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

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Introduction

The history of OSPF can be traced back to the ***early 1980s***, when the internet was still in its early stages of development. At the time, the most common routing protocol was RIP (Routing Information Protocol), but RIP had a number of limitations, such as its inability to support large networks or to distribute external routes.

In response to the limitations of RIP and to develop a new routing protocol, the ***IETF (Internet Engineering Task Force)*** -

- Formed a ***working group*** in ***1998***.
- In ***1991***, published ***RFC 1247***, which defined the ***first version of OSPF***.
- In ***1998***, published ***RFC 2328***, which defines the ***current version*** of OSPF ***(OSPFv2)***.
- In ***1999***, published ***RFC 2740***, which defines ***OSPFv3*** for ***IPv6 networks***.

OSPF is now one of the ***most widely used routing protocols worldwide***. In fact, it the ***most used IGP*** (Interior Gateway Protocol). OSPF has continued to evolve over the years, and the IETF continues to publish new RFCs that define new features and enhancements for OSPF. OSPF is an IGP (Interior Gateway Protocol) but it can also **Redistribute External Routes** from different Autonomous System into its routing table. This routing protocol is known for its scalability, reliability and support for advanced features such as authentication and traffic engineering.

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Key Features

- OSPF stands for ***Open Shortest Path First***. It 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***.
- Different **OSPF Processes** in a single autonomous system.
- Supports ***CIDR*** (Classless Inter-Domain Routing).
- ***No limit*** for number of ***Hops*** (routers) connected.

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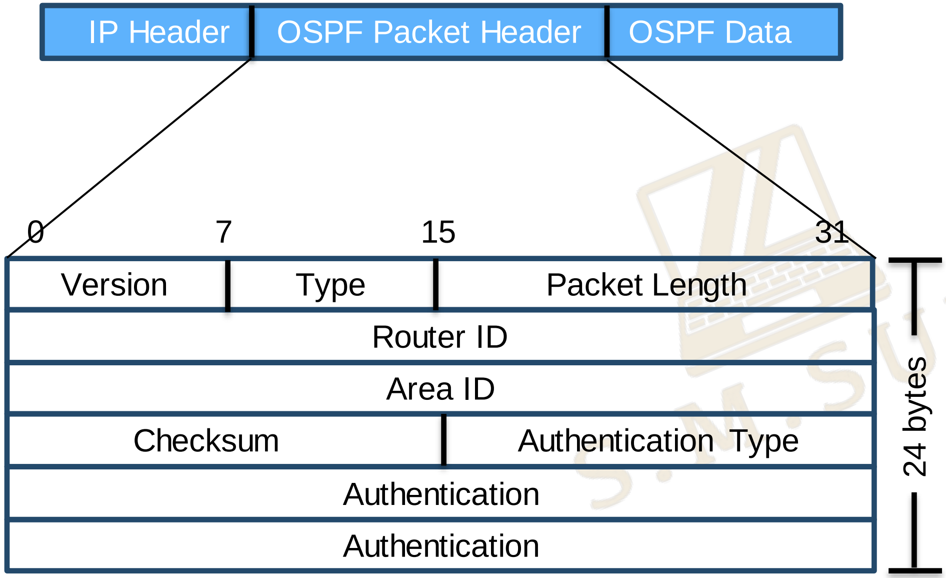
Packet Header Format



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.

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

Authentication: Data used for authentication.

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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'

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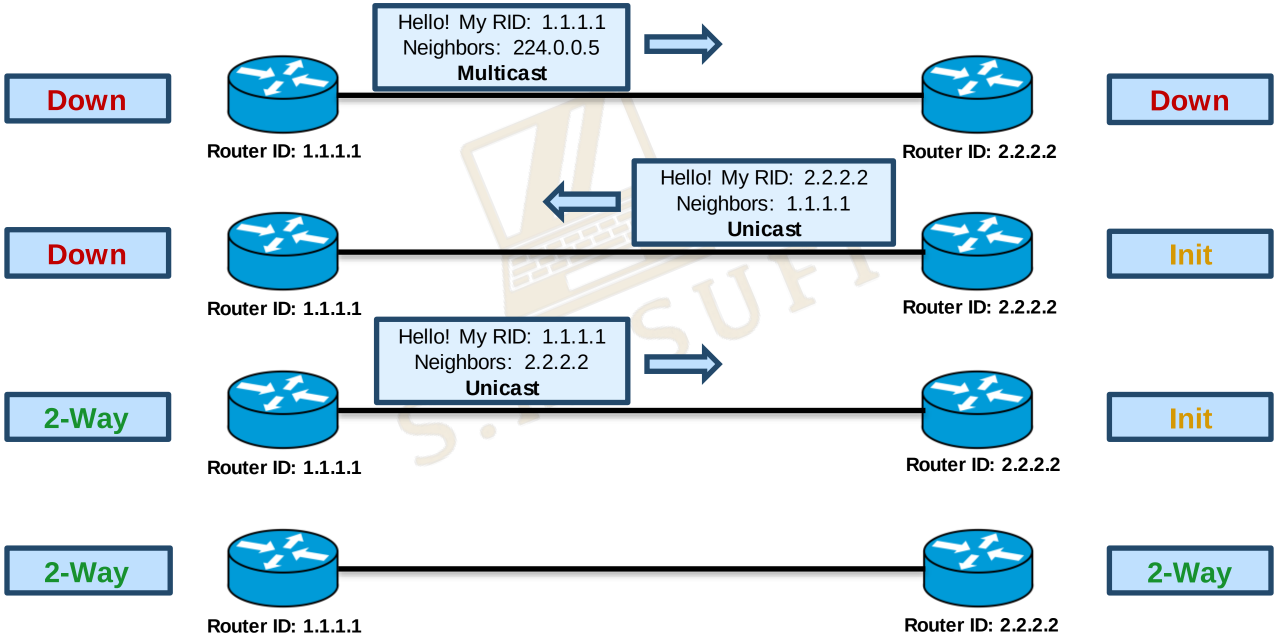
Becoming Neighbors

