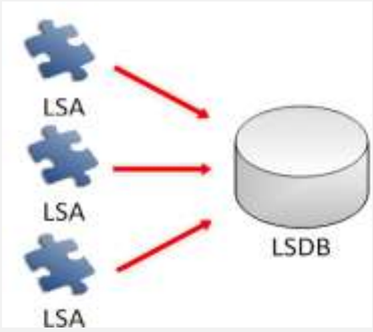
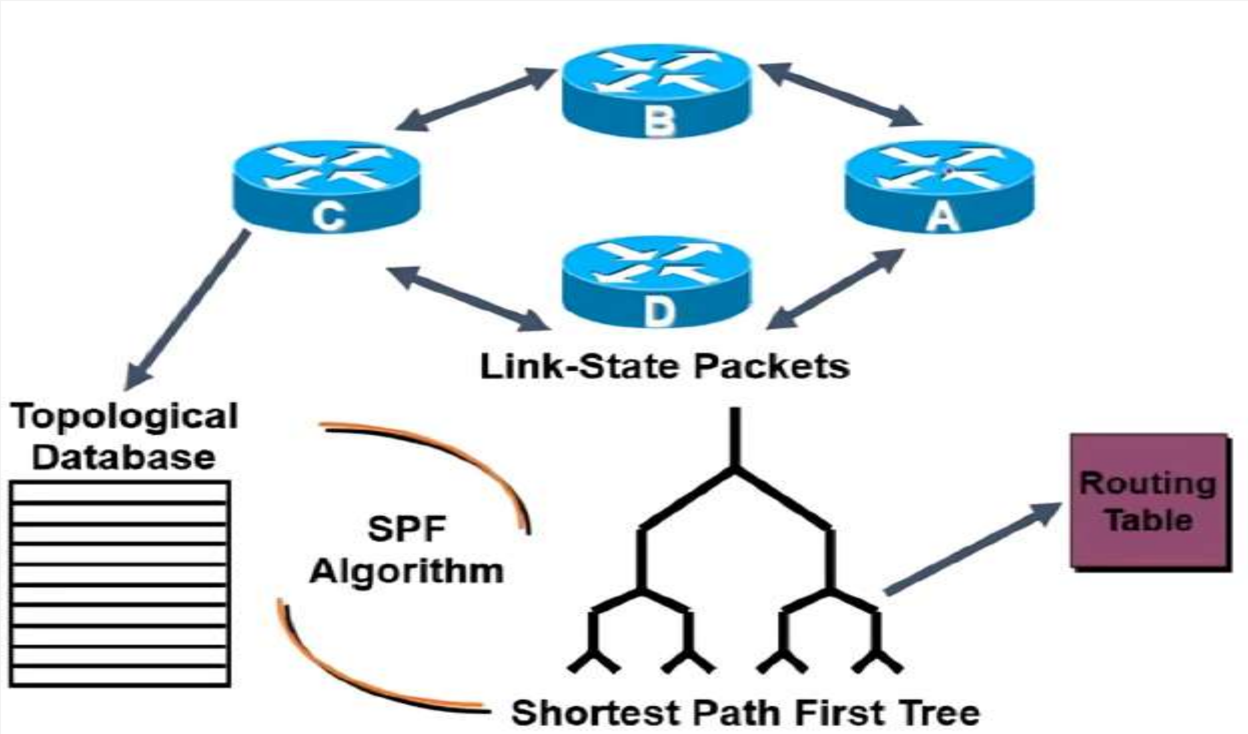
## Open Shortest Path First (OSPF)

- OSPF is a **link-state** routing protocol.
- ➔ **Link:** That's the interface of our router.
- ➔ **State**: Description of the interface and how it's connected to neighbor routers.
- It encapsulate its data directly in **IP packets** with **protocol number 89.**
- OSPF uses a metric called **cost** which is based on **the bandwidth of an interface.**
- **The output of the dijkstra is LSA Tree.**



