ETSF10 – Internet Protocols

Routing on the Internet

2012, Part 2, Lecture 1.2

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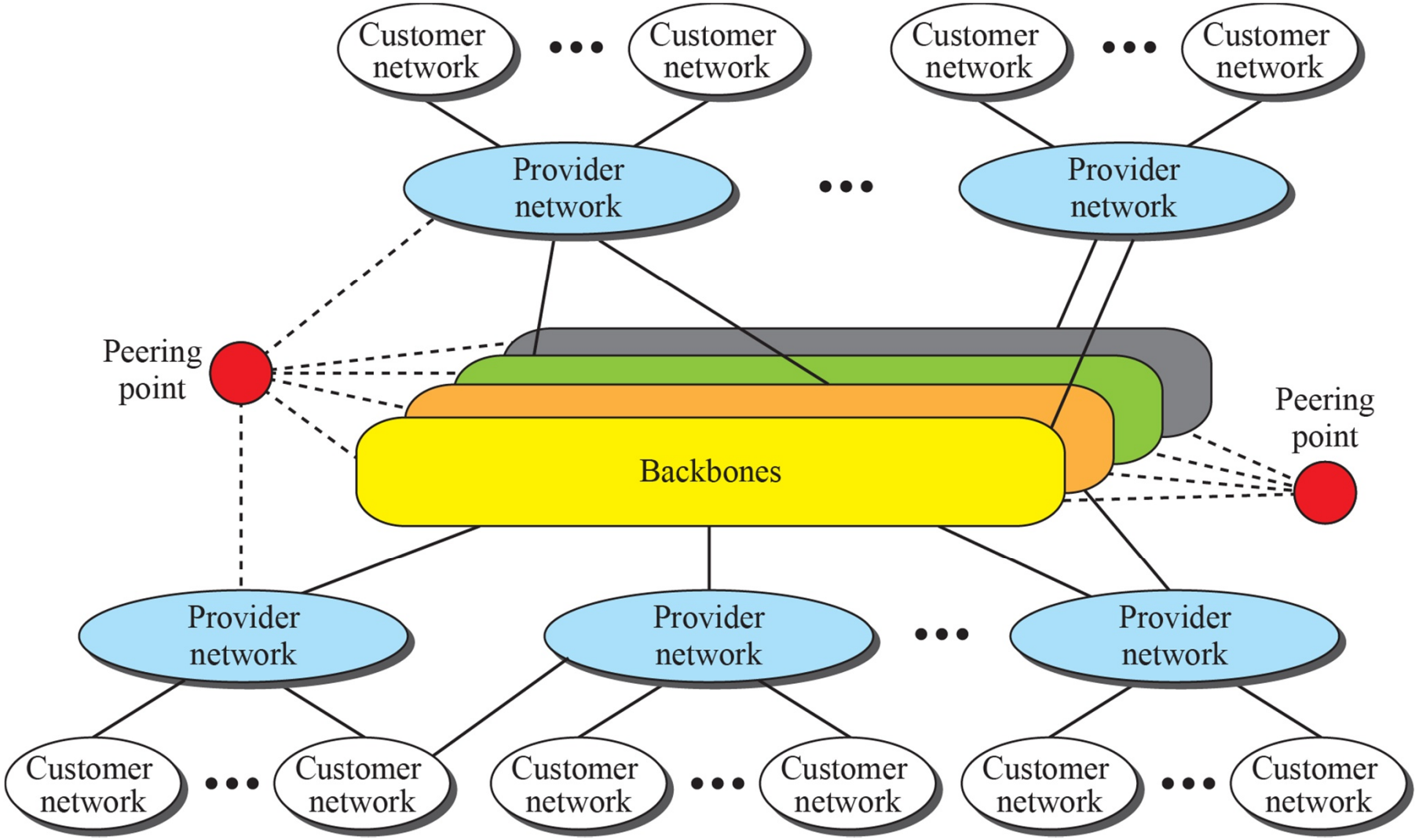
Routing on the Internet

- Unicast routing protocols (part 2)
  [ed.4 ch.22.4] [ed.5 ch.20.3]
- Forwarding process
  [ed.4 ch.22.2] [ed.5 ch.18.5.1]
- Multicast routing, IGMP
  [ed.4 ch.22.4+21.3] [ed.5 ch.21.1-5]

Internet Hierarchy



Hierarchical Routing

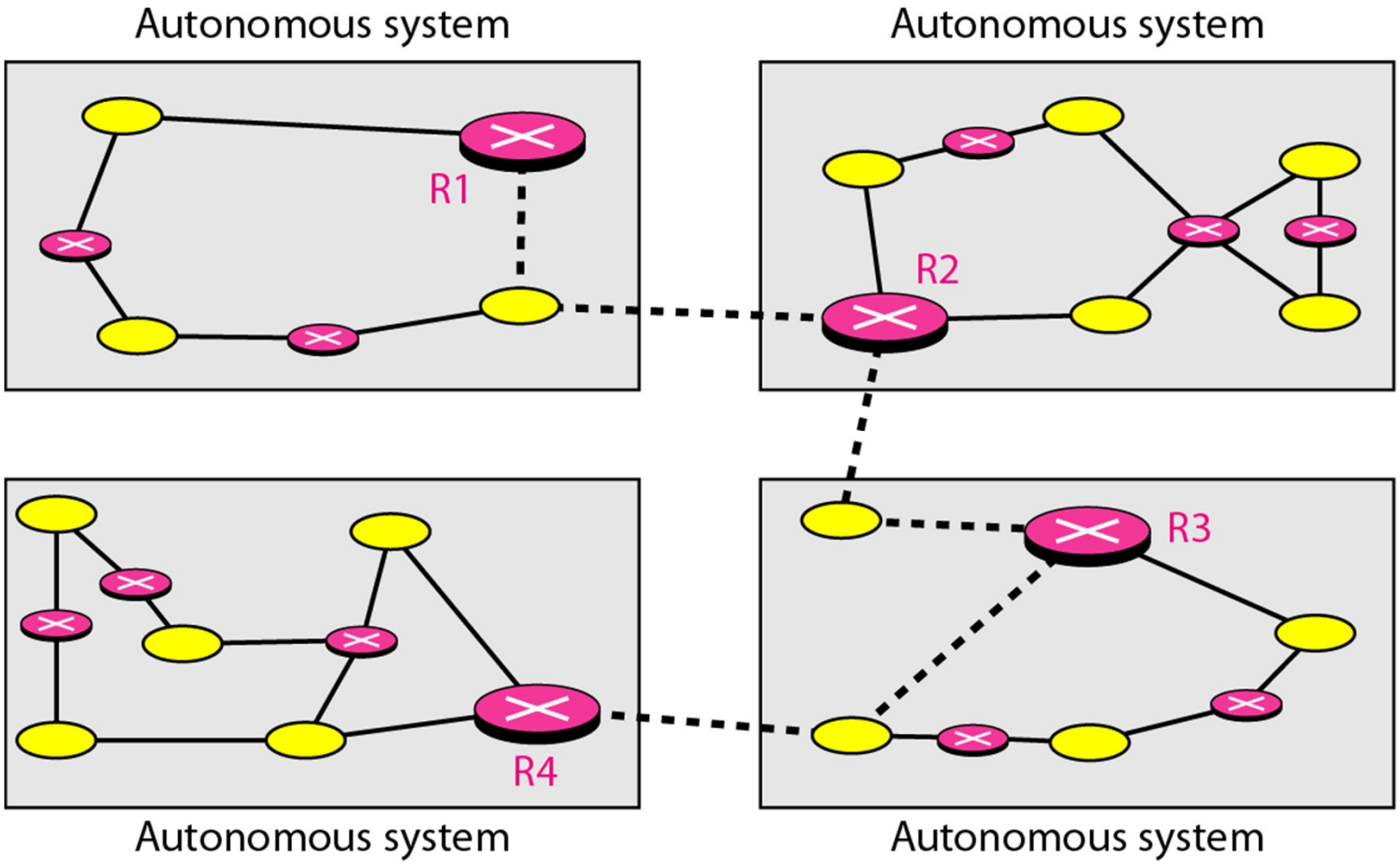
- aggregate routers into “autonomous systems”
- routers in same AS run same routing protocol
  - “intra-AS”
- routers in different AS can run different intra-AS routing protocol

Border Gateway Routers

- special routers in AS
  - run intra-AS routing protocol with all other routers in AS
- also responsible for routing to destinations outside AS
  - run inter-AS routing protocol with other gateway routers

Autonomous Systems

- Inter-AS border (exterior gateway) routers
  - R1
  - R2
  - R3
  - R4



Why different Intra- & Inter-AS routing?

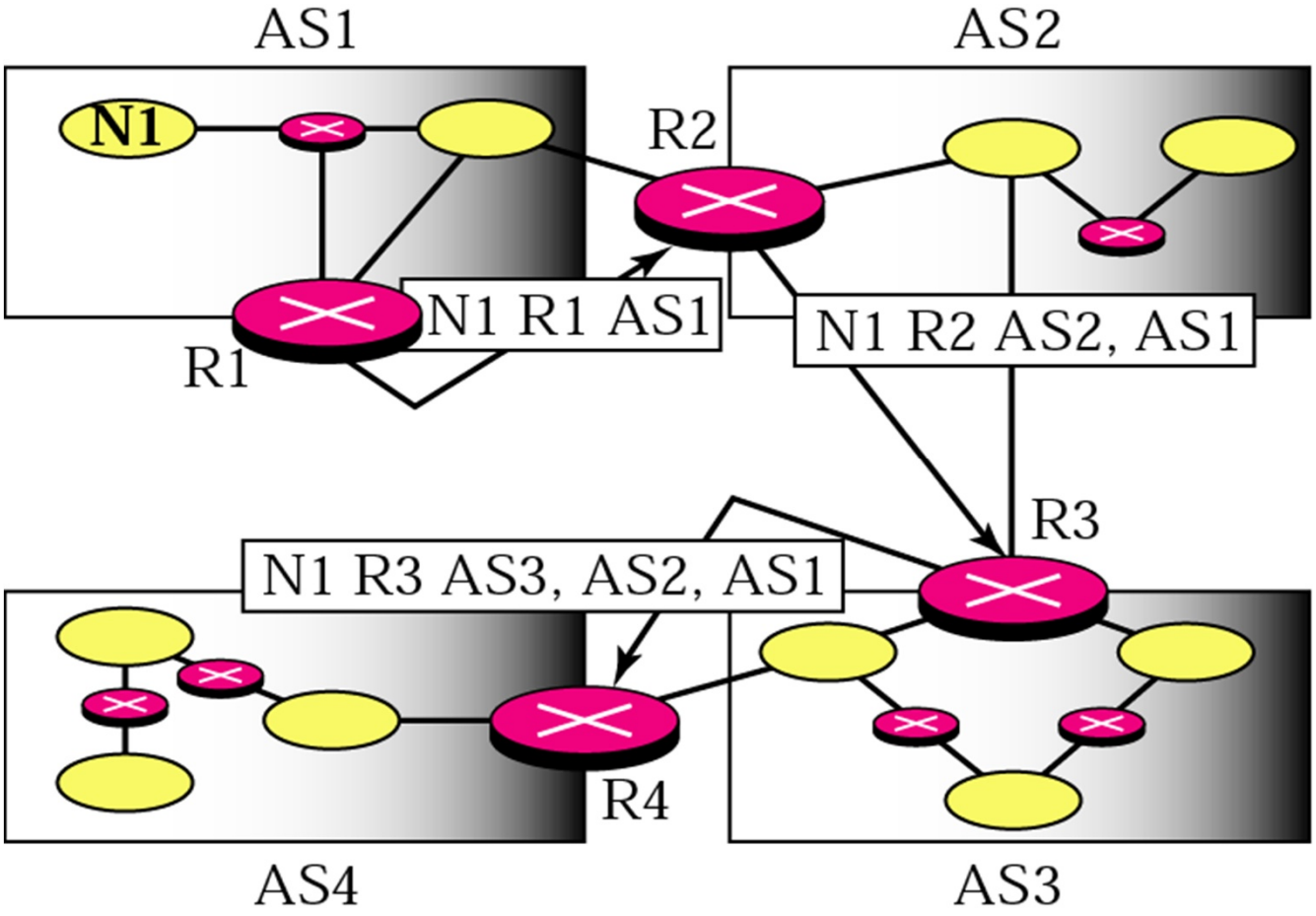
- Policy
  - Inter-AS: admin wants control over how its traffic routed, who routes through its net.
  - Intra-AS: single admin, so no policy decisions needed
- Scale
  - Hierarchical: saves table size, reduced update traffic
- Performance
  - Intra-AS: can focus on performance
  - Inter-AS: policy may dominate over performance

Internet Inter-AS routing: BGP

- Border Gateway Protocol: *de facto* standard
- Path Vector protocol:
  - Similar to *Distance Vector*
  - Border gateways broadcast to neighbours (peers) entire path (sequence of AS) to destination
  - BGP routes to networks (AS), not individual hosts

Path Vector Messages

- Same principle as distance vector routing



Path Vector Routing Table

Network	Next Router	Path
N01	R01	AS62, AS23, AS67
N02	R05	AS67, AS22, AS05, AS89
N03	R06	AS67, AS89, AS09, AS34
N03	R12	AS62, AS02, AS34

Network id

"Output port"