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



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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

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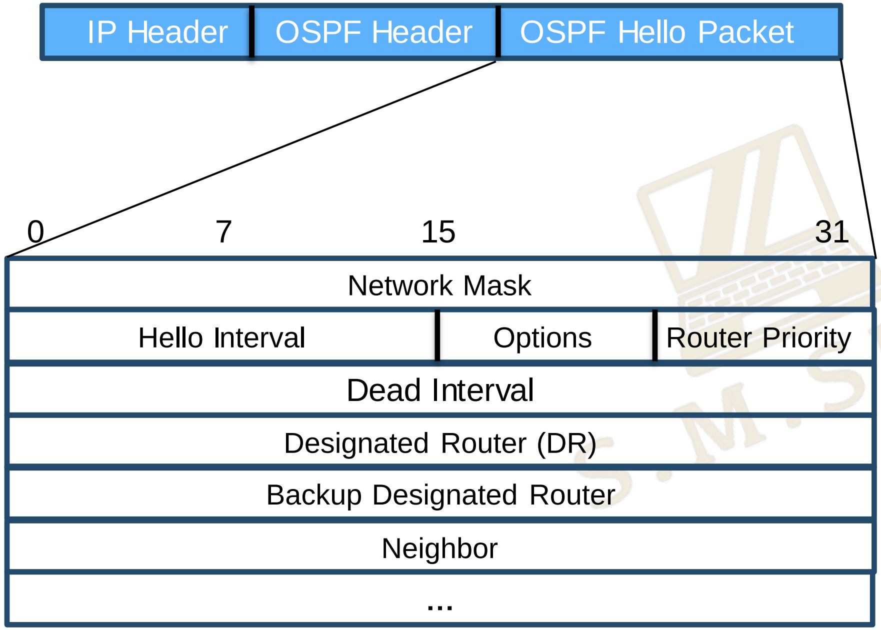
Packet Type 1 (Hello)



***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.

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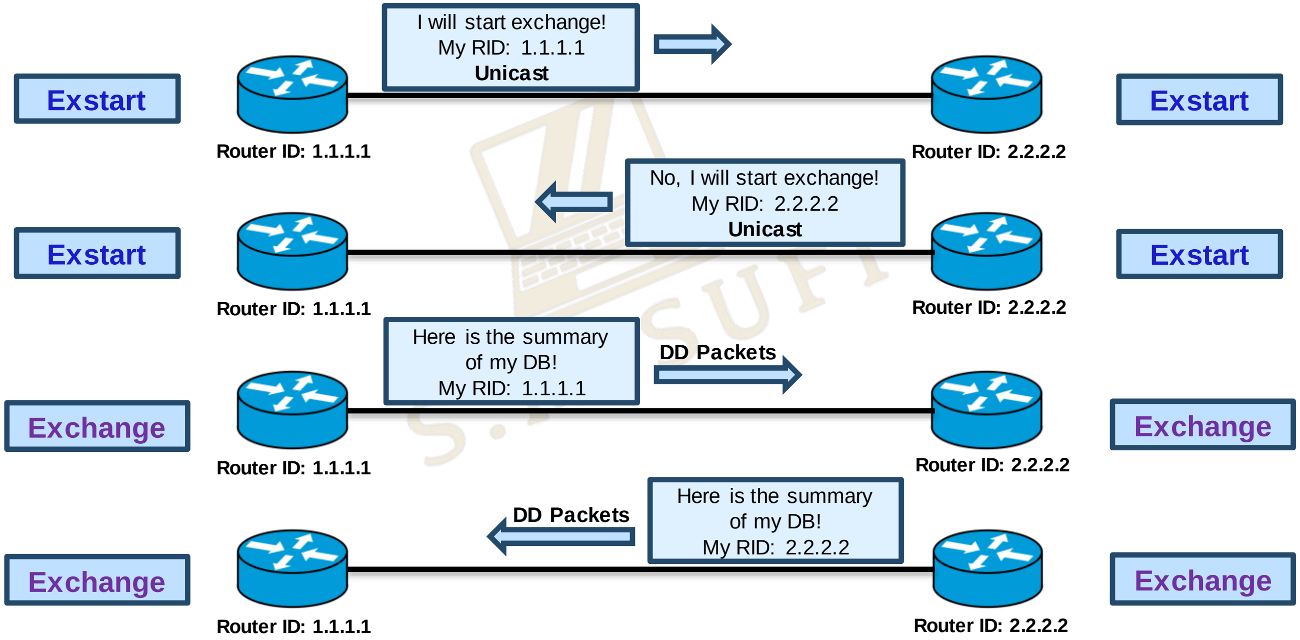
Exchanging Database