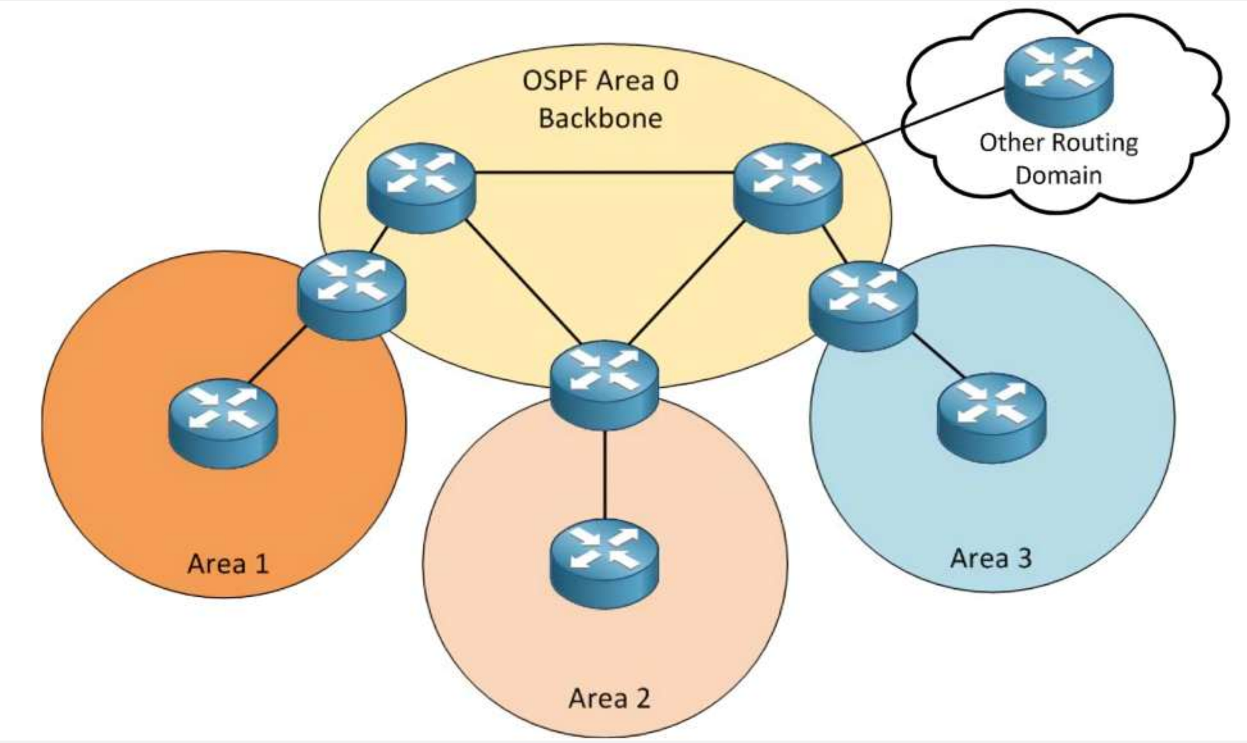

- Link-state routing protocols operate **by sending link-state advertisements** (LSA) to **all other link-state routers**.
- All the routers need to have these link-state advertisements so they can build their **link-state database or LSDB.**
- Basically all the link-state advertisements are a piece of the puzzle which builds the LSDB.
- This LSDB is **our full picture** of the network, in network terms we call this the **topology.**

**Over view about OSPF**



- Each router will send **hello packet** to all its interfaces to discover its direct connected neighbors.
- Each router will send LSA( Link State Advertisement) to all its neighbors, telling them about its LSA's.
- Every router receive LSA packet **will take copy** of it and send it as it is to its neighbors.
- Each router will form a LSDB (Link State Data Base) for all LSA's.
- Each router will draw a link state tree and **put itself as the root of the tree**.
- Each router will apply **SPF (Shortest Path First) (*dijkstra*) algorithm *to get the routing table.***

OSPF works with **the concepts of** areas and by default you will always have a single area, normally this **is area 0** or **also called the backbone area**.




You can have multiple areas however as in the picture above, we have area 1, 2 and 3. ***All of these areas must connect to the backbone area***. If you want to go from area 1 to area 2 **you must go through the backbone area** to get there. It's **impossible** to go from area 1 directly to area 2; you always have to pass the backbone area!

**NOTE:** -the smaller your map the faster your SPF algorithm works

**NOTES: -**

- Routers in the **backbone area** **(area 0)** are called **backbone routers**.
- **Area Border Routers** (**ABR**) Router that tie **between two areas** ***area 0*** **and another area like area 1.**
- **Routers that run** OSPF **and are connected to** another network **that runs another routing protocol** (**for example RIP**) are called **autonomous system border routers** or **ASBR**.
- Routers have to be **become neighbors first**; once we have become neighbors **we are going to exchange link- state advertisements**.

**To be neighbors**

1. must use the same network ID and subnet mask.
2. Must be direct connected
3. Must use the same hello interval
4. Must use the same dead interval
5. Must use the same area ID
6. Must use the same authentication and authorization type
7. Must agree on the same area flag (type of the area)

It's not just the sequence number that OSPF will look at to determine if a LSA is more recent. **It will consider the LSA to be more recent if it has:**

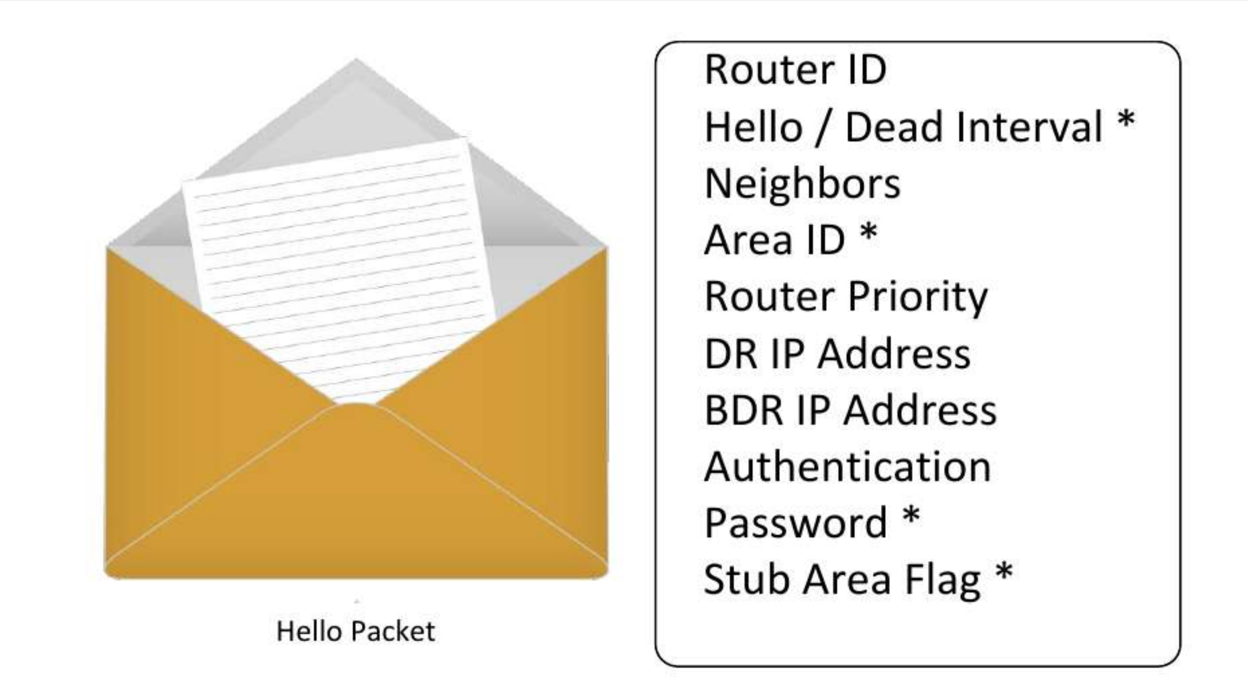
1. A higher sequence number.
2. A higher checksum number.
3. If the link-state age is much younger.

