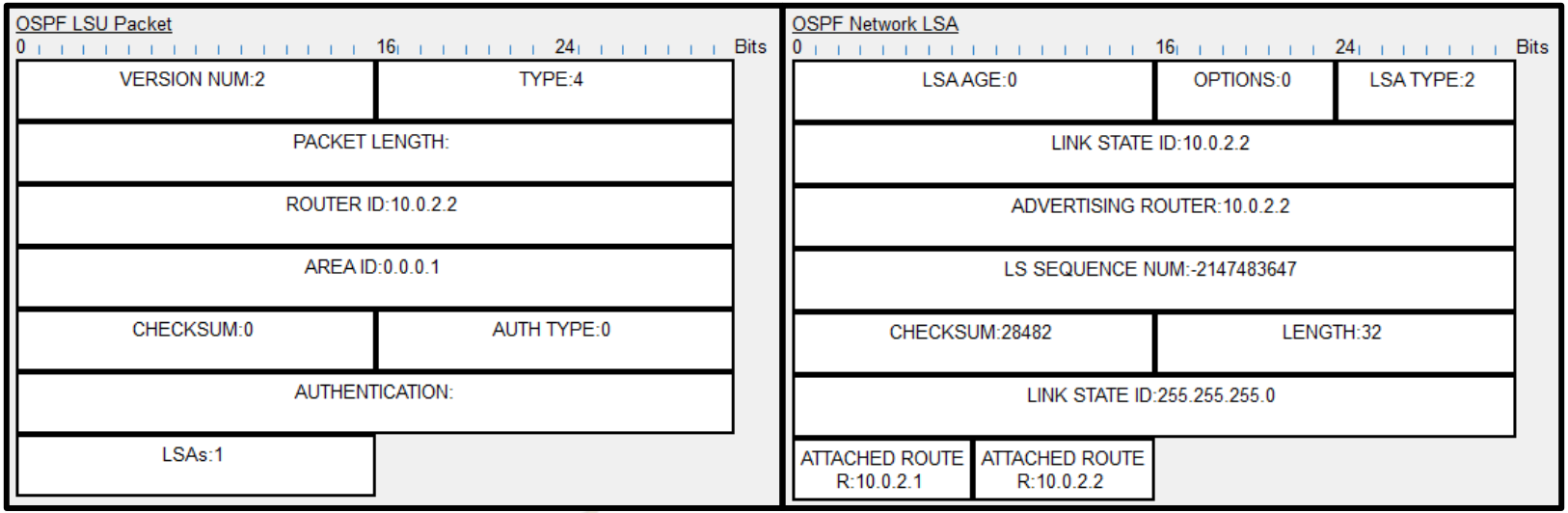
PDU – Network LSA



Thank You

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

 www.github.com/smsufi

 www.linkedin.com/in/smsufi

 safwanm.cse@gmail.com

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