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```
router bgp 65002
 no bgp ebgp-requires-policy
 neighbor 10.0.0.254 remote-as 65000
 neighbor 10.0.0.254 disable-connected-check
 !
 address-family ipv4 unicast
  network 172.16.2.0/24
 exit-address-family
```

Spoke3 configuration

Creating gre interface

```
ip tunnel add gre1 mode gre key 42 ttl 64
ip addr add 10.0.0.3/32 dev gre1
ip link set gre1 up
```

FRR config on Spoke3

```
interface gre1
 description DMVPN Tunnel Interface
 ip address 10.0.0.3/32
 ip nhrp network-id 1
 ip nhrp nhs dynamic nbma 198.51.100.1
 ip nhrp redirect
 ip nhrp registration no-unique
 ip nhrp shortcut
 no link-detect
 tunnel protection vici profile dmvpn
 tunnel source eth0
!
router bgp 65003
 no bgp ebgp-requires-policy
 neighbor 10.0.0.254 remote-as 65000
 neighbor 10.0.0.254 disable-connected-check
 !
 address-family ipv4 unicast
  network 172.16.3.0/24
 exit-address-family
```

3.10 OSPFv2

OSPF (Open Shortest Path First) version 2 is a routing protocol which is described in **RFC 2328**. OSPF is an IGP. Compared with RIP, OSPF can provide scalable network support and faster convergence times. OSPF is widely used in large networks such as ISP backbone and enterprise networks.

3.10.1 OSPF Fundamentals

OSPF is, mostly, a link-state routing protocol. In contrast to *distance-vector* protocols, such as RIP or BGP, where routers describe available *paths* (i.e. routes) to each other, in *link-state* protocols routers instead describe the state of their links to their immediate neighbouring routers.

Each router describes their link-state information in a message known as an LSA (Link State Advertisement), which is then propagated through to all other routers in a link-state routing domain, by a process called *flooding*. Each router thus builds up an LSDB (Link State Database) of all the link-state messages. From this collection of LSAs in the LSDB, each router can then calculate the shortest path to any other router, based on some common metric, by using an algorithm such as Edsger Dijkstra's SPF (Shortest Path First) algorithm.

By describing connectivity of a network in this way, in terms of routers and links rather than in terms of the paths through a network, a link-state protocol can use less bandwidth and converge more quickly than other protocols. A link-state protocol need distribute only one link-state message throughout the link-state domain when a link on any single given router changes state, in order for all routers to reconverge on the best paths through the network. In contrast, distance vector protocols can require a progression of different path update messages from a series of different routers in order to converge.

The disadvantage to a link-state protocol is that the process of computing the best paths can be relatively intensive when compared to distance-vector protocols, in which near to no computation need be done other than (potentially) select between multiple routes. This overhead is mostly negligible for modern embedded CPUs, even for networks with thousands of nodes. The primary scaling overhead lies more in coping with the ever greater frequency of LSA updates as the size of a link-state area increases, in managing the LSDB and required flooding.

This section aims to give a distilled, but accurate, description of the more important workings of OSPF which an administrator may need to know to be able best configure and trouble-shoot OSPF.

OSPF Mechanisms

OSPF defines a range of mechanisms, concerned with detecting, describing and propagating state through a network. These mechanisms will nearly all be covered in greater detail further on. They may be broadly classed as:

The Hello Protocol

The OSPF Hello protocol allows OSPF to quickly detect changes in two-way reachability between routers on a link. OSPF can additionally avail of other sources of reachability information, such as link-state information provided by hardware, or through dedicated reachability protocols such as BFD.

OSPF also uses the Hello protocol to propagate certain state between routers sharing a link, for example:

- Hello protocol configured state, such as the dead-interval.
- Router priority, for DR/BDR election.
- DR/BDR election results.
- Any optional capabilities supported by each router.

The Hello protocol is comparatively trivial and will not be explored in more detail.

LSAs

At the heart of OSPF are LSA messages. Despite the name, some LSA s do not, strictly speaking, describe link-state information. Common LSA s describe information such as:

- Routers, in terms of their links.
- Networks, in terms of attached routers.
- Routes, external to a link-state domain:

  External Routes Routes entirely external to OSPF. Routers originating such routes are known as ASBR (Autonomous-System Border Router) routers.

  Summary Routes Routes which summarise routing information relating to OSPF areas external to the OSPF link-state area at hand, originated by ABR (Area Boundary Router) routers.

LSA Flooding

OSPF defines several related mechanisms, used to manage synchronisation of LSDB s between neighbours as neighbours form adjacencies and the propagation, or *flooding* of new or updated LSA s.

Areas

OSPF provides for the protocol to be broken up into multiple smaller and independent link-state areas. Each area must be connected to a common backbone area by an ABR. These ABR routers are responsible for summarising the link-state routing information of an area into *Summary LSAs*, possibly in a condensed (i.e. aggregated) form, and then originating these summaries into all other areas the ABR is connected to.

Note that only summaries and external routes are passed between areas. As these describe *paths*, rather than any router link-states, routing between areas hence is by *distance-vector*, **not** link-state.

OSPF LSAs

The core objects in OSPF are LSA s. Everything else in OSPF revolves around detecting what to describe in LSAs, when to update them, how to flood them throughout a network and how to calculate routes from them.

There are a variety of different LSA s, for purposes such as describing actual link-state information, describing paths (i.e. routes), describing bandwidth usage of links for TE (Traffic Engineering) purposes, and even arbitrary data by way of *Opaque* LSA s.

LSA Header

All LSAs share a common header with the following information:

- Type

  Different types of LSA s describe different things in OSPF. Types include:

  - Router LSA
  - Network LSA
  - Network Summary LSA
  - Router Summary LSA

  - AS-External LSA

  The specifics of the different types of LSA are examined below.

- Advertising Router

  The Router ID of the router originating the LSA.

See also:

ospf router-id A.B.C.D.

- LSA ID

  The ID of the LSA, which is typically derived in some way from the information the LSA describes, e.g. a Router LSA uses the Router ID as the LSA ID, a Network LSA will have the IP address of the DR as its LSA ID.

  The combination of the Type, ID and Advertising Router ID must uniquely identify the LSA. There can however be multiple instances of an LSA with the same Type, LSA ID and Advertising Router ID, see *sequence number*.

- Age

  A number to allow stale LSA s to, eventually, be purged by routers from their LSDB s.

  The value nominally is one of seconds. An age of 3600, i.e. 1 hour, is called the *MaxAge*. MaxAge LSAs are ignored in routing calculations. LSAs must be periodically refreshed by their Advertising Router before reaching MaxAge if they are to remain valid.

  Routers may deliberately flood LSAs with the age artificially set to 3600 to indicate an LSA is no longer valid. This is called *flushing* of an LSA.

  It is not abnormal to see stale LSAs in the LSDB, this can occur where a router has shutdown without flushing its LSA(s), e.g. where it has become disconnected from the network. Such LSAs do little harm.

- Sequence Number

  A number used to distinguish newer instances of an LSA from older instances.

Link-State LSAs

Of all the various kinds of LSA s, just two types comprise the actual link-state part of OSPF, Router LSA s and Network LSA s. These LSA types are absolutely core to the protocol.

Instances of these LSAs are specific to the link-state area in which they are originated. Routes calculated from these two LSA types are called *intra-area routes*.

- Router LSA

  Each OSPF Router must originate a router LSA to describe itself. In it, the router lists each of its OSPF enabled interfaces, for the given link-state area, in terms of:

  Cost The output cost of that interface, scaled inversely to some commonly known reference value, `auto-cost reference-bandwidth (1-4294967)`.

  Link Type Transit Network

  A link to a multi-access network, on which the router has at least one Full adjacency with another router.

  PtP (Point-to-Point) A link to a single remote router, with a Full adjacency. No DR (Designated Router) is elected on such links; no network LSA is originated for such a link.

  Stub A link with no adjacent neighbours, or a host route.

- Link ID and Data

  These values depend on the Link Type:

Link Type	Link ID	Link Data
Transit	Link IP address of the DR	Interface IP address
Point-to-Point	Router ID of the remote router	Local interface IP address, or the IFINDEX (MIB-II interface index) for unnumbered links
Stub	IP address	Subnet Mask

  Links on a router may be listed multiple times in the Router LSA, e.g. a PTP interface on which OSPF is enabled must *always* be described by a Stub link in the Router LSA, in addition to being listed as PtP link in the Router LSA if the adjacency with the remote router is Full.

  Stub links may also be used as a way to describe links on which OSPF is *not* spoken, known as *passive interfaces*, see `ip ospf passive [A.B.C.D]`.

- Network LSA

  On multi-access links (e.g. ethernets, certain kinds of ATM and X.25 configurations), routers elect a DR. The DR is responsible for originating a Network LSA, which helps reduce the information needed to describe multi-access networks with multiple routers attached. The DR also acts as a hub for the flooding of LSA s on that link, thus reducing flooding overheads.

  The contents of the Network LSA describes the:

  - Subnet Mask

    As the LSA ID of a Network LSA must be the IP address of the DR, the Subnet Mask together with the LSA ID gives you the network address.

  - Attached Routers

    Each router fully-adjacent with the DR is listed in the LSA, by their Router-ID. This allows the corresponding Router LSA s to be easily retrieved from the LSDB.

Summary of Link State LSAs:

LSA Type	LSA ID	LSA Data Describes
Router LSA	Router ID	The OSPF enabled links of the router, within a specific link-state area.
Network LSA	The IP address of the DR for the network	The subnet mask of the network and the Router IDs of all routers on the network

With an LSDB composed of just these two types of LSA, it is possible to construct a directed graph of the connectivity between all routers and networks in a given OSPF link-state area. So, not surprisingly, when OSPF routers build updated routing tables, the first stage of SPF calculation concerns itself only with these two LSA types.

Link-State LSA Examples

The example below shows two LSA s, both originated by the same router (Router ID 192.168.0.49) and with the same LSA ID (192.168.0.49), but of different LSA types.

The first LSA being the router LSA describing 192.168.0.49's links: 2 links to multi-access networks with fully-adjacent neighbours (i.e. Transit links) and 1 being a Stub link (no adjacent neighbours).

The second LSA being a Network LSA, for which 192.168.0.49 is the DR, listing the Router IDs of 4 routers on that network which are fully adjacent with 192.168.0.49.

