Routing Protocols: EIGRP & OSPF

Course Title: Computer Networks

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Lecture Outline

1. Introduction
2. Metric
3. Neighbor Discovery
4. EIGRP Tables
5. EIGRP Tables
6. EIGRP Configuration
7. **Summary**

Routing Protocol: EIGRP

Metric

- Combination of different factors
  - Bandwidth
  - Delay
  - Load
  - Reliability

Default

Bandwidth

- No. of bits that can be sent over a link (kbps)
- Depends on interface type
- Use *bandwidth <1-10,000,000>* command to set bandwidth in kbps
- This is not real bandwidth; real bandwidth depends on clock rate
- The *bandwidth* command only influence route selection by routing protocol
- If no bandwidth is set, the default bandwidth of an interface is considered
- Calculated as the lowest bandwidth among all links in a route

Bandwidth

Table II Default bandwidth and delay

Interface	*Bandwdith*	*Delay (microseconds)*
Serial (T1)	1544 Kbps	20,000
Ethernet	10 Mbps	1000
Fast Ethernet	100 Mbps	100
Gigbit Ethernet	1000 Mbps	10
10 Gigbit Ethernet	10 Gbps	10

Delay

- *Delay* is a measure of the time for a packet to reach its destination over a route (In theory)
- In practice, it is a constant set by the network engineer
- To set delay for an interface, use *delay* <value> command
- The value can be anything between 10 to 167,772,140 microseconds
- If it is not set, the default value (Table II) of each interface comes into effect
- Calculated as sum of delays in exit interfaces of all routers in a route.

Metric Calculation

$$\boxed{Metric = \left[\frac{10^7}{least\ bandwidth} + delay_{total}\right] \times 256}$$

Units

Bandwidth: kbps

Delay: Tens of microsecond

If the total delay is 30 seconds, $delay_{total}$=30/10=3

Metric Calculation

$$Metric = \left[\frac{10^7}{least\ bandwidth} + delay_{total}\right] \times 256$$

Route: 1-4-2-B

$$Least\ BW = 56\ kbps$$

$$Total\ delay = 100/10 + 100/10 + 2000/10 = 220$$

$$Metric = \left[\frac{10^7}{56} + 220\right] \times 256 = 45770496^*$$

Route: 1-3-2-B

$$Least\ BW = 128\ kbps$$

$$Total\ delay = 100/10 + 100/10 + 1000/10 = 120$$

$$Metric = \left[\frac{10^7}{128} + 120\right] \times 256 = 20030720$$

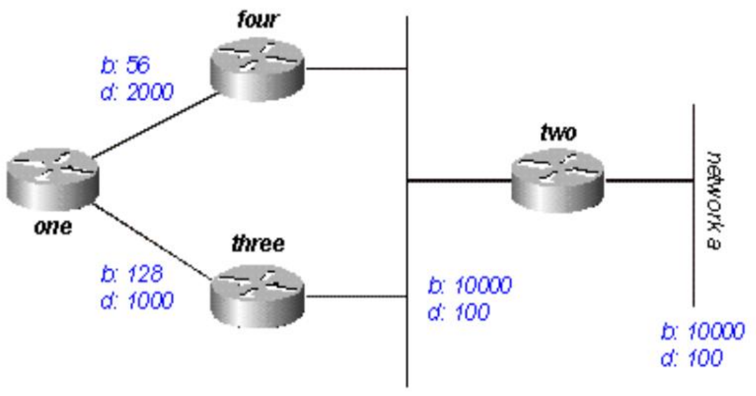


Fig. 1 A sample network [2]