What do the sequence numbers look like for OSPF LSAs?

| Link ID | ADV Router | Age | Seq# | Checksum | Link count |
|---|---|---|---|---|---|
| 1.1.1.1 | 1.1.1.1 | 11 | 0x80000002 | 0x004ED8 | 2 |
| 2.2.2.2 | 2.2.2.2 | 10 | 0x80000002 | 0x003ED8 | 2 |

- There are 4 bytes or 32-bits.
- Begins with 0x80000001 and ends at 0x7FFFFFFF.
- ***Every 30 minutes each LSA will age out and will be flooded*** .
- The sequence number will increment by one.

Once you configure OSPF your router will start **sending hello packets**. **If you also receive hello packets** from the other **router you will become neighbors.**




**Router ID:** Each OSPF router needs to have an unique ID which is the highest IP address on any active interface.

**Hello / Dead Interval**: Every X seconds we are going to send a hello packet, if we don't hear any hello packets from our network for X seconds we declare you "dead" and we are no longer neighbors. These values have to match on both sides in order to become neighbors.

**Neighbors:** All other routers who are your neighbors are specified in the hello packet.

**Area ID:** This is the area you are in. This value has to match on both sides in order to become neighbors.

**Router Priority**: This value is used to determine who will become designated or backup designated router.

**DR and BDR IP address**: Designated and Backup Designated router.

**Authentication password**: You can use clear text and MD5 authentication for OSPF which means every packet will be authenticated. Obviously you need the same password on both routers in order to make things work.

**Stub area flag:** Besides area numbers OSPF has different area types, we will Both routers have to agree on the area type in order to become neighbors.

## How to determine the router id

**locally significant on the router**

1. Configuration ➔ router-id 1.1.1.1
2. Highest IPv4 of any configuraed loopback interface.
3. Highest IPv4 of any active interface.

## OSPF packet types

| |
|---|
| **1. Hello** |
| **2. Database Description (DBD)** |
| **3. Link-State Request (LSR)** |
| **4. Link-State Update (LSU)** |
| **5. Link-State Acknowledgment (LSAck)** |

- **Hello**: neighbor discovery, build neighbor adjacencies and maintain them.
- **DBD**: This packet is used to **check if the LSDB between 2 routers is the same.** The DBD is a summary of the LSDB.
- **LSR**: Requests specific link-state records from an OSPF neighbor.
- **LSU**: Sends specific link-state records that were requested. This packet is like an envelope with multiple LSAs in it.
- **LSAck**: OSPF is a reliable protocol so we have a packet to acknowledge the others.

*Passive interface*

***stop sending and receving update***

*States and tables*

OSPF has to get through 7 states in order to become neighbors

1. **Down**: no OSPF neighbors detected at this moment.
2. **Init:** Hello packet received.
3. **Two-way:** own router ID found in received hello packet.
- **Neighbor table**
4. **Exstart**: master and slave roles determined. DR (Designated Router) and BDR (Backup Designated Router).
5. **Exchange**: database description packets (DBD) are sent.
- **Topology table (containes the backup routes)**
6. **Loading**: exchange of LSRs (Link state request) and LSUs (Link state update) packets.
7. **Full:** OSPF routers now have an adjacency.
- **Routing table**
- hello packet will be sent to **the multicast address 224.0.0.5.**
- the respond hello packet sent using **unicast**
- DR and BDR **listen** on **multicast 224.0.0.6**

## at convergence

- the router will send LSA refresh each 30 minutes
- the router will send a hello as a keepalive each hello interval
- **the relation between the DR OR BDR and another router reach to full. But between any 2 drother routers reach to 2-way.**

## at change

- the router will send partial triggered update

- **every processed id have it's own routing table.**
- **the same area, the same LSDB . So every change occure in the area run the dijkstra in all the router that include this area.**
- **the importance of the the area is reduce the load from the processor**

| State | Description |
|---|---|
| Down State | •No Hello packets received = Down.<br>•Router sends Hello packets.<br>•Transition to Init state. |
| Init State | •Hello packets are received from the neighbor.<br>•They contain the Router ID of the sending router.<br>•Transition to Two-Way state. |
| Two-Way State | •In this state, communication between the two routers is bidirectional.<br>•On multiaccess links, the routers elect a DR and a BDR.<br>•Transition to ExStart state. |

| State | Description |
|---|---|
| ExStart State | On point-to-point networks, the two routers decide which router will initiate the DBD packet exchange and decide upon the initial DBD packet sequence number. |
| Exchange State | •Routers exchange DBD packets.<br>•If additional router information is required then transition to Loading; otherwise, transition to the Full state. |
| Loading State | •LSRs and LSUs are used to gain additional route information.<br>•Routes are processed using the SPF algorithm.<br>•Transition to the Full state. |
| Full State | The link-state database of the router is fully synchronized. |

