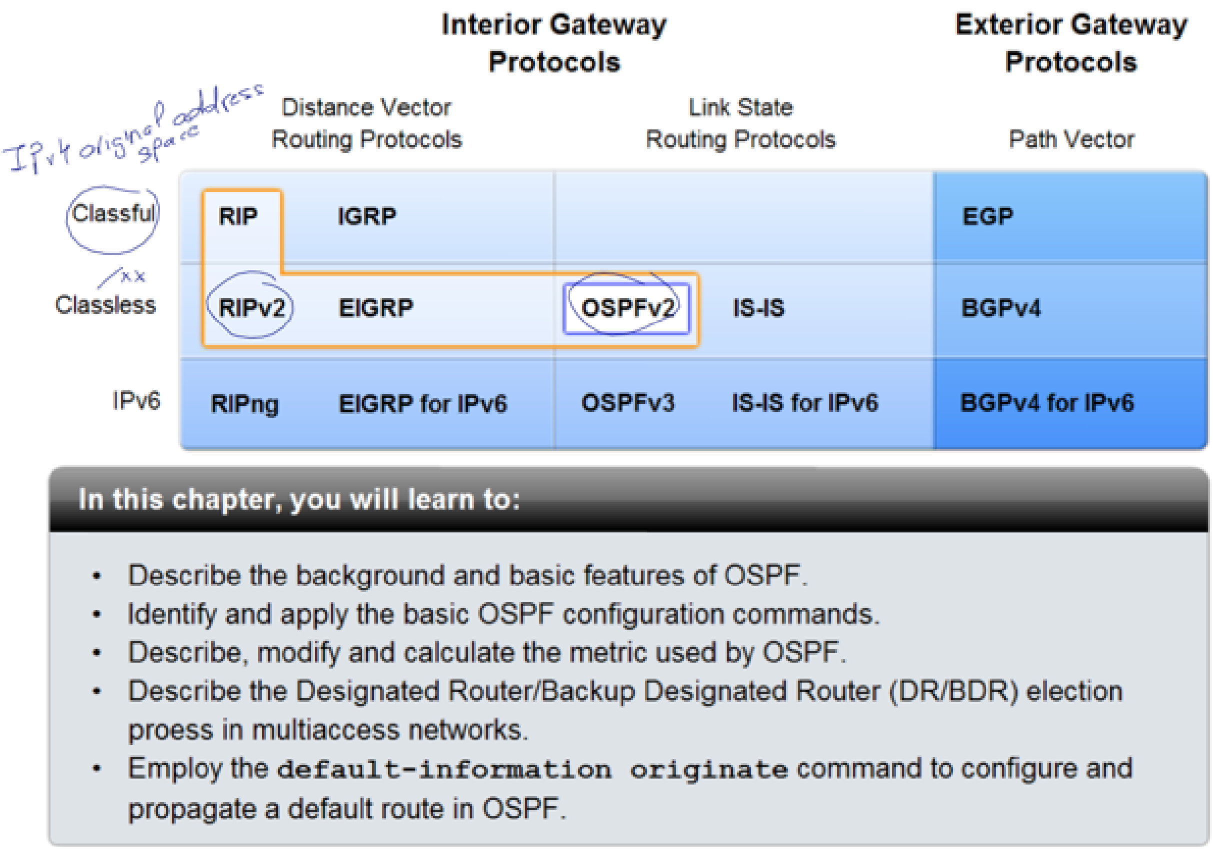
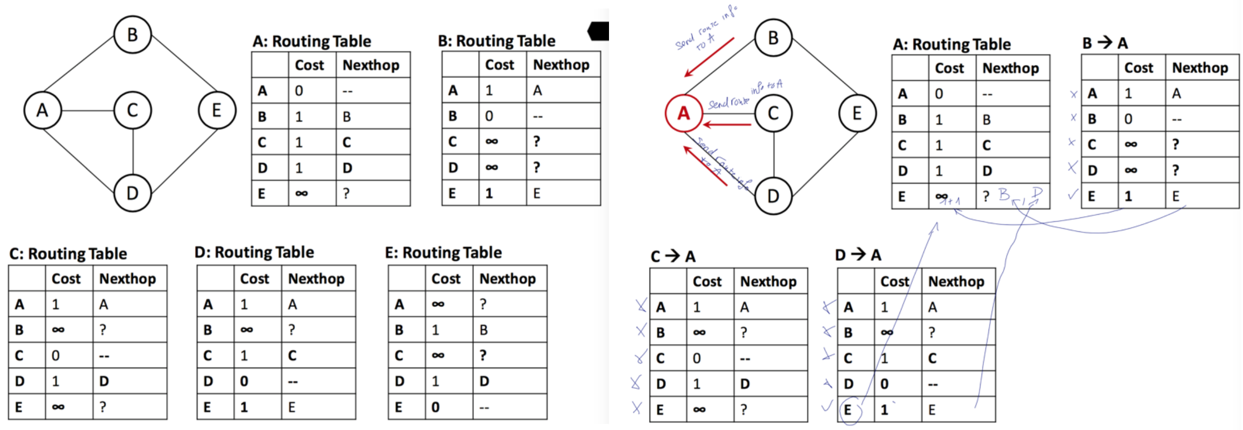
Chapter 06 - Routing Protocol: RIP (v1, v2) and OSPF

There are several routing protocols. This diagram classifies them into different categories, i.e. Interior Gateway Protocol, Exterior Gateway Protocol, Distance Vector Routing, or Link State Routing, etc.



Distance Vector Routing

Example:



A: Routing Table

	Cost	Nexthop
A	0	--
B	1	B
C	1	C
D	1	D
E	∞	?

B: Routing Table

	Cost	Nexthop
A	1	A
B	0	--
C	∞	?
D	∞	?
E	1	E

C: Routing Table

	Cost	Nexthop
A	1	A
B	∞	?
C	0	--
D	1	D
E	∞	?

D: Routing Table

	Cost	Nexthop
A	1	A
B	∞	?
C	1	C
D	0	--
E	1	E

E: Routing Table

	Cost	Nexthop
A	∞	?
B	1	B
C	∞	?
D	1	D
E	0	--

A: Routing Table

	Cost	Nexthop
A	0	--
B	1	B
C	1	C
D	1	D
E	∞	?

B → A

	Cost	Nexthop
A	1	A
B	0	--
C	∞	?
D	∞	?
E	1	E

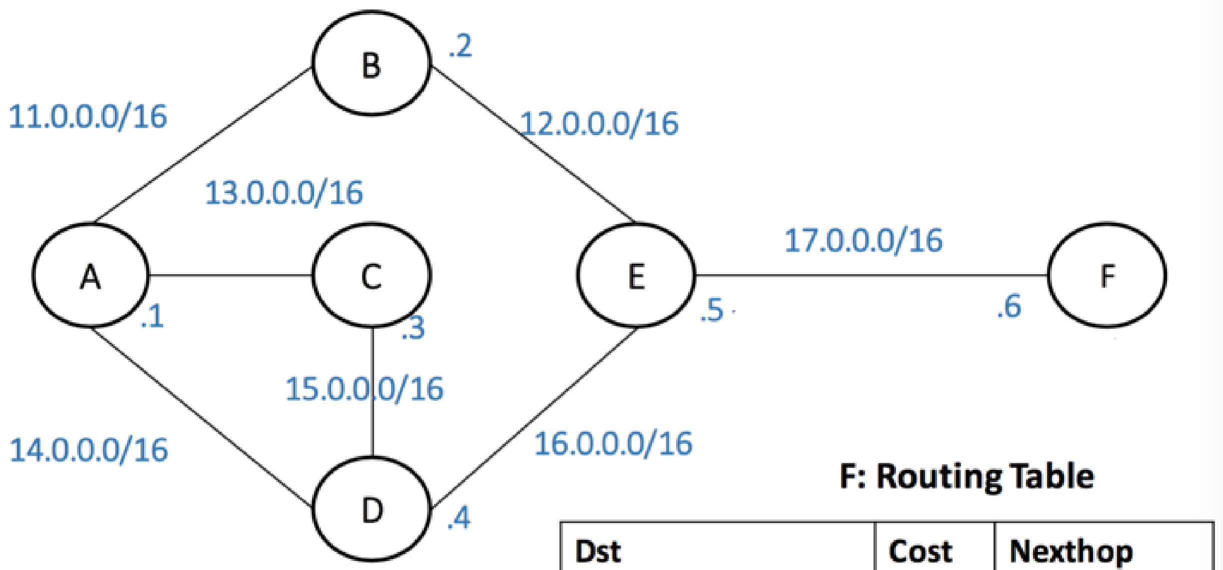
C → A

	Cost	Nexthop
A	1	A
B	∞	?
C	0	--
D	1	D
E	∞	?

D → A

	Cost	Nexthop
A	1	A
B	∞	?
C	1	C
D	0	--
E	1	E

Apply to networking:



F: Routing Table

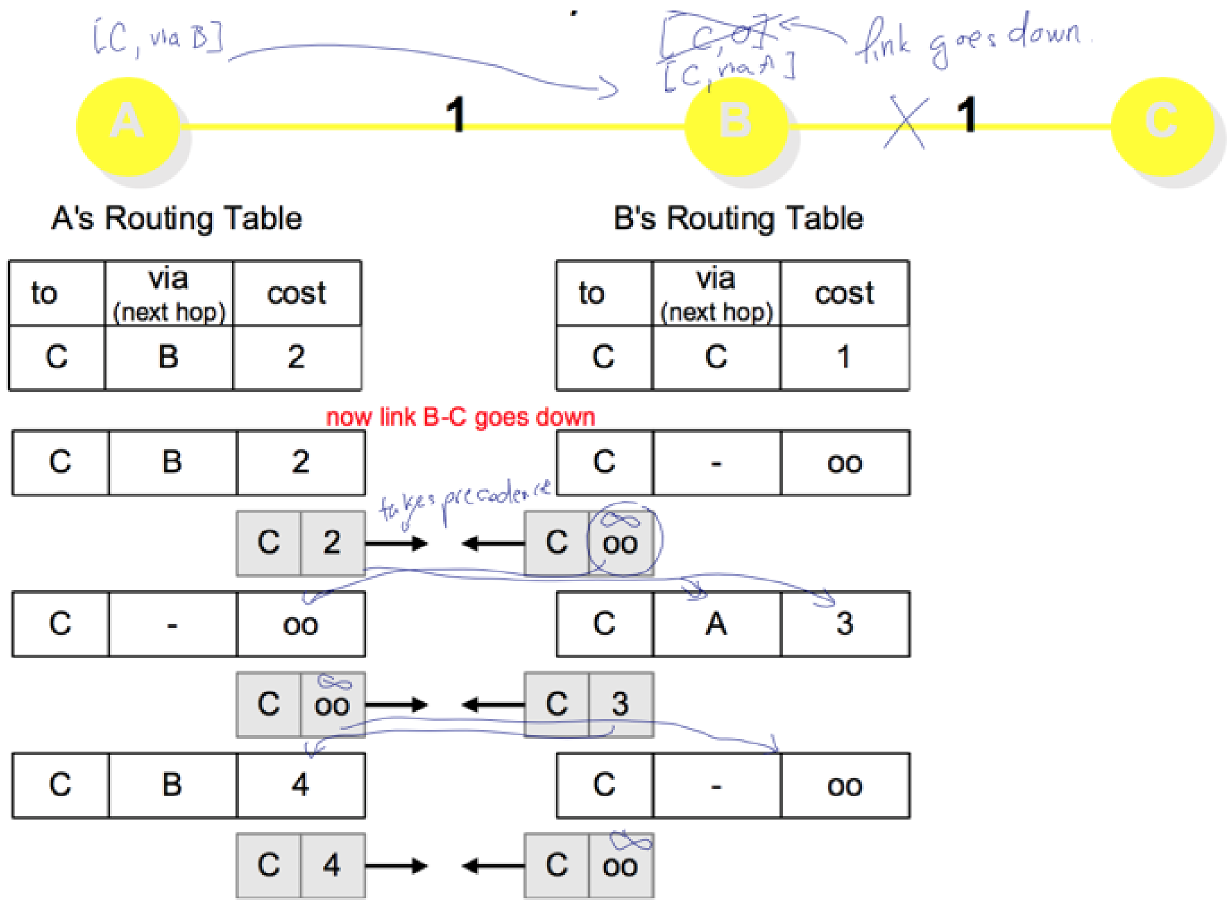
Dst	Cost	Nexthop
11.0.0.0/16	3	17.0.0.5
12.0.0.0/16	2	17.0.0.5
13.0.0.0/16	3	17.0.0.5
14.0.0.0/16	3	17.0.0.5
15.0.0.0/16	3	17.0.0.5
16.0.0.0/16	2	17.0.0.5
17.0.0.0/16	1	connected

