Routing

Content

- Static vs dynamic routing
- Routing protocols overview
- Autonomous systems
- Routing protocol types
- IGPs
- EGP
- Scalability
- Common misconceptions
- Commands

Static vs dynamic routing

- **Static routing**
  - Manually configured
  - Smaller networks
- **Dynamic routing**
  - Information shared automatically
  - Networks can scale easily

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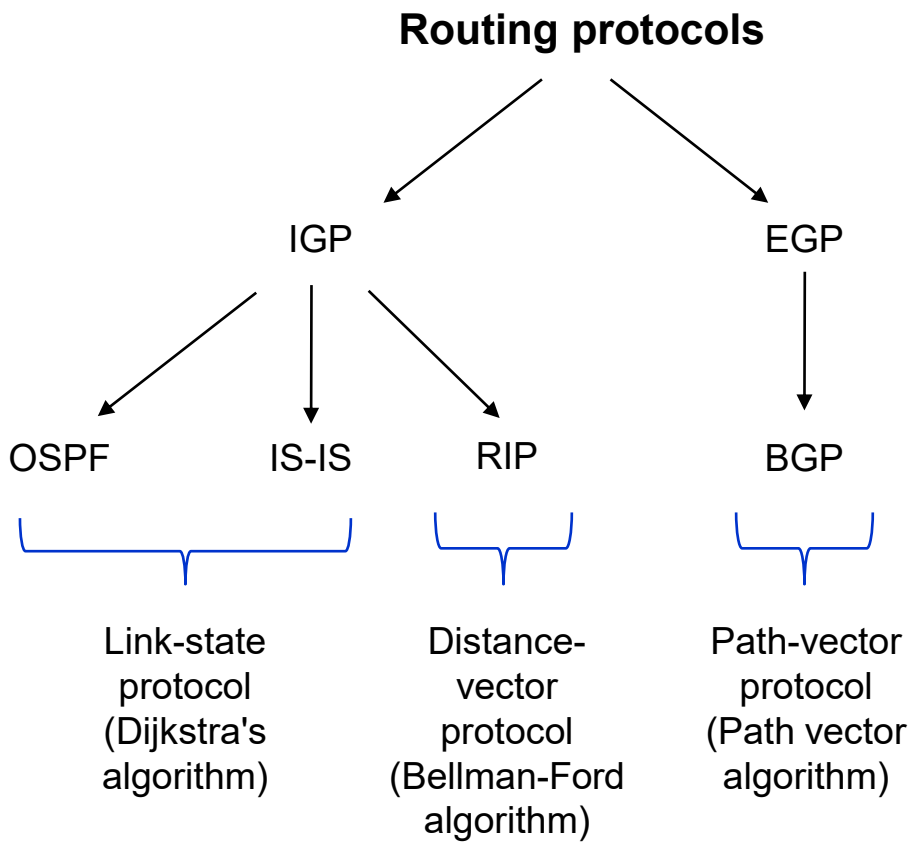
Routing protocols overview



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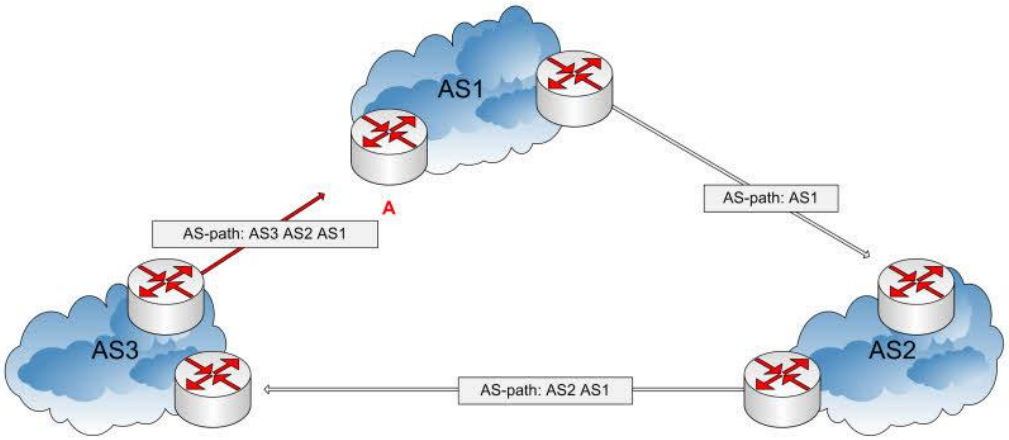
Autonomous Systems (ASes)

