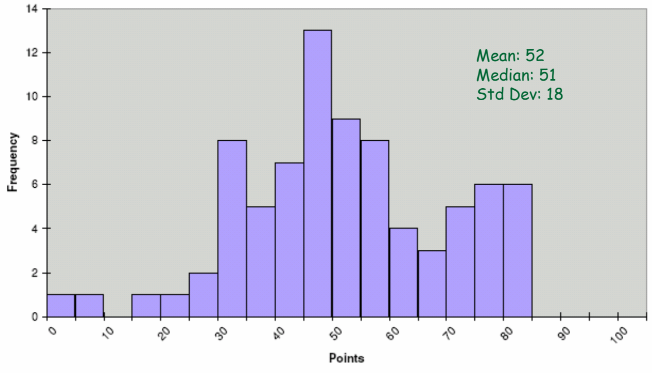
Multicast

EECS 122: Lecture 16

Department of Electrical Engineering and Computer Sciences
University of California
Berkeley

Midterm

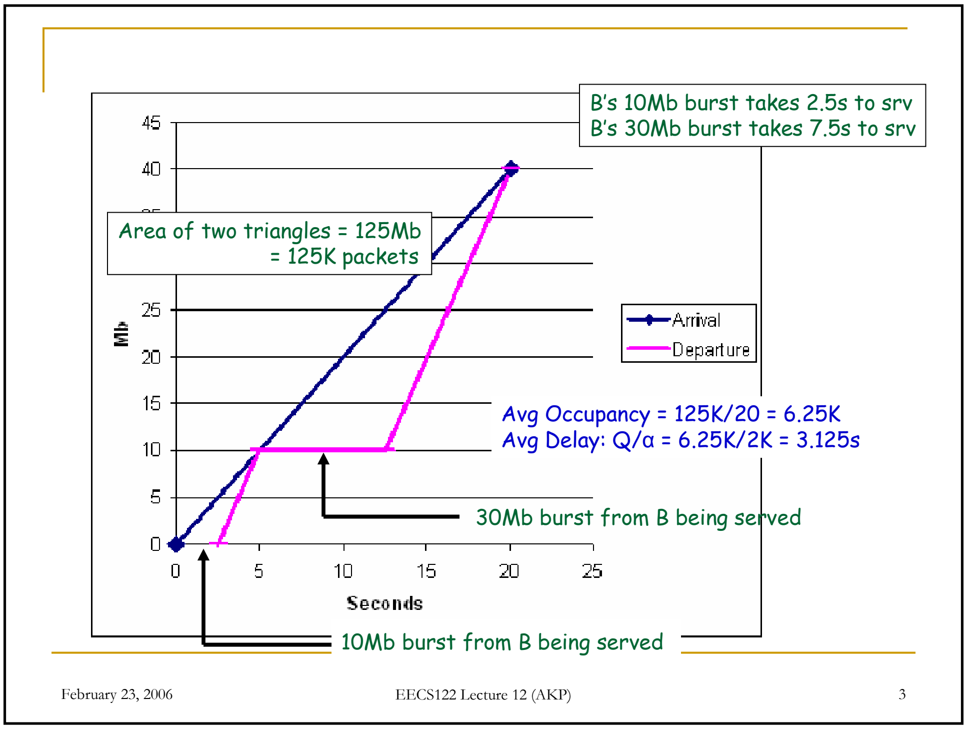
Exam was not meant to be easy…



Mean: 52
Median: 51
Std Dev: 18

Performance quite good!

Worth understanding the answers…



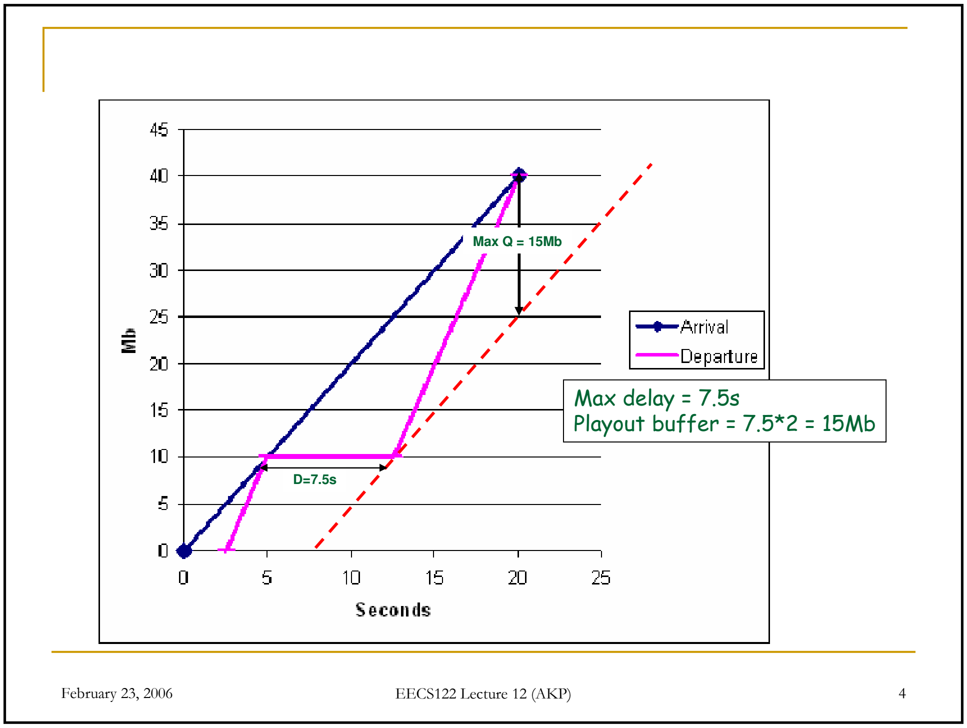
B's 10Mb burst takes 2.5s to srv
B's 30Mb burst takes 7.5s to srv

Area of two triangles = 125Mb
= 125K packets

Avg Occupancy = 125K/20 = 6.25K
Avg Delay: Q/α = 6.25K/2K = 3.125s

30Mb burst from B being served

10Mb burst from B being served



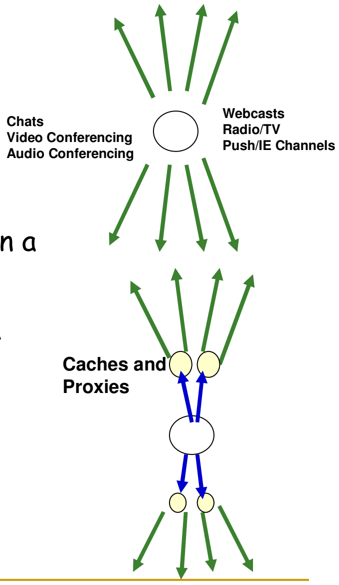
Max delay = 7.5s
Playout buffer = 7.5*2 = 15Mb