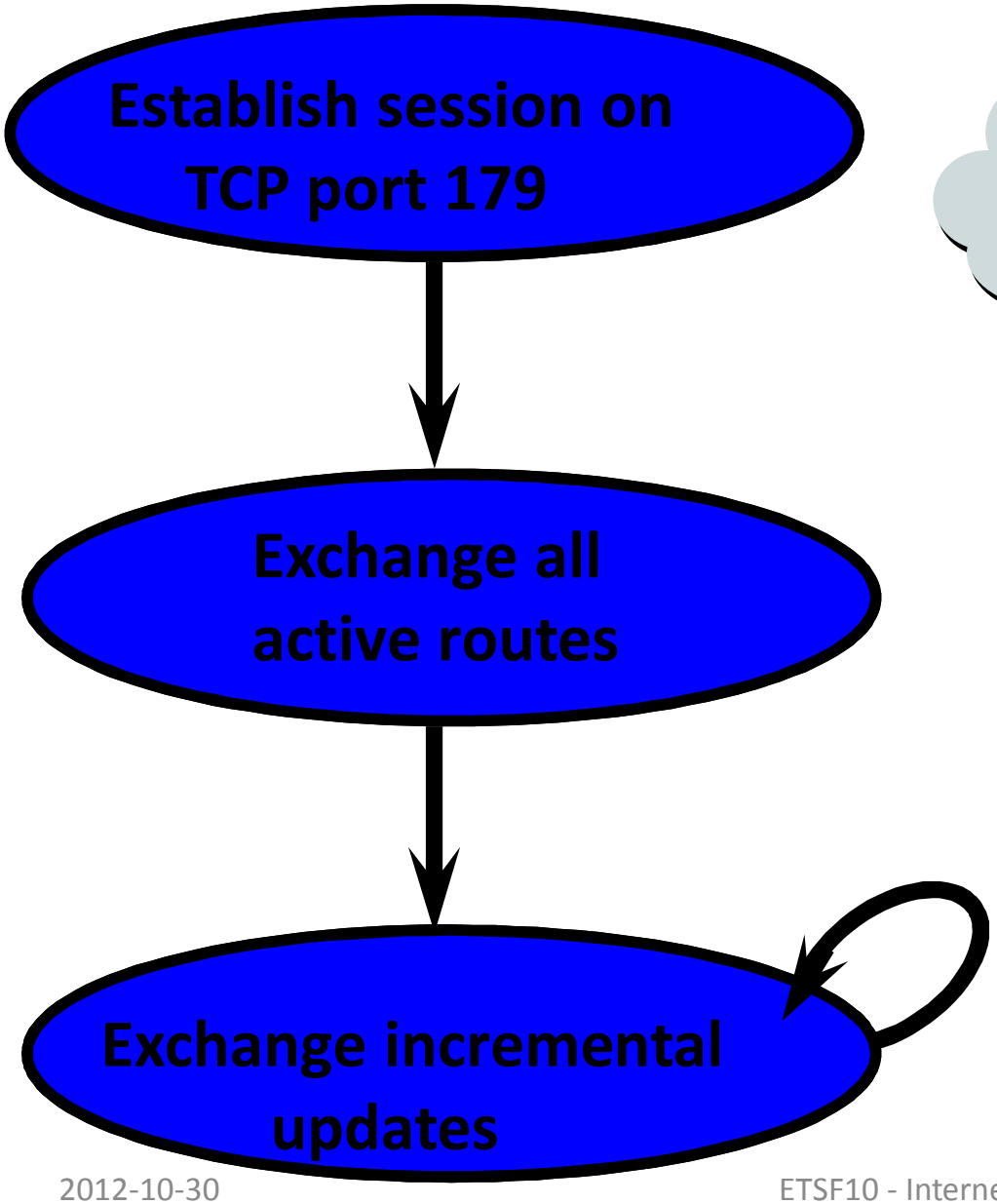
"Metric"
One of many
ATTRIBUTES

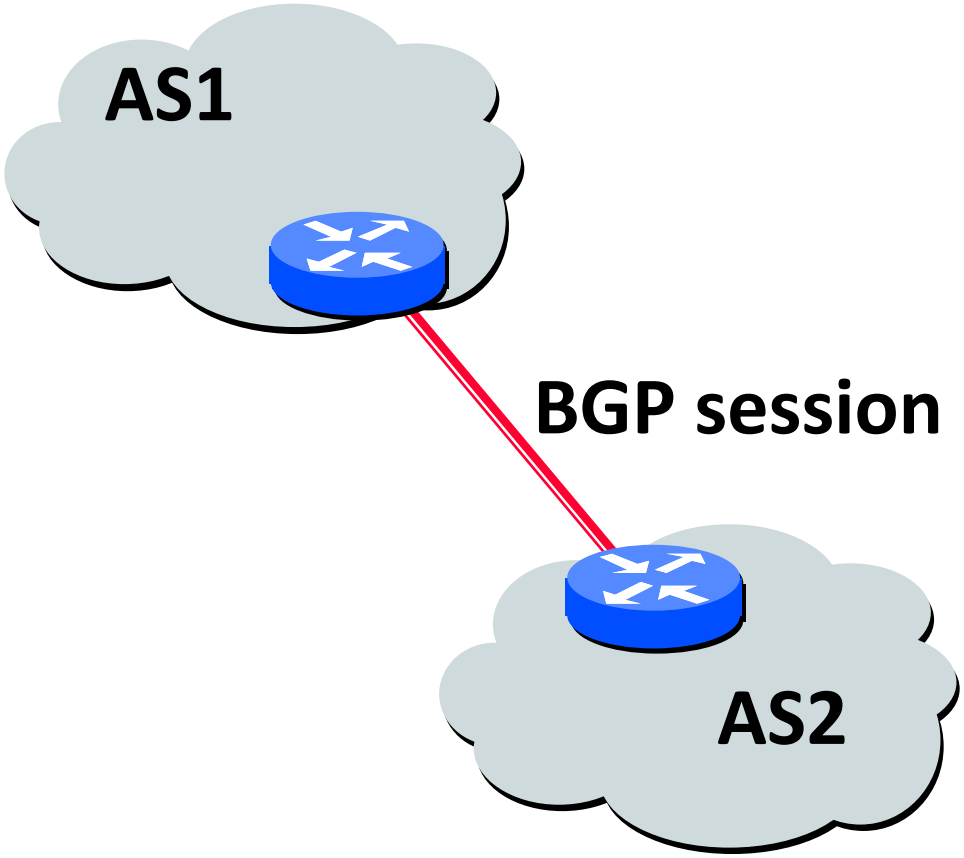
AS = Autonomous System = Organisation

BGP Router Operations

- Receiving and filtering route advertisements from directly attached neighbour(s)
- Route selection
  - To route to destination X, which path (of several advertised) will be taken?
- Sending route advertisements to neighbours

