Ecole Supérieure d'Informatique et du Numérique
COLLEGE OF ENGINEERING & ARCHITECTURE

Routing and Switching

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Chapter 7 : Dynamic Routing

Topics:

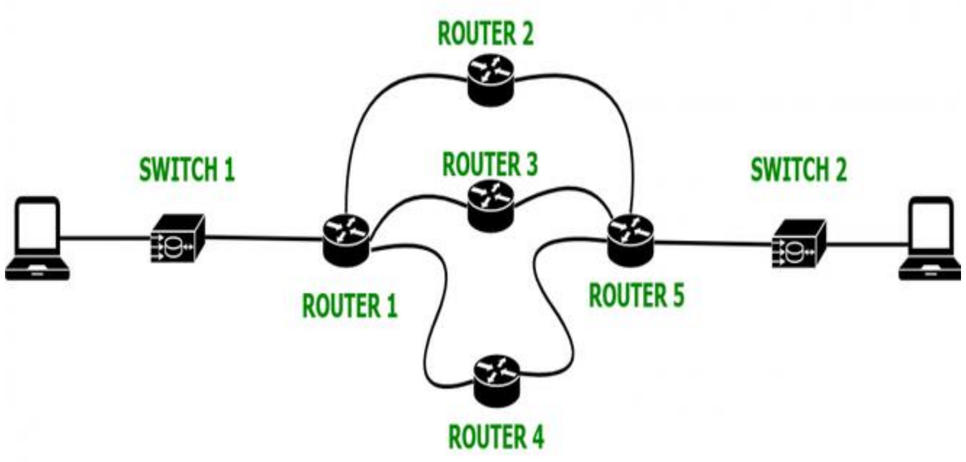
- ✓ Autonomous Systems
- ✓ Intradomain vs interdomain routing
- ✓ Dynamic routing
  - -RIP V1/rip V2
  - - IGRP/EIGRP
  - - OSPF
  - - BGP

Dynamic Routing

- Indispensable as soon as the topology becomes complex
- Routers use the paths that the routing protocol automatically creates

  from the information received from other routers.
- Routers exchange topology information using various protocols.
- Routers then calculate one or more *next hops* for each destination,

  trying to take the best possible path.



Dynamic Routing

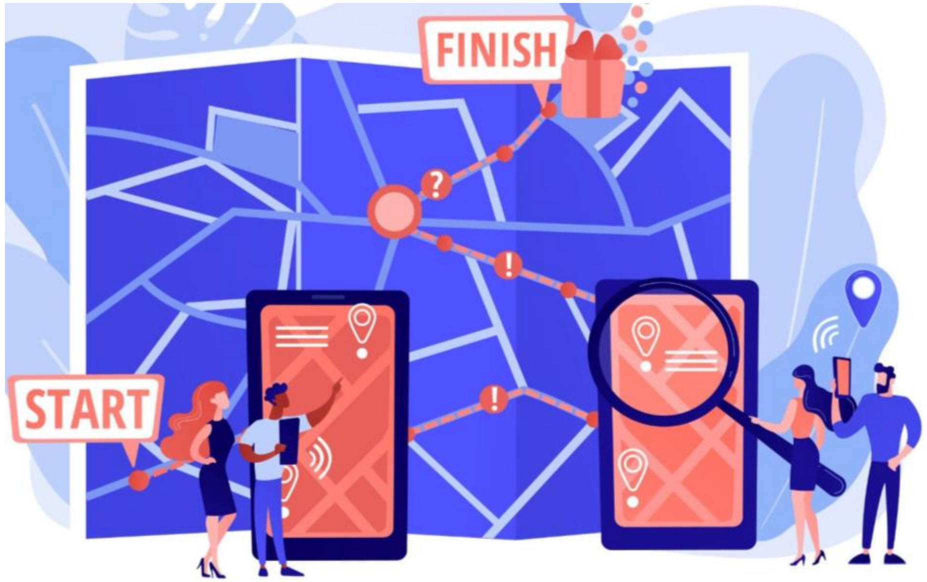
A routing protocol allows the following operations to be performed:

– Discovery of remote networks

– Updating of routing information

– Selection of the best path to destination networks

– Ability to find a new best path if the current path becomes unavailable



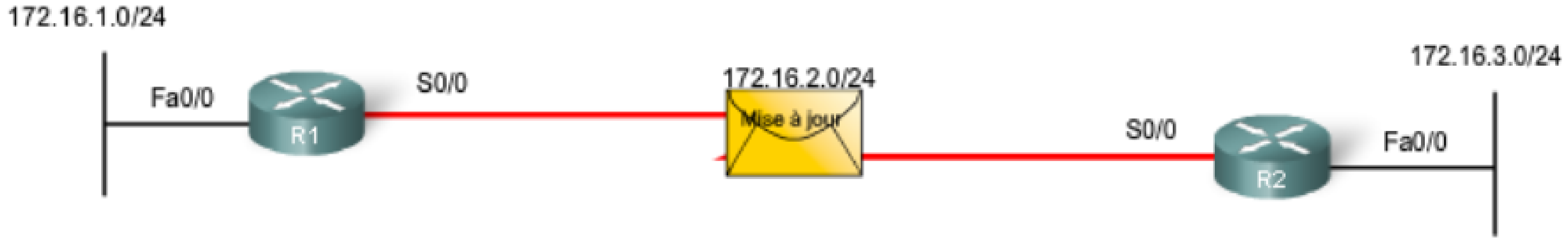
Components of routing protocol

– **Algorithm**

• Algorithms are used to facilitate the exchange of routing information and to determine the best access path.

– **Routing protocol messages**

• Used to discover neighbors and exchange routing information.



Dynamic Routing: How does it work?

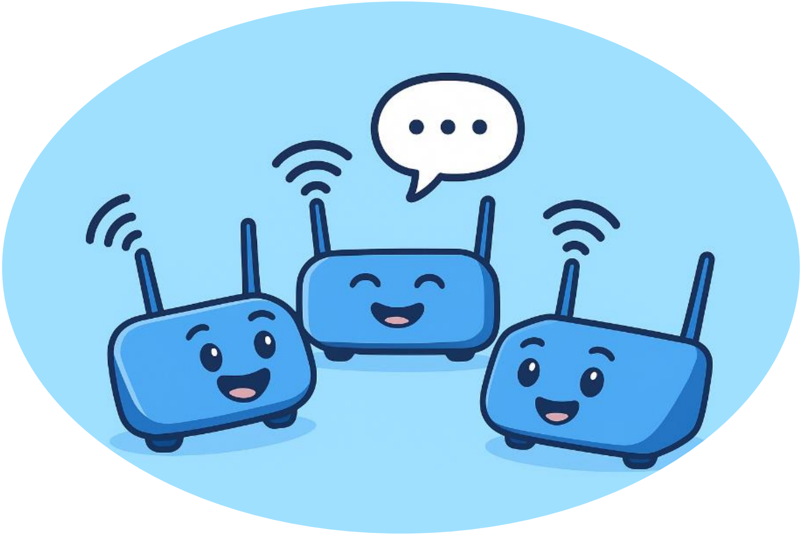
The operation of a dynamic routing protocol can be described as follows:

– The router sends and receives routing messages on its interfaces.

