Evaluation Method

- Interim and Final Report
- Attendance is not Checked, but, ...
- Questions or Comments are Mandated
  - In the quater, questions or comments with technical content must be made at least twice during lecture (may be in Japanese)
  - Good questions and comments will be awarded with points
  - Declare your name and student ID after each lecture, if you make questions or comments

Remaining Topics and Rescheduling

- only 3 days remaining: 7/26, 30 and 8/2
  - 8/6 and 8/9 is reserved for unscheduled cancellation
- the following topic will be omitted
  - 9. Routing: Traffic Engineering, ROLC, MPLS

Advanced Lecture on Internet Infrastructure

10. Routing: Multicast, Aggregation of Routing Table

Masataka Ohta

mohta@necom830.hpcl.titech.ac.jp

ftp://chacha.hpcl.titech.ac.jp/infra10e.ppt

What is Multicast?

- one to many, many to many communication by copying data in network
  - "broadcast" by network
- necessary in network not possible by end
  - copying end is called reflector or, IMHO improperly, application layer multicast
- intimately related to resource reservation
  - cannot adjust BW according to congestion
  - each multicast address consumes routing table entry

Networks

- Physical Distribution Networks
  - postal service, parcel services, convenience stores
- Information Communication Networks
  - Publishing Network (Book, News Paper, CD, Movie)
  - Financial Network
  - Phone Network
  - Broadcast Network
  - the Internet

Publishing Network

- Mass Distribution of Same Information
- Delay of the Distribution may be Tolerated
- Protected by Copyright Act
- The First Victim of the Internet
  - Collapsing

Financial Network

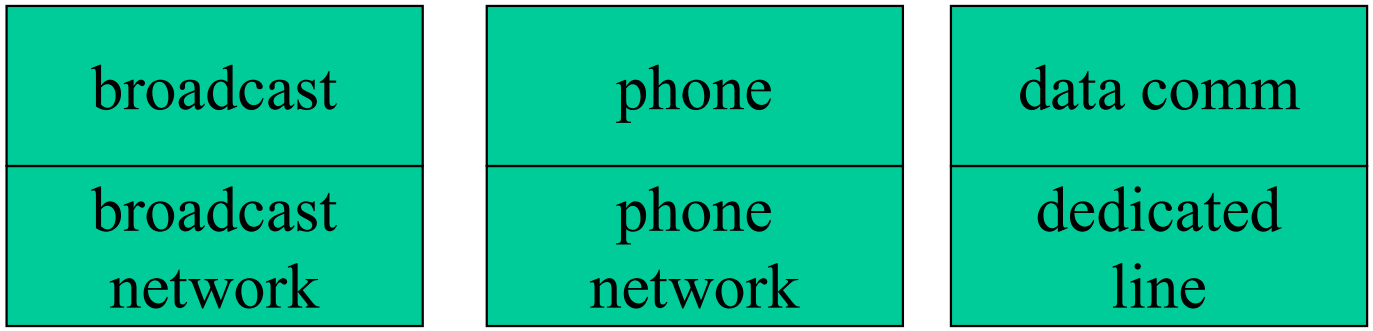
- Manage Transfer of Money
- Partly, Phisical Distribution Network, but, today, mostly ICN
- Security!!!
  - Not that there is no accident
  - Who will pay the loss on accidents