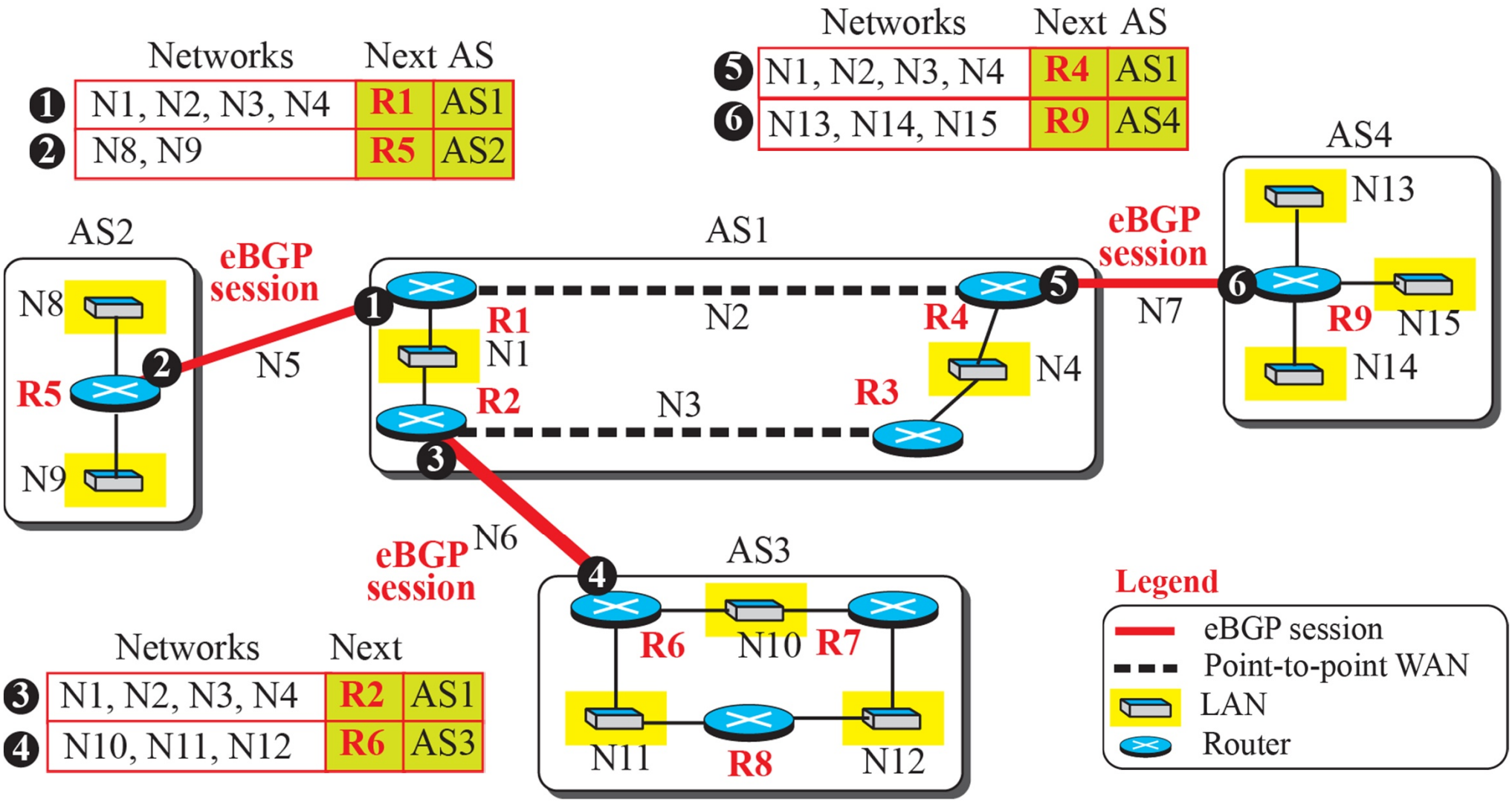
BGP Router Operations



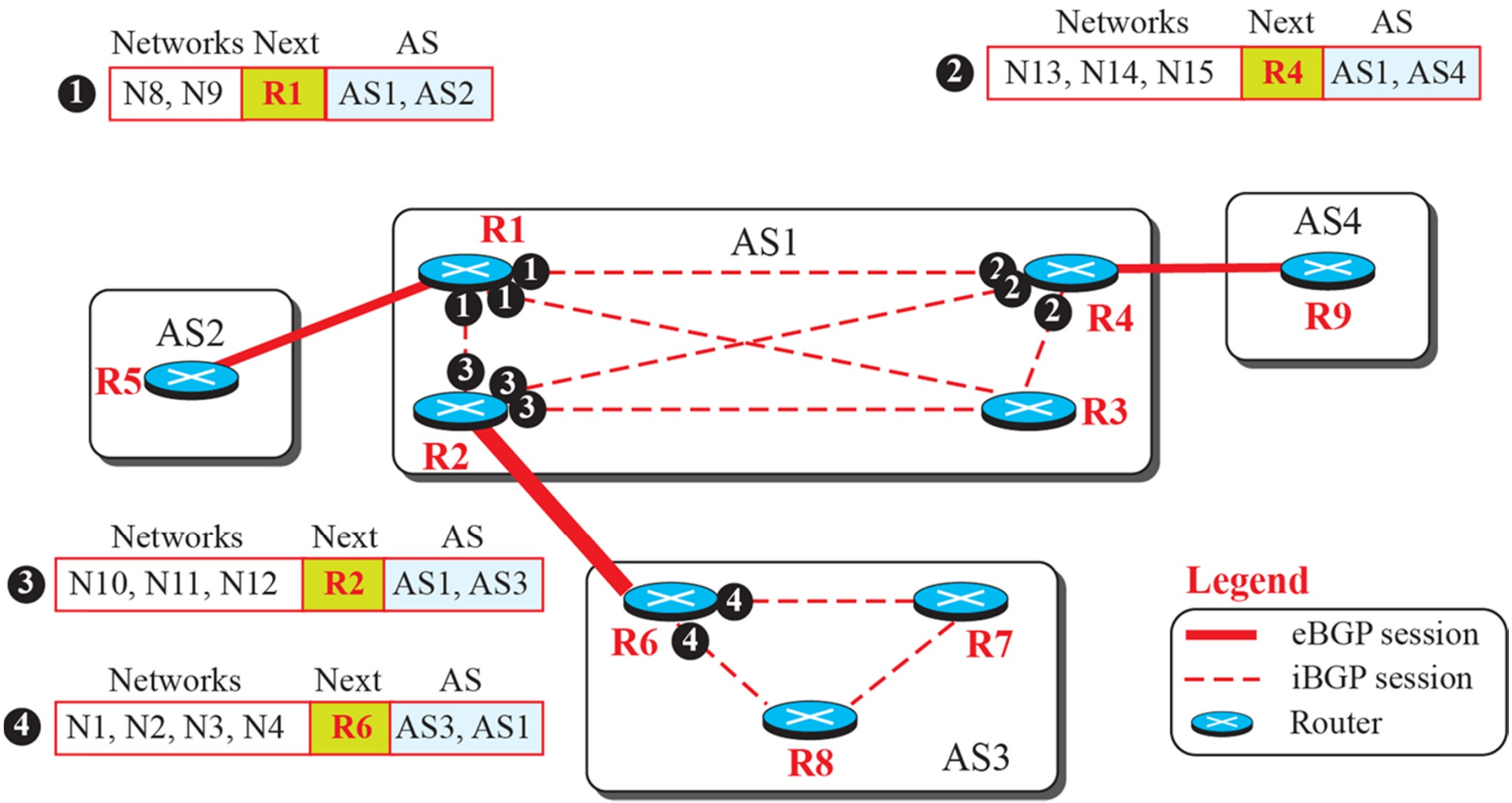


While connection is ALIVE exchange route UPDATE messages

eBGP Operation



eBGP combined with iBGP

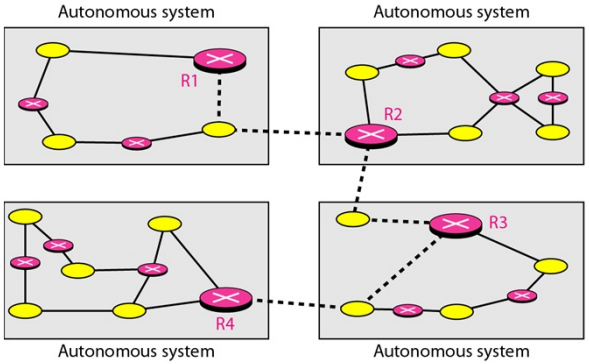


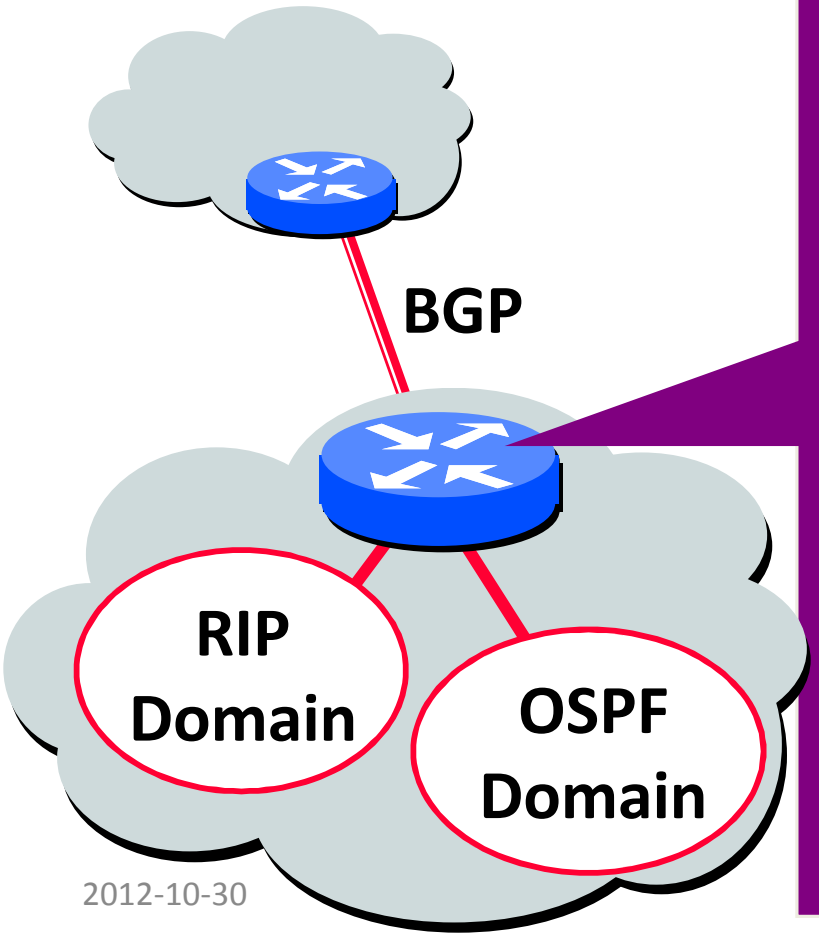
To Do Now: ”One Minute Paper”

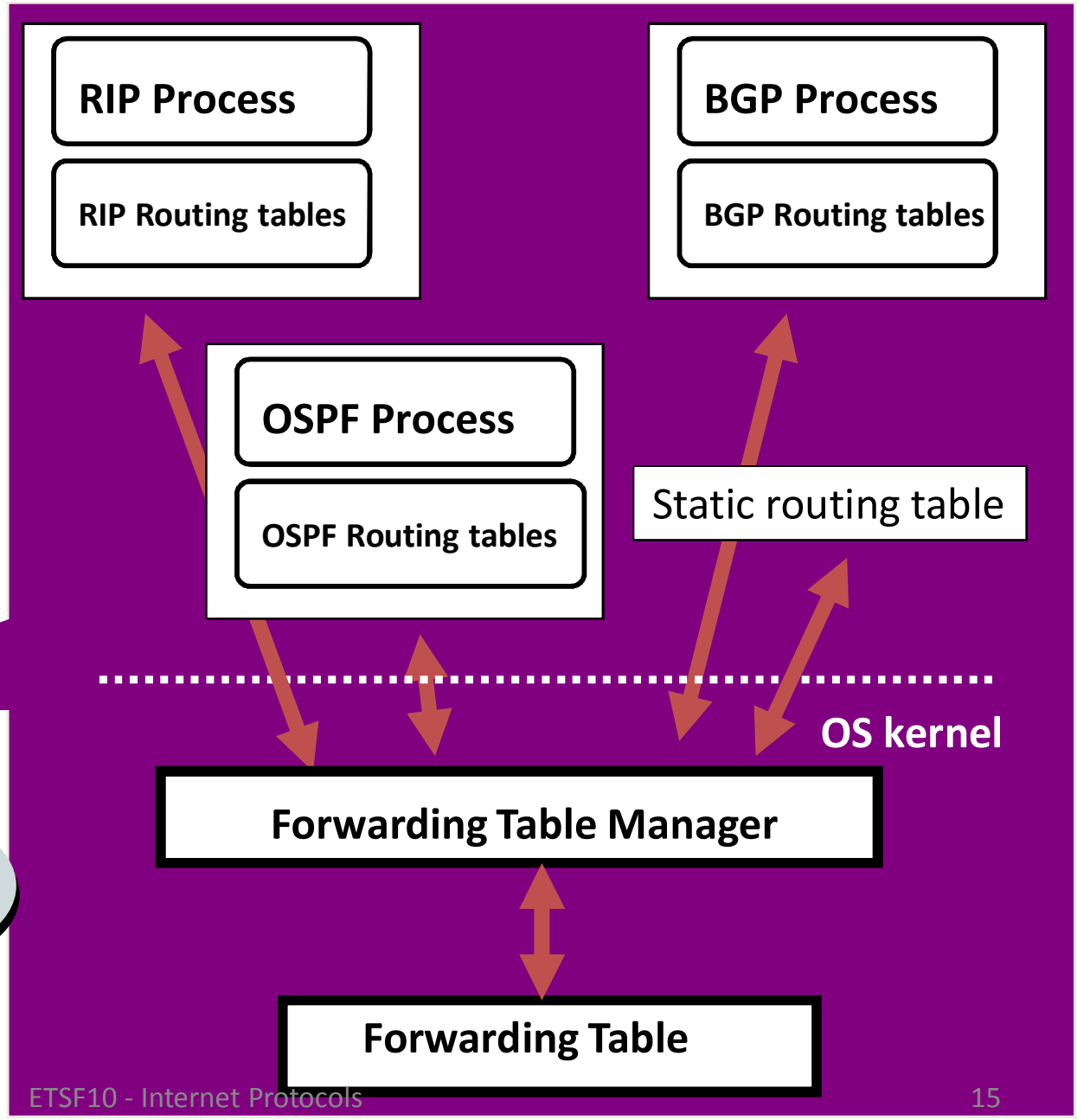
- Routers / switches
  - Functions and architecture
- Routing / forwarding
  - Intra- vs. inter-domain
  - RIP, OSPF, BGP

- **What was the most important thing you’ve learnt so far? Why?**

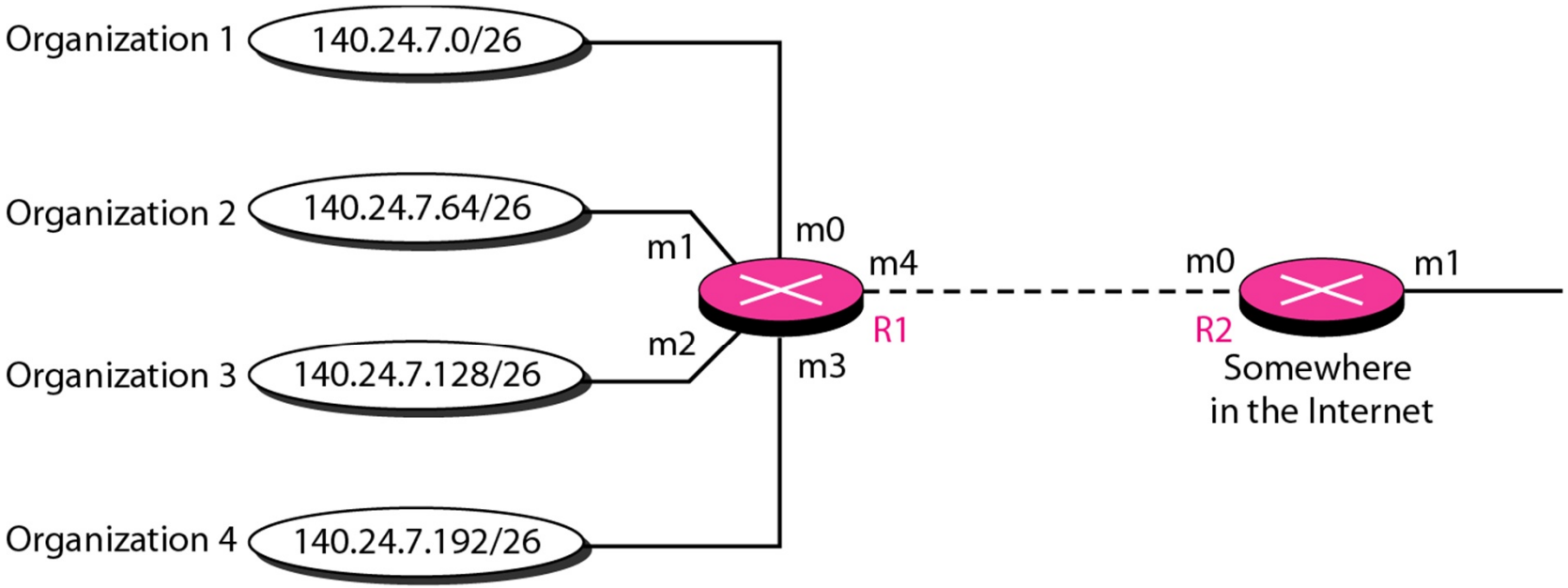
Routing Tables and Forwarding Table







Forwarding: Address aggregation



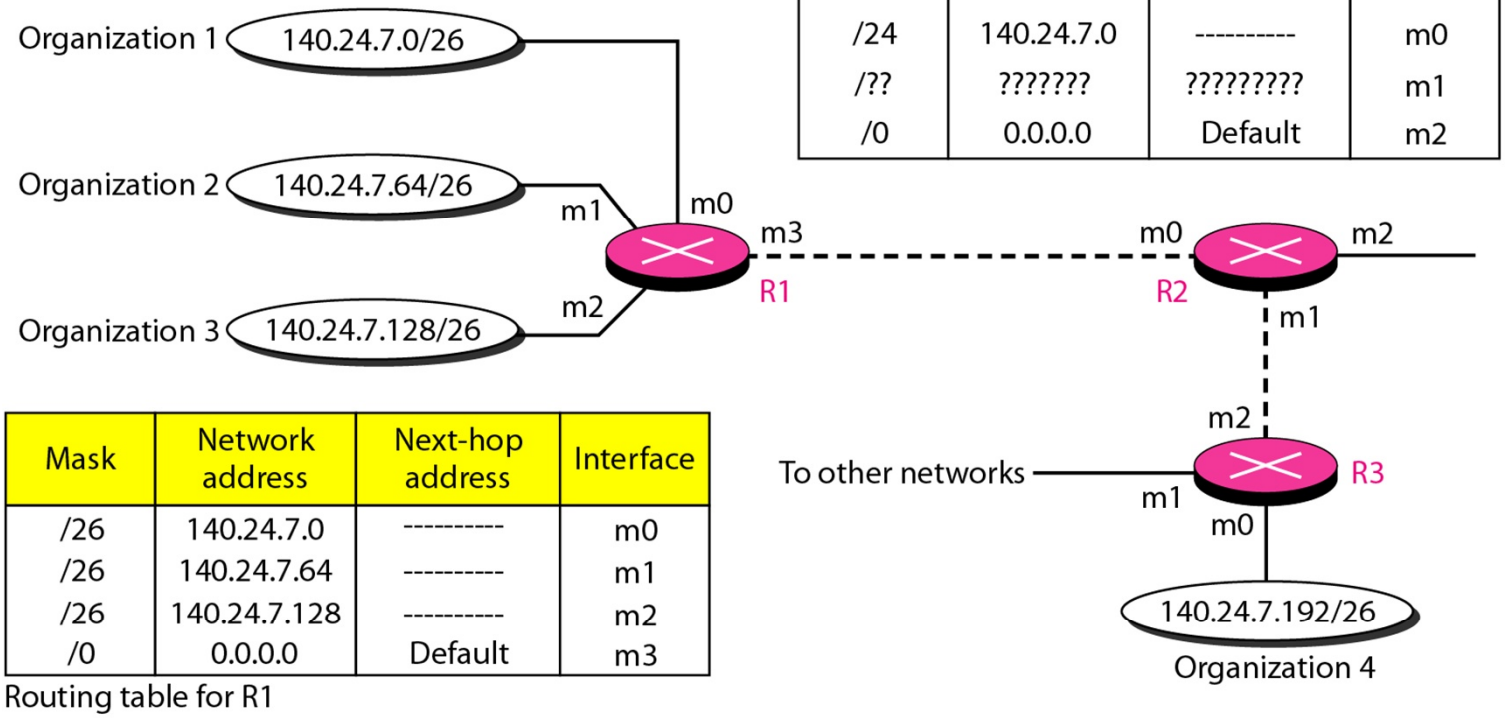
Mask	Network address	Next-hop address	Interface
/26	140.24.7.0	----------	m0
/26	140.24.7.64	----------	m1
/26	140.24.7.128	----------	m2
/26	140.24.7.192	----------	m3
/0	0.0.0.0	Default	m4