Characteristics

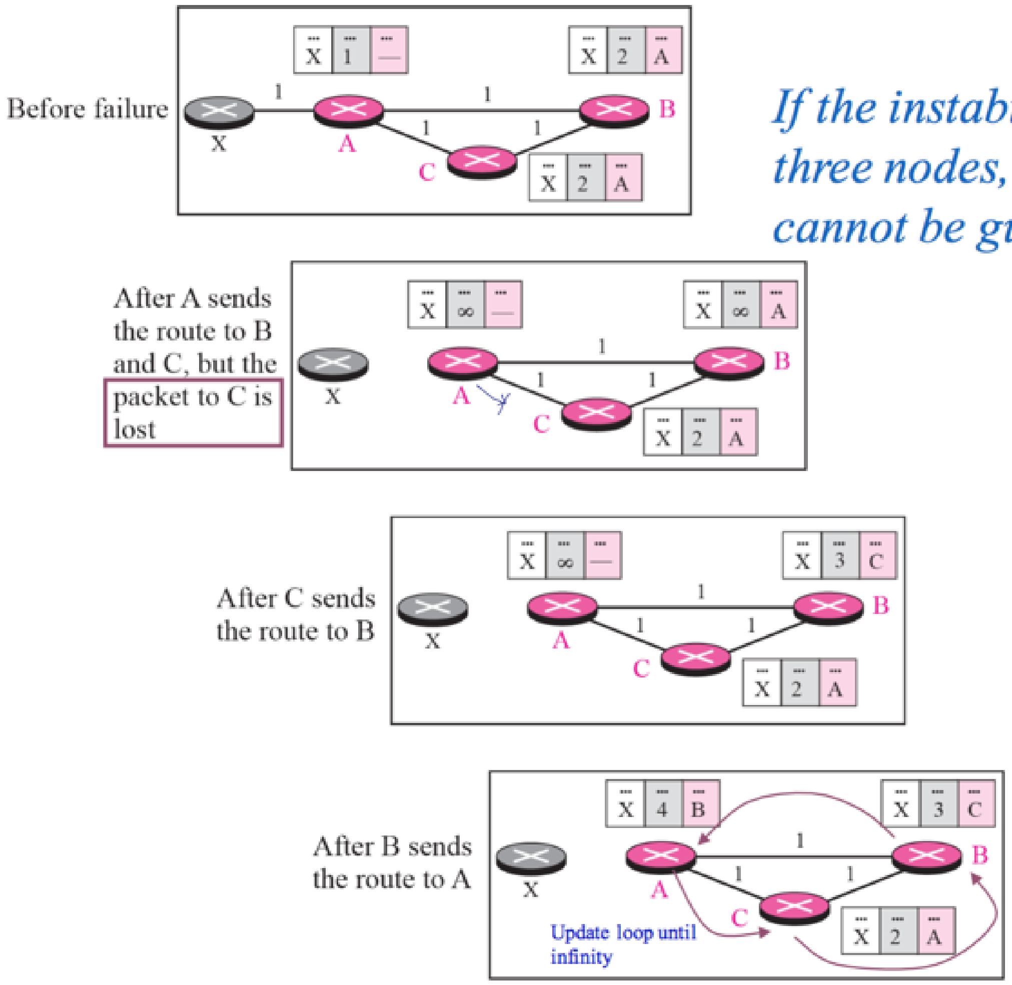
- **Periodic Updates**: updates sent after certain time period
- **Triggered Updates**: router sends updates immediately if there is a change on a link
- **Full Routing Table Update**: the entire routing table is sent in distance vector routing protocol.
- **Route Invalidation Timers**: each entry in routing table will be invalidated after certain time with no update (~3–6 update period)

Problems: Count-to-Infinity

- Problem Description:



  - **Solutions:**
    - **Split Horizon**: never advertise the cost to a neighbor <u>if that neighbor is the next hop on that path</u>.
      - <u>Drawback</u>: the neighbor might delete current node from their neighbor list if does not hear an update in near future.
    - thus we added 2nd solution in combination: **Poison Reverse**: still advertise to “that neighbor”, but replace the distance with infinity as a warning.
  - However, instability will occur if there are 3 nodes in the chains, so **Split Horizon + Poison Reverse won’t solve the problem completely**.



If the instability is btw three nodes, stability cannot be guaranteed

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RIP - Routing Information Protocol

Features

- a simple **intra-domain** protocol.
- implements **Distance Vector Routing**.
- **periodic update** is set to **30 seconds**.
- always **use 1 as link metric**.
- **max hop count is 15** (thus 16 is considered ∞)
- Send out **routing table**.

RIP Packet Format - MAC Frame Structure

MAC Hdr	IP Hdr	UDP Hdr	RIP Hdr	RIP type-specific Data

- RIP uses UDP
- **Mac Header**
  - **Src**: MAC of sending interface
  - **Dest**:
    - in IPv4, **0100:5E00:0009** - every time the switch sees a frame with 0100:5e00:0009 it will add the source interface to one multicast group because sure the source is a RIPv2 router, and it will froward frames with this address to members of this group.
    - in IPv6, **3333:0000:0009** (not sure why?)
  - **Type**:
    - in IPv4, **0x0800** - means the frame contains a IPv4 packet
    - in IPv6, **0x86DD** - means the frame contains a IPv6 packet
  - UDP Header:
    - in IPv4, **port 520**, and in IPv6, **port 521**

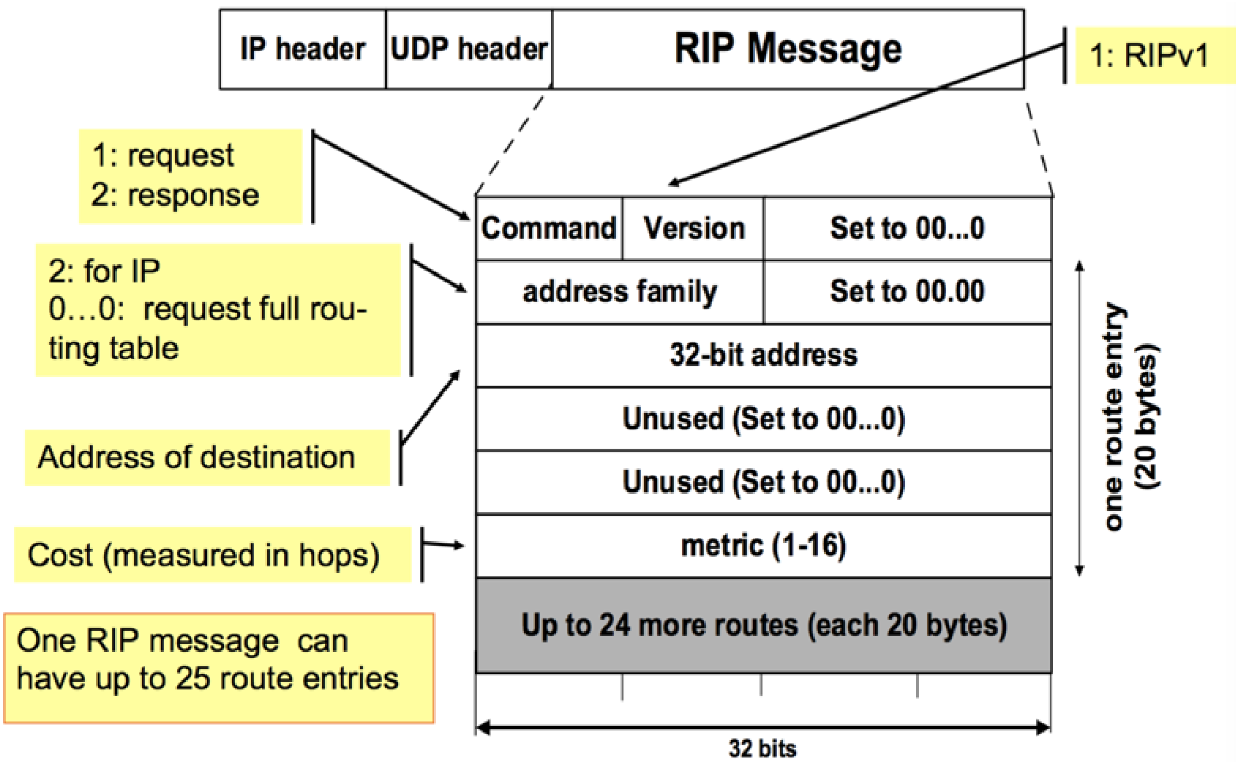
RIP Packet Format - RIP Content

There are 2 types of messages:

