IPv4 and IPv6 Routing

Fundamentos de Redes

Mestrado Integrado em
Engenharia de Computadores e Telemática
DETI-UA

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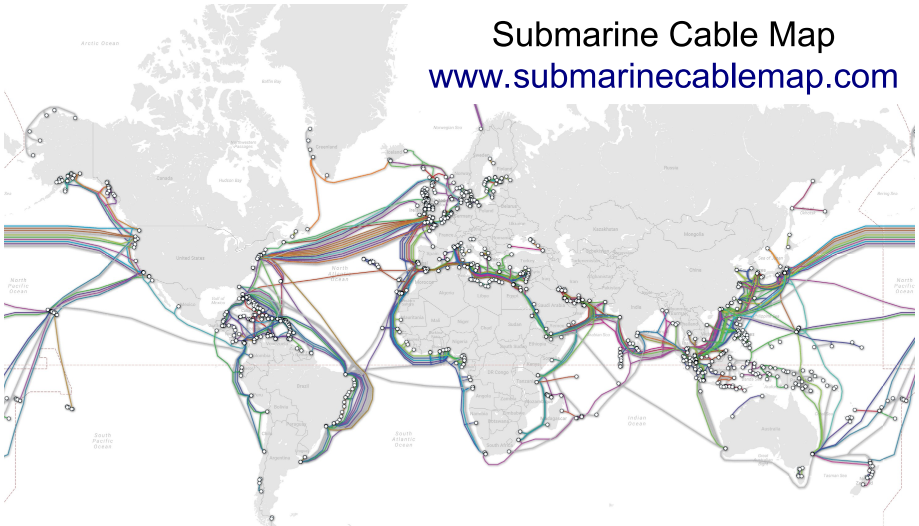
deti.ua.pt

Internet Physical Structure (1)

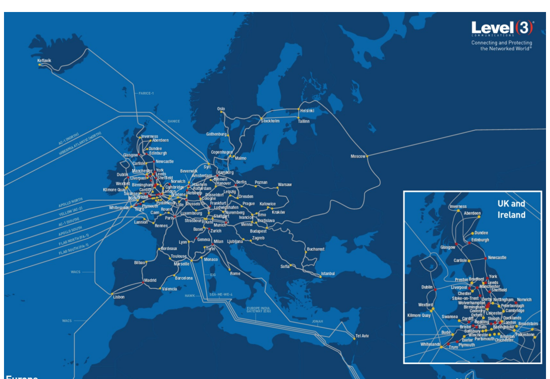
- Submarine Cables and IXs (majority of) information is public.
  - Internet Exchange (IX): Place where ISP exchange networking information/traffic.

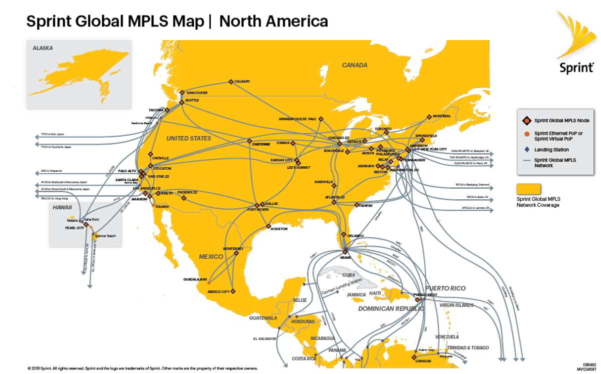
Submarine Cable Map
www.submarinecablemap.com

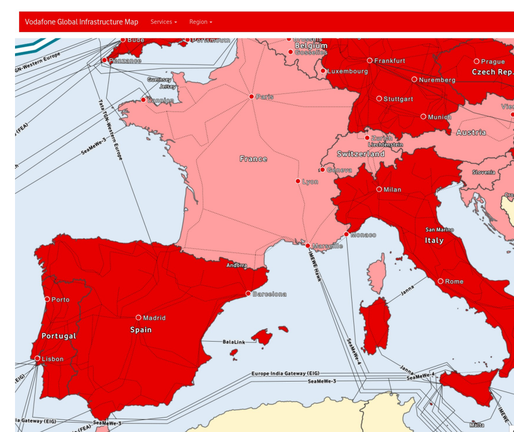


Internet Exchange Map
www.internetexchangemap.com

- Land Cables information is sparse (sometimes secret) and provider specific.

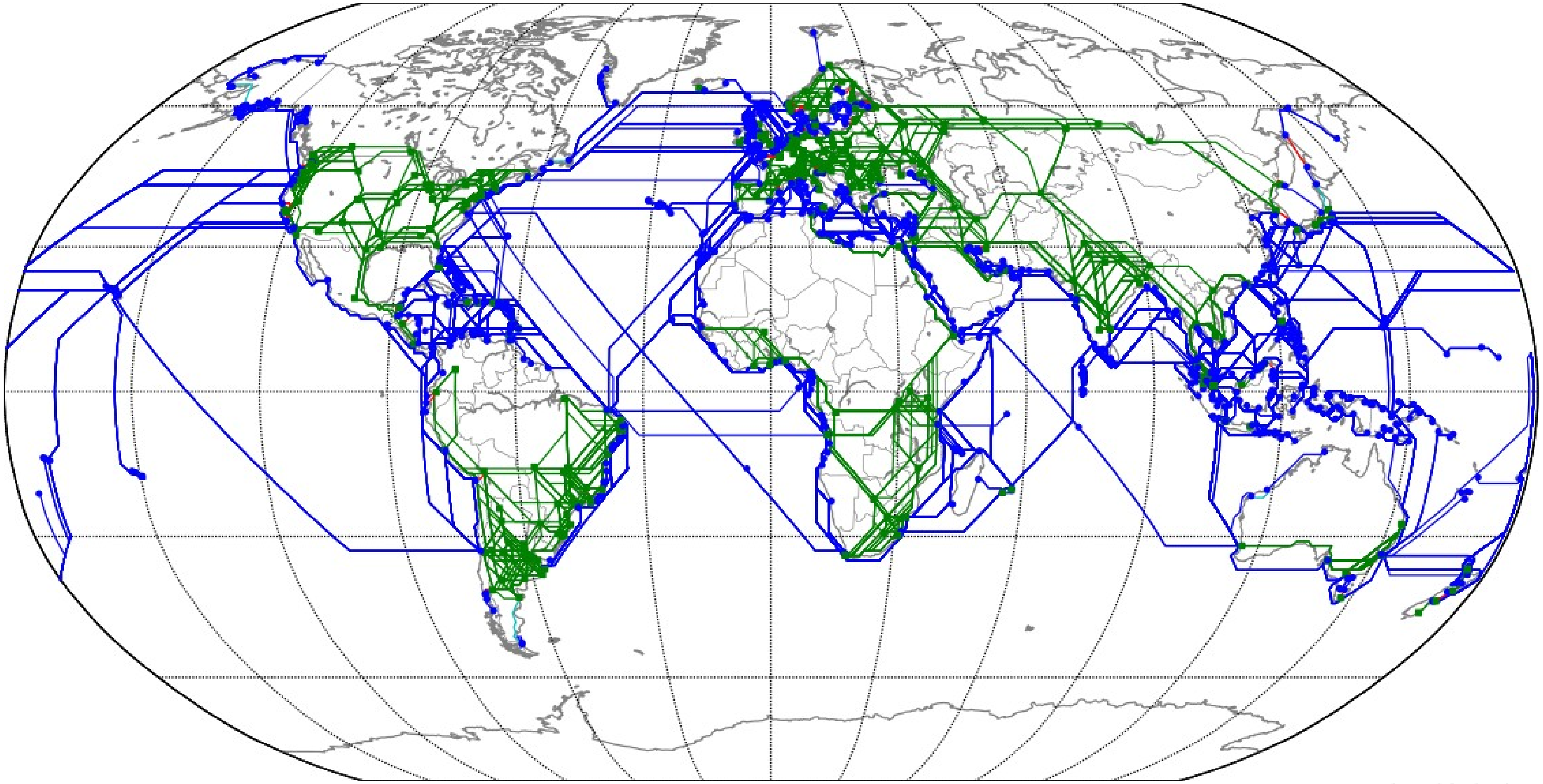






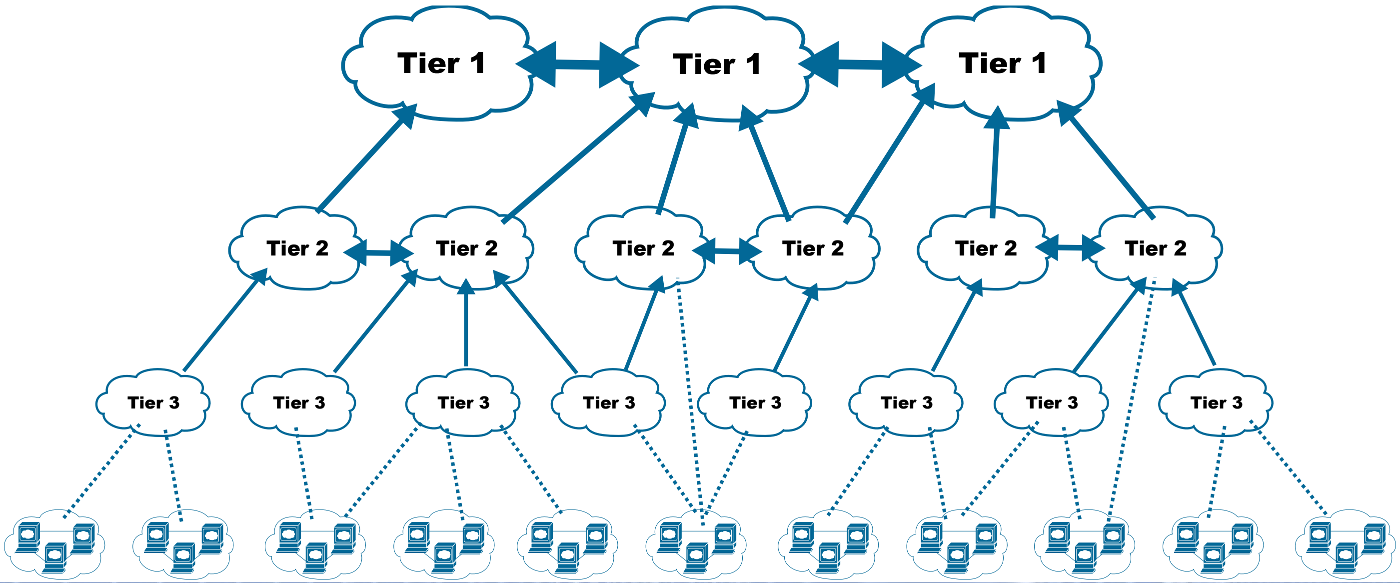
Internet Physical Structure (2)

- It is only possible to have an approximated overview of the Internet physical structure based on extrapolations of publicly available information.



