OSPF Tables

- Neighbor Table
  - directly connected OSPF Routers
  - state of Adj
- Topology Table sh ip ospf database.
  - Everything OSPF knows about.
  - Link State DataBase (LSDB)
    - Each entry in LSDB is known as:
      Link State Advertisement (LSA)

After converging, every router will have the same LSDB.

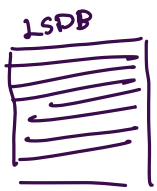
- Routing Table
  - Router's Routing Table (not solely a func in OSPF)
  - OSPF will contribute its best Routes to Routing Table.

Sh ip route

OSPF Packets.

- Hello
  - periodically sent to 224.0.0.5, multicast address for all OSPF routers.
  - Discover other OSPF Routers
  - Include info about the sending router
    Determines whether Adj will form

- DBD (Database Descriptor)
  - Summary of LSAs in each Router's LSDB



Topology Table.
each entry is a LSA.

It could have 1000 LSAs.
so $R_1 \rightleftharpoons R_2$, R_1 only send DBD (summary of LSAs)

  - Avoid sending full LSDB for each ~~nei~~

- LSR (Link State Request).
  - request a list of LSAs

- LSU (Link State Update)
  - Includes requested LSAs)

- Link State Acknowledgement (LSAck)
  - Sent to confirm reception of LSU

OSPF Areas

- OSPF Routers maintain identical LSDBs
  - change anywhere propagate everywhere.
- Network can be segregated using Areas.
  Limits propagation to confined sections.
- Area Design create a 2-tier hierarchy.
  - Area 0 – Top of Hierarchy – Backbone Area.
  - Area # – All other Areas : 1 – 4,294,967,295 (2^32)
- Traffic between areas must travel Area 0
  - Assures loop free area topology
  - Hub & spoke design (star Topology).

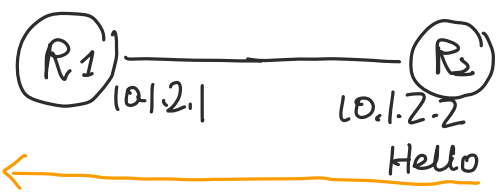
OSPF Types of Routers

- Internal Routers : All ints in a single Area.
- Backbone Routers : At least 1 int in Area 0.
- Area Border Routers : Int(s) in Area 0 & in Area #
  1. maintain LSDB for each area
  2. responsible for summarizes LSAs between Areas.
- ASBR – Autonomous System Border Routers.
  - Redistributing foreign routes into OSPF

Hello Package

- Discover OSPF nbrs.
- Sent periodically to 224.0.0.5 (multicast)
  Typically every 10s
- Some networks don't support multicast
  - router's peer IP must be manually configured
  - In this case, Hello Packets sent Unicast
    (typically every 30 ~ seconds)
- Content of Hello determines if Routers will become nbrs.

Content:



Router-ID	2.2.2.2
Hello Interval	10s
Dead Interval	40s
Nbrs	
Area ID	
Auth. Data	
Network mask	/24.

: Frequency of periodic Hellos

: Duration to rem Nbr (4x Hello interval)

Nbr router ID(s) seen on link validates 2-way reachability

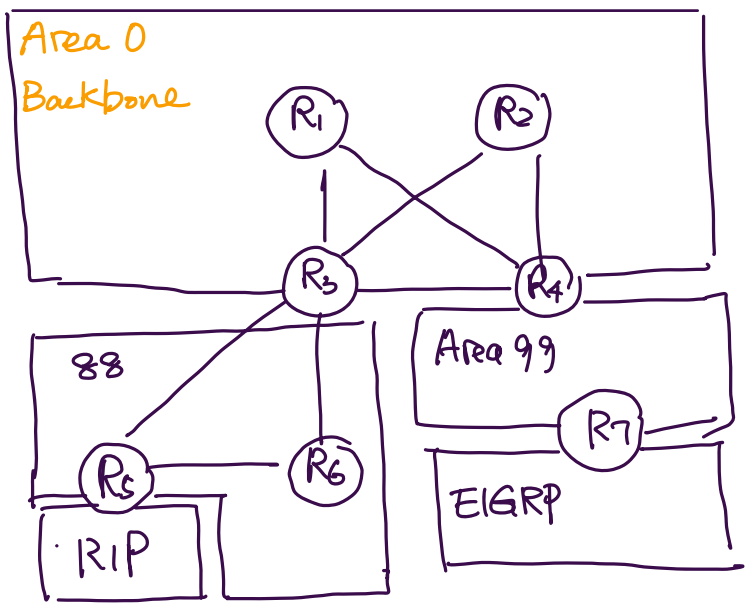
subnet mask for the link

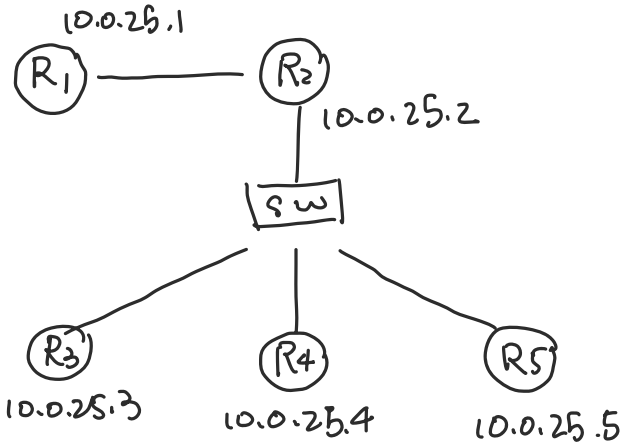
OSPF peering w/ the routers you designate