Perform rounding in every steps of calculation

Exercise

Calculate metric for all possible routes from router ONE to network A

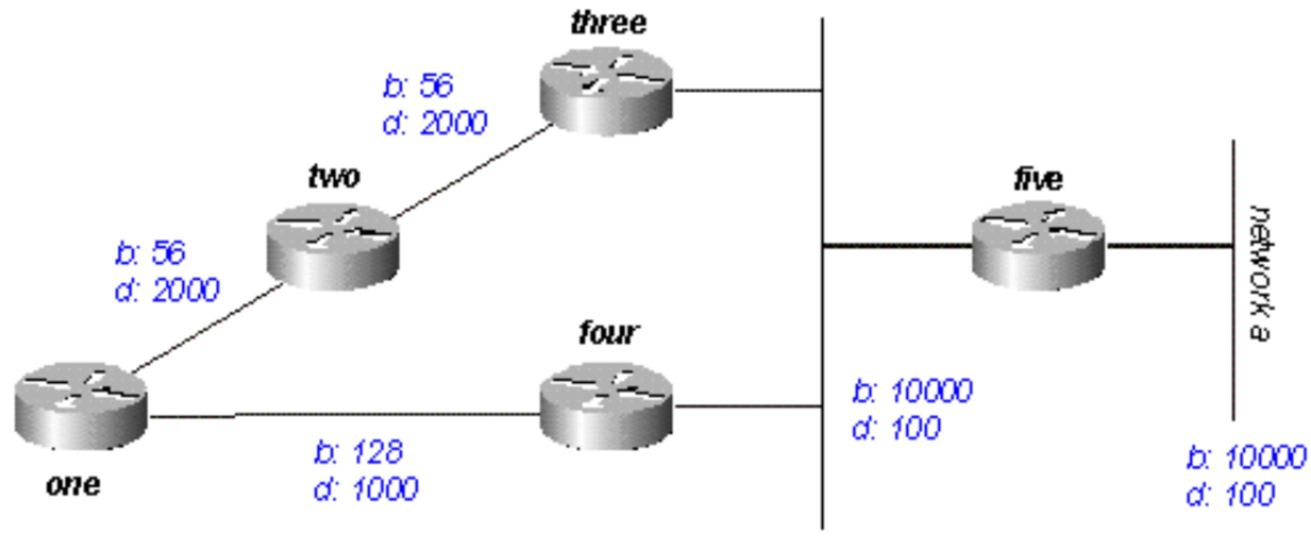


Fig. 2 A sample network [2]