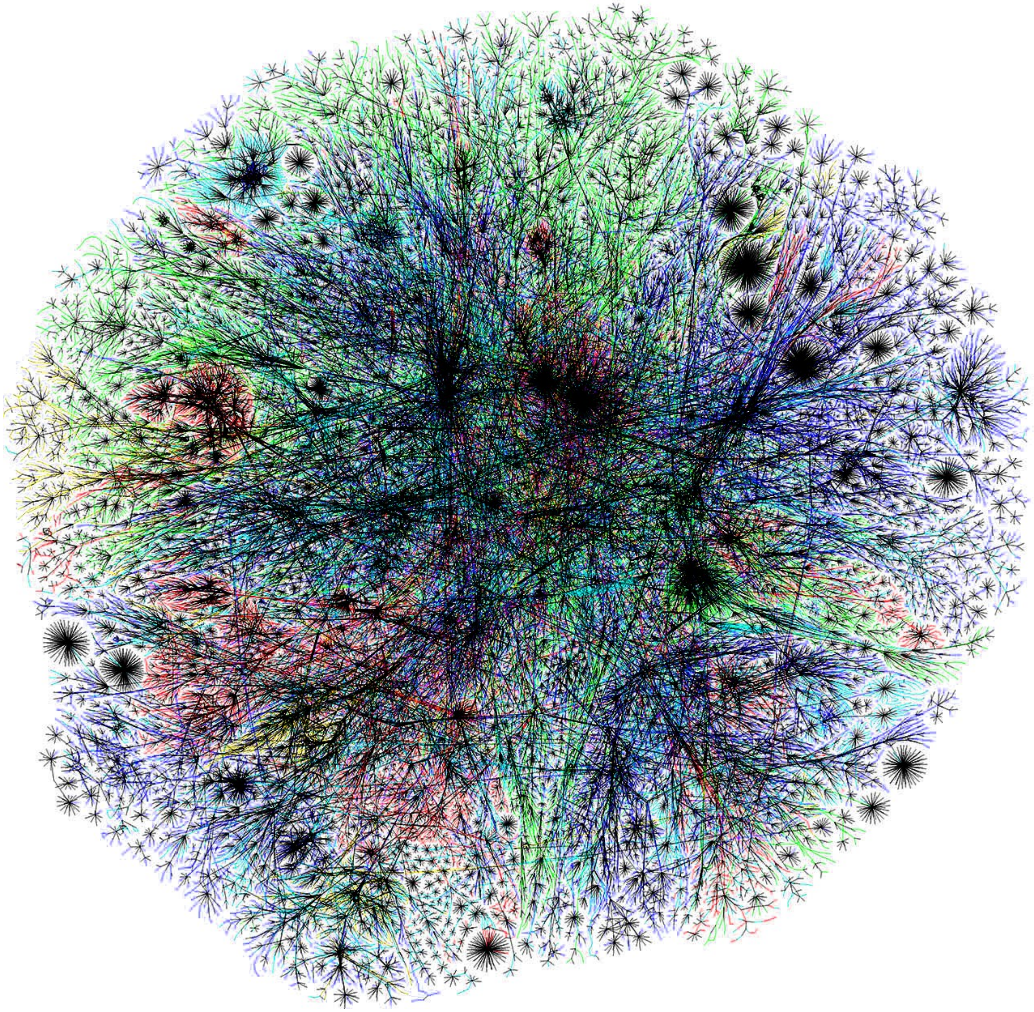
Internet Logical Structure (1)

- ISPs must agree on how there are going to exchange traffic (Peering agreement).
  - One ISP may only transport traffic from/to the other peer internal networks (non-transit), or
  - May transport traffic from/to any network the other peer sends towards it (transit).
- Tier ISP classification depends only how big the ISP is, in terms of geographical scope and how inter-operate with other ISPs.
  - Typically operate large high-capacity networks.
- Tier levels
  - Tier 1 ISPs often do not provide services to end-users, instead they provide Internet transit (transport of traffic from other ISPs networks).
  - Tier 2 ISPs also provide Internet transit at a non-global level, but require Tier1 ISPs to achieve global connectivity. May provide services to end-users.
  - Tier 3 operate at a regional level, provide services to end-users, and require Tier1 and Tier2 ISPs to achieve global connectivity.



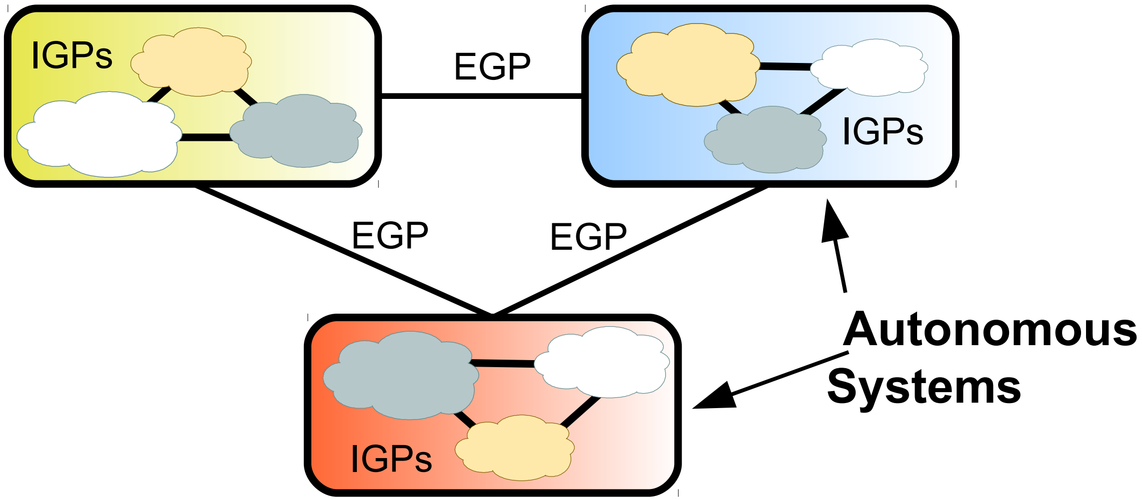
Internet Logical Structure (2)

- Internet complexity:



Autonomous Systems

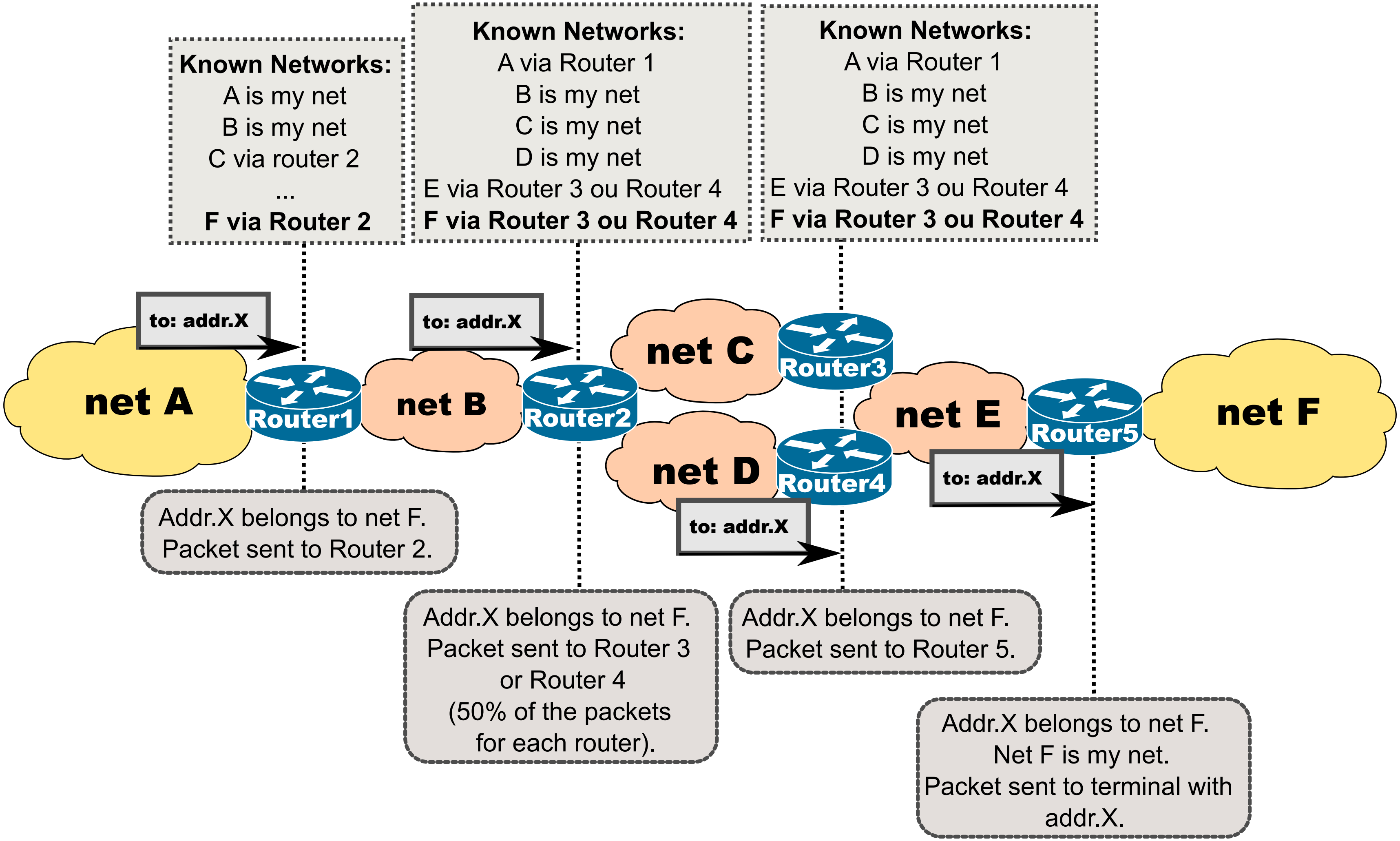
- AS (Autonomous System) – set of routers/networks with a common routing policy and under the same administration.
- Routing inside an AS is performed by IGPs (Interior Gateway Protocols) such as RIPv1, RIPv2, RIPng, OSPFv2, OSPFv3, IS-IS and EIGRP.
  - Called Internal Routing
- Routing between AS is performed by EGPs (Exterior Gateway Protocols) such as BGP and MP-BGP.
- IGPs and EGPs have different objectives:
  - IGPs: optimize routing performance
  - EGPs: optimize routing performance obeying political, economic and security policies.



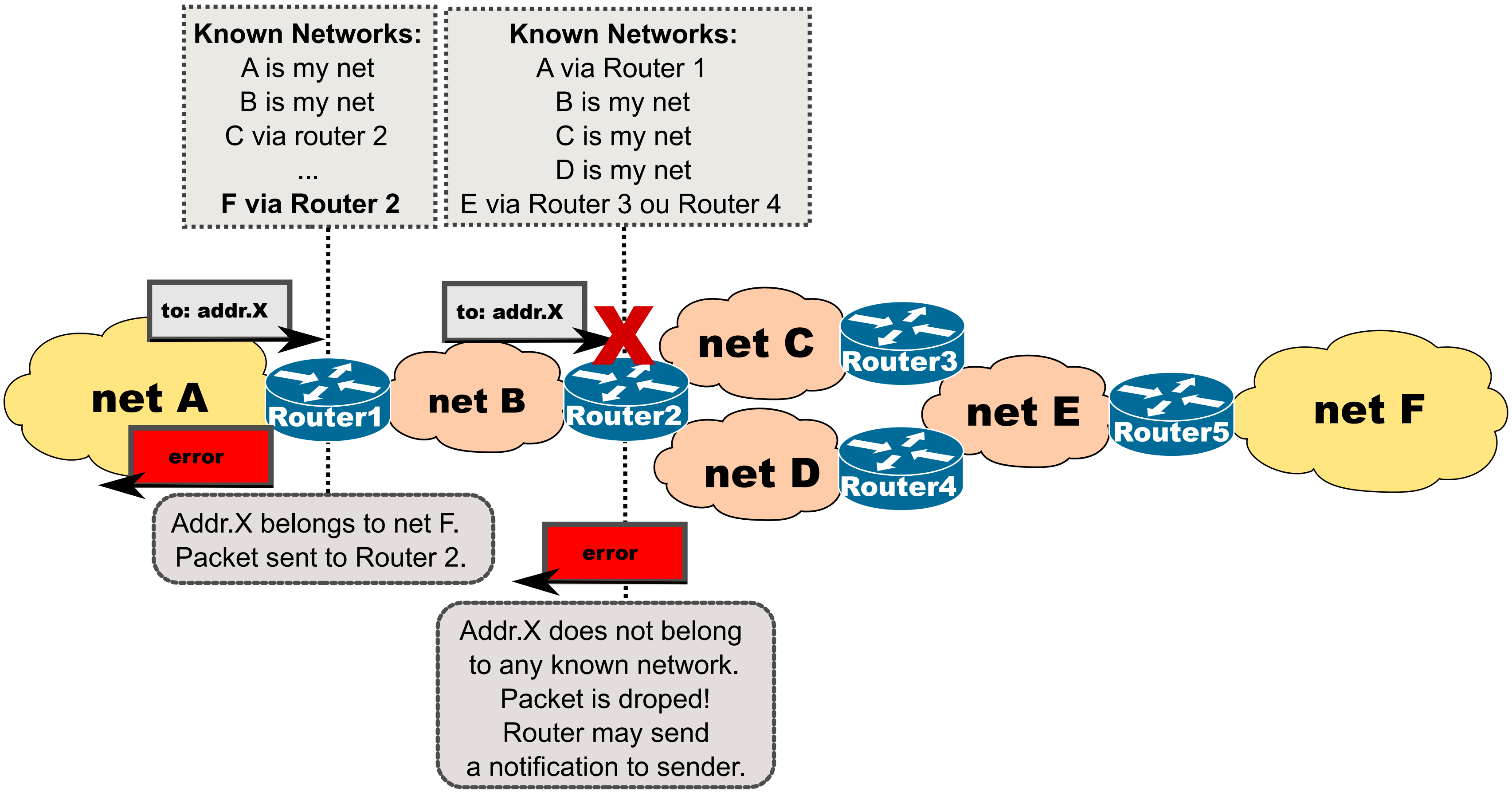
IP Routing Overview (1)

