Chapter 4
Adv. Internetworking

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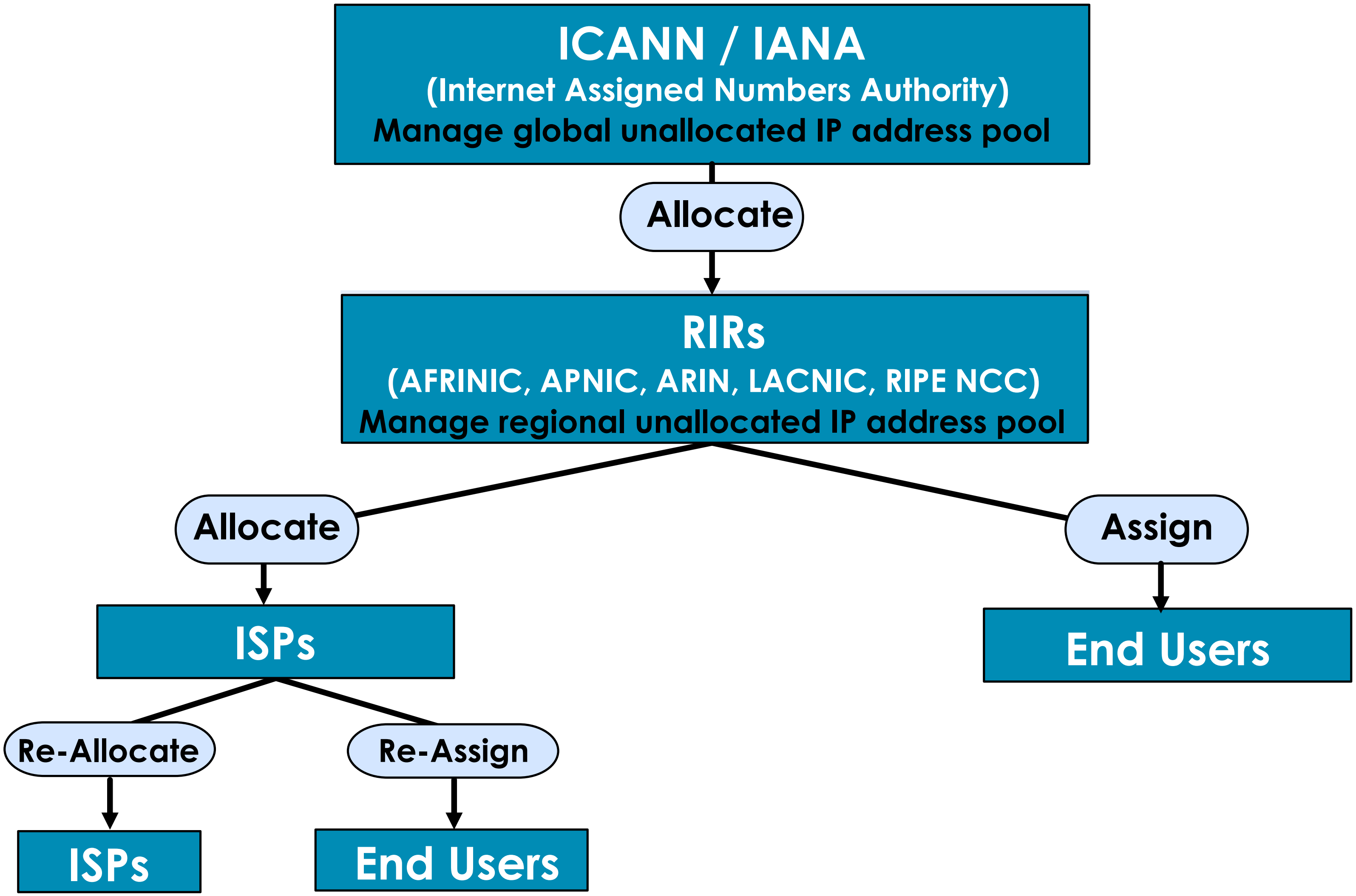
Agenda

Chapter 4. Adv. Internetworking

- Global Internet
  - *IANA, Routing Area, BGP, IPv6*
- Multicast
  - *Multicast Address, DVMRP*
- Multiprotocol Label Switching (MPLS)
- Routing Among Mobile Devices

Provisioning Hierarchy



RIR Service Region

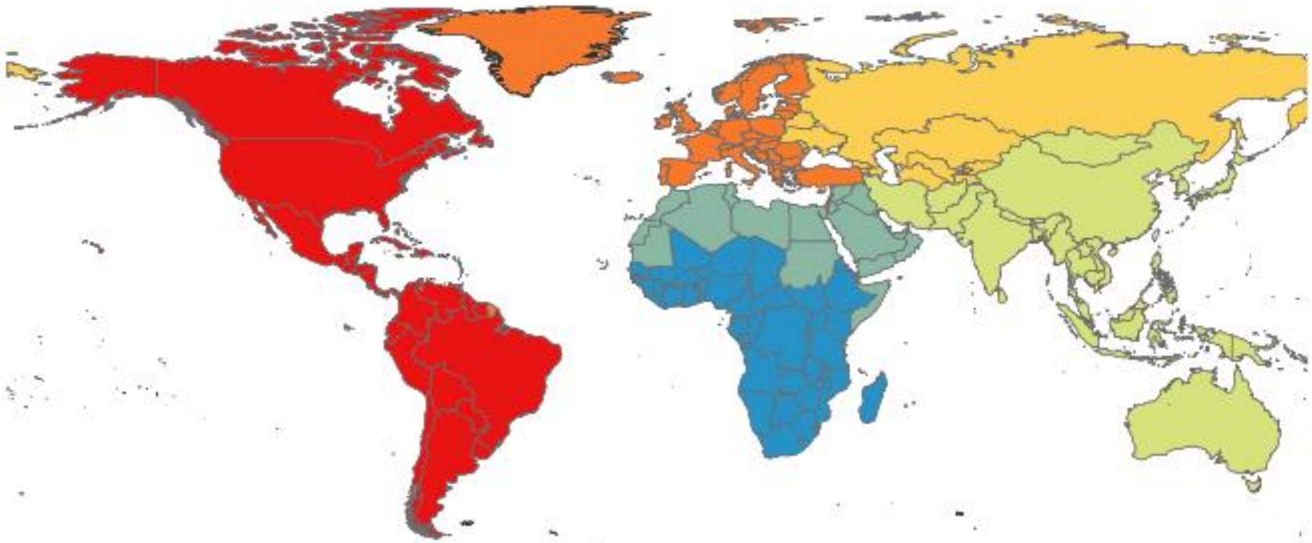
Regional Internet Registries (RIRs)
Internet Assigned Numbers Authority (IANA)

Subscriptions WWW in 2013

Americas
460 million subscriptions
48% penetration
28% CAGR (2010-2013)

Europe
422 million subscriptions
68% penetration
33% CAGR (2010-2013)

CIS
129 million subscriptions
46% penetration
27% CAGR (2010-2013)



Arab States
71 million subscriptions
19% penetration
55% CAGR (2010-2013)

Africa
93 million subscriptions
11% penetration
82% CAGR (2010-2013)

Asia-Pacific
895 million subscriptions
22% penetration
45% CAGR (2010-2013)

Source : ITU World Telecommunication

Problems

Identification :

- Internet’s topology has grown much more complex than this figure suggests.
- each provider and end-user is likely to be an administratively independent entity.

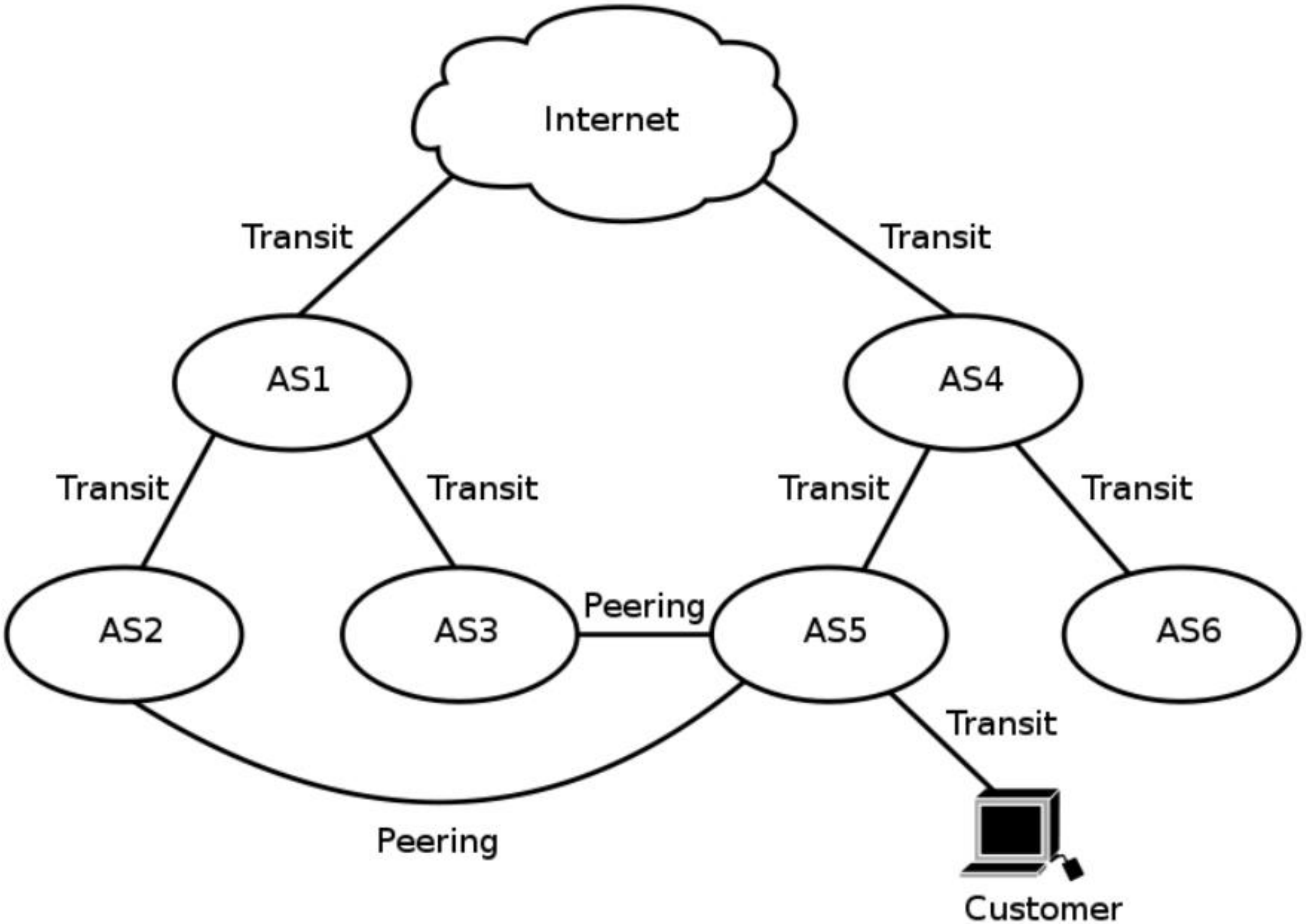
Problem Solving

- The first is the scalability of routing. (AS & CIDR)

  We need to find ways to minimize the number of network numbers that get carried around in routing protocols and stored in the routing tables of routers.
- The second is address utilization. (IPv6)

  That is, making sure that the IP address space does not get consumed too quickly.

