Georgia Tech College of Computing

CS 3251- Computer Networks:

Internet Routing & Multicast

Professor Patrick Traynor

Lecture 14

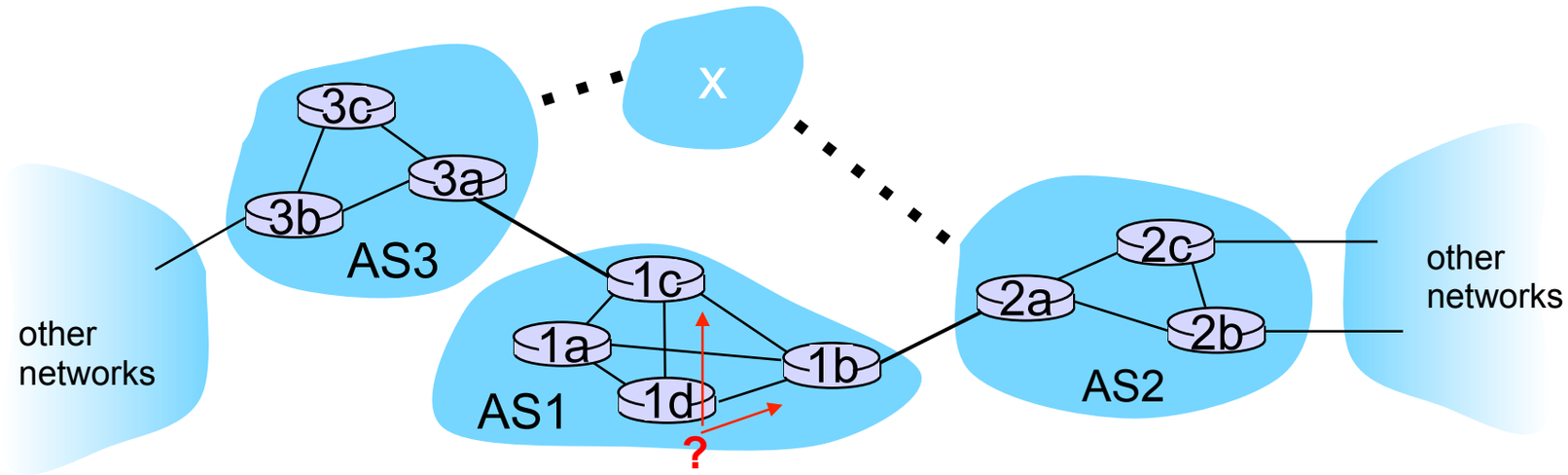
10/3/13

Announcements

- Project 2 due Tuesday!
  - Turn it in via T-Square.
  - Time to sign up for demos!
- Midterm is beginning to creep up on us...
  - Start looking back at your material.

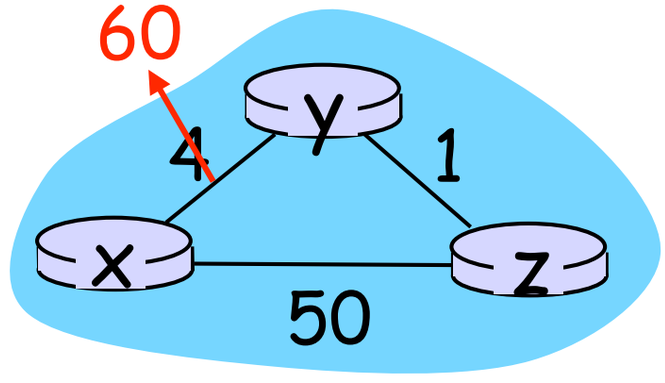
Last Time

- Link State (LS) versus Distance Vector (DV) algorithms:
  - What are some of the differences?
- What is an AS?
  - Why do they exist?



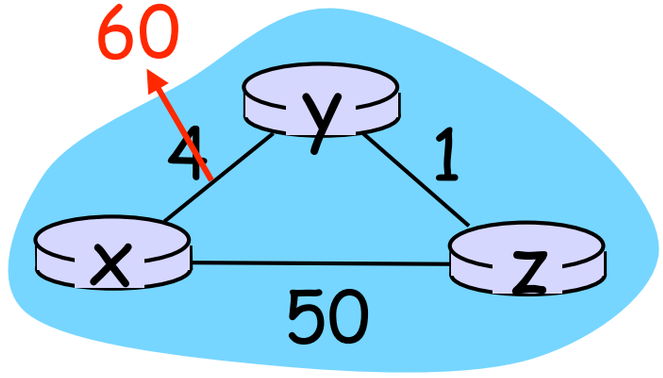
PREVIOUSLY ON 24

A Review of DV Convergence Problems



- Before the link cost changes, costs are:
  - Dy(x)=4, Dy(z)=1, Dz(y)=1, Dz(x)=5
- What does *y* see as the shortest route to x when c(y,x)=60?
  - Dy(x) = min{c(y,x) + Dx(x), c(y,z) + Dz(x)}
    = min{60+0 , 1+5} = 6
- What happens at node z after this?
  - Dy(z) = min{c(z,x) + Dx(x), c(z,y) + Dy(x)}
    = min{50+0 , 1+6} = 7
- Round and round it goes (44 times, to be exact)

Review: The Poison Reverse



- How can we get around this?
  - What is the root of the problem?
- z relies on y to get to x.
  - Knowing this, z should never advertise a route to y for x.
    - Instead, z tells y that $D_z(x)=\infty$, but keeps the real listing of 5 through y for itself.
- When c(x,y) spikes, y immediately sees 60 as the immediate shortest route.
  - Now z can tell y of its shorter route.

Apply Yourself

- Poison reverse is effective, but not in all cases.
  - Loops of three or more nodes...

- Let's solve the problem ourselves!

- How would you do this (without tinkering with link cost like this solution)?