```
# show ip ospf database router 192.168.0.49

       OSPF Router with ID (192.168.0.53)

                Router Link States (Area 0.0.0.0)

  LS age: 38
  Options: 0x2  : *|-|-|-|-|-|E|*
  LS Flags: 0x6
  Flags: 0x2 : ASBR
  LS Type: router-LSA
  Link State ID: 192.168.0.49
  Advertising Router: 192.168.0.49
  LS Seq Number: 80000f90
  Checksum: 0x518b
  Length: 60
   Number of Links: 3

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 192.168.1.3
     (Link Data) Router Interface address: 192.168.1.3
      Number of TOS metrics: 0
       TOS 0 Metric: 10

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 192.168.0.49
     (Link Data) Router Interface address: 192.168.0.49
      Number of TOS metrics: 0
       TOS 0 Metric: 10

    Link connected to: Stub Network
     (Link ID) Net: 192.168.3.190
     (Link Data) Network Mask: 255.255.255.255
      Number of TOS metrics: 0
       TOS 0 Metric: 39063
# show ip ospf database network 192.168.0.49

       OSPF Router with ID (192.168.0.53)

                Net Link States (Area 0.0.0.0)

  LS age: 285
  Options: 0x2  : *|-|-|-|-|-|E|*
```

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```
  LS Flags: 0x6
  LS Type: network-LSA
  Link State ID: 192.168.0.49 (address of Designated Router)
  Advertising Router: 192.168.0.49
  LS Seq Number: 80000074
  Checksum: 0x0103
  Length: 40
  Network Mask: /29
        Attached Router: 192.168.0.49
        Attached Router: 192.168.0.52
        Attached Router: 192.168.0.53
        Attached Router: 192.168.0.54
```

Note that from one LSA, you can find the other. E.g. Given the Network-LSA you have a list of Router IDs on that network, from which you can then look up, in the local LSDB, the matching Router LSA. From that Router-LSA you may (potentially) find links to other Transit networks and Routers IDs which can be used to lookup the corresponding Router or Network LSA. And in that fashion, one can find all the Routers and Networks reachable from that starting LSA.

Given the Router LSA instead, you have the IP address of the DR of any attached transit links. Network LSAs will have that IP as their LSA ID, so you can then look up that Network LSA and from that find all the attached routers on that link, leading potentially to more links and Network and Router LSAs, etc. etc.

From just the above two LSA s, one can already see the following partial topology:

```
------------------------ Network: ......
            |            Designated Router IP: 192.168.1.3
            |
      IP: 192.168.1.3
       (transit link)
        (cost: 10)
   Router ID: 192.168.0.49(stub)---------- IP: 192.168.3.190/32
        (cost: 10)        (cost: 39063)
       (transit link)
      IP: 192.168.0.49
            |
            |
------------------------------ Network: 192.168.0.48/29
  |        |           |       Designated Router IP: 192.168.0.49
  |        |           |
  |        |     Router ID: 192.168.0.54
  |        |
  |   Router ID: 192.168.0.53
  |
Router ID: 192.168.0.52
```

Note the Router IDs, though they look like IP addresses and often are IP addresses, are not strictly speaking IP addresses, nor need they be reachable addresses (though, OSPF will calculate routes to Router IDs).

External LSAs

External, or “Type 5”, LSA s describe routing information which is entirely external to OSPF, and is “injected” into OSPF. Such routing information may have come from another routing protocol, such as RIP or BGP, they may represent static routes or they may represent a default route.

An OSPF router which originates External LSA s is known as an ASBR. Unlike the link-state LSA s, and most other LSA s, which are flooded only within the area in which they originate, External LSA s are flooded through-out the OSPF network to all areas capable of carrying External LSA s (*Areas*).

Routes internal to OSPF (intra-area or inter-area) are always preferred over external routes.

The External LSA describes the following:

IP Network number The IP Network number of the route is described by the LSA ID field.

IP Network Mask The body of the External LSA describes the IP Network Mask of the route. This, together with the LSA ID, describes the prefix of the IP route concerned.

Metric The cost of the External Route. This cost may be an OSPF cost (also known as a “Type 1” metric), i.e. equivalent to the normal OSPF costs, or an externally derived cost (“Type 2” metric) which is not comparable to OSPF costs and always considered larger than any OSPF cost. Where there are both Type 1 and 2 External routes for a route, the Type 1 is always preferred.

Forwarding Address The address of the router to forward packets to for the route. This may be, and usually is, left as 0 to specify that the ASBR originating the External LSA should be used. There must be an internal OSPF route to the forwarding address, for the forwarding address to be usable.

Tag An arbitrary 4-bytes of data, not interpreted by OSPF, which may carry whatever information about the route which OSPF speakers desire.

AS External LSA Example

To illustrate, below is an example of an External LSA in the LSDB of an OSPF router. It describes a route to the IP prefix of 192.168.165.0/24, originated by the ASBR with Router-ID 192.168.0.49. The metric of 20 is external to OSPF. The forwarding address is 0, so the route should forward to the originating ASBR if selected.

```
# show ip ospf database external 192.168.165.0
  LS age: 995
  Options: 0x2  : *|-|-|-|-|-|E|*
  LS Flags: 0x9
  LS Type: AS-external-LSA
  Link State ID: 192.168.165.0 (External Network Number)
  Advertising Router: 192.168.0.49
  LS Seq Number: 800001d8
  Checksum: 0xea27
  Length: 36
  Network Mask: /24
        Metric Type: 2 (Larger than any link state path)
        TOS: 0
        Metric: 20
        Forward Address: 0.0.0.0
        External Route Tag: 0
```

We can add this to our partial topology from above, which now looks like::

```
--------------------- Network: ......
         |            Designated Router IP: 192.168.1.3
         |
   IP: 192.168.1.3      /---- External route: 192.168.165.0/24
    (transit link)     /                Cost: 20 (External metric)
     (cost: 10)       /
Router ID: 192.168.0.49(stub)---------- IP: 192.168.3.190/32
     (cost: 10)        (cost: 39063)
    (transit link)
   IP: 192.168.0.49
         |
         |
------------------------------ Network: 192.168.0.48/29
  |        |           |       Designated Router IP: 192.168.0.49
  |        |           |
  |        |     Router ID: 192.168.0.54
  |        |
  |   Router ID: 192.168.0.53
  |
Router ID: 192.168.0.52
```

Summary LSAs

Summary LSAs are created by ABR s to summarise the destinations available within one area to other areas. These LSAs may describe IP networks, potentially in aggregated form, or ASBR routers.

3.10.2 Configuring OSPF

ospfd accepts all *Common Invocation Options*.

-n, --instance
Specify the instance number for this invocation of *ospfd*.

-a, --apiserver
Enable the OSPF API server. This is required to use `ospfclient`.

ospfd must acquire interface information from *zebra* in order to function. Therefore *zebra* must be running before invoking *ospfd*. Also, if *zebra* is restarted then *ospfd* must be too.

Like other daemons, *ospfd* configuration is done in OSPF specific configuration file `ospfd.conf` when the integrated config is not used.

Multi-instance Support

OSPF supports multiple instances. Each instance is identified by a positive nonzero integer that must be provided when adding configuration items specific to that instance. Enabling instances is done with `/etc/frr/daemons` in the following manner:

```
...
ospfd=yes
ospfd_instances=1,5,6
...
```

The ospfd_instances variable controls which instances are started and what their IDs are. In this example, after starting FRR you should see the following processes:

```
# ps -ef | grep "ospfd"
frr      11816     1  0 17:30 ?        00:00:00 /usr/lib/frr/ospfd --daemon -A 127.0.0.1␣
↪-n 1
frr      11822     1  0 17:30 ?        00:00:00 /usr/lib/frr/ospfd --daemon -A 127.0.0.1␣
↪-n 2
frr      11828     1  0 17:30 ?        00:00:00 /usr/lib/frr/ospfd --daemon -A 127.0.0.1␣
↪-n 3
```

The instance number should be specified in the config when addressing a particular instance:

```
router ospf 5
   ospf router-id 1.2.3.4
   area 0.0.0.0 authentication message-digest
   ...
```

Routers

To start OSPF process you have to specify the OSPF router.

router ospf [{(1-65535)|vrf NAME}]

Enable or disable the OSPF process.