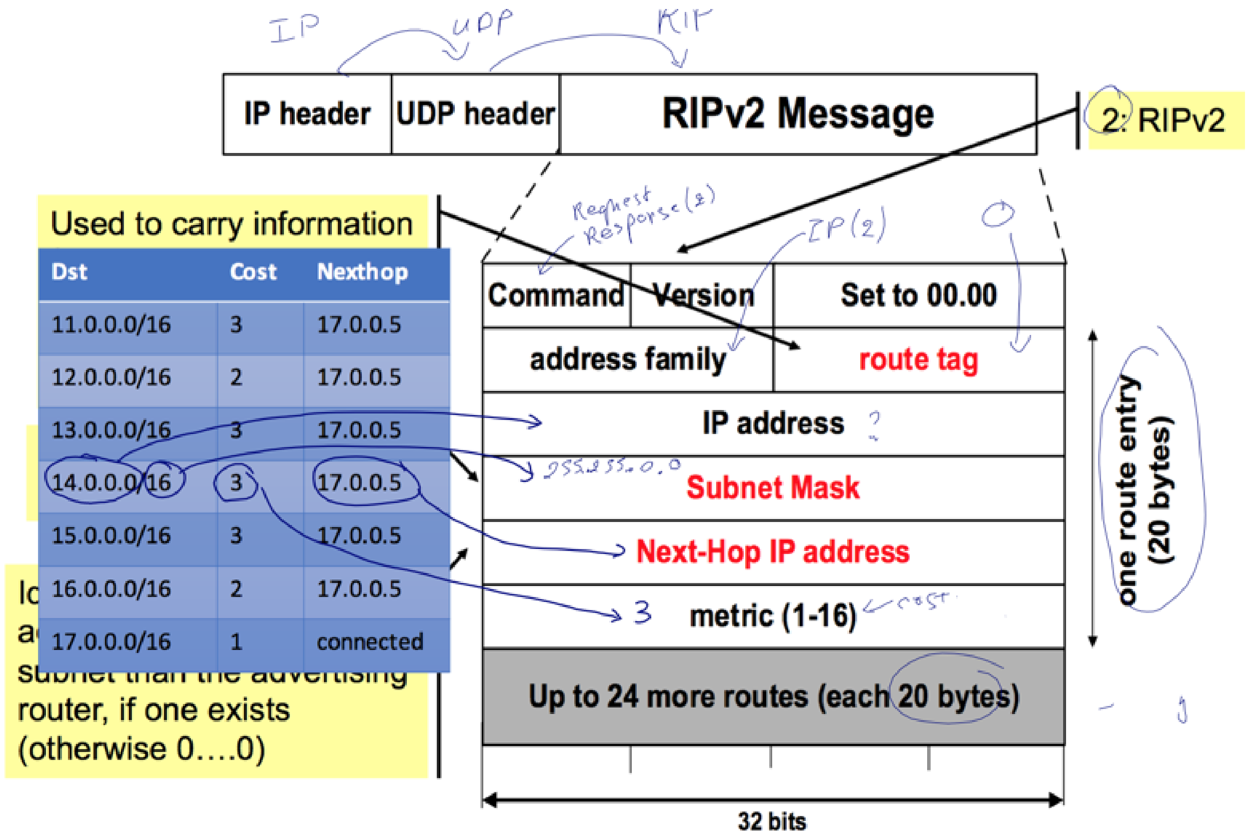
- **Request Message**: to ask for an update from neighbors.
- **Response Message**: to respond with an update.

RIPv1 Packet Format

(not to study)



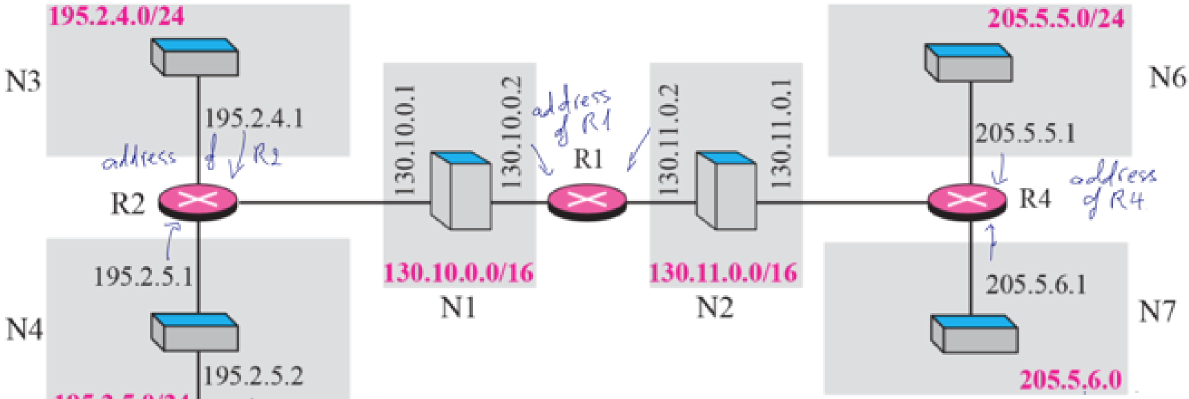
RIPv2 Packet Format

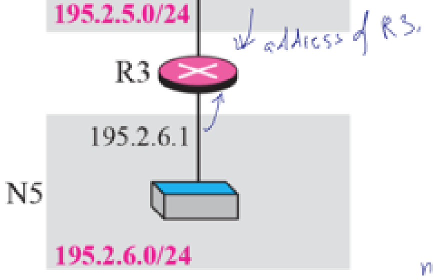


Differences of RIPv2 from RIPv1:

- v2 uses IP **Multicast** instead of Broadcast in v1, thus v2 Packet has **subnet masks**
- provides **authentication** of routing messages
- carries **next-hop address** in route information

Example





Dest.	Cost	Next
130.10.0.0/16	1	———
130.11.0.0/16	1	———
195.2.4.0/24	2	130.10.0.1
195.2.5.0/24	2	130.10.0.1
195.2.6.0/24	3	130.10.0.1
205.5.5.0/24	2	130.11.0.1
205.5.6.0/24	2	130.11.0.1

R1 Table

Legend

- Ethernet switch
- R Router
- N Network

not .1

Dest.	Cost	Next
130.10.0.0/16	1	———
130.11.0.0/16	2	130.10.0.2
195.2.4.0/24	1	———
195.2.5.0/24	1	———
195.2.6.0/24	2	195.2.5.2
205.5.5.0/24	3	130.10.0.2
205.5.6.0/24	3	130.10.0.2

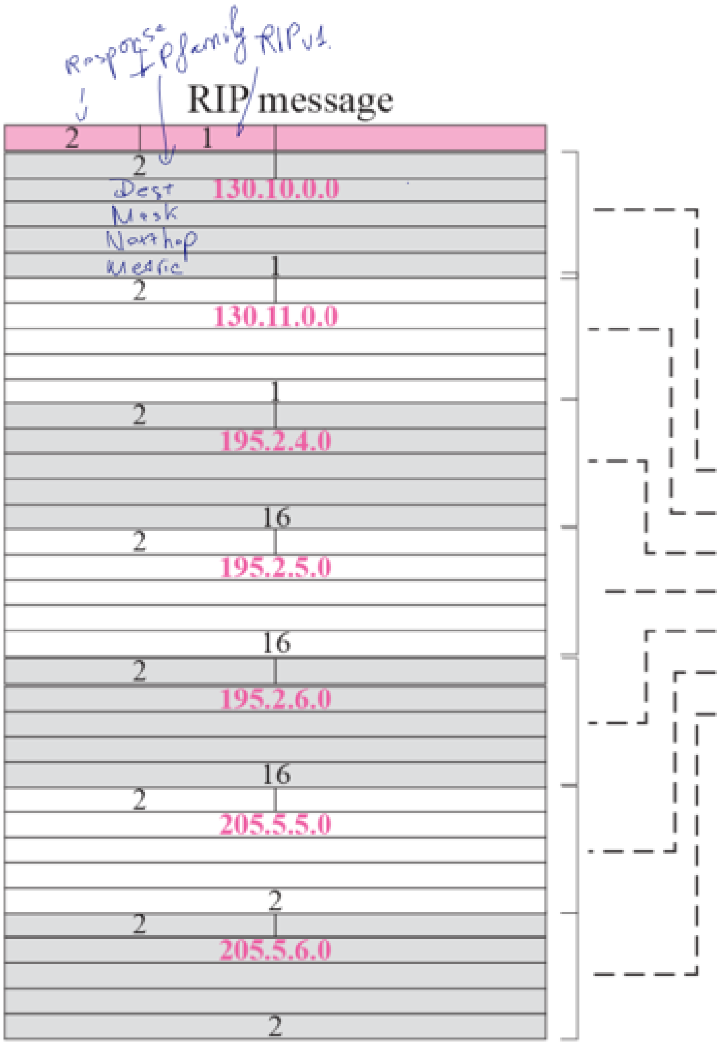
R2 Table

Dest.	Cost	Next
130.10.0.0/16	2	195.2.5.1
130.11.0.0/16	3	195.2.5.1
195.2.4.0/24	2	195.2.5.1
195.2.5.0/24	1	———
195.2.6.0/24	1	———
205.5.5.0/24	4	195.2.5.1
205.5.6.0/24	4	195.2.5.1

R3 Table

Dest.	Cost	Next
130.10.0.0/16	2	130.11.0.2
130.11.0.0/16	1	———
195.2.4.0/24	3	130.11.0.2
195.2.5.0/24	3	130.11.0.2
195.2.6.0/24	4	130.11.0.2
205.5.5.0/24	1	———
205.5.6.0/24	1	———

R4 Table



Dest.	Cost
130.10.0.0	1
130.11.0.0	1
195.2.4.0	16
195.2.5.0	16
195.2.6.0	16
205.5.5.0	2
205.5.6.0	2

Information extracted from message

RIP - Routing Process

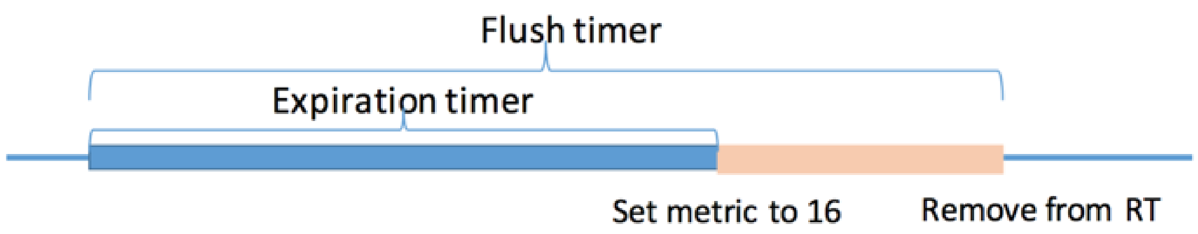
1. **Initialize**: send a request packet to all neighbors requesting routing tables
    a. Command = 1, address family = 0...0
    b. RIPv1: broadcast 255.255.255.255
    c. RIPv2: multicast 224.0.0.9
2. **Receive request**: neighbors receive request and respond with entire routing table
3. **Receive response**: update own routing table base on neighbors routing table

Besides, it also does:

- **Regular Routing Updates**: every 30 secs
- **Triggered Updates**: immediate when a link is changed