mandating u only form a nbr relationship w/ other routers that include the same password.

Area Type – Normal, Stub, NSSA

- Normal Area – Default Area Type.
- Stub Area
  - prevent any redistributed routes from appearing in
  - replace w/ Default route pointing to ABR
- NSSA – Not so stubby Area
  - No redistribution, except from local area
  - optionally replaced by w/ Default Rate





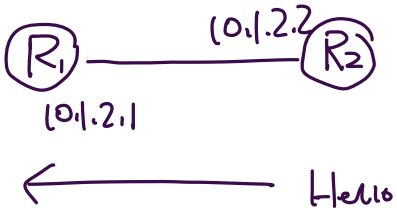
- DR – Designated Rt
- BDR – Backup ..
- Priority – 0~255 default 1

- On multi-access links a DR is elected.

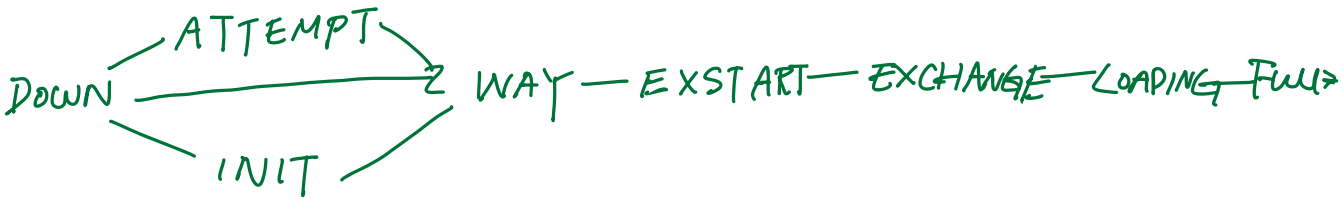
- central point for all updates on Link

BDR: take over DR when something happen to DR

multi-access: any link w/ potential for multi-access.



Router ID	2.2.2.2
Hello Interval	10s
Dead Interval	40s
Nbrs	(empty)
Area ID	0
Auth. Data	None.
Network Mask	/24.
Area Type	Normal
Designated Rtr	10.1.2.2
Backup D Rtr	0.0.0.0.
priority	1.



- STATE: DOWN
  - Initial State when OSPF first configured
  - Sending periodic Hello to 224.0.0.5
    - Initially Nbrs field is empty

Nbr Table is empty

(relationship w/ another router is down)

- STATE: ATTEMPT
  - NBMA Links only

non-broadcast multi-access links

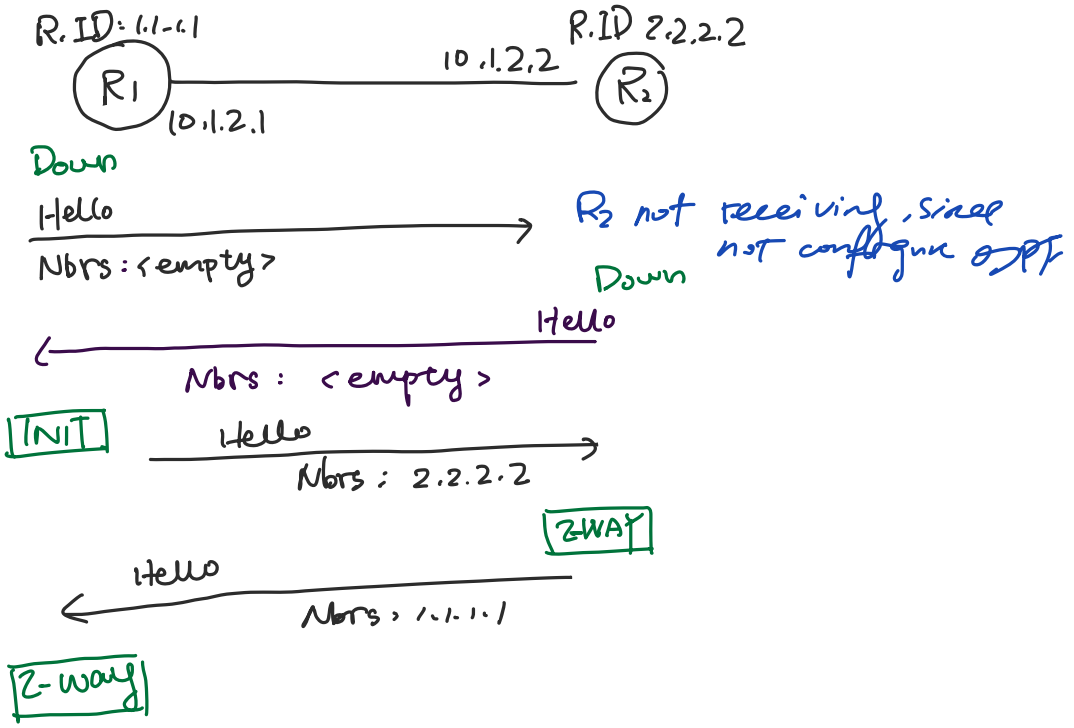
  - Manually Configured Nbrs
  - Sending Unicast Hellos