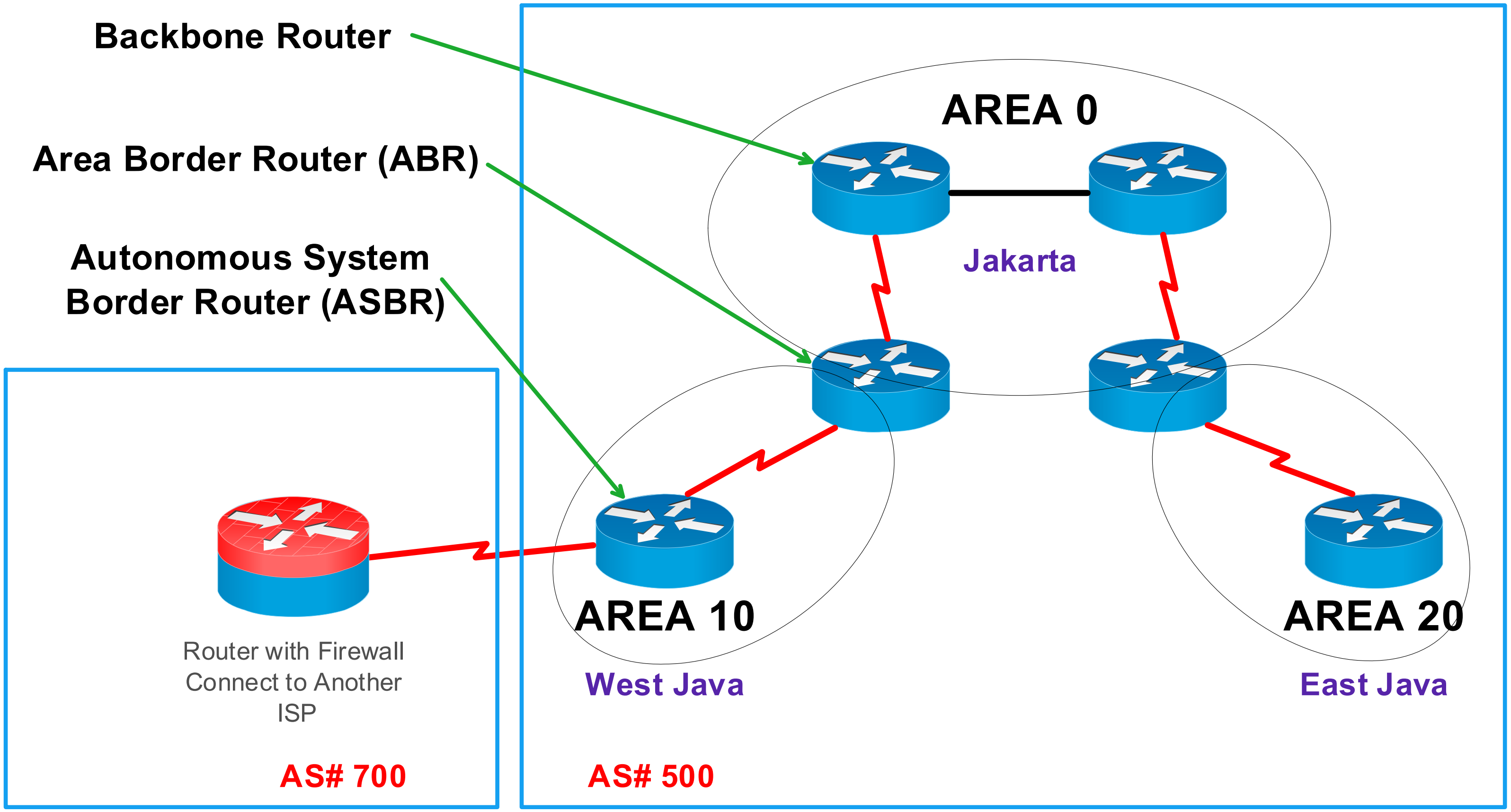
The Global Internet



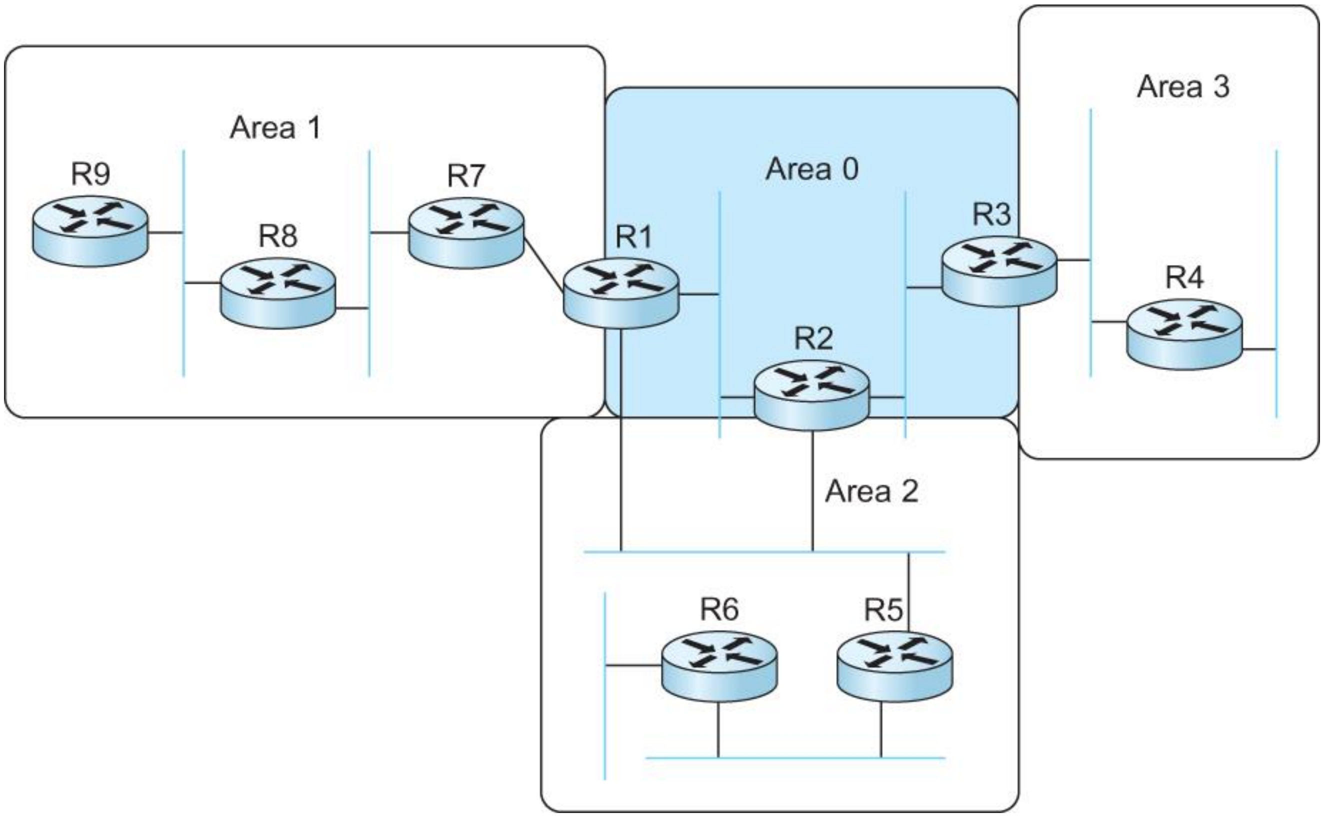
Routing Area

- We’ll examine how link-state routing protocols (such as OSPF and IS-IS) can be used to partition a routing domain into subdomains called areas.
- An area is a set of routers that are administratively configured to exchange link-state information with each other.
- There is one special area—the Backbone Area, also known as area **0**.

Routing Area



Routing Area

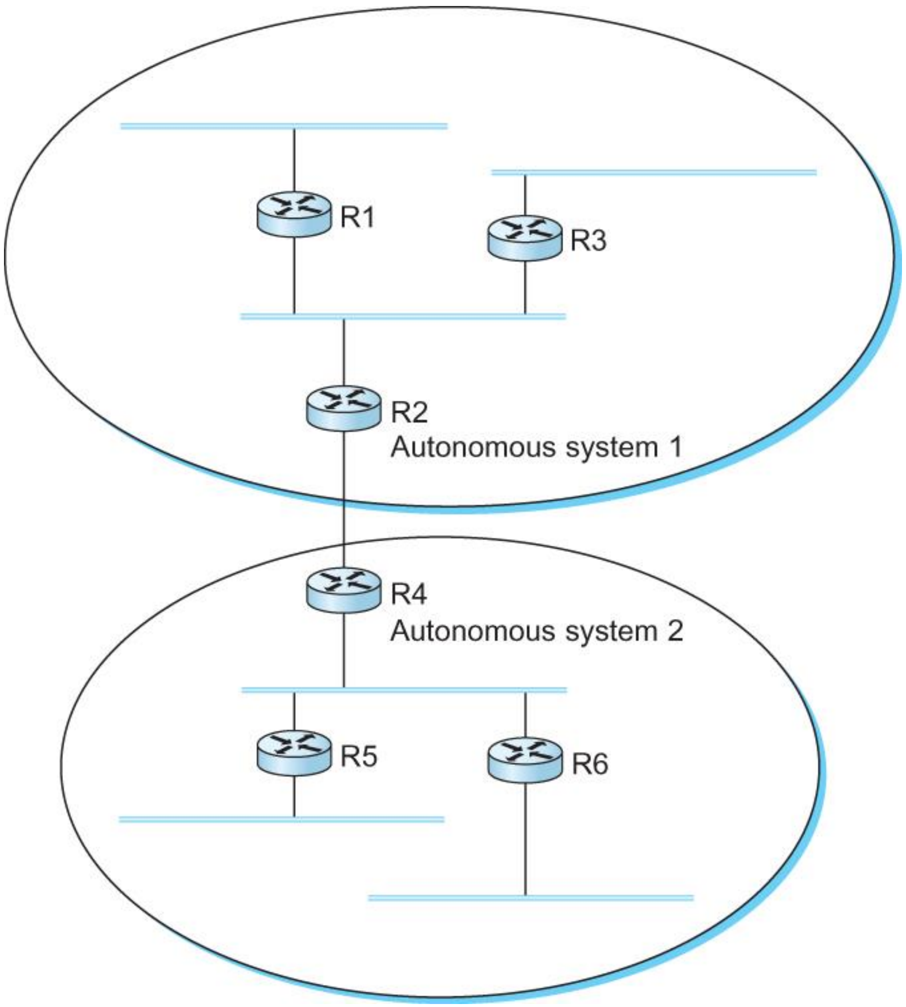


A domain divided into **Area**

Interdomain Routing (BGP)

- Internet is organized as Autonomous Systems (AS) each of which is under the control of a single administrative entity
- Autonomous System (AS)
  - corresponds to an administrative domain
  - examples: University, company, backbone network
- A corporation's Internal Network might be a single AS, as may the network of a single Internet Service Provider.