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



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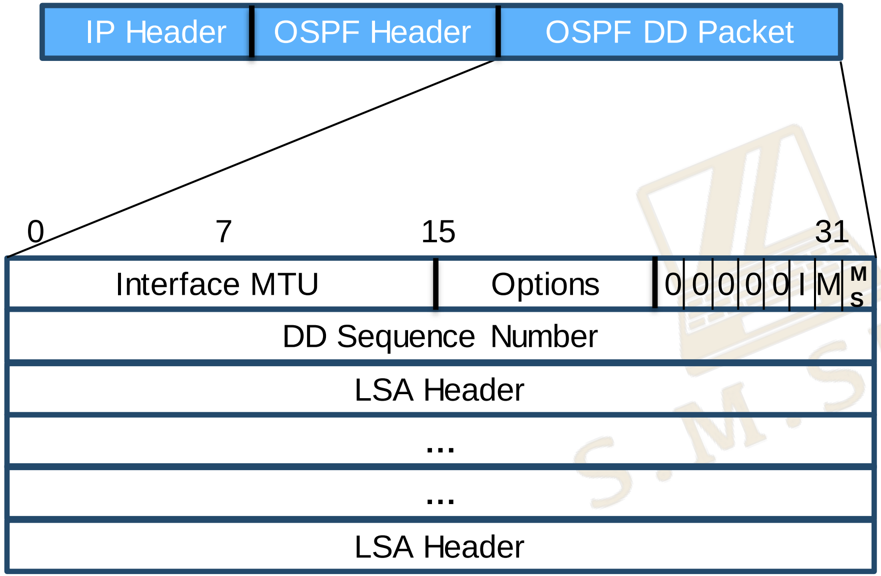
Packet Type 2 (DD-Database Descriptor)



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 (Initial): The Initial bit is set to 1 if the packet is the first DD packet. It is set to 0 if not.

M (More): The More bit 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 (Master/Slave): 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.

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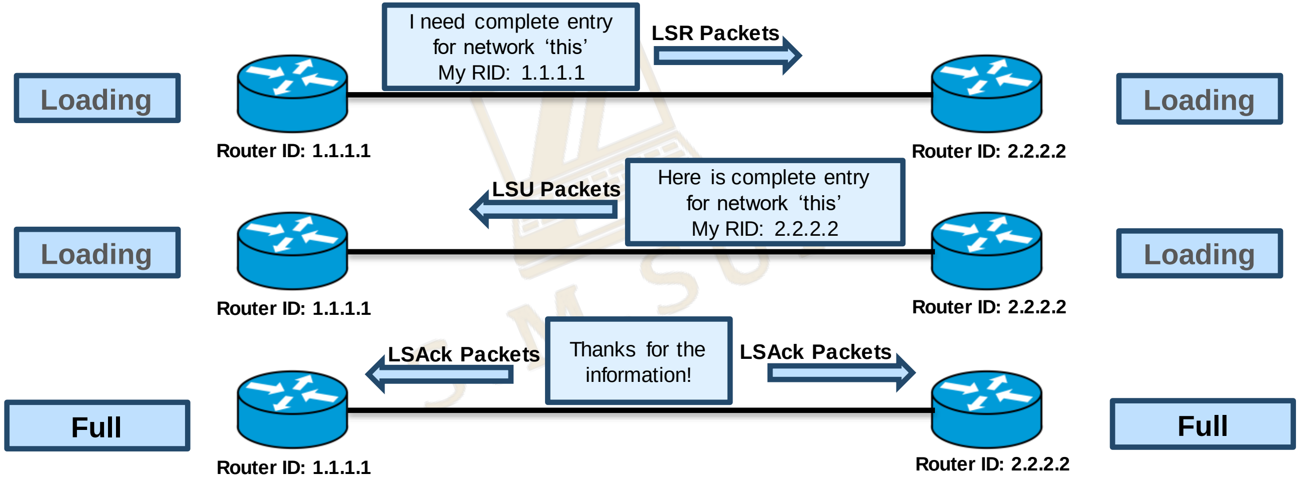
Calculating Best Route

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.