– The router shares routing messages and information with other routers that use the same routing protocol.

– Routers exchange routing information to discover remote networks.

– When a router detects a topological change, the routing protocol can announce it to the other routers



Dynamic Routing: Pros & Cons

- ✓ Automatically detect and adapt to topology changes
- ✓ Provide optimal routing
- ✓ Scalability
- ✓ Robustness
- ✓ Simplicity
- ✓ Rapid convergence
- ✓ Some control of routing choices

    E.g. which links we prefer to use

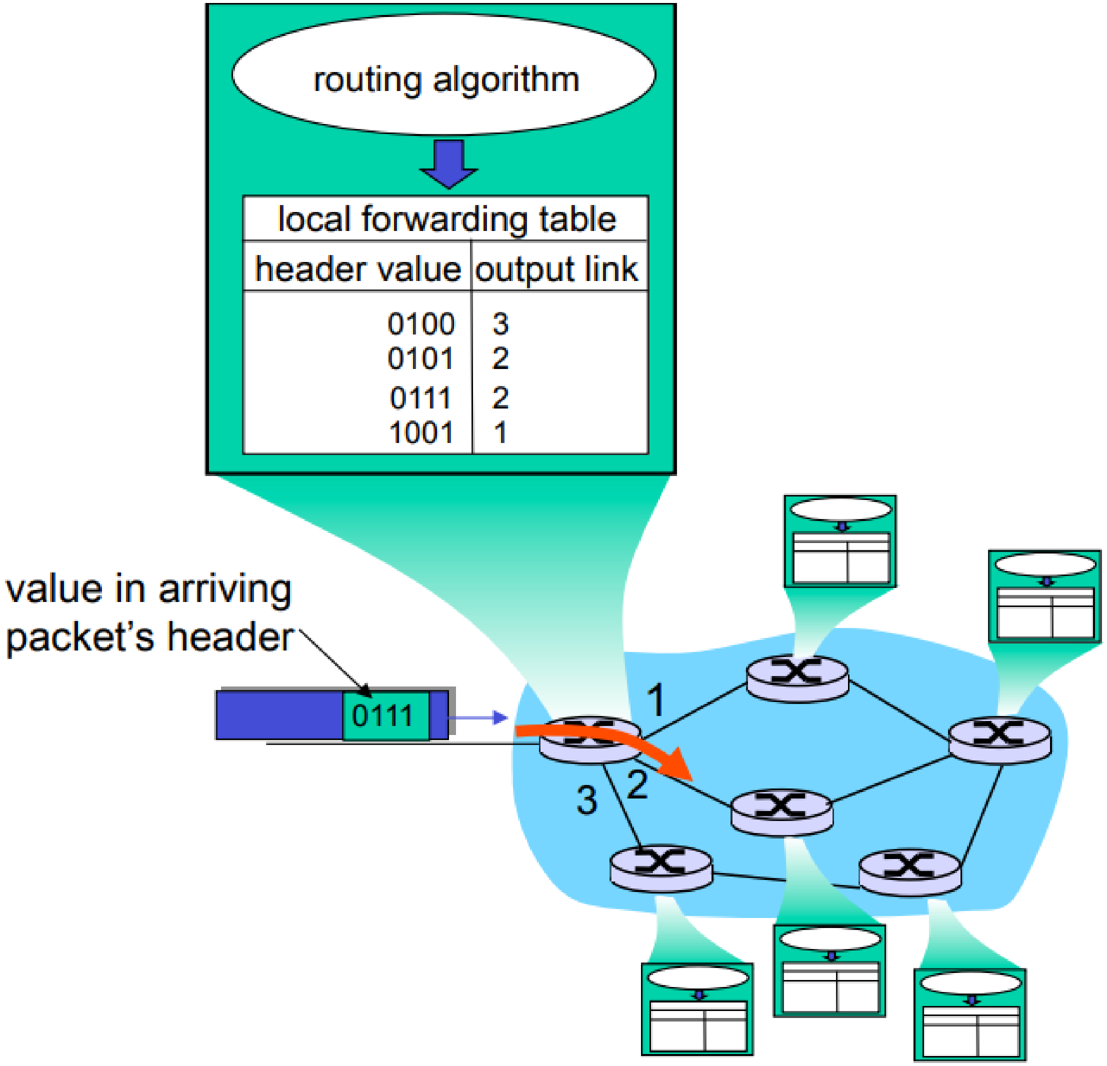
– Uses router resources (CPU cycles, memory, and link bandwidth).

– Administrators must have more advanced knowledge for configuration, verification, and troubleshooting

Dynamic vs Static routing Protocols

Routing type	Dynamic Routing	Static Routing
Configuration complexity	Generally independent of the network size	Increases with the size of the network
Administrator knowledge required	Advanced knowledge required	No additional knowledge required
Changes made to the topology	Automatically adapts to topology changes	Administrator intervention required
Scalability	Ideal for both simple and complex topologies	Ideal for simple topologies
Security	Less secure	More secure
Resource usage	Uses CPU, memory, and link bandwidth	No additional resources required
Predictability	Route depends on the current topology	The route to the destination is fixed

Interplay between routing & forwarding



Routing aspects

Acquisition of information about the IP subnets that are reachable through an internet :

- static routing configuration information
- dynamic routing information protocols (e.g., BGP4, OSPF, RIP, ISIS)
- each mechanism/protocol constructs a Routing Information Base (RIB)