Interdomain Routing (BGP)

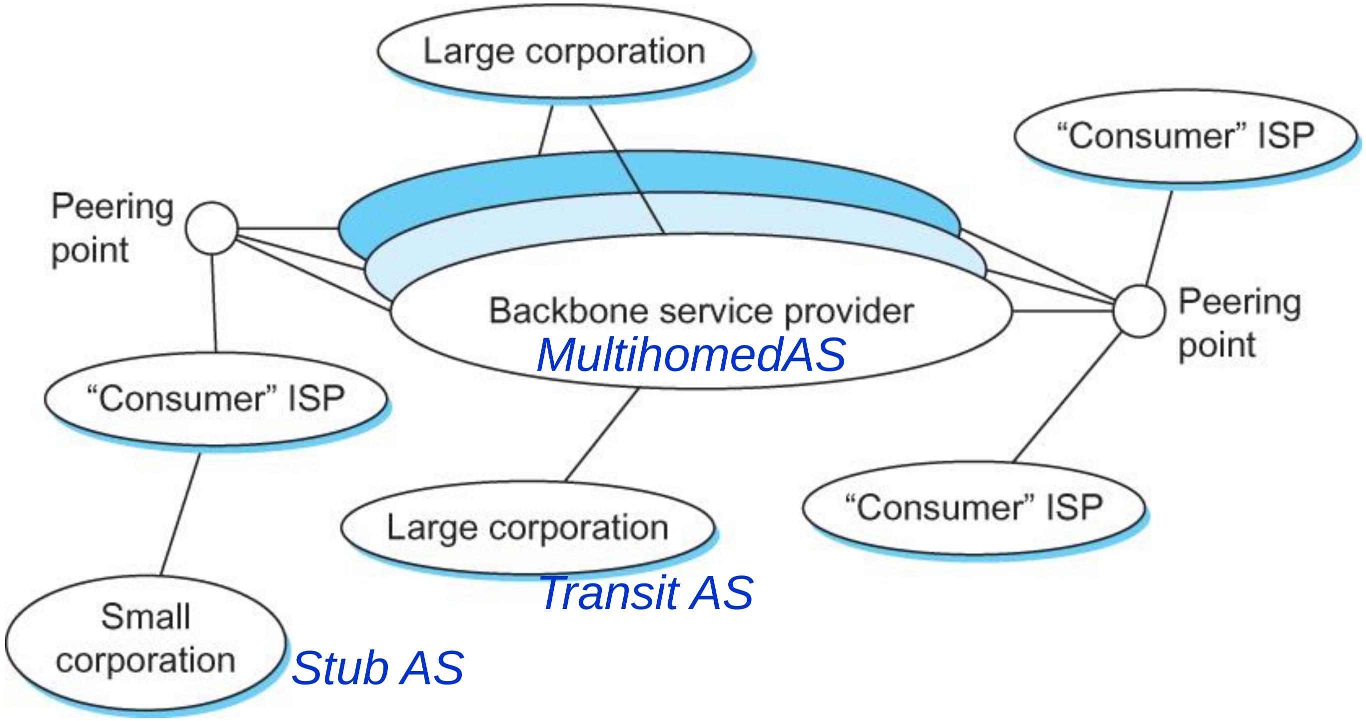


A network with two autonomous system

Route Propagation

- Idea: Provide an additional way to hierarchically aggregate routing information in a large internet.
  - Improves scalability
- Divide the routing problem in two parts:
  - Routing within a single autonomous system
  - Routing between autonomous systems
- Another name for autonomous systems in the Internet is routing domains
  - Two-level route propagation hierarchy
    - Inter-domain routing protocol (Internet-wide standard)
    - Intra-domain routing protocol (each AS selects its own)

The Global Internet



Stub AS: an AS that has only a single connection to one other AS; such an AS will only carry local traffic.

Multihomed AS: an AS that has connections to more than one other AS, but refuses to carry transit traffic.

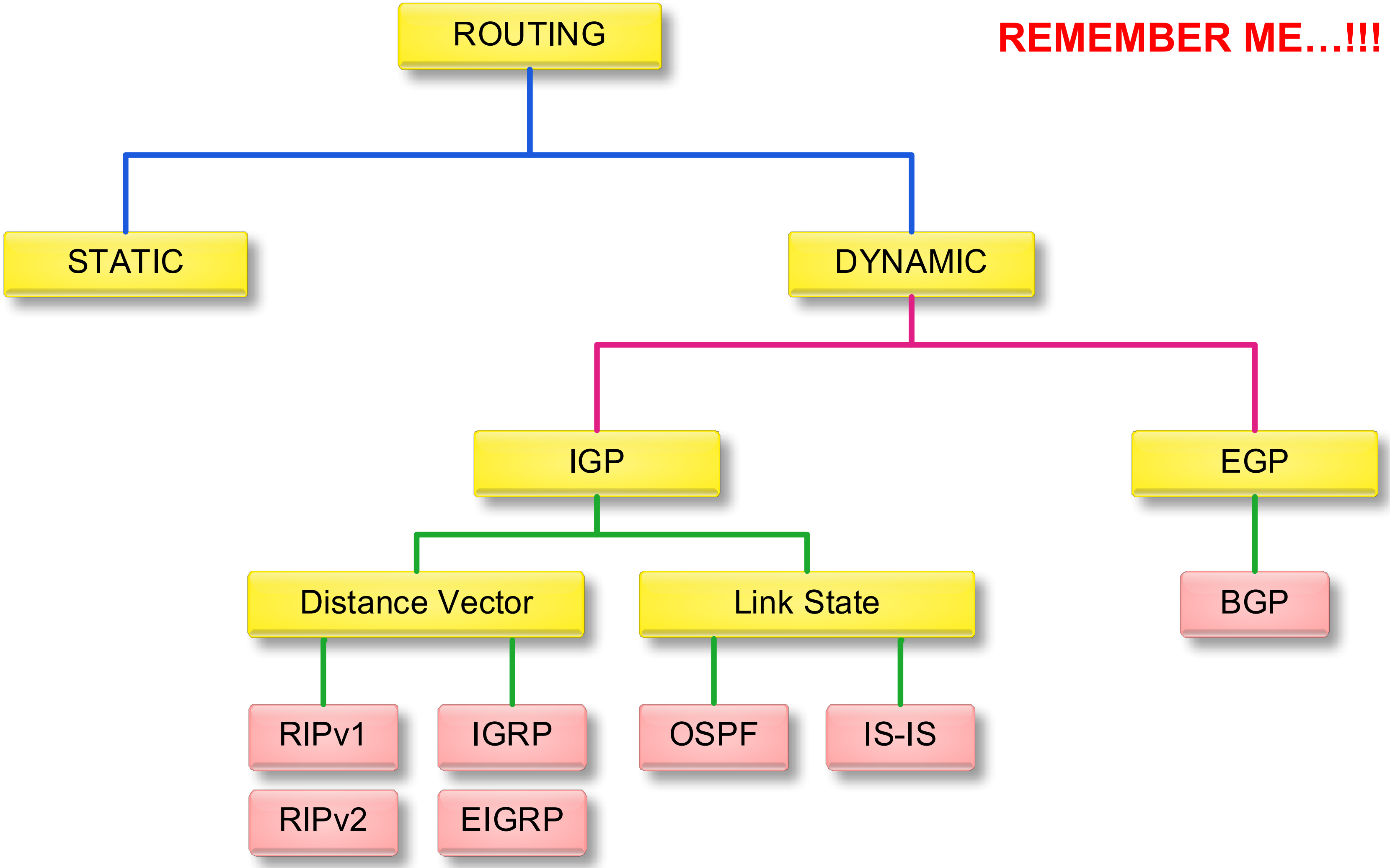
Transit AS: an AS that has connections to more than one other AS, and is designed to carry both transit and local traffic.

EGP and BGP

Inter-domain Routing Protocols

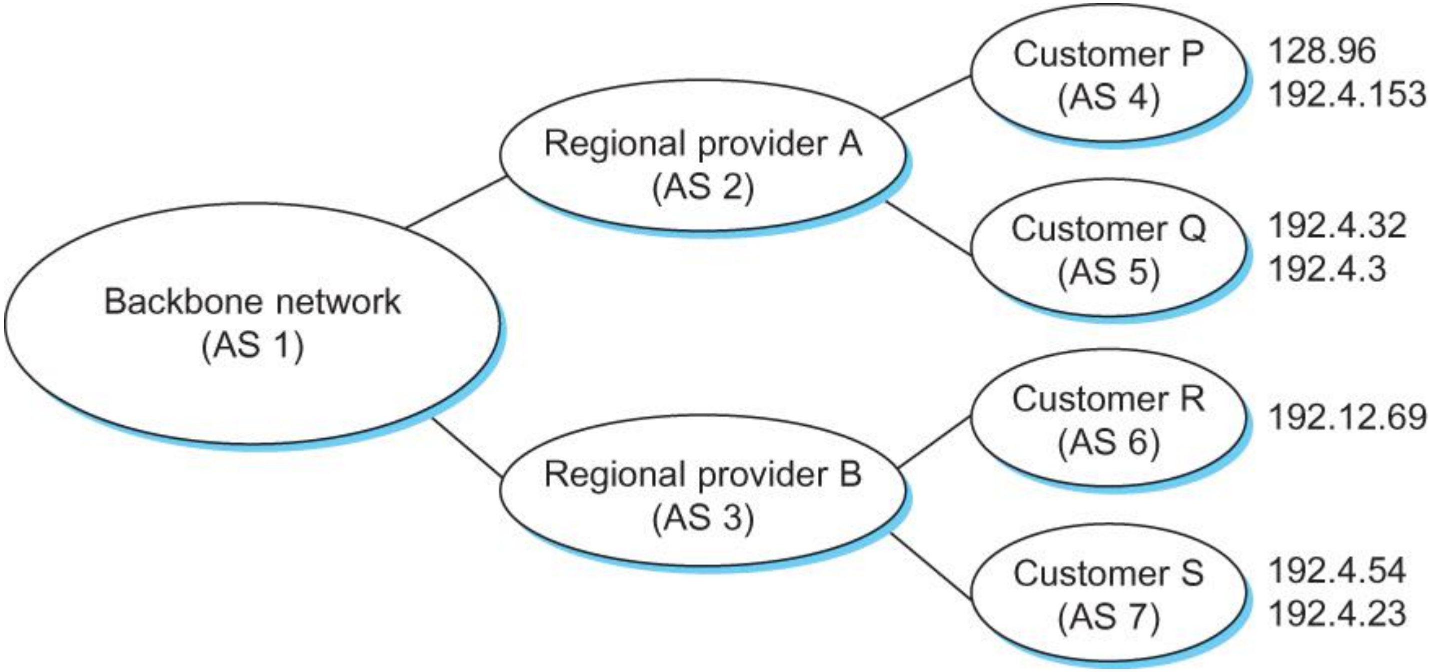
- Exterior Gateway Protocol (EGP)
  - Forced a tree-like topology onto the Internet
  - Did not allow for the topology to become general
    - Tree like structure: there is a single backbone and autonomous systems are connected only as parents and children and not as peers
- Border Gateway Protocol (BGP)
  - Assumes that the Internet is an arbitrarily interconnected set of ASs.
  - Today's Internet consists of an interconnection of multiple backbone networks (they are usually called service provider networks, and they are operated by private companies rather than the government)
  - Sites are connected to each other in arbitrary ways