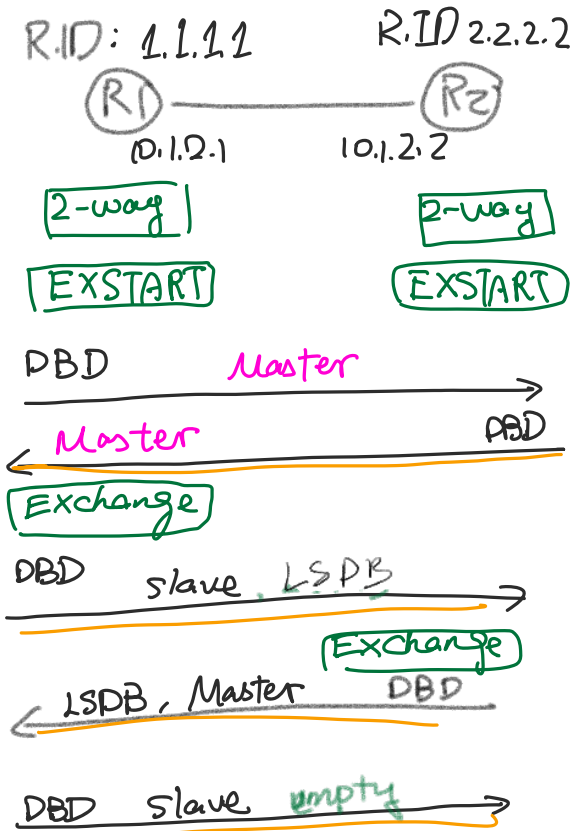
- STATE: INIT
- Received a Hello packet
- Outbound Hellos now include Peer R.ID.

STATE: 2WAY.

- Router sees itself in Nbr's Hello
- Router decide if Adj will proceed

DR & BDR election





- In Master / Slave election, first the 2 of them both send DBD indicating they're the master
- Higher router ID becomes Master, & slave into Exchange and send confirming DBD saying it is the slave.
- After receiving the confirmation, the master router into Exchange

master speaks, slave response

STATE : EXSTART

if they decide to proceed w/ adj.

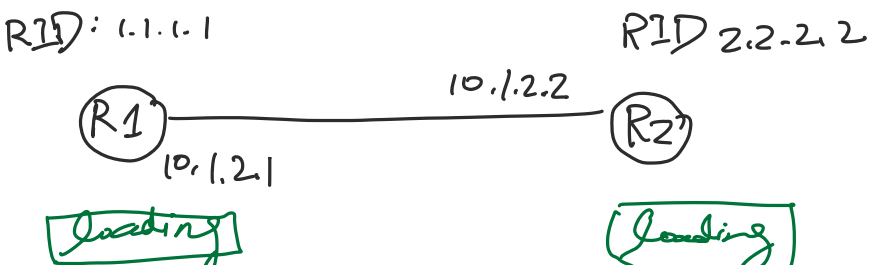
- Master / Slave Election of further
  - Governs reliable DBD exchange
    (see previous page)

STATE : EXCHANGE

- Master / Slave Election is complete

- peers exchange LSDB summaries.