Routing table for R1

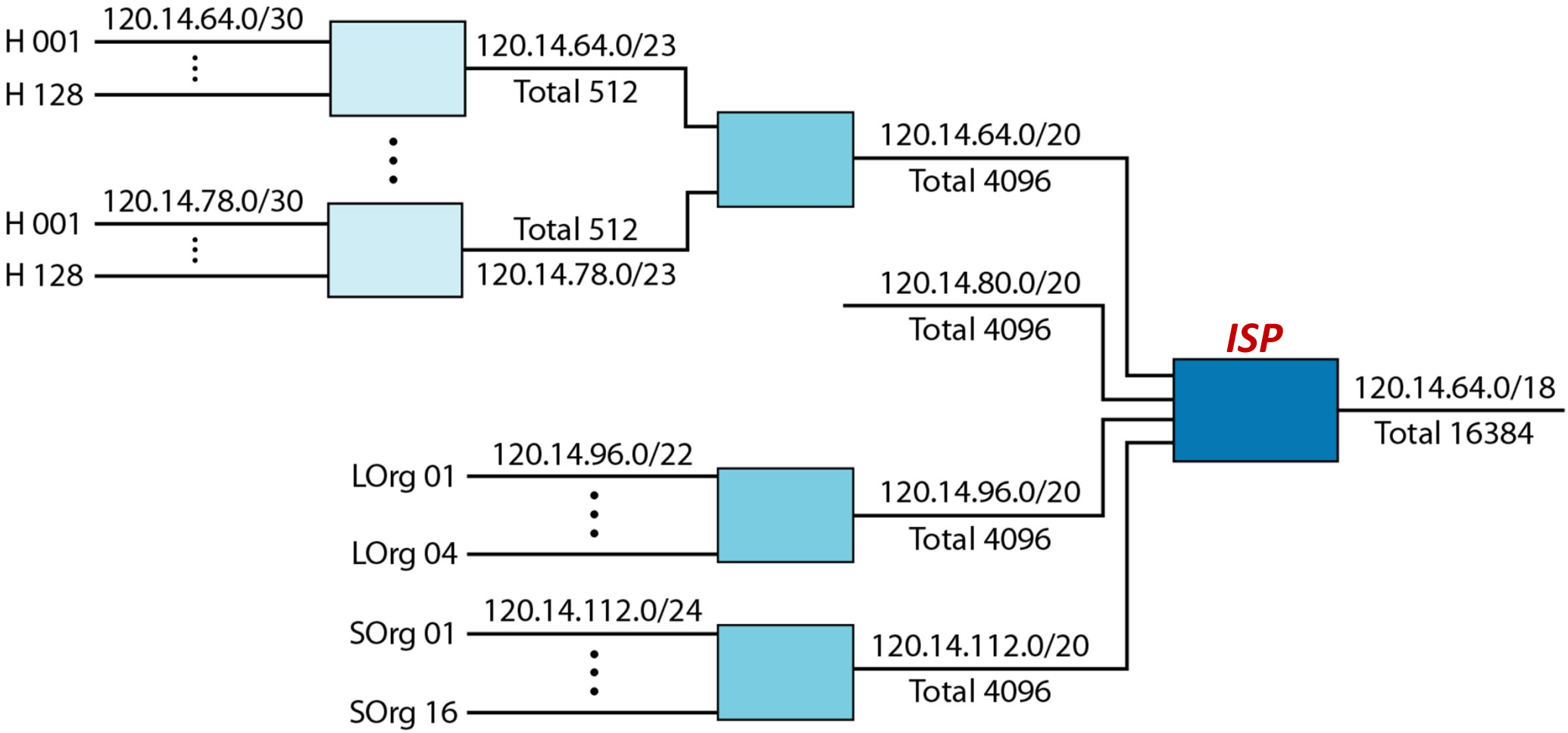
Mask	Network address	Next-hop address	Interface
/24	140.24.7.0	----------	m0
/0	0.0.0.0	Default	m1

Routing table for R2

Forwarding: Longest mask matching



Forwarding: Hierarchical routing



Announcements

- One subject moved to Extended Reading
  - P2P paradigm *[ed.5 §29.1+5]*
- Some subjects removed from Course Content
  - Client/server *[ed.4 §27.1-3][ed.5 §25.1+26.1]*

- Exercises to be repeated once only (same day)

- **Reminder: Student Representative Election**

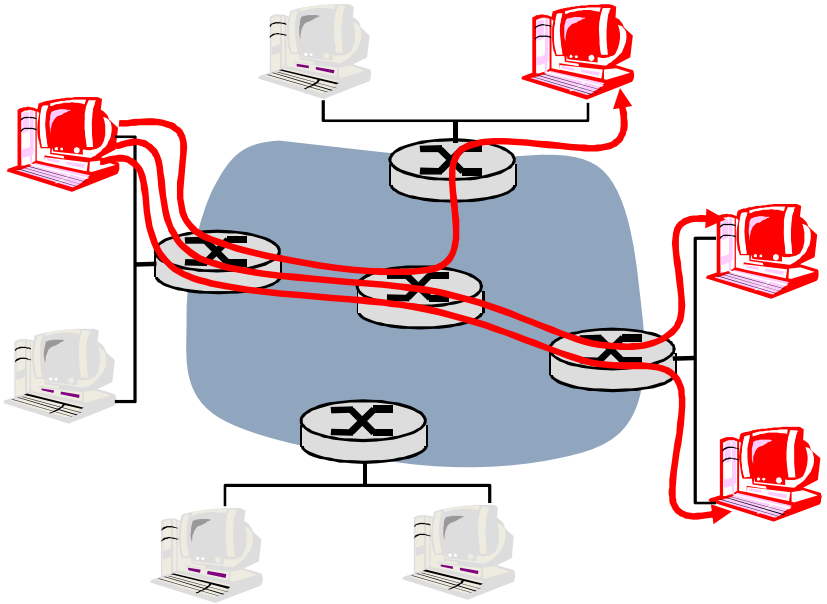
See you in 15’ :)

- After the break
  - Multicast routing
  - IGMP

Multicast: One-to-many Routing

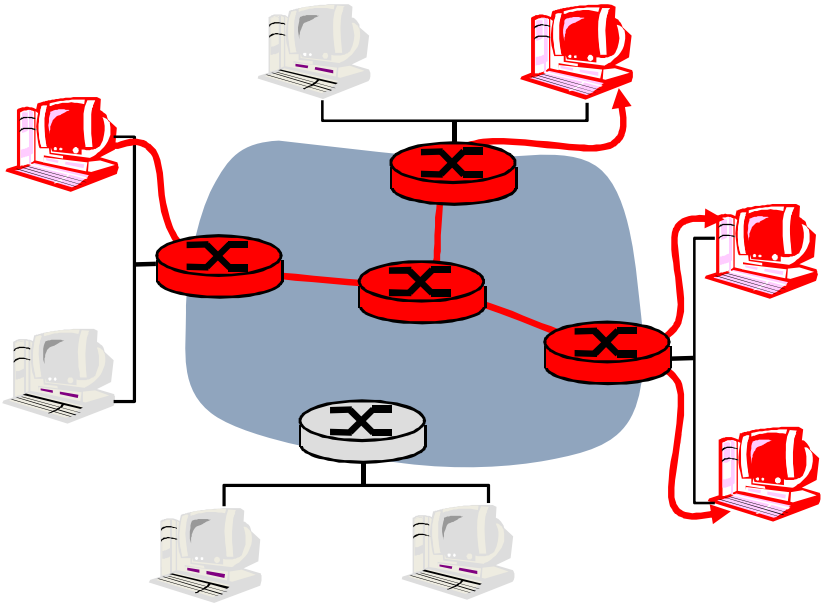
Unicast

- Routers forward multiple unicast datagrams

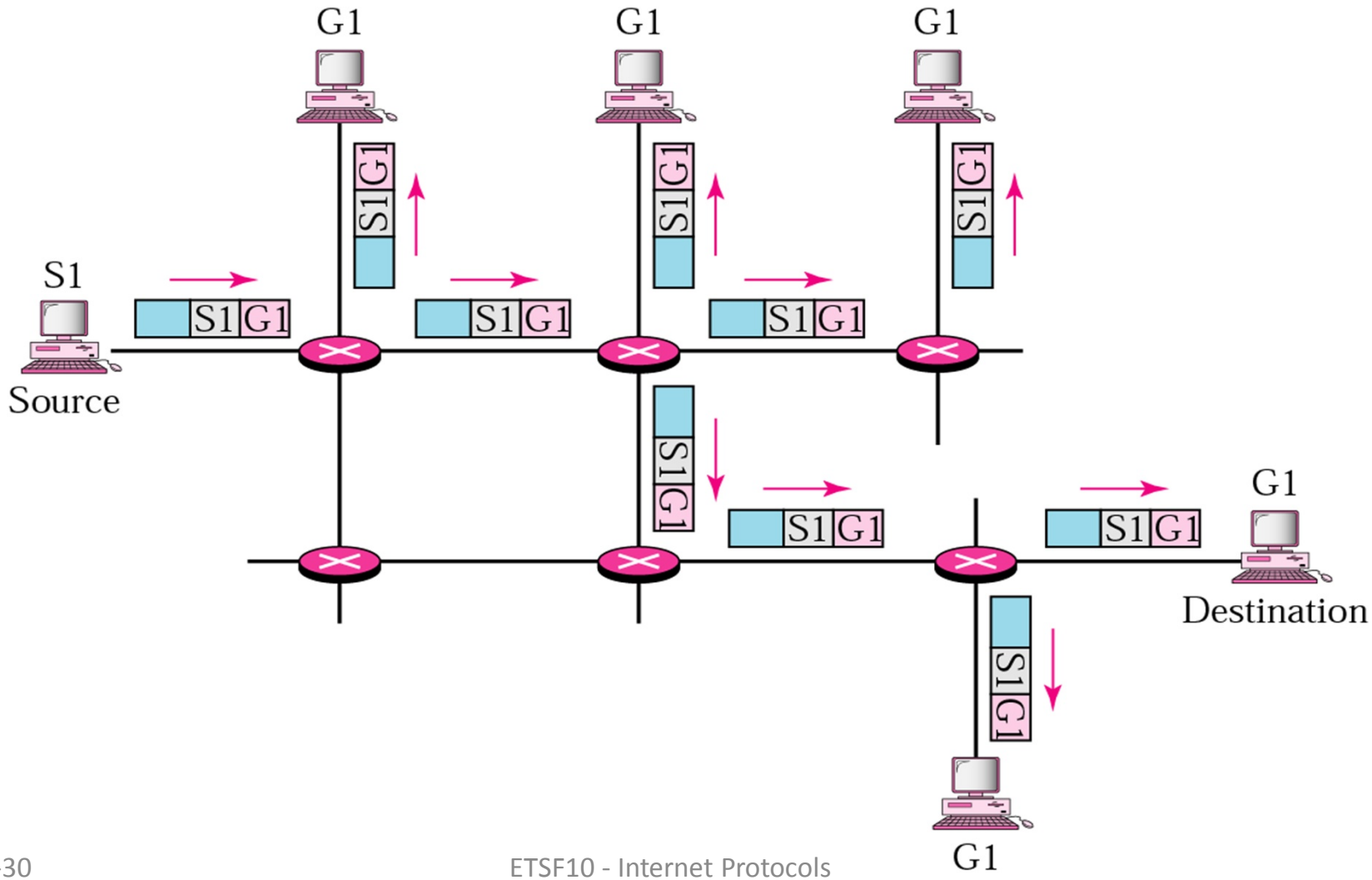


Multicast

- Routers (red) duplicate and forward multicast datagrams

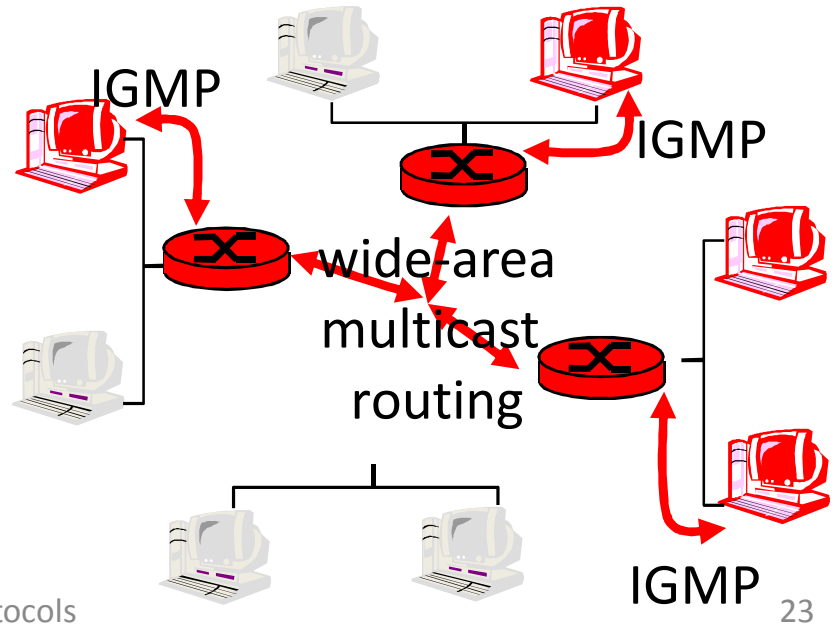


Source and Group Addresses



Joining a Multicast Group

- **Local**: host informs local multicast router
  - IGMP (Internet Group Management Protocol)
- **Wide area**: local router interacts with other routers to build forwarding tree and receive multicast data flow
  - MOSPF, DVMRP, PIM-DM
  - CBT, PIM-SM



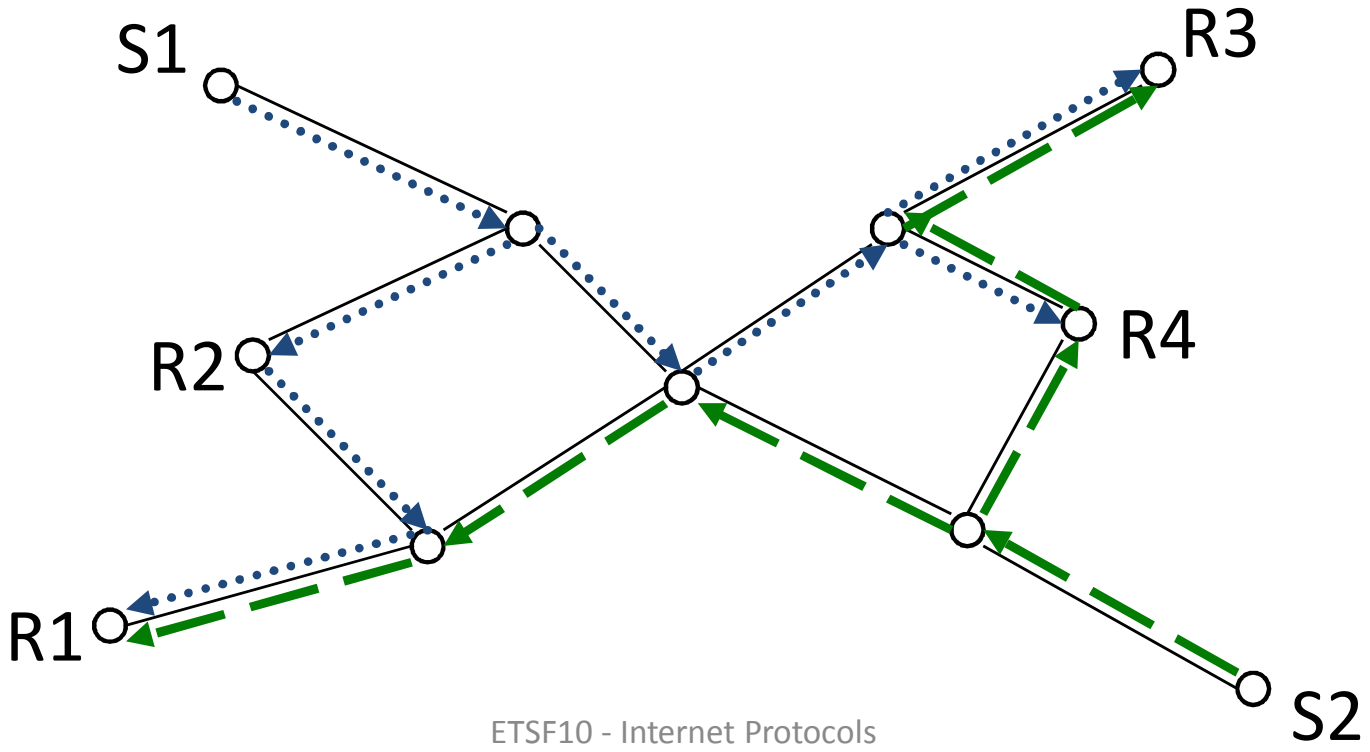
Multicast Routing Protocols

- Shortest path trees, again!