Routing Protocol



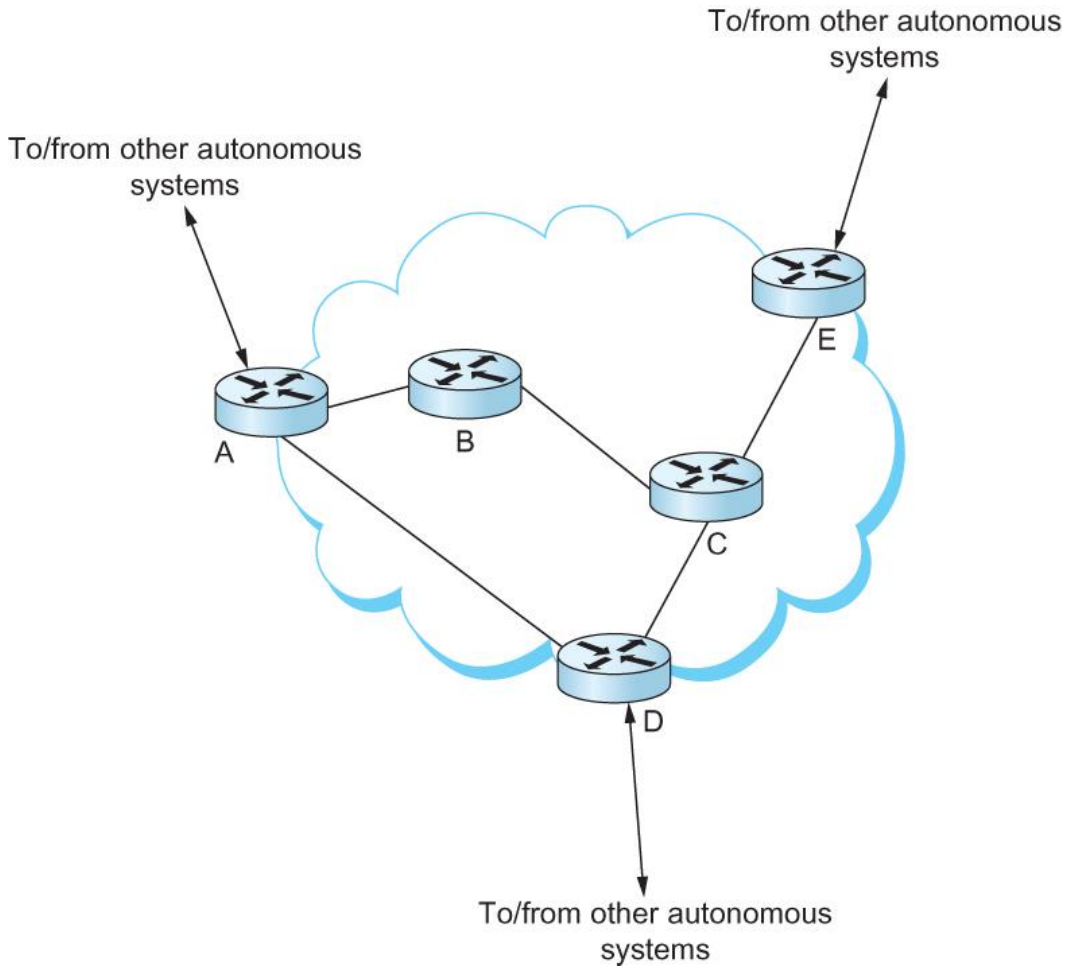
REMEMBER ME…!!!

BGP Example



Example of a network running BGP

Interdomain and Intradomain



iBGP
eBGP

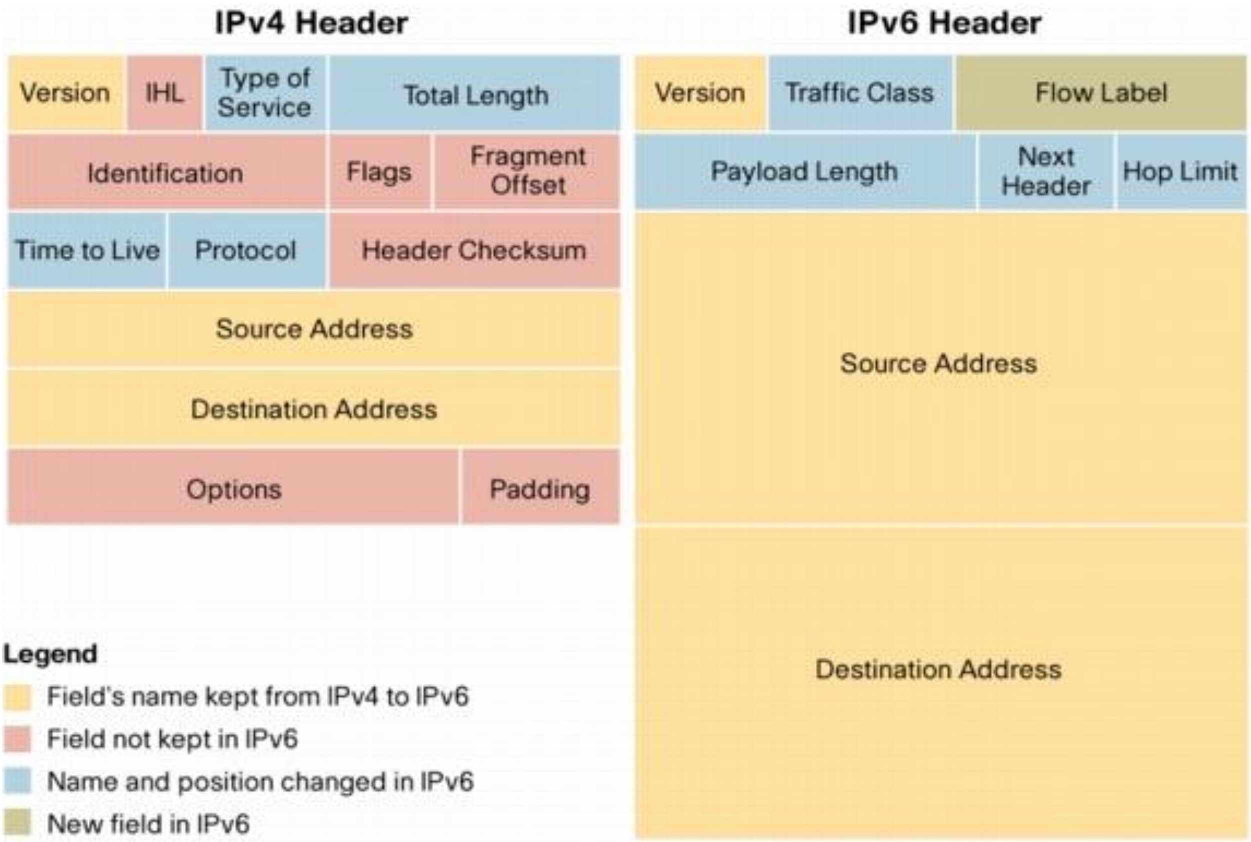
All routers run an intradomain routing protocol (RIP/ OSPF).
Border routers (A, D, E) also run BGP to other ASs

Need IPv6 ???

- In IPv4 we have VLSM/CIDR and NAT.
- IPv4 has only about 4.3 billion addresses available—in theory.
- There really are only about 250 million addresses that can he assigned to devices.
- The fact that there are about 6.5 billion people in the world today. [LAMMLE-2007]

- Now, the number of people and devices that connect to networks increases each and every day.
- *The Next-Generation Internet Protocol* – IPV6.

IPv4 and IPv6 Headers



IPv6 is…

- IPv6, formerly named IPng (***next generation***), is the latest version of the Internet Protocol (IP).
- IP is a packet-based protocol used to exchange data, voice, and video traffic over digital networks.
- IPv6 quadruples the number of network address bits from 32 bits (in IPv4) to 128 bits.

Benefits of IPv6

- Flexibility

  Shortened Expression
- Efficiency

  A lot of address (3.4x 10^{38} ≈ definitely enough)
- Capability

  Migrating to IPV6 (tunnel or dual stack)
- Support Security and Mobility

  Extension's header IPv6

IPv6 Addressing

- Actually 128 bits in length.

2001:0db8:3c4d:0012:0000:0000:1234:56ab

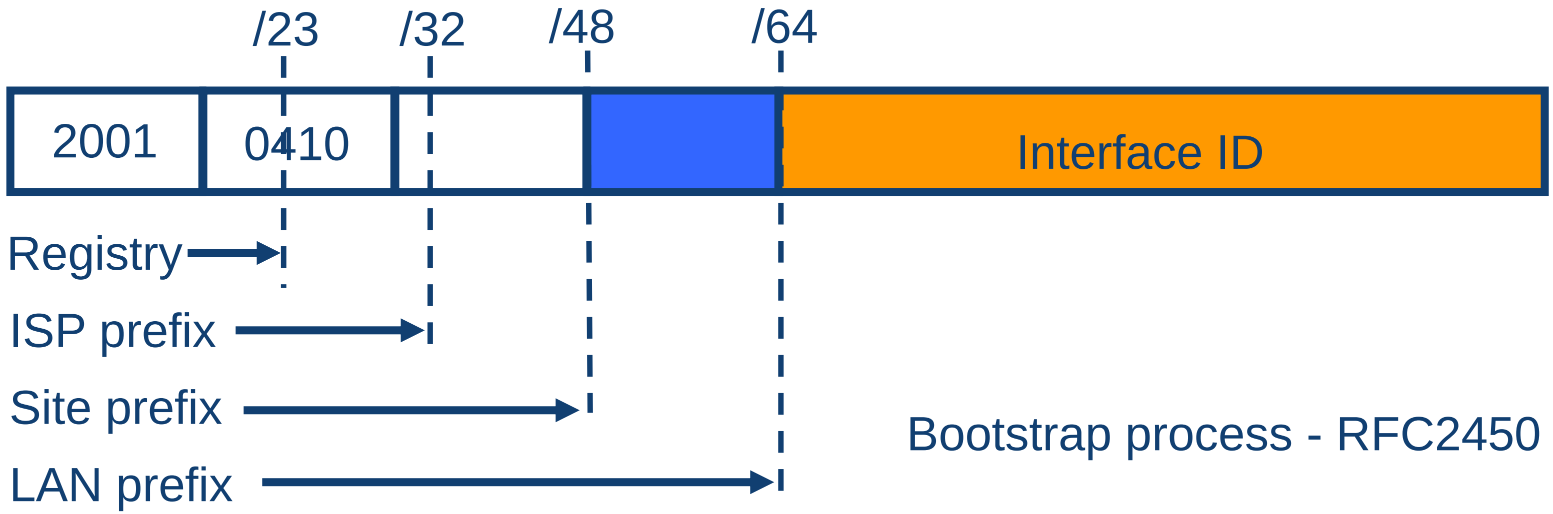
Global prefix | Subnet | Interface ID

- The address is expressed in hexadecimal just like a MAC address is, so you could say this address has *eight 16-bit hexadecimal* colon-delimited blocks.