Today

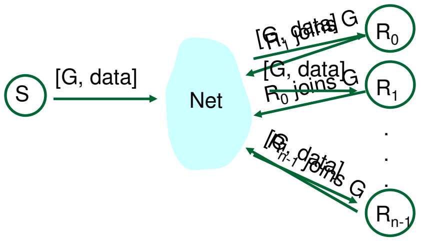
- Multicast
- RSVP

Broadcasting to Groups

- Many applications are not one-one
  - Webcasts
  - Group collaboration
  - Proxy/Cache updates
- Packets must reach a **<u>Group</u>** rather than a single destination
  - Group membership may be dynamic
  - More than one group member might be a source
- Idea: Notion of a Group Address
  - First sender establishes group, G
  - Interested receivers join the group
  - The network takes care of group management



The Multicast service Model



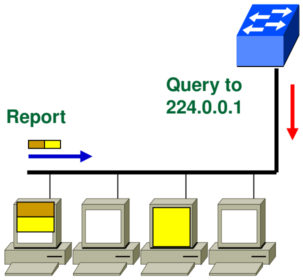
- To join a multicast
  - Host finds out the group address (a class D address)
  - Sends a “join” message to its local router
- To send to a group
  - Just send to the group
- Packet delivery is best effort

Internet Group Management Protocol IGMP

- Operates between Router and local Hosts, typically attached via a LAN (e.g., Ethernet)
  - Query response architecture

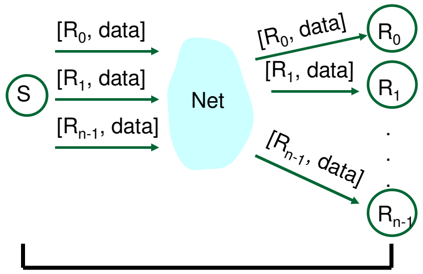
1. Router periodically queries the local Hosts for group membership information
   - Can be specific or general
2. Hosts receiving query set a random timer before responding
3. First host to respond sends membership reports
4. All the other hosts observe the query and suppress their own reports.

- To Join send a group send an unsolicited Join
  - Start a group by joining it
- To leave don’t have to do anything
  - Soft state



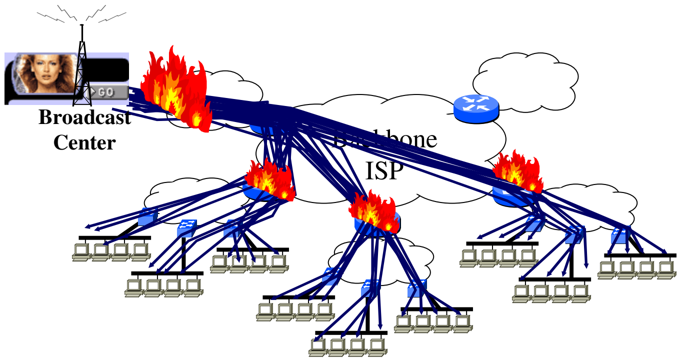
Naïve Routing Option: Don't change anything

Point-to point routing



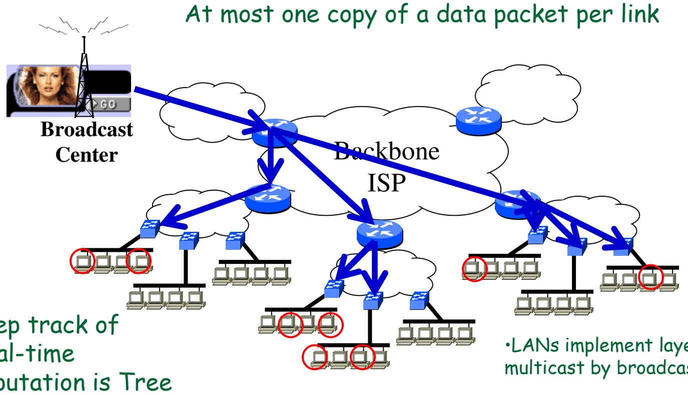
Group abstraction not implemented in the network

This approach does not scale…



Instead build trees

Copy data at routers
At most one copy of a data packet per link



•Routers keep track of groups in real-time
•"Path" computation is Tree computation

•LANs implement layer 2 multicast by broadcasting

Issues

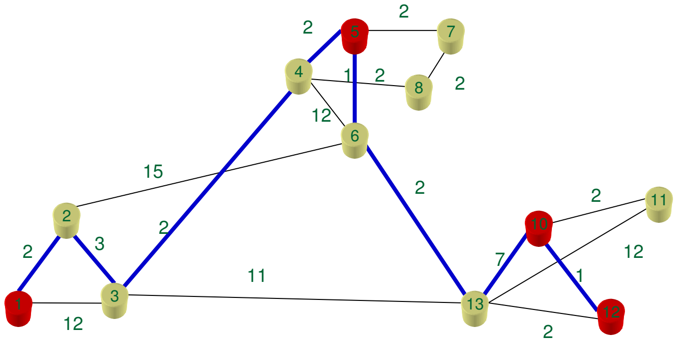
- How many trees per group?
  - Source-based
  - Shared
- Tree computation
  - Steiner Tree
  - Spanning Tree
  - Center based Shared Trees
  - Source based Trees with Reverse Path Forwarding
- Routing Protocols
  - DVMRP
  - PIM

How Many Trees per Group?

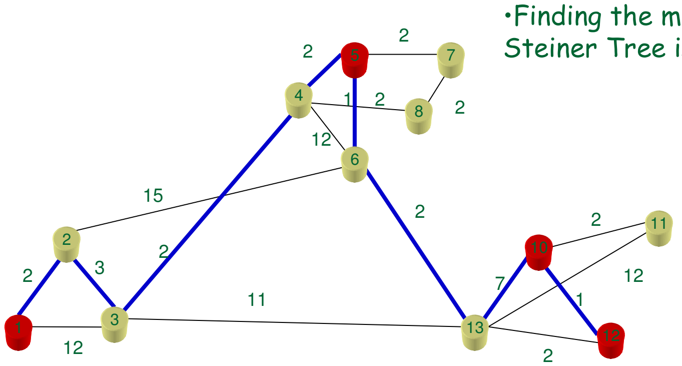
- Source-based: One tree for each source
  - Pros
    - Works well for webcasts
    - Can compute “Good” trees
  - Cons
    - In conference type applications everyone could be a source
      - Too many trees!
      - Router state explodes
- Shared Trees: one tree per group
  - Pros
    - Works well for multisource groups
    - Easier to maintain and compute
  - Cons
    - Link choice may not be the best for minimizing delay, maximizing throughput