Multiple instances don't support *vrf NAME*.

ospf router-id A.B.C.D

This sets the router-ID of the OSPF process. The router-ID may be an IP address of the router, but need not be - it can be any arbitrary 32bit number. However it MUST be unique within the entire OSPF domain to the OSPF speaker - bad things will happen if multiple OSPF speakers are configured with the same router-ID! If one is not specified then *ospfd* will obtain a router-ID automatically from *zebra*.

ospf abr-type TYPE

type can be cisco|ibm|shortcut|standard. The "Cisco" and "IBM" types are equivalent.

The OSPF standard for ABR behaviour does not allow an ABR to consider routes through non-backbone areas when its links to the backbone are down, even when there are other ABRs in attached non-backbone areas which still can reach the backbone - this restriction exists primarily to ensure routing-loops are avoided.

With the "Cisco" or "IBM" ABR type, the default in this release of FRR, this restriction is lifted, allowing an ABR to consider summaries learned from other ABRs through non-backbone areas, and hence route via non-backbone areas as a last resort when, and only when, backbone links are down.

Note that areas with fully-adjacent virtual-links are considered to be "transit capable" and can always be used to route backbone traffic, and hence are unaffected by this setting (`area A.B.C.D virtual-link A.B.C.D`).

More information regarding the behaviour controlled by this command can be found in **RFC 3509**, and *draft-ietf-ospf-shortcut-abr-02.txt*.

Quote: "Though the definition of the ABR in the OSPF specification does not require a router with multiple attached areas to have a backbone connection, it is actually necessary to provide successful routing to the inter-area and external destinations. If this requirement is not met, all traffic destined for the areas not connected to such an ABR or out of the OSPF domain, is dropped. This document describes alternative ABR behaviors implemented in Cisco and IBM routers."

ospf rfc1583compatibility

RFC 2328, the successor to **RFC 1583**, suggests according to section G.2 (changes) in section 16.4 a change to the path preference algorithm that prevents possible routing loops that were possible in the old version of OSPFv2. More specifically it demands that inter-area paths and intra-area backbone path are now of equal preference but still both preferred to external paths.

This command should NOT be set normally.

`log-adjacency-changes [detail]`

Configures ospfd to log changes in adjacency. With the optional detail argument, all changes in adjacency status are shown. Without detail, only changes to full or regressions are shown.

`passive-interface default`

Make all interfaces that belong to this router passive by default. For the description of passive interface look at `ip ospf passive [A.B.C.D]`. Per-interface configuration takes precedence over the default value.

`timers throttle spf (0-600000) (0-600000) (0-600000)`

This command sets the initial *delay*, the *initial-holdtime* and the *maximum-holdtime* between when SPF is calculated and the event which triggered the calculation. The times are specified in milliseconds and must be in the range of 0 to 600000 milliseconds.

The *delay* specifies the minimum amount of time to delay SPF calculation (hence it affects how long SPF calculation is delayed after an event which occurs outside of the holdtime of any previous SPF calculation, and also serves as a minimum holdtime).

Consecutive SPF calculations will always be separated by at least 'hold-time' milliseconds. The hold-time is adaptive and initially is set to the *initial-holdtime* configured with the above command. Events which occur within the holdtime of the previous SPF calculation will cause the holdtime to be increased by *initial-holdtime*, bounded by the *maximum-holdtime* configured with this command. If the adaptive hold-time elapses without any SPF-triggering event occurring then the current holdtime is reset to the *initial-holdtime*. The current holdtime can be viewed with `show ip ospf`, where it is expressed as a multiplier of the *initial-holdtime*.

```
router ospf
timers throttle spf 200 400 10000
```

In this example, the *delay* is set to 200ms, the initial holdtime is set to 400ms and the *maximum holdtime* to 10s. Hence there will always be at least 200ms between an event which requires SPF calculation and the actual SPF calculation. Further consecutive SPF calculations will always be separated by between 400ms to 10s, the hold-time increasing by 400ms each time an SPF-triggering event occurs within the hold-time of the previous SPF calculation.

This command supersedes the *timers spf* command in previous FRR releases.

`max-metric router-lsa [on-startup|on-shutdown] (5-86400)`

`max-metric router-lsa administrative`

This enables **RFC 3137** support, where the OSPF process describes its transit links in its router-LSA as having infinite distance so that other routers will avoid calculating transit paths through the router while still being able to reach networks through the router.

This support may be enabled administratively (and indefinitely) or conditionally. Conditional enabling of max-metric router-lsas can be for a period of seconds after startup and/or for a period of seconds prior to shutdown.

Enabling this for a period after startup allows OSPF to converge fully first without affecting any existing routes used by other routers, while still allowing any connected stub links and/or redistributed routes to be reachable. Enabling this for a period of time in advance of shutdown allows the router to gracefully excuse itself from the OSPF domain.

Enabling this feature administratively allows for administrative intervention for whatever reason, for an indefinite period of time. Note that if the configuration is written to file, this administrative form of the stub-router command will also be written to file. If *ospfd* is restarted later, the command will then take effect until manually deconfigured.

Configured state of this feature as well as current status, such as the number of second remaining till on-startup or on-shutdown ends, can be viewed with the `show ip ospf` command.

`auto-cost reference-bandwidth (1-4294967)`

This sets the reference bandwidth for cost calculations, where this bandwidth is considered equivalent to an OSPF cost of 1, specified in Mbits/s. The default is 100Mbit/s (i.e. a link of bandwidth 100Mbit/s or higher will have a cost of 1. Cost of lower bandwidth links will be scaled with reference to this cost).

This configuration setting MUST be consistent across all routers within the OSPF domain.

`network A.B.C.D/M area A.B.C.D`

`network A.B.C.D/M area (0-4294967295)`

This command specifies the OSPF enabled interface(s). If the interface has an address from range 192.168.1.0/24 then the command below enables ospf on this interface so router can provide network information to the other ospf routers via this interface.

```
router ospf
network 192.168.1.0/24 area 0.0.0.0
```

Prefix length in interface must be equal or bigger (i.e. smaller network) than prefix length in network statement. For example statement above doesn't enable ospf on interface with address 192.168.1.1/23, but it does on interface with address 192.168.1.129/25.

Note that the behavior when there is a peer address defined on an interface changed after release 0.99.7. Currently, if a peer prefix has been configured, then we test whether the prefix in the network command contains the destination prefix. Otherwise, we test whether the network command prefix contains the local address prefix of the interface.

In some cases it may be more convenient to enable OSPF on a per interface/subnet basis (*`ip ospf area AREA [ADDR]`*).

`proactive-arp`

This command enables or disables sending ARP requests to update neighbor table entries. It speeds up convergence for /32 networks on a P2P connection.

This feature is enabled by default.

`clear ip ospf [(1-65535)] process`

This command can be used to clear the ospf process data structures. This will clear the ospf neighborship as well and it will get re-established. This will clear the LSDB too. This will be helpful when there is a change in router-id and if user wants the router-id change to take effect, user can use this cli instead of restarting the ospfd daemon.

`clear ip ospf [(1-65535)] neighbor`

This command can be used to clear the ospf neighbor data structures. This will clear the ospf neighborship and it will get re-established. This command can be used when the neighbor state get stuck at some state and this can be used to recover it from that state.

`maximum-paths (1-64)`

Use this command to control the maximum number of equal cost paths to reach a specific destination. The upper limit may differ if you change the value of MULTIPATH_NUM during compilation. The default is MULTIPATH_NUM (64).

`write-multiplier (1-100)`

Use this command to tune the amount of work done in the packet read and write threads before relinquishing control. The parameter is the number of packets to process before returning. The defult value of this parameter is 20.