- How about HTTP connection in IPv6?

```
http://[2001:0db8:3c4d:0012:0000:0000:1234:56ab]/default.html
```

Address Allocation Policy



Bootstrap process - RFC2450

The allocation process is under reviewed by the Registries:

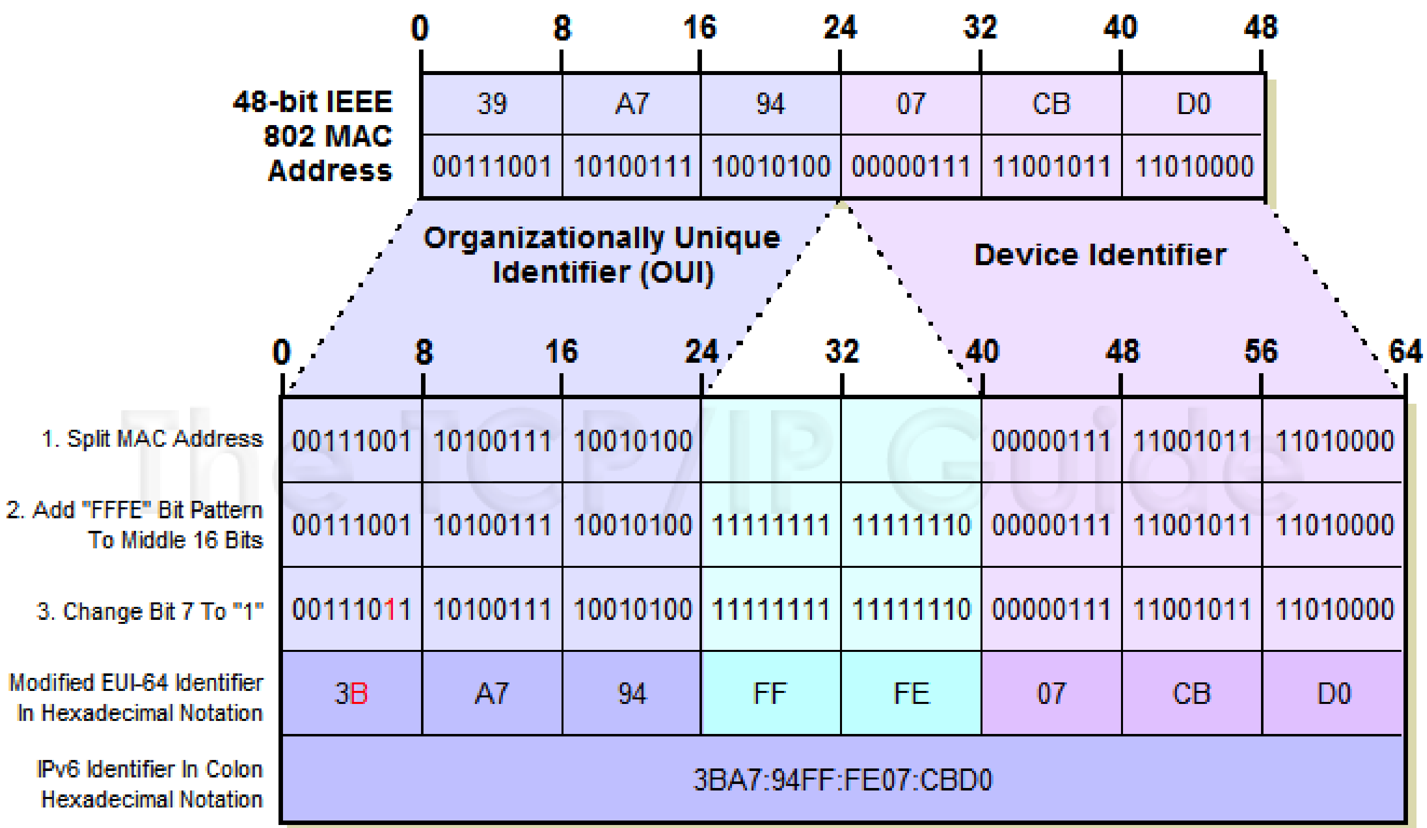
- IANA allocates 2001::/16 to registries
- Each registry gets a /23 prefix from IANA
- Formely, all ISP were getting a /35
- With the new policy, Registry allocates a /32 prefix to an IPv6 ISP
- Then the ISP allocates a /48 prefix to each customer (or potentially /64)
- ftp://ftp.cs.duke.edu/pub/narten/ietf/global-ipv6-assign-2002-06-26.txt

Interface IDs

Lowest-order 64-bit field of unicast address may be assigned in several different ways:

- auto-configured from a 64-bit EUI-64, or expanded from a 48-bit MAC address (e.g., Ethernet address)
- auto-generated pseudo-random number (to address privacy concerns)
- assigned via DHCP
- manually configured

Modified EUI-64 Interface ID



64-Bit IPv6 Modified EUI-64 Interface Identifier

Address Type

- We're all familiar with IPv4’s unicast, broadcast, and multicast addresses that basically define who or at least how many other devices we're talking to.

- IPv6 adds to that trio and introduces the anycast. Broadcasts, as we know them, have been eliminated in IPv6 because of their cumbersome inefficiency.

- Type of IPv6 Addressing

  Unicast , Global Unicast Addresses, Link-local Addresses, Unique Local Addresses, Multicast, and *Anycast*

Types of IPv6 Addresses

- Unicast
  - Address of a single interface
  - Delivery to single interface
- Multicast
  - Address of a set of interfaces
  - Delivery to all interfaces in the set
- Anycast
  - Address of a set of interfaces
  - Delivery to a single interface in the set
- No more broadcast addresses

Discovery Protocol

- The process of resolving a destination's IP address to that destination's MAC address is referred to as, unsurprisingly, address resolution.
- In IPv4. this task is performed by the *Address Resolution Protocol (ARP)*. In IPv6, this function is performed by the *Neighbor Discovery protocol (ND)*.

IPv6 Neighbor Discovery

- Neighbor discovery is a function that enables a node to identify other hosts and routers on its links.
- The node needs to know of at least one router so that it knows where to forward packets if a target node is not on its local link.
- Neighbor discovery also allows a router to redirect a node to use a more appropriate router if the node has initially made an incorrect choice.
- There are two ways that neighbor discovery are performed in IPv6. ***Statelessly via ICMPv6*** and ***Statefuly via DHCPv6.***

Migration Techniques

A wide range of techniques have been identified and implemented, basically falling into three categories:

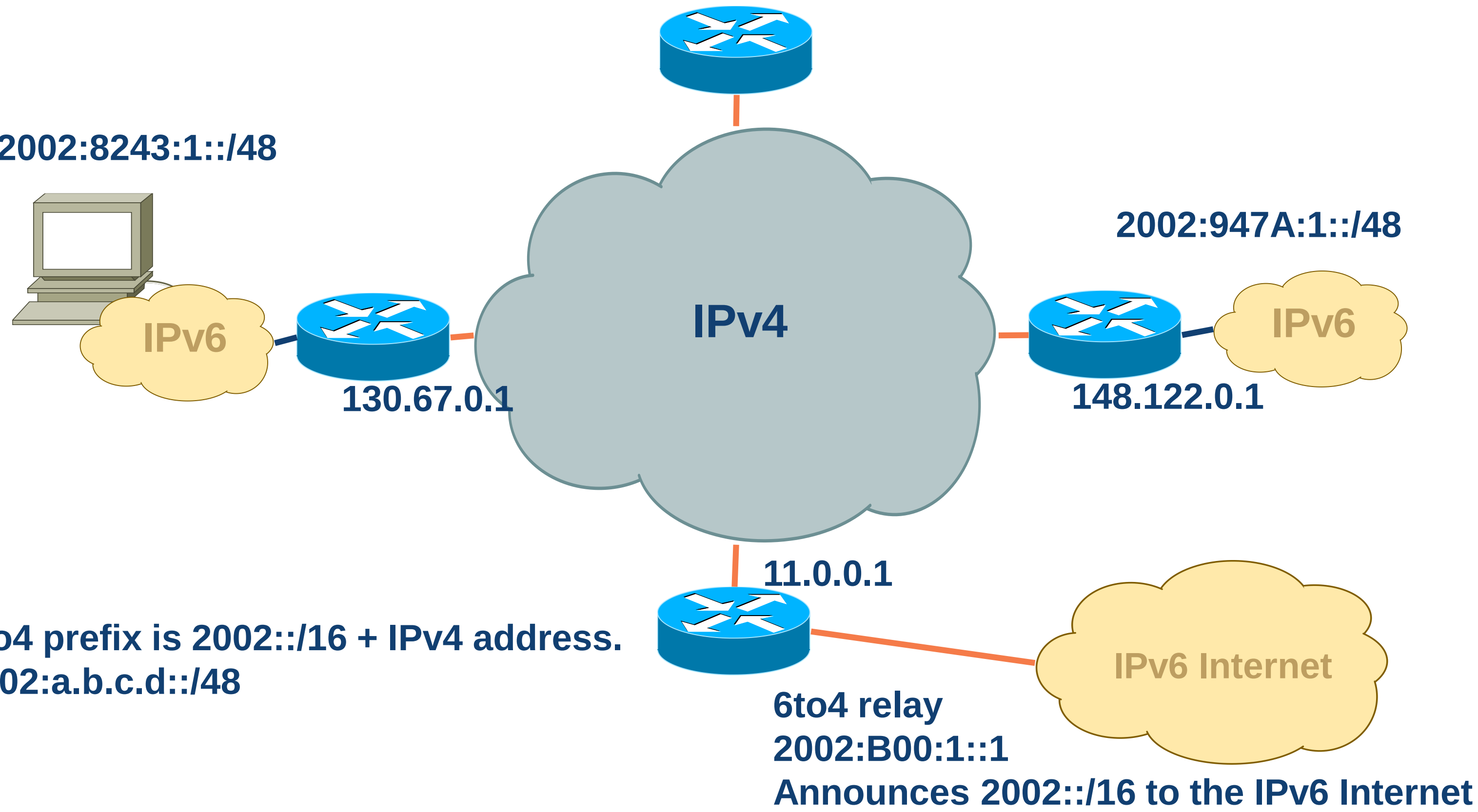
(1) **dual-stack** techniques, to allow IPv4 and IPv6 to co-exist in the same devices and networks