- In unicast routing
  - One path (on tree) used at a time
- In multicast routing
  - Whole tree used each time
  - Each source needs a tree

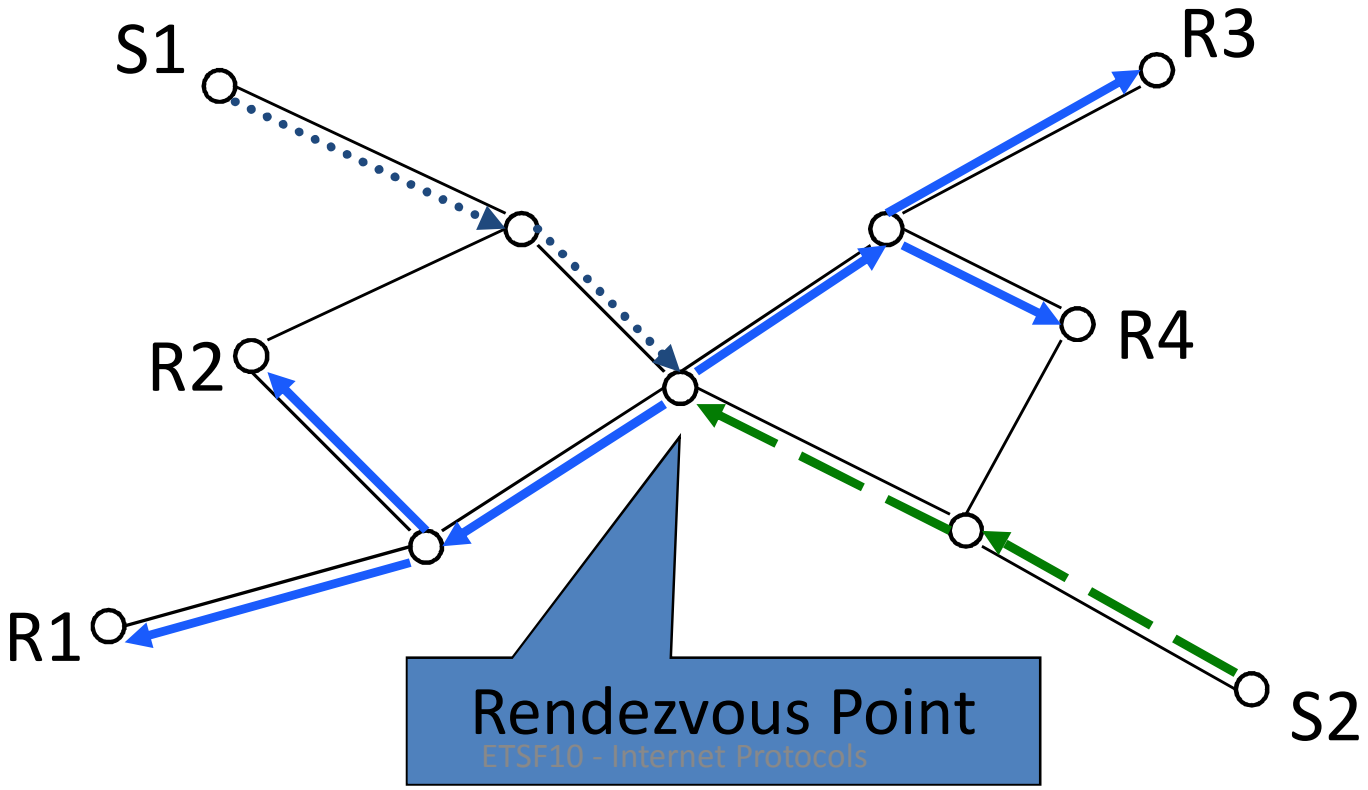
Source-Based Tree

- One tree per source (at each router)
- One source per group
- High complexity, high efficiency

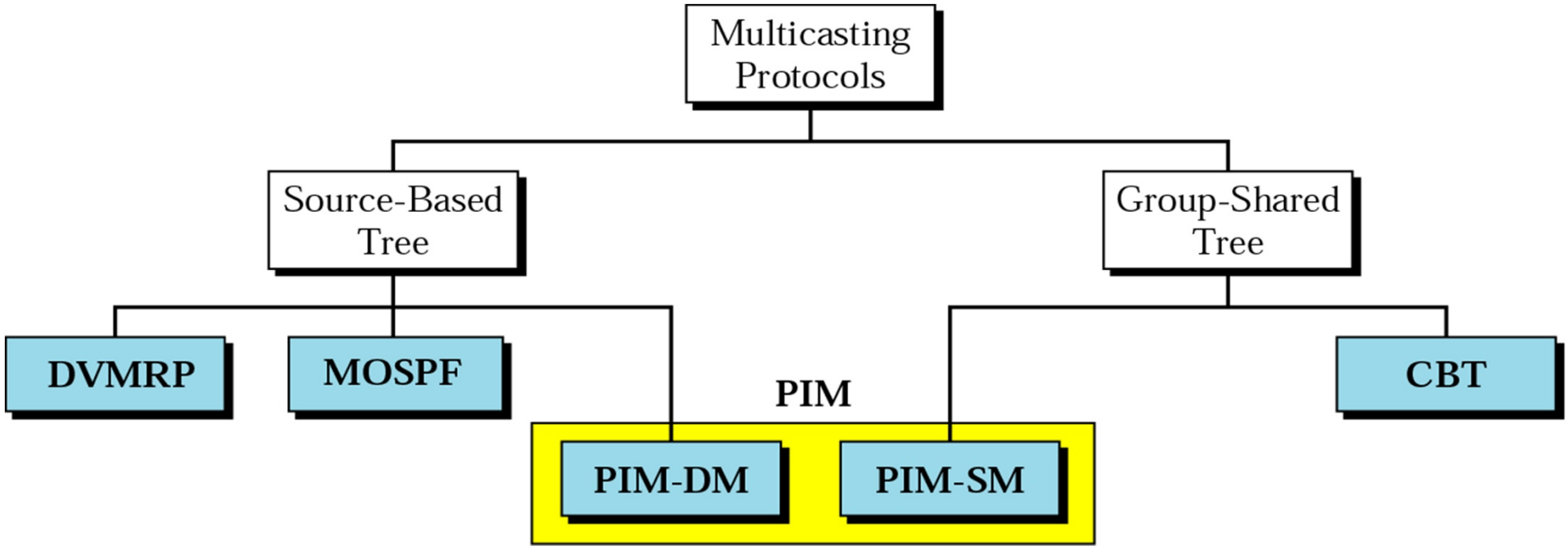


Group-Shared Tree

- One tree per group (at one router)
- Shared by multiple sources in group
- Lower complexity, lower efficiency



Classification of Algorithms



PIM

- Independent from unicast protocol
- Uses available routing info for path lookups
- Two modes:
  - Sparse Mode
  - Dense Mode

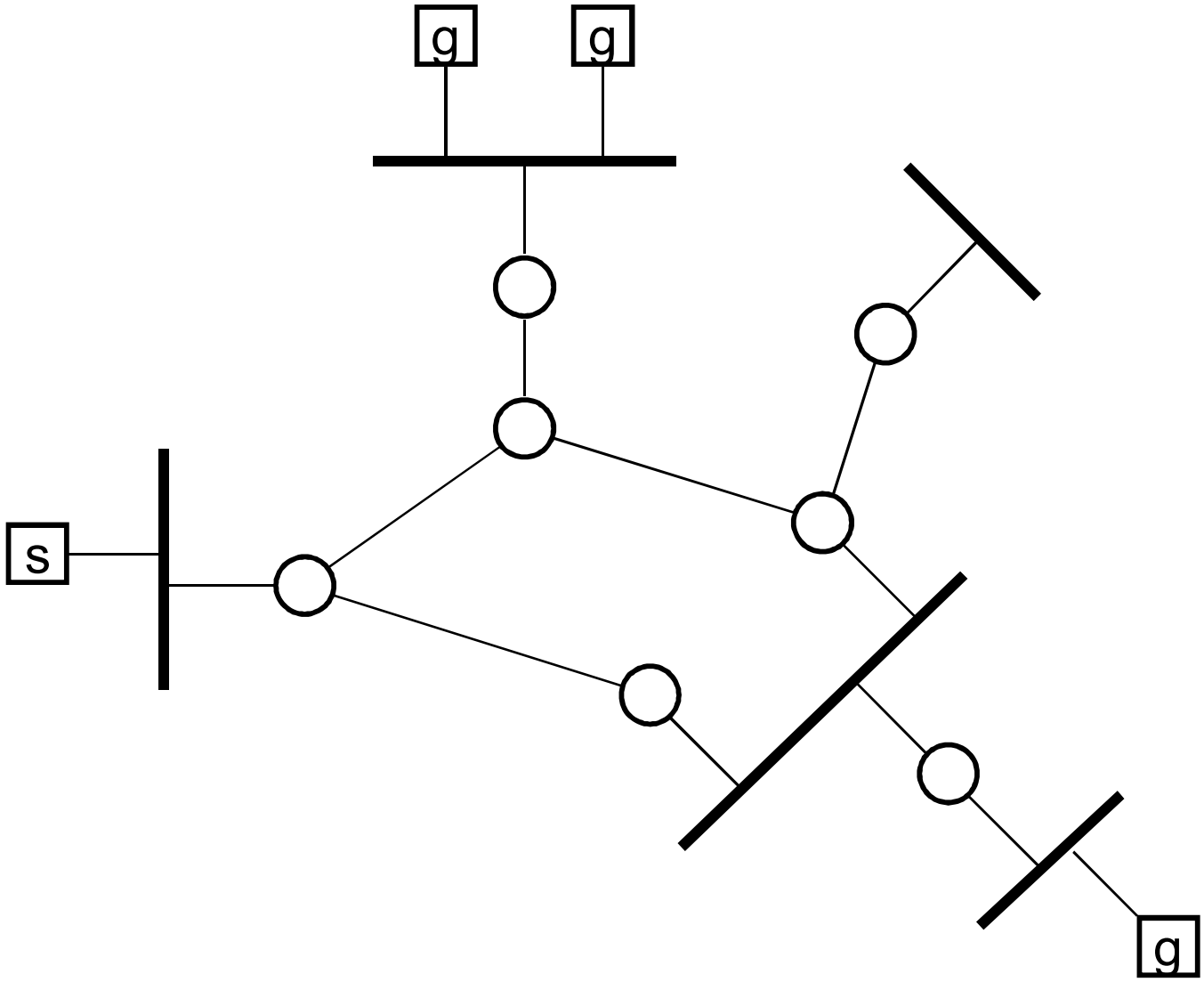
PIM-SM

- Relatively few members assumed
- Trees are built on demand (when needed)
  - Group-shared trees with rendezvous points
- Methods for tree construction
  - Grafting
  - Pruning
- Can switch from group-shared to source-based if more efficient

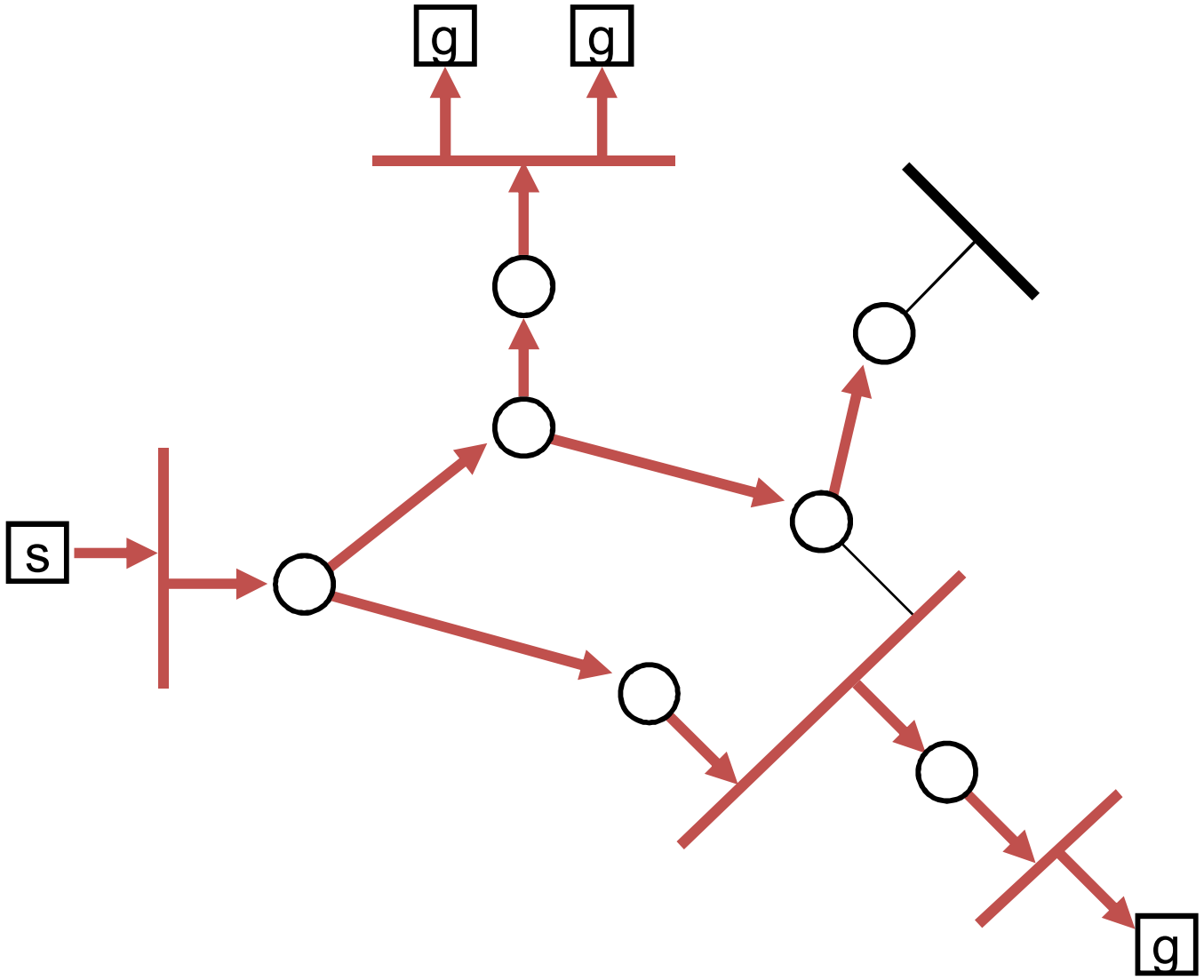
PIM-DM

- All hosts assumed to be members
- Build source-based tree from source
- Routers without members prune tree
- Grafting used to add new members