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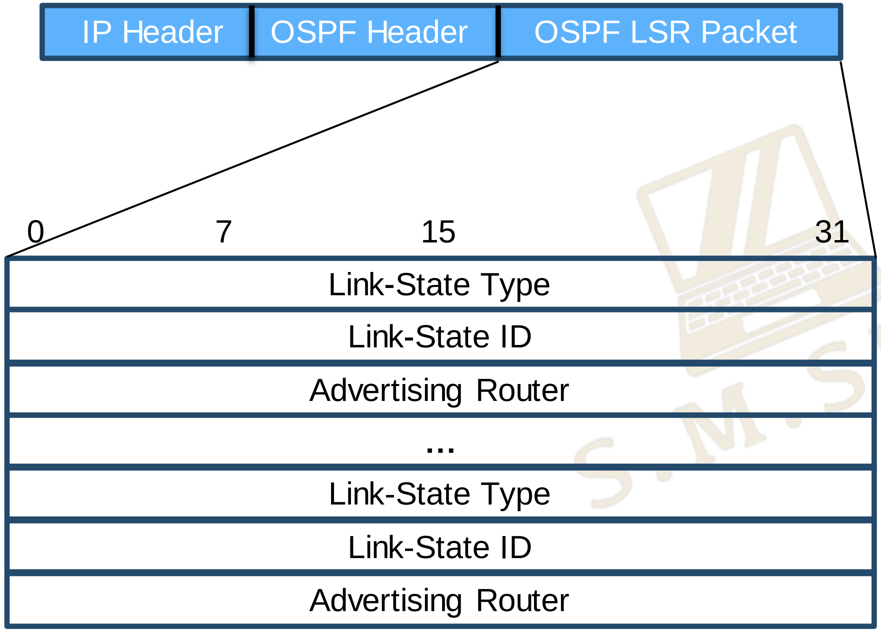
Packet Type 3 (LSR-Link State Request)

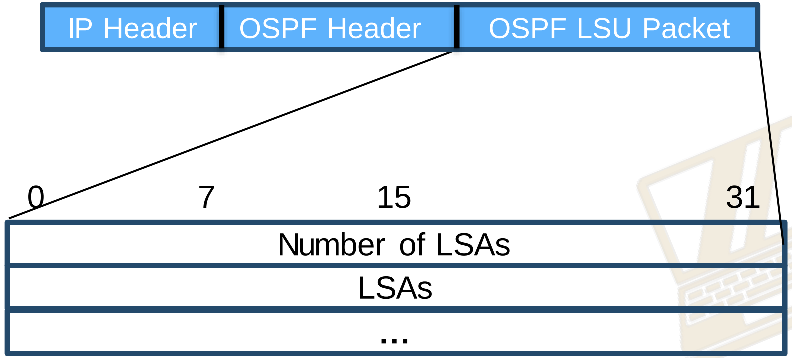


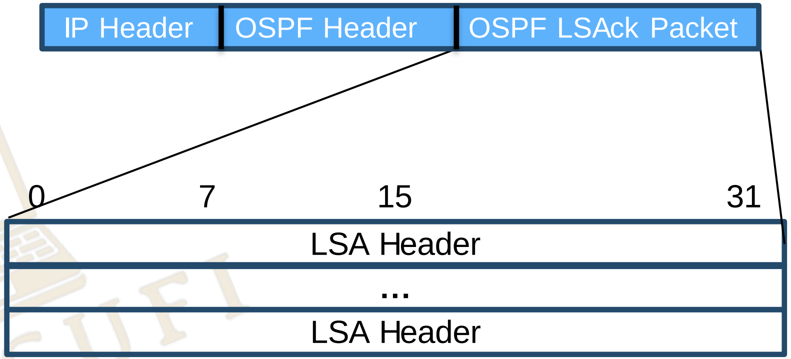
Advertising Router: The router ID of the router that generated the LSA.

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..