Neighbor Discovery

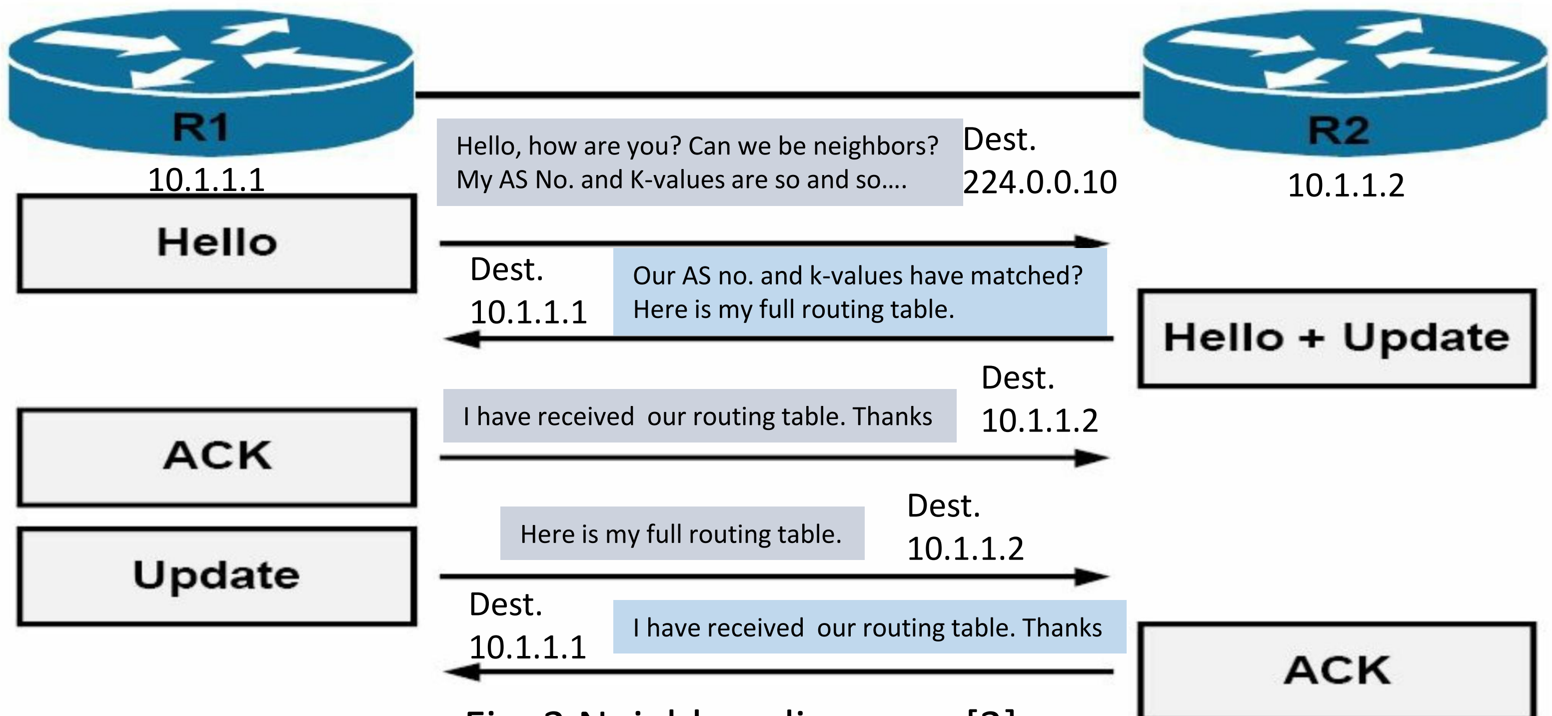


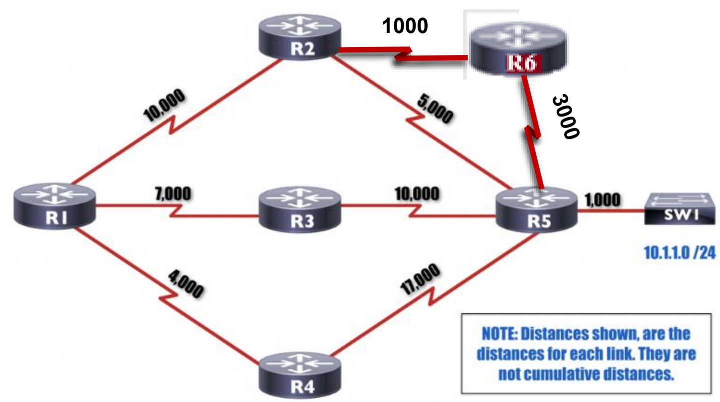
Fig. 3 Neighbor discovery [3]

Neighbor Maintenance

- In neighbor discovery process, full routing table is sent
- Otherwise, only the change in routing table is sent
- After a neighbor discovery, the Hello packet is sent in every 5 second to know if the neighbor is still alive
- If a router does not receive any Hello packet from a neighbor within 15 seconds (called hold time), the neighbor is considered dead.
- For low-bandwidth link (e.g., T1), the periods are 60 sec and 180 sec.

EIGRP Tables

Feasibility condition: reported distance must be less than the feasible distance through the successor



Neighbor	Reported Distance (RD)	Feasible Distance (FD)	(Feasible) Successor?
R2	6,000	16,000	Yes: Successor
R3	11,000	18,000	Yes: Feasible Successor
R4	18,000	22,000	No

Reported distance:
Distance advertised from neighbor as the distance between the Neighbor and the destination.

Feasible distance (FD):
Sum of Reported distance and distance between the router and the neighbor which reports the distance.

A is the route whose reported distance is less than the feasible distance of the best path.

EIGRP Tables

- Neighbor Table

  EIGRP shares routing information only with neighbors. To know who the neighbors are, it uses neighbor table. When a new neighbor is discovered, EIGRP would add its address and interface on which neighbor is connected in neighbor table [4].