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- 4.2 Virtual circuit and datagram networks
- 4.3 What's inside a router
- 4.4 IP: Internet Protocol
  - Datagram format
  - IPv4 addressing
  - ICMP
  - IPv6
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  - RIP
  - OSPF
  - BGP
- 4.7 Broadcast and multicast routing

Intra-AS Routing

- Also known as Interior Gateway Protocols (IGP)
- Most common Intra-AS routing protocols:
  - RIP: Routing Information Protocol
  - OSPF: Open Shortest Path First
  - IGRP/EIGRP: Interior Gateway Routing Protocol/ Enhanced IGRP (Cisco proprietary)

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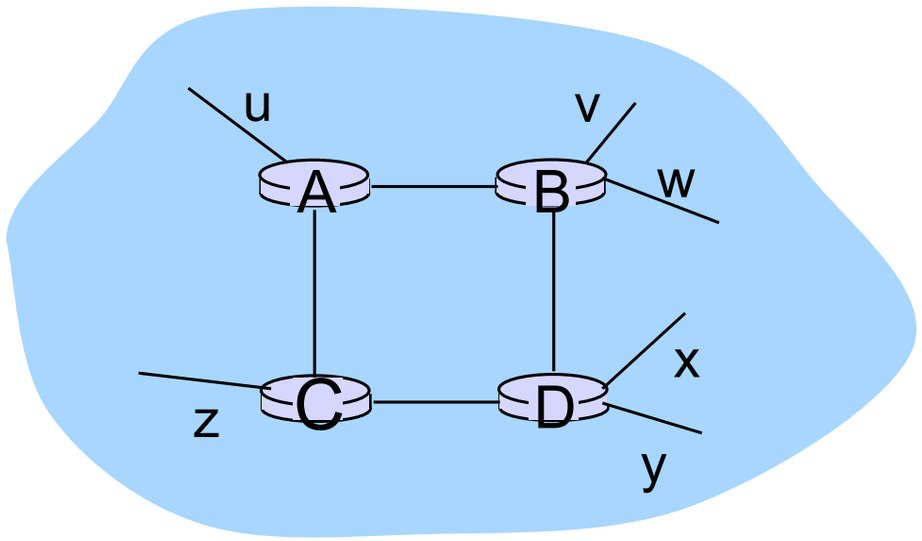
RIP (Routing Information Protocol)

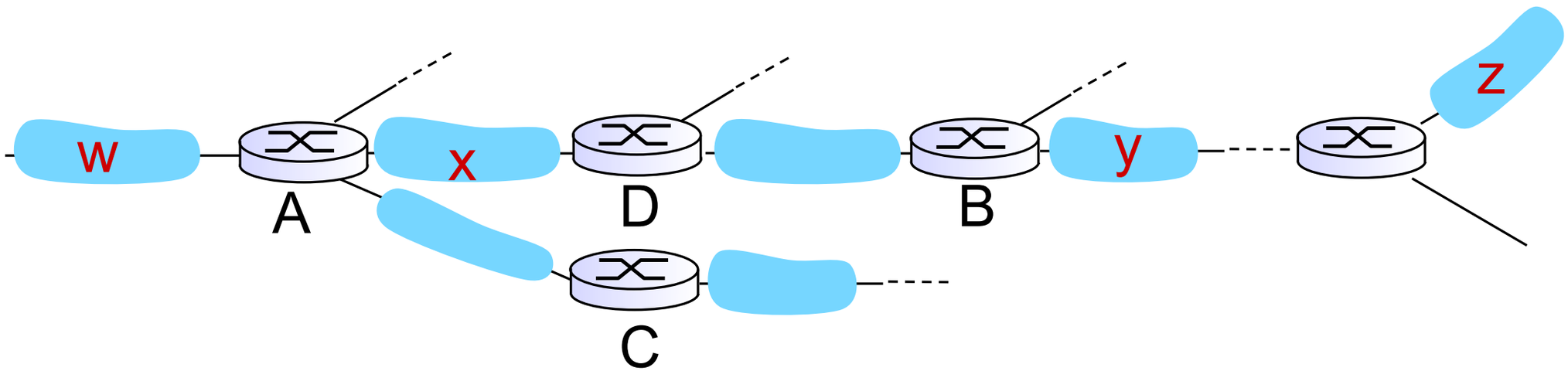
- Distance vector algorithm
  - distance metric: # hops (max = 15 hops), each link has cost 1
  - DVs exchanged with neighbors every 30 sec in response message (aka advertisement)
  - each advertisement: list of up to 25 destination subnets (in IP addressing sense)



from router A to destination *subnets:*

subnet	hops
u	1
v	2
w	2
x	3
y	3
z	2

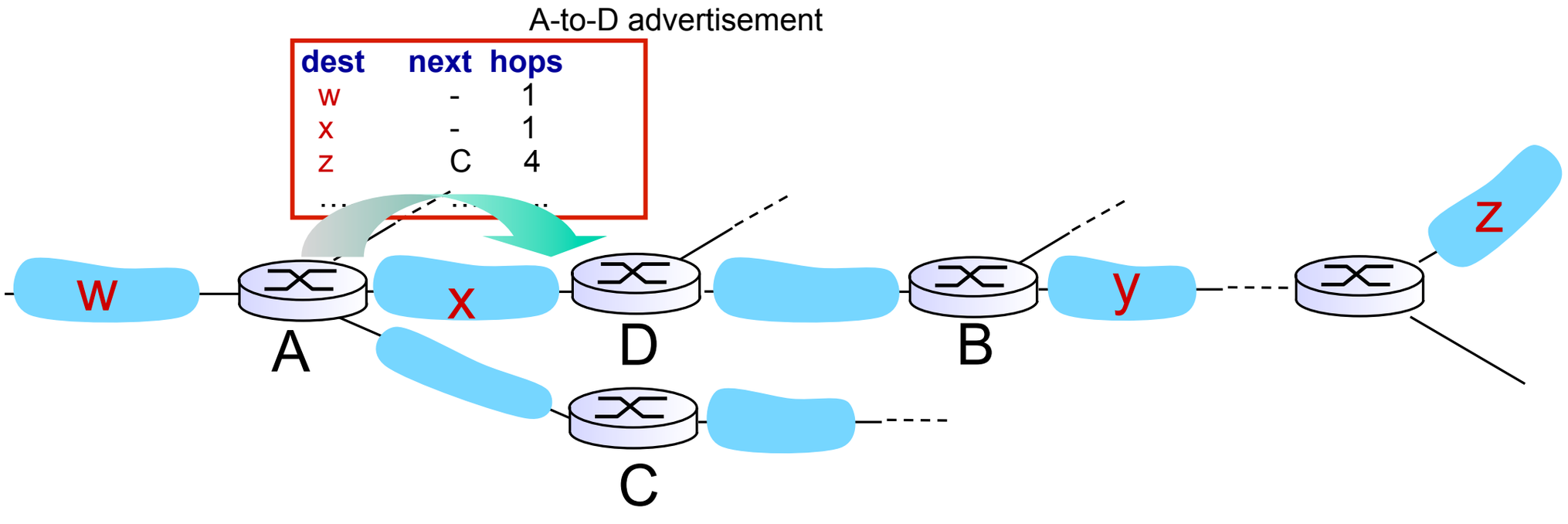
RIP: Example



routing table in router D

destination subnet	next router	# hops to dest
w	A	2
y	B	2
z	B	7
x	--	1
….	….	….