Forwarding Table

Construction of a Forwarding Table

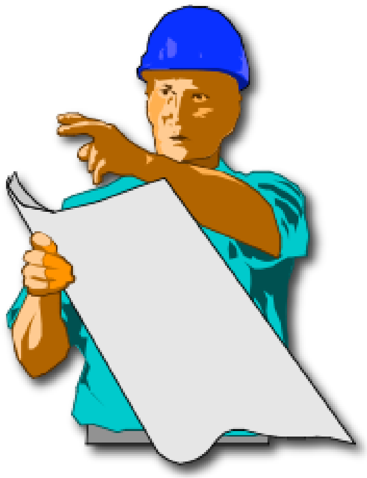
- ✓ Synthesis of a single table from all the Routing Information Bases (RIBs)
- ✓ information about a destination subnet may be acquired multiple ways
- ✓ a precedence is defined among the RIBs to arbitrate conflicts on the same subnet
- ✓ Also called a Forwarding Information Base (FIB)

Use of a Forwarding Table to forward individual packets

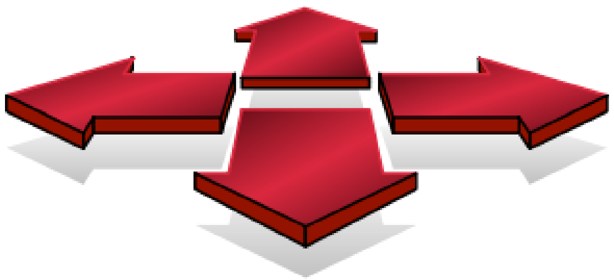
- ✓ selection of the next-hop router and interface
- ✓ hop-by-hop, each router makes an independent decision

RIB vs FIB

- Routing = building maps and giving directions



- Forwarding = moving packets between interfaces according to the "directions"



RIB vs FIB

RIB (Routing Information Base)

It contains:

- ✓ All routes learned by the router
  (static routes, dynamic routing protocols, connected networks, etc.)
- ✓ Multiple possible paths to the same destination
- ✓ Routes that may NOT be used for forwarding
  (e.g., backup routes, less-preferred routes)

☞ **The RIB is built by routing protocols (OSPF, EIGRP, BGP, RIP)**

and by the administrator (static routes).

FIB (Forwarding Information Base)

It contains:

Only the *best* route selected by the RIB

Optimized routes used directly for **packet forwarding**

Next-hop IP and exit interface information

☞ The FIB is used by the forwarding plane (CEF in Cisco).

☞ It is optimized for speed and performance.

RIB Construction

- ✓ Each routing protocol builds its own Routing Information Base (RIB)
- ✓ Each protocol has its own “view” of “costs”

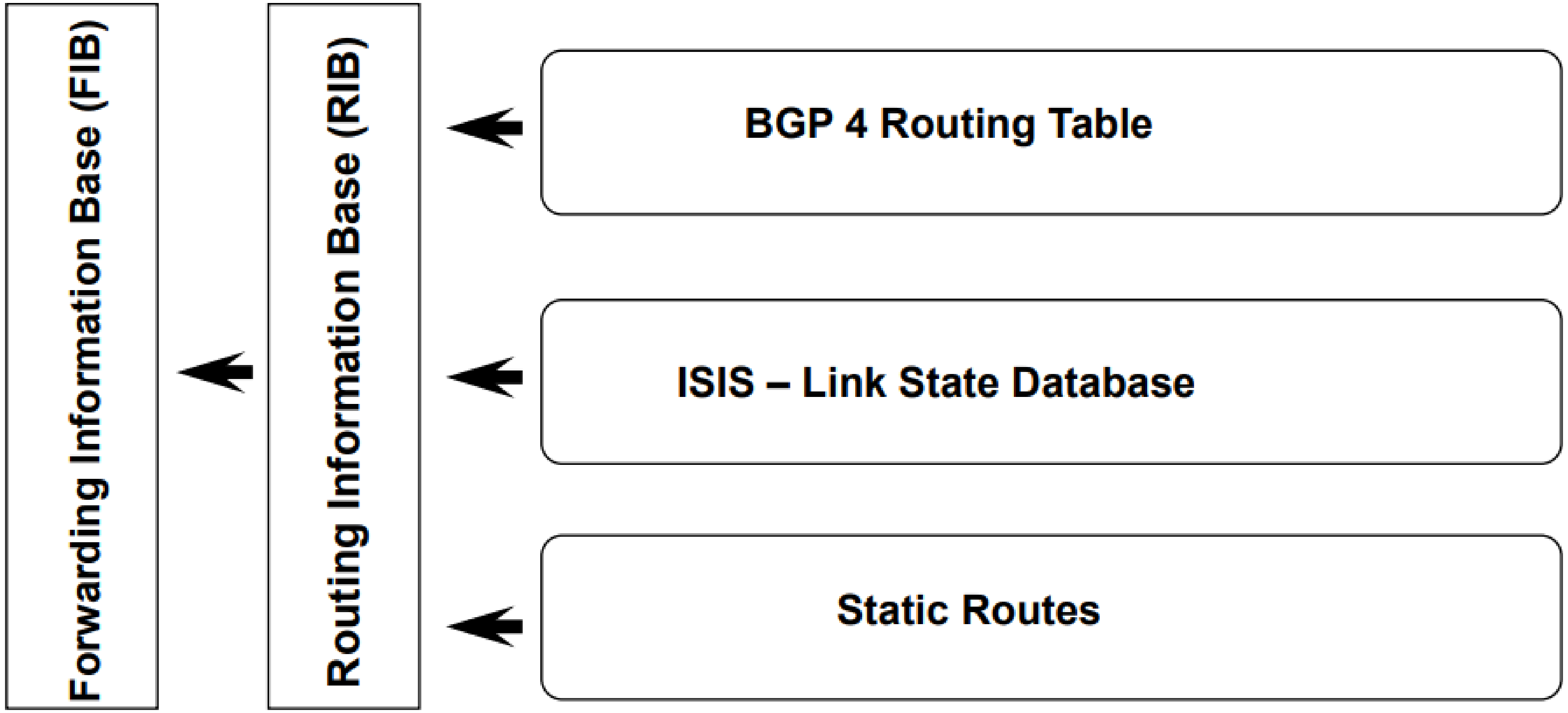
e.g., BGP4 is Autonomous System path length

FIB Construction

- ✓ **There is only ONE forwarding table!**
- ✓ An algorithm is used to choose one next-hop toward each IP destination known by any routing protocol
- ✓ the set of IP destinations present in any RIB are collected
- ✓ if a particular IP destination is present in only one RIB, that RIB determines the next hop forwarding path for that destination

RIB vs FIB

Routing Tables feed the forwarding tables



RIB vs FIB: **What if i have 2 paths to the same destination?**

Longest Prefix Match (LPM) — ALWAYS the first rule

The router *always* prefers the route with the most specific prefix.