- Routers forward packets toward destination networks.
- Routers must be aware of destination networks to be able to forward packets to them.
- A router knows about the networks directly attached to its interfaces
- For networks not directly connected to one of its interfaces, however, the router must rely on outside information.
- A router can be made aware of remote networks by:
  - Static routing: An administrator manually configure the information.
  - Dynamic routing: Learns from other routers.
  - Routing policies: Manually routing rules that outweigh static/dynamic routing.
- If a packet for un unknown network reaches the router this will drop the packet, and MAY notify the sender about the routing error.

IP Routing Overview (2)



IP Routing Overview (3)



Routing Tables (1)

- Define how a remote network is reachable:
  - Next-hop (identified by its address), and
  - Local interface that provides connection.
- A network may be reachable using more than one path: (next-hop,local interface) pair.
- Mandatory elements
  - **Destination prefix**
  - **Destination mask**
  - **Metric**
    - Could be defined by key tags.
      - e.g., Directly Connected
  - One or both
    - **Next-hop address**
    - **Output interface**
- Optional elements
  - **Administrative distance**
  - **Protocol**
  - **Entry age (last time information received)**
  - **Scope**
  - **Flags**
  - **Source-specific**
- The next path hop (next hop address) may be found using more than one table entry (recursive resolution).
  - e.g., Network A is reachable through address from network B, Network B is reachable through address from network C, …
- The next-hop address may be obtained from external information (configurations or other mechanisms).
  - e.g., Tunnels, Point-to-point connections, etc…
- When an entry uses a next-hop address from an unknown network, that entry is removed.
- All entries obtain by dynamic methods may have an entry age (time since last update/confirmation).
  - After a timeout value without an update/confirmation the entry is removed.

Cisco IOS

```
R     200.1.1.0/24 [120/1] via 200.19.14.10, 00:00:16, FastEthernet0/1
      200.19.14.0/24 is variably subnetted, 2 subnets, 2 masks
C        200.19.14.0/24 is directly connected, FastEthernet0/1
L        200.19.14.4/32 is directly connected, FastEthernet0/1
R     200.38.0.0/24 [120/1] via 200.43.0.8, 00:00:03, FastEthernet1/1
      200.43.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        200.43.0.0/24 is directly connected, FastEthernet1/1
L        200.43.0.1/32 is directly connected, FastEthernet1/1
```

Linux: route -n

```
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         193.136.92.1    0.0.0.0         UG    100    0        0 enp5s0f1
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 enp5s0f1
193.136.92.0    0.0.0.0         255.255.254.0   U     100    0        0 enp5s0f1
```

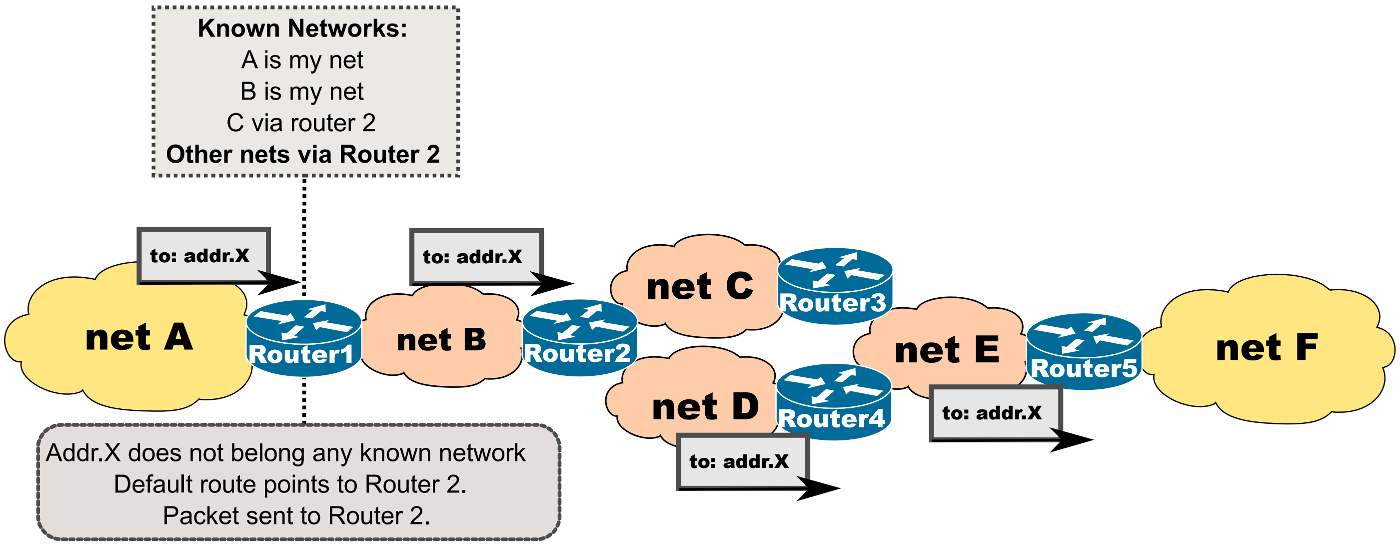
Linux: ip route

```
default via 193.136.92.1 dev enp5s0f1  proto static  metric 100
169.254.0.0/16 dev enp5s0f1  scope link  metric 1000
193.136.92.0/23 dev enp5s0f1  proto kernel  scope link  src 193.136.93.104  metric 100
```

Routing Tables (2)

- An IP address may have multiple matches on a Routing Table:
  - Example: 192.168.1.12
  - Will match:
    - 192.168.1.0/25 via ...
    - 192.168.1.0/24 via ...
    - 192.168.0.0/23 via ...
    - 192.168.0.0/16 via ...
    - …
  - Router will choose entry with the largest network prefix (most specific network).
    - i.e., 192.168.1.0/25 via ...
- Load balancing
  - Routing tables may have more than one path for each network
    - Traffic will be divided by all entries.
    - By packet, flow (TCP session, UDP IPs/port), etc...
      - E.g, packet 1 path 1, packet 2 path 2, packet 3 path 1, …
      - Flow 1 path 1, flow 2 path 2, flow 3 path 3, flow 4 path 1, flow 5 path 2, ...

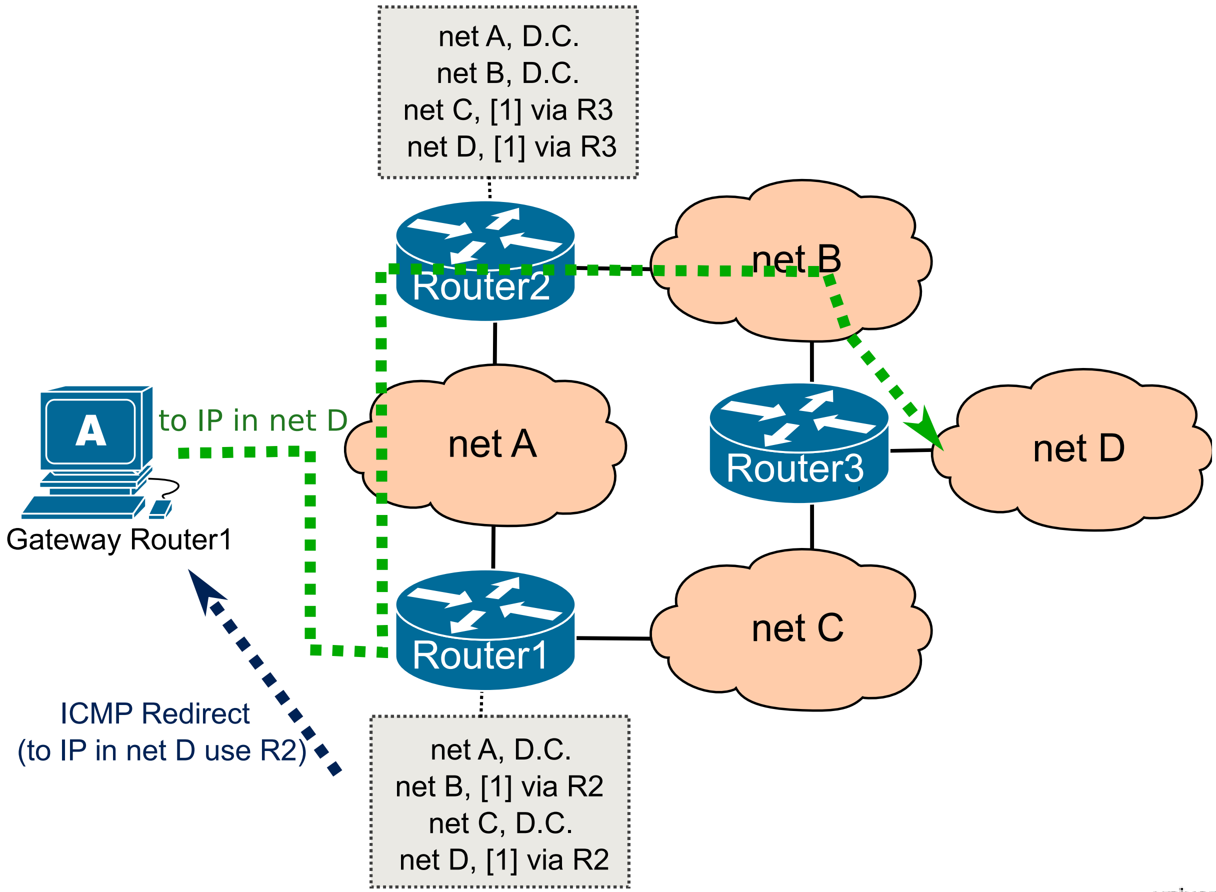
Default Routes



- In some circumstances, a router does not need to recognize the details of remote networks.
- The router can be configured to send all traffic (or all traffic for which there is not a more specific entry in the routing table) to a specific neighbor router.
- This is known as a default route.
- Default routes are either dynamically advertised using routing protocols or statically configured.
- IPv4 default route - 0.0.0.0/0
- IPv6 default route - ::/0

ICMP Redirect

- When a Router has a path defined via the interface from which received a packet:
  - The router sends an **ICMP Redirect** to the sender, defining a new gateway for that specific destination (IP address),
  - The sender updates its routing table for that specific destination address.



