Document Name: OSPF

Open Shortest Path First or OSPF is an open standard routing protocol. OSPF is a non-proprietary link-state IGP routing protocol. OSPFv2 is defined in RFC2328 and OSPFv3 which introduces IPv6 support is defined in RFC5340.

Link-State Advertisements or LSAs contains the link state and link metric and is sent to neighbors. Received LSAs are stored in the **Link-State Data Base or LSDB**. Received LSAs are advertised after they have been added to the LSDB, this effectively floods LSAs throughout the OSPF domain. The LSDB gives a router a topological map of the network.

Each router runs the LSDB against the Dijkstra's shortest path (SPF) algorithm to determine the shortest, fastest, and a loop free path to all know networks. Changes in the topology require all routers with-in the same routing domain to recalculate the SPF tree. The SPF calculated will look different on each router in the domain and it is calculated from their point of view on the network.

Areas

Segments of the OSPF routing domain can be split into Areas. Areas provide logical groupings of routers/interfaces as the area is set at the interface level. Each area has its own LSDB and each router will maintain a LSDB and calculate the SPF algorithm separately for each area.

Area 0 is considered the "backbone" area and it's expected by OSPF that all routing information is injected into area 0 so that it can advertise those routes to other areas. This is a loop prevention feature.

Area Border Routers or ABRs advertise routes from area 0 into another area and vice versa. ABRs must be connected to area 0.

Inter-Router Communication

OSPF operates using protocol number 89.

AllSPFRouters – IPv4: *224.0.0.5* IPv6: *FF02::5* MAC Address: *01:00:5e:00:00:05*

AllDRouters – IPv4: *224.0.0.6* IPv6: *FF02::6* MAC Address: *01:00:5e:00:00:06*

OSPF uses these five packet types for communication.

Type	Packet Name	Function
1	Hello	Sent periodically, unsure reachability to neighbors.
2	Database Description (DBD)	Describe the contents of the LSDB when neighbor relationship is formed.
3	Link-State Request	Used to request a portion of a neighbors LSDB when a portion is believed to be stale.
4	Link-State Update	An explicit LSA for a specific link, normally sent directly to the LSR.
5	Link-State Acknowledgement	Sent in response to a flooded LSA, makes flooding reliable for transport.

Hello Packets

Hello packets are responsible for discovering and maintaining relationships with neighbors. Most of the time these packets are sent using the 224.0.0.5 AllSPFRouters address. See the contents of hello packets below.

Field	Function
Router ID	Routers ID unique to each router.
Authentication Options	Allows “secure” communication between routers running OSPF
Area ID	The area that the sending interface belongs too
Interface Address Mask	The subnet mask for the interface that sent the hello.
Interface Priority	Router interface priority for DR selection
Hello Interval	The interval in which a router sends hello packets.
Dead Interval	Elapsed time where an Active Neighbor is considered dead.
DR and BDR IP Address(es)	IP Address for the Designated and Backup Designated Router(s).
Active Neighbor	List of neighbors seen on that network segment which a router is still receiving hello packets.

Neighbors

Neighbors are discovered via hello packets. Neighbors shared a synchronized OSPF database. Each OSPF process maintains a state table for each neighbor, see a table of those states below.

State	Description
Down	Router has not received any hellos from this neighbor
Attempt	Relevant to NBMA networks where neighbor configuration is explicit. Indicates the router is attempting communication but has not heard back.
Init	A hello packet has been received but bidirectional communication has not been established.
2-Way	Bidirectional communication has been established. DR/BDR election happens here too
ExStart	First state in adjacency, routers identify the primary and secondary router for the LSDB synchronization.
Exchange	Routers are exchanging link states using DBD packets.
Loading	LSR has been sent to the neighbor asking for a more recent LSAs that have not been received during the Exchange state.
Full	Neighboring routers are full adjacent.

External Routes

These are routes learned from outside the OSPF domain that are injected and redistributed into the OSPF domain.

A router that imports external routes into an OSPF domain is called an **Autonomous System Border Router or ASBR**. This function is separate and independent of the ABR function, and any router can be an ASBR without being an ABR. Or both at the same time.

There are two types of external routes, Type 1 and Type 2. Type 1 is preferred over Type 2.

- Type 1 metric is equivalent to the redistribution metric plus the total path metric.
- Type 2 metric only includes the redistribution metric regardless of the number of hops.