Example:

RoutePrefix 192.168.1.0/24less specific192.168.1.0/26 **more specific — selected**

So even if the /24 comes from OSPF and the /26 is static, the router chooses **/26**.

Longest prefix match > everything else.

What if 2 routes have the same LPM?

Dynamic Routing

– Routing protocols have different natures depending on whether they:

process routing information **within a routing domain**,

or **connect several routing domains**.

– These routing domains are called **Autonomous Systems (AS)**

Autonomous Systems

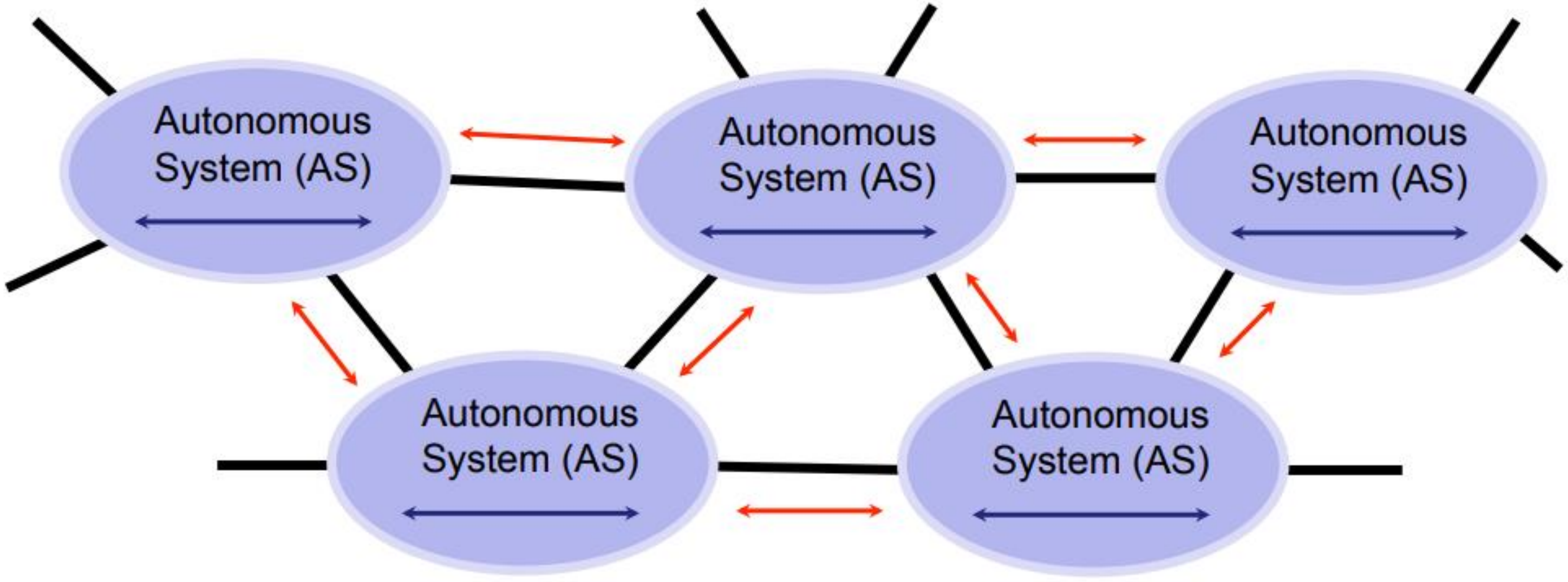
– An autonomous system is a set of networks under the administrative control of a single entity that shares a common routing policy on the Internet (RFC 1930).

• Example: ISPs (Internet Service Providers)

• Most companies and institutions with IP networks do not need an AS number because they are under the control of a larger entity such as an ISP.

– An AS is identified by a unique number assigned by **IANA (Internet Assigned Numbers Authority)**, the authority responsible for allocating IP address spaces. Before 2007, AS numbers were 16-bit; now they are 32-bit.