Phone Network

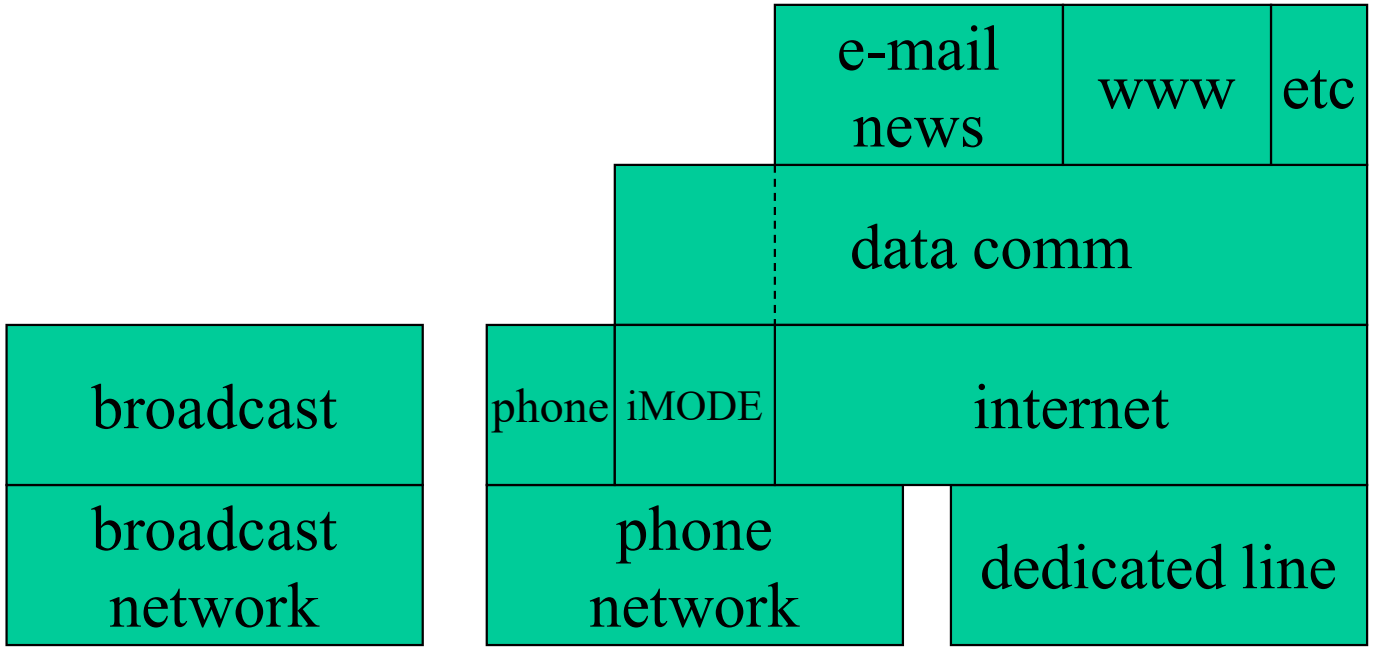
- Network for Realtime Voice Transfer
  - Allocate bandwidth for voice transfer
  - Minimize (guarantee) delay for voice transfer
- Dedicated line service may be Offerred
  - but, primary service is voice transfer
- Slow and Expensive
- Was Protected as National Company
  - Leberated by Telecommunication Business Act