- **AS** = set of routers under the control of a single organization/entity.
- Uses Interior Gateway Protocol (IGP) to route traffic within an AS.
- Uses Exterior Gateway Protocol (EGP) to route traffic between ASs.
- Each AS has a globally unique number, called ASN.
  - Today: 32-bit AS numbers assigned



Source: Network Encyclopedia

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Routing protocol type

Link-State Routing Protocol

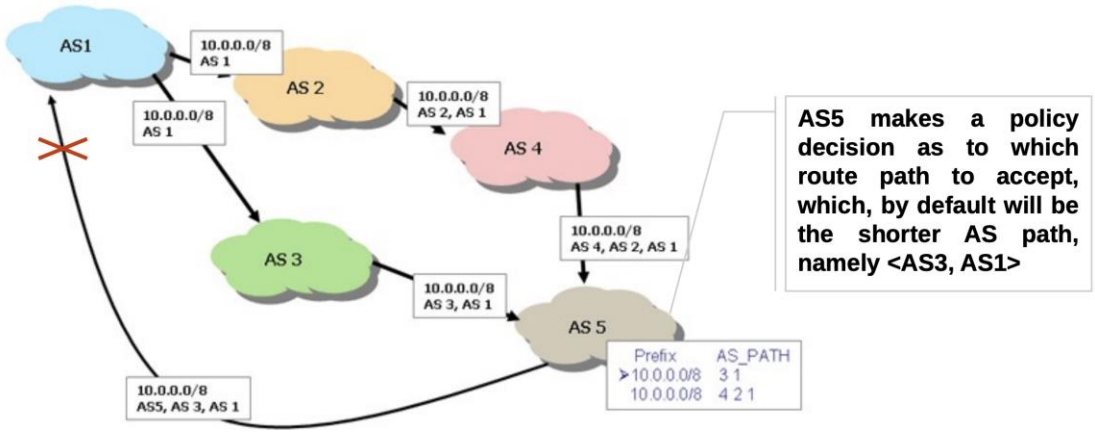
- Each router builds a complete topology map of the network
- Every router has the same map of the network
- How it works:
  - Every router uses this map to compute the shortest path to every destination using **Dijkstra's algorithm**
  - Shortest path is saved in the **Forwarding information database (FIB)**
  - To keep the FIB updated, each router does 2 things:
    - Send **"hello" messages** to directly connected neighbors (routers on the same network) to test if they are alive and reachable.
    - Periodically flood **Link state messages (LSA)** to neighbors. Each LSA lists the routers links and their costs. All routers collect LSAs into their Link State Database (LSDB) to maintain an up-to-date map.

Routing protocol type
Distance-Vector Routing Protocol

- Don’t have a full map of the network, only a local view
- How it works:
  - Every router has a routing table containing:
    - **Distance** (hop count) to each destination
    - **Direction** (next-hop neighbor) to send packets
  - Periodically, every router sends its entire routing table to its directly connected neighbours.
  - Neighbrs update their own routing tables, if a shorter path is found, update the entry

Routing protocol type
Path-Vector Routing Protocol

- Each router advertises the complete AS path to reach a destination prefix.
- How it works:
  - The path is a list of AS numbers the route has passed through to reach a prefix.
  - Loop prevention, if a router sees its own as in an advertised path, it discards the route.
  - Does not pick the shortest path, but uses policies



Routing protocol type
Comparison

Category	Link-State	Distance-Vector	Path-Vector
Examples	OSPF, IS-IS	RIP	BGP
Topology knowledge	Each router builds a complete map of the entire network	Hop count to each destination + next hop neighbour	Each router advertises the complete AS path to reach a destination prefix
Algorithm	Dijkstra's	Bellman-Ford	Path vector algorithm
Convergence	Fast	Slow	Slow
Scalability	Good	Poor	Excellent
Use Case	Within an AS (IGP)	Small/legacy networks (IGP)	Between ASes (EGP)