(2) **tunneling** techniques, to avoid order dependencies when upgrading hosts, routers, or regions

(3) **translation** techniques, to allow IPv6-only devices to communicate with IPv4-only devices

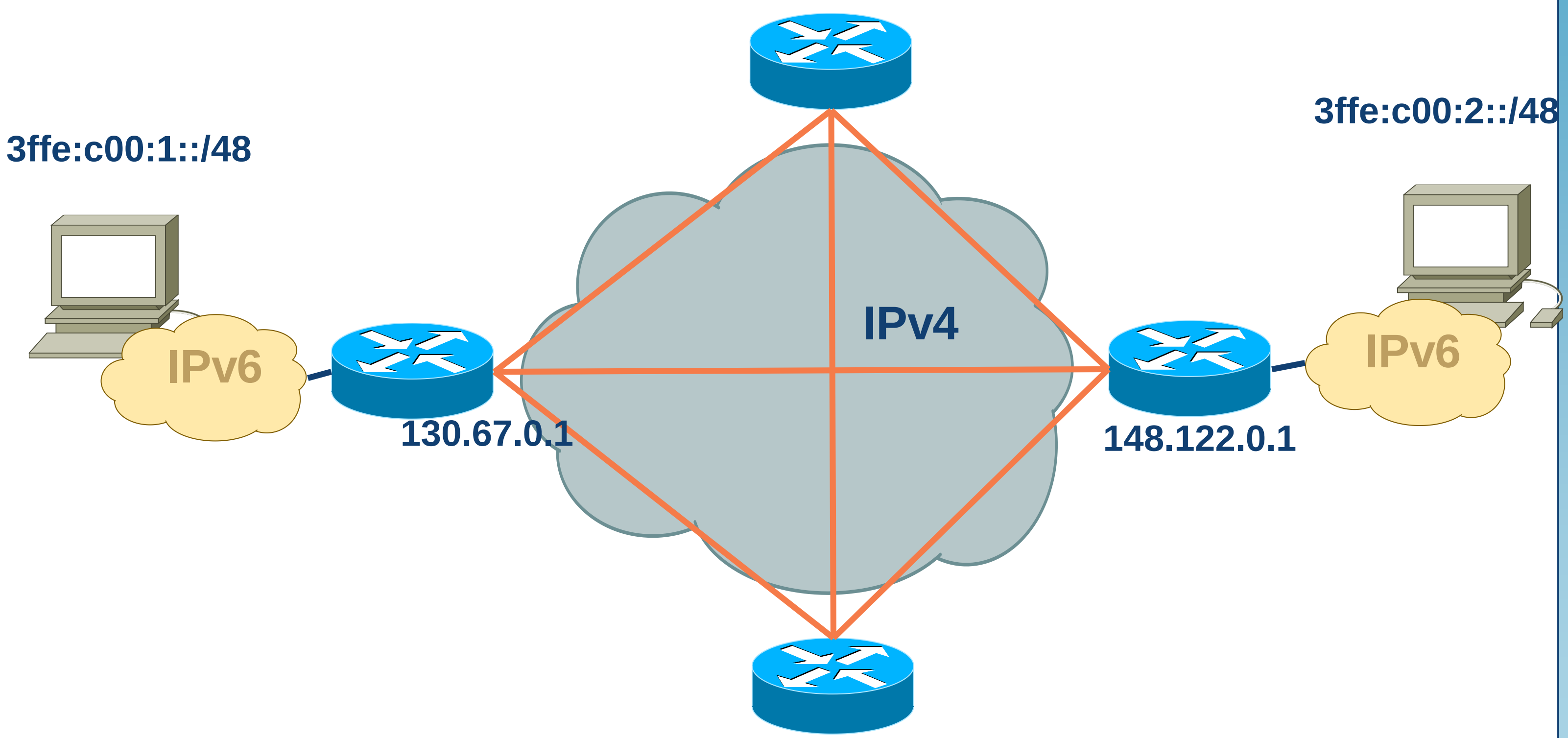
Expect all of these to be used, in combination

Ex 1: 6to4 Tunnel



6to4 prefix is 2002::/16 + IPv4 address.
2002:a.b.c.d::/48

Ex 2: Configured Tunnel




```
---------------------------------------
|IPv4 header|IPv6 header IPv6 payload|
---------------------------------------
IPv4 protocol type = 41
```

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  - *Multicast Address, IGMP, Multicast Routing, DVMRP*
- Multiprotocol Label Switching (MPLS)
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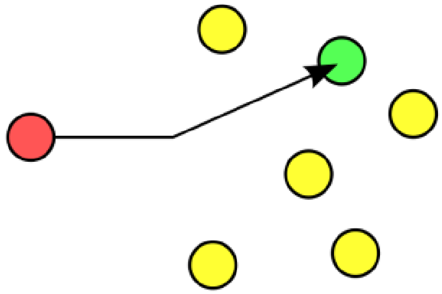
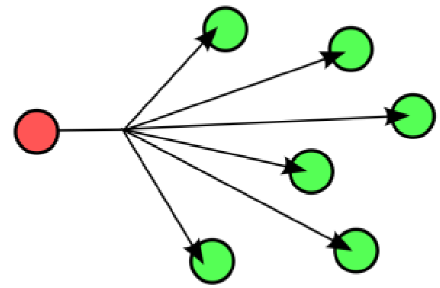
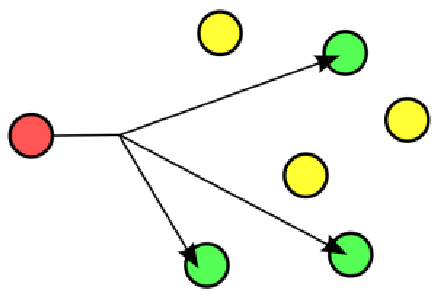
Trio Cast



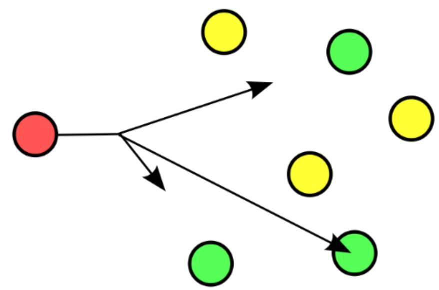
UNICAST



BROADCAST



MULTICAST



ANYCAST (IPV6)

Overview

Example Analogy Multicast :

- One-to-many
  - Radio station broadcast
  - Transmitting news, stock-price
  - Software updates to multiple hosts
- Many-to-many
  - Multimedia teleconferencing
  - Online multi-player games
  - Distributed simulations

Problem Identification

- Without multicast support:
  - A source needs to send a separate packet with the identical data to each member of the group
    - This redundancy consumes more bandwidth
    - Redundant traffic is not evenly distributed, concentrated near the sending host
  - Source needs to keep track of the IP address of each member in the group
    - Group may be dynamic
- To support many-to-many and one-to-many IP provides an IP-level multicast

Overview M’cast

- Basic IP multicast model is many-to-many based on multicast groups
  - Each group has its own IP multicast address
  - Hosts that are members of a group receive copies of any packets sent to that group’s multicast address
  - A host can be in multiple groups
  - A host can join and leave groups

Overview M’cast

- Using IP multicast to send the identical packet to each member of the group
  - A host sends a single copy of the packet addressed to the group’s multicast address
  - The sending host does not need to know the individual unicast IP address of each member
  - Sending host does not send multiple copies of the packet

Overview M’cast

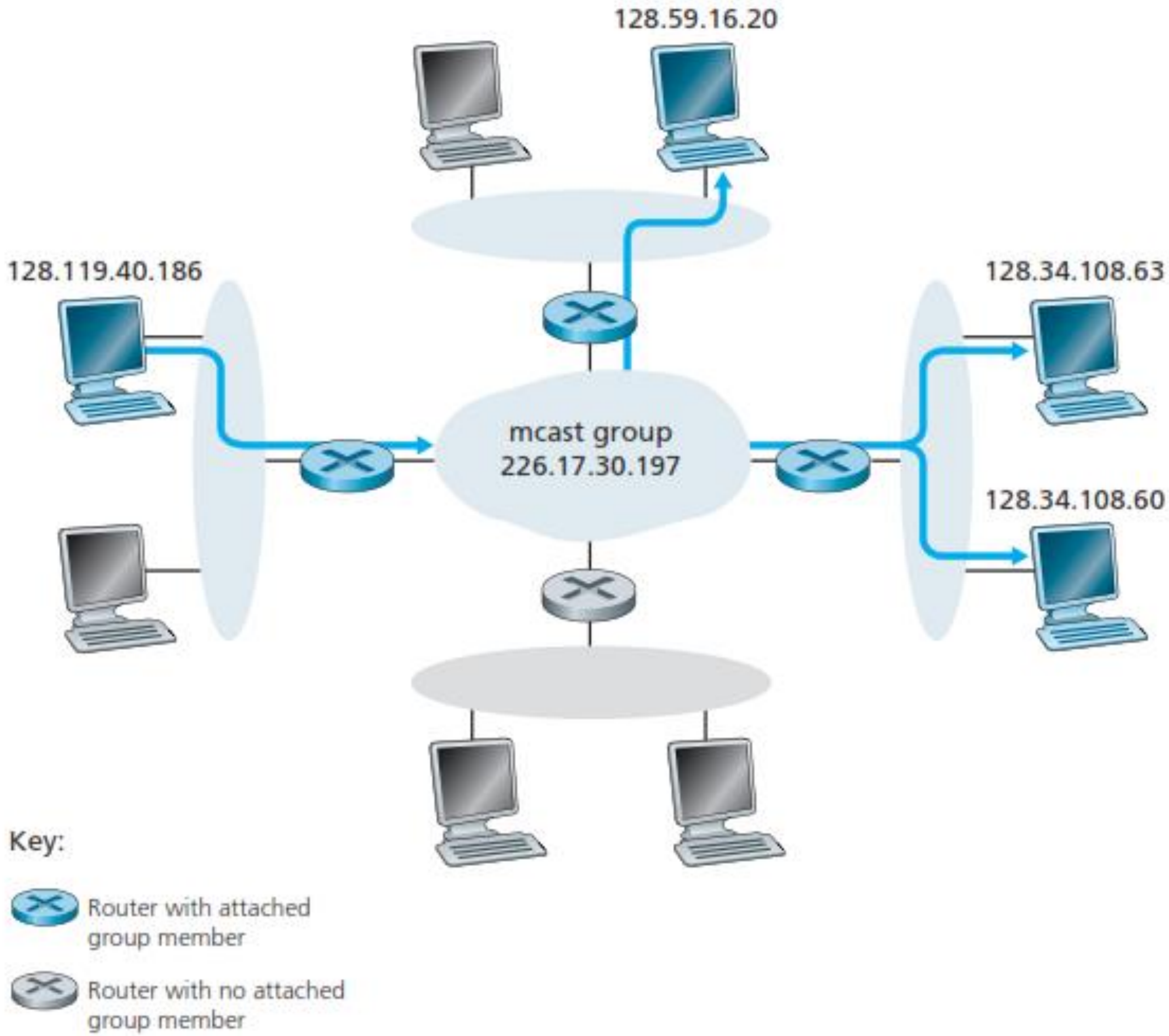
- One-to-many multicast
  - Source specific multicast (SSM)
  - A receiving host specifies both a multicast group and a specific sending host
- Many-to-many model
  - Any source multicast (ASM)

IGMP

- How does a group get started and how does it terminate?
- How is the group address chosen?
- How are new hosts added to the group (either as senders or receivers)?
- Can anyone join a group (and send to, or receive from, that group) or is group membership restricted and, if so, by whom?
- Do group members know the identities of the other group members as part of the network-layer protocol?
- How do the network nodes interoperate with each other to deliver a multicast datagram to all group members?