Broadcast Network

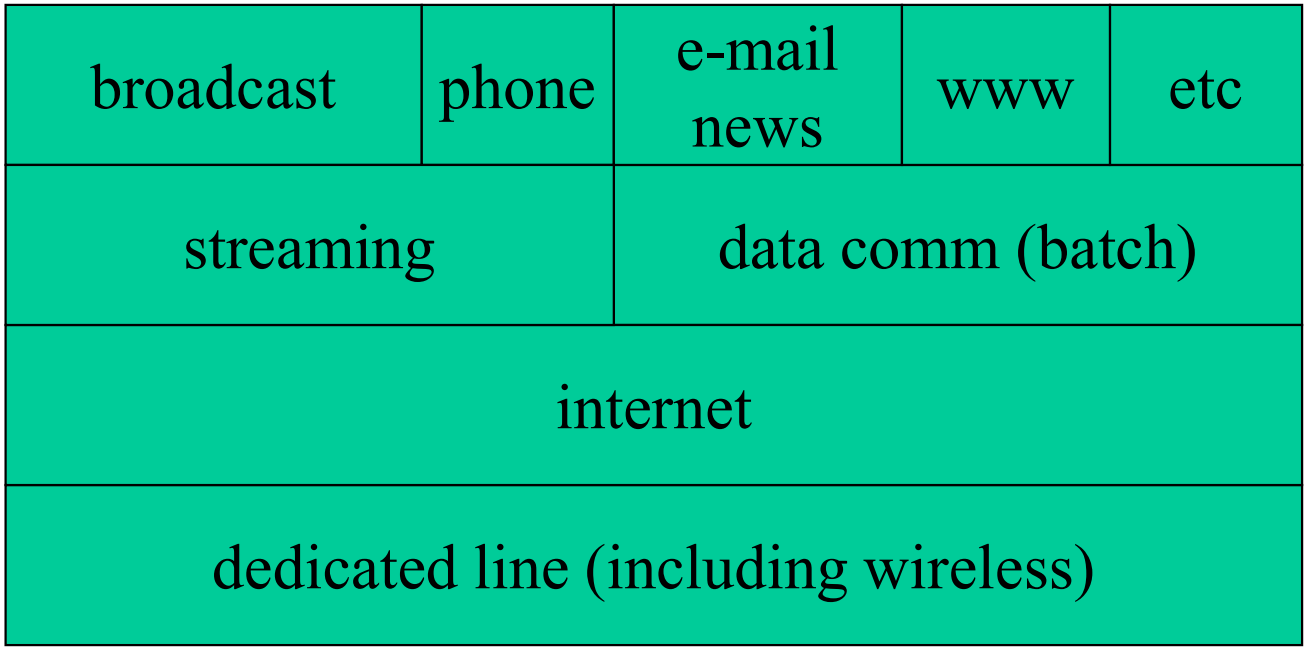
- Network to Transfer Voice/Image to Many in Realtime
  - Allocate bandwidth for the transfer
  - Minimize delay
- Wide Area One to Many Communication over Radio Waves
  - Broadcast/Multicast
- Protected by Broadcast Act