Autonomous Systems

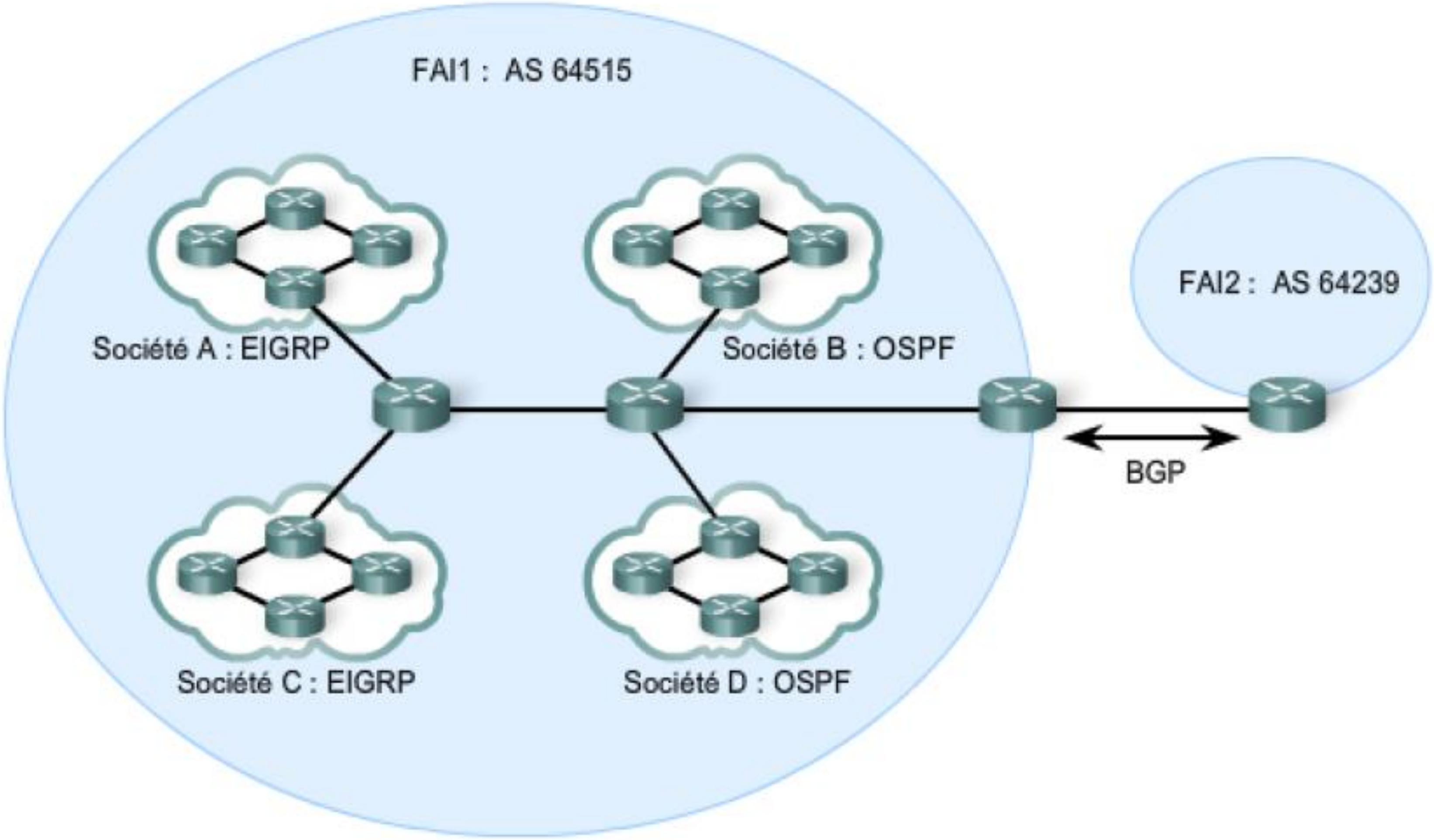


Autonomous System: A collection of IP subnets and routers under the same administrative authority.

Interior Routing Protocol

Exterior Routing Protocol

Autonomous Systems



Note: BGP is the only routing protocol that uses a real autonomous system number in its configuration.

Dynamic routing protocols

Routing protocols can be classified into different groups

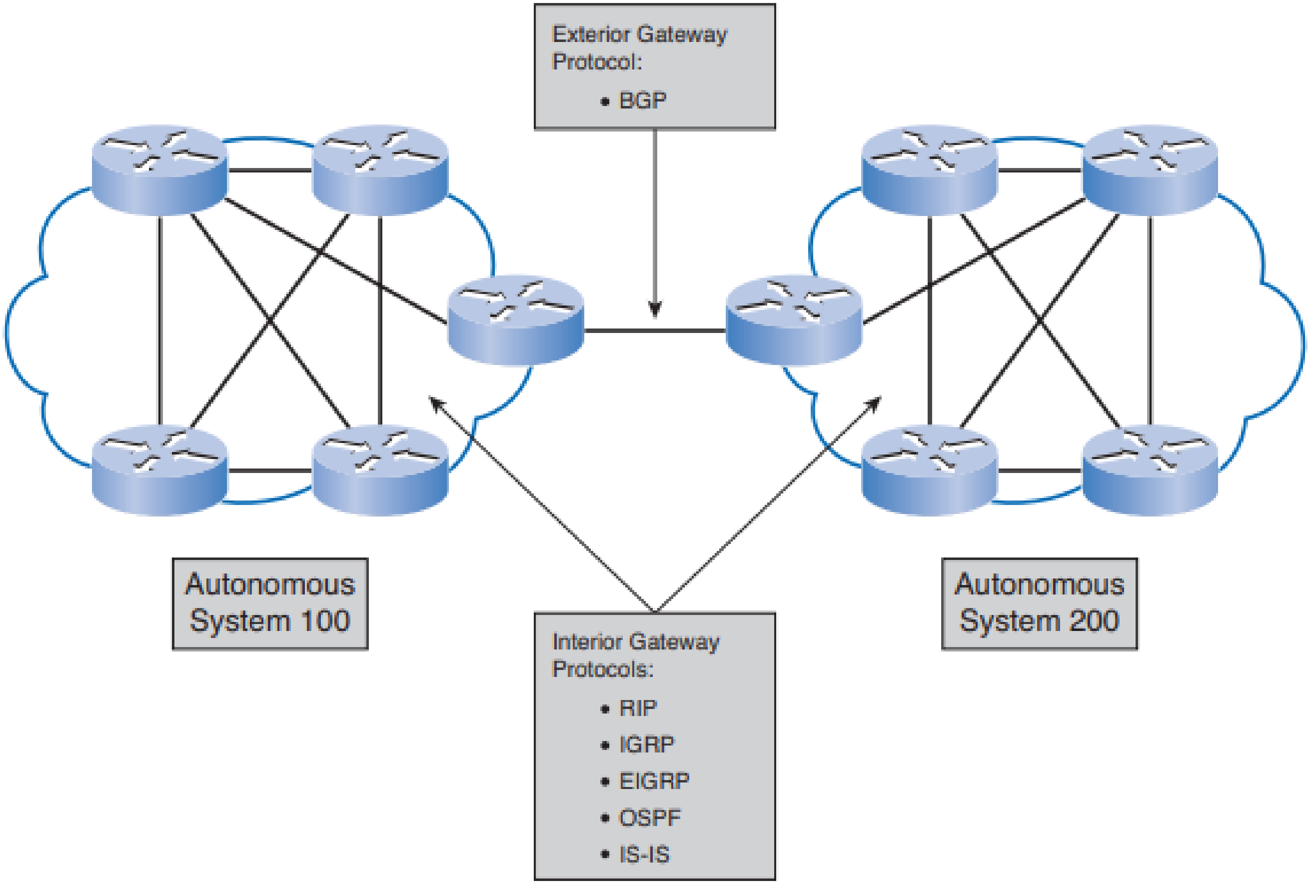
according to their characteristics:

- IGP or EGP
- Distance vector or link-state or path vector
- Classful or classless

IGP and EGP

■ Interior gateway protocols (IGP): Used for intra-autonomous system routing, that is, routing inside an autonomous system

■ Exterior gateway protocols (EGP): Used for inter-autonomous system routing, that is, routing between autonomous systems



Link state vs Distance vector vs path vector

Distance Vector Protocols

- Routers share **their routing tables** with **direct neighbors only**
- Routing decisions are based on **distance (metric)** and **direction (vector)**
- **Periodic updates** → even if no change occurs
- Slower convergence
- More prone to routing loops
- **Examples:** RIP, EIGRP (advanced distance vector)

Link-State Protocols

- Each router builds a **complete map (topology)** of the network
- Routers flood **link-state advertisements (LSAs)** to all routers in the area
- Only **triggered updates** sent when topology changes
- Faster convergence
- More scalable and more reliable
- **Examples:** OSPF, IS-IS

Link state vs Distance vector vs path vector

What does an LSA contain?