RIP Timers

- Periodic Update: 30 secs
- Expiration Timer: 180 secs
- Garbage Collection (Flush Timer): 240 secs
- Holddown Timer: 180 secs



RIP Security

- Only **RIPv2** uses **simple authentication** scheme (password)

Issues with RIP

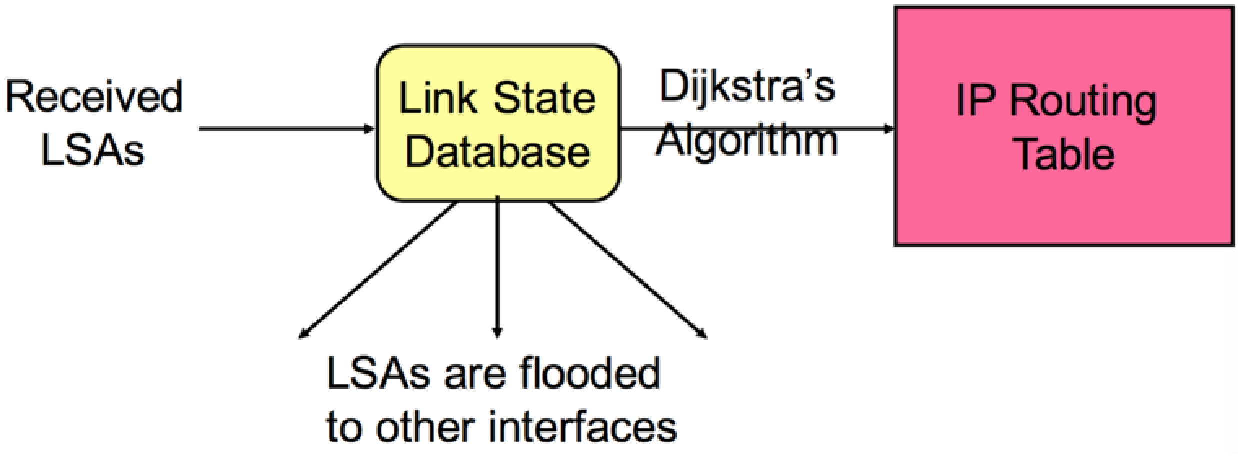
- long time to stabilize
- count-to-infinity (problem of distance vector algo)
- max path is 15 hops

Link State Routing

Principles

- Establishes a relation with the neighbors (**adjacency**)
- Generates LSAs (Link State Advertisements = link id, state of link, cost, neighbors of link) and sends to all routers.

- The receiver router maintains a database of all LSAs - called **Topological Database** or **Link State Database** - and apply Dijkstra's algorithm to produce shortest path for all routings.
- Each node has a map that describes the routing to all other nodes.



OSPF

History

- OSPFv1 (1989) - never deployed.
- OSPFv2 (1991) - classless by design.
- OSPFv3 (1999) - supports IPv6

Features

- Classless
- Efficient (no periodic updates), use SPF algorithm to choose best path
- Fast convergence
- Scalable - hierarchical
- Secure - support MD5 auth
- Send out **network topology**.

Terminology

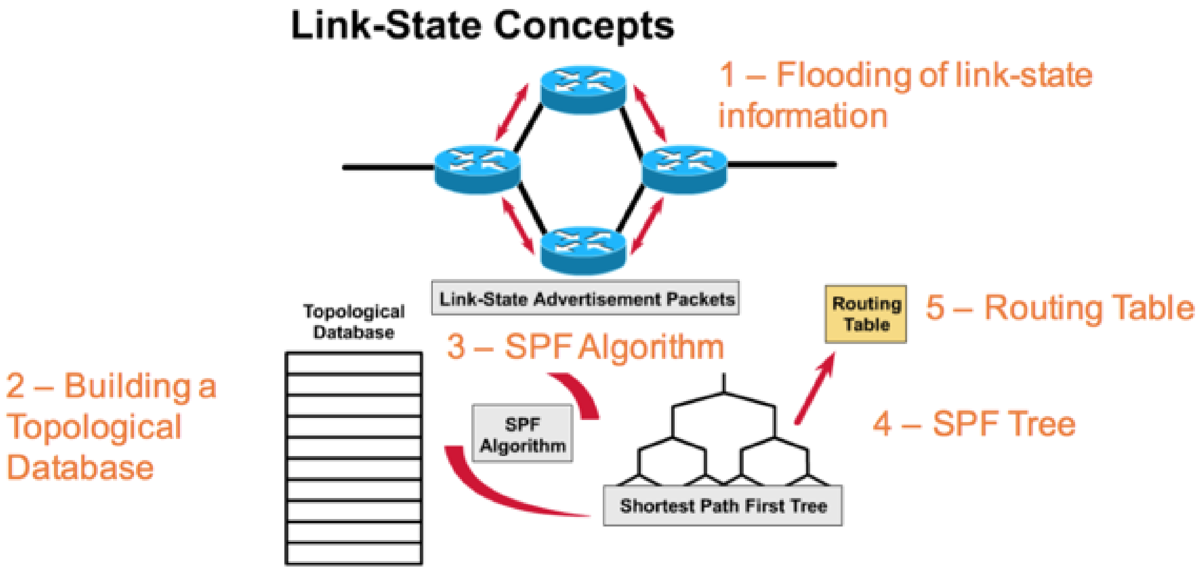
- **Link**: interface on router
- **Link State**: description of an interface and its relationship to the neighboring routers, includes:
    - routers it connect to
        - Router ID: ip address configured with OSPF Router ID. IP address can be:
            - highest loopback address (configuration coming): never going down
            - highest active ip address (any ip)
    - IP address & mask of the interface
    - type of network

- metric of the link
- Autonomous System (or OSPF Routing Domain): includes several OSPF areas
- Single Area OSPF uses only one area, usually Area 0

Link State & SPF Algorithm

This is the high level process of a router communicating and building its network topology and routing table.

1. **Flooding of link-state information**: announces its link state info to other routers on the network.
2. **Building Topological Database**: collects the link state info from other routers and put into a database.
3. Uses Dijkstra's algorithm to **build the Shortest Path First (SPF)** representing the topology graph of the network.
4. Based on the algorithm and topology, it **creates an SPF tree**, with itself as the root and shortest path to each other nodes
5. Using the tree, the router **creates the routing table**.



Example: router A has this topological database from other routers' link states

RouterB:

- Connected to RouterA on network 11.0.0.0/8, cost of 15
- Connected to RouterE on network 15.0.0.0/8, cost of 2
- Has a "leaf" network 14.0.0.0/8, cost of 15

RouterC:

- Connected to RouterA on network 12.0.0.0/8, cost of 2
- Connected to RouterD on network 16.0.0.0/8, cost of 2
- Has a "leaf" network 17.0.0.0/8, cost of 2

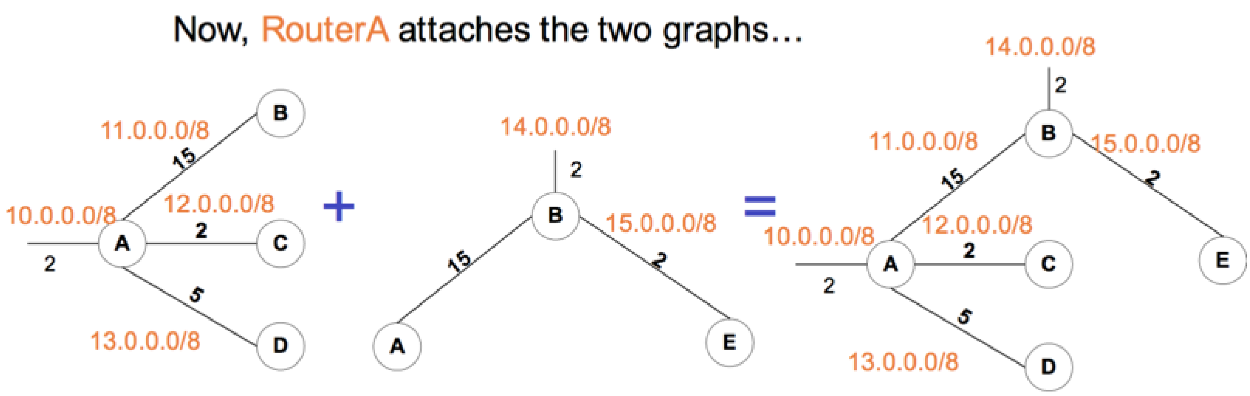
RouterD:

- Connected to RouterA on network 13.0.0.0/8, cost of 5
- Connected to RouterC on network 16.0.0.0/8, cost of 2
- Connected to RouterE on network 18.0.0.0/8, cost of 2
- Has a "leaf" network 19.0.0.0/8, cost of 2

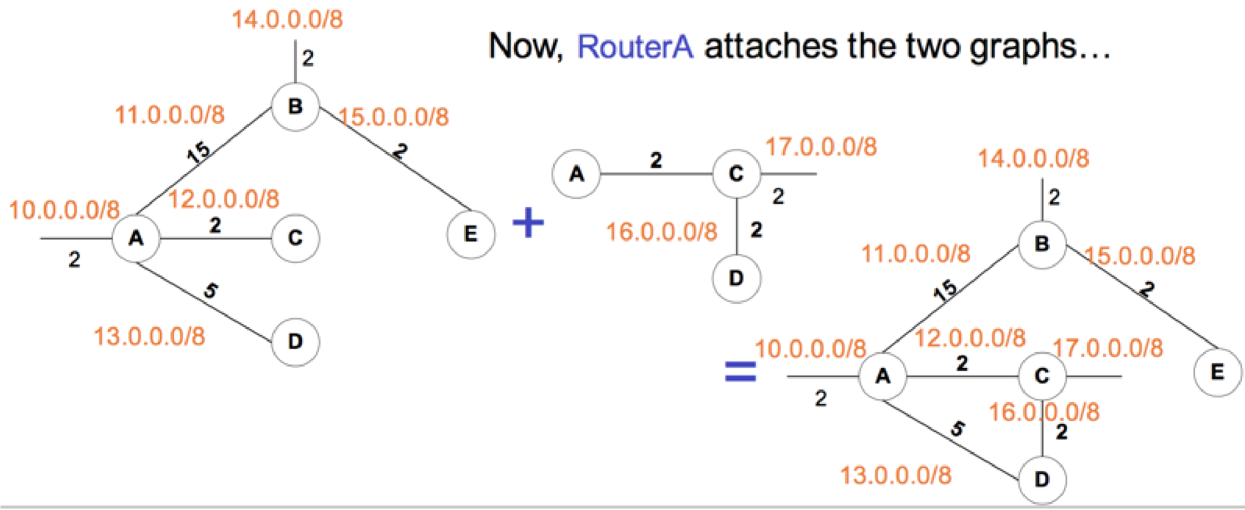
RouterE:

- Connected to RouterB on network 15.0.0.0/8, cost of 2
- Connected to RouterD on network 18.0.0.0/8, cost of 10
- Has a "leaf" network 20.0.0.0/8, cost of 2

- when it merges with B's link states



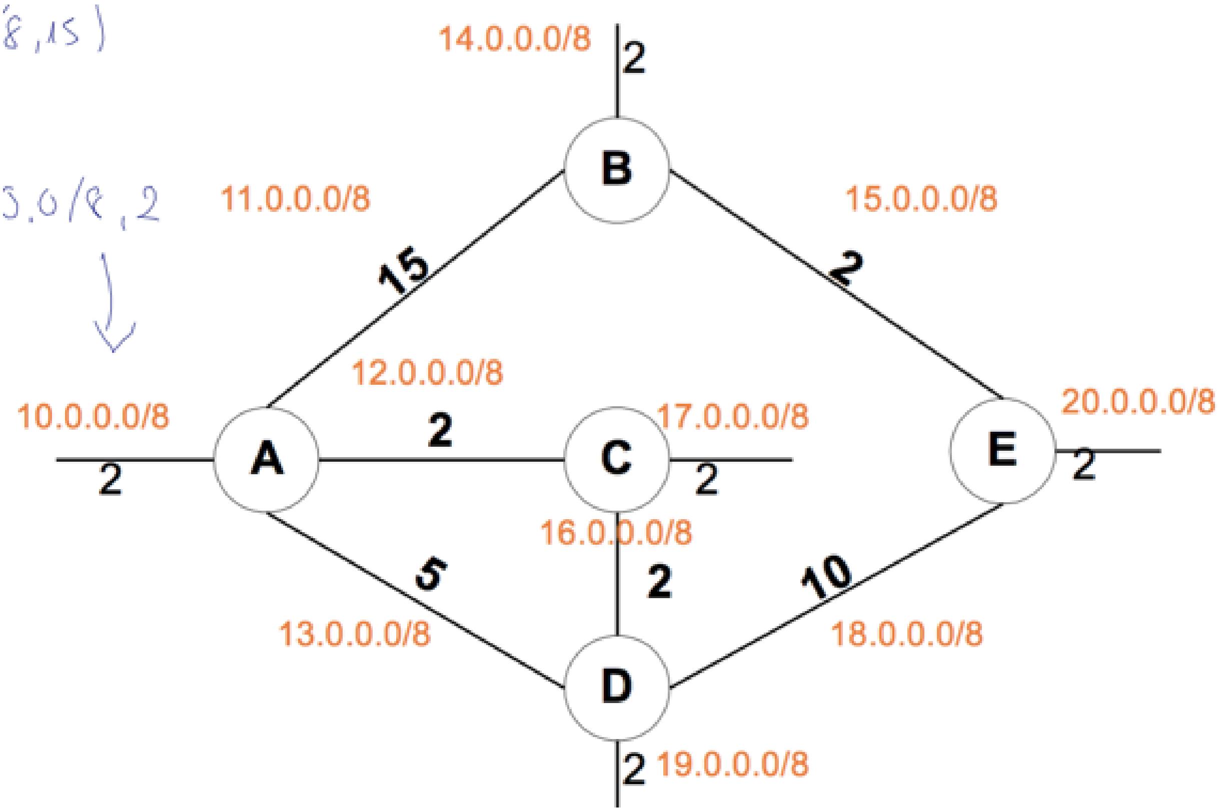
- Merges with C's



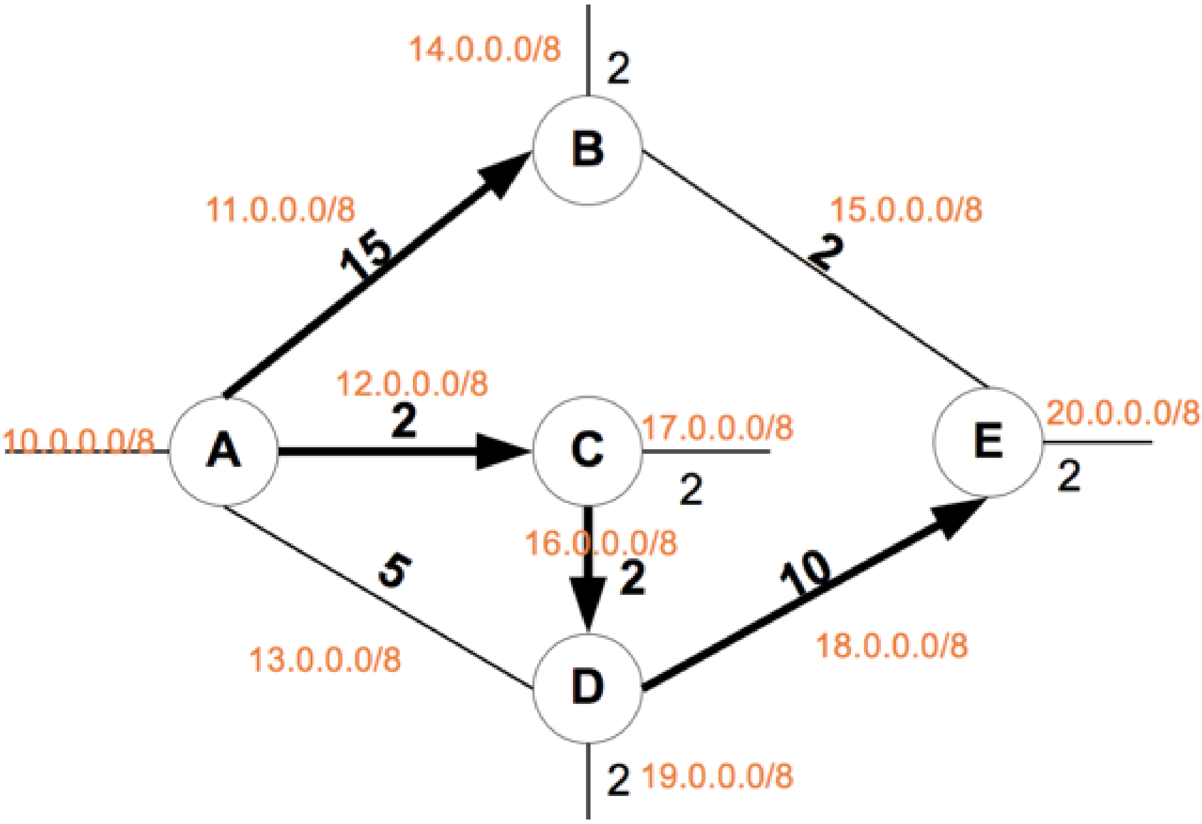
- etc., final result:

(8,15)

5.0/8, 2



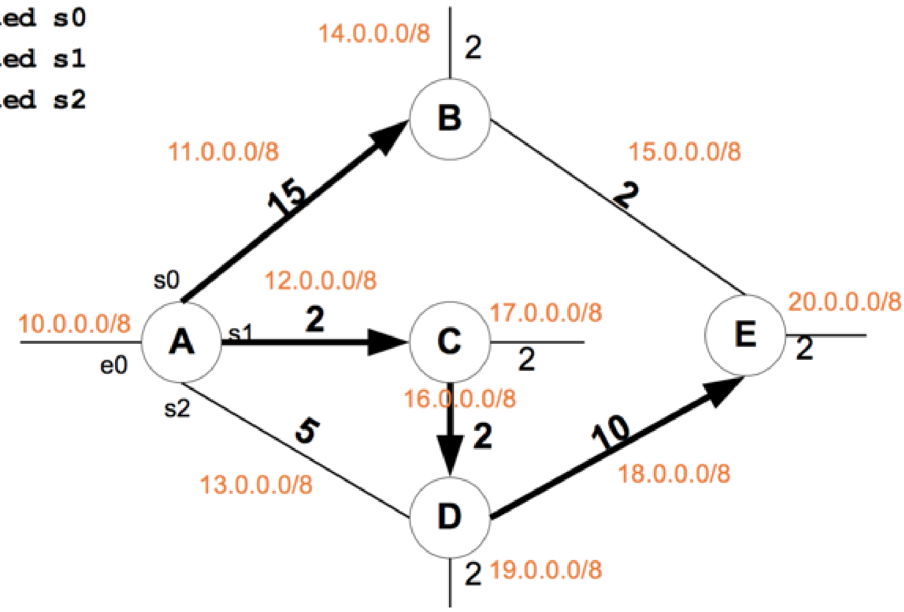
- Choosing best path i.e. Shortest Path Tree (SPT)



- and build the routing table

RouterA's Routing Table

10.0.0.0/8	connected	e0
11.0.0.0/8	connected	s0
12.0.0.0/8	connected	s1
13.0.0.0/8	connected	s2
14.0.0.0/8	17	s0
15.0.0.0/8	17	s1
16.0.0.0/8	4	s1
17.0.0.0/8	4	s1
18.0.0.0/8	14	s1
19.0.0.0/8	6	s1
20.0.0.0/8	16	s1



OSPF's Metric

- is mainly defined by Cost
- in Cisco terms: Cost ~ Bandwidth, Cost = 10^8 / BW, thus the lower the cost the better
  - 10^8 is the **reference bandwidth.**
- Cost of a route: is the cumulative costs of the outgoing interfaces from this router to the network.

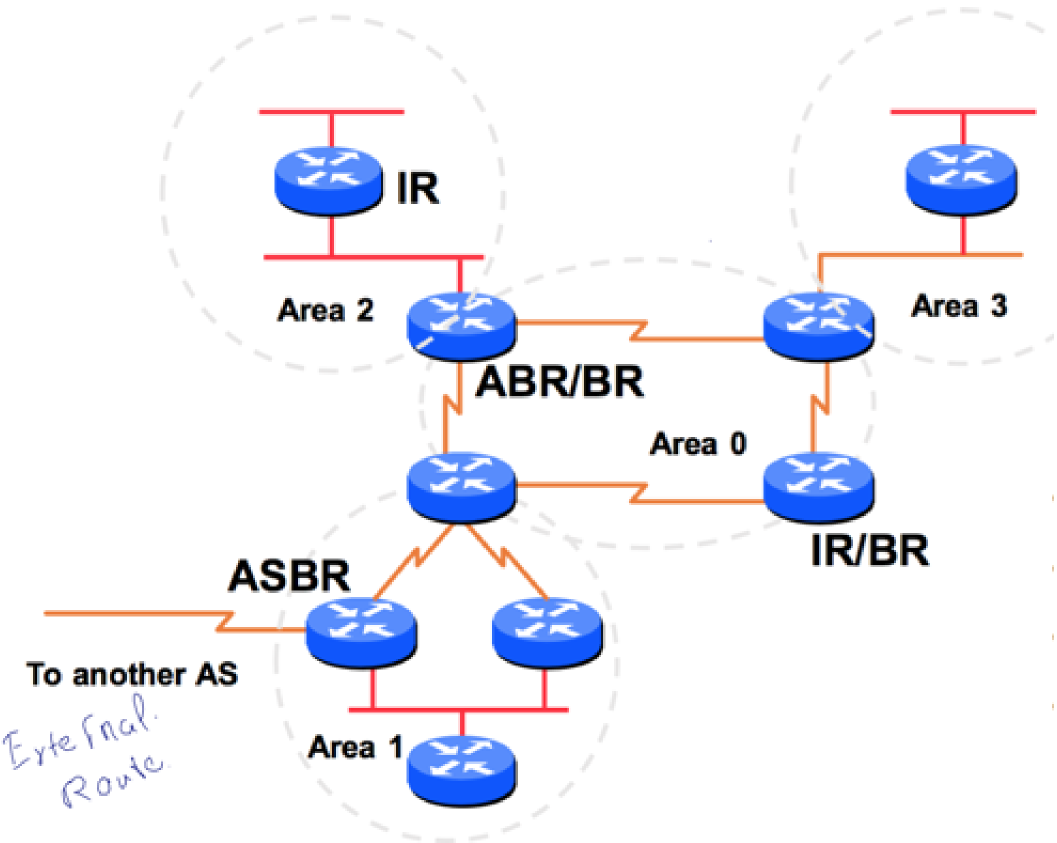
OSPF Areas

- OSPF Areas is a group of contiguous nodes or networks
- Backbone Area (Area 0) is contiguous, i.e. all other areas must connect to the backbone.
- A router has separate database for each area it belongs
- Routers in same area share an identical database
- each area uses separate SPF calculation
- LSA flooding is limited to its particular area