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



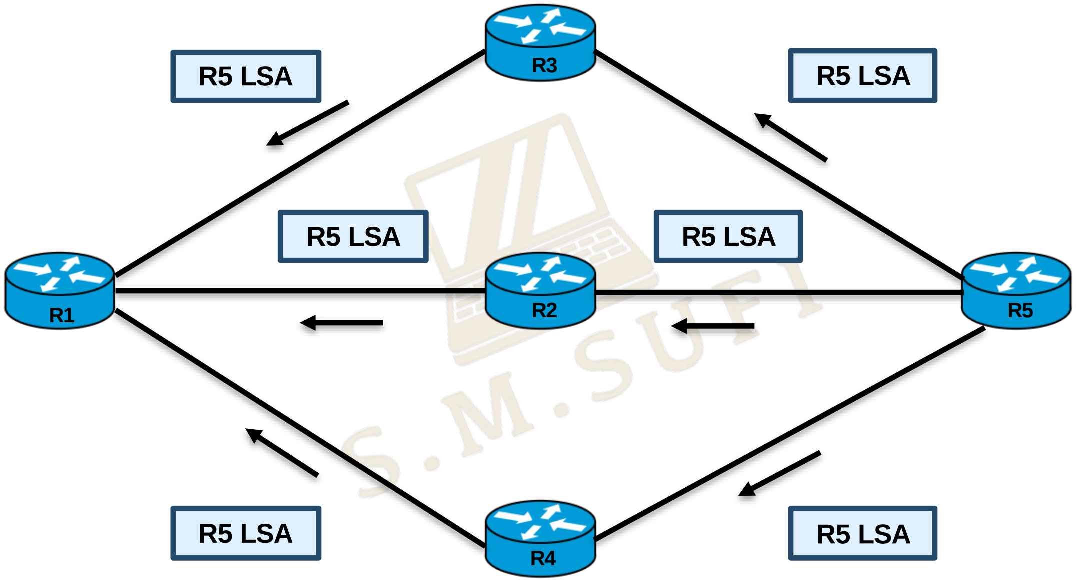


Number of LSAs: the number of LSAs contained in the LSU packet.

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.

LSA Flooding



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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.

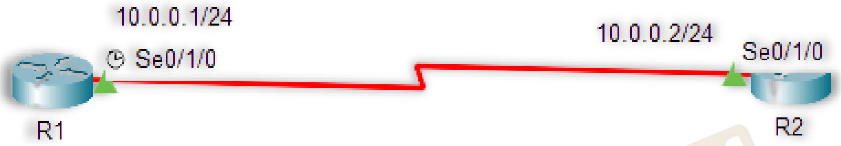
```
Router#sh ip ospf nei


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
```

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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.

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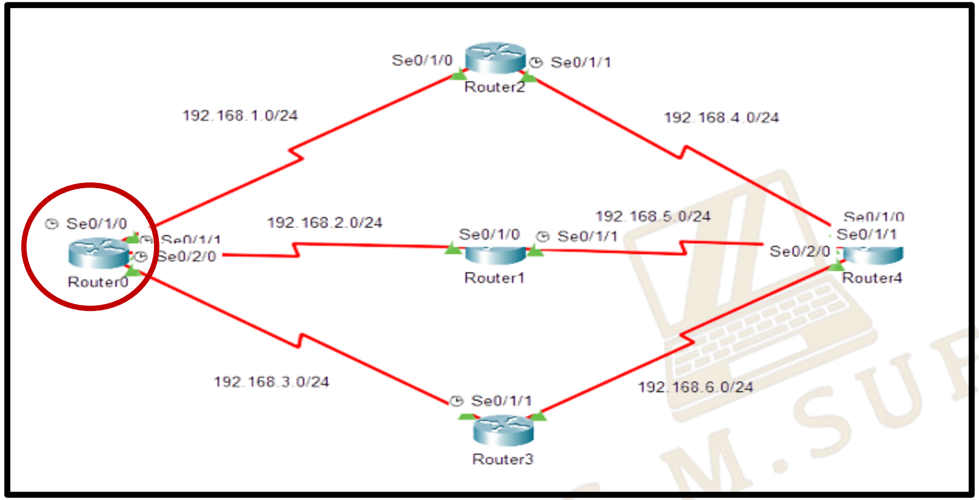
Neighbor Table




```
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.

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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.

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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.**

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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.

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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.

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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'

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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:

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

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**

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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>'***

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

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>'***