networks before the Internet



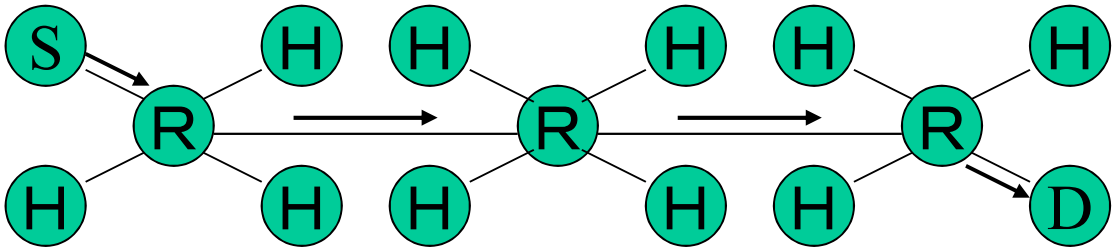
networks with the Internet



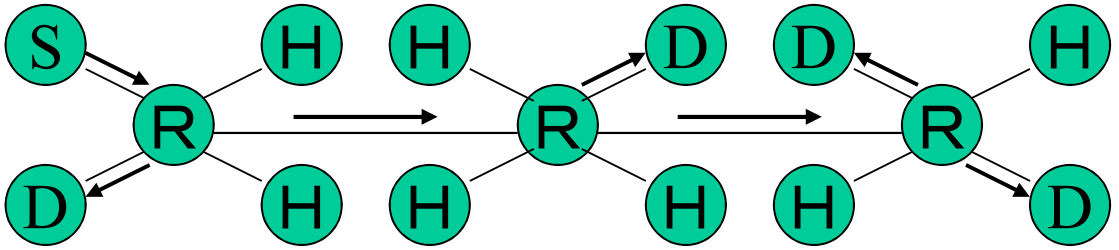
network in the future

Multicast and Broadcast

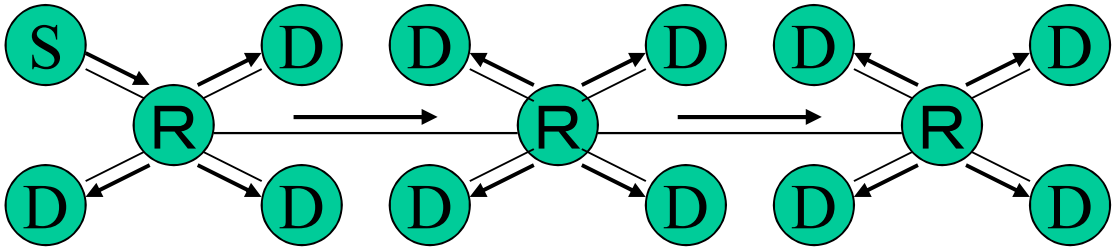
- broadcast
  - send to all the hosts within a region
  - not realistic over the entire internet
- multicast
  - send to all the members of a group
    - # of members can be arbitrary large
      - member management by network impossible
      - members tell network their existence
  - group is identified by multicast address
    - 224.0.0.0~239.255.255.255