Router Classification

4 types of router, these types are not exclusive (i.e. a router can be up to 3 types at the same time)

- **IR** - Internal Router: a router that has **all of its interfaces within the same area**
- **BR** - Backbone Router: has **at least 1 OSPF interface connecting to Backbone Area** (Area 0)
- **ABR** - Area Border Router: has **at least 1 OSPF interface connecting to Backbone Area** (Area 0) and **at least 1 OSPF interface connect to a non-Backbone area**
- **ASBR** - Autonomous System Border Route: an OSPF router that performs **route injection (redistribution)** from another route source (RIP, EIGRP, IS-IS, BGP, etc)



OSPF Route Types

3 types:

- Intra-area Route: routes within an area
- Inter-area Route: routes announced from area to another via ABR
- External Router: routes imported into OSPF from outside.

OSPF Packet Format

MAC Hdr	IP Hdr	OSPF Hdr	OSPF type-specific Data

89 means next is OSPF

- MAC Header
  - Src – MAC addr of sending interface
  - Dst – 0100:5E00:0005 or 0100:5E00:0006
  - Type – 0x0800

multicast IP → multicast MAC addr

lower 23 bits

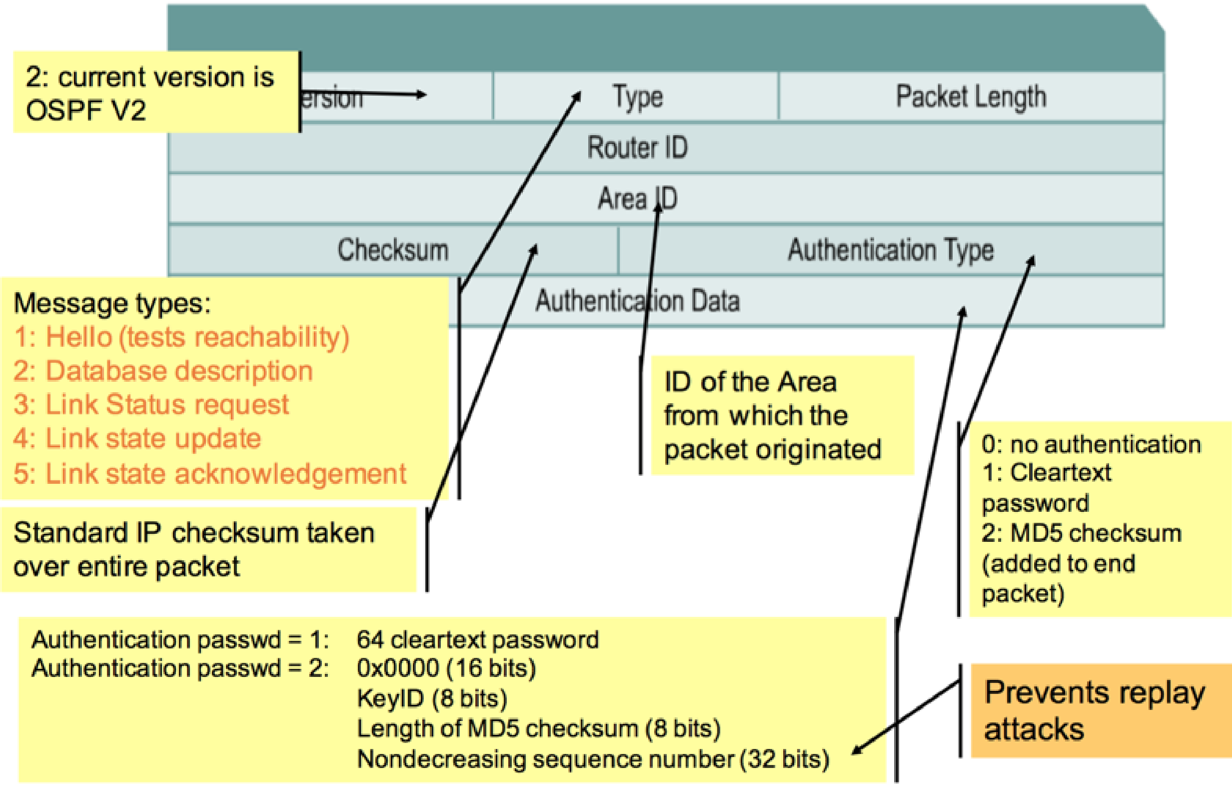
can guess this belongs to OSPF

- IP Header
  - Src – IP addr of sending interface
  - Dst – 224.0.0.5 or 224.0.0.6 ← OSPF designated router
  - Protocol – 89

OSPF router

OSPF protocol no

- OSPF Header
  - Version
  - Type
  - Router ID
  - Area ID



OSPF Packet Types

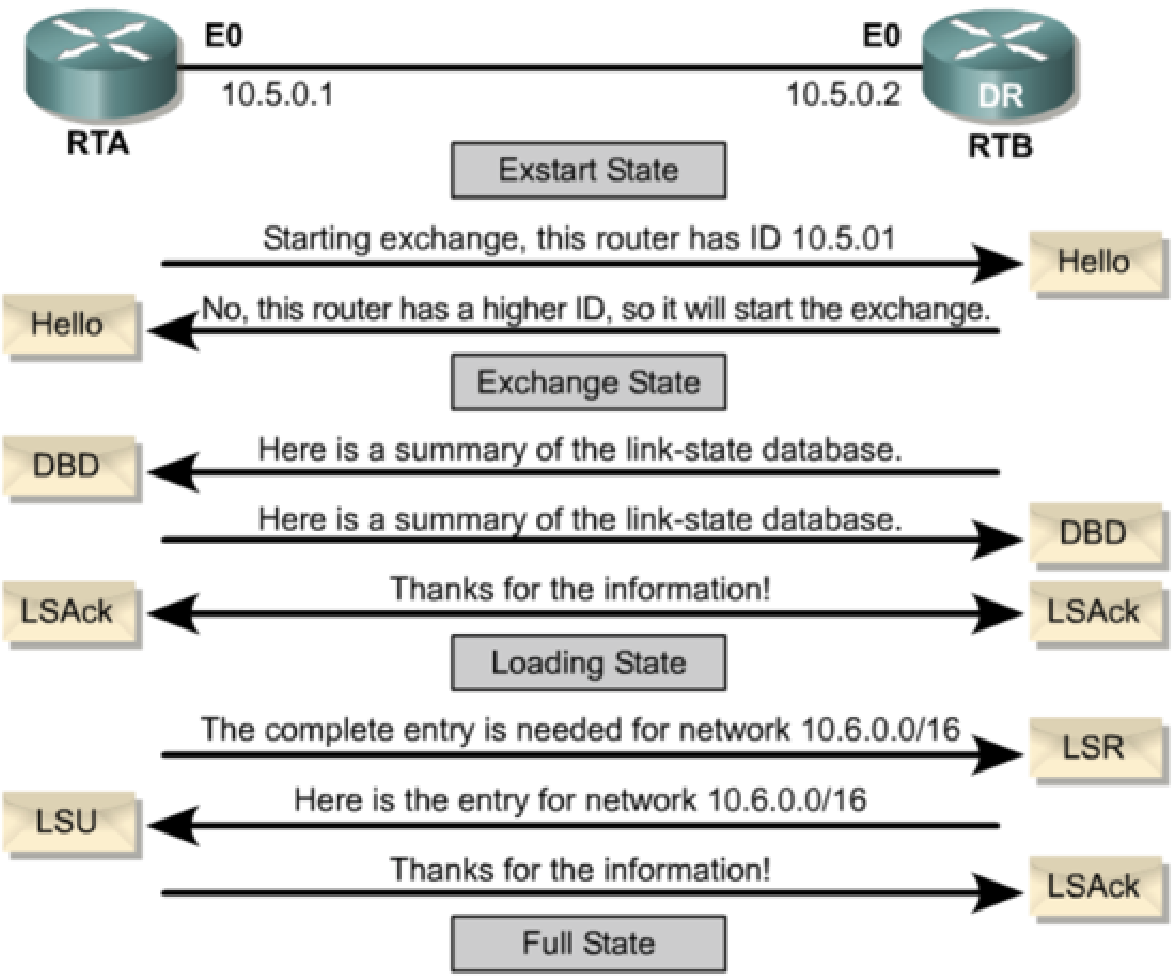
Type	Description
1	Hello (establishes and maintains adjacency relationships with neighbors)
2	Database description packet (describes the contents of an OSPF router's link-state database) OSPF Type-2 (DBD)
3	Link-state request (requests specific pieces of a neighbor router's link-state database) OSPF Type-3 (LSR)
4	Link-state update (transports link-state advertisements (LSAs) to neighbor routers) OSPF Type-4 (LSU)
5	Link-state acknowledgement (Neighbor routers acknowledge receipt of the LSAs) OSPF Type-5 (LSAck)

OSPF Operations

The OSPF Operation involves 3 steps.