Steiner Trees

•A tree which connects all the group nodes is a Steiner Tree

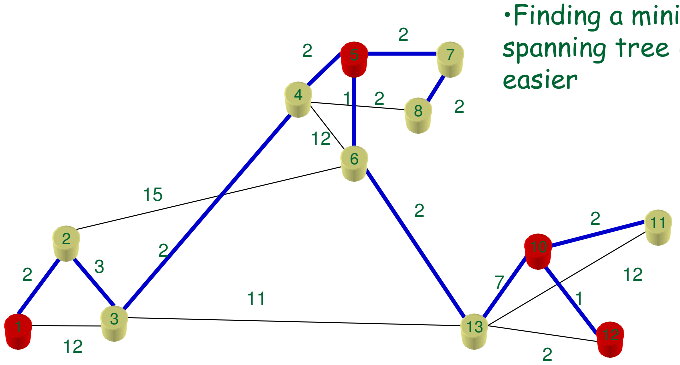


Steiner Tree



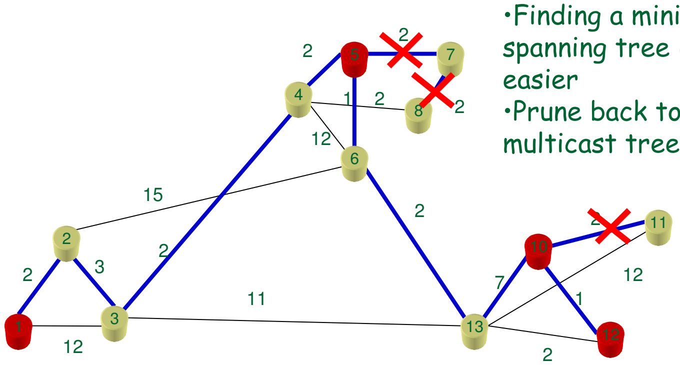
- A tree which connects all the group nodes is a Steiner Tree
- Finding the min cost Steiner Tree is NP hard

Spanning Tree



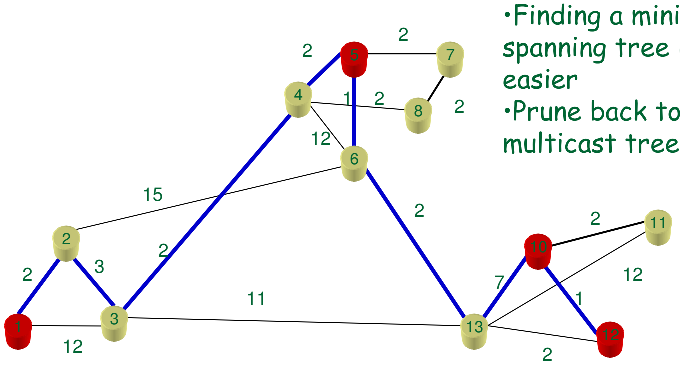
- A tree that connects all of the nodes in the graph is a spanning tree
- Finding a minimum spanning tree is much easier

Spanning Tree



- A tree that connects all of the nodes in the graph is a spanning tree
- Finding a minimum spanning tree is much easier
- Prune back to get a multicast tree

Spanning Tree



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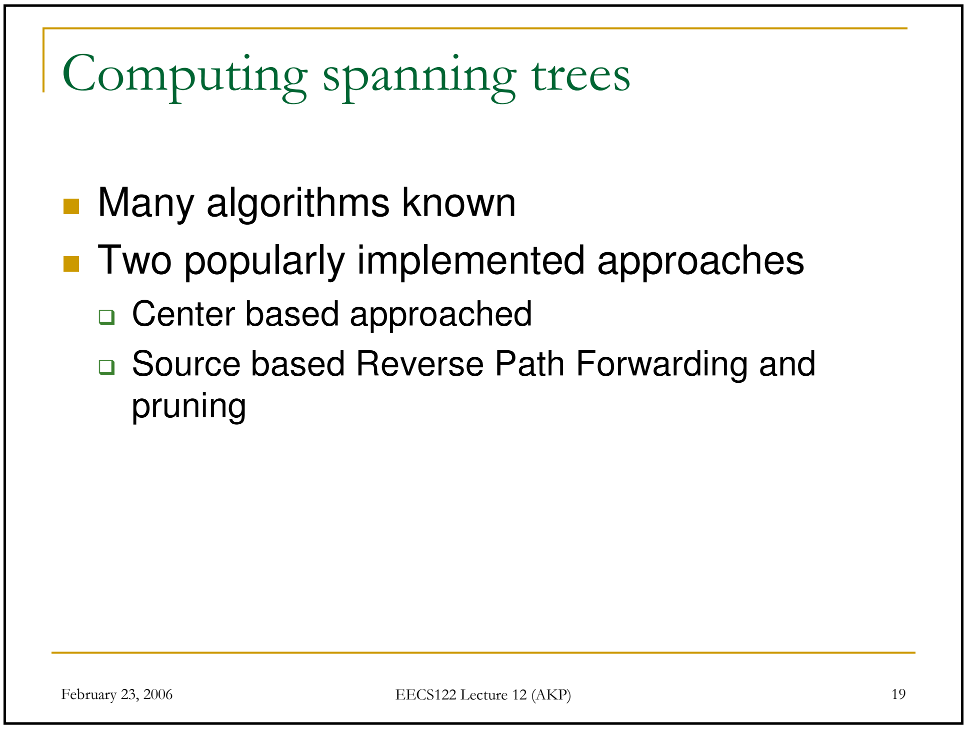
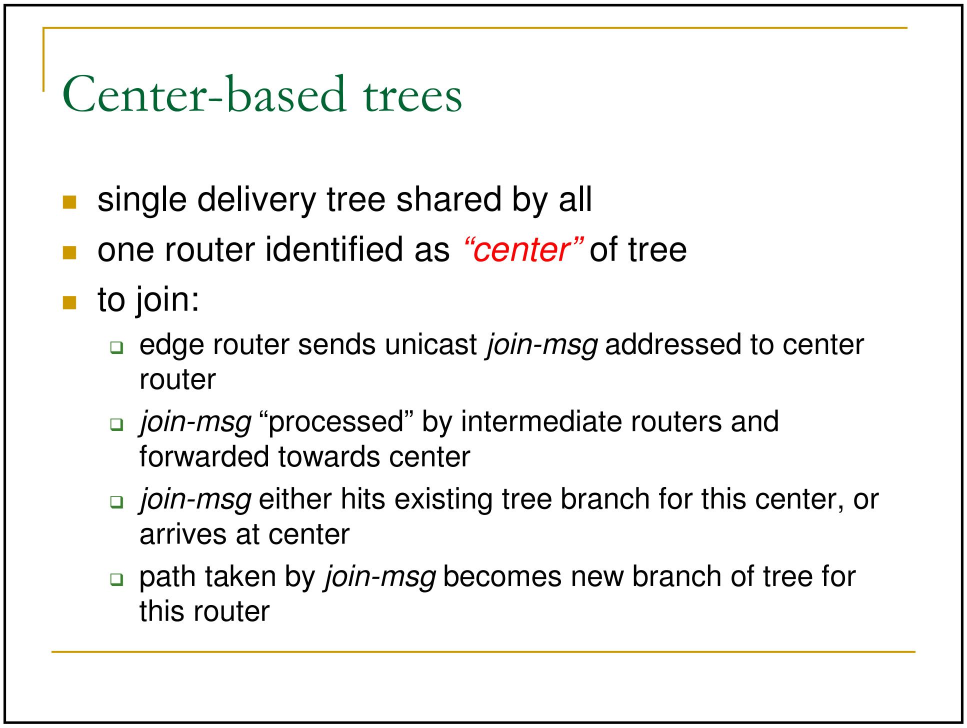