a) unicast



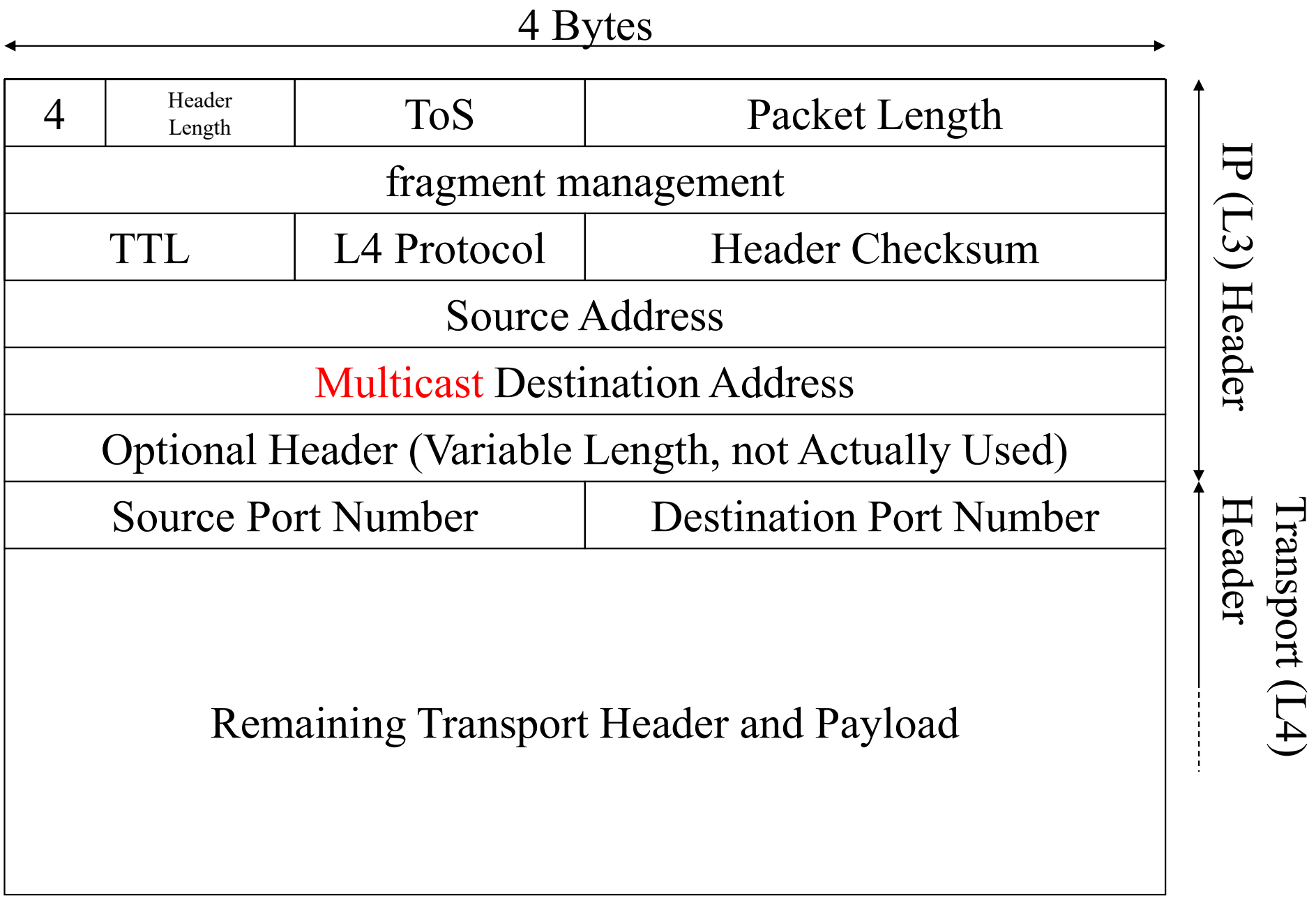
b) multicast



c) broadcast

H: host R: router S: source D: destination ⟶: data flow

unicast, multicast and broadcast



Format of IPv4 Packets (rfc791)

Multicast by IGMP (1)

- destination hosts
  - changes dynamically
  - register their existence by IGMP (Internet Group Management Protocol, rfc988)
    - IGMP is independent from multicast routing protocols (?)
- source hosts
  - changes dynamically
  - just send multicast packets
  - independent from multicast routing protocols

Multicast by IGMP (2)

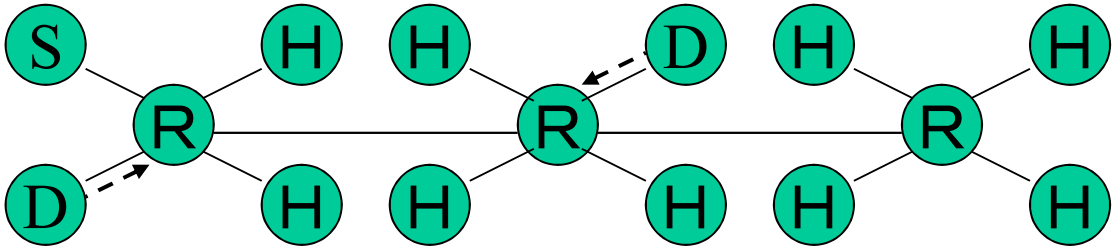
- routers
  - process some multicast routing protocol
  - depending on multicast routing protocol
    - react to IGMP packets
    - react to multicast packets sent
  - against the E2E principle?

Multicast and Ends

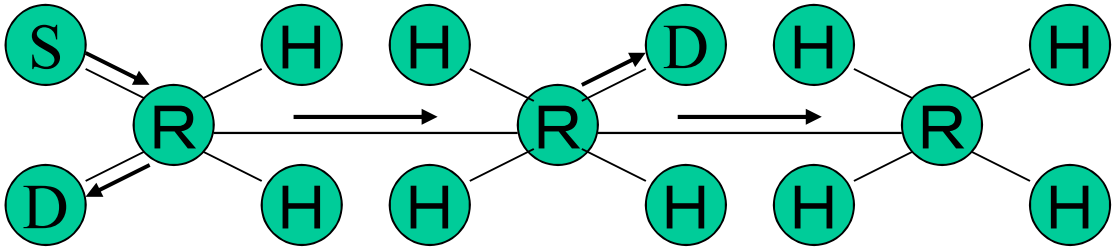
- destination: represented by destination host
- source: represented by source host
- group: represented by ?
  - no one?
  - ISP?
  - source (SSM, single source multicast)?
  - group management host!