| Database | Table | Description |
|---|---|---|
| Adjacency Database | Neighbor Table | •List of all neighbor routers to which a router has established bi-directional communication.<br>•This table is unique for each router.<br>•Can be viewed using the `show ip ospf neighbor` command. |
| Link-state Database (LSDB) | Topology Table | •Lists information about all other routers in the network.<br>•The database represents the network LSDB.<br>•All routers within an area have identical LSDB.<br>•Can be viewed using the `show ip ospf database` command. |
| Forwarding Database | Routing Table | •List of routes generated when an algorithm is run on the link-state database.<br>•Each router's routing table is unique and contains information on how and where to send packets to other routers.<br>•Can be viewed using the `show ip route` command. |

| OSPF verification | |
|---|---|
| R1#show ip protocols | Shows information about the running routing protocol process |
| R1#show ip route | Shows the entire routing table |
| R1#show ip route ospf | Shows routes learned via OSPF only |
| R1#show ip ospf neighbors | Shows all neighboring routers along with their respective adjacency state |
| R1#show ip ospf database | Shows all the information contained in the LSDB |
| R1#show ip ospf interfaces serial 0/0 | Shows detailed information about OSPF running on a specific interface |

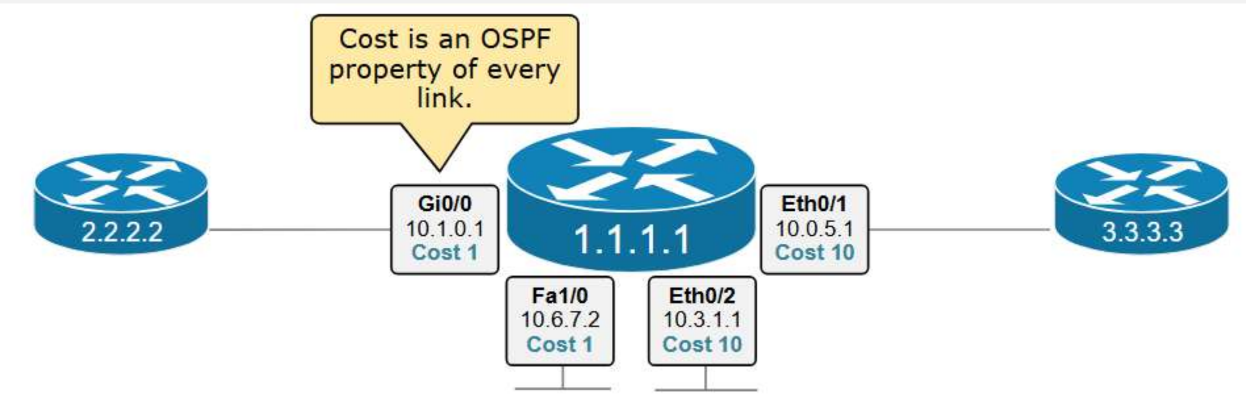
**<u>What is the mechanism that the router use to route the data (to determine the best route )?</u>**

- **Long perfix match**
- **The lowest addministrative distance**
- **Origine code (in OSPF)**
- **The lowest metric**
- **Equal cost load balance**

**The metric in ospf is the cost**

$$cost = \frac{10^8}{Bandwidth\{bps\}} = \frac{100}{Bandwidth\{Mbps\}}$$

| Interface type | Bandwidth | Cost |
|---|---|---|
| Fast Ethernet and Faster | 100 Mbps and higher | 1 |
| Ethernet | 10 Mbps | 10 |
| E1 | 2.048 Mbps | 48 |
| T1 | 1.544 Mbps | 64 |
| 64 kbps | 64 kbps | 1562 |
| 56 kbps | 56 kbps | 1785 |




**If you want to determine the cost from R-1 to R-2 you see the interface type in R-1 (the interface that it used to reach to R-2)**

*OSPF Network Types*

| Network Type | Hello Timer | Adjacency | RFC or Cisco |
|---|---|---|---|
| **Broadcast** | 10 | Automatic + DR/BDR | Cisco |
| **Non-Broadcast** | 30 | Manual + DR/BDR | RFC |
| **Point-to-Multipoint** | 30 | Automatic no DR/BDR | RFC |
| **Point-to-Multipoint non-broadcast** | 30 | Manual no DR/BDR | Cisco |
| **Point-to-Point** | 10 | Automatic no DR/BDR | Cisco |

| Network Type | Neighbor Discovery | DR / BDR Election | Traffic | Defined by |
|---|---|---|---|---|
| Non-broadcast (NBMA) | Static | Yes | Unicast | RFC |
| Point-to-multipoint | Dynamic | No | Multicast | RFC |
| Point-to-multipoint (non-broadcast) | Static | No | Unicast | Cisco |
| Broadcast | Dynamic | Yes | Multicast | Cisco |
| Point-to-point | Dynamic | No | Multicast | RFC |

Each network **type with the word "point" in it does NOT require a DR/BDR!** Even if you use point-to-multipoint you are telling OSPF you have a collection of multiple point-to-point links

**Dead interval =4*hello timer**

**Point-to-Point**

a connection between two specific points (or OSPF routers) On a point-to-point link, a packet delivered from one of the routers will always have precisely one recipient.

**DR and BDR (Designated router) (Backup Designated Router)**

**How to elect the DR**

1. The first router that comes up within 40 sec
2. The router with the highest priority on interface
3. The router with the highest RID

DR/BDR election **is non-preemptive.** This means if you change the priority or router ID you have to reset OSPF in order to select a new DR/BDR.