Depending on the type, an LSA may include:

Router ID

Connected networks (links)

Cost/metric of each link

Neighbor information

Subnets and masks

Area information

External routes (from other ASes)

Path Vector Protocols

Used for **inter-domain routing (between ASs)**.
Routers exchange **path information**, not metrics or LSAs.

Exchange: **Path + attributes** (AS-PATH, NEXT-HOP…)

Knowledge: Path through multiple ASes

Algorithm: **Path Vector Algorithm**

Updates: **Incremental**

Convergence: **Slower** than link-state

Loop risk: **Low** (AS-PATH loop detection)

Scalability: **Very high (Internet scale)**

BGP (the only widely used path vector protocol)

The path: A list of all Autonomous Systems the route has passed through

Classless vs Classful

Classful

- The subnet mask is **not included** → routers assume **default mask** (Class A, B, or C).
- Cannot support **VLSM (Variable Length Subnet Masking)**.

Limitations:

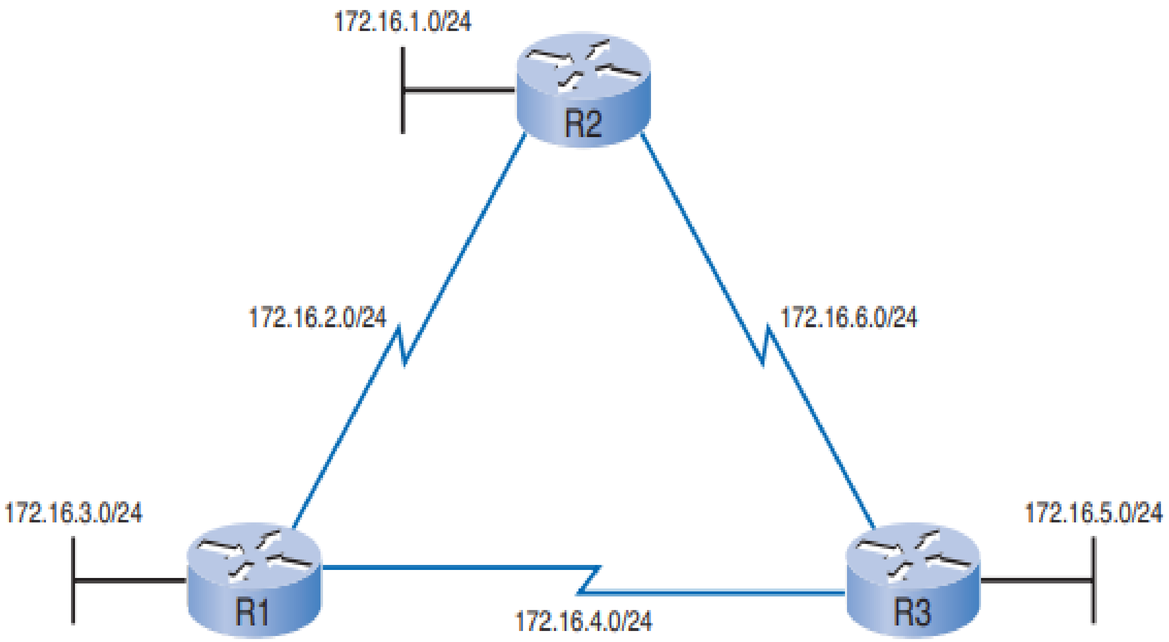
- Waste of IP addresses
- No discontiguous networks
- No flexible subnetting
- Examples: RIP v1 /IGRP

Classless

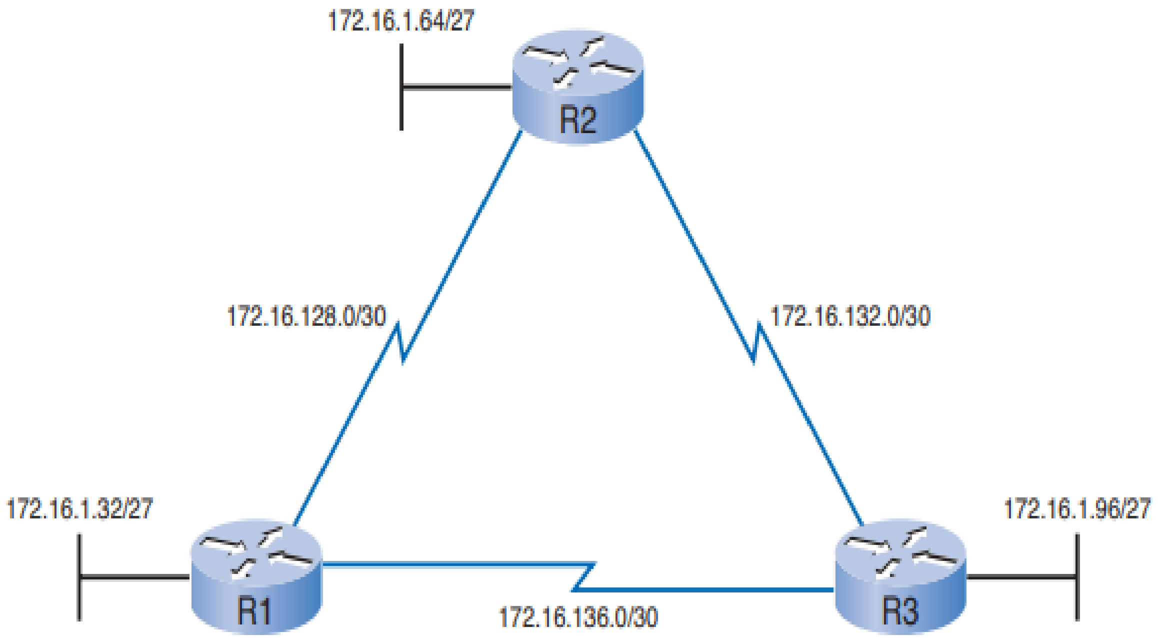
- Support for **VLSM**
- Support for **CIDR**
- Allow **discontiguous networks**
- Much more flexible and scalable
- Efficient IP address usage
- Better route summarization
- Works with modern networks
- Examples: **RIP v2** – **EIGRP**- **OSPF**- **BGP**