RIP: Example



routing table in router D

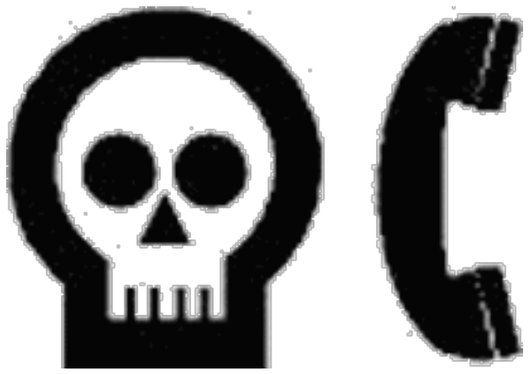
destination subnet	next router	# hops to dest
w	A	2
y	B	2
z	B A	7 5
x	--	1
….	….	….

RIP: Link Failure and Recovery

If no advertisement heard after 180 sec --> neighbor/link declared dead

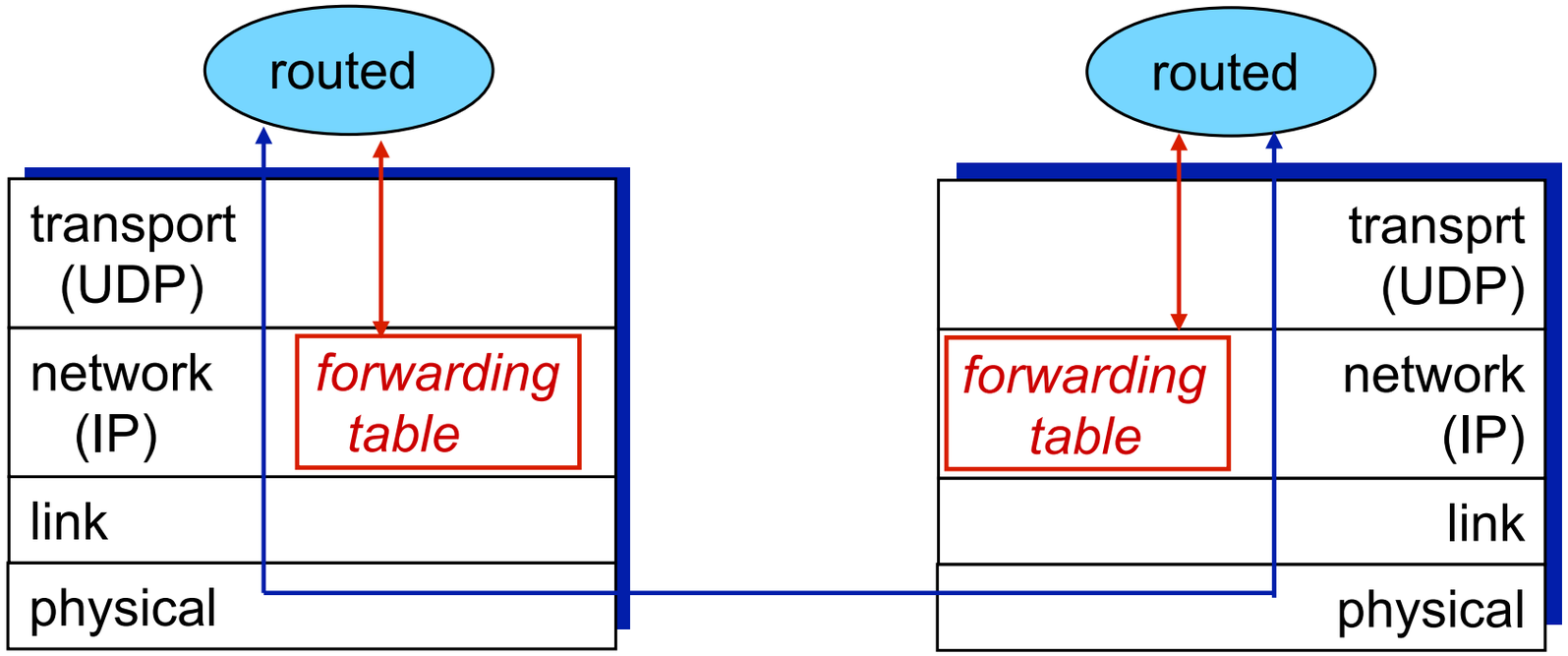
- routes via neighbor invalidated
- new advertisements sent to neighbors
- neighbors in turn send out new advertisements (if tables changed)

- link failure info quickly (?) propagates to entire net
- *poison reverse* used to prevent ping-pong loops (infinite distance = 16 hops)



RIP Table processing

- RIP routing tables managed by application-level process called route-d (daemon)
- advertisements sent in UDP packets, periodically repeated



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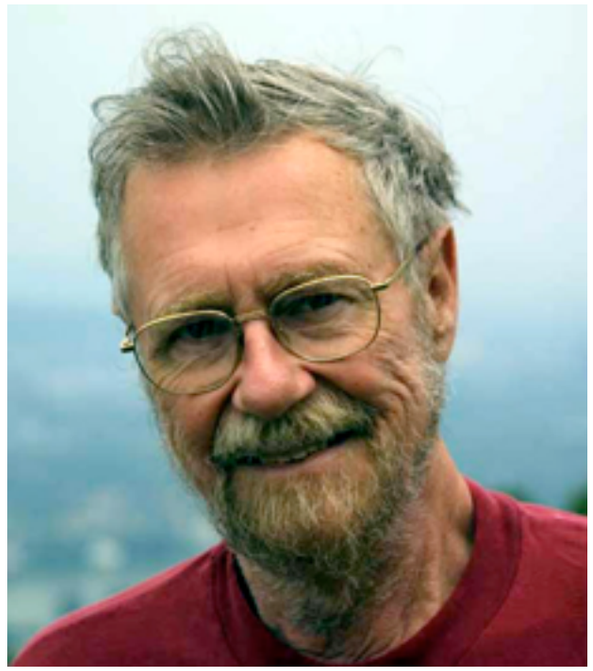
OSPF (Open Shortest Path First)