Routers that are not DR or BDR show up as **DROTHER.**

- **The default priority is 1 for interface.**
- A priority of **0** means you **will never** be elected as DR or BDR.

**Multicast DR/BDR** ➔ **224.0.0.6** ➔ the DR and BDR lisiten on the this ip for any change happening in the network and after this send it to all the other routers on 224.0.0.5

***Dr and BDR per segment.***

## Non-Broadcast (NBMA)

- Non-Broadcast Multable access
- **Multi-access** means we have to select a DR and BDR.
- ***Non-broadcast means that OSPF expects us to configure neighbors ourselves. (and the traffic Is unicast)***

By default I should to build a neighbour relationship with **static method.**

## broadcast

If you understand non-broadcast then this one is easy. It's the EXACT same thing except **we don't have to configure neighbors**. **OSPF will use multicast and discover OSPF neighbors automatically**. The **broadcast network type is the default** for **Ethernet interfaces** as well.

## point-to-multipoint

- Automatic neighbor discovery so no need to configure OSPF neighbors yourself.
- No DR/BDR election since OSPF sees the network as a **collection of point-to-point links.**
- Only a single IP subnet is used.
- Make sure your frame-relay network is configured with the broadcast keyword.

What about the **point-to-multipoint non-broadcast** network type? It's exactly the same as **point-to-multipoint** but **the difference is in the non-broadcast**. You'll have to specify neighbors yourself .

**Notes**

- **Broadcast , non-broadcast need DR and BDR**
- **Broadcast and point-to-point hello interval =10 sec and the rest is 30 sec**
- **Non-broadcast and point-to-multipoint non-broadcast traffic (unicast)and neighbour discovery (static)**

## 1. Broadcast Network

In a broadcast network, OSPF routers automatically discover each other using multicast.

**Router 1:**

```
R1(config)#interface GigabitEthernet0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#ip ospf network broadcast
R1(config-if)#router ospf 1
R1(config-router)#network 192.168.1.0 0.0.0.255 area 0
```

**Router 2:**

```
R2(config)#interface GigabitEthernet0/0
R2(config-if)#ip address 192.168.1.2 255.255.255.0
R2(config-if)#ip ospf network broadcast
R2(config-if)#router ospf 1
R2(config-router)#network 192.168.1.0 0.0.0.255 area 0
```

## 2. Non-Broadcast Network

In a non-broadcast network, you need to manually configure neighbors.

**Router 1:**

```
R1(config)#interface Serial0/0
R1(config-if)#ip address 192.168.2.1 255.255.255.0
R1(config-if)#ip ospf network non-broadcast
R1(config-if)#router ospf 1
R1(config-router)#network 192.168.2.0 0.0.0.255 area 0
R1(config-router)#neighbor 192.168.2.2
```

**Router 2:**

```
R2(config)#interface Serial0/0
R2(config-if)#ip address 192.168.2.2 255.255.255.0
R2(config-if)#ip ospf network non-broadcast
R2(config-if)#router ospf 1
R2(config-router)#network 192.168.2.0 0.0.0.255 area 0
R2(config-router)#neighbor 192.168.2.1
```

## 3. Point-to-Point Network

In a point-to-point network, OSPF assumes there are only two routers.

**Router 1:**

```
R1(config)#interface Serial0/1
R1(config-if)#ip address 192.168.3.1 255.255.255.252
R1(config-if)#ip ospf network point-to-point
R1(config-if)#router ospf 1
R1(config-router)#network 192.168.3.0 0.0.0.3 area 0
```

**Router 2:**

```
R2(config)#interface Serial0/1
R2(config-if)#ip address 192.168.3.2 255.255.255.252
R2(config-if)#ip ospf network point-to-point
R2(config-if)#router ospf 1
R2(config-router)#network 192.168.3.0 0.0.0.3 area 0
```

## 4. Point-to-Multipoint Network

In a point-to-multipoint network, OSPF treats the network as a collection of point-to-point links.

**Router 1:**

```
R1(config)#interface Serial0/2
R1(config-if)#ip address 192.168.4.1 255.255.255.0
R1(config-if)#ip ospf network point-to-multipoint
R1(config-if)#router ospf 1
R1(config-router)#network 192.168.4.0 0.0.0.255 area 0
```

**Router 2:**

```
R2(config)#interface Serial0/2
R2(config-if)#ip address 192.168.4.2 255.255.255.0
R2(config-if)#ip ospf network point-to-multipoint
R2(config-if)#router ospf 1
R2(config-router)#network 192.168.4.0 0.0.0.255 area 0
```

## 5. Point-to-Multipoint Non-Broadcast Network

In a point-to-multipoint non-broadcast network, you need to manually configure neighbors.