```
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.
```

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)#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.***

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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***.

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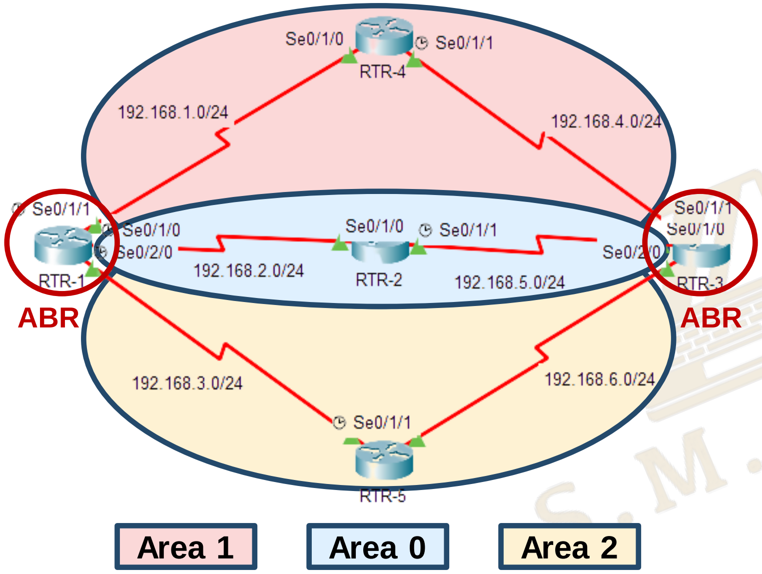
Multiple Area Configuration



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
```

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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***

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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
```

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.

Network Types

Primarily, there are ***three*** types of OSPF network-

OSPF

1. Point-to-Point

A point-to-point network is a network where two routers are ***directly connected*** to each other. This type of network is typically used for ***serial links*** by default.

2. Broadcast Multi Access

A broadcast network is a network where all routers are connected to a ***single broadcast domain***. This type of network is typically used for ***Ethernet*** networks by default.

3. NBMA (Non Broadcast Multi Access

An NBMA network is a network where multiple routers are connected to a ***shared medium,*** but they ***don't have broadcast capabilities*** and this type of network is typically used for ***Frame Relay*** & ***ATM*** networks.

Point-to-Point Network

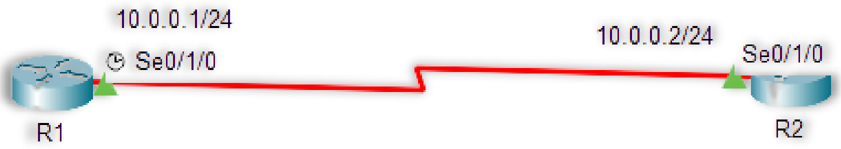
- A single point-to-point link is a ***single pair*** of router.
- Does not support the ability to add a third router to the link.
- Usually a serial interface running either ***PPP*** or ***HDLC***.
- May also be a point-to-point ***sub-interface*** running ***Frame Relay*** or ***ATM***.
- ***No election*** 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
```

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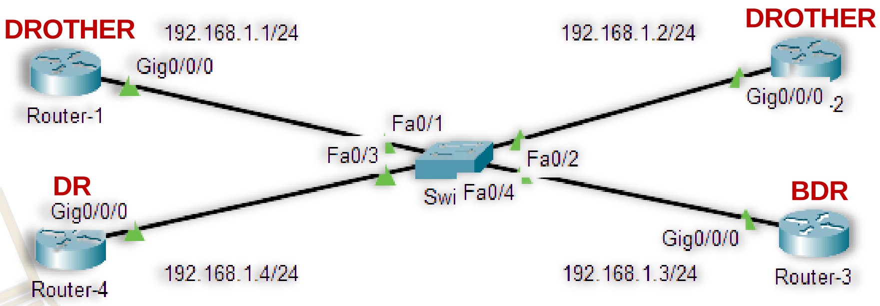
Broadcast Network

- 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

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) 192.168.1.4, 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 00:00:05
  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 3, Adjacent neighbor count is 3
    Adjacent with neighbor 192.168.1.1
    Adjacent with neighbor 192.168.1.2
    Adjacent with neighbor 192.168.1.4  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

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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 <interface name>'

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

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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

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- ***'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 ?'***

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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.