- "open": publicly available
- Uses Link State algorithm
  - LS packet dissemination
  - Topology map at each node
  - Route computation using Dijkstra's algorithm

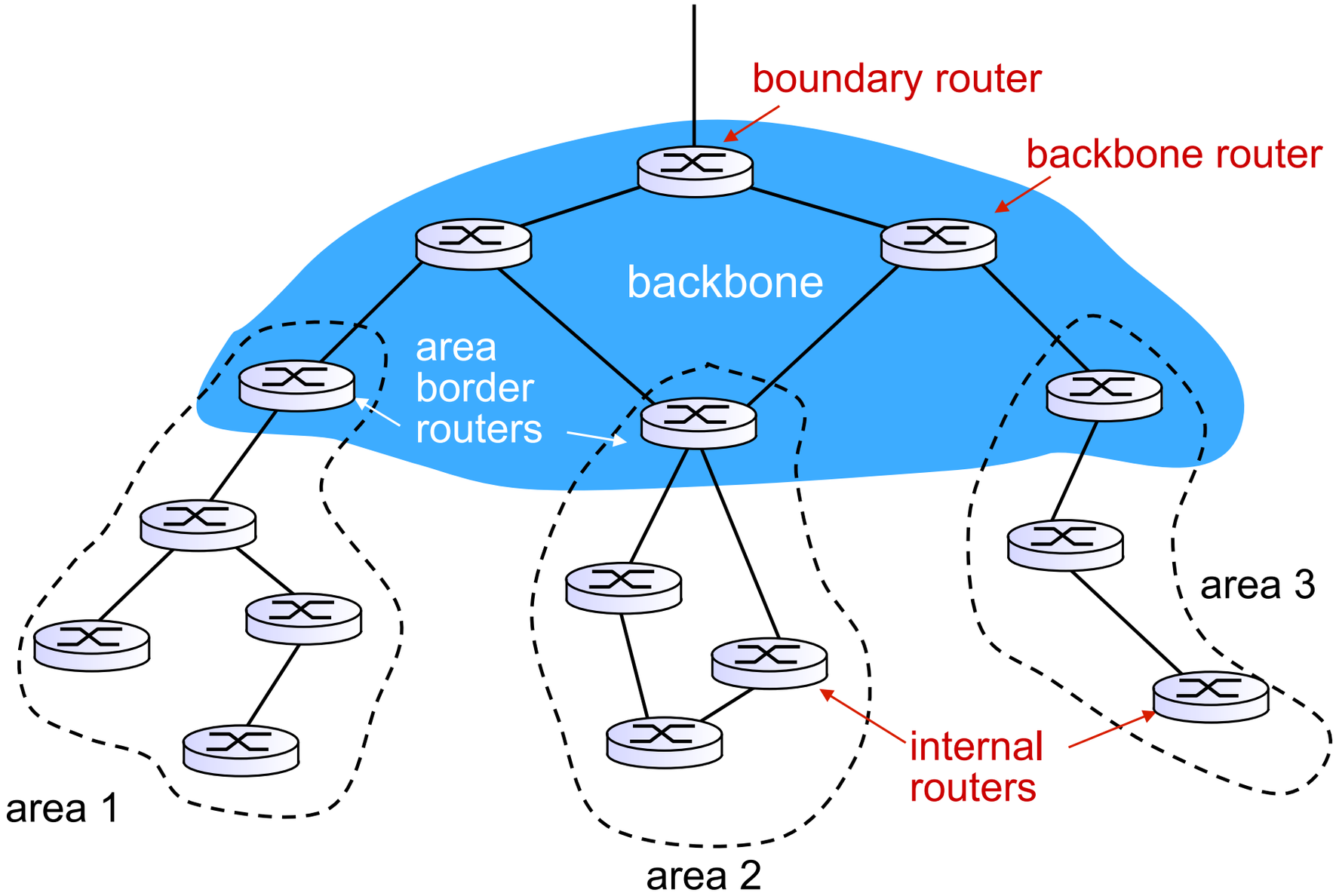


- OSPF advertisement carries one entry per neighbor router
- Advertisements disseminated to entire AS (via flooding)
  - Carried in OSPF messages directly over IP (rather than TCP or UDP)
- *IS-IS routing* protocol: nearly identical to OSPF

OSPF "advanced" features (not in RIP)

- Security: all OSPF messages authenticated (to prevent malicious intrusion)
- Multiple same-cost paths allowed (only one path in RIP)
- For each link, multiple cost metrics for different TOS (e.g., satellite link cost set "low" for best effort; high for real time)
- Integrated uni- and multicast support:
  - Multicast OSPF (MOSPF) uses same topology data base as OSPF
- Hierarchical OSPF in large domains.

Hierarchical OSPF



Hierarchical OSPF

- Two-level hierarchy: local area, backbone.
  - Link-state advertisements only in area
  - each nodes has detailed area topology; only know direction (shortest path) to nets in other areas.
- Area border routers: "summarize" distances to nets in own area, advertise to other Area Border routers.
- Backbone routers: run OSPF routing limited to backbone.
- Boundary routers: connect to other AS's.