**Router 1:**

```
R1(config)#interface Serial0/3
R1(config-if)#ip address 192.168.5.1 255.255.255.0
R1(config-if)#ip ospf network point-to-multipoint non-broadcast
R1(config-if)#router ospf 1
R1(config-router)#network 192.168.5.0 0.0.0.255 area 0
R1(config-router)#neighbor 192.168.5.2
```

**Router 2:**

```
R2(config)#interface Serial0/3
R2(config-if)#ip address 192.168.5.2 255.255.255.0
R2(config-if)#ip ospf network point-to-multipoint non-broadcast
R2(config-if)#router ospf 1
R2(config-router)#network 192.168.5.0 0.0.0.255 area 0
R2(config-router)#neighbor 192.168.5.1
```

## Point-to-Multipoint Non-Broadcast Network per neighbour cost

**This configuration allows you to control the OSPF cost for each neighbor individually, which can help optimize routing decisions based on the desired path cost.**

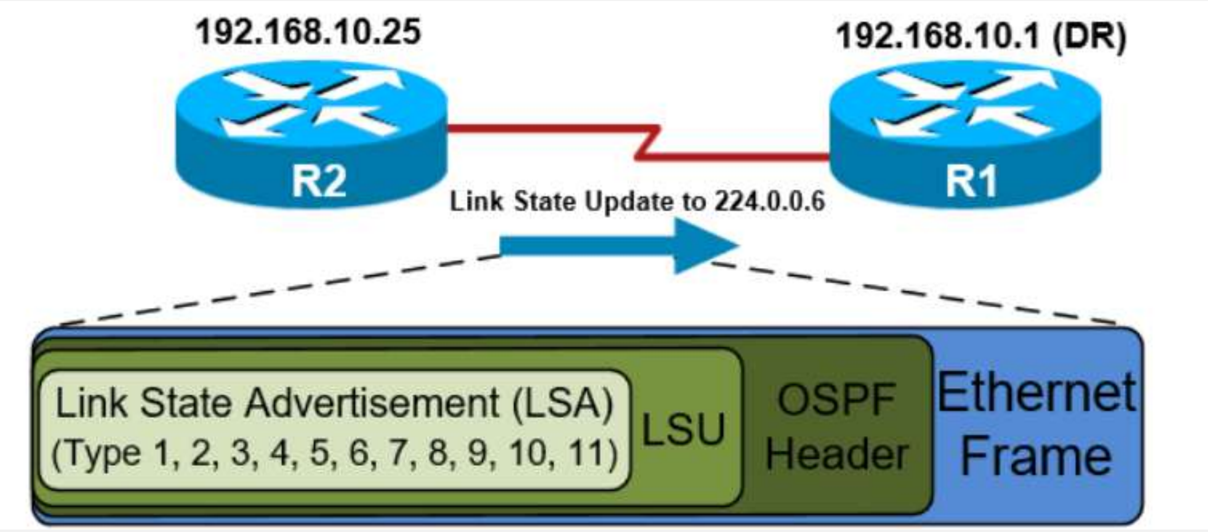
**Router 1:**

```
R1(config)#interface Serial0/3
R1(config-if)#ip address 192.168.5.1 255.255.255.0
R1(config-if)#ip ospf network point-to-multipoint non-broadcast
R1(config-if)#router ospf 1
R1(config-router)#network 192.168.5.0 0.0.0.255 area 0
R1(config-router)#neighbor 192.168.5.2 cost 10
```

**Router 2:**

```
R2(config)#interface Serial0/3
R2(config-if)#ip address 192.168.5.2 255.255.255.0
R2(config-if)#ip ospf network point-to-multipoint non-broadcast
R2(config-if)#router ospf 1
R2(config-router)#network 192.168.5.0 0.0.0.255 area 0
R2(config-router)#neighbor 192.168.5.1 cost 20
```

*OSPF LSA Types*




**LSA Type 1:** Router LSA

**LSA Type 2:** Network LSA

**LSA Type 3:** Summary LSA

**LSA Type 4:**Summary ASBR LSA

**LSA Type 5:** Autonomous system external LSA

**LSA Type 6:** Multicast OSPF LSA

**LSA Type 7:** Not-so-stubby area LSA (external)

**LSA Type 8:** External attribute LSA for BGP (OSPFv2) / Link Local LSA

**LSA Type 9**: OSPF Link Scope Opaque (OSPFv2) / Intra Area Prefix LSA

**LSA Type 10**: OSPF Area Scope Opaque LSA

**LSA Type 11**:OSPF AS (Autonomous System) Scope Opaque LSA

| | | | |
|---|---|---|---|
| Type 1 | Router | All the routers | List of all direct connected linkes of the router. |
| Type 2 | network | DR | -prograte within the area scope .<br>-use to calculate the routes for networks , within the area. |
| Type 3 | summary | ABR | Creat type 3 and flood it in to arae 0 .<br>Knowing all the areas about some. |
| Type 4 | Summary ASBR | ABR | -will include the router id of the ASBR in the link state id field.<br>-located the ASBR router. |
| Type 5 | AS external LSA | ASBR | -redistributing information from the rip router into ospf .<br>-know about the perfixes that are redistributed from the rip<br>-**blocked by the NOT-so-stubby area** |
| Type 6 | Multicast OSPF LSA | | Not supported by cisco |
| Type 7 | Not-so-stubby area LSA (external) | ASBR | Same as type 5 but not blocked by the NSSA. |

| LSA TYPE | Description | Originator | Flooded To | Purpose |
|---|---|---|---|---|
| Type 1 | Router LSA | Router | Same Area | Describes router's Link |
| Type 2 | Network LSA | DR | Same Network | Describes routers on a network segment |
| Type 3 | Summary LSA | ABR | Other Area | Advertise routes between areas |
| Type 4 | Summary ASBR LSA | ABR | | Informs about an ASBR |
| Type 5 | Autonomous System external LSA | ASBR | OSPF Domain | Advertises external routes |
| Type 6 | Multicast OSPF LSA | OSPFv3 router | Same Area | Used for multicast group memberships |
| Type 7 | NSSA External LSA | ASBR in NSSA | NSSA | Carries external routes in NSSA configuration |