LSAs

LSA types depend on who sends them in addition to the routers type, OSPF network type, and the Area type. Types are as below

Type	LSA Name	Description
Type 1	Router LSA	Describes links within an Area, not flooded outside the Area. Used to build the SPF tree
Type 2	Network LSA	Generated by the DR, not flooded outside the origin Area. Describes who is adjacent to the DR.
Type 3	Network Summary LSA	Generated by the ABR, flooded from Area 0 into non backbone areas and vice versa. Describes ABRs reachability to links in other areas. SPF is not run on ABR routes. This makes inter-area more like distance vector.
Type 4	ASBR Summary LSA	Generated by the ABR flooded from Area 0 into non backbone areas and vice versa. Describes the ABRs reachability to ASBRs in other areas. SPF is not run.
Type 5	External LSA	Generated by ASBR, flooded to all non-stub areas, Describes the routes that the ASBR is redistributing.
Type 7	NSSA External LSA	Not So Stubby Area Generated by ASBR

Other types exist but are outside the scope.

There are three route types of which LSA are grouped in.

- Intra-Area Router (O)
    - LSA 1 & 2
- Inter-Area Router (O IA)
    - LSA 3 & 4
- External Routes
    - E1/E2
        - LSA 5
    - N1/N2
        - LSA 7

Media Dependencies

OSPF behaves differently depending on the media that it is configured on. Such as Ethernet, Frame Relay, and PPP. OSPF has different network types used to deal with these different medias. There are six OSPF network types and they are listed below.

- Broadcast
- Non-Broadcast
- Point-to-Point
- Point-to-Multipoint
- Point-to-Multipoint Non-Broadcast
- Loopback

Network type has no bearing on the formation of an adjacency. But things such as timers still must match.

Stub Area

Using stub areas will rename external routes in favor of a default route. Inter area routes will stay. This is because a stub area will only have one way out of that area. Stub areas prevent type 5 and type 4 LSAs from entering the area at the ABR.

There are four types of stub areas.

- **Stub Area** – Stops external routes.
- **Totally Stubby Area** – Stops inter-area and external routes.
- **Not-So-Stubby Area (NSSA)** – Stops external routes but allows local redistribution.
- **Totally Not-So-Stubby Area** – Stops inter-area and external routes, prohibits local redistribution.

Default OSPF interface cost formula

Reference bandwidth ÷ interface bandwidth
Reference bandwidth = 100,000,000 bps = 100 mbps

Interface Bandwidth	Cost
56K	1785
64K	1562
T1	64
10 mb	10
100 mb	1
1000 mb	1

Example: 100 mbps (reference bandwidth) ÷ 10 mbps (interface bandwidth)
Fast ethernet and gigabit ethernet will have the same default port cost.
You should use the auto-cost command to set the reference bandwidth at least as high as the bandwidth of your fastest interface, or higher.

Router(router-config)# auto-cost reference-bandwidth [bandwidth in mbps]

Configuration

This section is configuration of OSPFv2. The process ids don't have to match, they are locally significant. The passive interface command stops OSPF update from going out that interface.

```
Router(config)# router ospf [process i.d.]
Router(config-router)# network A.B.C.D [wildcard mask] area [area number]
Router(config-router)# passive-interface [interface ex. gig 0/1]
```

Priority

Highest Priority wins. This can be configured, setting a value of 0 prevents a device from participating in the election process. Default is 1 maximum of 255.

```
Router(config-if)# ip ospf priority [number]
```

If a tie is reached the highest Router-ID is used to determine DR and BDR. The router ID is determined first by the router-id command if configured, if not then highest IP on a loopback interface is used, if no loopback then highest IP address on an interface is used.

Route Filtering

Inter-area

This will work for filtering routes between areas.
The le stands for less than or equal to, permitting anything with a subnet mask less than or equal to 32.

```
Router(config)# ip prefix-list [Name] seq 10 deny 2.2.2.2/32
Router(config)# ip prefix-list [Name] seq 20 deny 3.3.3.3/32
Router(config)# ip prefix-list [Name] seq 30 permit 0.0.0.0/0 le 32
Router(config)# router ospf 2
```

This filters out router being advertised INTO area 0.

```
Router(config-router)# area 0 filter-list prefix [Name] in
```

Intra-area

You must use a distribution list to "filter" out a route within an area. The route will still be installed in the OSPF database, but the distribution list prevents the routes from being installed into the route table. The LSDB in an area must match on all routers in that area.

```
Router(config)# ip prefix-list [Name] seq 10 deny 10.2.2.0/24
Router(config)# ip prefix-list [Name] seq 20 permit 0.0.0.0/32 le 32
Router(config)# router ospf 2
Router(config)# distribute-list prefix-list [Name] in
```