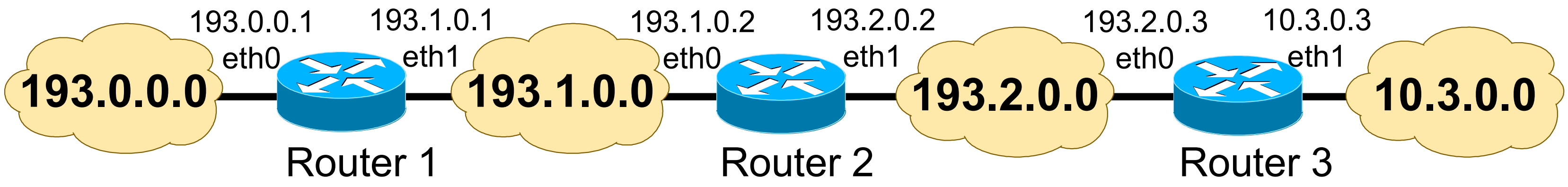
Administrative Distance

- Most routing protocols have metric structures and algorithms that are incompatible with other protocols.
- It is critical that a network using multiple routing protocols be able to seamlessly exchange route information and be able to select the best path across multiple protocols.
- Routers use a value called administrative distance to select the best path when they learn from different routing protocols the same destination (same network prefix and mask length).
- The Protocol/Method with the lowest Administrative Distance is preferred
  - The Administrative Distance value is configurable.
- Example:
  - Static [**1**/0] 192.168.1.0/24 via … ← Chosen!
  - RIP [**120**/1] 192.168.1.0/24 via …
  - OSPF [**110**/1] 192.168.1.0/24 via ...

Static Routing

- Stating routing do not react to network topology changes.
  - If a link fails, the static route is no longer valid if it is configured to use that failed link, so a new static route must be configured.
  - Connectivity may be lost until intervention of an administrator.
- Static routing does not scale well when network grows.
  - Administrative burden to maintain routes may can become excessive.
- Static routes can be used in the following circumstances:
  - When the administrator needs total control over the routes used by the router.
  - When a backup to a dynamically recognized route is necessary.
  - When it is used to reach a network accessible by only one path (a stub network).
    - There is no backup link, so dynamic routing has no advantage.
  - When a router connects to its ISP and needs to have only a default route pointing toward the ISP router, rather than learning many routes from the ISP.
    - Again, a single path of access without backup.
  - When a router is underpowered and does not have the CPU or memory resources necessary to handle a dynamic routing protocol.
  - When it is undesirable to have dynamic routing updates forwarded across low bandwidth links.

Static Routing Examples



- Example 1
  - Router2 do not know networks 193.0.0.0/24 and 10.3.0.0/24
  - Necessary static routes:
    - 193.0.0.0/24 accessible through 193.1.0.1 (eth1, Router1)
    - 10.3.0.0/24 accessible through 193.2.0.3 (eth0,Router3)
- Example 2
  - Router1 do not know networks 193.2.0.0/24 and 10.3.0.0/24
  - Necessary static routes:
    - 193.2.0.0/24 accessible through 193.1.0.2 (eth0, Router2)
    - 10.3.0.0/24 accessible through 193.1.0.2 (eth0, Router2)

      OR
    - Using default route: 0.0.0.0/0 accessible through 193.1.0.2 (eth0, Router2)

Dynamic Routing

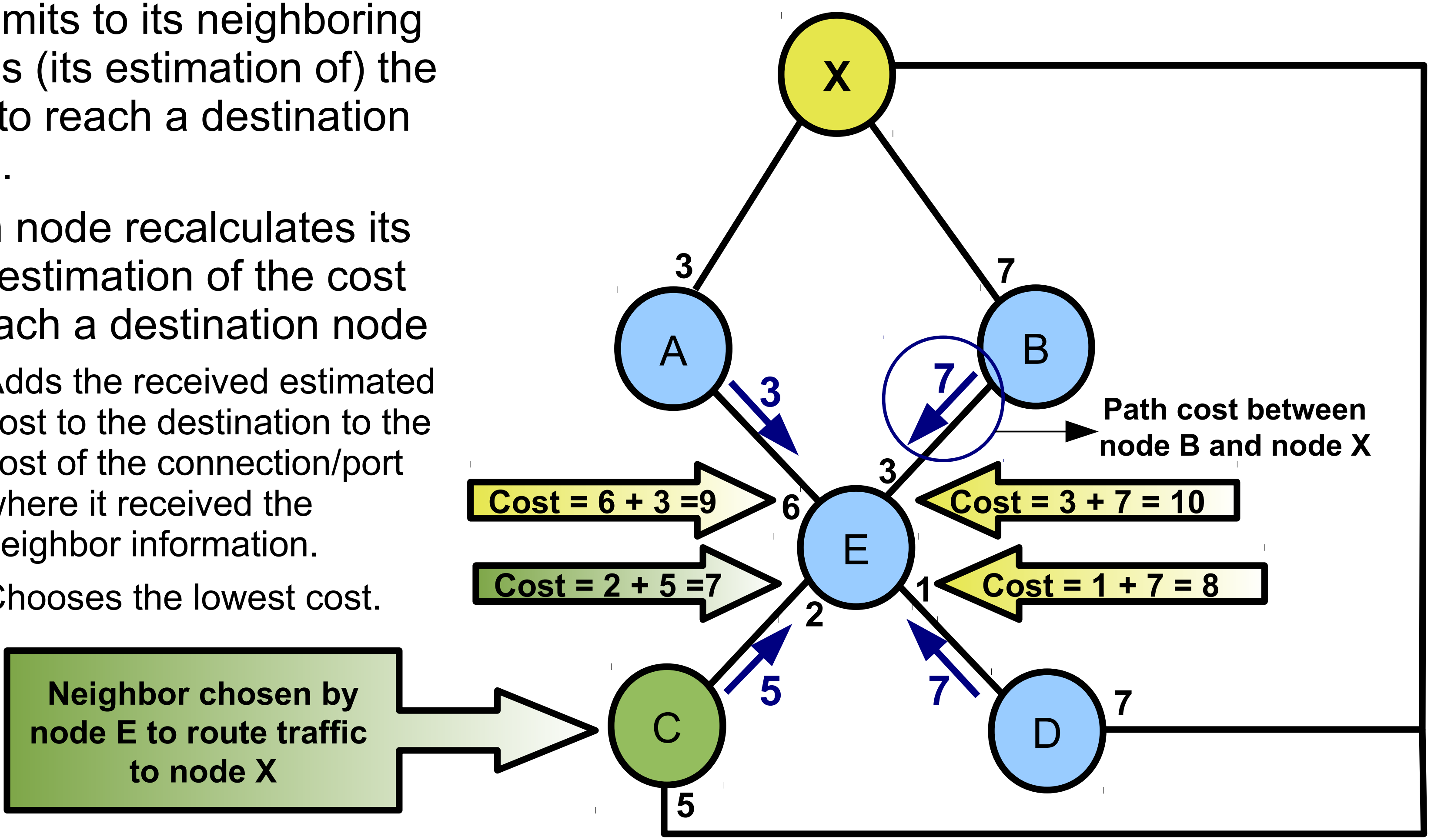
- Dynamic routing allows the network to adjust to changes in the topology automatically, without administrator involvement.
- Routers exchange information about the reachable networks and the state of each network/link.
  - Routers exchange information only with other routers running the same routing protocol.
  - When the network topology changes, the new information is dynamically propagated throughout the network, and each router updates its routing table to reflect the changes.

Distance Vector vs. Link State

- *Distance vector*
  - Each router knows only the distance/cost to all network destinations.
  - Information (distances to all known destinations) is periodically sent by routers to its neighbors
  - Each router determines the lowest cost paths to all destinations based on a distributed and asynchronous version of the Bellman-Ford algorithm
  - Examples: RIP, IGRP, EIGRP
- *Link state*
  - Routers know the complete network topology.
  - Use a centralized algorithm to determine the lowest cost path to all destinations.
  - The required information to build and maintain the network topology in each
  - Examples: OSPF, IS-IS

Distributed and Asynchronous Bellman-Ford Algorithm

- Each node periodically transmits to its neighboring nodes (its estimation of) the cost to reach a destination node.
- Each node recalculates its own estimation of the cost to reach a destination node
  - Adds the received estimated cost to the destination to the cost of the connection/port where it received the neighbor information.
  - Chooses the lowest cost.



RIP (Routing Information Protocol)

- Is a *distance vector* protocol
  - Each router maintains a list of known networks and, for each network, an estiamtion of the cost to reach it – this is called a distance vector.
  - Each router periodically send to its neighboring routers its own distance vector (partially or complete) – announcement/update.
  - Each router uses the distance vector sent by its neighbors to update its own distance vector.
- The path cost to a destination is given by the number of output router interfaces (or more simplistically the number of routers/hops in the path).
  - Maximum cost is 15.
  - A cost of 16 is considered infinite (or unattainable destination).
- Each router determines the entries in its own routing table, based on the constructed distance vector.
  - For each destination (network) learned, it adds an entry to that network that uses the path (or paths) with the lowest cost, using as next-hop the neighboring router(s) that announced that network with that lowest cost path.

RIP Version 1

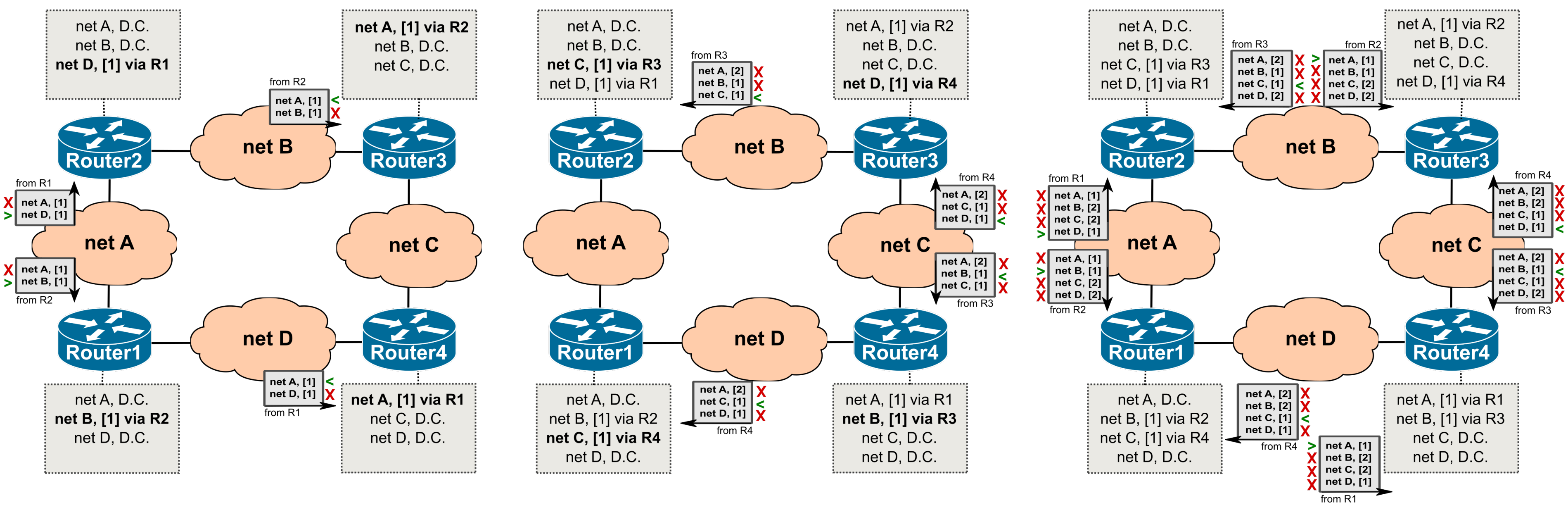
- RIP Version 1 (RIPv1) is a classfull protocol.
  - Does not announces (sub-)networks masks, only network prefixes.
  - Network masks are assumed based on the incoming interface mask.
    - If all networks have the same mask it works perfectly, however, when networks with different masks exist it is problematic.
- RIPv1 uses the broadcast address 255.255.255.255 to send announcements/updates.
  - All network devices must process the packets.
- Does not support authentication.
  - Messages may be forged by an attacker.