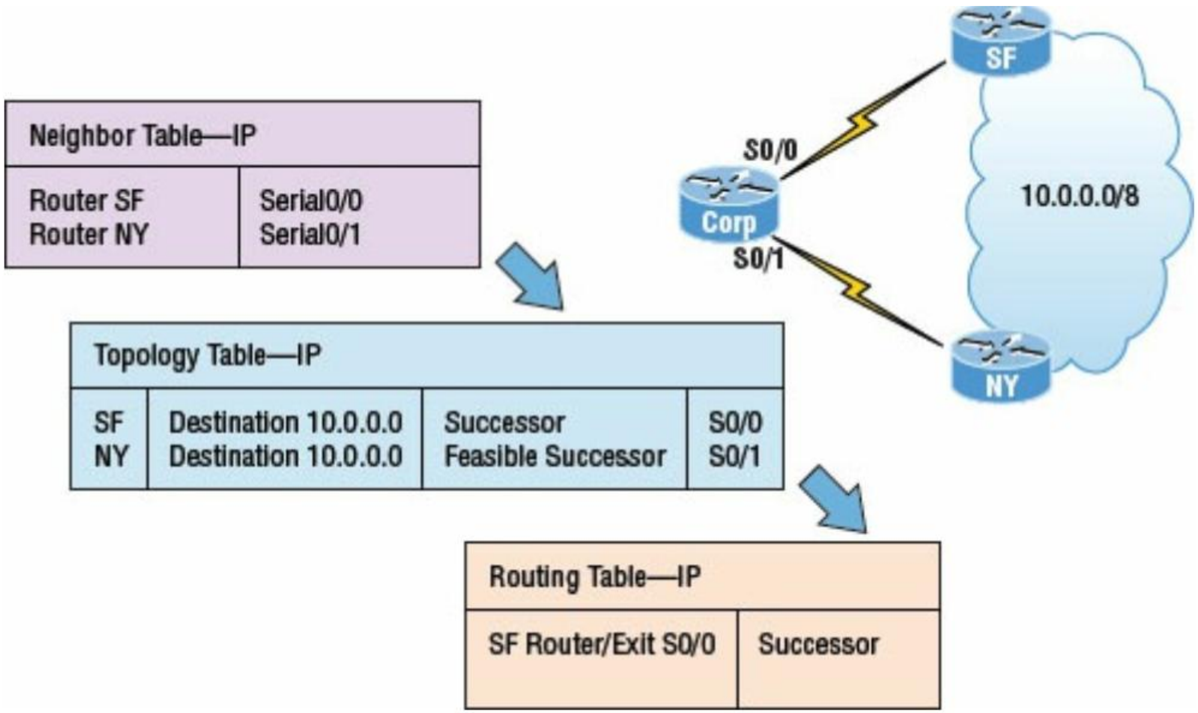
- Topology Table

  Stores all feasible successors along with the successor (best route) for each destination network. EIGRP can store up to 32 feasible successors.

- Routing Table

  EIGRP stores single best route for each destination in this table. Router uses this table to forward the packet.

EIGRP Tables: Example



Routing Protocol: OSPF

OSPF Area

- An autonomous system (AS) is divided into one or more area.
- Each area is given an area ID
- An AS must have an area having ID 0 (zero) for multi-area OSPF. Such area is called backbone area.
- All areas of an AS must be connected to the backbone area.
- A router in an area exchanges routing information with the routers of its area only (by default)

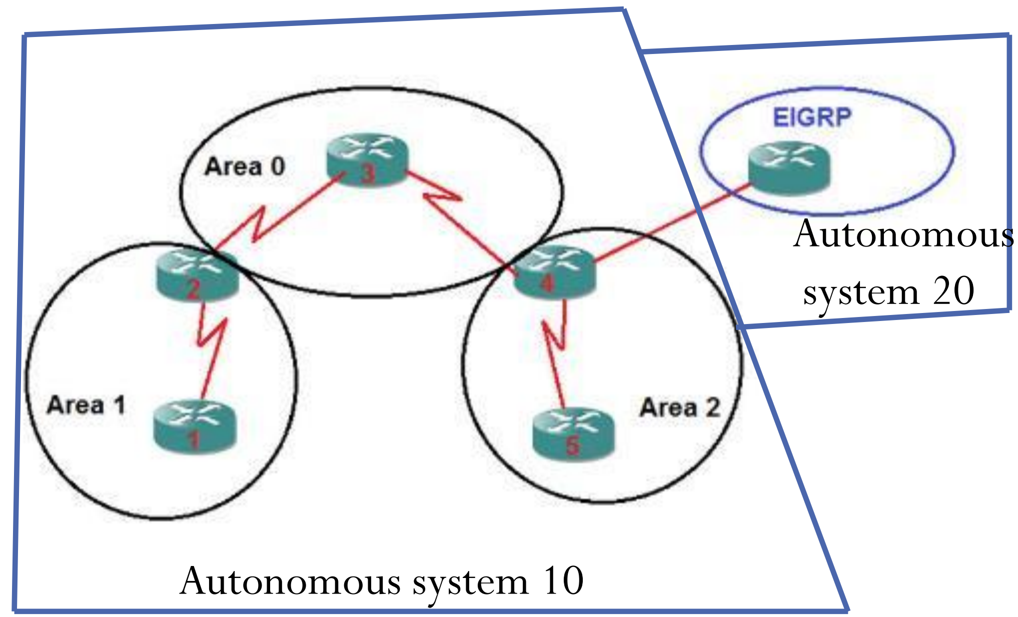


Fig. 1 Autonomous systems and area

OSPF Routers

- **Internal Router (IR):** The router for which all its interface belong to one area. Router 1 and Router 5.
- **Area Border Router (ABRs):** The router that contains interfaces in more than one area. Router 2 and Router 4
- **Backbone Router:** The router that has all or at least one interface in Area 0. Router 3, Router 2 and Router 4.