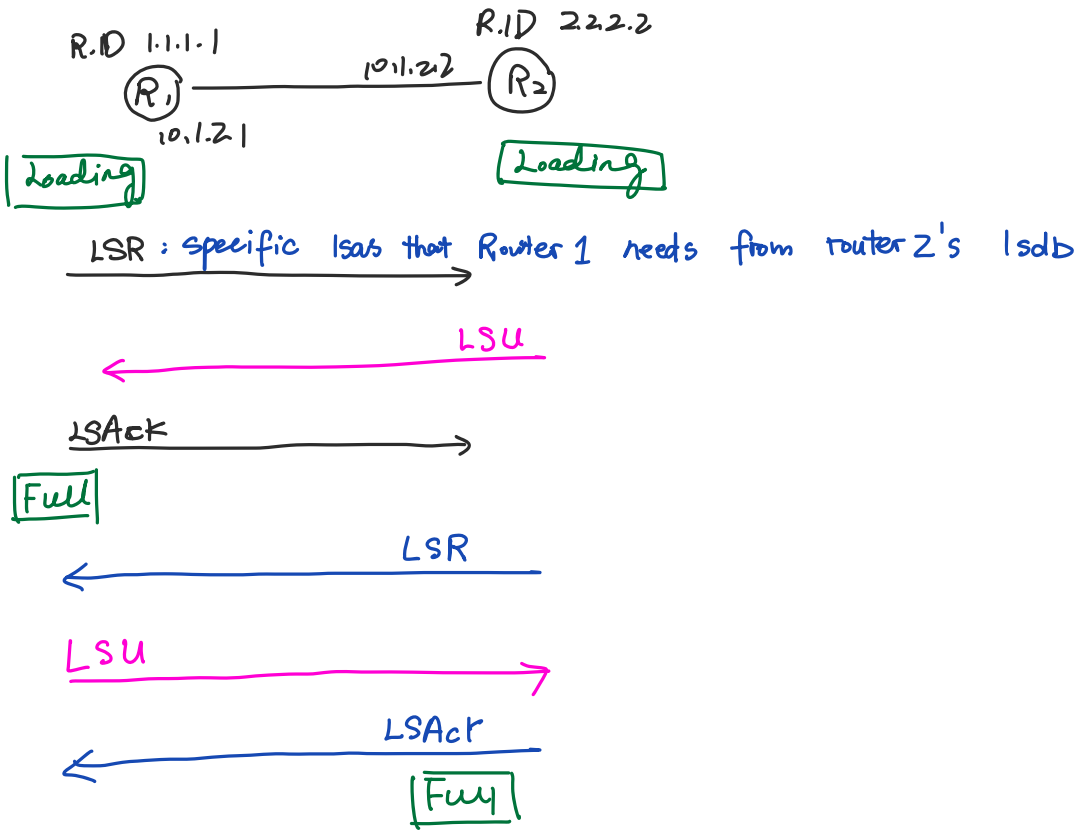
At this point, both peers have exchanged their lsdb summary, which means both peers are now in the loading stage



State : Loading

exponential backoff

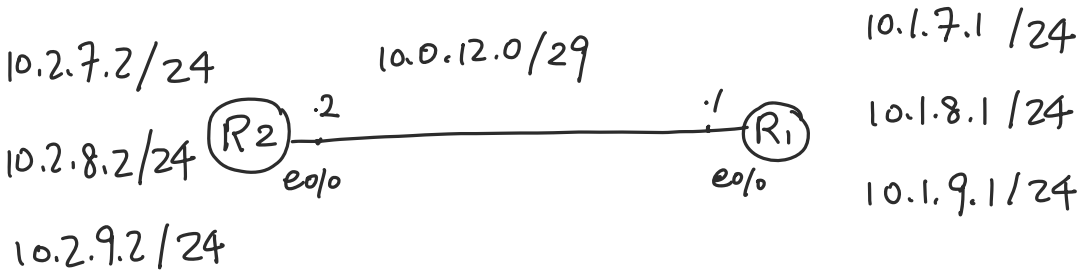
- Both peers know the LSAs in neighbor's LSDB, and they can pick from that lists the ones that they actually need
- peers request full LSAs through
  - LSR, LSU, LSAck



- State : Full
- LSDB's are Synchronized
- Adj complete.

Down → init → 2 way → exstart → exchange → loading → full

Configuration



R1 #

1. See if the router has done any dynamic routing

Show ip protocols

2. turn on ospf config t

router ospf 110 -> process id number

3. Setting a router id

conf t → global config

router ospf 110 → go into ospf process id

router-id 1.1.1.1 → Set the router-id.

sh ip protocols → Router ID 1.1.1.1

sh ip ospf database → also sh router id & process id

4. add interface to ospf

(network command)

config t

router ospf 110

do sh ip int brief | e una ← See all the int

network 10.0.12.1 0.0.0.0 area 0

wildcard mask

→ sh sp ospf interface brief

Interface w/ ospf configured.

➡ sh ip ospf database (link state database for this router)

R2#

5. Verify if an ospf nbr exist

sh ip ospf neighbor → nothing comes up

6. Setup ospf

config t

router ospf 110

router-id 2.2.2.2

network 10.0.12.2 0.0.0.0 area

➡ sh ip ospf database

2 type-1 LSA and 1 type-2 LSA

⇓ ⇓

Router Link States (Area 0) Net Link States (Area 0)

7. command that make the content in ospf DB more like route

sh ip ospf rib (routing information base) : routing table

8. Sh ospf learned path that made into the routing table.

sh ip route ospf

R2# (put the loopback interface into ospf)

sh run | section router

(router ospf 110

network 10.0.12.2 0.0.0.0 area 0)

conf t

router ospf 110

network 10.2.0.0 0.0.255.255 area 0

^Z (back out)

R1#sh ip ospf rib 10.2.9.0 ⇒ show more info about that particular route

LSA 1/2.2.2.2/2.2.2.2
↓ ↓ ↓
type 1 link ID ADV Router

can be matched w/ "sh ip ospf database"

9. another way to add ints

conf t
interface Loopback 27 ▶ go into interface configuration
ip ospf 110 area 0

^Z

▶ Interface range

Interface range Loopback 28-29
ip ospf 110 area 0

10. LSDB
sh ip ospf database

Configuration Commands :

- router ospf <#> process id
- router id <#>
- adding interface to OSPF :
  - network <net id> < wildcard > area <#>

go into interface

conf t
int e1/1.