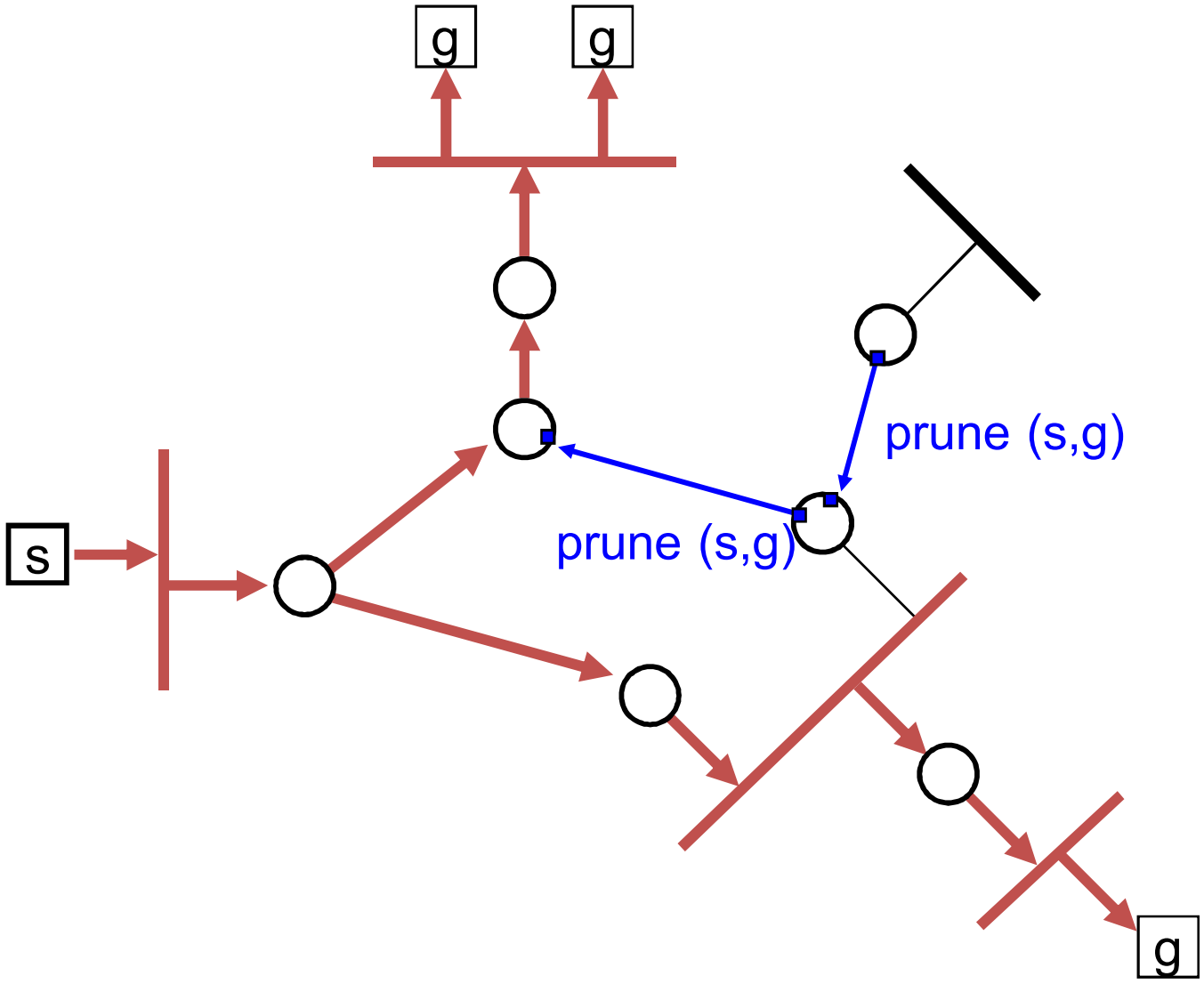
Example Topology



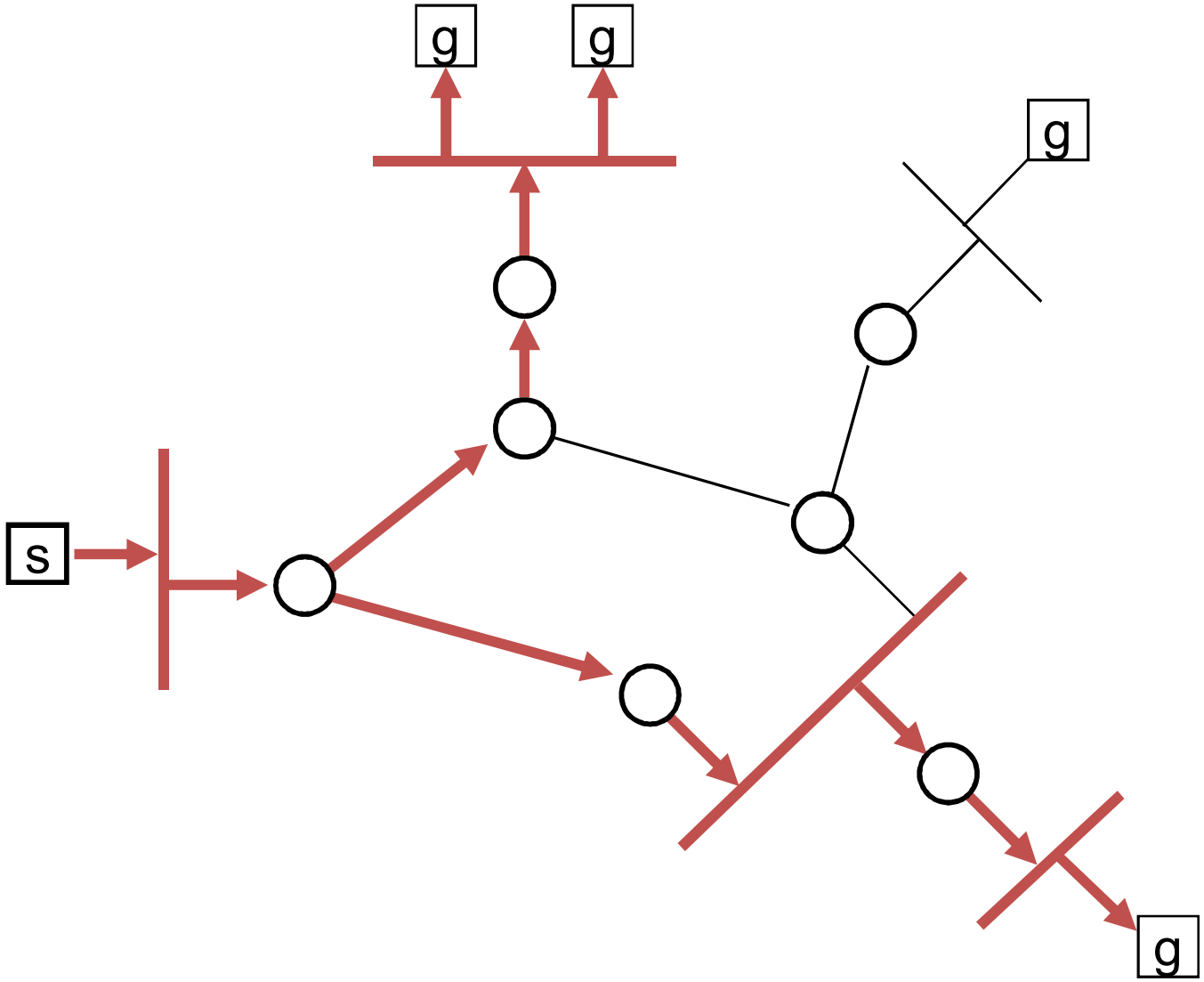
Truncated Broadcast



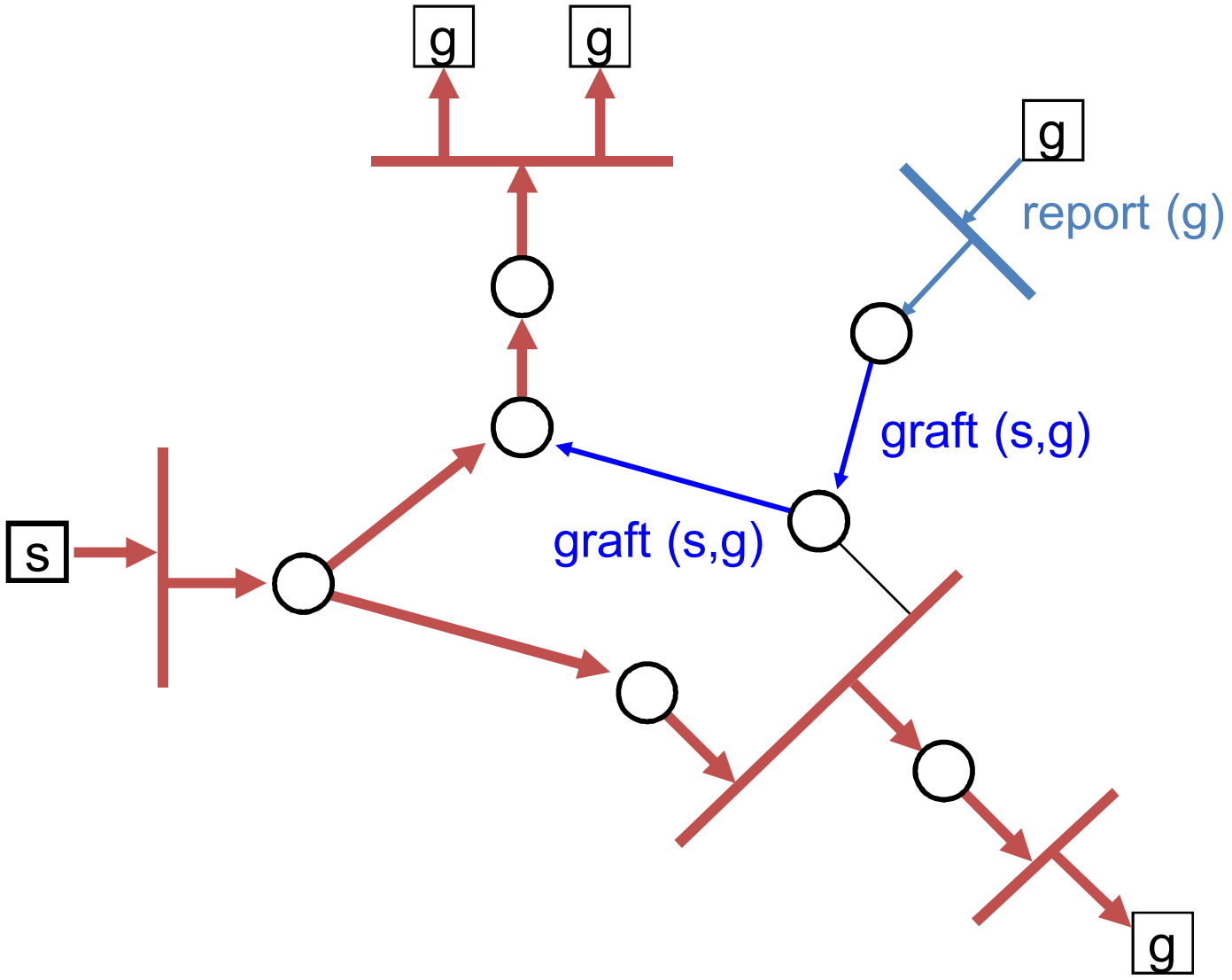
Pruning



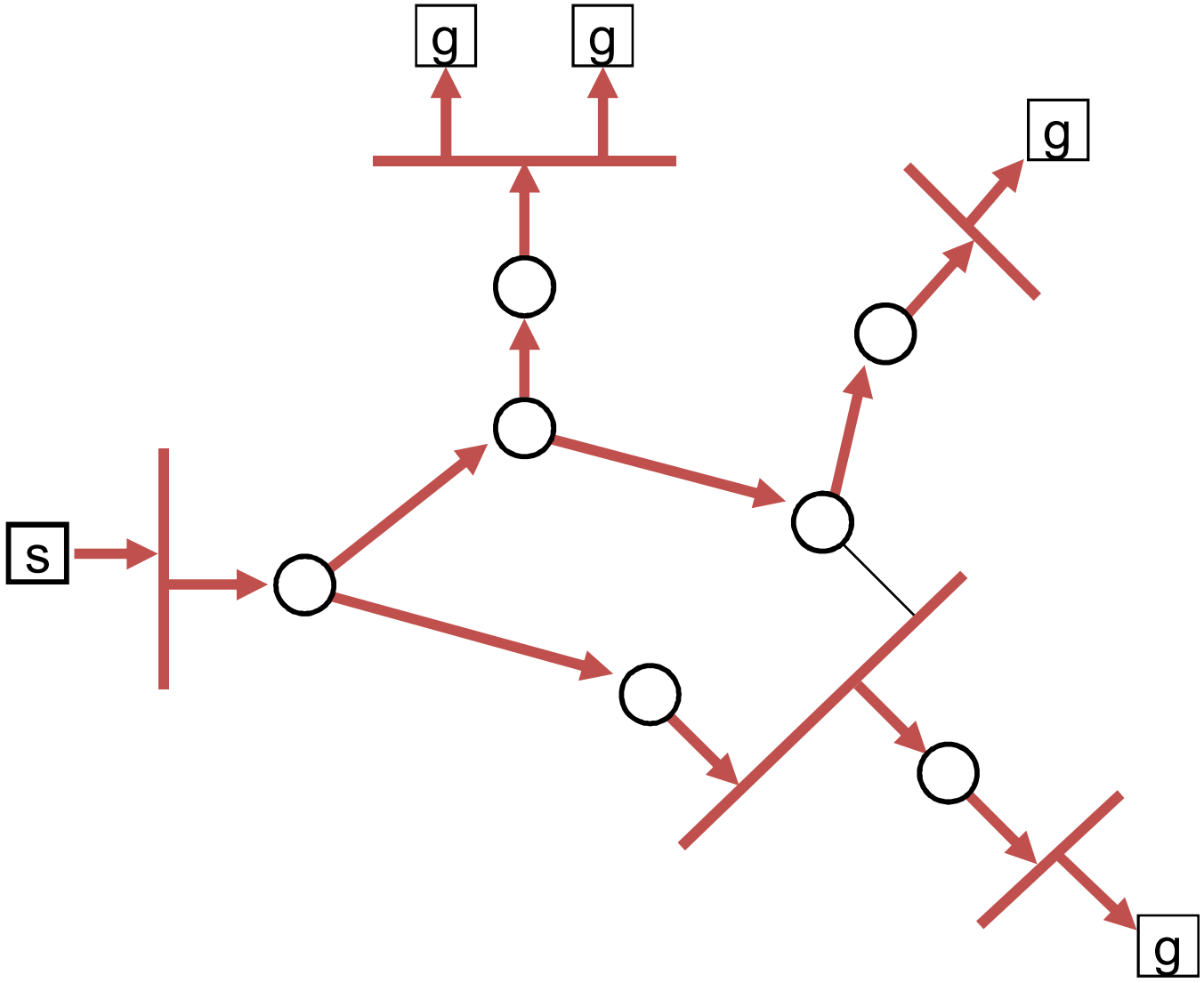
Steady State after Pruning



Grafting on New Receivers

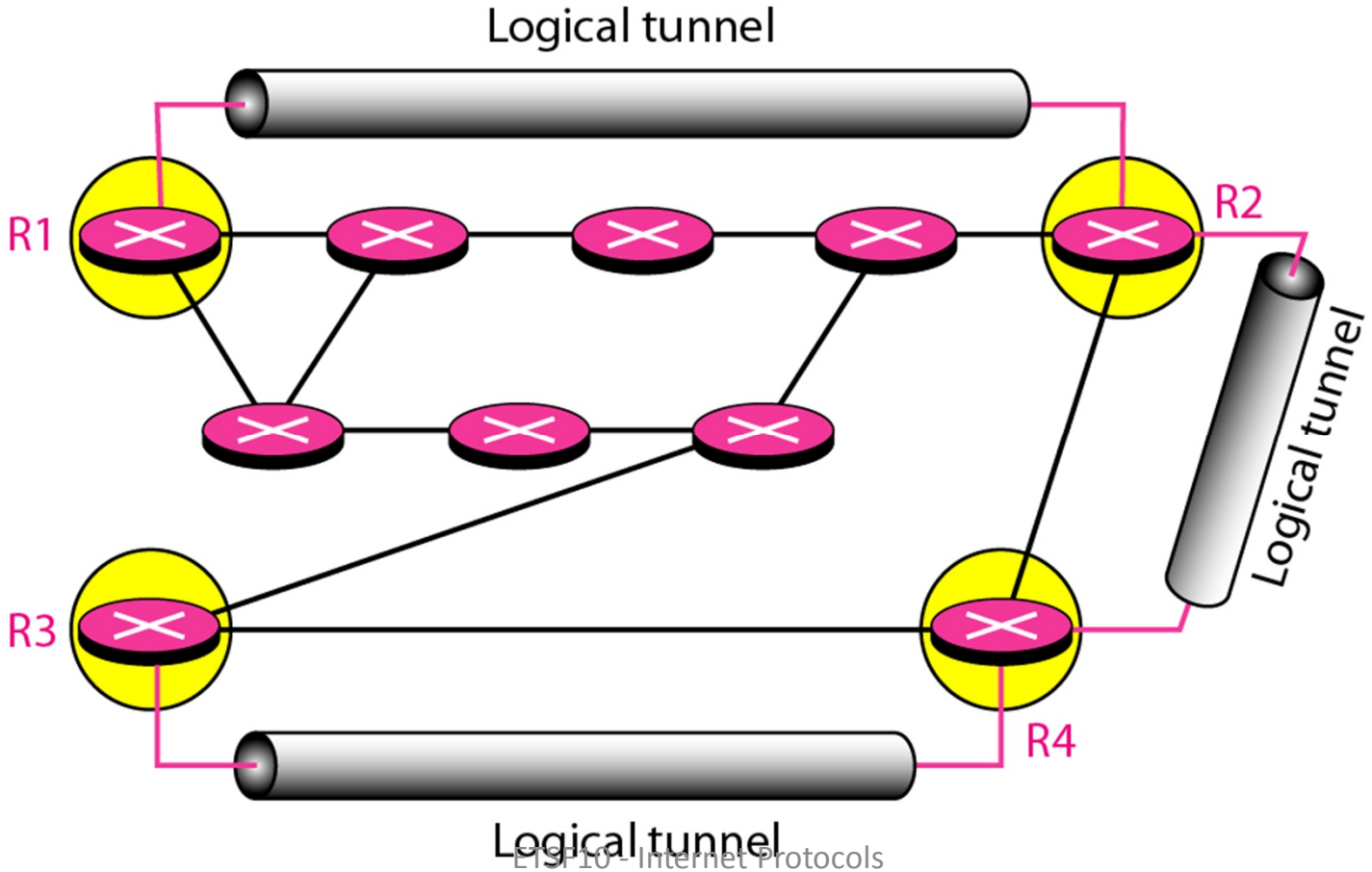


Steady State after Grafting



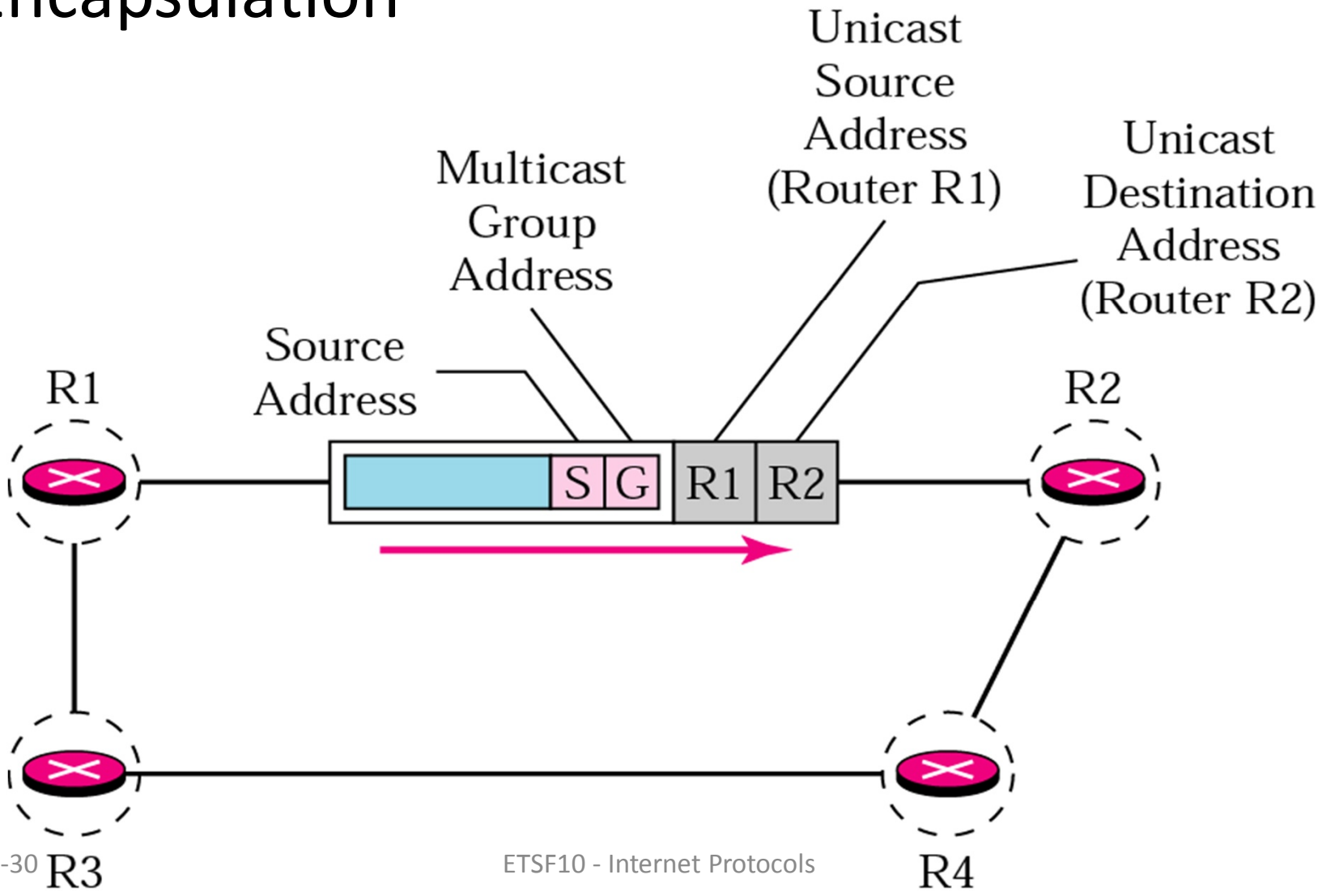
Logical Tunnelling