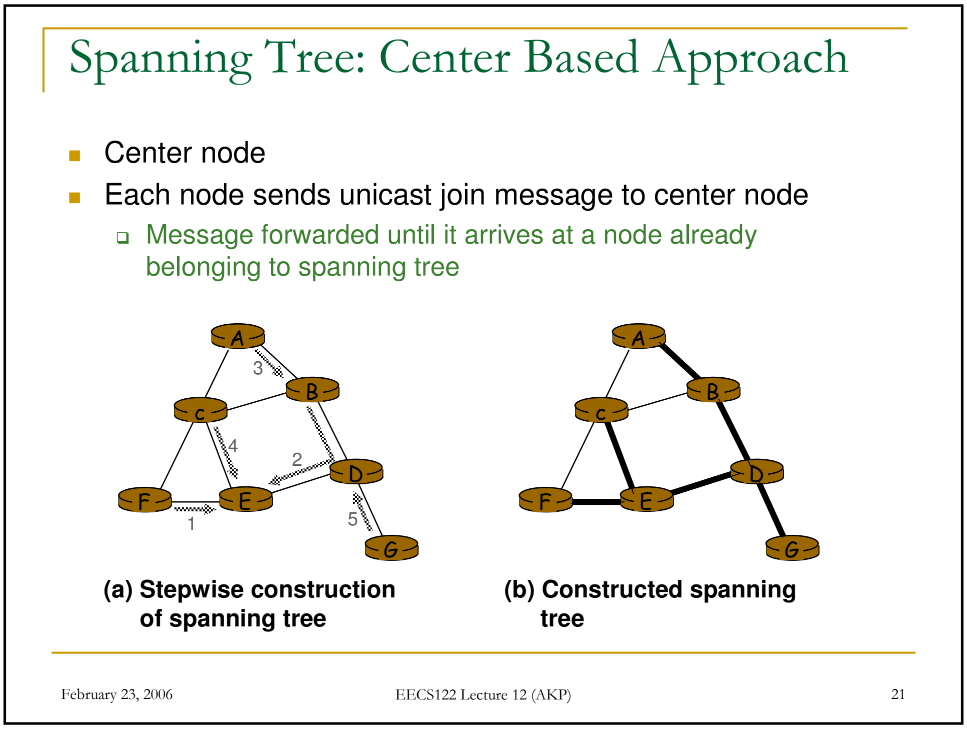
Computing spanning trees

- Many algorithms known
- Two popularly implemented approaches
  - Center based approached
  - Source based Reverse Path Forwarding and pruning



Center-based trees

- single delivery tree shared by all
- one router identified as *"center"* of tree
- to join:
  - edge router sends unicast *join-msg* addressed to center router
  - *join-msg* "processed" by intermediate routers and forwarded towards center
  - *join-msg* either hits existing tree branch for this center, or arrives at center
  - path taken by *join-msg* becomes new branch of tree for this router

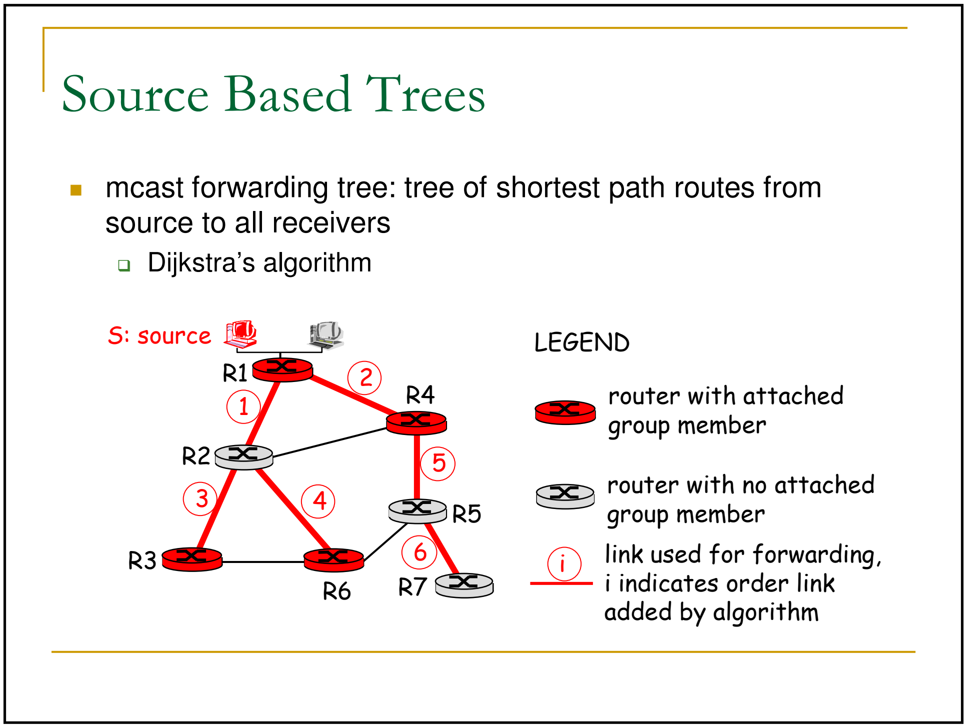


Spanning Tree: Center Based Approach

- Center node
- Each node sends unicast join message to center node
  - Message forwarded until it arrives at a node already belonging to spanning tree