RIP Version 2

- RIP Version 2 (RIPv2) is a *classless* protocol.
  - RIPv2 announcements include network prefix and mask.
  - Supports variable length masks.
- RIPv2 used the multicast address 224.0.0.9 to send announcements/updates only to routers running RIPv2.
- RIPv2 supports authentication using message-digest and clear text password.
  - Clear text password authentication <u>should</u> not be used!

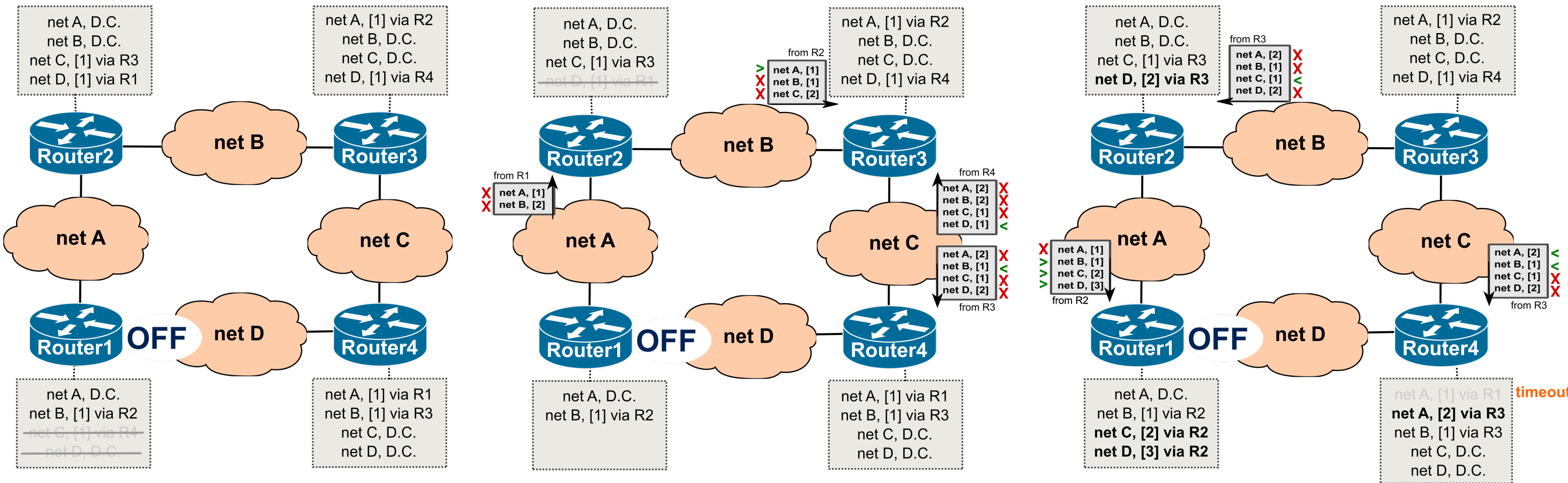
RIP Algorithm (1)

- Assuming that Router1 and Router2 send announcements first.
  - With split-horizon disabled.



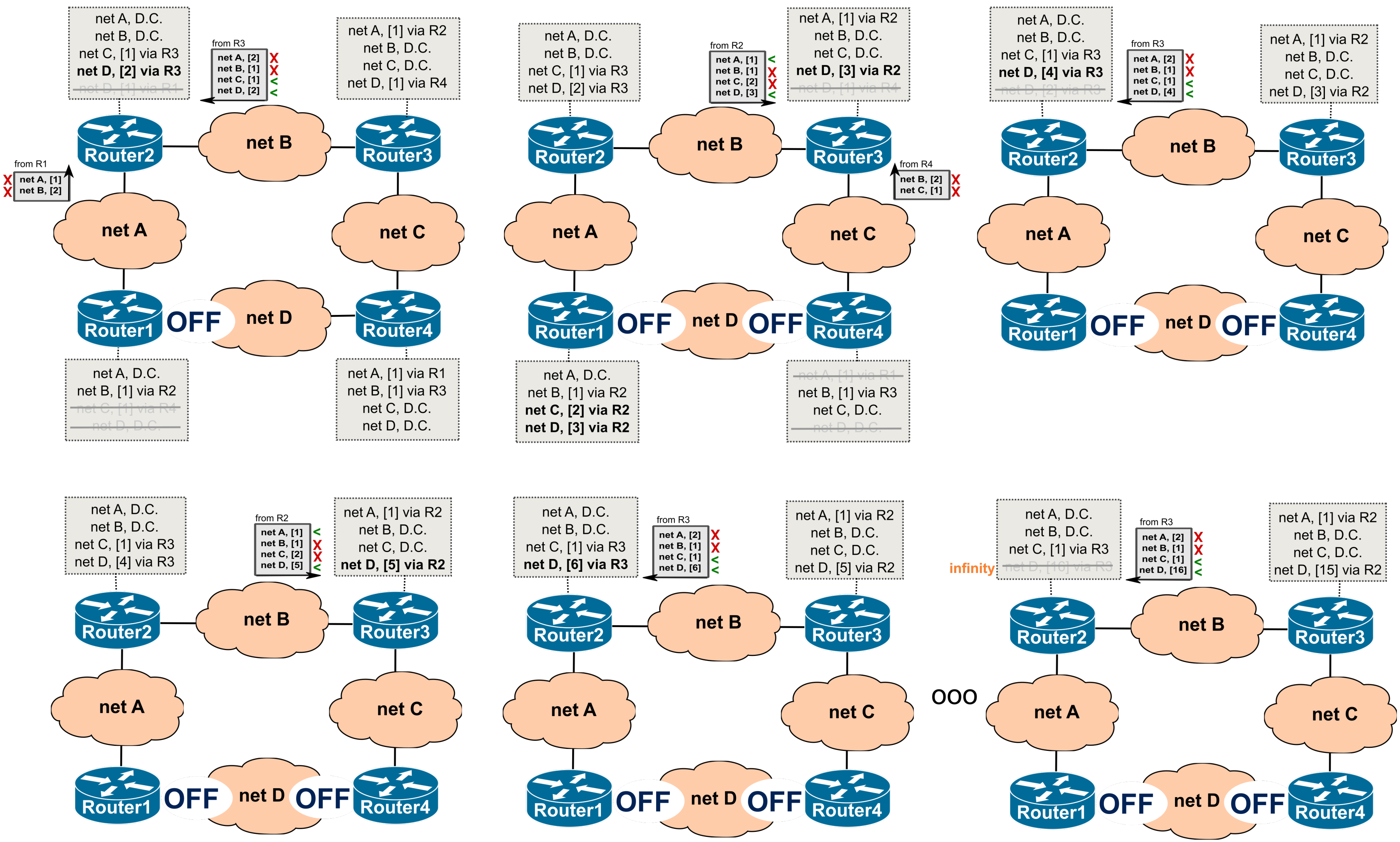
RIP Algorithm (2)

- Assuming Router1 connection to network D goes down.
  - No triggered updates.



Count to Infinity Problem

- When multiple failures occur before algorithm convergence!



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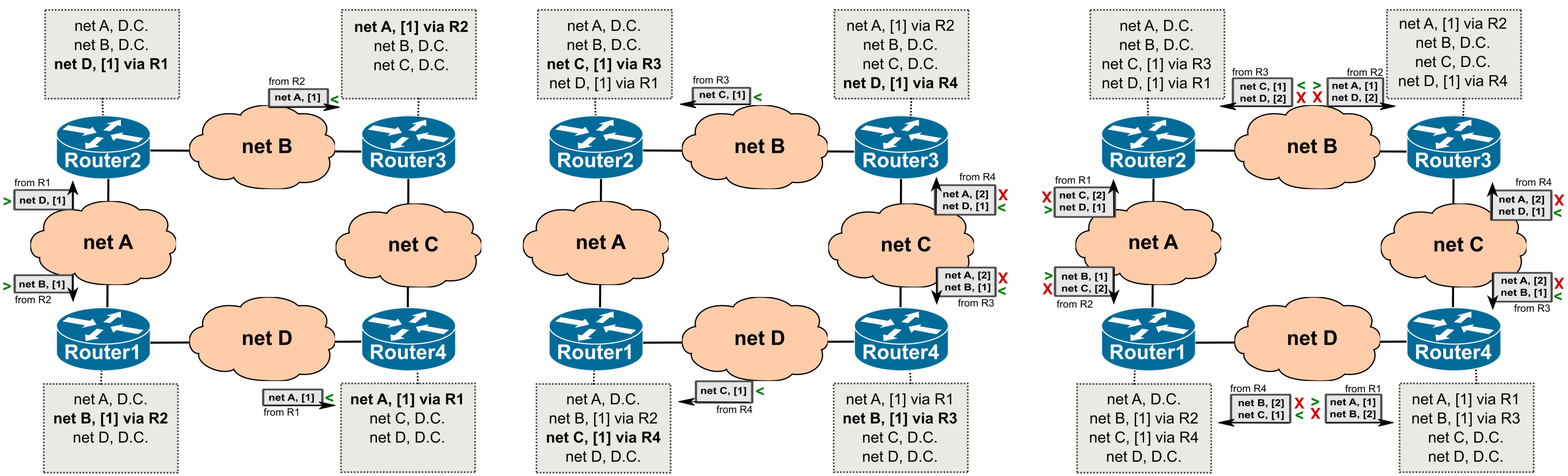
Split-Horizon (1)

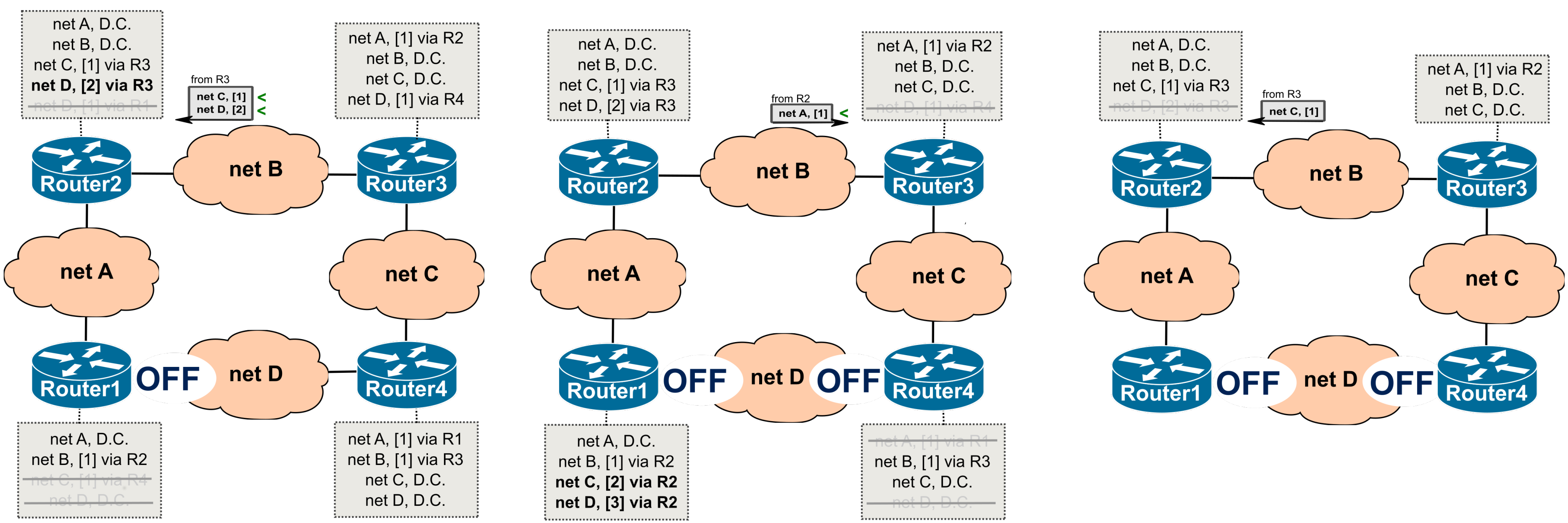
- Solution for the count to infinity problem.
- Each Router, in each interface, announces only the networks in which that interface is not used to provide the best path to that destination.
- Split horizon lowers the convergence time of the routing tables when there is a topology change.
  - RIPv1 e RIPv2 supports it.
- Assuming Router1 and Router2 start sending announcements first:



- In Split horizon with Poisoned Reverse, routers announce all networks but set metric to infinity (16) for networks learned by the interface by which they are sending the announcement.
  - Larger update messages.