Areas

area A.B.C.D range A.B.C.D/M

area (0-4294967295) range A.B.C.D/M

Summarize intra area paths from specified area into one Type-3 summary-LSA announced to other areas. This command can be used only in ABR and ONLY router-LSAs (Type-1) and network-LSAs (Type-2) (i.e. LSAs with scope area) can be summarized. Type-5 AS-external-LSAs can't be summarized - their scope is AS. Summarizing Type-7 AS-external-LSAs isn't supported yet by FRR.

```
router ospf
 network 192.168.1.0/24 area 0.0.0.0
 network 10.0.0.0/8 area 0.0.0.10
 area 0.0.0.10 range 10.0.0.0/8
```

With configuration above one Type-3 Summary-LSA with routing info 10.0.0.0/8 is announced into backbone area if area 0.0.0.10 contains at least one intra-area network (i.e. described with router or network LSA) from this range.

area A.B.C.D range IPV4_PREFIX not-advertise

Instead of summarizing intra area paths filter them - i.e. intra area paths from this range are not advertised into other areas. This command makes sense in ABR only.

area A.B.C.D range IPV4_PREFIX substitute IPV4_PREFIX

Substitute summarized prefix with another prefix.

```
router ospf
 network 192.168.1.0/24 area 0.0.0.0
 network 10.0.0.0/8 area 0.0.0.10
 area 0.0.0.10 range 10.0.0.0/8 substitute 11.0.0.0/8
```

One Type-3 summary-LSA with routing info 11.0.0.0/8 is announced into backbone area if area 0.0.0.10 contains at least one intra-area network (i.e. described with router-LSA or network-LSA) from range 10.0.0.0/8. This command makes sense in ABR only.

area A.B.C.D virtual-link A.B.C.D

area (0-4294967295) virtual-link A.B.C.D

area A.B.C.D shortcut

area (0-4294967295) shortcut

Configure the area as Shortcut capable. See **RFC 3509**. This requires that the 'abr-type' be set to 'shortcut'.

area A.B.C.D stub

area (0-4294967295) stub

Configure the area to be a stub area. That is, an area where no router originates routes external to OSPF and hence an area where all external routes are via the ABR(s). Hence, ABRs for such an area do not need to pass AS-External LSAs (type-5s) or ASBR-Summary LSAs (type-4) into the area. They need only pass Network-Summary (type-3) LSAs into such an area, along with a default-route summary.

area A.B.C.D stub no-summary

area (0-4294967295) stub no-summary

Prevents an *ospfd* ABR from injecting inter-area summaries into the specified stub area.

area A.B.C.D nssa

area (0-4294967295) nssa

Configure the area to be a NSSA (Not-So-Stubby Area). This is an area that allows OSPF to import external routes into a stub area via a new LSA type (type 7). An NSSA autonomous system boundary router (ASBR) will generate this type of LSA. The area border router (ABR) translates the LSA type 7 into LSA type 5, which is propagated into the OSPF domain. NSSA areas are defined in RFC 3101.

area A.B.C.D nssa suppress-fa

area (0-4294967295) nssa suppress-fa

Configure the router to set the forwarding address to 0.0.0.0 in all LSA type 5 translated from LSA type 7. The router needs to be elected the translator of the area for this command to take effect. This feature causes routers that are configured not to advertise forwarding addresses into the backbone to direct forwarded traffic to the NSSA ABR translator.

area A.B.C.D default-cost (0-16777215)

Set the cost of default-summary LSAs announced to stubby areas.

area A.B.C.D export-list NAME

area (0-4294967295) export-list NAME

Filter Type-3 summary-LSAs announced to other areas originated from intra- area paths from specified area.

```
router ospf
 network 192.168.1.0/24 area 0.0.0.0
 network 10.0.0.0/8 area 0.0.0.10
 area 0.0.0.10 export-list foo
!
access-list foo permit 10.10.0.0/16
access-list foo deny any
```

With example above any intra-area paths from area 0.0.0.10 and from range 10.10.0.0/16 (for example 10.10.1.0/24 and 10.10.2.128/30) are announced into other areas as Type-3 summary-LSA's, but any others (for example 10.11.0.0/16 or 10.128.30.16/30) aren't.

This command is only relevant if the router is an ABR for the specified area.

area A.B.C.D import-list NAME

area (0-4294967295) import-list NAME

Same as export-list, but it applies to paths announced into specified area as Type-3 summary-LSAs.

area A.B.C.D filter-list prefix NAME in

area A.B.C.D filter-list prefix NAME out

area (0-4294967295) filter-list prefix NAME in

area (0-4294967295) filter-list prefix NAME out

Filtering Type-3 summary-LSAs to/from area using prefix lists. This command makes sense in ABR only.

area A.B.C.D authentication

area (0-4294967295) authentication

Specify that simple password authentication should be used for the given area.

area A.B.C.D authentication message-digest

area (0-4294967295) authentication message-digest

Specify that OSPF packets must be authenticated with MD5 HMACs within the given area. Keying material must also be configured on a per-interface basis (`ip ospf message-digest-key`).

MD5 authentication may also be configured on a per-interface basis (*ip ospf authentication message-digest*). Such per-interface settings will override any per-area authentication setting.

Interfaces

ip ospf area AREA [ADDR]

Enable OSPF on the interface, optionally restricted to just the IP address given by *ADDR*, putting it in the *AREA* area. Per interface area settings take precedence to network commands (`network A.B.C.D/M area A.B.C.D`).

If you have a lot of interfaces, and/or a lot of subnets, then enabling OSPF via this command may result in a slight performance improvement.

ip ospf authentication-key AUTH_KEY

Set OSPF authentication key to a simple password. After setting *AUTH_KEY*, all OSPF packets are authenticated. *AUTH_KEY* has length up to 8 chars.

Simple text password authentication is insecure and deprecated in favour of MD5 HMAC authentication.

ip ospf authentication message-digest

Specify that MD5 HMAC authentication must be used on this interface. MD5 keying material must also be configured. Overrides any authentication enabled on a per-area basis (`area A.B.C.D authentication message-digest`)

Note that OSPF MD5 authentication requires that time never go backwards (correct time is NOT important, only that it never goes backwards), even across resets, if ospfd is to be able to promptly reestablish adjacencies with its neighbours after restarts/reboots. The host should have system time be set at boot from an external or non-volatile source (e.g. battery backed clock, NTP, etc.) or else the system clock should be periodically saved to non-volatile storage and restored at boot if MD5 authentication is to be expected to work reliably.

ip ospf message-digest-key KEYID md5 KEY

Set OSPF authentication key to a cryptographic password. The cryptographic algorithm is MD5.

KEYID identifies secret key used to create the message digest. This ID is part of the protocol and must be consistent across routers on a link.

KEY is the actual message digest key, of up to 16 chars (larger strings will be truncated), and is associated with the given KEYID.

ip ospf cost (1-65535)

Set link cost for the specified interface. The cost value is set to router-LSA's metric field and used for SPF calculation.

ip ospf dead-interval (1-65535)

ip ospf dead-interval minimal hello-multiplier (2-20)

Set number of seconds for RouterDeadInterval timer value used for Wait Timer and Inactivity Timer. This value must be the same for all routers attached to a common network. The default value is 40 seconds.

If 'minimal' is specified instead, then the dead-interval is set to 1 second and one must specify a hello-multiplier. The hello-multiplier specifies how many Hellos to send per second, from 2 (every 500ms) to 20 (every 50ms). Thus one can have 1s convergence time for OSPF. If this form is specified, then the hello-interval advertised in Hello packets is set to 0 and the hello-interval on received Hello packets is not checked, thus the hello-multiplier need NOT be the same across multiple routers on a common link.

ip ospf hello-interval (1-65535)

Set number of seconds for HelloInterval timer value. Setting this value, Hello packet will be sent every timer value seconds on the specified interface. This value must be the same for all routers attached to a common network. The default value is 10 seconds.

This command has no effect if `ip ospf dead-interval minimal hello-multiplier (2-20)` is also specified for the interface.

`ip ospf network (broadcast|non-broadcast|point-to-multipoint|point-to-point [dmvpn])`

When configuring a point-to-point network on an interface and the interface has a /32 address associated with then OSPF will treat the interface as being *unnumbered*. If you are doing this you *must* set the net.ipv4.conf.<interface name>.rp_filter value to 0. In order for the ospf multicast packets to be delivered by the kernel.

When used in a DMVPN network at a spoke, this OSPF will be configured in point-to-point, but the HUB will be a point-to-multipoint. To make this topology work, specify the optional 'dmvpn' parameter at the spoke.

Set explicitly network type for specified interface.

`ip ospf priority (0-255)`

Set RouterPriority integer value. The router with the highest priority will be more eligible to become Designated Router. Setting the value to 0, makes the router ineligible to become Designated Router. The default value is 1.

`ip ospf retransmit-interval (1-65535)`

Set number of seconds for RxmtInterval timer value. This value is used when retransmitting Database Description and Link State Request packets. The default value is 5 seconds.

`ip ospf transmit-delay (1-65535) [A.B.C.D]`

Set number of seconds for InfTransDelay value. LSAs' age should be incremented by this value when transmitting. The default value is 1 second.

`ip ospf passive [A.B.C.D]`

Do not speak OSPF on the interface, but do advertise the interface as a stub link in the router-LSA for this router. This allows one to advertise addresses on such connected interfaces without having to originate AS-External/Type-5 LSAs (which have global flooding scope) - as would occur if connected addresses were redistributed into OSPF (*Redistribution*). This is the only way to advertise non-OSPF links into stub areas.

`ip ospf area (A.B.C.D|(0-4294967295))`

Enable ospf on an interface and set associated area.

3.10.3 OSPF route-map

Usage of *ospfd*'s route-map support.

`set metric [+|-](0-4294967295)`

Set a metric for matched route when sending announcement. Use plus (+) sign to add a metric value to an existing metric. Use minus (-) sign to substract a metric value from an existing metric.