Multicast Routing Protocols

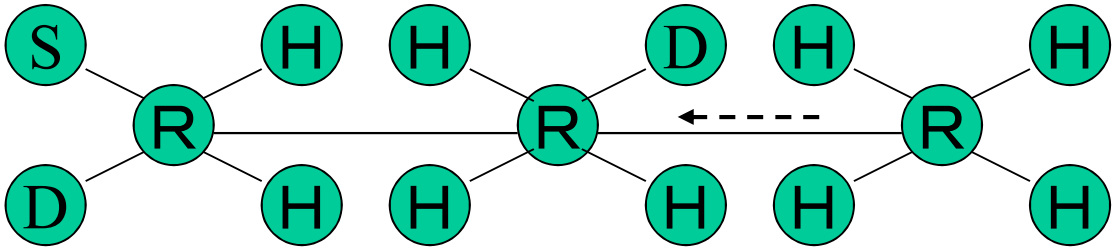
- dense
  - broadcast data and detect part of network where data is not necessary
  - DVMRP (rfc1075), PIM-DM
- MOSPF (rfc1584)
  - broadcast locations of sources and destinations
- sparse
  - have a center to control data flow
  - CBT (rfc2189), PIM-SM(rfc2362)



a) registration by IGMP



b) first data flow



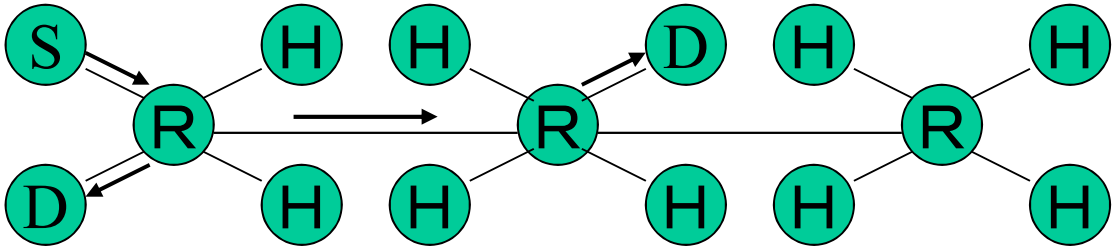
c) delete leaf with no destination

H: host R: router S: source D: destination

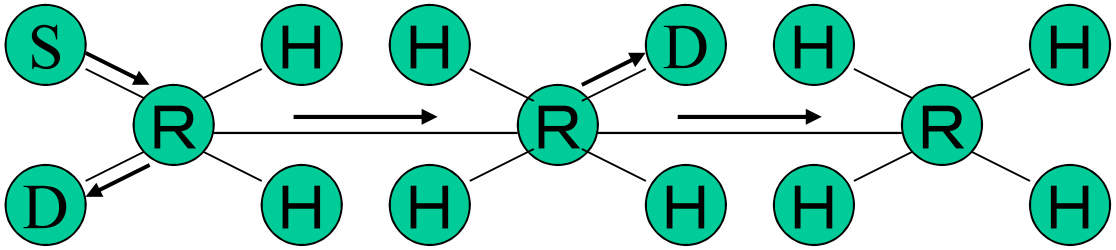
→: data flow

- - →: control flow

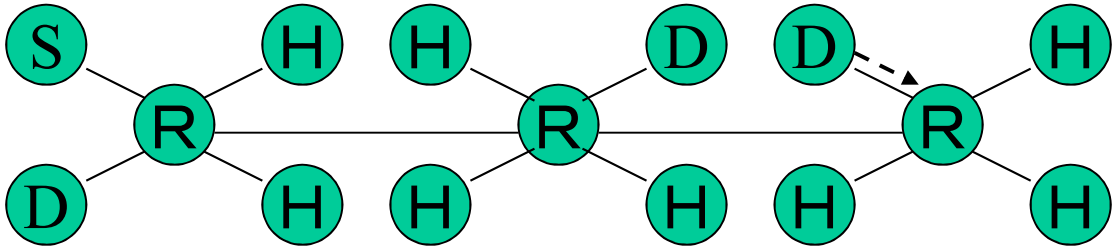
operation of DVMRP



d) data flow after deletion



e) data flow after certain period of time



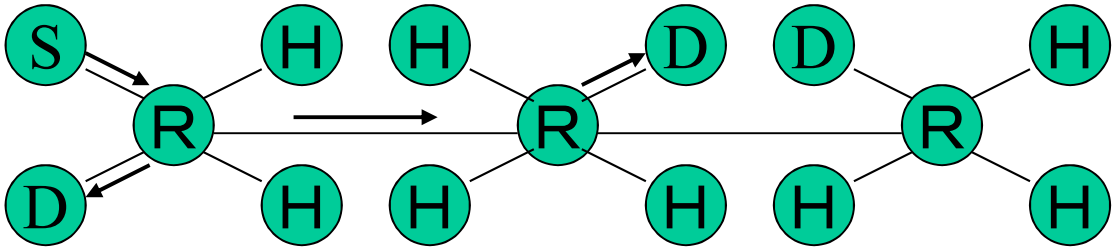