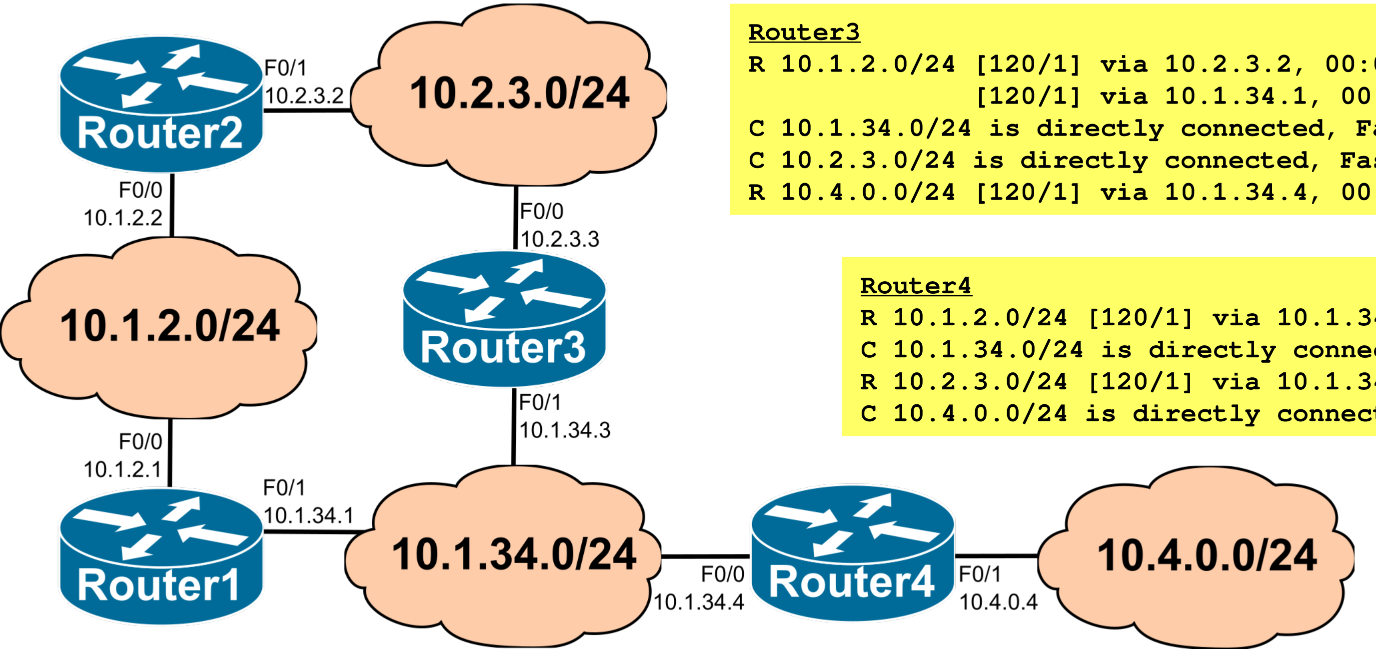
Split-Horizon (2)

- Solution for the count to infinity problem.
- Prevents any routing loops that involve two routers.
  - It is possible to end up with patterns in which three or more routers are engaged in mutual deception.
- Assuming Router1 and Router4 loose connection to network D almost simultaneously:



Routing Tables with RIP

```
Router2
C 10.1.2.0/24 is directly connected, FastEthernet0/0
R 10.1.34.0/24 [120/1] via 10.2.3.3, 00:00:21, FastEthernet0/1
               [120/1] via 10.1.2.1, 00:00:11, FastEthernet0/0
C 10.2.3.0/24 is directly connected, FastEthernet0/1
R 10.4.0.0/24 [120/2] via 10.2.3.3, 00:00:21, FastEthernet0/1
              [120/2] via 10.1.2.1, 00:00:11, FastEthernet0/0
```




```
Router3
R 10.1.2.0/24 [120/1] via 10.2.3.2, 00:00:08, FastEthernet0/0
              [120/1] via 10.1.34.1, 00:00:28, FastEthernet0/1
C 10.1.34.0/24 is directly connected, FastEthernet0/1
C 10.2.3.0/24 is directly connected, FastEthernet0/0
R 10.4.0.0/24 [120/1] via 10.1.34.4, 00:00:24, FastEthernet0/1
```

```
Router4
R 10.1.2.0/24 [120/1] via 10.1.34.1, 00:00:18, FastEthernet0/0
C 10.1.34.0/24 is directly connected, FastEthernet0/0
R 10.2.3.0/24 [120/1] via 10.1.34.3, 00:00:29, FastEthernet0/0
C 10.4.0.0/24 is directly connected, FastEthernet0/1
```

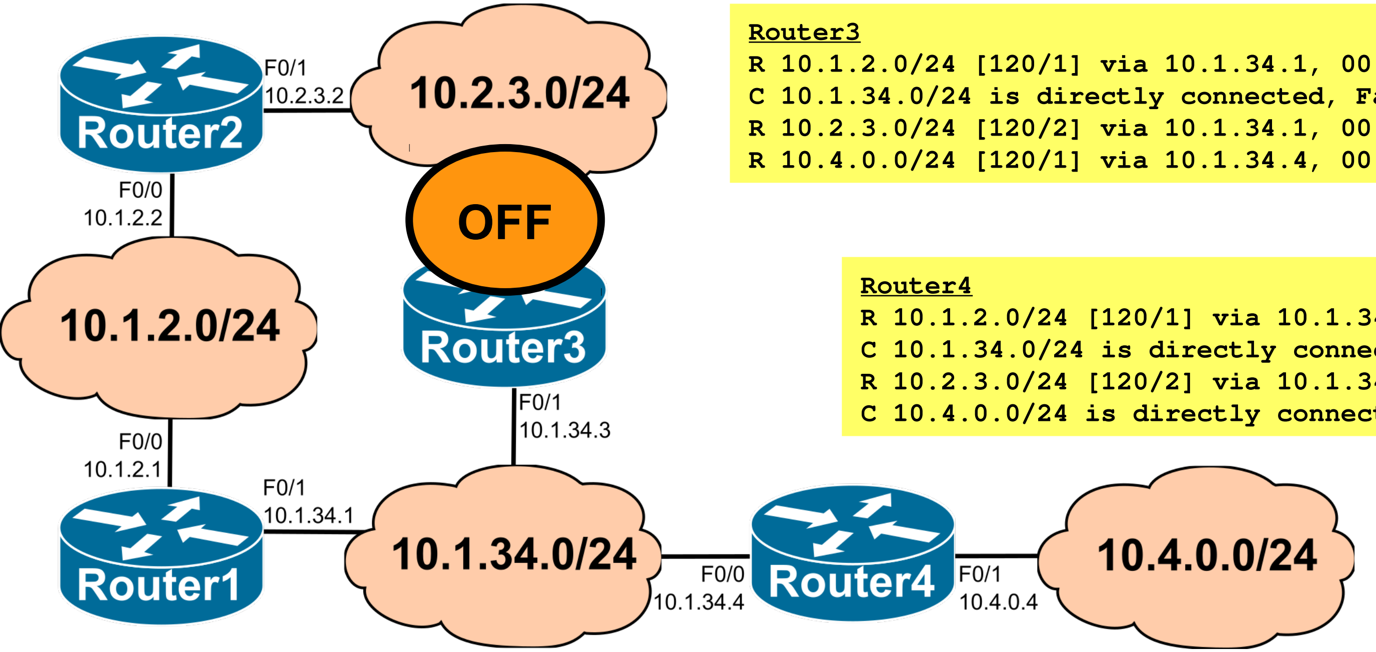
```
Router1
C 10.1.2.0/24 is directly connected, FastEthernet0/0
C 10.1.34.0/24 is directly connected, FastEthernet0/1
R 10.2.3.0/24 [120/1] via 10.1.34.3, 00:00:11, FastEthernet0/1
              [120/1] via 10.1.2.2, 00:00:01, FastEthernet0/0
R 10.4.0.0/24 [120/1] via 10.1.34.4, 00:00:24, FastEthernet0/1
```

Routing Tables with RIP

```
Router2 (AFTER 3 minutes TIMEOUT)
C 10.1.2.0/24 is directly connected, FastEthernet0/0
R 10.1.34.0/24 [120/1] via 10.1.2.1, 00:00:25, FastEthernet0/0
C 10.2.3.0/24 is directly connected, FastEthernet0/1
R 10.4.0.0/24 [120/2] via 10.1.2.1, 00:00:25, FastEthernet0/0
```

```
Router3
R 10.1.2.0/24 [120/1] via 10.1.34.1, 00:00:22, FastEthernet0/1
C 10.1.34.0/24 is directly connected, FastEthernet0/1
R 10.2.3.0/24 [120/2] via 10.1.34.1, 00:00:22, FastEthernet0/1
R 10.4.0.0/24 [120/1] via 10.1.34.4, 00:00:19, FastEthernet0/11
```

```
Router4
R 10.1.2.0/24 [120/1] via 10.1.34.1, 00:00:18, FastEthernet0/0
C 10.1.34.0/24 is directly connected, FastEthernet0/0
R 10.2.3.0/24 [120/2] via 10.1.34.1, 00:00:29, FastEthernet0/0
C 10.4.0.0/24 is directly connected, FastEthernet0/1
```




```
Router1
C 10.1.2.0/24 is directly connected, FastEthernet0/0
C 10.1.34.0/24 is directly connected, FastEthernet0/1
R 10.2.3.0/24 [120/1] via 10.1.2.2, 00:00:01, FastEthernet0/0
R 10.4.0.0/24 [120/1] via 10.1.34.4, 00:00:24, FastEthernet0/1
```