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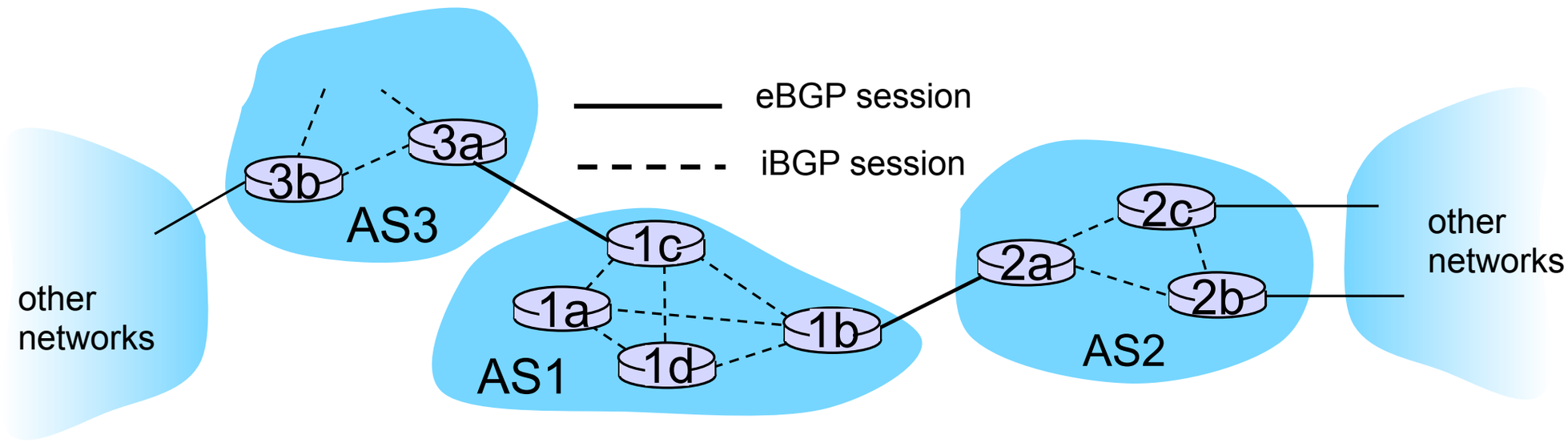
Internet inter-AS routing: BGP

- BGP (Border Gateway Protocol): the de facto standard
- BGP provides each AS a means to:
  1. eBGP: Obtain subnet reachability information from neighboring ASs.
  2. iBGP: Propagate reachability information to all AS-internal routers.
  3. Determine "good" routes to subnets based on reachability information and policy.
- allows subnet to advertise its existence to rest of Internet: "I am here"

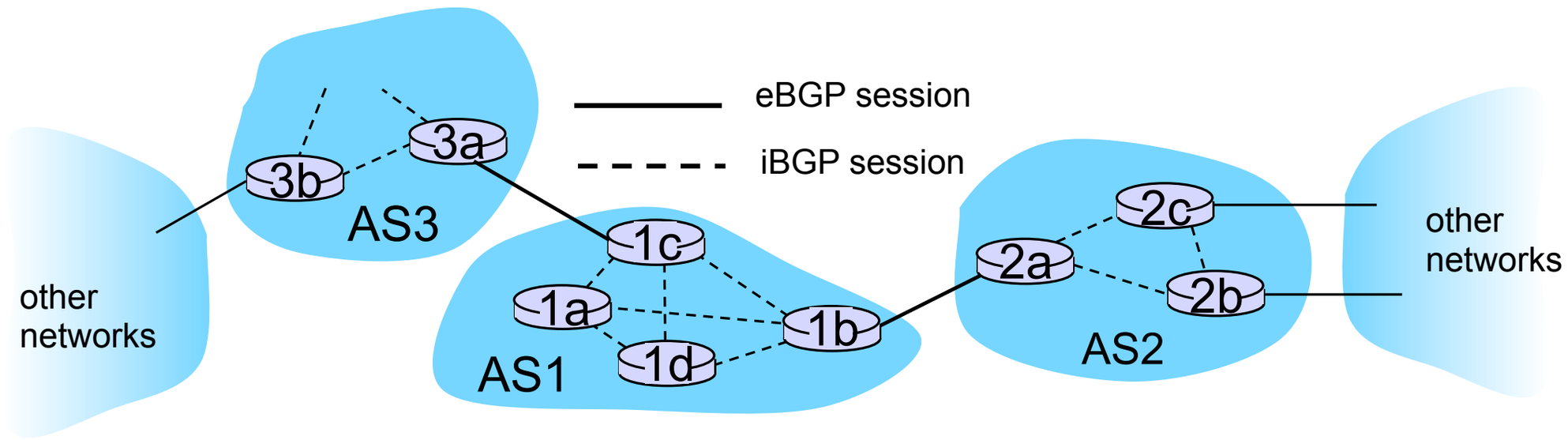
BGP basics

- BGP session: two BGP routers ("peers") exchange BGP messages:
  - advertising *paths* to different destination network prefixes ("path vector" protocol)
  - exchanged over semi-permanent TCP connections
- When AS3 advertises a prefix to AS1:
  - AS3 *promises* it will forward datagrams towards that prefix
  - AS3 can aggregate prefixes in its advertisement



Distributing reachability info

- Using an eBGP session between `3a` and `1c`, `AS3` sends prefix reachability info to `AS1`.
  - `1c` can then use iBGP to distribute this new prefix reach info to all routers in `AS1`
  - `1b` can then re-advertise new reachability info to `AS2` over `1b`-to-`2a` eBGP session
- When router learns of new prefix, creates entry for prefix in its forwarding table.



Path attributes & BGP routes

- When advertising a prefix, advert includes BGP attributes.
  - prefix + attributes = "route"
- Two important attributes:
  - AS-PATH: contains ASs through which prefix advertisement has passed: AS 67 AS 17
  - NEXT-HOP: Indicates specific internal-AS router to next-hop AS. (There may be multiple links from current AS to next-hop-AS.)
- When gateway router receives route advertisement, uses import policy to accept/decline.
  - e.g., never route through AS x
  - *policy-based* routing