Classless vs Classful

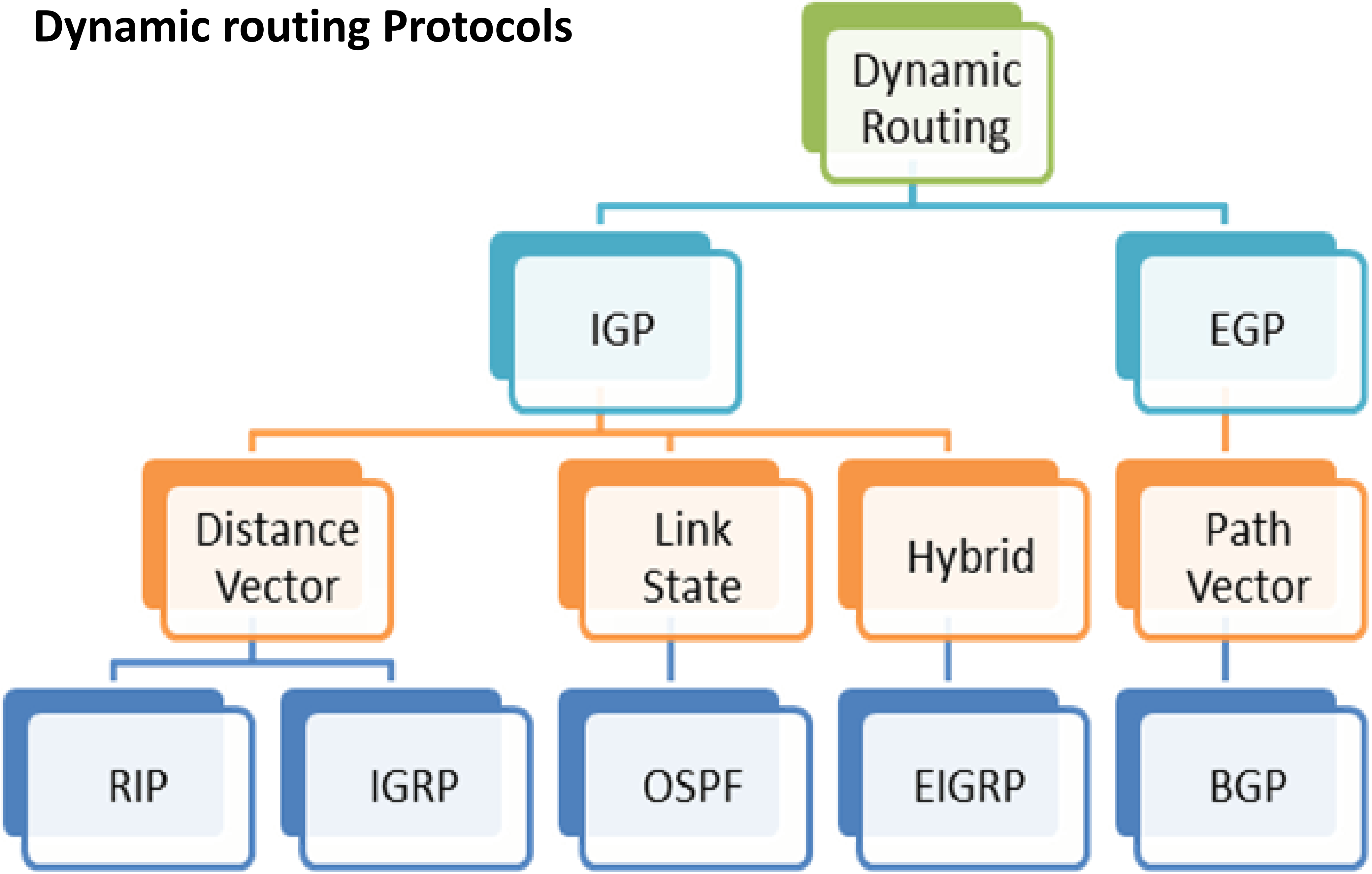
Classful



Classless



Dynamic routing Protocols



Convergence

The router updates its routing table automatically based on the information received from other routers and then distributes it to all routers.

- Updates take some time before reaching all routers.
- Convergence time is the time required for routers to share information, calculate the best paths, and update their routing tables.
- It depends on the speed at which routing information propagates and on the calculation of optimal paths.
- Convergence occurs when all routers have complete and accurate information about the network. It is triggered after a change in the status of a router or a link.
- Routing protocols can be classified according to their convergence speed:

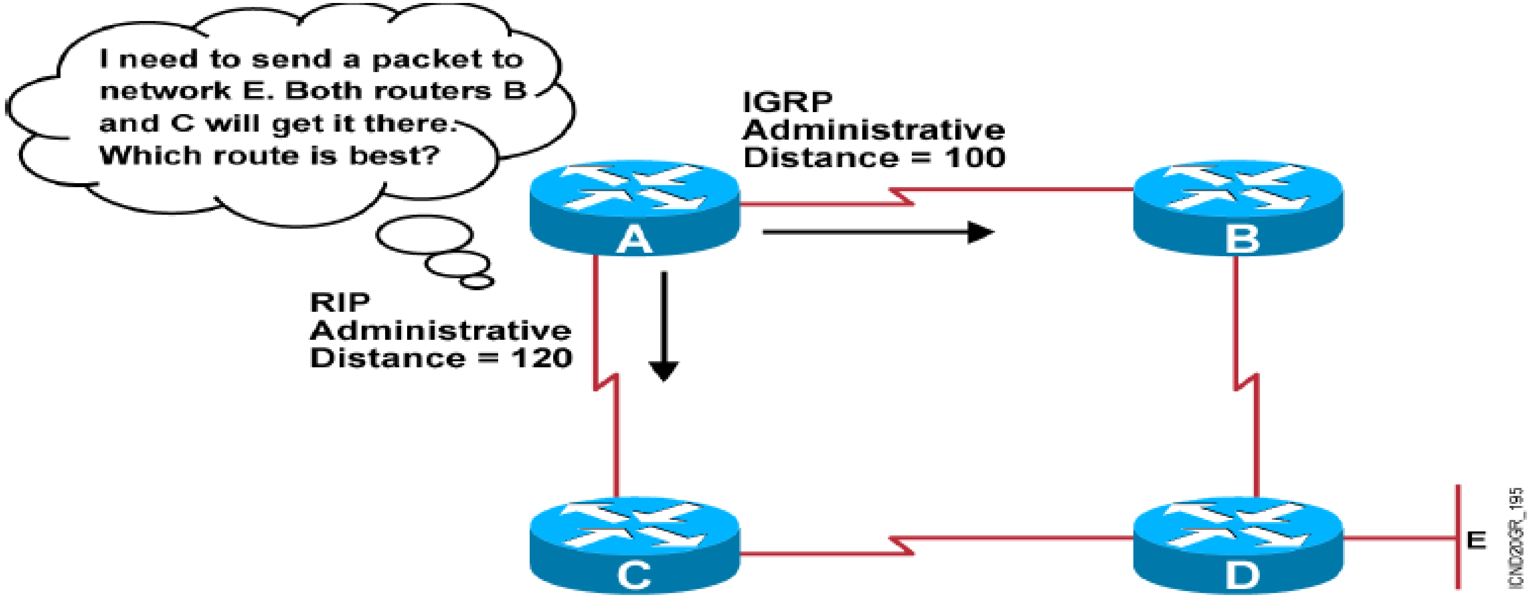
– Slower convergence: RIP and IGRP

– Faster convergence: EIGRP and OSPF

Administrative Distance

Administrative Distance

- The lower the value, the more the route source is preferred.
- An administrative distance of 0 is ideal.
- Only a directly connected network has an administrative distance equal to 0, which cannot be modified.
- By default, a static route will always be more prioritized than a route learned by OSPF.