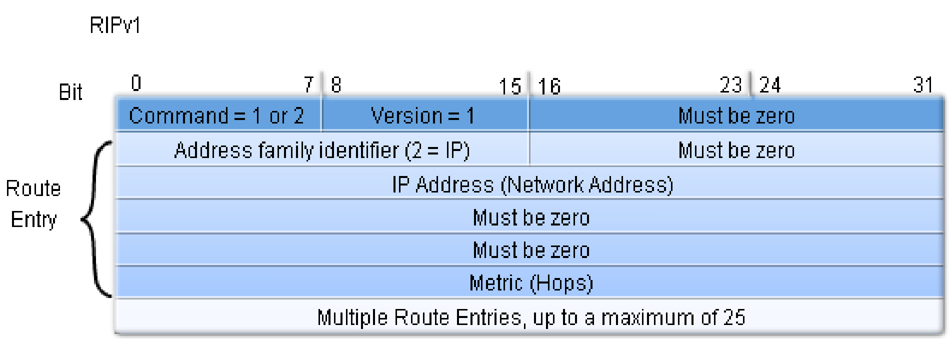
RIP Message Types

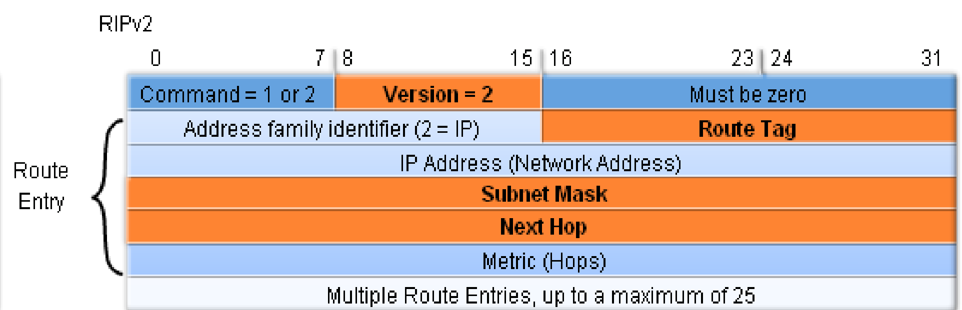
- RIP Response
  - Distance vector announcement/update message.
    - Contains the distance vector.
  - It is sent:
    - 1 – Periodically (~30 seconds by default, there is a random component).
    - 2 – Optionally, when some information changes (triggered updates).
    - 3 – In response to a RIP Request.

    - In cases 1 and 2:
      - In RIPv1, is sent to the broadcast address.
      - In RIPv2, is sent to the multicast address 224.0.0.9 (Routers com RIP).
    - In case 3, it is sent only (unicast) to the router that sent the RIP Request.
- RIP Request (Optional)
  - Sent by a router that was recently started (bootstrap) or, when the validity of some of the distance vector information has expired (default timeout = 180 seconds)
  - It may request specific information (a specific network) or, the complete neighbor distance vector.

RIPv1 vs. RIPv2 Responses (1)

- New RIPv2 message fields in Response packets:
  - Subnet mask
    - Supports variable length masks.
    - Makes RIPv2 *classless* protocol.
  - Route tag
    - Attribute assigned to a specifc network that must be reserved a re-announced.
    - Provides a method to separate internal (to the RIP domain) and external networks.
  - Next hop
    - Address to which the packets must be routed.
    - 0.0.0.0 indicates that th epackets ,must be routed to the router that sent the RIP message.





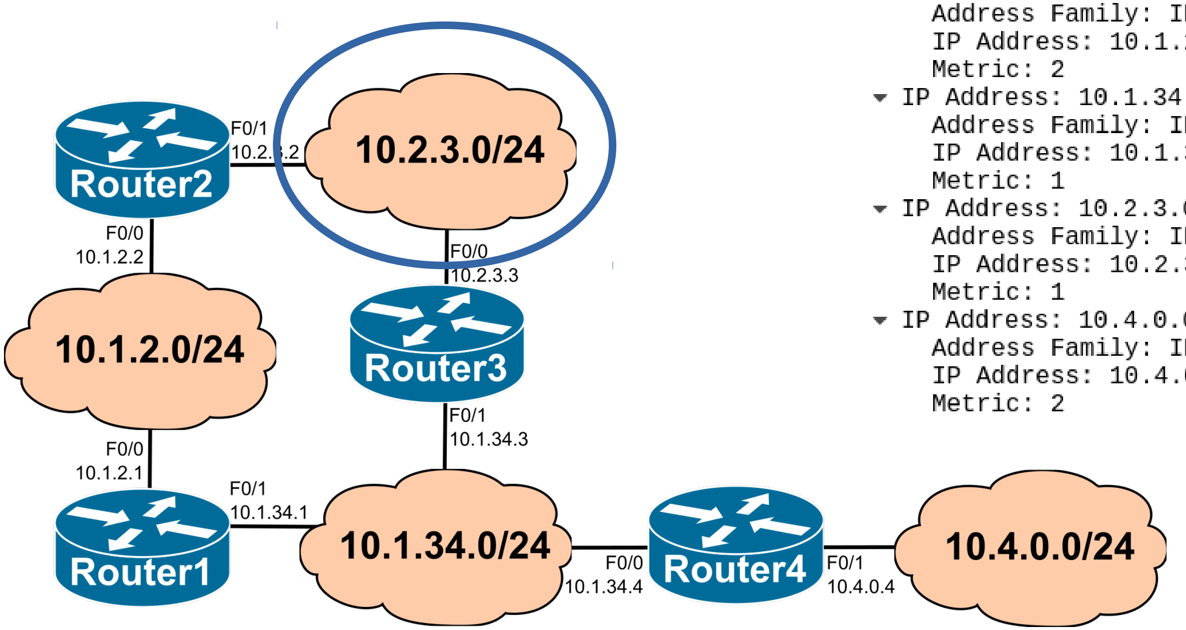
RIPv1 Messages (Example)

Sent by Router3 with Split-Horizon

```
▸ Internet Protocol Version 4, Src: 10.2.3.3, Dst: 255.255.255.255
▸ User Datagram Protocol, Src Port: 520, Dst Port: 520
▾ Routing Information Protocol
    Command: Response (2)
    Version: RIPv1 (1)
  ▾ IP Address: 10.1.34.0, Metric: 1
      Address Family: IP (2)
      IP Address: 10.1.34.0
      Metric: 1
  ▾ IP Address: 10.4.0.0, Metric: 2
      Address Family: IP (2)
      IP Address: 10.4.0.0
      Metric: 2
```

Sent by Router3 without Split-Horizon

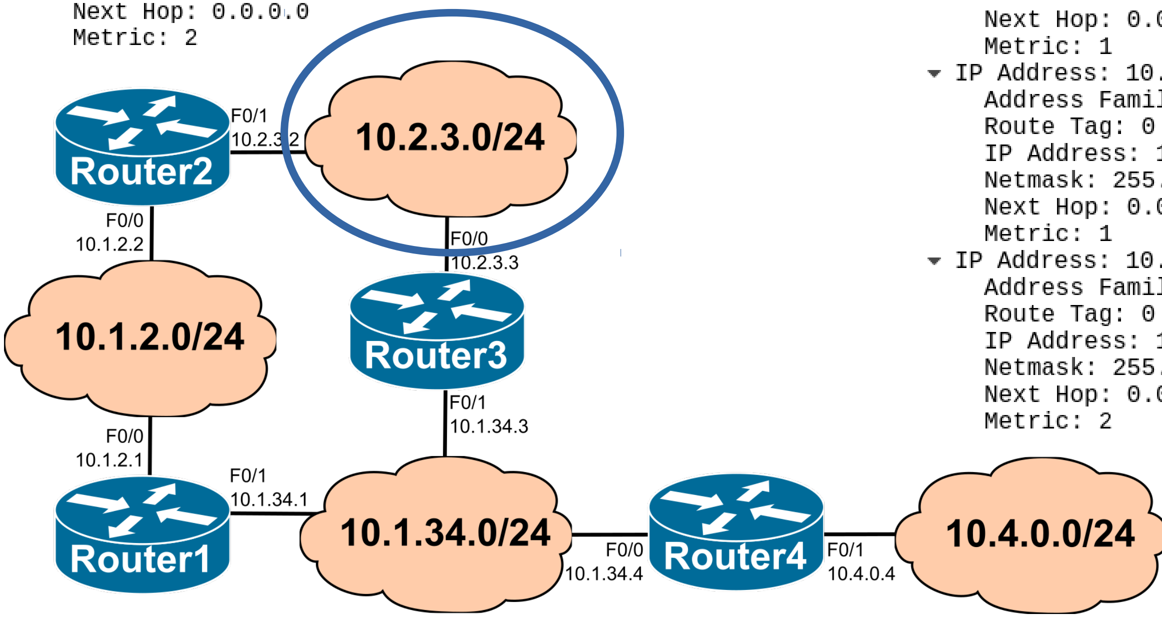
```
▸ Internet Protocol Version 4, Src: 10.2.3.3, Dst: 255.255.255.255
▸ User Datagram Protocol, Src Port: 520, Dst Port: 520
▾ Routing Information Protocol
    Command: Response (2)
    Version: RIPv1 (1)
  ▾ IP Address: 10.1.2.0, Metric: 2
      Address Family: IP (2)
      IP Address: 10.1.2.0
      Metric: 2
  ▾ IP Address: 10.1.34.0, Metric: 1
      Address Family: IP (2)
      IP Address: 10.1.34.0
      Metric: 1
  ▾ IP Address: 10.2.3.0, Metric: 1
      Address Family: IP (2)
      IP Address: 10.2.3.0
      Metric: 1
  ▾ IP Address: 10.4.0.0, Metric: 2
      Address Family: IP (2)
      IP Address: 10.4.0.0
      Metric: 2
```



RIPv2 Messages (Example)

Sent by Router3 with Split-Horizon

```
▸ Internet Protocol Version 4, Src: 10.2.3.3, Dst: 224.0.0.9
▸ User Datagram Protocol, Src Port: 520, Dst Port: 520
▾ Routing Information Protocol
    Command: Response (2)
    Version: RIPv2 (2)
  ▾ IP Address: 10.1.34.0, Metric: 1
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.1.34.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 1
  ▾ IP Address: 10.4.0.0, Metric: 2
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.4.0.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 2
```