Redistribution

`redistribute <babel|bgp|connected|eigrp|isis|kernel|openfabric|ospf|rip|sharp|static|table> [metric-typ`

Redistribute routes of the specified protocol or kind into OSPF, with the metric type and metric set if specified, filtering the routes using the given route-map if specified. Redistributed routes may also be filtered with distribute-lists, see *ospf distribute-list configuration*.

Redistributed routes are distributed as into OSPF as Type-5 External LSAs into links to areas that accept external routes, Type-7 External LSAs for NSSA areas and are not redistributed at all into Stub areas, where external routes are not permitted.

Note that for connected routes, one may instead use the `ip ospf passive [A.B.C.D]` configuration.

`default-information originate`

`default-information originate metric (0-16777214)`

`default-information originate metric (0-16777214) metric-type (1|2)`

`default-information originate metric (0-16777214) metric-type (1|2) route-map WORD`

default-information originate always

default-information originate always metric (0-16777214)

default-information originate always metric (0-16777214) metric-type (1|2)

default-information originate always metric (0-16777214) metric-type (1|2) route-map WORD

Originate an AS-External (type-5) LSA describing a default route into all external-routing capable areas, of the specified metric and metric type. If the 'always' keyword is given then the default is always advertised, even when there is no default present in the routing table.

distribute-list NAME out <kernel|connected|static|rip|isis|bgp|eigrp|nhrp|table|vnc|babel|openfabric>

Apply the access-list filter, NAME, to redistributed routes of the given type before allowing the routes to be redistributed into OSPF (*ospf redistribution*).

default-metric (0-16777214)

distance (1-255)

distance ospf (intra-area|inter-area|external) (1-255)

3.10.4 Graceful Restart

graceful-restart [grace-period (1-1800)]

Configure Graceful Restart (RFC 3623) restarting support. When enabled, the default grace period is 120 seconds.

To perform a graceful shutdown, the "graceful-restart prepare ip ospf" EXEC-level command needs to be issued before restarting the ospfd daemon.

graceful-restart helper enable [A.B.C.D]

Configure Graceful Restart (RFC 3623) helper support. By default, helper support is disabled for all neighbours. This config enables/disables helper support on this router for all neighbours. To enable/disable helper support for a specific neighbour, the router-id (A.B.C.D) has to be specified.

graceful-restart helper strict-lsa-checking

If 'strict-lsa-checking' is configured then the helper will abort the Graceful Restart when a LSA change occurs which affects the restarting router. By default 'strict-lsa-checking' is enabled"

graceful-restart helper supported-grace-time

Supports as HELPER for configured grace period.

graceful-restart helper planned-only

It helps to support as HELPER only for planned restarts. By default, it supports both planned and unplanned outages.

graceful-restart prepare ip ospf

Initiate a graceful restart for all OSPF instances configured with the "graceful-restart" command. The ospfd daemon should be restarted during the instance-specific grace period, otherwise the graceful restart will fail.

This is an EXEC-level command.

3.10.5 Showing Information

show ip ospf [json]
Show information on a variety of general OSPF and area state and configuration information.

show ip ospf interface [INTERFACE] [json]
Show state and configuration of OSPF the specified interface, or all interfaces if no interface is given.

show ip ospf neighbor [json]

show ip ospf neighbor INTERFACE [json]

show ip ospf neighbor detail [json]

show ip ospf neighbor INTERFACE detail [json]
Display lsa information of LSDB. Json o/p of this command covers base route information i.e all LSAs except opaque lsa info.

show ip ospf [vrf <NAME|all>] database [json]

show ip ospf [vrf <NAME|all>] database (asbr-summary|external|network|router|summary) [json]

show ip ospf [vrf <NAME|all>] database (asbr-summary|external|network|router|summary) LINK-STATE-ID [js

show ip ospf [vrf <NAME|all>] database (asbr-summary|external|network|router|summary) LINK-STATE-ID adv-

show ip ospf [vrf <NAME|all>] database (asbr-summary|external|network|router|summary) adv-router ADV-ROU

show ip ospf [vrf <NAME|all>] database (asbr-summary|external|network|router|summary) LINK-STATE-ID sel

show ip ospf [vrf <NAME|all>] database (asbr-summary|external|network|router|summary) self-originate [j

show ip ospf [vrf <NAME|all>] database max-age [json]

show ip ospf [vrf <NAME|all>] database self-originate [json]
Show the OSPF database summary.

show ip ospf route [json]
Show the OSPF routing table, as determined by the most recent SPF calculation.

show ip ospf graceful-restart helper [detail] [json]
Displays the Grcaeful Restart Helper details including helper config changes.

3.10.6 Opaque LSA

ospf opaque-lsa

capability opaque
ospfd supports Opaque LSA (**RFC 2370**) as partial support for MPLS Traffic Engineering LSAs. The opaque-lsa capability must be enabled in the configuration. An alternate command could be "mpls-te on" (*Traffic Engineering*). Note that FRR offers only partial support for some of the routing protocol extensions that are used with MPLS-TE; it does not support a complete RSVP-TE solution.

show ip ospf [vrf <NAME|all>] database (opaque-link|opaque-area|opaque-external)

show ip ospf [vrf <NAME|all>] database (opaque-link|opaque-area|opaque-external) LINK-STATE-ID

show ip ospf [vrf <NAME|all>] database (opaque-link|opaque-area|opaque-external) LINK-STATE-ID adv-rout

show ip ospf [vrf <NAME|all>] database (opaque-link|opaque-area|opaque-external) adv-router ADV-ROUTER

show ip ospf [vrf <NAME|all>] database (opaque-link|opaque-area|opaque-external) LINK-STATE-ID self-orig

show ip ospf [vrf <NAME|all>] database (opaque-link|opaque-area|opaque-external) self-originate
Show Opaque LSA from the database.

3.10.7 Traffic Engineering

Note: At this time, FRR offers partial support for some of the routing protocol extensions that can be used with MPLS-TE. FRR does not support a complete RSVP-TE solution currently.

mpls-te on
Enable Traffic Engineering LSA flooding.

mpls-te router-address <A.B.C.D>
Configure stable IP address for MPLS-TE. This IP address is then advertise in Opaque LSA Type-10 TLV=1 (TE) option 1 (Router-Address).

mpls-te inter-as area <area-id>|as
Enable **RFC 5392** support - Inter-AS TE v2 - to flood Traffic Engineering parameters of Inter-AS link. 2 modes are supported: AREA and AS; LSA are flood in AREA <area-id> with Opaque Type-10, respectively in AS with Opaque Type-11. In all case, Opaque-LSA TLV=6.

mpls-te export
Export Traffic Engineering Data Base to other daemons through the ZAPI Opaque Link State messages.

show ip ospf mpls-te interface

show ip ospf mpls-te interface INTERFACE
Show MPLS Traffic Engineering parameters for all or specified interface.

show ip ospf mpls-te router
Show Traffic Engineering router parameters.

show ip ospf mpls-te database [verbose|json]

show ip ospf mpls-te database vertex [self-originate|adv-router ADV-ROUTER] [verbose|json]

show ip ospf mpls-te database edge [A.B.C.D] [verbose|json]

show ip ospf mpls-te database subnet [A.B.C.D/M] [verbose|json]
Show Traffic Engineering Database

3.10.8 Router Information

router-info [as | area]
Enable Router Information (**RFC 4970**) LSA advertisement with AS scope (default) or Area scope flooding when area is specified. Old syntax *router-info area <A.B.C.D>* is always supported but mark as deprecated as the area ID is no more necessary. Indeed, router information support multi-area and detect automatically the areas.

pce address <A.B.C.D>

pce domain as (0-65535)

pce neighbor as (0-65535)

pce flag BITPATTERN

pce scope BITPATTERN
The commands are conform to **RFC 5088** and allow OSPF router announce Path Computation Element (PCE) capabilities through the Router Information (RI) LSA. Router Information must be enable prior to this. The

command set/unset respectively the PCE IP address, Autonomous System (AS) numbers of controlled domains, neighbor ASs, flag and scope. For flag and scope, please refer to :rfc`5088` for the BITPATTERN recognition. Multiple 'pce neighbor' command could be specified in order to specify all PCE neighbours.

`show ip ospf router-info`
Show Router Capabilities flag.

`show ip ospf router-info pce`
Show Router Capabilities PCE parameters.

3.10.9 Segment Routing

This is an EXPERIMENTAL support of Segment Routing as per *RFC 8665* for MPLS dataplane.

`segment-routing on`
Enable Segment Routing. Even if this also activate routing information support, it is preferable to also activate routing information, and set accordingly the Area or AS flooding.

`segment-routing global-block (16-1048575) (16-1048575) [local-block (16-1048575) (16-1048575)]`
Set the Segment Routing Global Block i.e. the label range used by MPLS to store label in the MPLS FIB for Prefix SID. Optionally also set the Local Block, i.e. the label range used for Adjacency SID. The negative version of the command always unsets both ranges.

`segment-routing local-block (16-1048575) (16-1048575)`
Set the Segment Routing Local Block i.e. the label range used by MPLS to store label in the MPLS FIB for Adjacency SID. This command is deprecated in favor of the combined command above.