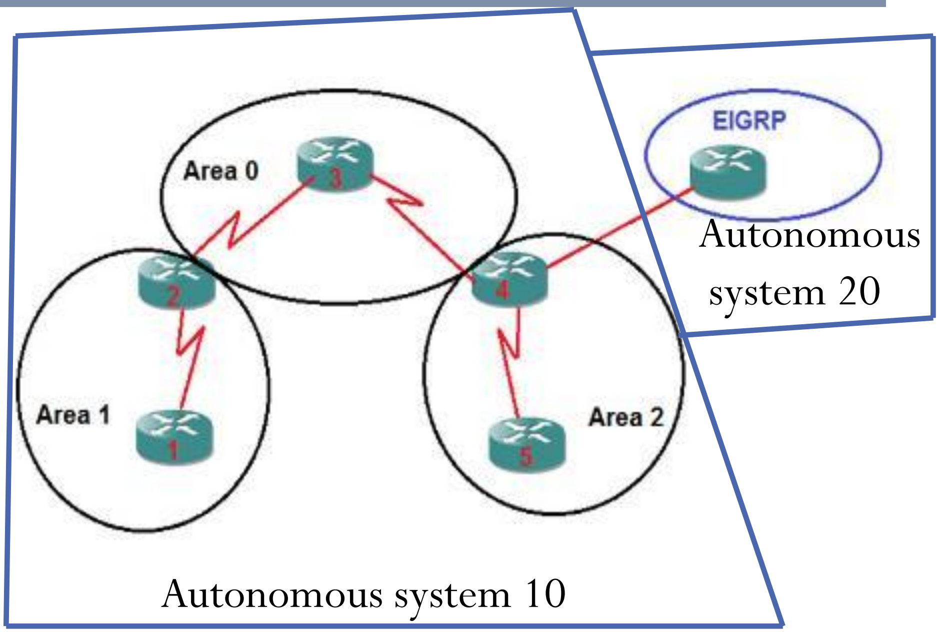


Fig. 1 Autonomous systems and area

- **Autonomous System Boundary Router (ASBR):** The routers with connection to a separate autonomous system. R4 in the example is connected to EIGRP [4].

OSPF Data Structure & Packets

- Link state advertisement (LSA)
  - A data structure with some specific information about the networks [2].
  - Depending on its type, it holds information about
    - a router's interfaces,
    - all routers attached to network,
    - summary routing information of an area,
    - all routers of an AS.
- Link state database (LSDB)
  - A collection of all LSAs known to a router
  - In a convergent network, all routers of a network have the same LSDB.

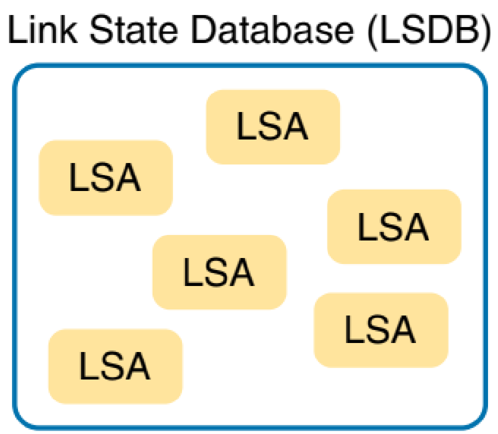


Fig. 2 LSA & LSDB relationship

OSPF Data Structure & Packets

- Hello

  Used to build and maintain neighbor relationships.
- DBD – Database Description

  List of LSAs contained in a LSDB. This packet type is circulated when two routers are initially exchanging their link-state databases.
- Link State Request (LSR)

  Used to request complete information about a link learned from another router.
- Link State Update (LSU)

  Used to send one or LSA(s)
- Links State Acknowledgement (LSAck)

  Used to acknowledge the reception of an LSA

Neighbor Discovery

Parameters need to be identical for two routers to become neighbors

- Network mask—*net mask of the sending router*
- Subnet number —derived using the subnet mask and each router's interface Internet Protocol (IP) address
- Area ID—*area ID of the sending interface*
- Hello interval—*how often Hello packets are transmitted*
- Dead interval—*how long to wait for Hello packets before terminating neighbor*
- Authentication type and password—*optional*
- Stub area flag—*specifies the type of stub area, if applicable* [3]

Hello packet contains all these information

Neighbor Discovery

Example:

The scenario begins with the link down, so the routers have no knowledge of each other as OSPF neighbors

1. Link between R1 and R2 comes up
2. R1 sends the first Hello to multicast IP address 224. 0.0.5, so R2 learns of the existence of R1 as an OSPF router. At that point, R2 lists R1 as a neighbor, with an interim beginning state of init.