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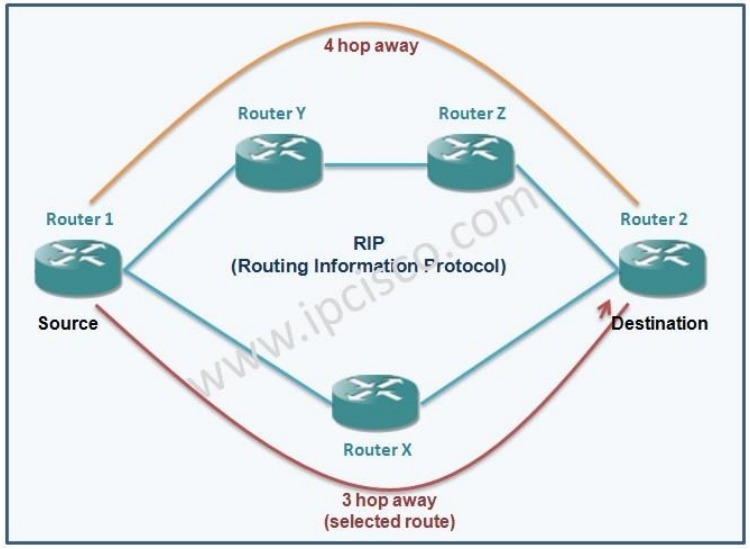
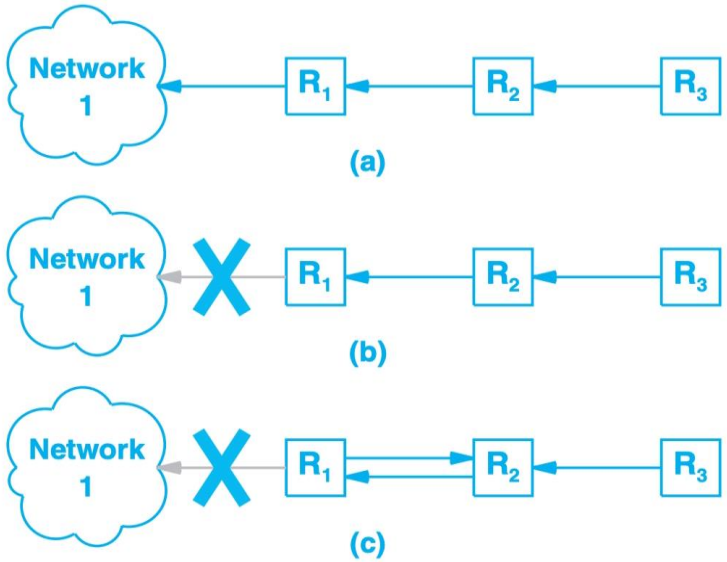
IGPs - RIP



Routing Information Protocol (RIP):

- It is a **distance-vector routing protocol** (Bellman Ford algorithm)
  - **Active** and **passive** participants in the network
  - Distance is measured in number of **hops** (routers to pass through – maximum 16 hops)



- Very simple
- Main problem is **slow convergence** (Update every 30 sec)
- One of the oldest protocols, not much used anymore
  - Rip RIP?

Source: https://www.freepnglogos.com/images/one-piece-logo-75.html

IGPs – OSPF

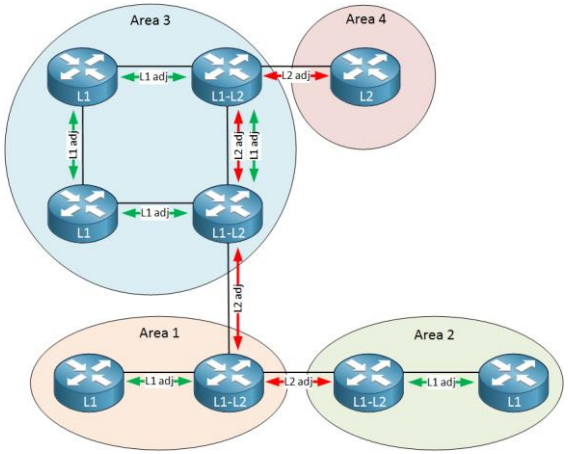
Open Shortest Path First (OSPF):

- It is a **link-state routing protocol** (Dijkstra's algorithm)
- **OSPFv2** for IPv4
- **OSPFv3** for IPv6
- Operates at OSI layer 3 (Network)
- Open standard
- Uses **areas** to limit the flooding of LSAs within each area
- Preferred by enterprise networks

IGPs – IS-IS

IS-IS (Intermediate System to Intermediate System):

- **Link-state routing protocol** (Dijkstra's algorithm)
- Operates at OSI layer 2 (Data Link) – does not use IP for adjacency
- Two level Hierarchy: L1 (Intra-area) and L2 (Inter-area backbone)
- Preferred by large-scale ISPs for stability and scalability