`segment-routing node-msd (1-16)`
Fix the Maximum Stack Depth supported by the router. The value depend of the MPLS dataplane. E.g. for Linux kernel, since version 4.13 it is 32.

`segment-routing prefix A.B.C.D/M [index (0-65535)|no-php-flag|explicit-null]`
prefix with /32 corresponding to a loopback interface are currently supported. The 'no-php-flag' means NO Penultimate Hop Popping that allows SR node to request to its neighbor to not pop the label. The 'explicit-null' means that neighbor nodes must swap the incoming label by the MPLS Explicit Null label before delivering the packet.

`show ip ospf database segment-routing <adv-router ADVROUTER|self-originate> [json]`
Show Segment Routing Data Base, all SR nodes, specific advertised router or self router. Optional JSON output can be obtained by appending 'json' to the end of the command.

3.10.10 External Route Summarisation

This feature summarises originated external LSAs(Type-5 and Type-7). Summary Route will be originated on-behalf of all matched external LSAs.

`summary-address A.B.C.D/M [tag (1-4294967295)]`
This command enable/disables summarisation for the configured address range. Tag is the optional parameter. If tag configured Summary route will be originated with the configured tag.

`summary-address A.B.C.D/M no-advertise`
This command to ensure not advertise the summary lsa for the matched external LSAs.

`aggregation timer (5-1800)`
Configure aggregation delay timer interval. Summarisation starts only after this delay timer expiry. By default, delay interval is 5 secs.

Resetting the aggregation delay interval to default value.

show ip ospf [vrf <NAME|all>] summary-address [detail] [json]
Show configuration for display all configured summary routes with matching external LSA information.

3.10.11 TI-LFA

Experimental support for Topology Independent LFA (Loop-Free Alternate), see for example 'draft-bashandy-rtgwg-segment-routing-ti-lfa-05'. Note that TI-LFA requires a proper Segment Routing configuration.

fast-reroute ti-lfa [node-protection]
Configured on the router level. Activates TI-LFA for all interfaces.

Note that so far only P2P interfaces are supported.

3.10.12 Debugging OSPF

debug ospf bfd
Enable or disable debugging for BFD events. This will show BFD integration library messages and OSPF BFD integration messages that are mostly state transitions and validation problems.

debug ospf packet (hello|dd|ls-request|ls-update|ls-ack|all) (send|recv) [detail]
Dump Packet for debugging

debug ospf ism

debug ospf ism (status|events|timers)
Show debug information of Interface State Machine

debug ospf nsm

debug ospf nsm (status|events|timers)
Show debug information of Network State Machine

debug ospf event
Show debug information of OSPF event

debug ospf nssa
Show debug information about Not So Stub Area

debug ospf lsa

debug ospf lsa (generate|flooding|refresh)
Show debug detail of Link State messages

debug ospf te
Show debug information about Traffic Engineering LSA

debug ospf zebra

debug ospf zebra (interface|redistribute)
Show debug information of ZEBRA API

debug ospf graceful-restart helper
Enable/disable debug information for OSPF Graceful Restart Helper

show debugging ospf

debug ospf lsa aggregate
Debug commnd to enable/disable external route summarisation specific debugs.

3.10.13 Sample Configuration

A simple example, with MD5 authentication enabled:

```
!
interface bge0
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 ABCDEFGHIJK
!
router ospf
 network 192.168.0.0/16 area 0.0.0.1
 area 0.0.0.1 authentication message-digest
```

An ABR router, with MD5 authentication and performing summarisation of networks between the areas:

```
!
password ABCDEF
log file /var/log/frr/ospfd.log
service advanced-vty
!
interface eth0
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 ABCDEFGHIJK
!
interface ppp0
 ip ospf passive
!
interface br0
 ip ospf authentication message-digest
 ip ospf message-digest-key 2 md5 XYZ12345
!
router ospf
 ospf router-id 192.168.0.1
 redistribute connected
 network 192.168.0.0/24 area 0.0.0.0
 network 10.0.0.0/16 area 0.0.0.0
 network 192.168.1.0/24 area 0.0.0.1
 area 0.0.0.0 authentication message-digest
 area 0.0.0.0 range 10.0.0.0/16
 area 0.0.0.0 range 192.168.0.0/24
 area 0.0.0.1 authentication message-digest
 area 0.0.0.1 range 10.2.0.0/16
!
```

A Traffic Engineering configuration, with Inter-ASv2 support.

First, the `zebra.conf` part:

```
interface eth0
 ip address 198.168.1.1/24
 link-params
  enable
  admin-grp 0xa1
  metric 100
```

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```
  max-bw 1.25e+07
  max-rsv-bw 1.25e+06
  unrsv-bw 0 1.25e+06
  unrsv-bw 1 1.25e+06
  unrsv-bw 2 1.25e+06
  unrsv-bw 3 1.25e+06
  unrsv-bw 4 1.25e+06
  unrsv-bw 5 1.25e+06
  unrsv-bw 6 1.25e+06
  unrsv-bw 7 1.25e+06
!
interface eth1
 ip address 192.168.2.1/24
 link-params
  enable
  metric 10
  max-bw 1.25e+07
  max-rsv-bw 1.25e+06
  unrsv-bw 0 1.25e+06
  unrsv-bw 1 1.25e+06
  unrsv-bw 2 1.25e+06
  unrsv-bw 3 1.25e+06
  unrsv-bw 4 1.25e+06
  unrsv-bw 5 1.25e+06
  unrsv-bw 6 1.25e+06
  unrsv-bw 7 1.25e+06
  neighbor 192.168.2.2 as 65000
   hostname HOSTNAME
   password PASSWORD
   log file /var/log/zebra.log
   !
   interface eth0
    ip address 198.168.1.1/24
    link-params
     enable
     admin-grp 0xa1
     metric 100
     max-bw 1.25e+07
     max-rsv-bw 1.25e+06
     unrsv-bw 0 1.25e+06
     unrsv-bw 1 1.25e+06
     unrsv-bw 2 1.25e+06
     unrsv-bw 3 1.25e+06
     unrsv-bw 4 1.25e+06
     unrsv-bw 5 1.25e+06
     unrsv-bw 6 1.25e+06
     unrsv-bw 7 1.25e+06
   !
   interface eth1
    ip address 192.168.2.1/24
    link-params
     enable
```

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```
     metric 10
     max-bw 1.25e+07
     max-rsv-bw 1.25e+06
     unrsv-bw 0 1.25e+06
     unrsv-bw 1 1.25e+06
     unrsv-bw 2 1.25e+06
     unrsv-bw 3 1.25e+06
     unrsv-bw 4 1.25e+06
     unrsv-bw 5 1.25e+06
     unrsv-bw 6 1.25e+06
     unrsv-bw 7 1.25e+06
     neighbor 192.168.2.2 as 65000
```

Then the `ospfd.conf` itself:

```
hostname HOSTNAME
password PASSWORD
log file /var/log/ospfd.log
!
!
interface eth0
 ip ospf hello-interval 60
 ip ospf dead-interval 240
!
interface eth1
 ip ospf hello-interval 60
 ip ospf dead-interval 240
!
!
router ospf
 ospf router-id 192.168.1.1
 network 192.168.0.0/16 area 1
 ospf opaque-lsa
 mpls-te
 mpls-te router-address 192.168.1.1
 mpls-te inter-as area 1
!
line vty
```

A router information example with PCE advertisement:

```
!
router ospf
 ospf router-id 192.168.1.1
 network 192.168.0.0/16 area 1
 capability opaque
 mpls-te
 mpls-te router-address 192.168.1.1
 router-info area 0.0.0.1
 pce address 192.168.1.1
 pce flag 0x80
 pce domain as 65400
```

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```
 pce neighbor as 65500
 pce neighbor as 65200
 pce scope 0x80
!
```

3.11 OSPFv3

ospf6d is a daemon support OSPF version 3 for IPv6 network. OSPF for IPv6 is described in **RFC 2740**.

3.11.1 OSPF6 router

router ospf6 [vrf NAME]

ospf6 router-id A.B.C.D

Set router's Router-ID.

timers throttle spf (0-600000) (0-600000) (0-600000)

This command sets the initial *delay*, the *initial-holdtime* and the *maximum-holdtime* between when SPF is calculated and the event which triggered the calculation. The times are specified in milliseconds and must be in the range of 0 to 600000 milliseconds.

The *delay* specifies the minimum amount of time to delay SPF calculation (hence it affects how long SPF calculation is delayed after an event which occurs outside of the holdtime of any previous SPF calculation, and also serves as a minimum holdtime).

Consecutive SPF calculations will always be separated by at least 'hold-time' milliseconds. The hold-time is adaptive and initially is set to the *initial-holdtime* configured with the above command. Events which occur within the holdtime of the previous SPF calculation will cause the holdtime to be increased by *initial-holdtime*, bounded by the *maximum-holdtime* configured with this command. If the adaptive hold-time elapses without any SPF-triggering event occurring then the current holdtime is reset to the *initial-holdtime*.