BGP route selection

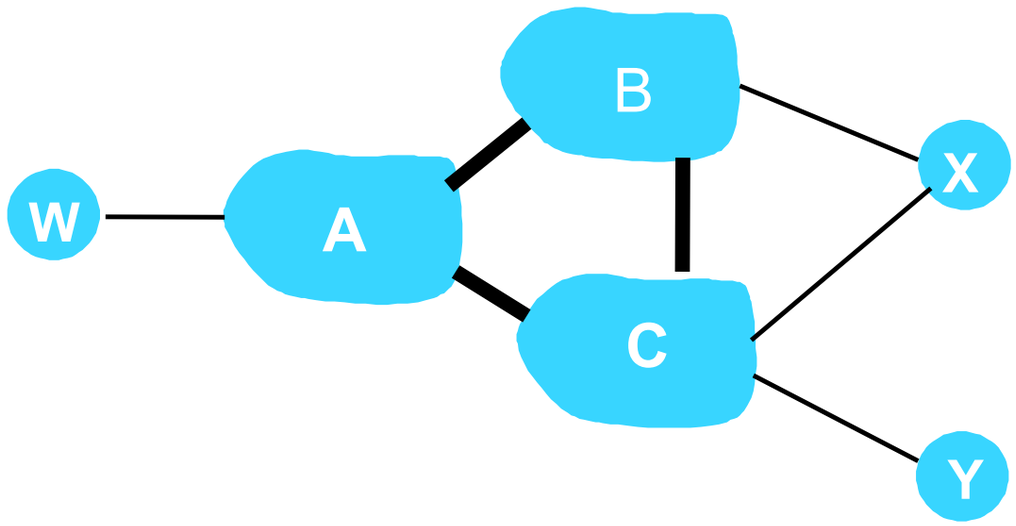
- Router may learn about more than 1 route to some prefix. Router must select route.
- Elimination rules:

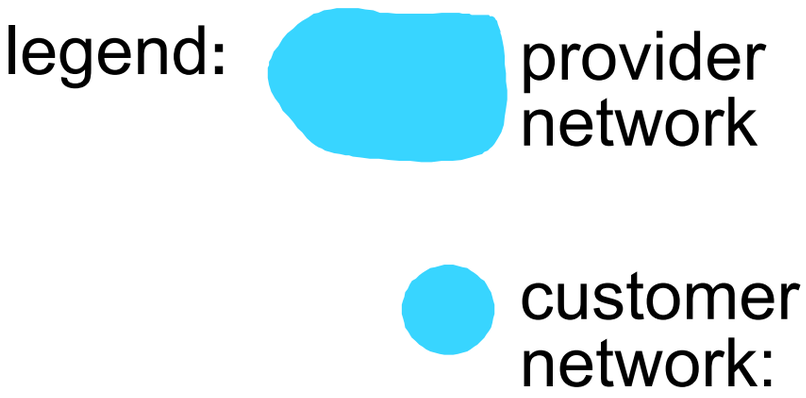
1. Local preference value attribute: policy decision
2. Shortest AS-PATH
3. Closest NEXT-HOP router: hot potato routing
4. Additional criteria

BGP messages

- BGP messages exchanged using TCP.
- BGP messages:
  - OPEN: opens TCP connection to peer and authenticates sender
  - UPDATE: advertises new path (or withdraws old)
  - KEEPALIVE keeps connection alive in absence of UPDATES; also ACKs OPEN request
  - NOTIFICATION: reports errors in previous msg; also used to close connection

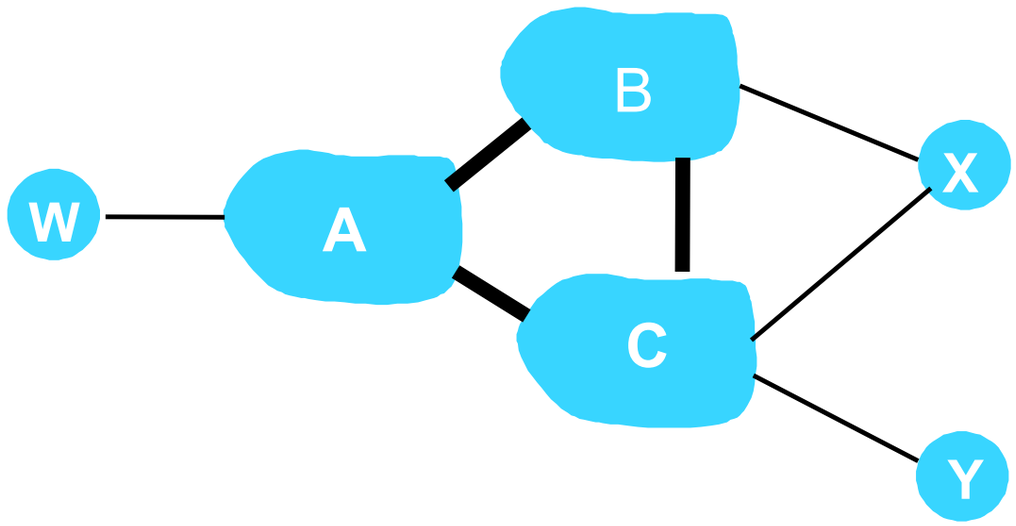
BGP routing policy

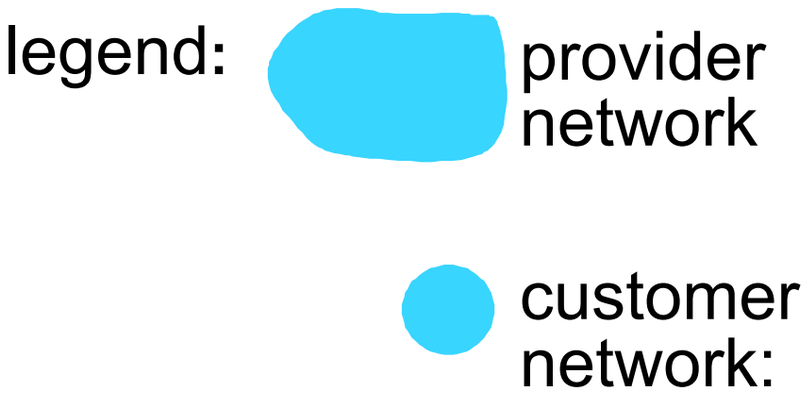




- A,B,C are provider networks
- X,W,Y are customer (of provider networks)
- X is multi-homed: attached to two networks
  - X does not want to route from B via X to C
  - ... so X will not advertise to B a route to C

BGP routing policy (2)





- A advertises to B the path AW
- B advertises to X the path BAW
- Should B advertise to C the path BAW?
  - No way! B gets no "revenue" for routing CBAW since neither W nor C are B's customers
  - B wants to force C to route to w via A
  - B wants to route only to/from its customers!