**Note**

**It is recommended to make a manually summarization in ABR and ASBR.**

*OSPF Special Area Types*

1. Backbone area
2. normal area
3. Stub area
4. Totally stub area
5. NSSA (not so stubby area)
6. Totally NSSA (totally not so stubby area)

| AREA TYPE | SUPPORTED LSA TYPES | SUPPORTS ASBR? |
|---|---|---|
| Normal Area | 1, 2, 3, 4, 5 | Yes |
| Stub Area | 1, 2, 3, ~~4, 5~~ | No |
| Stub Area no-summary (aka totally stubby) | 1, 2, 3 (only default route injected by ABR), ~~4, 5~~ | No |
| NSSA Area | 1, 2, 3, ~~4, 5~~, and 7 | Yes |
| NSSA Area no-summary (aka totally not so stubby) | 1, 2, 3 (only default route injected by ABR; can be changed to 7), ~~4, 5~~, and 7 | Yes |

These special area types are used to insert **default routes into an area and replace type 3 summary LSAs and type 5 external LSAs. This will keep the LSA flooding to a minimum, LSDB smaller, fewer SPF calculations, and a smaller routing table.**

**Areas type used to reduce the routing table size and replace the removed network with default route to the ABR.**

**Normal Area**
- LSAs : **Permit** {Type 1 2 3 4 5} **(O , OIA , OE2 , OE1)**

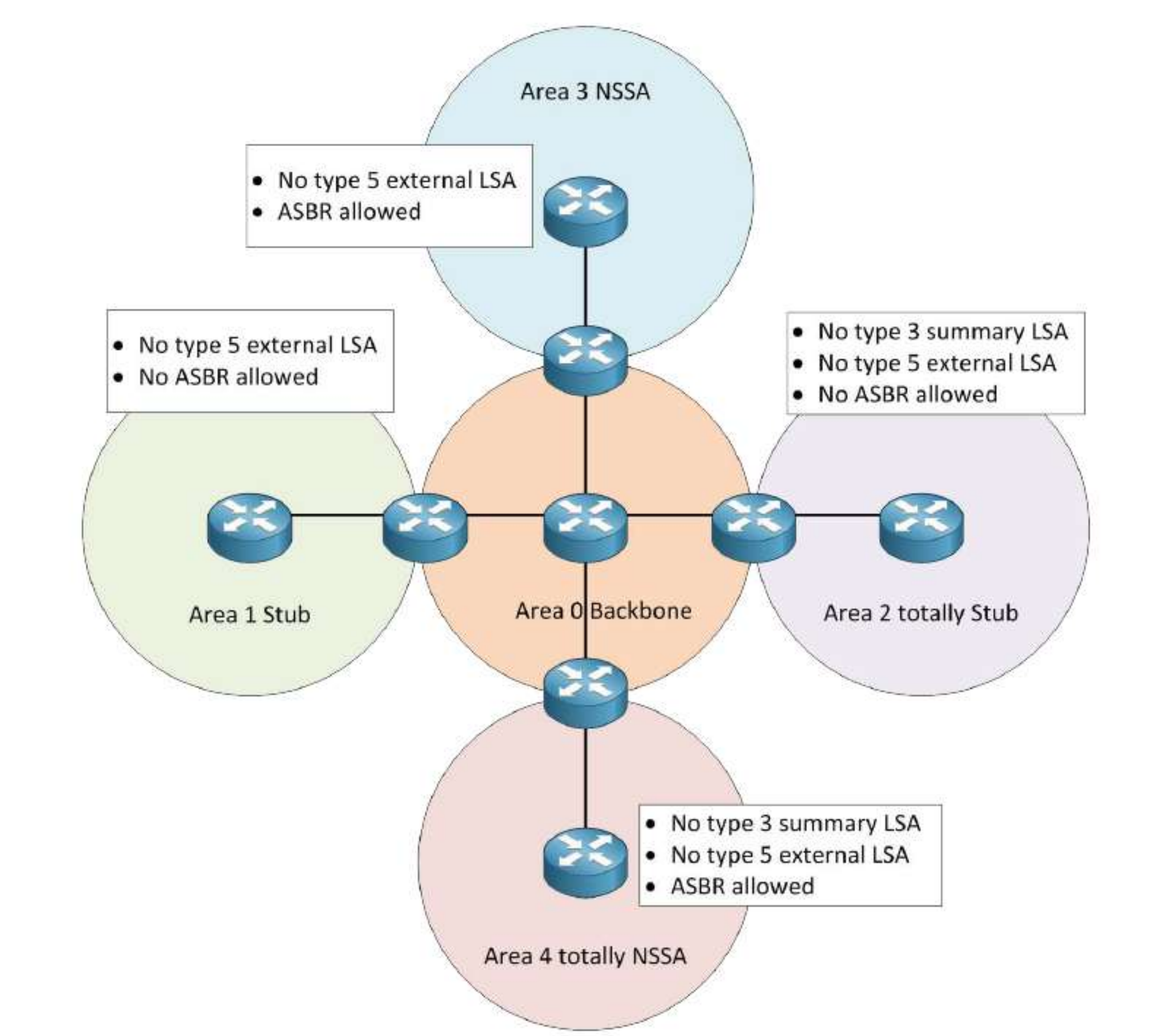
**Stub Area**
- LSAs : **Permit** {Type 1 2 3} **(O , OIA , O*)**
- LSAs : **Block** {Type 4 5} Default Route **(ABR)**

**Totally Stub Area**
- LSAs : **Permit** {Type 1 2} **(O , O*)**
- LSAs : **Block** {Type 3 4 5} Default Route **(ABR)**

**Not So Stubby Area (NSSA)**
- LSAs : **Permit** {Type 1 2 3 7} **(O , OIA , ON2 , O*)**
- LSAs : **Block** {Type 4 5} **Default Route (ABR)**
- LSAs **: Type 7** Redistributed **Via same Area**