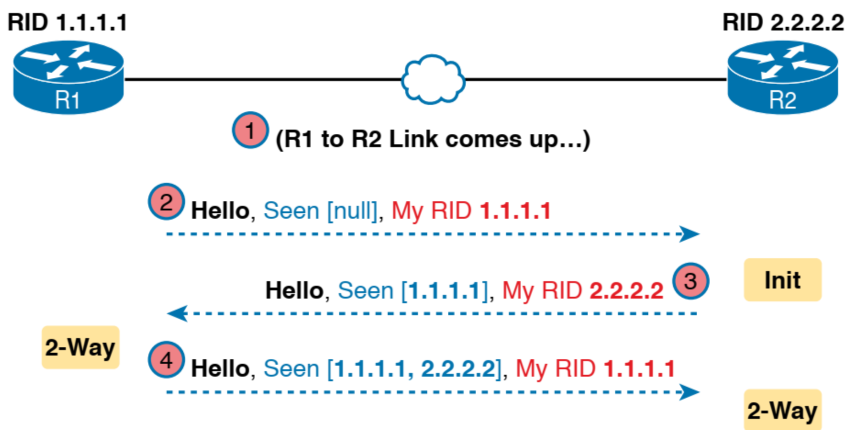


Fig. 3 Neighbor discovery

3. R2 sends back a Hello which tells R1 that R2 exists, and it allows R1 to move through the init state and quickly to a 2-way state.
4. R2 receives the next Hello from R1, and R2 can also move to a 2-way state [2]

Router ID

- 32-bit unique dotted decimal number

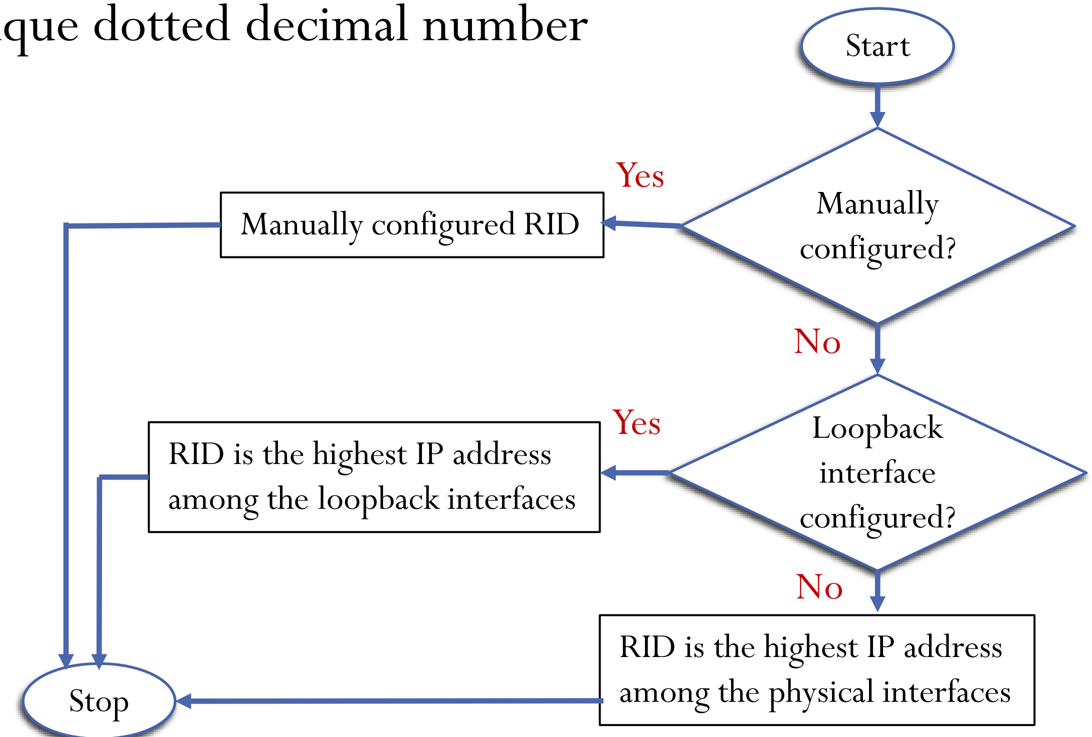


Fig. 4 Flow chart of Router ID selection

DR and BDR

- Point-to-point network: A network in an area connecting only two routers directly.
- Broadcast network: A network in an area connecting more than two routers
- Designated router (DR):
  - In a broadcast network, a router with the highest priority.
  - If the priorities tie, the router has the highest RID (Router ID)
  - All database exchange is done via DR
- Backup Designated router (BDR)
  - In a broadcast network, a router with the second highest priority.
  - If the priorities tie, the router having the second-highest RID
  - If the DR fails, the BDR takes over.
- DROTHER: The router which is neither DR nor BDR [2]