  - ip ospf <#> area <#>

- Show Command

sh ip protocols

sh ip ospf interface [brief]

sh ip ospf neighbors

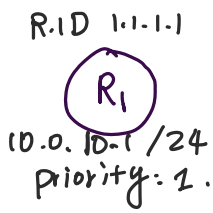
sh ip ospf database

sh ip ospf rib (10.0.0.1). show more info about this route).

sh ip route (ospf)

DR & BDR

- Reduce redundant LSA flooding
- Elected using interface priority number
  - range 0-255
  - default 1
  - highest router-id break the tie
- Elected on all Multi-Access links
  - link w/ potential for multi access (ethernet)
  - Broadcast / NBMA



In default multi-access network:

Hello : 10

Dead : 40

R1 initial Hello packet

R.ID: 1.1.1.1

Priority: 1

DR IP: 0.0.0.0

BDR IP: 0.0.0.0

- Check if DR already exist
- Duration: Wait timer same as Dead interval

After wait timer, it's going to determine that there is no DR on this link & the router elects itself as DR

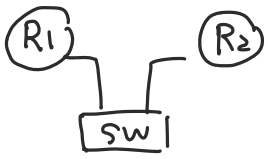
continue to send out hello packet until another router join the link

R.ID 1.1.1.1

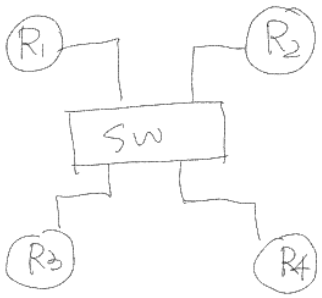
Priority 1

DR IP 10.0.10.1

BPR IP 0.0.0.0



- R_2's initial Hello packet
  - R.ID: 2.2.2.2
  - priority: 1
  - DR IP: 0.0.0.0
  - BDR IP: 0.0.0.0
- Checking if DR already exists
- Receives Hello packets from R1
  - R_2 has same priority #, but better router-ID
  - Does not preempt current DR.
- R_2 elects itself BDR
  - R.ID 2.2.2.2
  - priority: 1
  - DR IP 10.0.10.1
  - BDR IP 10.0.10.2



- R_3 & R_4 join the network, and they will first send out hello packets w/ 0.0.0.0 DR & BDR.
- they will receive hello packet from R_1 & R_2 and they will tell them a DR & BDR already exist.
- Hello packets include DR & BDR.

DROther

DR/BDR status & priority is per interface, not per router.

priority number : can influence DR election

- 0 ~ 255 - Default 1 - Higher better
- special case → 0 never become DR / BDR interface is always DROTHER

```
Router#  conf  t
     #   int   Ethernet 0/0
     #   ip ospf priority [0-255]
```

How are Routing Updates propagated ?

- 224.0.0.5 - all OSPF routers
- 224.0.0.6 - only DR / BDR

➤ When DR has routing updates :

DR sends LSU to 224.0.0.5

BDR sends LSAck to 224.0.0.5
(confirm BDR is healthy & doing its job)

DROTHER send LSAck to 224.0.0.6

➤ when BDR has routing updates :

BDR sends LSU to 224.0.0.5

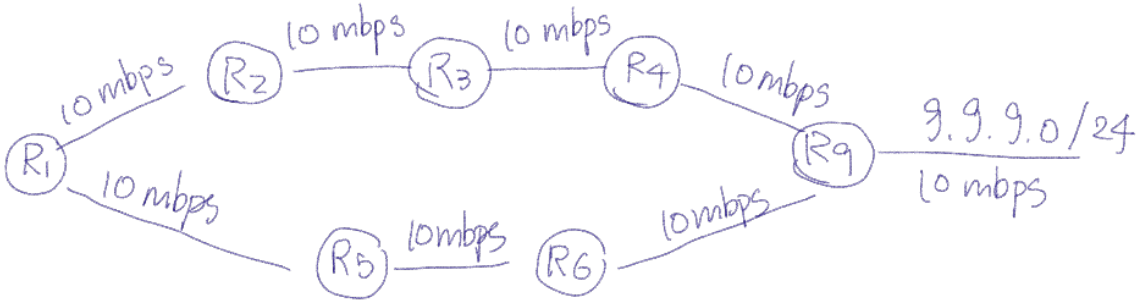
DR sends LSAck to 224.0.0.5

DROTHER send LSAck to 224.0.0.6

When DROTHER has a routing update:

- DROTHER Sends LSU to 224.0.0.6
- DR sends LSU to 224.0.0.5
- BDR sends LSAck to 224.0.0.5
- Remaining DROTHERs send LSArk to 224.0.0.6

OSPF cost / metric



- RIP = Hop count
- EIGRP = Minimum Bandwidth / Load / Delay / Reliability
- OSPF = Delay → additive metric based on link speed

Cost formula =
Reference Bandwidth / Link Bandwidth

Default Reference Bandwidth = 100 Mbps

---

1. See reference Bandwidth :

```
sh ip ospf
```

going down & we will see the reference bandwidth.