f) new destination appears

H: host R: router S: source D: destination

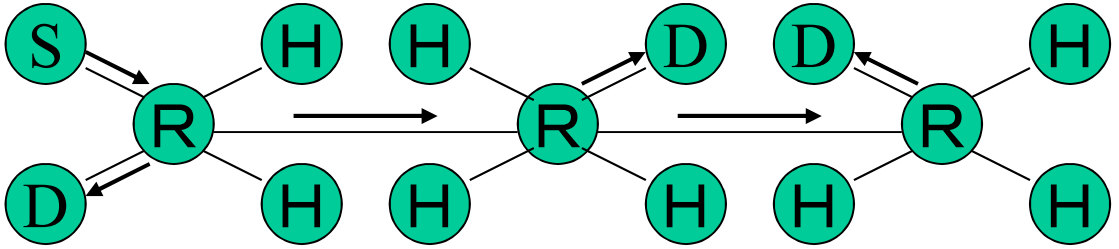
→: data flow

- - →: control flow

operation of DVMRP



g) data flow immediately after f)



h) data flow after certain period of time

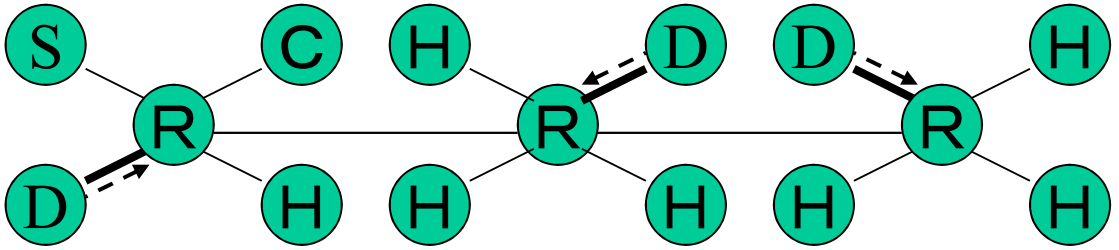
H: host R: router S: source D: destination →: data flow

- - →: control flow

operation of DVMRP

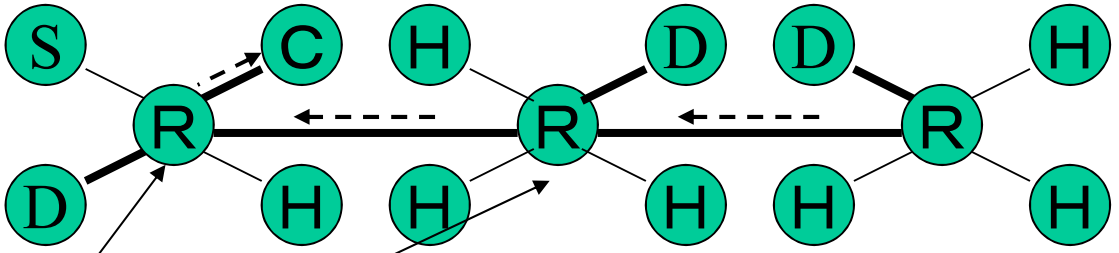
CBT (Core Based Tree)

- routers around destinations send registration message toward Core (center)
  - multiple registration messages are merged
  - bi-directional tree including Core and destinations formed
- packets from source is relayed toward Core
  - if the packets arrives to the bi-directional tree, copied over the tree