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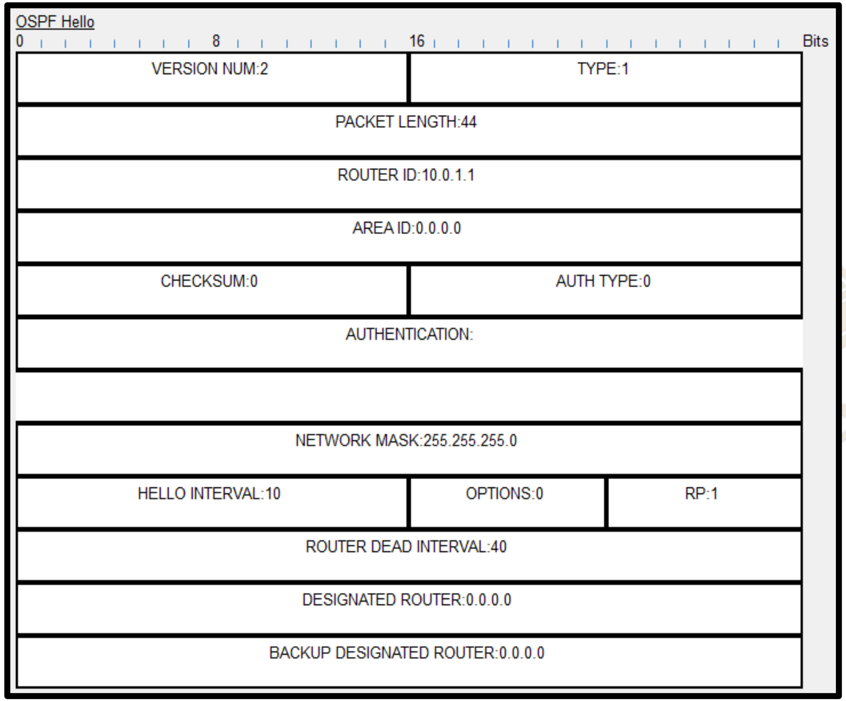
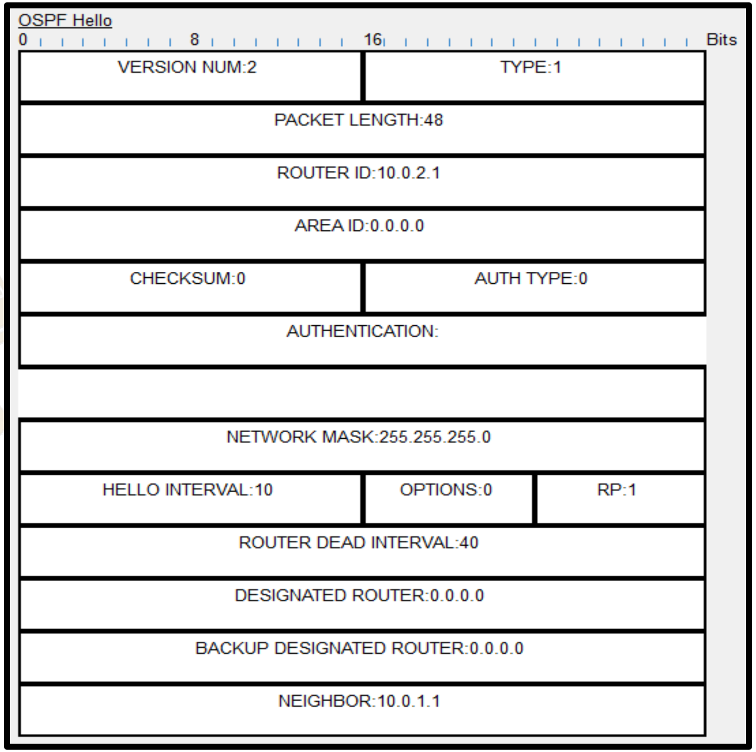
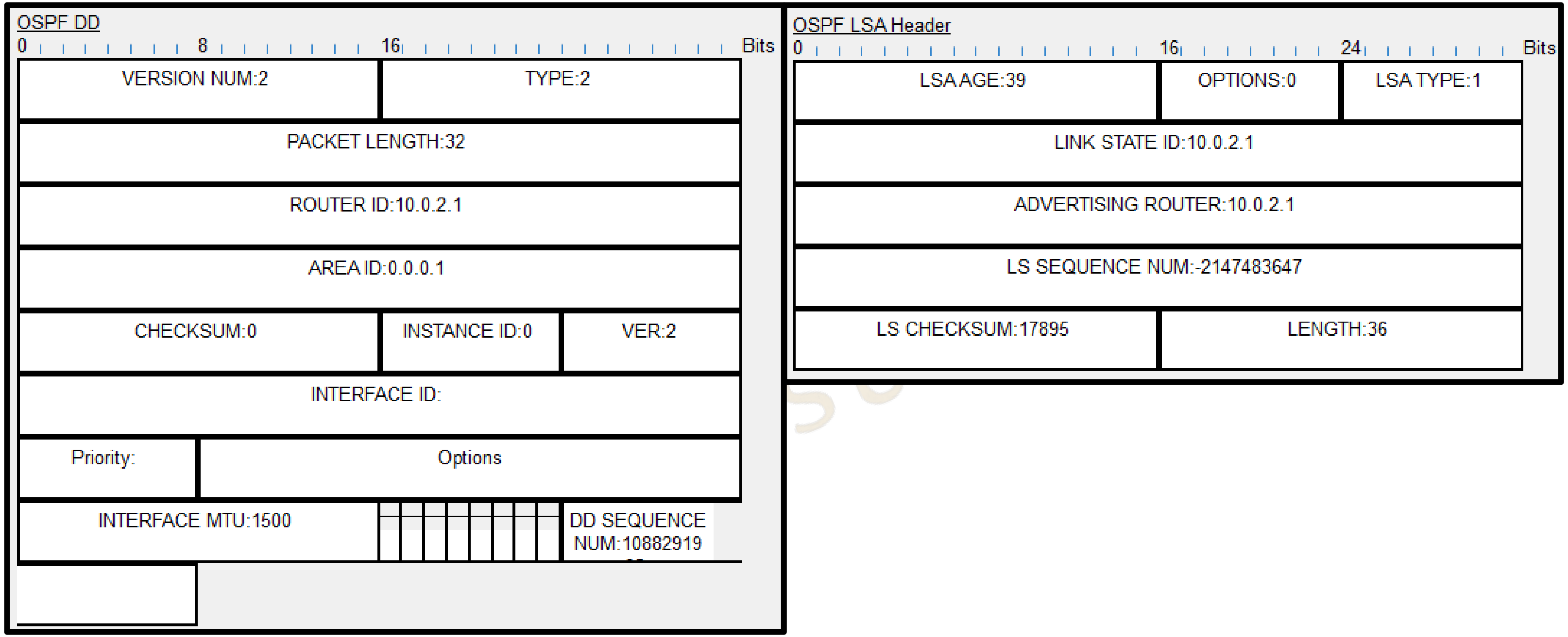
PDU – Packet Type 1 (Hello)