2. link bandwidth : we can see using sh interface command.

```
sh interface e0/0
sh ip ospf interface brief
```

3. config link bandwidth

```
conf t
int eth 0/0
bandwidth ?   ( Bandwidth in kilobits )
bandwidth 10000   (10 mbps)
```

do sh ip ospf int brief , under cost

Cost calculation :

minimum bandwidth on a link is 1

no decimal, so a cost like 3.33 is truncated into 3.

OSPF Reference bandwidth :

check current reference bandwidth: sh ip ospf | i Ref

include.

what we have configured in our router ospf process

sh run | s router

change reference bandwidth

router ospf 110

auto-cost reference-bandwidth 100 (mbps)

show all costs on every interface in this router

sh ip ospf int brief

the range of cost is 1 – 65535

Be careful w/ the reference bandwidth

Type 1 LSA : Router LSA - Router identifies itself & it's links

- IP Networks / Subnet Mask / Costs for each Router link
- used to build topology map of local area.

Type 2 LSA : Sent by Designated Router (DR)

- When multiple routers connected to the same multi-access link.

Type 3 LSA : Contain IP Networks from foreign areas

- Sent by Area Border Routers (ABRs)
- Summarizes Type 1 and Type 2 LSAs and Type 3 LSAs
- Each Type 3 LSA typically contains 1 IP subnet

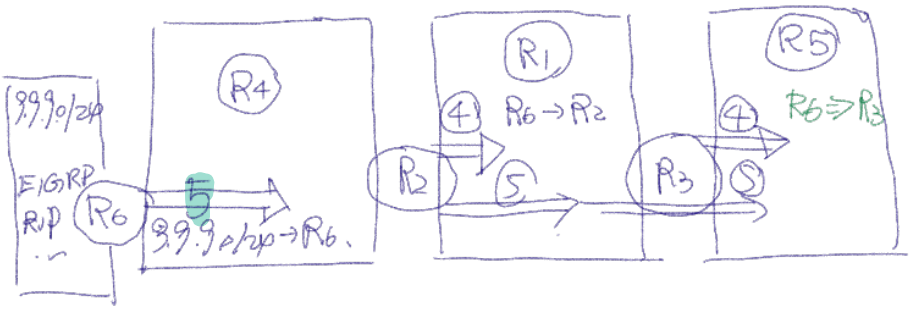
  Type 3 LSAs can create IP summarization boundaries.

Type 1 and Type 2 : - Intra-Area - within local area

- Inter-Area - outside local area

Type 5 LSA – contain an IP Subnet redistribution into OSPF

- Sent by Autonomous Syster Border routers (ASBRs)
- Forwarded unchanged throughout OSPF domain

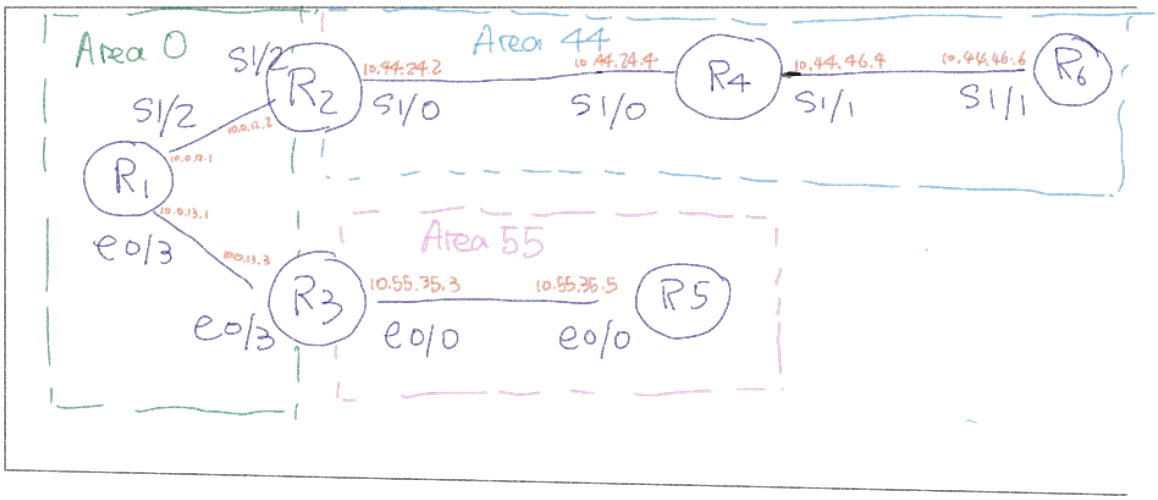


Type 4 LSA – instructions to reach ASBRs

- Sent by ABR, when ASBR in a foreign Area.