(a) Stepwise construction of spanning tree

(b) Constructed spanning tree



Source Based Trees

- mcast forwarding tree: tree of shortest path routes from source to all receivers
  - Dijkstra's algorithm

LEGEND

router with attached group member

router with no attached group member

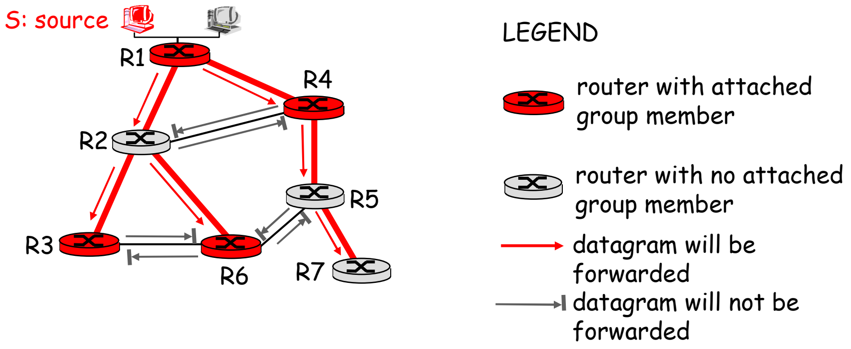
link used for forwarding, i indicates order link added by algorithm

Reverse Path Forwarding

- ❑ rely on router's knowledge of unicast shortest path from it to sender
- ❑ each router has simple forwarding behavior:

```
if (mcast datagram received on incoming link
    on shortest path back to center)
  then flood datagram onto all outgoing links
  else ignore datagram
```

Reverse Path Forwarding: example



LEGEND

🟥 router with attached group member

⬜ router with no attached group member

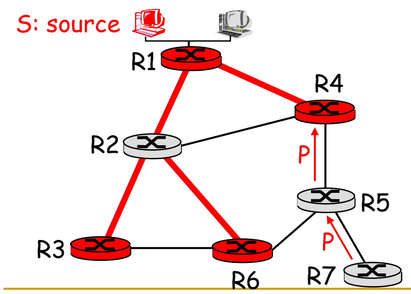
→ datagram will be forwarded

→| datagram will not be forwarded

Note: Every link carries every multicast packet!

Reverse Path Forwarding: pruning

- forwarding tree contains subtrees with no mcast group members
  - no need to forward datagrams down subtree
  - "prune" msgs sent upstream by router with no downstream group members



LEGEND

🟥 router with attached group member

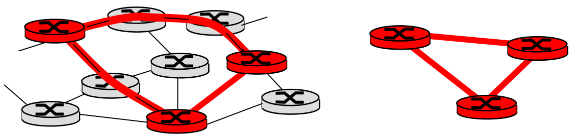
⬜ router with no attached group member

P → prune message

━ links with multicast forwarding

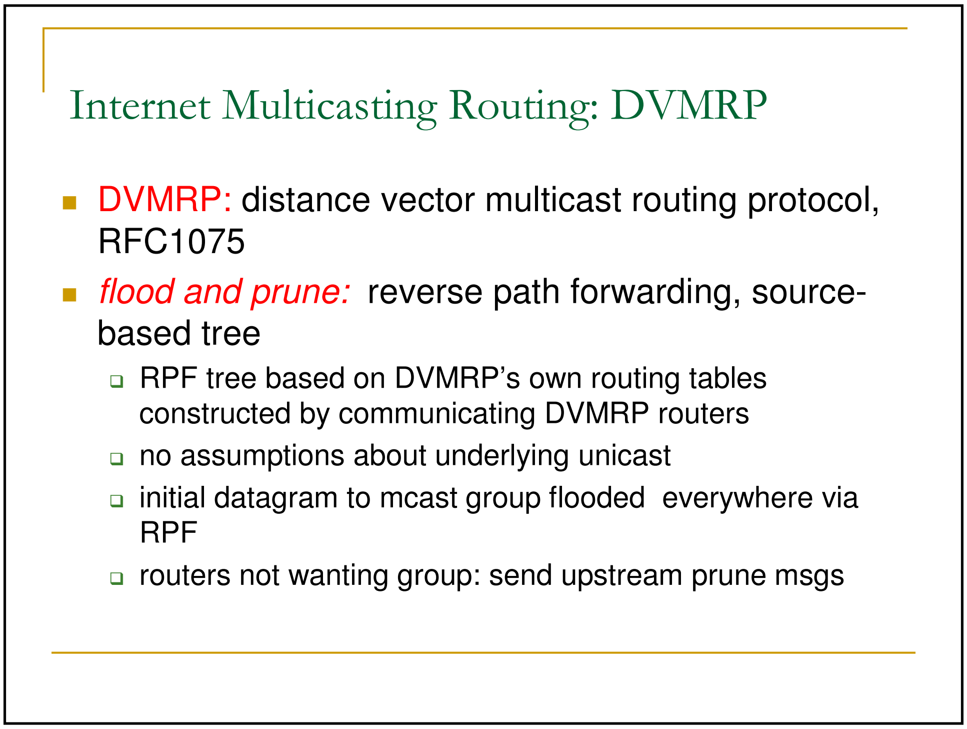
Tunneling

Q: How to connect "islands" of multicast routers in a "sea" of unicast routers?