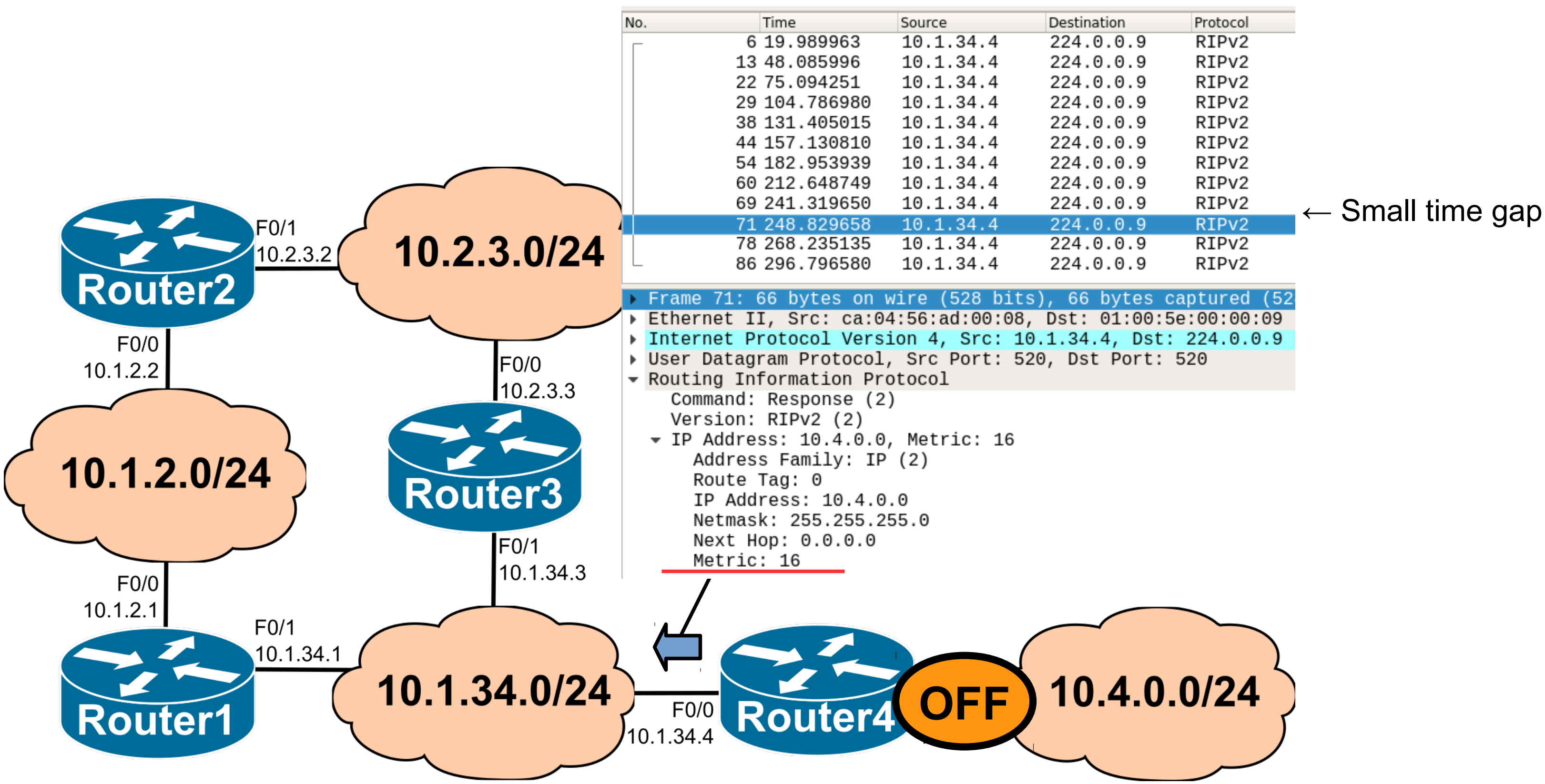


Sent by Router3 without Split-Horizon

```
▸ Internet Protocol Version 4, Src: 10.2.3.3, Dst: 224.0.0.9
▸ User Datagram Protocol, Src Port: 520, Dst Port: 520
▾ Routing Information Protocol
    Command: Response (2)
    Version: RIPv2 (2)
  ▾ IP Address: 10.1.2.0, Metric: 2
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.1.2.0
      Netmask: 255.255.255.0
      Next Hop: 10.2.3.2
      Metric: 2
  ▾ IP Address: 10.1.34.0, Metric: 1
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.1.34.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 1
  ▾ IP Address: 10.2.3.0, Metric: 1
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.2.3.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 1
  ▾ IP Address: 10.4.0.0, Metric: 2
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.4.0.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 2
```

Triggered Updates

- Prevents any routing loops that involve more than two routers.
- Whenever a router changes the metric for a route, it is required to send update messages almost immediately, even if it is not yet time for one of the regular update message.
- Neighboring routers update routing tables faster and overall convergence is faster.
  - Including entries that were removed by timeout!



RIPv2 Message Authentication

With Keyed Message Digest (MD5)

```
▸ Internet Protocol Version 4, Src: 10.2.3.3, Dst: 224.0.0.9
▸ User Datagram Protocol, Src Port: 520, Dst Port: 520
▾ Routing Information Protocol
    Command: Response (2)
    Version: RIPv2 (2)
  ▾ Authentication: Keyed Message Digest
      Authentication type: Keyed Message Digest (3)
      Digest Offset: 64
      Key ID: 1
      Auth Data Len: 20
      Seq num: 0
      Zero adding:
    ▾ Authentication Data Trailer
        Authentication Data: 7f7d4fc23f02a76b9986f517f3b6a8cf
  ▾ IP Address: 10.1.34.0, Metric: 1
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.1.34.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 1
  ▾ IP Address: 10.4.0.0, Metric: 2
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.4.0.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 2
```

With Clear Text Authentication
<u>Useless</u>!

```
▸ Internet Protocol Version 4, Src: 10.2.3.3, Dst: 224.0.0.9
▸ User Datagram Protocol, Src Port: 520, Dst Port: 520
▾ Routing Information Protocol
    Command: Response (2)
    Version: RIPv2 (2)
  ▾ Authentication: Simple Password
      Authentication type: Simple Password (2)
      Password: labcom
  ▾ IP Address: 10.1.2.0, Metric: 2
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.1.2.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 2
  ▾ IP Address: 10.1.34.0, Metric: 1
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.1.34.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 1
  ▾ IP Address: 10.4.0.0, Metric: 2
      Address Family: IP (2)
      Route Tag: 0
      IP Address: 10.4.0.0
      Netmask: 255.255.255.0
      Next Hop: 0.0.0.0
      Metric: 2
```

RIPng for IPv6 Routing

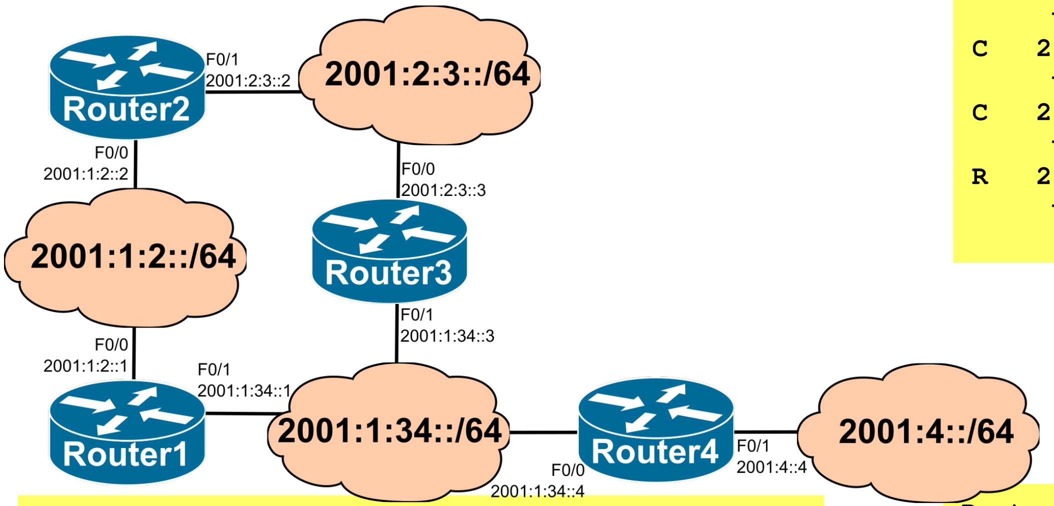
- Similar to IPv4 RIPv2:
  - Distance-vector concept, radius of 15 hops, infinity metric is 16, split-horizon, triggered update.
- Differences between RIPv2 and RIPng
  - Uses IPv6 for transport.
    - Uses link-local addresses (not the global ones).
  - IPv6 prefix, next-hop IPv6 link-local address.
  - Uses multicast group address FF02::9 (all-RIP-routers) as the destination address for RIP updates.
  - Routers always add the cost of the interface to the metric received.
    - Metric is sum of “output interfaces” costs to destination and not number of hops.
    - If all costs are 1, metric is number of “output interfaces” to destination.
  - Allows for node/interface costs other than 1.
    - Cisco calls it “cost offset” per interface (out or in direction).
    - Cost to network is given by the <u>sum of all output interfaces costs</u> along the path.
    - With the infinity metric value at 16, this require careful configurations.
  - Routers always announce directed connected networks.
  - in IOS Cisco
    - Activation per interface, named process, more than one active process.

IPv6 Routing Tables with RIPng

Assuming all interfaces with cost 1.

```
Router2
C   2001:1:2::/64 [0/0]
     via FastEthernet0/0, directly connected
R   2001:1:34::/64 [120/2]
     via FE80::C801:54FF:FE41:8, FastEthernet0/0
     via FE80::C803:56FF:FE0A:8, FastEthernet0/1
C   2001:2:3::/64 [0/0]
     via FastEthernet0/1, directly connected
R   2001:4::/64 [120/3]
     via FE80::C801:54FF:FE41:8, FastEthernet0/0
     via FE80::C803:56FF:FE0A:8, FastEthernet0/1
```

```
Router3
R   2001:1:2::/64 [120/2]
     via FE80::C802:54FF:FEF5:6, FastEthernet0/0
     via FE80::C801:54FF:FE41:6, FastEthernet0/1
C   2001:1:34::/64 [0/0]
     via FastEthernet0/1, directly connected
C   2001:2:3::/64 [0/0]
     via FastEthernet0/0, directly connected
R   2001:4::/64 [120/2]
     via FE80::C804:56FF:FEAD:8, FastEthernet0/1
```




```
Router1
C   2001:1:2::/64 [0/0]
     via FastEthernet0/0, directly connected
C   2001:1:34::/64 [0/0]
     via FastEthernet0/1, directly connected
R   2001:2:3::/64 [120/2]
     via FE80::C802:54FF:FEF5:8, FastEthernet0/0
     via FE80::C803:56FF:FE0A:6, FastEthernet0/1
R   2001:4::/64 [120/2]
     via FE80::C804:56FF:FEAD:8, FastEthernet0/1
```

```
Router4
R   2001:1:2::/64 [120/2]
     via FE80::C801:54FF:FE41:6, FastEthernet0/0
C   2001:1:34::/64 [0/0]
     via FastEthernet0/0, directly connected
R   2001:2:3::/64 [120/2]
     via FE80::C803:56FF:FE0A:6, FastEthernet0/0
C   2001:4::/64 [0/0]
     via FastEthernet0/1, directly connected
```

RIPng Messages (Example)

Sent by Router2 with Split-Horizon

```
▸ Internet Protocol Version 6, Src: fe80::c802:54ff:fef5:6, Dst: ff02::9
▸ User Datagram Protocol, Src Port: 521, Dst Port: 521
▾ RIPng
    Command: Response (2)
    Version: 1
    Reserved: 0000
  ▾ Route Table Entry: IPv6 Prefix: 2001:1:2::/64 Metric: 1
      IPv6 Prefix: 2001:1:2::
      Route Tag: 0x0000
      Prefix Length: 64
      Metric: 1
  ▾ Route Table Entry: IPv6 Prefix: 2001:2:3::/64 Metric: 1
      IPv6 Prefix: 2001:2:3::
      Route Tag: 0x0000
      Prefix Length: 64
      Metric: 1
```

Sent by Router3 with Split-Horizon

```
▸ Internet Protocol Version 6, Src: fe80::c803:56ff:fe0a:8, Dst: ff02::9
▸ User Datagram Protocol, Src Port: 521, Dst Port: 521
▾ RIPng
    Command: Response (2)
    Version: 1
    Reserved: 0000
  ▾ Route Table Entry: IPv6 Prefix: 2001:2:3::/64 Metric: 1
      IPv6 Prefix: 2001:2:3::
      Route Tag: 0x0000
      Prefix Length: 64
      Metric: 1
  ▾ Route Table Entry: IPv6 Prefix: 2001:1:34::/64 Metric: 1
      IPv6 Prefix: 2001:1:34::
      Route Tag: 0x0000
      Prefix Length: 64
      Metric: 1
  ▾ Route Table Entry: IPv6 Prefix: 2001:4::/64 Metric: 2
      IPv6 Prefix: 2001:4::
      Route Tag: 0x0000
      Prefix Length: 64
      Metric: 2
```