As a helper LSA to type 5 LSA.

LSAs Deep Dive



(1) LSA Type 1 and Type 2

1. Loopback

R1 # router ospf 110

router-id 1.1.1.1

conf t ← adding a loopback int

int l1

ip add 10.0.1.1 255.255.255.0

Sh ip int br | e una

int l1

ip ospf 110 area 0

To see the result : sh ip ospf int brief

sh ip ospf database

We have one Type 1 (router) LSA,

To see in detail:

Sh ip ospf database router 1.1.1.1

router LSA Link ID

Link count expand :

By default, ospf always advertise a loopback int as /32 network

Loopback int is advertised w/in a Type 1 LSA using a stub network.

2. Loopback point-to-point (network type) w/ no neighbors.

int l1

ip ospf network point-to-point

We can check the result by

Sh ip ospf int loopback 1

sh ip ospf database

Sh ip ospf database router 1.1.1.1

(Now the network mask is /24) ← but still a stub network

stub network: network id, subnet mask, cost

3. Serial link (show u how point to point network works)

point-to-point network: Layer-2 vpns, Metro Ethernet, MPLS and so on, & perhaps setting an ethernet link as point to point

Stub type link inside a type I LSA

R2#: conf t

int s1/2

ip ospf 110 area 0

sh ip ospf database

now we have a link count of 2

sh ip ospf database router 1.1.1.1 (inspect further)

sh ip ospf int s1/2

4 Serial link with neighbor

sh ip ospf neighbor

(stub & point-to-point)

5 Ethernet no neighbor.

stub

Type I - Router LSA

1
Point-to-Point
Connection to another OSPF Router on a P2P link

2
Transit Network
Designated Router for Multi-Access Link with OSPF Neighbors

3
Stub Network
Net ID, Subnet Mask, and Cost of directly connected network

4
Virtual Link
Virtual link w/ remote Router ID and local Int IP

Router identifying itself, attached Links, and each Link's cost.

Type 2 - Network LSA

Designated Router announcing information about multi-access link w/ 2+ OSPF Routers

- DR interface IP
- DR Router ID
- Network Mask
- Router-ID of all attached Routers

Type 3 LSAs : Summary LSA (do not do summarization by default).

Configure R2 as an ABR,

use range to summarize

R2 area 0 range 10.1.0.0 255.255.0.0

area 1 range 10.0.0.0 255.255.0.0

verify: sh ip protocols

Number of areas in this router is 1.

Type 3 LSA summarize the Type 1 & Type 2 LSAs from foreign areas.

- Includes Net ID, & Mask and Cost for ABR to reach Target Network.
- ABRs generate a Type 3 LSA for each IP Network in a foreign Area.
- ABRs generate Type 3 LSAs in each direction, for each Area they border
- ABRs generate Type 3 LSAs from other Type 3 LSAs from foreign Areas.

Type 4 LSA : asbr-summary LSA Type 5 LSA : External LSA

Configure R6 as ASBR

Command to show whether R6 is ASBR or not :

sh ip protocols

sh ip route Connected

conf t

router ospf 110

redistribute connected

$2^7 = 8 \times 16 = 128$ bit

$196 + 32 = 228$. $192 + 32 = 224$

verify ASBR

sh ip protocols (It is an autonomous system boundary router)

sh ip ospf database router 6.6.6.6

AS Boundary Router

tell the router all the LSAs that it is originating into OSPF

sh ip ospf database self-originate

Type 4 : asbr-summary LSA

Area Border Routers advertising information about ASBRs in a foreign area.

- ASBR Router-ID
- ABR Router-ID
- Cost for ABR to reach ASBR

(still advertising even though no LSA 5 sent by ASBR)

Type 5 : External LSA

Autonomous System Border Router advertising external networks redistributed into OSPF domain.

- Network ID / Subnet Mask
- ASBR Router-ID
- Cost and Metric Type for ASBR to reach redistributed Network.

Adv router is ASBR & LSAs will be the same in other areas.

(Same sub-net)
Network Types

Full mesh: every router on this link can speak to every other router on this link.