**Totally Not So Stubby Area (NSSA)**
- LSAs : **Permit** {Type 1 2 7} **(O , ON2 , O*)**
- LSAs : **Block** {Type 3 4 5} Default Route **(ABR)**
- LSAs **: Type 7** Redistributed **Via same Area**

**ABR tie between more than arae and at least one of it's interfaces tie to backbone area. (backbone area used to summarize tobology information between areas). (ABR used to move information from area 0 to the other areas )**




If you configure an **area as a stub**, it will **block all type 5 external LSAs**. **All the prefixes you redistributed into OSPF from another routing protocol are not welcome in the stub area**. Since you are not allowed to have type 5 external LSAs in the stub area, it's also impossible to have an ASBR in the stub area. You can still learn networks from other OSPF areas.

**Of course, there's always an exception**. **So what if you want an area to be a stub area, but you also have an ASBR in this area?** You can use the **NSSA (not-so-stubby-area)**. This is the same thing as the stub area **except that you are allowed to have an ASBR within the area.** How does it work? **This is where the type 7 external LSA kicks in. Since we are not allowed to use the type 5 external LSA, we'll use a new LSA type**.

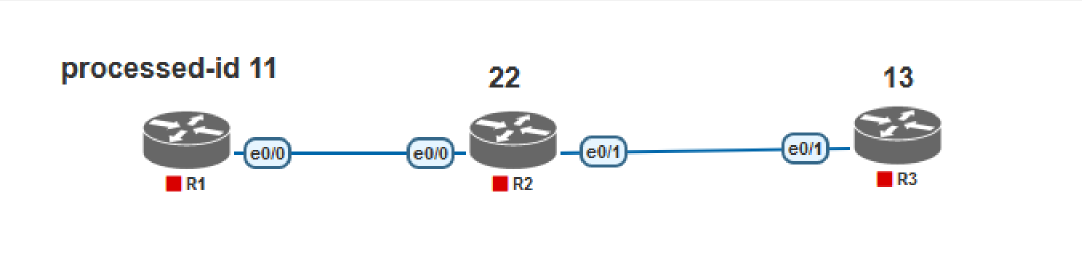
**If you want to block type 3 summary LSAs and type 5 external LSAs but still need an ASBR** within **the totally stub area you can turn it into a** **totally NSSA (totally not-so-stubby-area).** This will block both LSA types, but you can still have an ASBR in this area type.

**Note**:

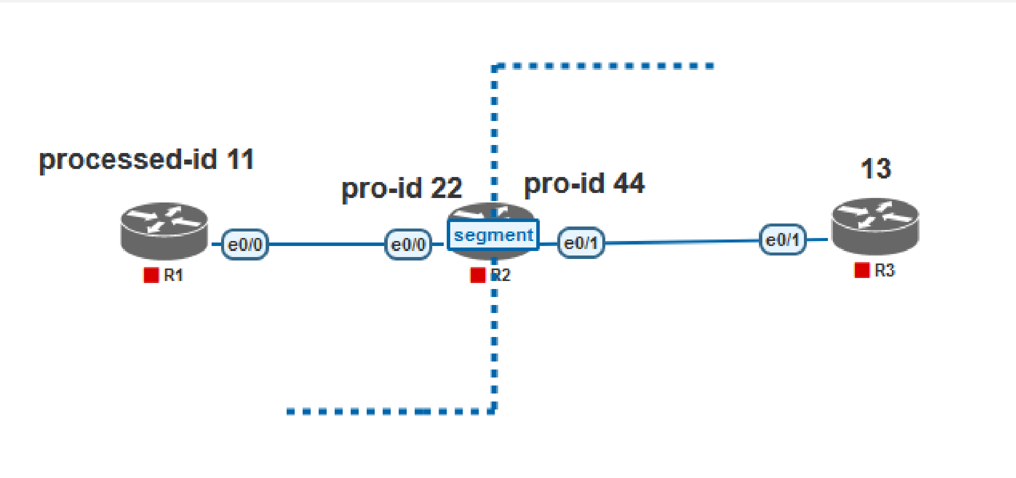
**Processed-ID segment the router this means that the routers with the same processed-ID see each other (same routing table ) and If I have to routers in different processed id they can't see each other.**

**Processed-id is a locally significant.**

## scenarios




**Router-1 in processed-id 11 and router-2 in processed-id 22 and router-3 in processed-id 13 the all router can see each other.**




**I used 2 processed-id in R2 one to interface e0/0 (22) and one to interface e0/1 (44) and connected to R1&3 this means that there are two routing table will generated one for the R1 network and one for R3 network .and the two network can't see each other .**

**To make the two network see each other use redistribution.**

*Path origin code*

**to route the data**

1. **Long perfix match**
2. **The lowest addministrative distance**
3. **Origin code**
4. **The lowest metric**
5. **Equal cost load balance**

**OSPF Path Selection (Path Origin Within OSPF)**

**After IOS 15.1(2)S**

1- O >>> Same Area

2- OIA >>> Different Area

3- N1 >>> NSSA External Type 1

4- E1 >>> External Type 1

5- N2 >>> NSSA External Type 2

6- E2 >>> External Type 2

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**Before IOS 15.1**

O > OIA > E1 > E2 > N1 > N2

**External means I make a redistribution .**

**External OSPF** routes are routes that distributed into OSPF at an ASBR.

**An E1 route uses the external metric + the internal metric to reach the destination**.

**An E2 route just uses the external metric to reach the destination.**