DR and BDR

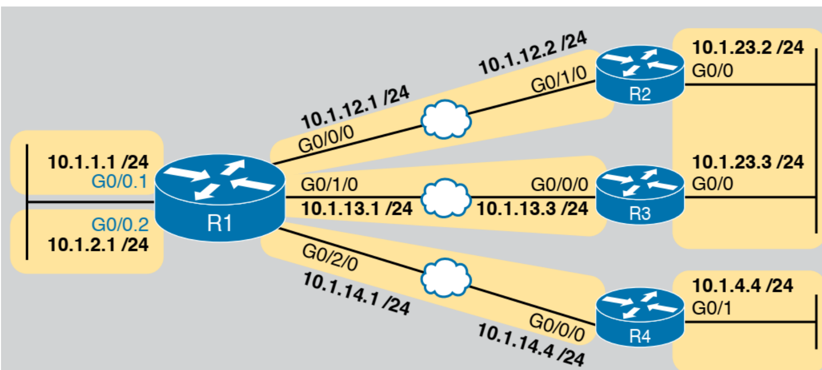


Fig. 5 point-to-point network

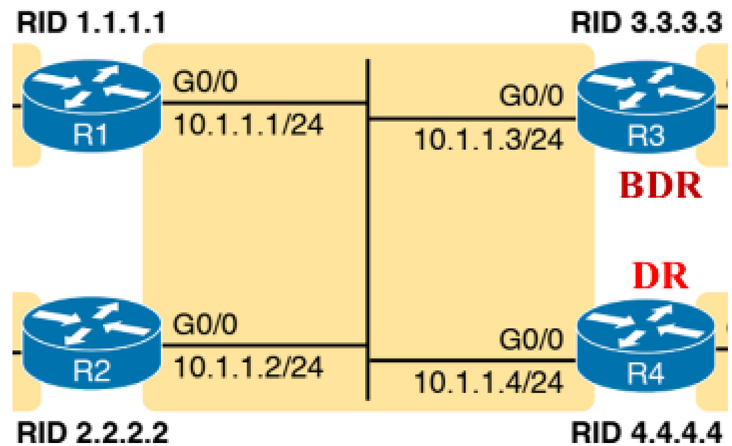


Fig. 6 Broadcast network， DR and BDR election

DR and BDR

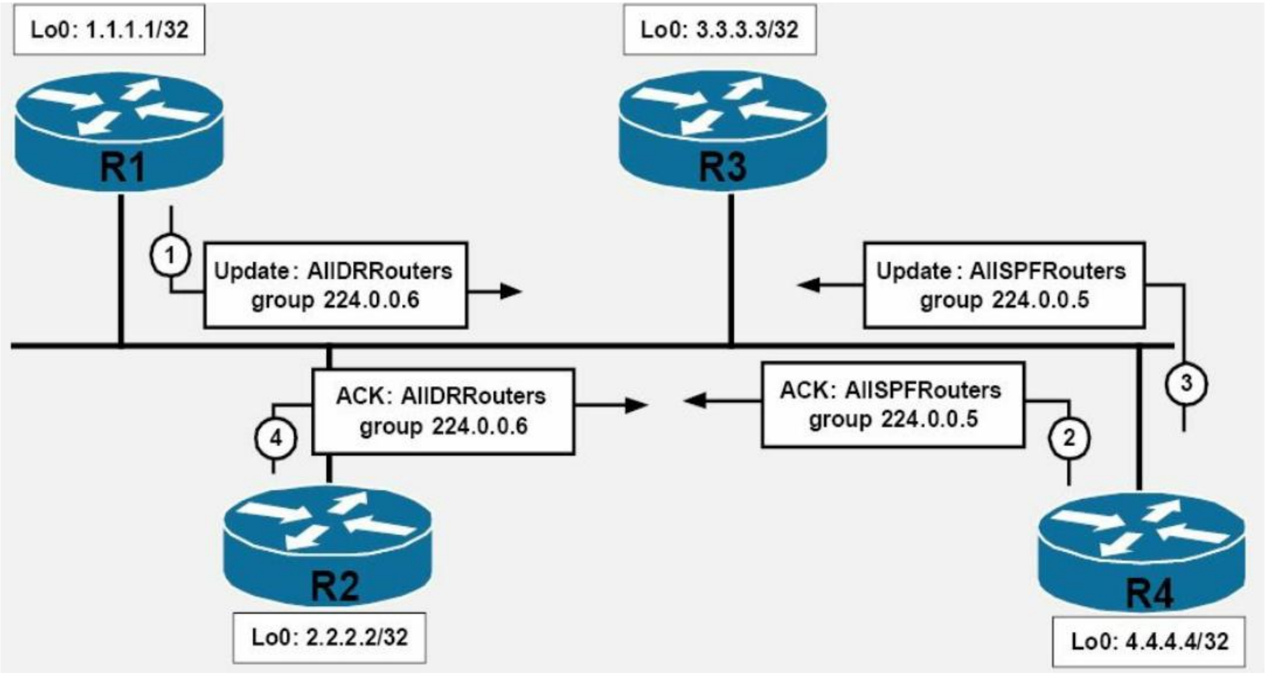


Fig. 7 Illustration of update exchange through DR and BDR

Wildcard Mask

- Used to specify a range of network addresses.
- Inverted subnet mask
- Used in EIGRP, OSPF and Access-List.