Why different Intra- and 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 routing saves table size, reduced update traffic

Performance:

- Intra-AS: can focus on performance
- Inter-AS: policy may dominate over performance

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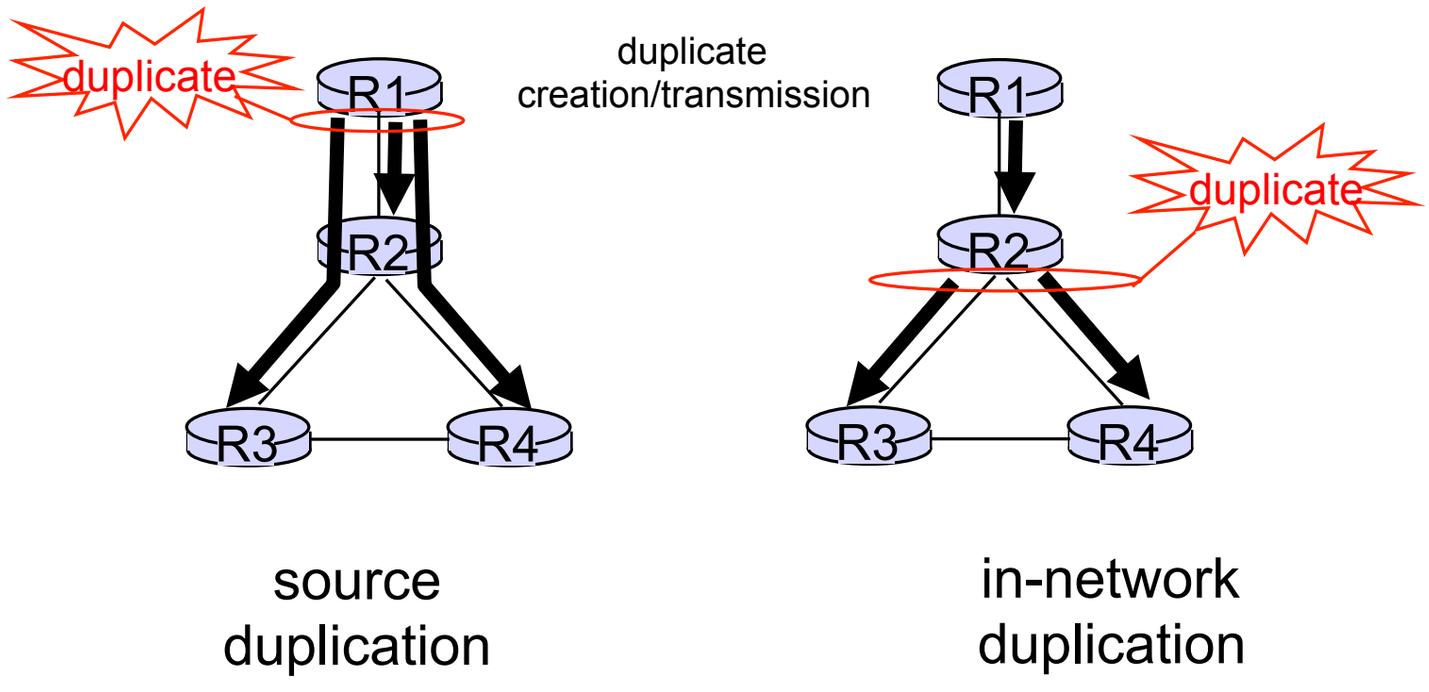
Broadcast Routing

- Deliver packets from source to all other nodes
- Source duplication is inefficient:



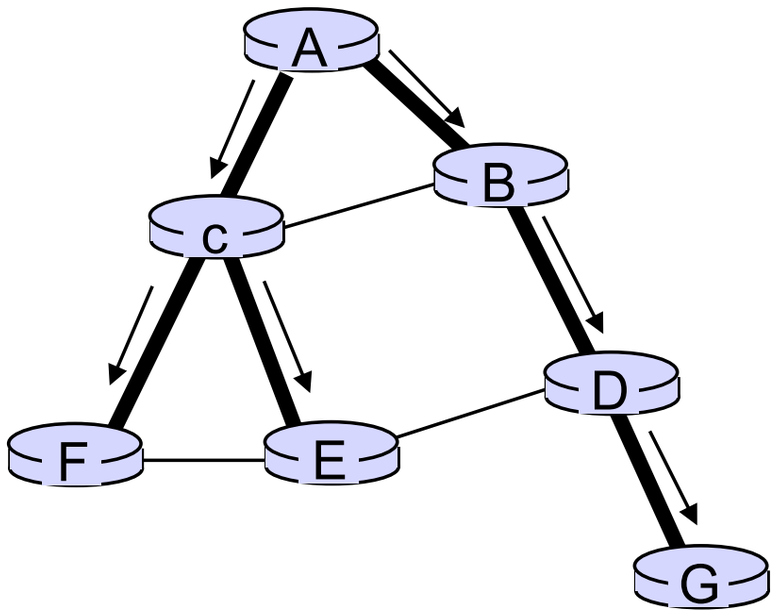
- Source duplication: how does source determine recipient addresses?

In-network duplication

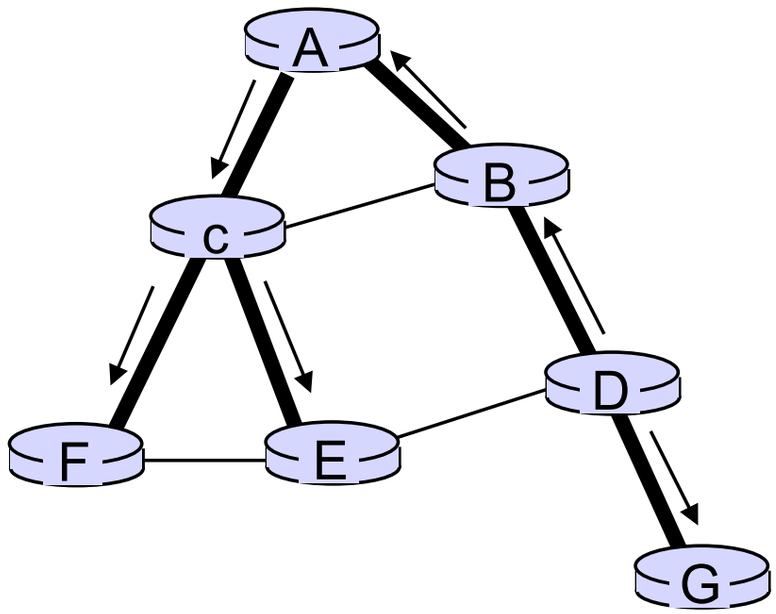
- *Flooding*: when node receives brdcst pckt, sends copy to all neighbors
  - Problems: cycles & broadcast storm
- *Controlled flooding*: node only brdcsts pkt if it hasn't brdcst same packet before
  - Node keeps track of pckt ids already brdcsted
  - Or reverse path forwarding (RPF): only forward pckt if it arrived on shortest path between node and source
- *Spanning tree*:
  - No redundant packets received by any node