Route Summarization

This will show how to summarize routes on an ASBR and an ABR, starting with an ASBR. Both examples were summarizing 4 /24 subnets into a single /22.

```
Router(config)# router ospf 1
Router(config-router)# summary-address 172.18.0.0 255.255.252.0
```

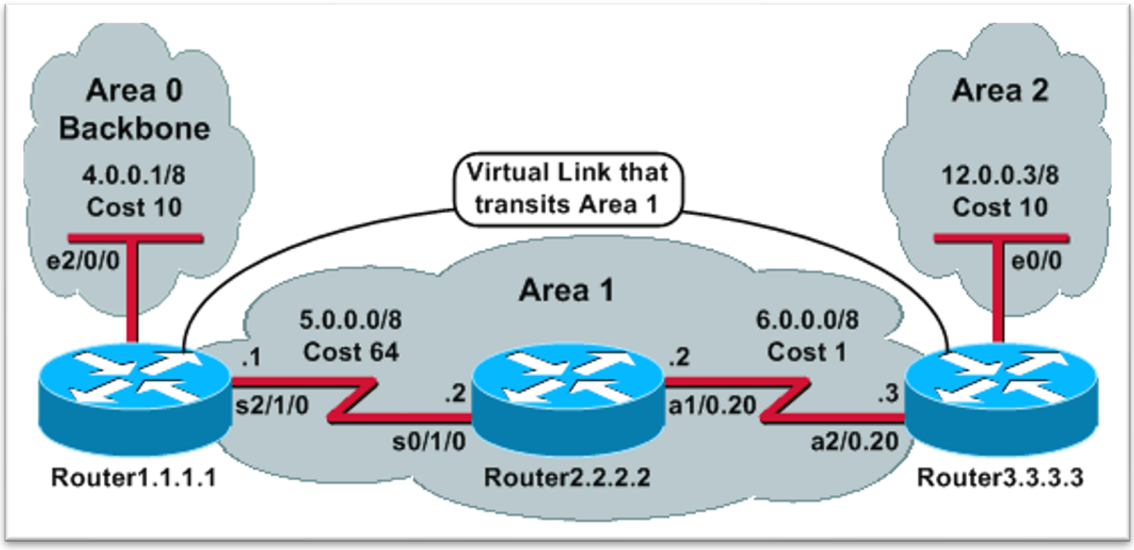
This will show summarizing on an ABR, keep in mind that you will be specifying the area from which the routes exist, so that same area that was used in the ospf network command

```
Router(config)# router ospf 1
Router(config-router)# area 1 range 172.17.0.0 255.255.252.0
```

Virtual Links

Virtual Links are used to link an area that is not directly connected (physically or logically) to area 0.

Virtual Links have to be configured on both sides.




```
Router(config)# router ospf [process i.d.]
Router(config-router)# area [area between area 0 and the other area] virtual-link A.B.C.D
```

In this case A.B.C.D is the R.I.D or Router ID.

Default Routes

You can advertise a default route into the OSPF domain.

```
Router(config-router)# default-information originate [always]
```

The always keyword allows you to advertise a default route even if you don't have one in the routing table.

Stub Area

All routers in a stub area must be configured as stubs. This includes the ABR.

```
Router(config)# router ospf [area-id]
Router(config-router)# area [area-id] stub
```

Totally Stubby Area

This is configured on the ABR and prevents Type 3 LSAs from being advertised into the stubby area.

```
Router(config)# router ospf [area-id]
Router(config-router)# area [area-id] stub no-summary
```

Not So Stubby Area

All routers in an NSSA must be configured with the NSSA option. This prevents Type 5 LSAs from being advertised to the ABR.

```
Router(config)# router ospf [area-id]
Router(config-router)# area [area-id] nssa
```

This is configured on the ABR if you need a default route in the NSSA.

```
Router(config)# router ospf [area-id]
Router(config-router)# area [area-id] nssa default-information-originate
```

Totally Not So Stubby Area

This is configured on the ABR. Member routers use the same configuration as a NSSA.

```
Router(config)# router ospf [area-id]
Router(config-router)# area [area-id] nssa no-summary
```

Show and Debug commands

Router# show ip route ospf
Router# show ip ospf neighbor
Router# show ip ospf database
Router# show ip ospf interface
Router# show ip ospf border-routers
Router# show ip protocols
Router# debug ip ospf hello

Best Practices

- No router should be in more than 3 areas
- No area should contain more than 50 routers
- No router should contain more than 60 neighbors
- There should only be on OSPF process on an ABR