Internet Group Management Protocol (IGMP)

IGMP

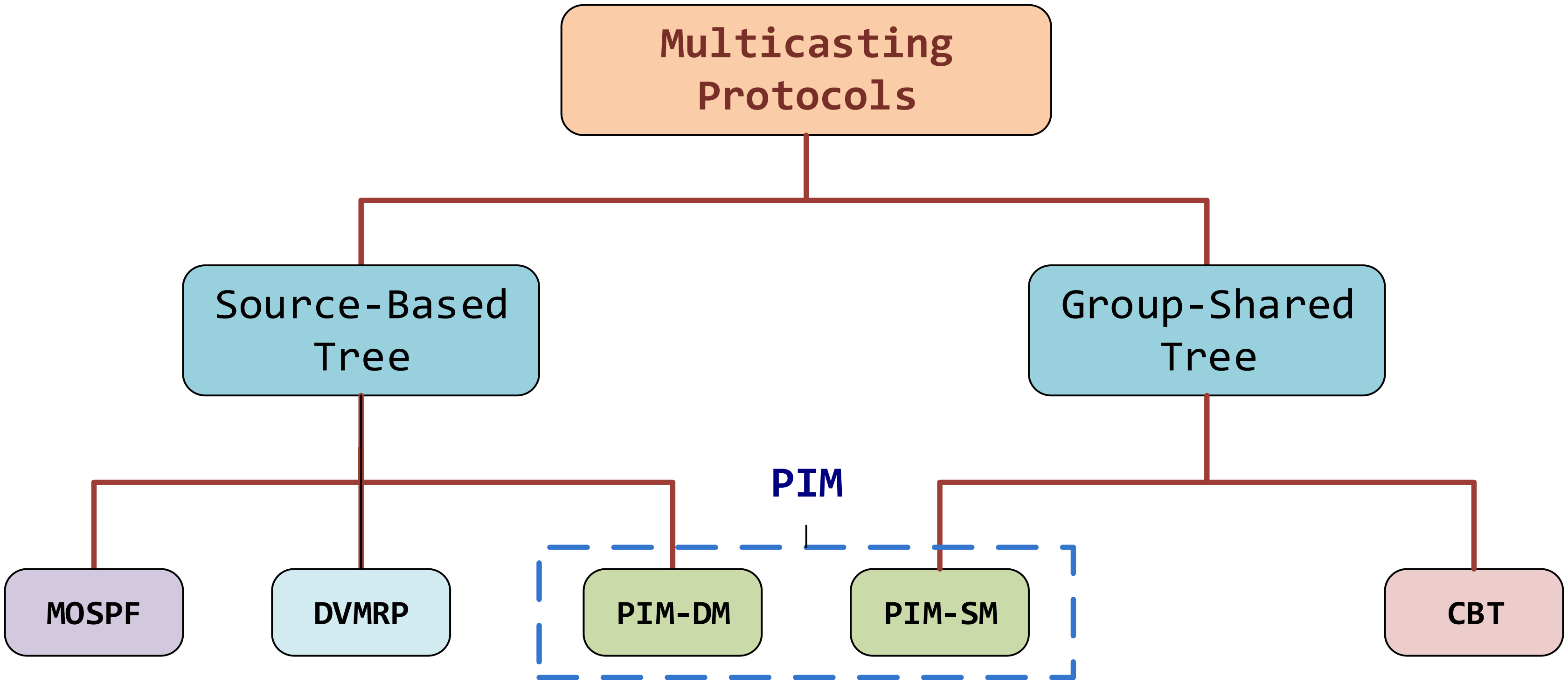


128.59.16.20
128.119.40.186
128.34.108.63
mcast group
226.17.30.197
128.34.108.60
Key:
Router with attached
group member
Router with no attached
group member

Multicast Group

- A host signals its desire to join or leave a multicast group by communicating with its local router using a special protocol
  - In IPv4, the protocol is Internet Group Management Protocol (IGMP)
  - In IPv6, the protocol is Multicast Listener Discovery (MLD)
- The router has the responsibility for making multicast behave correctly with regard to the host

Multicast Routing



Multicast Routing

- To support multicast, a router must additionally have multicast forwarding tables that indicate, based on multicast address, which links to use to forward the multicast packet

- Unicast forwarding tables collectively specify a set of paths
- Multicast forwarding tables collectively specify a set of trees
  - Multicast distribution trees

Multicast Routing

- To support source specific multicast, the multicast forwarding tables must indicate which links to use based on the combination of multicast address and the unicast IP address of the source

- ***Multicast Routing*** *is the process by which multicast distribution trees are determined.*

Distance-Vector Multicast

- DVMRP is one of several multicast routing protocols described as *flood-and-prune protocols*.

- Given a unicast routing table, each router knows that the current shortest path to a given destination goes through **NextHop**.
- Thus, whenever it receives a multicast packet from source **S**, the router forwards the packet on all outgoing links (except the one on which the packet arrived)
- IFF the packet arrived over the link that is on the shortest path to **S** (i.e., the packet came *from the **NextHop** associated with **S** in the routing table).*

- This strategy effectively floods packets outward from S but does not loop packets back toward S.

Distance-Vector Multicast

Reverse Path Broadcast (RPB)

Goal: Prune networks that have no hosts in group G

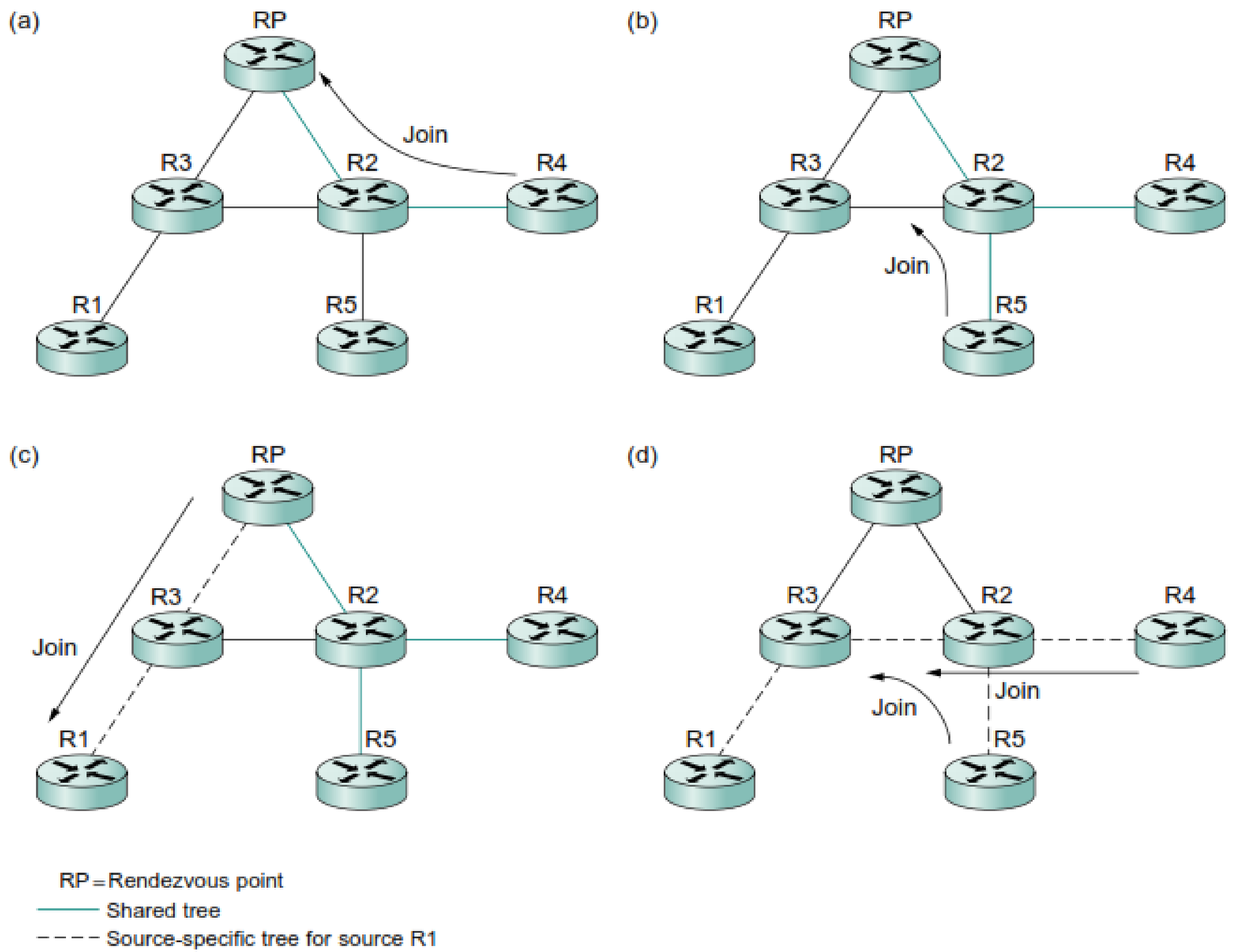
Step 1: Determine LAN that is a *leaf* with no members in G

- leaf if parent is only router on the LAN
- determine if any hosts are members of G using IGMP