- Very few Internet routers can multicast
  - How to connect them?



Multicast Backbone (MBONE)

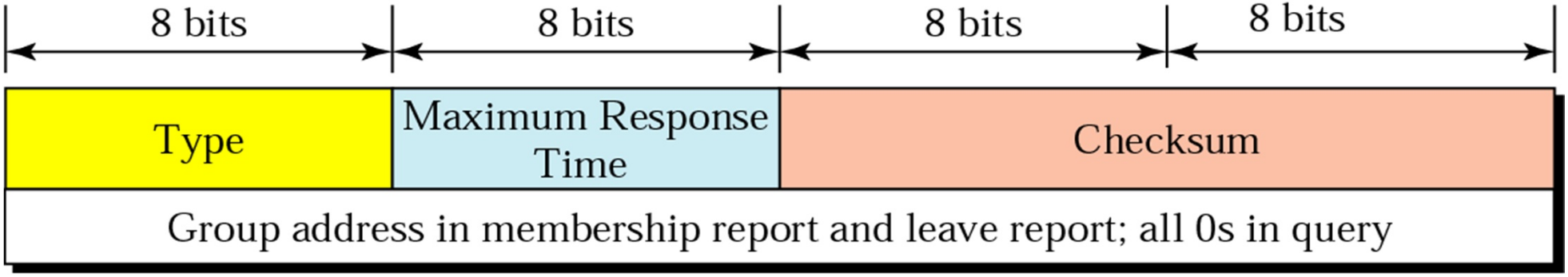
- Encapsulation

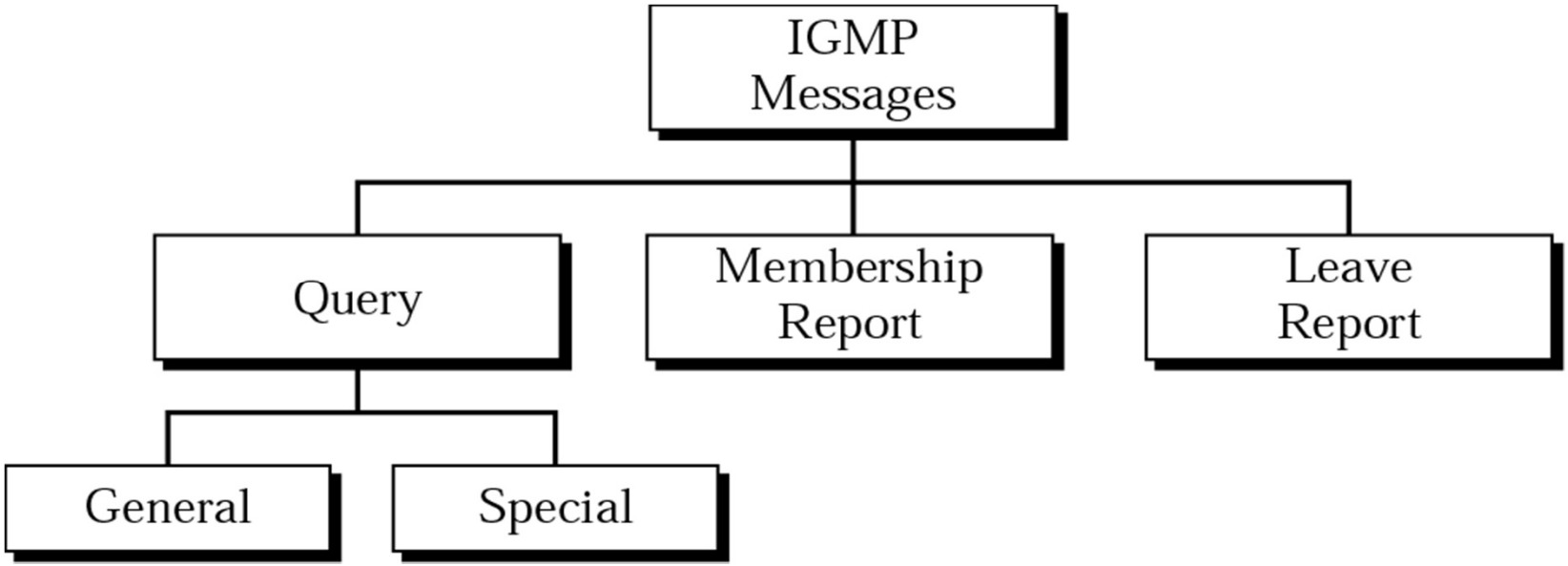


Internet Group Management Protocol

- IGMP, runs on top of IP
- Not a multicast protocol
  - Complementary
  - Runs in the leaves of the network
- Manages group membership
  - Provides multicast router with info