Metric

Each routing protocol uses a metric to select the best path.
A metric is a value used by routing protocols to assign access costs to remote networks and to select the best path.

The following metrics are used in routing protocols:

– **Hop count:** Counts the number of routers a packet must pass through.

– **Bandwidth:** Influences path selection by preferring the path with the highest bandwidth.

– **Load:** Takes into account the utilization of a specific link in terms of traffic.

– **Delay:** Considers the time required for a packet to travel along a path.

– **Reliability:** Evaluates the probability of link failure, calculated from the number of interface errors or past link failures.

– **Cost:** A value determined by IOS or by the network administrator to indicate a preferred route. The cost may represent a single metric, a combination of metrics, or a policy.

Administrative Distance

- It is possible to deploy multiple dynamic routing protocols on the same network, but it is less common.
- In certain situations, it may be necessary to route the same network address using multiple routing protocols such as RIP and OSPF.
- Since each routing protocol uses different metrics, with RIP using hop count and OSPF using bandwidth, it is not possible to compare the metrics to determine the best path.
- In this case, how does a router determine which route to install in the routing table when it has discovered the same network from multiple routing sources?

Administrative Distance

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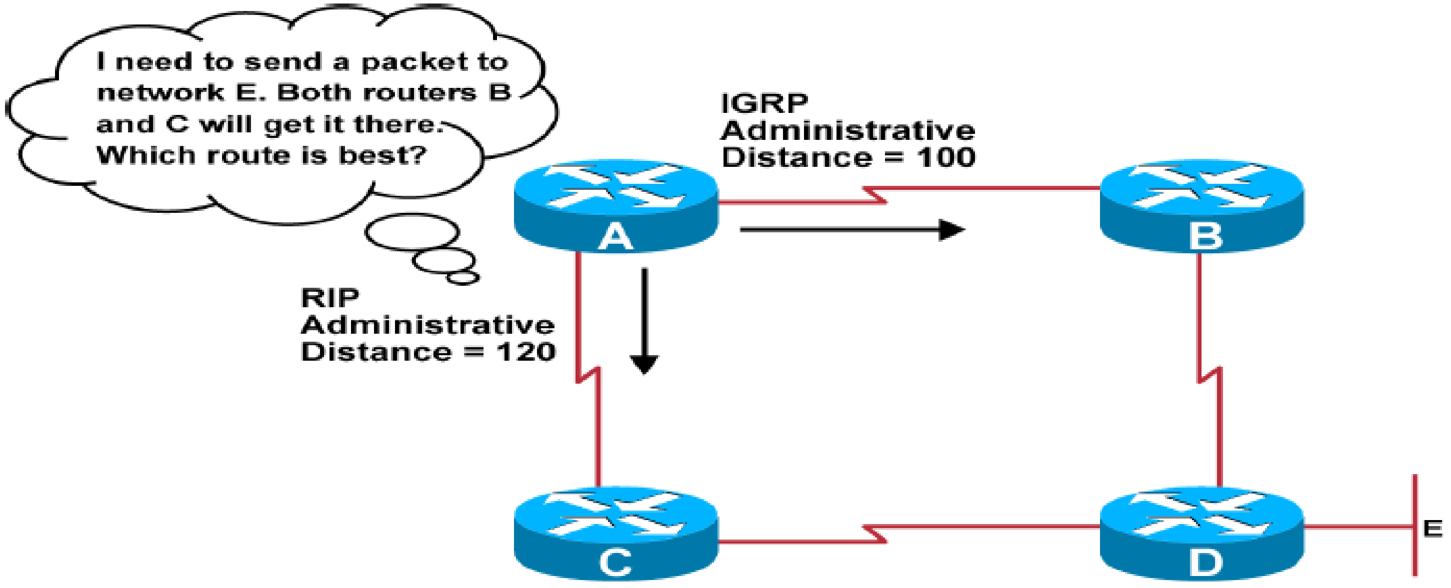

Administrative Distance

Routing protocols	Administrative distance
Interface connectée	0
Route statique	1
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP v1, v2	120
External EIGRP	170
Internal BGP	200
Inconnu	255

Administrative Distance

Administrative distance is the first number in brackets in the routing table.

Administrative distance values are verified using the commands:

show ip route

show ip protocols

```
R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

D    192.168.1.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0/0
C    192.168.2.0/24 is directly connected, Serial0/0/0
C    192.168.3.0/24 is directly connected, FastEthernet0/0
C    192.168.4.0/24 is directly connected, Serial0/0/1
R    192.168.5.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
D    192.168.6.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0/0
R    192.168.7.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
R    192.168.8.0/24 [120/2] via 192.168.4.1, 00:00:08, Serial0/0/1
```

Administrative distance

```
R 192.168.1.0/24 [120/2] via 10.0.0.2
```

The numbers in brackets **[120/2]** represent:

120 = Administrative Distance (AD)

2 = Metric (in this case, 2 hops for RIP)

RIP

- ✓ **It is a classful routing protocol**
- ✓ Administrative distance is 120
- ✓ Request and response messages are carried by UDP port 520
- ✓ The metric = hop count
- ✓ A route with hop count > 15 is considered unreachable.
- ✓ Routing table update by broadcast every 30 seconds.
- ✓ Lifetime of a non-refreshed entry: 90 seconds.
- ✓ Deletion of unusable entries: 180 seconds

RIP

Enabling the RIP protocol (global command)

```
router rip
```

Removing the RIP protocol (global command)

```
no router rip
```

Declaring the networks that RIP will broadcast (advertise) - here we only declare the networks to which the router is physically connected.

```
network network-number
```