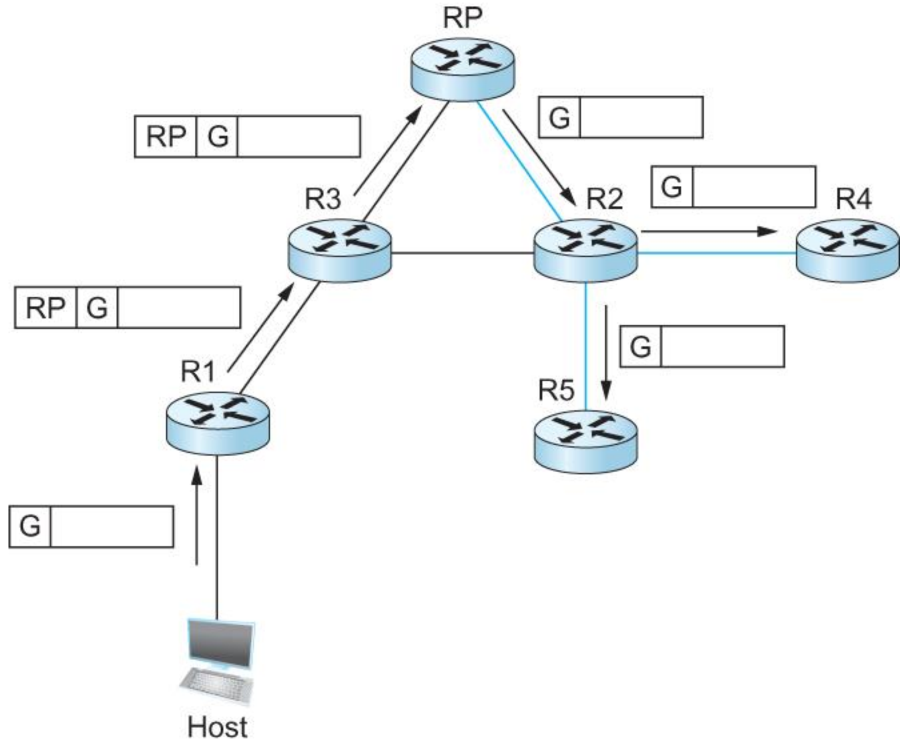
Step 2: Propagate “no members of G here” information

- augment **`<Destination, Cost>`** update sent to neighbors with set of groups for which this network is interested in receiving multicast packets.
- only happens when multicast address becomes active.

Protocol Independent Multicast (PIM)



Protocol Independent Multicast (PIM)



Delivery of a packet along a shared tree. R1 tunnels the packet to the RP, which forwards it along the shared tree to R4 and R5.

Interdomain Multicast

- The PIM-SM protocol is typically not used across domains, only within a domain.
- To extend multicast across domains using PIM-SM, the Multicast Source Discovery Protocol (MSDP).

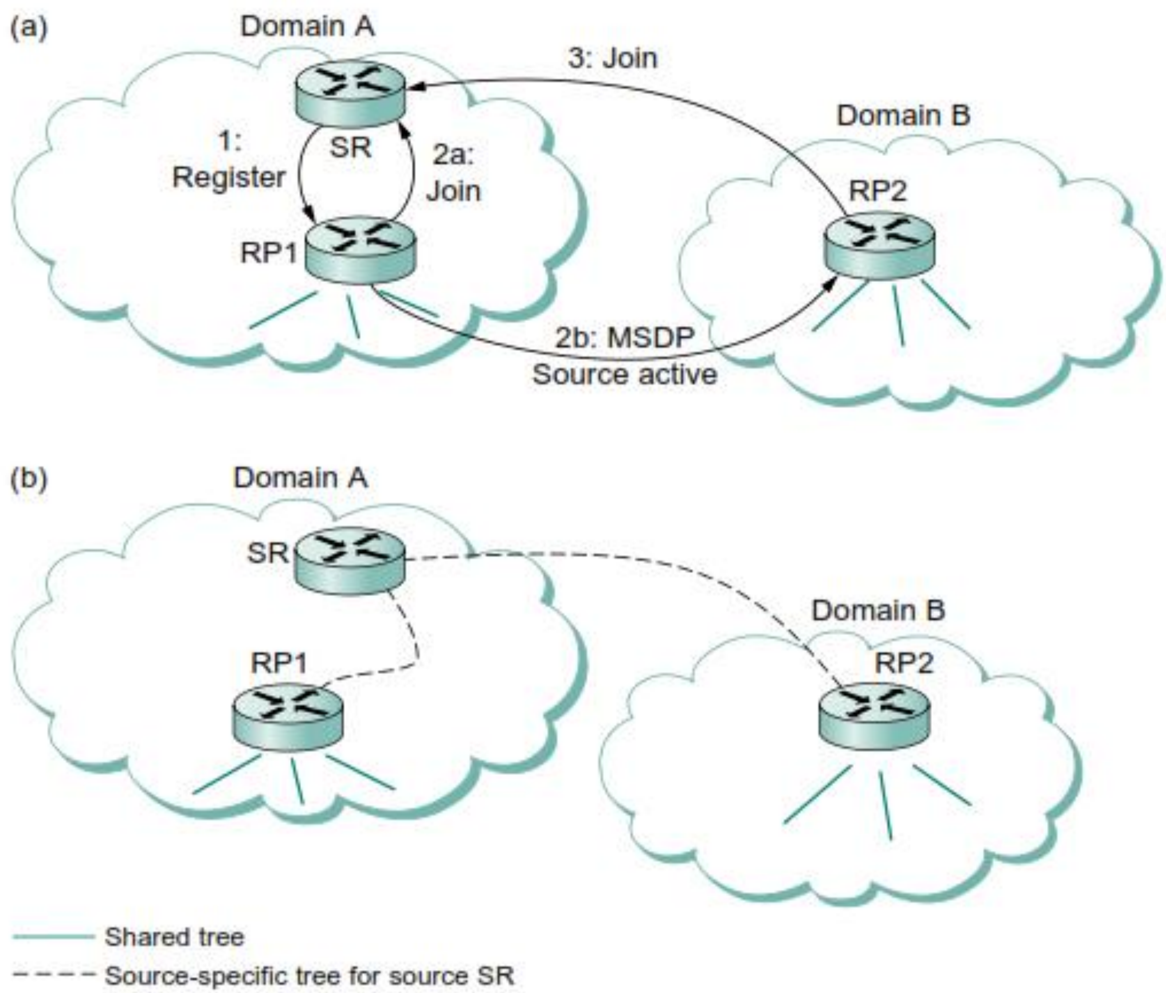
- MSDP is used to connect different domains—each running PIM-SM internally, with its own RPs—by connecting the RPs of the different domains.
- Each RP has one or more MSDP peer RPs in other domains.
- Each pair of MSDP peers is connected by a TCP connection over which the MSDP protocol runs.

Source-Specific Multicast (SSM)

- In the original PIM design, this optimization was invisible to hosts—only routers joined source-specific trees.
- However, once the need for a one-to-many service model was recognized, it was decided to make the source-specific routing capability of PIM-SM explicitly available to hosts.

- PIM-SSM introduces a new concept, the channel, which is the combination of a source address S and a group address G. The group address G looks just like a normal IP multicast address, and both IPv4 and IPv6 have allocated subranges of the multicast address space for SSM.

Source-Specific Multicast (SSM)

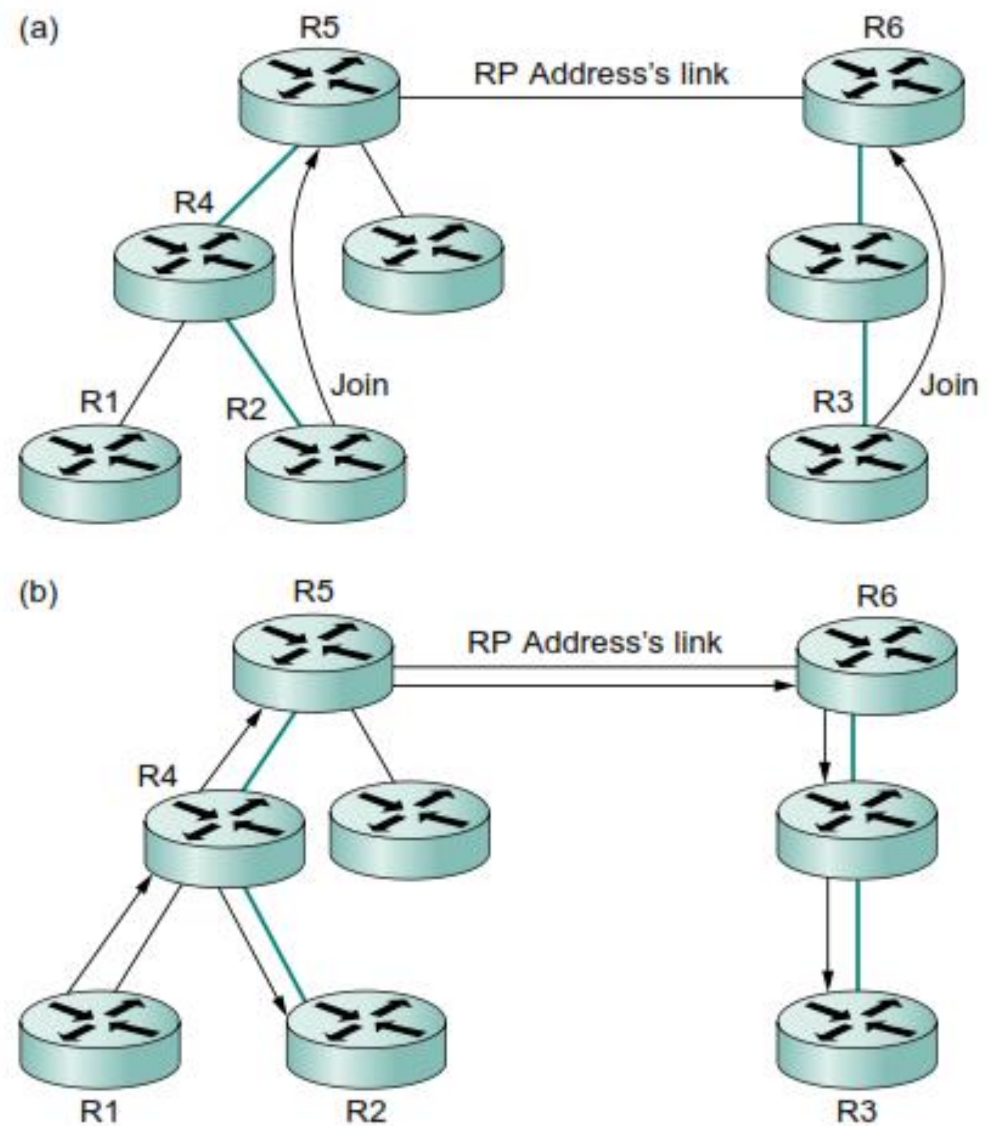


Bidirectional Trees (BIDIR-PIM)

- BIDIR-PIM is a recent variant of PIMSM that is well suited to many-to-many multicasting within a domain, especially when senders and receivers to a group may be the same, as in a multiparty videoconference.

- BIDIR-PIM's trees are bidirectional—a router that receives a multicast packet from a downstream branch can forward it both up the tree and down other branches.

Bidirectional Trees (BIDIR-PIM)



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