1. <u>Step 1</u>**:** **Establishing Adjacencies**
    - In this step, each router moves from
        - "**Down State**": continues multicasting the **OSPF Hello type 1 packets (224.0.0.5**, to all SPF Routers) to **advertising its own Router ID.** Router ID can be **highest loopback address** or else **highest active IP address.**
        - "**Init State**" (receives first Hello packet) and
        - reach "**Two-way State**" (i.e. knowing each other's ID) aka **adjacencies**. Note: states between 2 adjacent routers may be different as they transition, thus adjacencies is **asymmetric**.
    - "full adjacency": is when the router moves from 2-way state to full-state to exchange data (not yet in this state).
2. <u>Step 2</u>: **Electing DR and BDR** - Multi-access (broadcast) segments only
    - there are 2 possibilities depending on the link type
        - **Point-to-point** link: 2 routers enter **ExStart state**. (exchange start)
        - **Multi-access** link: the RTB (real-time bidding?) enters an election process to see who it will establish a full adjacency with.
    - a DR (Designated Router, central node to collect and supply routing information) and BDR (Backup Designated Router, back ups the DR, only listen) will be elected.
        - without DR, the flooding on the network will be chaotic.
        - highest Router ID wins the election for DR, next is BDR.
            - all routers send **OSPF LSA packets** to only DR and BDR: 224.0.0.6 - all DR routers
            - DR sends **OSPF LSA packets** to all neighbor routers: 224.0.0.5 - all other routers
        - Note: a new router entering the network with higher priority **will NOT become DR or BDR** until DR fails (and BDR takes over) then BDR position will be re-elected.
    - <u>**Step 3**</u>**: Discovering Routes**

- **ExStart State**
  - starts by exchanging **OSPF Type-2 DBD packets** (Database Description)
    - Router with higher router ID (literally) become master in the master/slave exchange relationship.
  - Routers compare these DBDs with its own database
  - if the LSA is not in its LSDB (or more recent version), then the router adds it to the **Link State Request list**.
- **Exchange State**
  - if router has entries in Link State Request list (i.e. need info), it enters **loading state,** otherwise it enters **full state**.
  - the other router replies to the LSR by a LSU (Link State Update) packet.



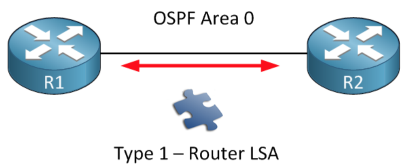
OSPF LSA Types

LSA Type	Common Name	Originated by	Advertised to	Carry
LSA-1	Router-LSA	Every router	all routers within the originated	all local routes

			area	
LSA-2	Network-LSA	DR	all routers within the originated area	all routes
LSA-3	Summary-LSA	ABR (Area Border Router)	all routers in a single area	**summary routes** (i.e. all detailed routes will be trimmed off) of other areas (networks)
LSA-4	ASBR Summary-LSA	ABR	all routers in a single area	summary routes to an ASBR
LSA-5	AS-External LSA	ASBR	All non-stub areas	external routes outside the AS
LSA-7	NSSA (Not So Stubby Area) External LSA	ASBR	Within the NSSA originated	Routers in a NSSA do not receive external LSAs from ABR, but are allowed to send external routing information for redistribution. They use type 7 LSAs to tell the ABRs about these external routes.

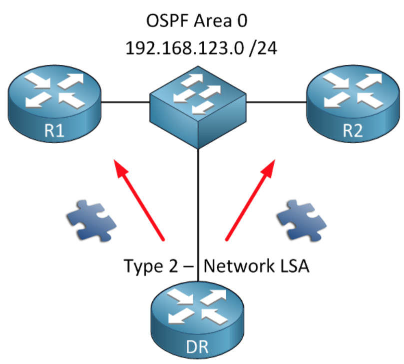
LSA Examples

LSA-1



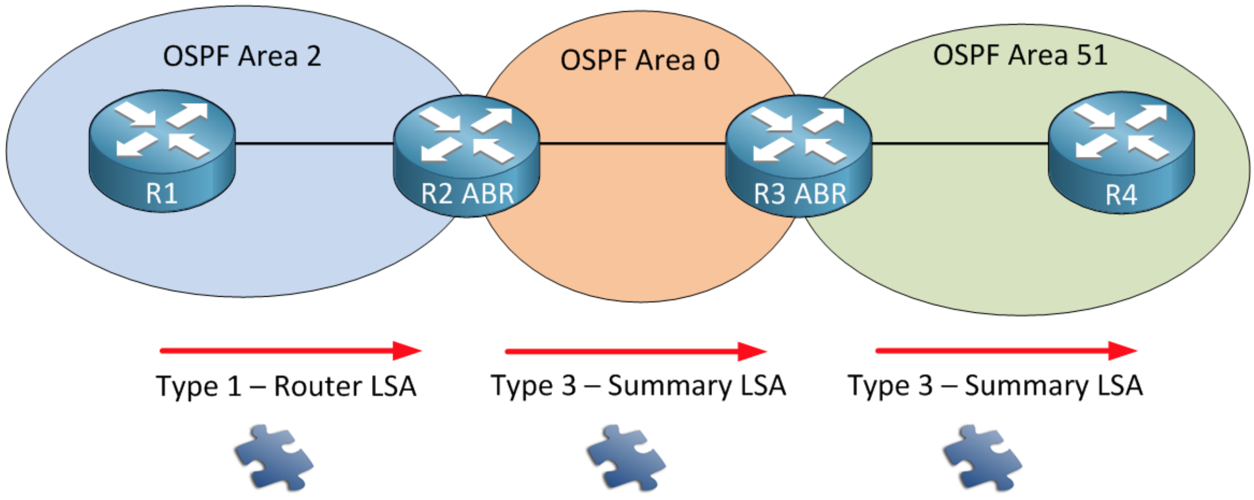
Each router within the area will flood a **type 1 router LSA within the area**.

LSA-2



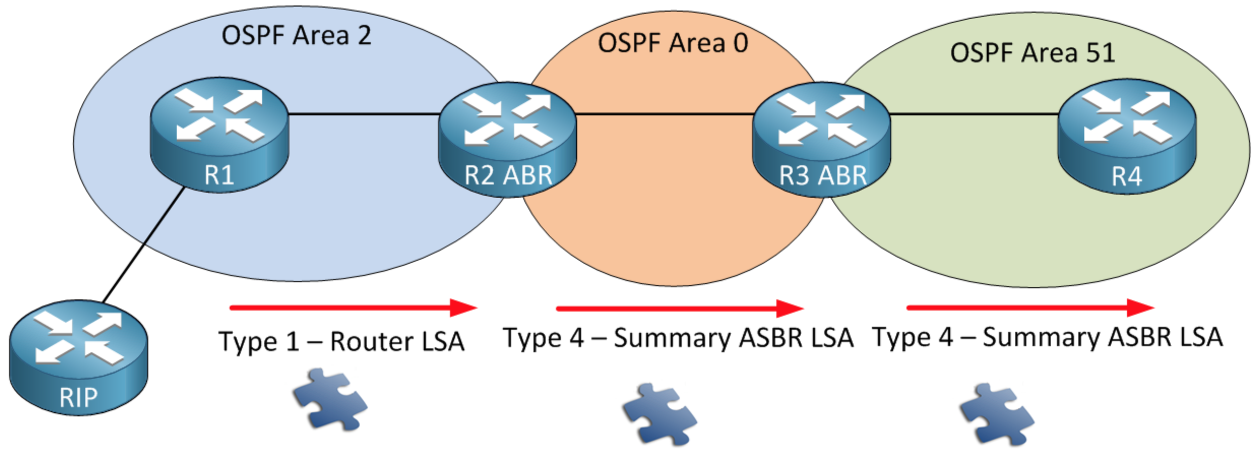
In this LSA we will find all the routers **within the area** that are connected to the multi-access network, the DR and of course the prefix and subnet mask.
In this example above we will find R1, R2 and the DR in the network LSA. We will also see the prefix 192.168.123.0 /24 in this LSA.

LSA-3



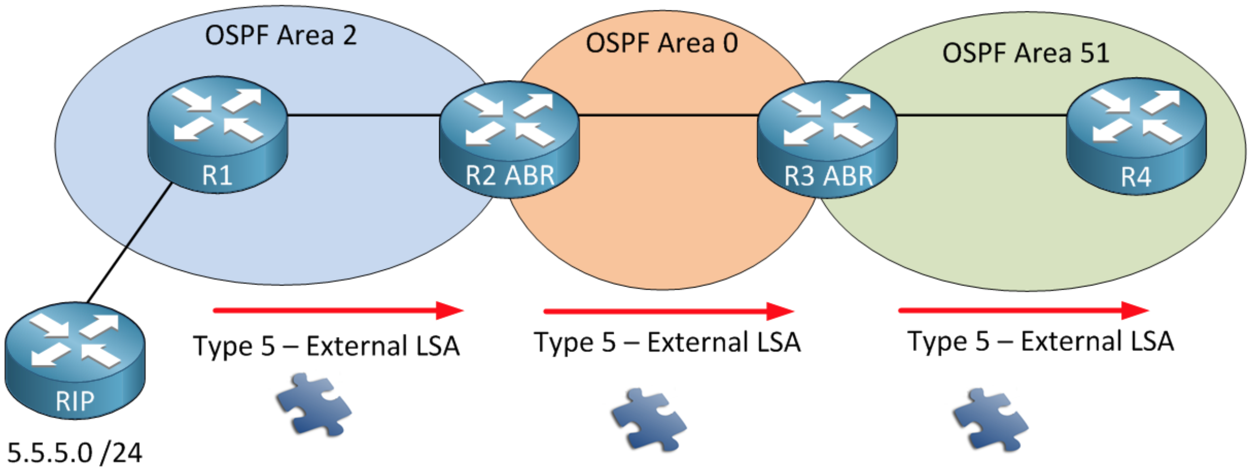
Type 1 router LSAs **always stay within the area**. OSPF however works with multiple areas and you probably want full connectivity within all of the areas. R1 is flooding a router LSA within the area so R2 will store this in its LSDB. R3 and R4 also need to know about the networks in Area 2. R2 is going to create a **Type 3 summary LSA** and flood it into area 0. This LSA will flood into all the other areas of our OSPF network. This way all the routers in other areas will know about the prefixes from **other areas.**

LSA-4



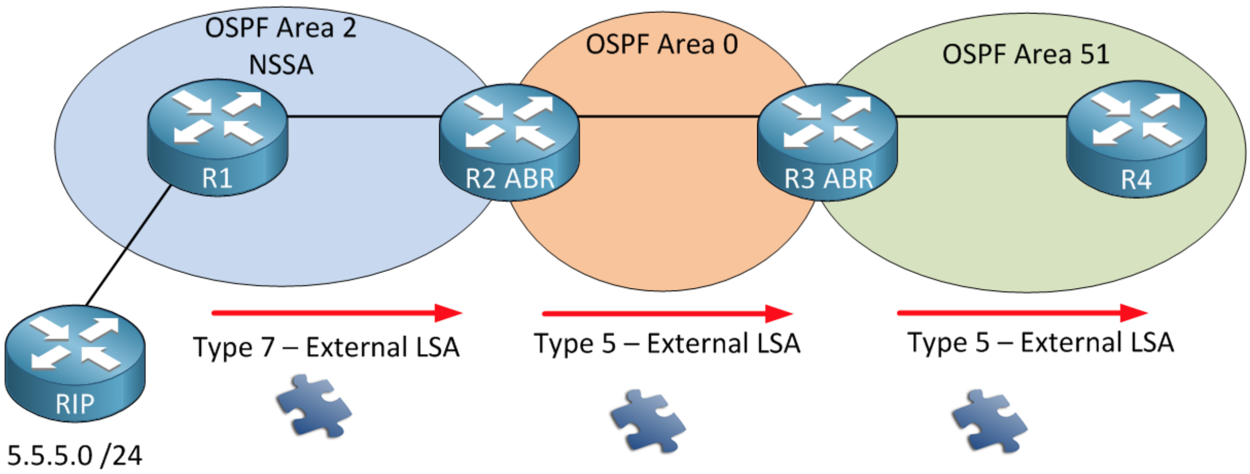
In this example we have R1 that is redistributing information from the RIP router into OSPF. This makes R1 an **ASBR (Autonomous System Border Router).** What happens is that R1 will flip a bit in the router LSA to identify itself as an ASBR. When R2 who is an ABR receives this router LSA it will create a **type 4 summary ASBR LSA** and flood it into area 0 to tell who is the ASBR / or to locate ASBR (R1 in this case). This LSA will also be flooded in all other areas and is required so all OSPF routers know where to find the ASBR.