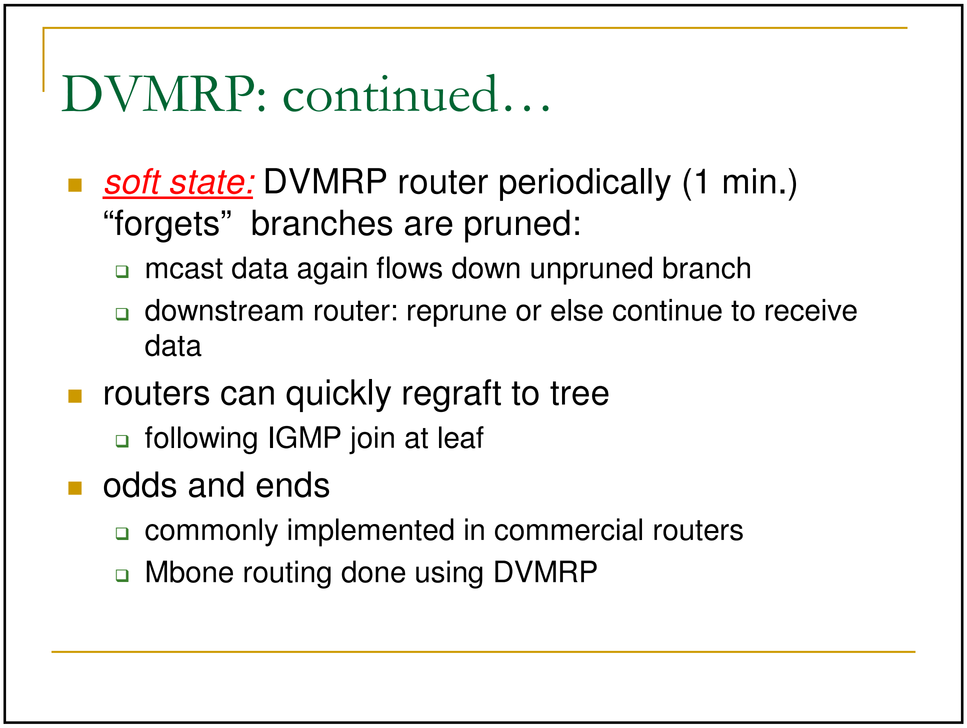
physical topology | logical topology

- mcast datagram encapsulated inside "normal" (non-multicast-addressed) datagram
- normal IP datagram sent thru "tunnel" via regular IP unicast to receiving mcast router
- receiving mcast router unencapsulates to get mcast datagram



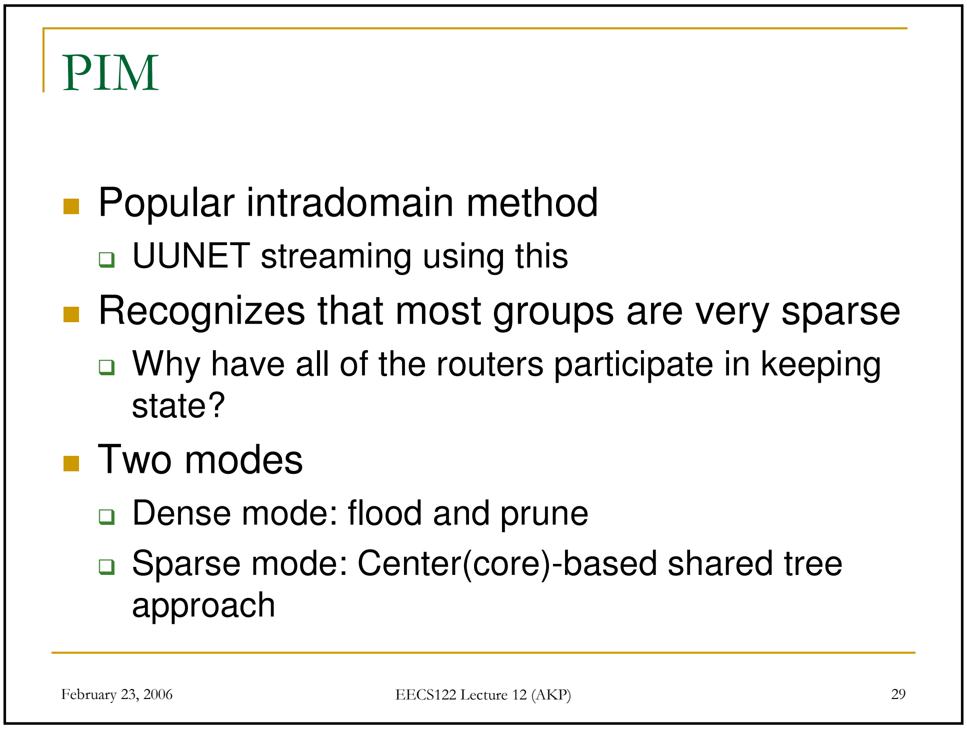
Internet Multicasting Routing: DVMRP

- DVMRP: distance vector multicast routing protocol, RFC1075
- *flood and prune:* reverse path forwarding, source-based tree
  - RPF tree based on DVMRP's own routing tables constructed by communicating DVMRP routers
  - no assumptions about underlying unicast
  - initial datagram to mcast group flooded everywhere via RPF
  - routers not wanting group: send upstream prune msgs



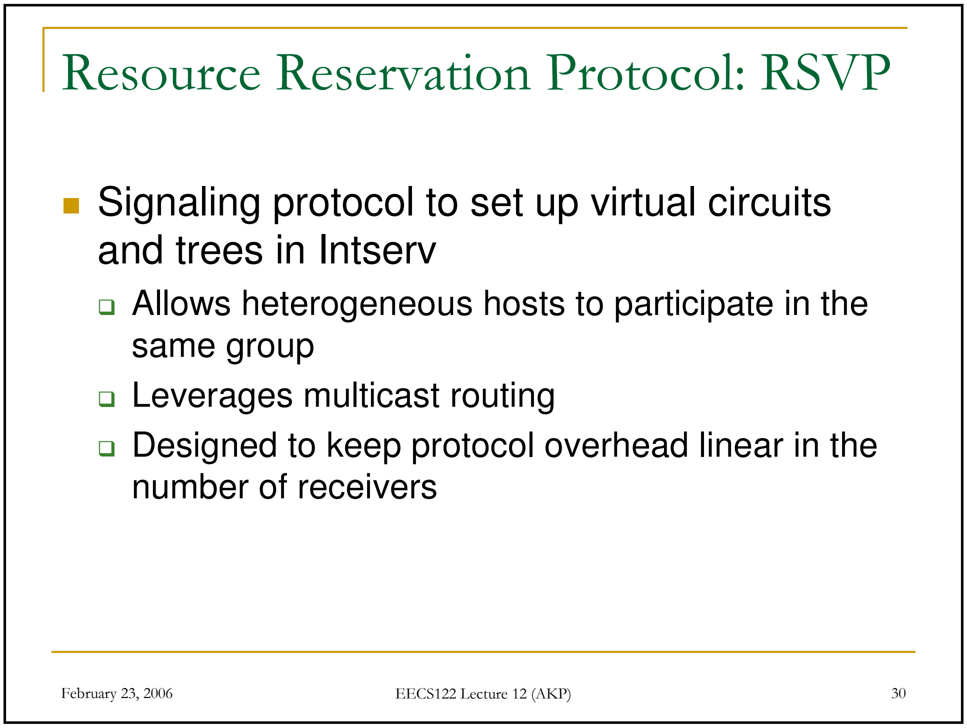
DVMRP: continued…

- *soft state:* DVMRP router periodically (1 min.) "forgets" branches are pruned:
  - mcast data again flows down unpruned branch
  - downstream router: reprune or else continue to receive data
- routers can quickly regraft to tree
  - following IGMP join at leaf
- odds and ends
  - commonly implemented in commercial routers
  - Mbone routing done using DVMRP