PDU – Packet Type 2 (DD)



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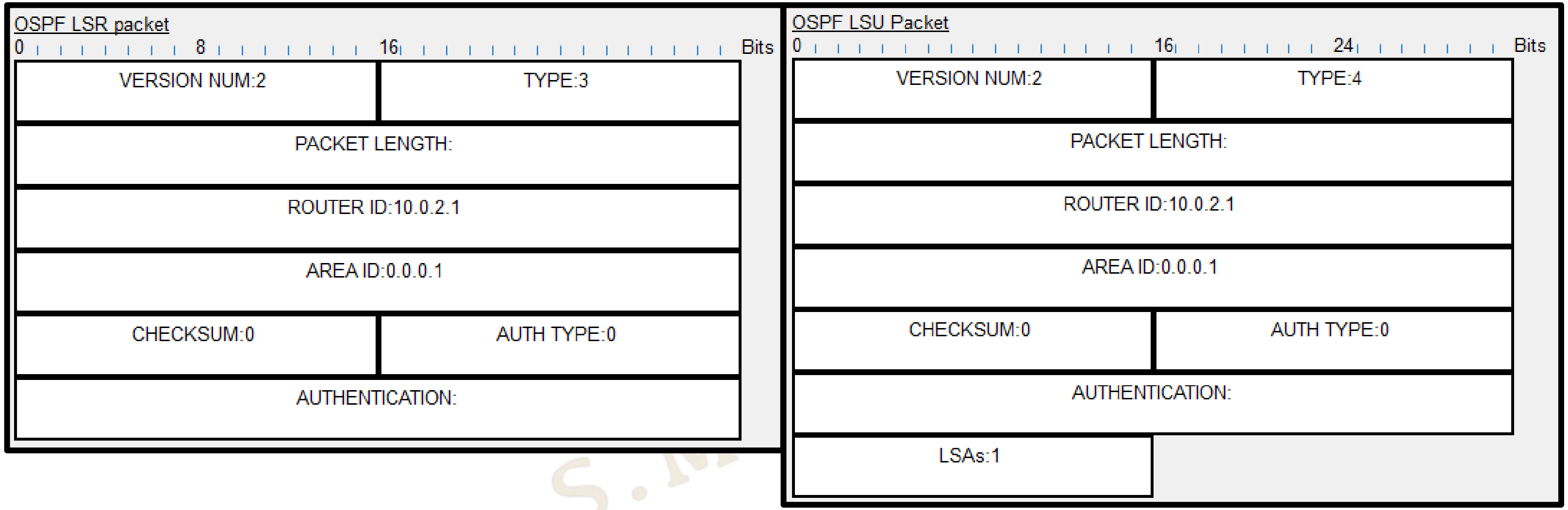
PDU – Packet Type 3 (LSR) & Type 4 (LSU)



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PDU – Packet Type 5 (LSAck)

OSPF Link State Acknowledgment

0	16	24 Bits
VERSION NUM:2	TYPE:5	
PACKET LEN:		
ROUTER ID:10.0.2.2		
AREA ID:0.0.0.1		
CHECKSUM:0	AUTH TYPE:0	
AUTHENTICATION:		

OSPF LSA Header

0	16	24 Bits
LSA AGE:0	OPTIONS:0	LSA TYPE:1
LINK STATE ID:10.0.2.1		
ADVERTISING ROUTER:10.0.2.1		
LS SEQUENCE NUM:-2147483646		
LS CHECKSUM:56895	LENGTH:36	

PDU: A protocol data unit is a single unit of information transmitted among peer entities of a computer network.

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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