```
router ospf6
 timers throttle spf 200 400 10000
```

In this example, the *delay* is set to 200ms, the initial holdtime is set to 400ms and the *maximum holdtime* to 10s. Hence there will always be at least 200ms between an event which requires SPF calculation and the actual SPF calculation. Further consecutive SPF calculations will always be separated by between 400ms to 10s, the hold-time increasing by 400ms each time an SPF-triggering event occurs within the hold-time of the previous SPF calculation.

auto-cost reference-bandwidth COST

This sets the reference bandwidth for cost calculations, where this bandwidth is considered equivalent to an OSPF cost of 1, specified in Mbits/s. The default is 100Mbit/s (i.e. a link of bandwidth 100Mbit/s or higher will have a cost of 1. Cost of lower bandwidth links will be scaled with reference to this cost).

This configuration setting MUST be consistent across all routers within the OSPF domain.

maximum-paths (1-64)

Use this command to control the maximum number of parallel routes that OSPFv3 can support. The default is 64.

write-multiplier (1-100)

Use this command to tune the amount of work done in the packet read and write threads before relinquishing control. The parameter is the number of packets to process before returning. The default value of this parameter is 20.

`clear ipv6 ospf6 process [vrf NAME]`

This command clears up the database and routing tables and resets the neighborship by restarting the interface state machine. This will be helpful when there is a change in router-id and if user wants the router-id change to take effect, user can use this cli instead of restarting the ospf6d daemon.

3.11.2 ASBR Summarisation Support in OSPFv3

External routes in OSPFv3 are carried by type 5/7 LSA (external LSAs). External LSAs are generated by ASBR (Autonomous System Boundary Router). Large topology database requires a large amount of router memory, which slows down all processes, including SPF calculations. It is necessary to reduce the size of the OSPFv3 topology database, especially in a large network. Summarising routes keeps the routing tables smaller and easier to troubleshoot.

External route summarization must be configured on ASBR. Stub area do not allow ASBR because they don't allow type 5 LSAs.

An ASBR will inject a summary route into the OSPFv3 domain.

Summary route will only be advertised if you have at least one subnet that falls within the summary range.

Users will be allowed an option in the CLI to not advertise range of ipv6 prefixes as well.

The configuration of ASBR Summarisation is supported using the CLI command

`summary-address X:X::X:X/M [tag (1-4294967295)] [{metric (0-16777215) | metric-type (1-2)}]`

This command will advertise a single External LSA on behalf of all the prefixes falling under this range configured by the CLI. The user is allowed to configure tag, metric and metric-type as well. By default, tag is not configured, default metric as 20 and metric-type as type-2 gets advertised. A summary route is created when one or more specific routes are learned and removed when no more specific route exist. The summary route is also installed in the local system with Null0 as next-hop to avoid leaking traffic.

`no summary-address X:X::X:X/M [tag (1-4294967295)] [{metric (0-16777215) | metric-type (1-2)}]`

This command can be used to remove the summarisation configuration. This will flush the single External LSA if it was originated and advertise the External LSAs for all the existing individual prefixes.

`summary-address X:X::X:X/M no-advertise`

This command can be used when user do not want to advertise a certain range of prefixes using the no-advertise option. This command when configured will flush all the existing external LSAs falling under this range.

`no summary-address X:X::X:X/M no-advertise`

This command can be used to remove the previous configuration. When configured, tt will resume originating external LSAs for all the prefixes falling under the configured range.

`aggregation timer (5-1800)`

The summarisation command takes effect after the aggregation timer expires. By default the value of this timer is 5 seconds. User can modify the time after which the external LSAs should get originated using this command.

`no aggregation timer (5-1800)`

This command removes the timer configuration. It reverts back to default 5 second timer.

`show ipv6 ospf6 summary-address [detail] [json]`

This command can be used to see all the summary-address related information. When detail option is used, it shows all the prefixes falling under each summary-configuration apart from other information.

3.11.3 OSPF6 area

`area A.B.C.D range X:X::X:X/M [<advertise|not-advertise|cost (0-16777215)>]`

`area (0-4294967295) range X:X::X:X/M [<advertise|not-advertise|cost (0-16777215)>]`

Summarize a group of internal subnets into a single Inter-Area-Prefix LSA. This command can only be used at the area boundary (ABR router).

By default, the metric of the summary route is calculated as the highest metric among the summarized routes. The *cost* option, however, can be used to set an explicit metric.

The *not-advertise* option, when present, prevents the summary route from being advertised, effectively filtering the summarized routes.

`area A.B.C.D nssa [no-summary]`

`area (0-4294967295) nssa [no-summary] [default-information-originate [metric-type (1-2)] [metric (0-167`

Configure the area to be a NSSA (Not-So-Stubby Area).

The following functionalities are implemented as per RFC 3101:

1. Advertising Type-7 LSA into NSSA area when external route is redistributed into OSPFv3.
2. Processing Type-7 LSA received from neighbor and installing route in the route table.
3. Support for NSSA ABR functionality which is generating Type-5 LSA when backbone area is configured. Currently translation of Type-7 LSA to Type-5 LSA is enabled by default.
4. Support for NSSA Translator functionality when there are multiple NSSA ABR in an area.

An NSSA ABR can be configured with the *no-summary* option to prevent the advertisement of summaries into the area. In that case, a single Type-3 LSA containing a default route is originated into the NSSA.

NSSA ABRs and ASBRs can be configured with *default-information-originate* option to originate a Type-7 default route into the NSSA area. In the case of NSSA ASBRs, the origination of the default route is conditioned to the existence of a default route in the RIB that wasn't learned via the OSPF protocol.

`area A.B.C.D export-list NAME`

`area (0-4294967295) export-list NAME`

Filter Type-3 summary-LSAs announced to other areas originated from intra- area paths from specified area.