PIM

- Popular intradomain method
  - UUNET streaming using this
- Recognizes that most groups are very sparse
  - Why have all of the routers participate in keeping state?
- Two modes
  - Dense mode: flood and prune
  - Sparse mode: Center(core)-based shared tree approach



Resource Reservation Protocol: RSVP

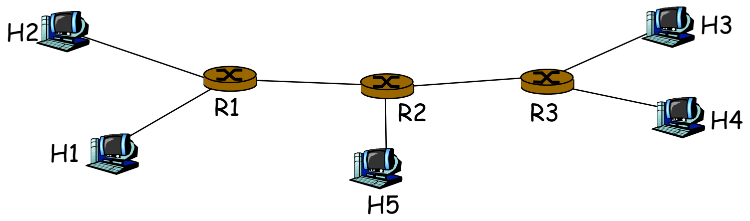
- Signaling protocol to set up virtual circuits and trees in Intserv
  - Allows heterogeneous hosts to participate in the same group
  - Leverages multicast routing
  - Designed to keep protocol overhead linear in the number of receivers

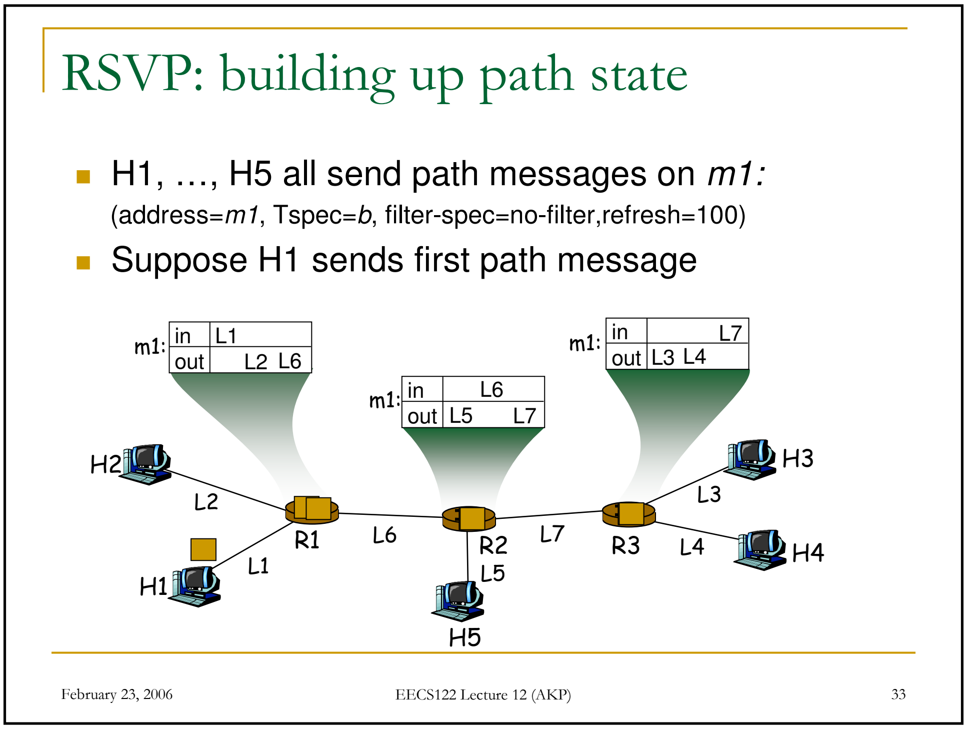
RSVP: overview of operation

- Senders, receiver join a multicast group
- Path message from sender
  - make sender presence known to routers
  - path teardown: delete sender's path state from routers
- Reservation message from receiver
  - *reservation message:* reserve resources from sender(s) to receiver
  - reservation teardown: remove receiver reservations

RSVP: simple audio conference

- H1, H2, H3, H4, H5 both senders and receivers
- multicast group m1
- no filtering: packets from any sender forwarded
- audio rate: *b*
- only one multicast routing tree possible





RSVP: building up path state

- H1, …, H5 all send path messages on *m1:*
  (address=*m1*, Tspec=*b*, filter-spec=no-filter,refresh=100)
- Suppose H1 sends first path message

m1:

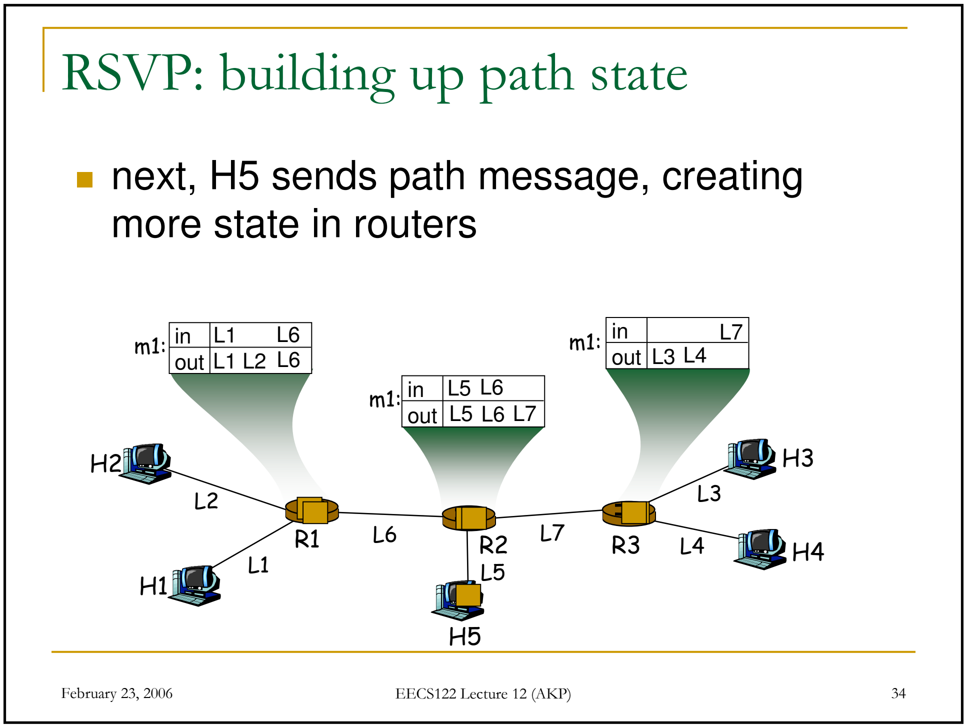
in	L1
out	L2 L6

m1:

in	L6
out	L5 L7

m1:

in	L7
out	L3 L4



RSVP: building up path state

- next, H5 sends path message, creating more state in routers

m1:

in	L1 L6
out	L1 L2 L6

m1:

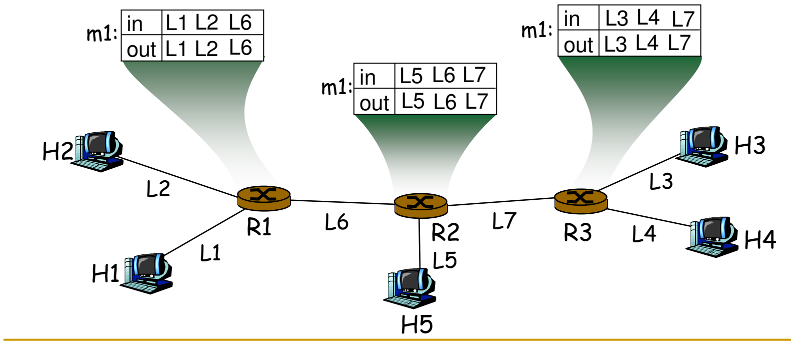
in	L5 L6
out	L5 L6 L7

m1:

in	L7
out	L3 L4

RSVP: building up path state

- H2, H3, H5 send path msgs, completing path state tables



m1:

in	L1 L2 L6
out	L1 L2 L6

m1:

in	L5 L6 L7
out	L5 L6 L7

m1:

in	L3 L4 L7
out	L3 L4 L7

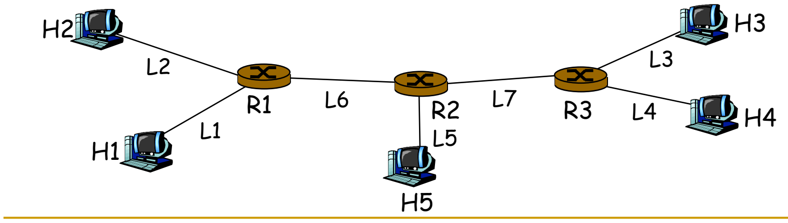
Reservation Msgs: *receiver-to-network* signaling

- reservations flow upstream from receiver-to-senders, reserving resources, creating additional, *receiver-related* state at routers

RSVP: *receiver* reservation

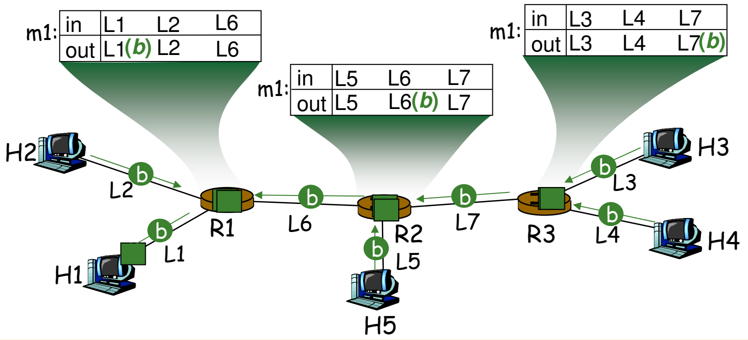
H1 wants to receive audio from all other senders

- H1 reservation msg flows uptree to sources
- H1 only reserves enough bandwidth for 1 audio stream
- reservation is of type “no filter” – any sender can use reserved bandwidth



RSVP: *receiver* reservation

- H1 reservation msgs flows uptree to sources
- routers, hosts reserve bandwidth b needed on downstream links towards H1



m1:

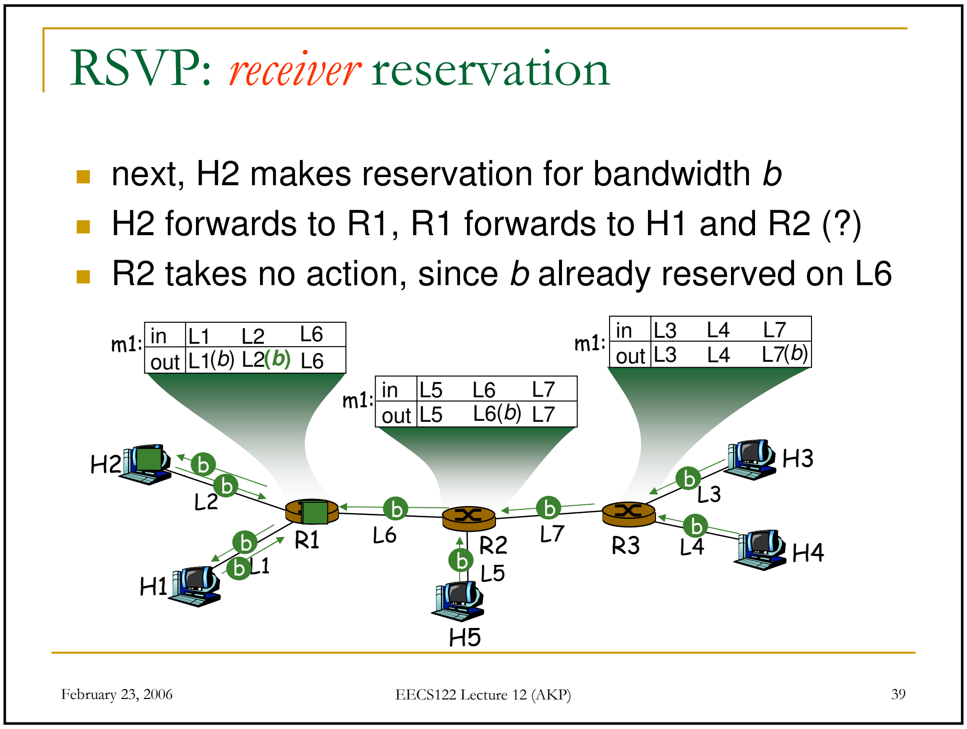
in	L1	L2	L6
out	L1(*b*)	L2	L6

m1:

in	L5	L6	L7
out	L5	L6(*b*)	L7

m1:

in	L3	L4	L7
out	L3	L4	L7(*b*)



RSVP: *receiver* reservation

- next, H2 makes reservation for bandwidth *b*
- H2 forwards to R1, R1 forwards to H1 and R2 (?)
- R2 takes no action, since *b* already reserved on L6

m1:

in	L1	L2	L6
out	L1(*b*)	L2(***b***)	L6

m1:

in	L5	L6	L7
out	L5	L6(*b*)	L7

m1:

in	L3	L4	L7
out	L3	L4	L7(*b*)

H2
L2
b
b
R1
b
b
L1
H1
L6
b
R2
b
L5
H5
L7
b
R3
b
L3
H3
b
L4
H4

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