- How to get wildcard mask of an IP address?

  Subtract the subnet mask from 255.255.255.255

- What does each bit of a wildcard mask mean?

  0 : All IP address in the range must match the bit

  1 : Different IP address in the range can have different value in the bit position

Wildcard Mask

- Only 192.168.3.0

  All bits must match.

  WCM: All bits 0. (00000000.00000000.00000000.00000000)

  WCM: 0.0.0.0

- IP address range: 192.168.3.0 to 192.168.3.255

  Match first three block (24 bits) and fourth block can take any value

  WCM: 0.0.0.255

- IP address range: 192.168.3.4 to 192.168.3.13

  11000000.10101000.00000011.00000100

  11000000.10101000.00000011.00001101

First 28 bits same.

Match first 28 bits; make them all zero

Make rest of the bits 1

00000000.0000000.00000000.00001111

WCM: 0.0.0.15

Actual IP range: 192.168.3.0 to 192.168.3.15 under WCM: 0.0.0.15

Summary – RIP v/s EIGRP v/s OSPF

RIP	EIGRP	OSPF
It support maximum 15 routers in the network. 16 router is unreachable.	It supports maximum 255 routers in the network. However, the default is 100 routers.	Supports unlimited number of routers.
Slow convergence.	Fast convergence due to feasible successor.	Fastest convergence speed due to the area concept.
In RIP routing protocol, we cannot create a separate administrative boundary in the network.	In EIGRP routing protocol we can create a separate administrative boundary in the network with the help of autonomous system.	Open standard protocol and can be implement in any router.
It calculates the metric in terms of Hop Count from source network to destination network.	It calculates the metric In terms of bandwidth and delay.	It calculates the metric In terms of bandwidth only.
RIP works on Bellman Ford algorithm.	EIGRP works on DUAL (Diffusing Update Algorithm) Algorithm.	OSPF works on Dijkstra Algorithm.
It only maintains the best route to each destination.	It maintains the best route and some other alternative routes for each destination.	It maintains the best route in routing table and all routes in database table.
It is basically use for smaller size organization.	It is basically use for medium to lager size organization in the network.	It is basically use for lager size organization in the network.

Summary – EIGRP Metric

$$Metric = \left[\frac{10^7}{least\ bandwidth} + delay_{total}\right] \times 256$$

- Lowest available bandwidth among the routers.
- Total delay for each router communication divided by 10.
- Using calculator is not necessary. You can keep as it is after identifying the lowest bandwidth, calculating the total delay divided by 10, and replacing the values correctly in the equation.
- This is a very simple math. Create your own examples and practice.

Summary – OSPF Wildcard Mask

- You already know what is subnet mask and how to calculate that.
- Ex: 10.0.0.1; 240.100.38.7; 10.20.30.40/10; 140.40.240.4/26;
- OSPF Wildcard Mask is the invert of the calculated subnet mask.
- Ex: if subnet mask is 255.255.255.0, Wildcard Mask is 0.0.0.255.
- Create your own examples and practice.

References

- [1] Computer Networking Class, https://computernetworkingclass.blogspot.com/2016/08/comparison-between-rip-eigrp-igrp-and.html, [Accessed: April. 27, 2020].
- [2] Cisco, “https://www.cisco.com/c/en/us/support/docs/ip/enhanced-interior-gateway-routing-protocol-eigrp/16406-eigrp-toc.html, [Accessed: April. 27, 2020].
- [3] P. Browning, F. Tafa, D. Gheorghe, and D. Barinic, *Cisco CCNA in 60 Days*, Reality Press Ltd., UK, 2014, pp. 581
- [4] Computer Networking Notes, https://www.computernetworkingnotes.com/ccna-study-guide/eigrp-tutorial-basic-concept-explained.html, [Accessed: April. 27, 2020].

Recommended Books

1. **Official Cert Guide CCNA 200-301 , vol. 1**, *W. Odom*, Cisco Press, First Edition, 2019, USA.
2. **CCNA Routing and Switching**, *T. Lammle*, John Wily & Sons, Second Edition, 2016, USA.