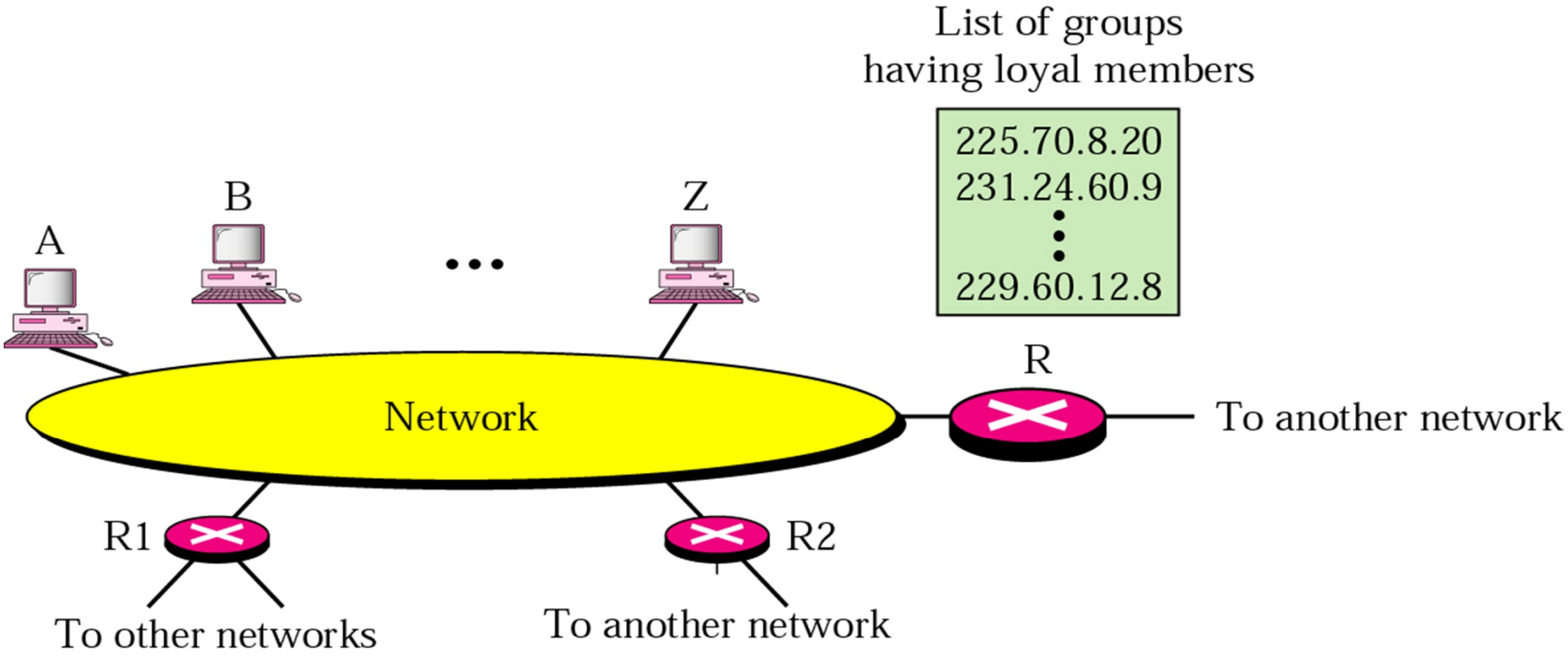
IGMP Message Format





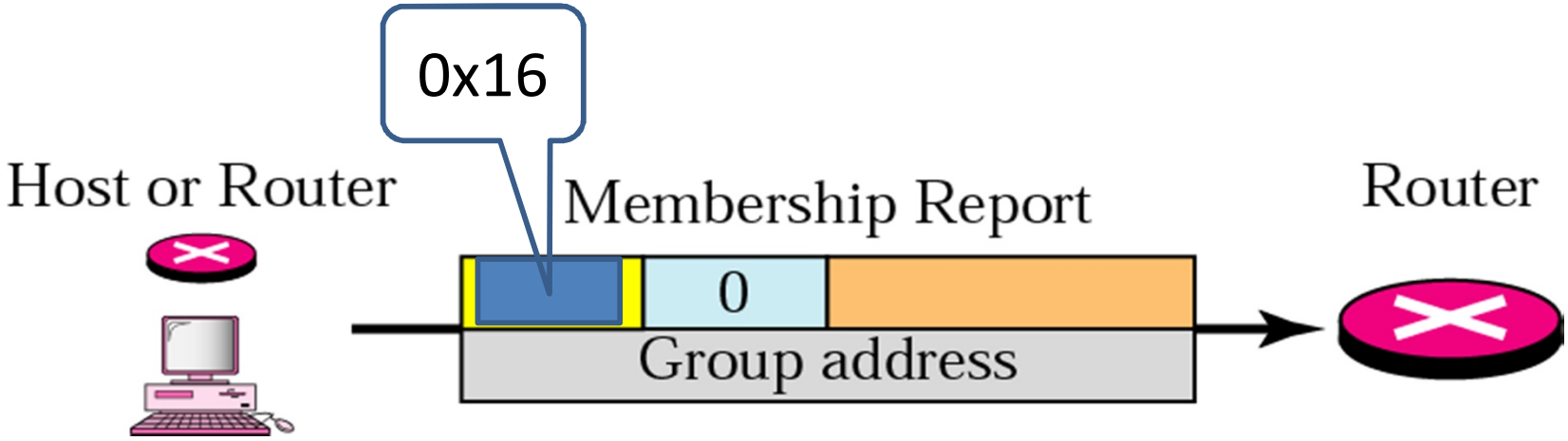
IGMP Operation

- Only one router distributes packets in a group
  - Other routers may be serving their networks

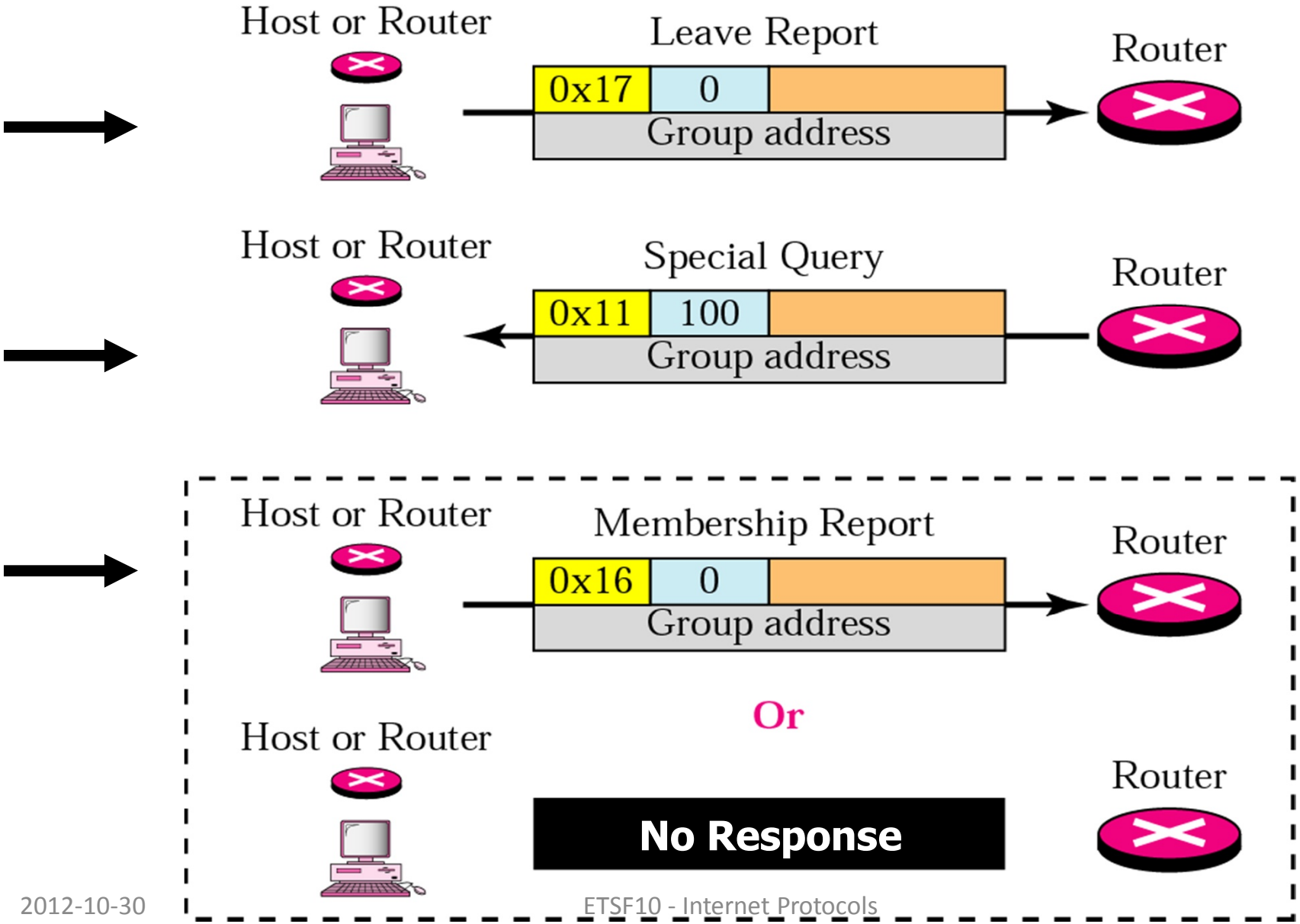


Joining a Group

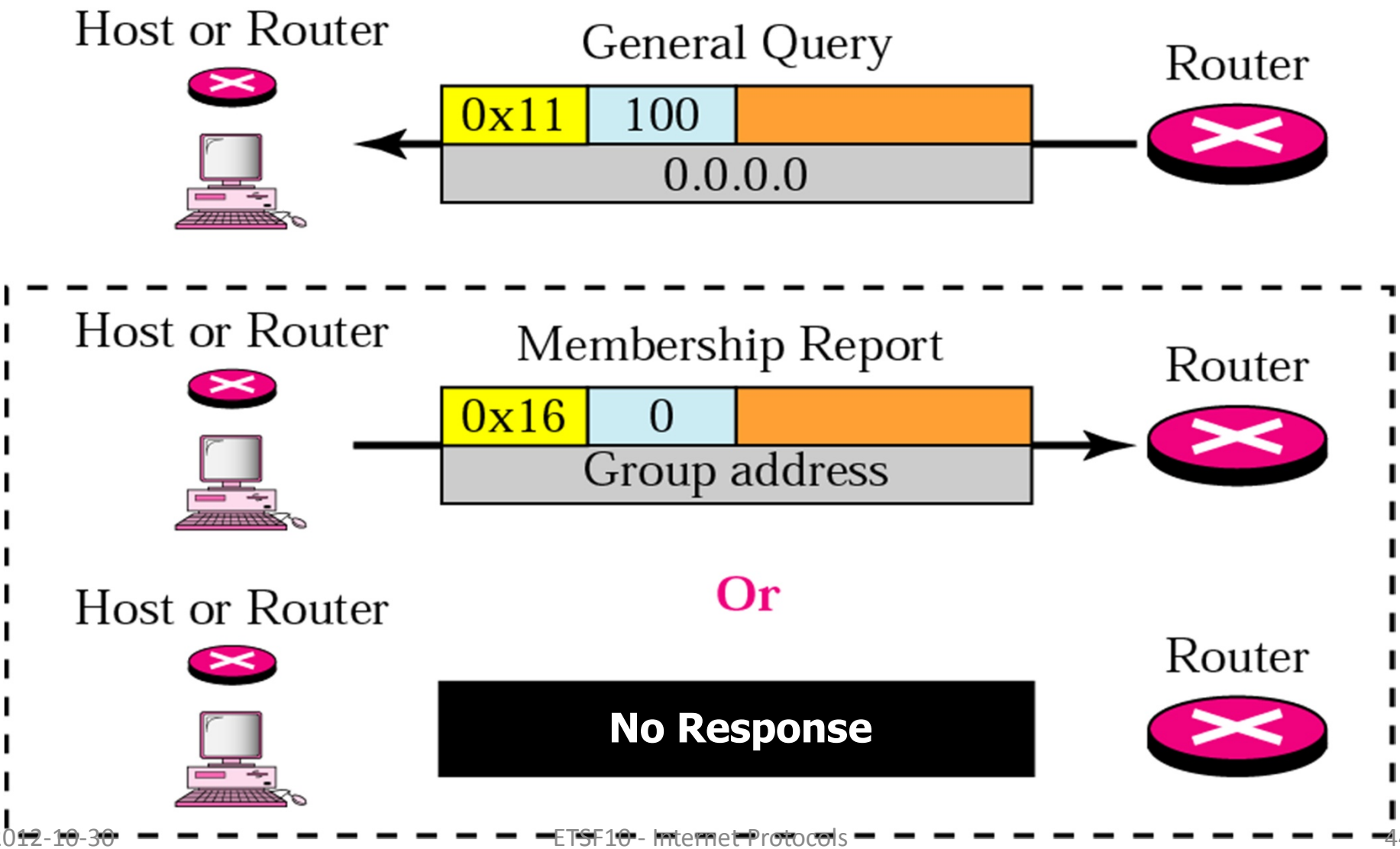
- Request to router
  - Forwarded if first for a group



Leaving a Group



IGMP General Query



Next Lecture Group in 2 Weeks

- Process-to-process delivery
- TCP, congestion control
- ***Special Topic:***
  Network performance and Quality of Service
- Real-time interactive audio/video
- RTP/RTCP, UDP
- ***Special Topic:***
  Voice over IP (VoIP)