LSA-5



Same topology but we added a prefix (5.5.5.0 /24) at our RIP router. This prefix will be redistributed into OSPF. R1 (our ASBR) will take care of this and create a **type 5 external LSA** for this.

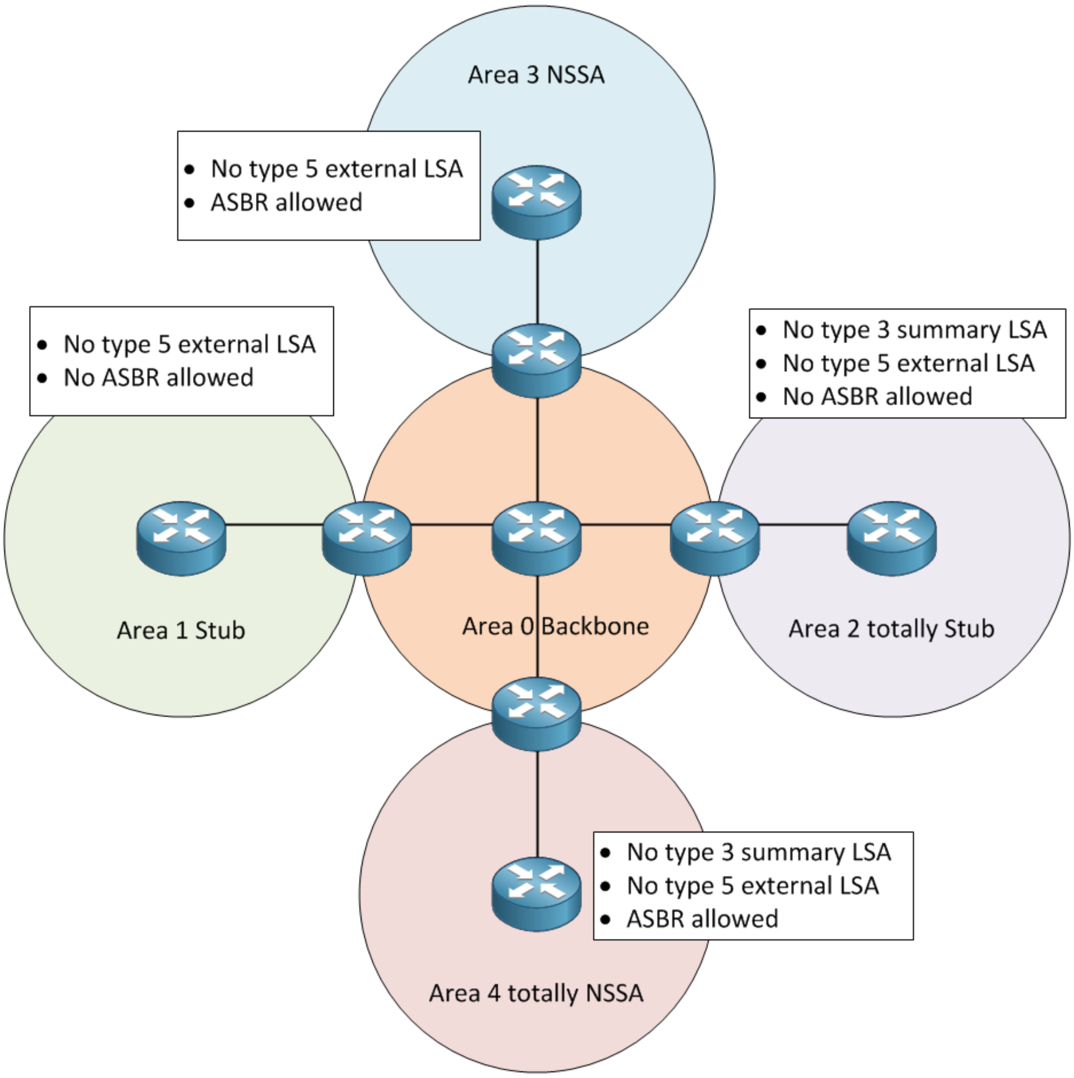
LSA-7



NSSA areas (Not So Stubby Area) do not allow type 5 external LSAs. In the picture R1 is still our ASBR redistributing information from RIP into OSPF. Since type 5 is not allowed we have to think of something else. That's why we have a **type 7 external LSA** that carries the exact same information but is not blocked within the NSSA area. R2 will translate this type 7 into a type 5 and flood it into the other areas.

Special Area Types

Example & elaboration:



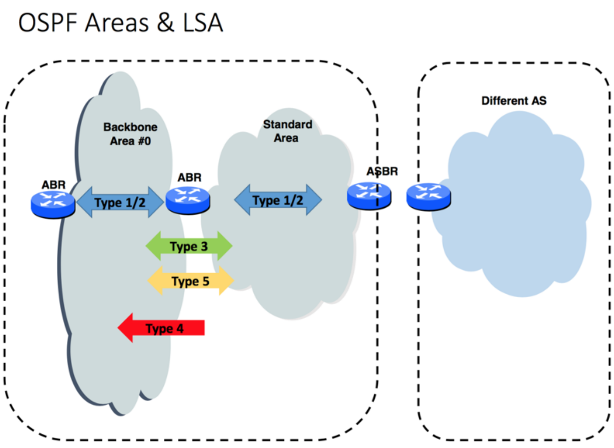
- **Stub area: Eg. Area 1**
  If you configure an area as stub it will **block all type 5 external LSAs.** All the prefixes that you redistributed into OSPF from another routing protocol are not welcome in the **stub area**. Since you are not allowed to have type 5 external LSAs in the stub area it's also impossible to have an ASBR in the stub area. In order to reach networks in other areas there will be a **default route**.

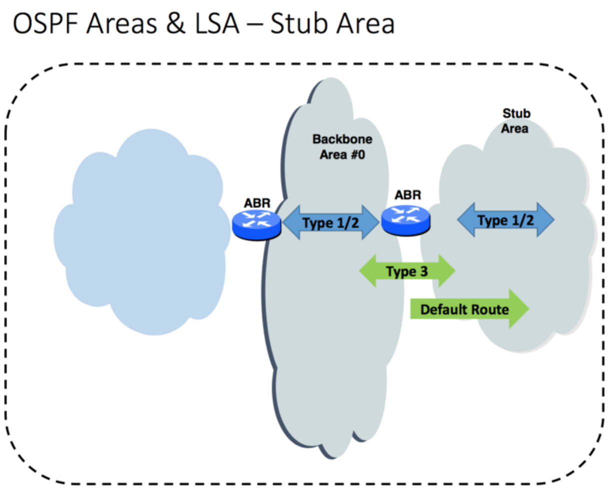
- **NSSA (not so stubby area)**
  Of course there's always an exception. So what if you want an area to be stub area but you also have an ASBR in this area? You can use the **NSSA (not-so-stubby-area)**. This is the same thing as the stub area with the **exception** that you are **allowed to have an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

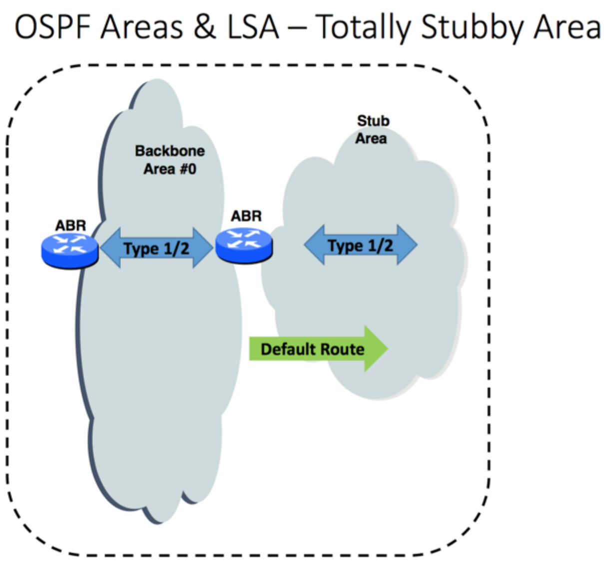
- **Totally stub area**
  This area type will **block type 5 external LSAs and type 3 summary LSAs.** It's impossible to have an ASBR in the totally stub area since type 5 external LSAs are blocked.

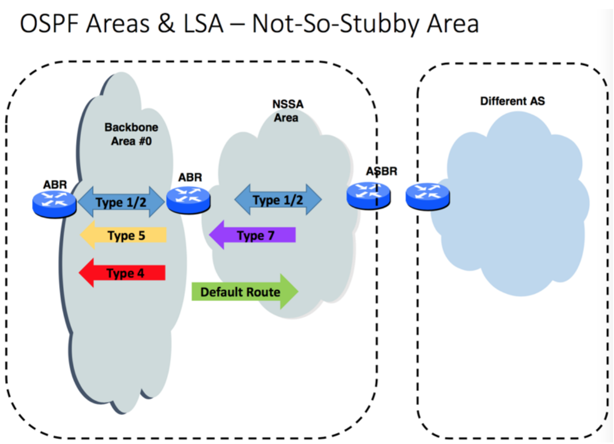
- **Totally NSSA (totally not so stubby area)**
  If you want to **block type 3 summary LSAs and type 5 external LSAs** but **still need an ASBR** within the totally stub area you can turn it into a **totally NSSA (totally not-so-stubby-area).**

This will block both LSA types but you can still have an ASBR in this area type.









References:

- https://en.wikipedia.org/wiki/Link-state_advertisement
- https://networklessons.com/ospf/ospf-lsa-types-explained/

Distance Vector Routing v/s Link State Routing