Spanning Tree

- First construct a spanning tree
- Nodes forward/make copies only along spanning tree



(a) broadcast initiated at A



(b) broadcast initiated at D

Multicast

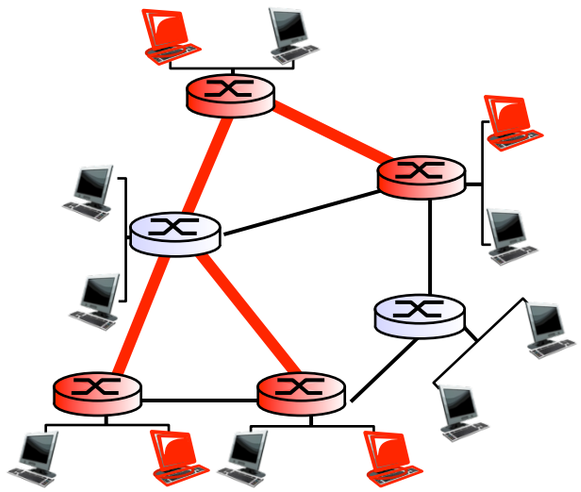
- Challenge: You wish to deliver the exact same message to multiple (n) clients.

- Constraint: Sending the same packet n times is wasteful.

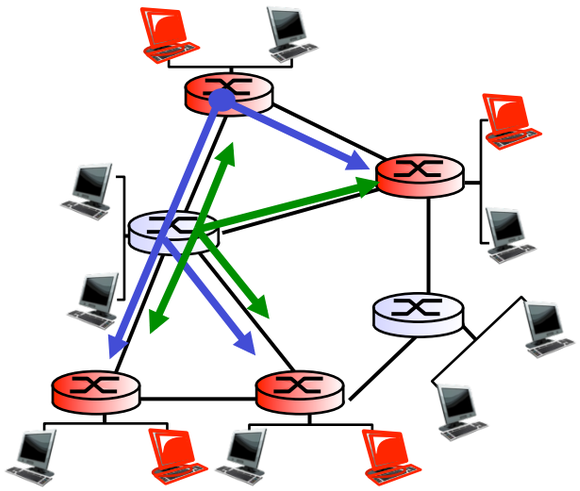
- *Multicast* allows a sender to transmit a single message and have the network deliver it to multiple hosts.
  - How is this done?

Multicast Routing: Problem Statement

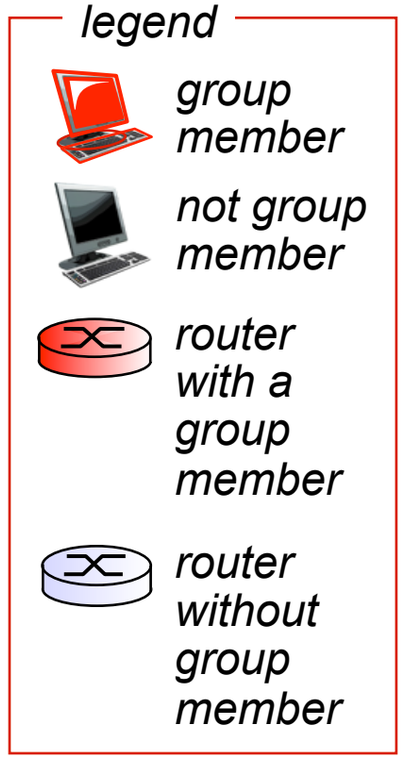
- Goal: find a tree (or trees) connecting routers having local mcast group members
  - tree: not all paths between routers used
  - source-based: different tree from each sender to rcvrs
  - shared-tree: same tree used by all group members



shared tree



source-based trees



Approaches for Building MCast Trees

Approaches:

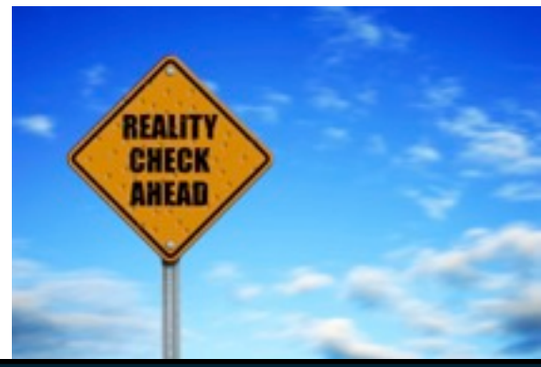
- source-based tree: one tree per source
  - shortest path trees
  - reverse path forwarding
- group-shared tree: group uses one tree
  - minimal spanning (Steiner)
  - center-based trees

End to End?

- Multicast puts new functionality in the network core.
  - Routers may have to duplicate packets and send them out over multiple interfaces.
- Is this a violation of the end to end argument?
- If Internet purists get upset about NAT using one address to represent multiple hosts, should they object to multicast?

M-Bone, Reality and the Future

- The Multicast Backbone (M-Bone) provided experimental multicast functionality for the Internet
  - Widespread use never happened - figuring out efficient access control capabilities made commercialization hard.
- Question: Even if we figure out this problem, what do current content consumption habits tell us about the potential success of large-scale multicast.
  - Think about the impact of Tivo and YouTube.



Next Time

- Read Sections 5.1 to 5.3
  - Link Layer