```
router ospf6
 area 0.0.0.10 export-list foo
!
ipv6 access-list foo permit 2001:db8:1000::/64
ipv6 access-list foo deny any
```

With example above any intra-area paths from area 0.0.0.10 and from range 2001:db8::/32 (for example 2001:db8:1::/64 and 2001:db8:2::/64) are announced into other areas as Type-3 summary-LSA's, but any others (for example 2001:200::/48) aren't.

This command is only relevant if the router is an ABR for the specified area.

`area A.B.C.D import-list NAME`

`area (0-4294967295) import-list NAME`

Same as export-list, but it applies to paths announced into specified area as Type-3 summary-LSAs.

`area A.B.C.D filter-list prefix NAME in`

`area A.B.C.D filter-list prefix NAME out`

`area (0-4294967295) filter-list prefix NAME in`

area (0-4294967295) filter-list prefix NAME out
Filtering Type-3 summary-LSAs to/from area using prefix lists. This command makes sense in ABR only.

3.11.4 OSPF6 interface

ipv6 ospf6 area <A.B.C.D|(0-4294967295)>
Enable OSPFv3 on the interface and add it to the specified area.

ipv6 ospf6 cost COST
Sets interface's output cost. Default value depends on the interface bandwidth and on the auto-cost reference bandwidth.

ipv6 ospf6 hello-interval HELLOINTERVAL
Sets interface's Hello Interval. Default 10

ipv6 ospf6 dead-interval DEADINTERVAL
Sets interface's Router Dead Interval. Default value is 40.

ipv6 ospf6 retransmit-interval RETRANSMITINTERVAL
Sets interface's Rxmt Interval. Default value is 5.

ipv6 ospf6 priority PRIORITY
Sets interface's Router Priority. Default value is 1.

ipv6 ospf6 transmit-delay TRANSMITDELAY
Sets interface's Inf-Trans-Delay. Default value is 1.

ipv6 ospf6 network (broadcast|point-to-point)
Set explicitly network type for specified interface.

3.11.5 OSPF6 route-map

Usage of *ospfd6*'s route-map support.

set metric [+|-](0-4294967295)
Set a metric for matched route when sending announcement. Use plus (+) sign to add a metric value to an existing metric. Use minus (-) sign to substract a metric value from an existing metric.

3.11.6 Redistribute routes to OSPF6

redistribute <babel|bgp|connected|isis|kernel|openfabric|ripng|sharp|static|table> [metric-type (1-2)]
Redistribute routes of the specified protocol or kind into OSPFv3, with the metric type and metric set if specified, filtering the routes using the given route-map if specified.

default-information originate [{always|metric (0-16777214)|metric-type (1-2)|route-map WORD}]
The command injects default route in the connected areas. The always argument injects the default route regardless of it being present in the router. Metric values and route-map can also be specified optionally.

3.11.7 Graceful Restart

graceful-restart [grace-period (1-1800)]
Configure Graceful Restart (RFC 5187) restarting support. When enabled, the default grace period is 120 seconds.

To perform a graceful shutdown, the "graceful-restart prepare ipv6 ospf" EXEC-level command needs to be issued before restarting the ospf6d daemon.

graceful-restart helper enable [A.B.C.D]
Configure Graceful Restart (RFC 5187) helper support. By default, helper support is disabled for all neighbours. This config enables/disables helper support on this router for all neighbours. To enable/disable helper support for a specific neighbour, the router-id (A.B.C.D) has to be specified.

graceful-restart helper strict-lsa-checking
If 'strict-lsa-checking' is configured then the helper will abort the Graceful Restart when a LSA change occurs which affects the restarting router. By default 'strict-lsa-checking' is enabled"

graceful-restart helper supported-grace-time (10-1800)
Supports as HELPER for configured grace period.

graceful-restart helper planned-only
It helps to support as HELPER only for planned restarts. By default, it supports both planned and unplanned outages.

graceful-restart prepare ipv6 ospf
Initiate a graceful restart for all OSPFv3 instances configured with the "graceful-restart" command. The ospf6d daemon should be restarted during the instance-specific grace period, otherwise the graceful restart will fail.

This is an EXEC-level command.

3.11.8 Showing OSPF6 information

show ipv6 ospf6 [vrf <NAME|all>] [json]
Show information on a variety of general OSPFv3 and area state and configuration information. JSON output can be obtained by appending 'json' to the end of command.

show ipv6 ospf6 [vrf <NAME|all>] database [<detail|dump|internal>] [json]
This command shows LSAs present in the LSDB. There are three view options. These options helps in viewing all the parameters of the LSAs. JSON output can be obtained by appending 'json' to the end of command. JSON option is not applicable with 'dump' option.

show ipv6 ospf6 [vrf <NAME|all>] database <router|network|inter-prefix|inter-router|as-external|group-me
These options filters out the LSA based on its type. The three views options works here as well. JSON output can be obtained by appending 'json' to the end of command.

show ipv6 ospf6 [vrf <NAME|all>] database adv-router A.B.C.D linkstate-id A.B.C.D [json]
The LSAs additinally can also be filtered with the linkstate-id and advertising-router fields. We can use the LSA type filter and views with this command as well and visa-versa. JSON output can be obtained by appending 'json' to the end of command.

show ipv6 ospf6 [vrf <NAME|all>] database self-originated [json]
This command is used to filter the LSAs which are originated by the present router. All the other filters are applicable here as well.

show ipv6 ospf6 [vrf <NAME|all>] interface [json]
To see OSPF interface configuration like costs. JSON output can be obtained by appending "json" in the end.

show ipv6 ospf6 [vrf <NAME|all>] neighbor [json]
Shows state and chosen (Backup) DR of neighbor. JSON output can be obtained by appending 'json' at the end.

show ipv6 ospf6 [vrf <NAME|all>] interface traffic [json]
Shows counts of different packets that have been recieved and transmitted by the interfaces. JSON output can be obtained by appending "json" at the end.

show ipv6 route ospf6
This command shows internal routing table.

show ipv6 ospf6 zebra [json]
Shows state about what is being redistributed between zebra and OSPF6. JSON output can be obtained by appending "json" at the end.

show ipv6 ospf6 [vrf <NAME|all>] redistribute [json]
Shows the routes which are redistributed by the router. JSON output can be obtained by appending 'json' at the end.

show ipv6 ospf6 [vrf <NAME|all>] route [<intra-area|inter-area|external-1|external-2|X:X::X:X|X:X::X:X/M|detail|summary>] [json]
This command displays the ospfv3 routing table as determined by the most recent SPF calculations. Options are provided to view the different types of routes. Other than the standard view there are two other options, detail and summary. JSON output can be obtained by appending 'json' to the end of command.

show ipv6 ospf6 [vrf <NAME|all>] route X:X::X:X/M match [detail] [json]
The additional match option will match the given address to the destination of the routes, and return the result accordingly.

show ipv6 ospf6 [vrf <NAME|all>] interface [IFNAME] prefix [detail|<X:X::X:X|X:X::X:X/M> [<match|detail>]] [json]
This command shows the prefixes present in the interface routing table. Interface name can also be given. JSON output can be obtained by appending 'json' to the end of command.

show ipv6 ospf6 [vrf <NAME|all>] spf tree [json]
This commands shows the spf tree from the recent spf calculation with the calling router as the root. If json is appended in the end, we can get the tree in JSON format. Each area that the router belongs to has it's own JSON object, with each router having "cost", "isLeafNode" and "children" as arguments.

show ipv6 ospf6 graceful-restart helper [detail] [json]
This command shows the graceful-restart helper details including helper configuration parameters.

3.11.9 OSPFv3 Debugging

The following debug commands are supported:

debug ospf6 abr
Toggle OSPFv3 ABR debugging messages.

debug ospf6 asbr
Toggle OSPFv3 ASBR debugging messages.

debug ospf6 border-routers
Toggle OSPFv3 border router debugging messages.

debug ospf6 flooding
Toggle OSPFv3 flooding debugging messages.

debug ospf6 interface
Toggle OSPFv3 interface related debugging messages.

debug ospf6 lsa
Toggle OSPFv3 Link State Advertisements debugging messages.

debug ospf6 lsa aggregation
Toggle OSPFv3 Link State Advertisements summarization debugging messages.

debug ospf6 message
Toggle OSPFv3 message exchange debugging messages.

debug ospf6 neighbor
Toggle OSPFv3 neighbor interaction debugging messages.

debug ospf6 nssa
Toggle OSPFv3 Not So Stubby Area (NSSA) debugging messages.

debug ospf6 route
Toggle OSPFv3 routes debugging messages.

debug ospf6 spf
Toggle OSPFv3 Shortest Path calculation debugging messages.

debug ospf6 zebra
Toggle OSPFv3 zebra interaction debugging messages.

debug ospf6 graceful-restart
Toggle OSPFv3 graceful-restart helper debugging messages.

3.11.10 Sample configuration

Example of ospf6d configured on one interface and area:

```
interface eth0
 ipv6 ospf6 area 0.0.0.0
 ipv6 ospf6 instance-id 0
!
router ospf6
 ospf6 router-id 212.17.55.53
 area 0.0.0.0 range 2001:770:105:2::/64
!
```

Larger example with policy and various options set:

```
debug ospf6 neighbor state
!
interface fxp0
 ipv6 ospf6 area 0.0.0.0
 ipv6 ospf6 cost 1
 ipv6 ospf6 hello-interval 10
 ipv6 ospf6 dead-interval 40
 ipv6 ospf6 retransmit-interval 5
 ipv6 ospf6 priority 0
 ipv6 ospf6 transmit-delay 1
 ipv6 ospf6 instance-id 0
!
interface lo0
 ipv6 ospf6 cost 1
 ipv6 ospf6 hello-interval 10
```

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```
 ipv6 ospf6 dead-interval 40
 ipv6 ospf6 retransmit-interval 5
 ipv6 ospf6 priority 1
 ipv6 ospf6 transmit-delay 1
 ipv6 ospf6 instance-id 0
!
router ospf6
 router-id 255.1.1.1
 redistribute static route-map static-ospf6
!
access-list access4 permit 127.0.0.1/32
!
ipv6 access-list access6 permit 3ffe:501::/32
ipv6 access-list access6 permit 2001:200::/48
ipv6 access-list access6 permit ::1/128
!
ipv6 prefix-list test-prefix seq 1000 deny any
!
route-map static-ospf6 permit 10
 match ipv6 address prefix-list test-prefix
 set metric-type type-2
 set metric 2000
!
line vty
 access-class access4
 ipv6 access-class access6
 exec-timeout 0 0
!
```

3.12 PATH

PATH is a daemon that handles the installation and deletion of Segment Routing (SR) Policies.

3.12.1 Starting PATH

Default configuration file for *pathd* is `pathd.conf`. The typical location of `pathd.conf` is /etc/frr/pathd.conf.

If the user is using integrated config, then `pathd.conf` need not be present and the `frr.conf` is read instead.

PATH supports all the common FRR daemon start options which are documented elsewhere.

3.12.2 PCEP Support

A pceplib is included in the frr source tree and build by default.

To start pathd with pcep support the extra parameter *-M pathd_pcep* should be passed to the pathd daemon.

3.12.3 Pathd Configuration

Example:

```
debug pathd pcep basic
segment-routing
 traffic-eng
  mpls-te on
  mpls-te import ospfv2
  segment-list SL1
   index 10 mpls label 16010
   index 20 mpls label 16030
  !
  segment-list SL2
   index 10 nai prefix 10.1.2.1/32 iface 1
   index 20 nai adjacency 10.1.20.1 10.1.20.2
   index 30 nai prefix 10.10.10.5/32 algorithm 0
   index 40 mpls label 18001
  !
  policy color 1 endpoint 1.1.1.1
   name default
   binding-sid 4000
   candidate-path preference 100 name CP1 explicit segment-list SL1
   candidate-path preference 200 name CP2 dynamic
    affinity include-any 0x000000FF
    bandwidth 100000
    metric bound msd 16 required
    metric te 10
    objective-function mcp required
  !
  pcep
   pce-config GROUP1
    source-address ip 1.1.1.1
    tcp-md5-auth secret
    timer keep-alive 30
   !
   pce PCE1
    config GROUP1
    address ip 10.10.10.10
   !
   pce PCE2
    config GROUP1
    address ip 9.9.9.9
   !
   pcc
    peer PCE1 precedence 10
    peer PCE2 precedence 20
```

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