Point to point : "Full Mesh" connectivity

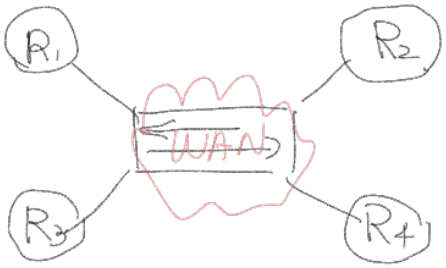
Serial link default point to point network type

If ethernet or fiber, we need to manually set it to be point-to-point

Broadcast

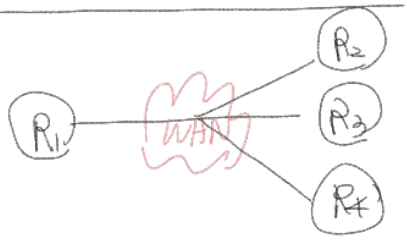
Full Mesh connectivity

ethernet link default to broadcast.



when broadcast or multicast not supported,
Non-broadcast multi-access (NBMA)

Point to multipoint



used in Hub and spoke type deployments.

Meaning: topology:
A router, the hub can see all the other routers (the spoke).
while all the other routers (the spoke) can only see the hub.

when broadcast or multicast
not supported,
point to Multipoint Non-broadcast

Network Type	P2P	Broadcast	NBMA	P2MP	P2MP-NB
Max Routers per Link	2	∞	∞	∞	∞
Full Mesh Connectivity Assumed	Yes	Yes	Yes	No	No
Designated Router / BDR Election	No	Yes	Yes	No	No
Hello / Dead Timer (Cisco default)	10/40	10/40	30/120	30/120	30/120
Automatic Neighbor Discovery	Yes	Yes	No	Yes	No
Discovery & periodic Hello sent to	224.0.0.5	224.0.0.5	manually. Neighbor IP	224.0.0.5	Neighbor IP.
continued neighbor communication to	224.0.0.5	unicast	unicast	unicast	unicast.
LSA(s) Sent to	224.0.0.5	Multicast DR / BDR	Unicast DR / BDR	unicast	Unicast
Next-Hop IP	peer	Orig. Rtr	Orig Rtr -	Hub	Hub

Normal area

- LSAs: 1, 2, 3, 4, 5

Stub area

- LSAs: 1, 2, 3 4, 5 → without
- Inject a default route via Type 3 By ABR.

Totally Stub area.

- LSAs: 1 2 3 4 5
- inject a default route via Type 3 by ABR
  only 1 type 3 ABR

Not so Stubby Area (NSSA)

- LSAs 1 2 3 4 5 7

Redistribution via Type 7

there is no default route, the admin should account for how do we want the routers in area 44 to deal with traffic going to subnets without a route

Totally not so stubby area.

- LSAs : 1 2 3 4 5 7
- Redistribution via type 7.
- Default Route via type 3.

area type

Hello packet flag:

E: External route (type 5) allowed

N: NSSA.

E=1 , N=0	Normal	
E=0 , N=0	Stub	
E=0 , N=1	NSSA	

Totally Stub Area

Totally Nbe So Stub Area

} additional options we can turn on on the ABR in front of a stub or NSSA

Stub Area

- On all routers in the Area
  - area <#> stub

---

sh run | s router

conf t

router ospf 110

area 0 stub — we cannot make backbone stub.

X

Additional ABR options : - No Type-3 LSAs from foreign area.

- area <#> stub no-summary. Totally stub.
- area <#> stub no-ext-capability

- No Opaque LSAs

Not So Stubby Area (NSSA)

- On all routers In the Area:
  - area <#> nssa
- Additional ABR opeions:
  - ... default-information-originate — Inject Default Route via Type 7 LSA by ABR
  - ... no-summary — Inject Default Type 3, No other Type 3: (totally NSSA)
  - ... no-ext-capability — No opaque LSAs (9,10,11)
  - ... no-redistribution — No redistribution from ABR into NSSA. (when ABR is also a ASBR)

Type 7 LSA only exisn in a NSSA,
In Routing Table, routing type is ON2/N1
In other areas, it becomes LSA 5 and the adv router change to ABR w/out LSA4.

O	Intra Area	Subnets in local area	Type 1 & 2 LSAs
O IA	Inter Area	Subnets in foreign areas	Type 3 LSAs
O E2/E1	External OSPF	Subnets redistributed into	Type 5
O N2/N1	External NSSA.	Subnets redistributed into NSSA	Type 7.

- Passive Interface – disable sending Hello Packets
- Continue to allow IP subnet advertisement
- configuration:

```
R1(config)# router ospf 110
            router-id 1.1.1.1
            passive-interface Ethernet0/0
            passive-interface Ethernet0/1
```

Command to verify passive interface:

sh ip protocols

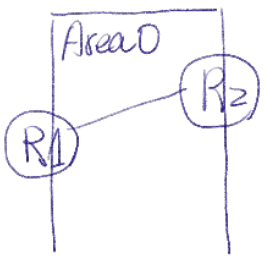
sh ip ospf interface

passive interface default:

We can set all interfaces as passive interface.

- Selectively disable passive interface on specific interfaces

```
router ospf 110
 router-id 1.1.1.1
passive-interface default
no passive-interface Ethernet0/0
no passive-interface Ethernet0/1
```


Area 0
R2
R1