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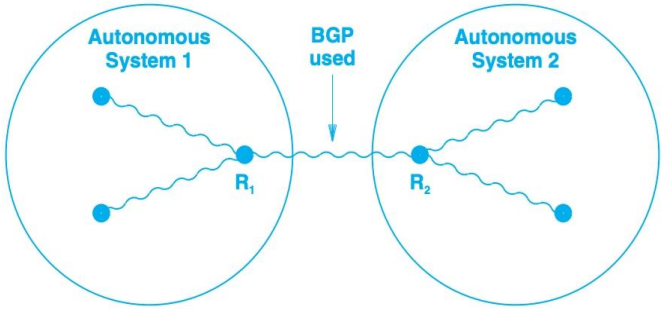
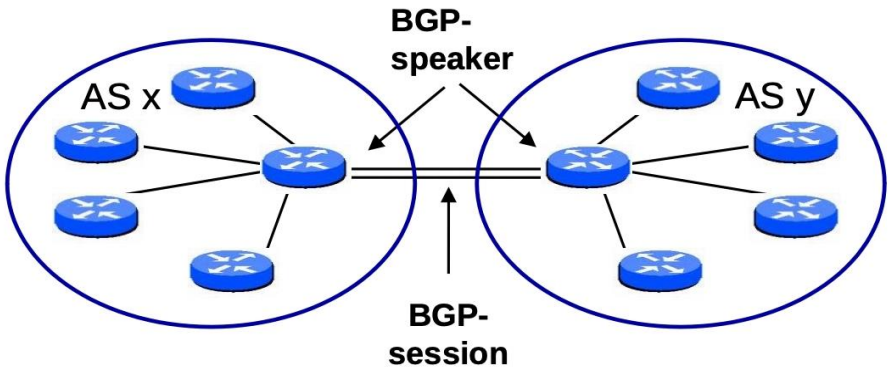
EGP - BGP

Border Gateway Protocol (BGP):

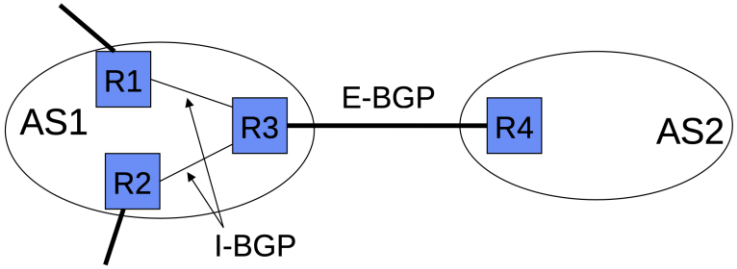
- It is a **path-vector routing protocol**
- Primary function = exchange network reachability information with other BGP systems
- Support IPv4 and IPv6
- **BGP speaker** is a border router in each AS
- Border router become **BGP peers**
- **BGP session** is a TCP session connecting the BGP peers to they can exchange routing information





EGP - BGP

iBGP and eBGP



eBGP = external BGP

- Between routers in different autonomous systems
- Typically, direct connections (TTL = 1 by default)
- Next-hop changes when route is advertised
- Often used between ISPs, or ISP and customer

iBGP = internal BGP

- Between routers in the same autonomous systems
- Does not change next-hop-by default
- Full mesh problem - n(n-1)/2 sessions
- Scalability: Route Reflector or Confederation

PS! iBGP isn't really used for internal routing, but for sharing routes learned by eBGP.

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Scalability

Discussion about Scalability of Link-State protocol

- Both OSPF and IS-IS use areas to limit the size of the link-state database and reduce CPU load

OSPF:

- Area 0 is backbone (All areas must connect to area 0)
- Routers between two areas called Area Border Router (ABR)
- Non-backbone areas must have direct connection to area 0

IS-IS:

- Level 2 is backbone
- L1/L2-routers are border routers
- More flexible – No strict requirements for areas to connect directly to backbone

Scalability

Discussion about Scalability of Routing

Areas:

- Divides network into zones – router only maintain full topology map of their own area
- Changes in one area does not trigger Dijkstras in other areas
- Reduce LSDB size and CPU load significantly

Reliable flooding:

- LSA must reach every router in the area. Incomplete delivery results in inconsistent LSDB and can cause wrong paths
- Mechanism: Receiver acknowledges each LSA, if no ACK – retransmit
- Sequence numbering on LSA – Discard duplicated and older versions

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Common misconceptions

- "Routing table (RIB) and FIB are the same thing"
- "Distance-vector routers know the full network topology"
- "BGP always picks the shortest path"
- "iBGP is an IGP protocol and eBGP is an EGP protocol"
- "OSPF floods LSAs to neighbors"

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Routing commands

Console — FRR router (vtysh / GNS3)

Command	Short form	! Explanation
— General —		
show ip route connected	sh ip route connected	! Only directly-connected routes
show running-config	sh run	! The full running configuration
show interface eth0	sh int eth0	! Details for a single interface
show interface brief	sh int brief	! All interfaces + IPs at a glance
show ip prefix-list	sh ip prefix-list	! Configured prefix-lists
— OSPF —		
show ip ospf neighbor	sh ip ospf nei	! OSPF neighbour state & details
show ip route ospf	sh ip route ospf	! Routes learned via OSPF
— BGP —		
show bgp summary	sh bgp summ	! BGP neighbour connections & state