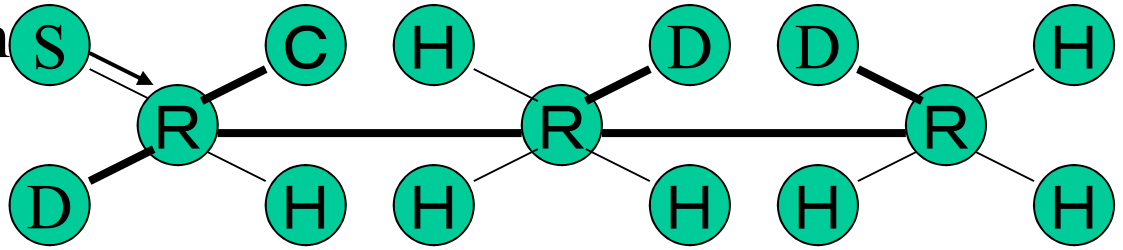
a) registration of destinations

—: multicast tree



b) propagation of registration requests (tree is formed)

merge registration requests



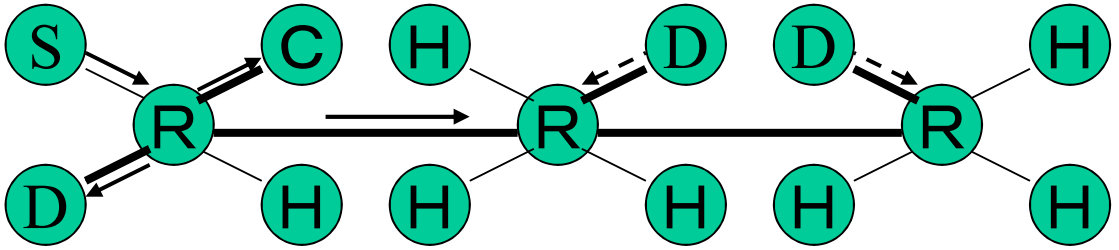
c) sending packets toward core

H: host R: router S: source D: destination

→: data flow

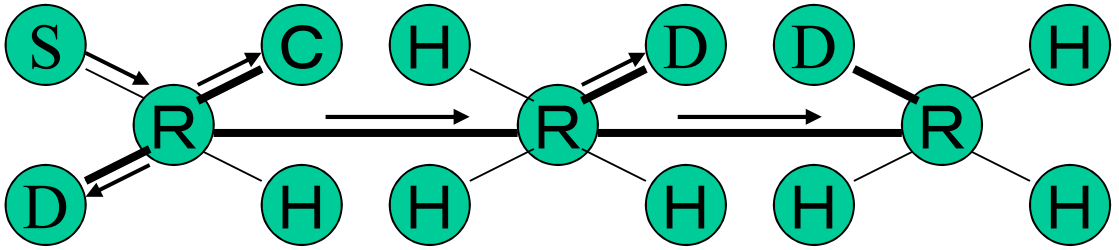
- - →: control flow

operation of CBT

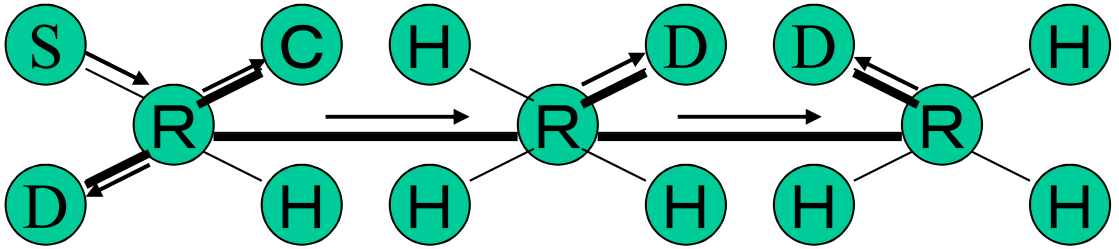


d) packet copied over tree 1

: multicast tree



e) packet copied over tree 2



f) packet copied over tree 3

H: host R: router S: source D: destination

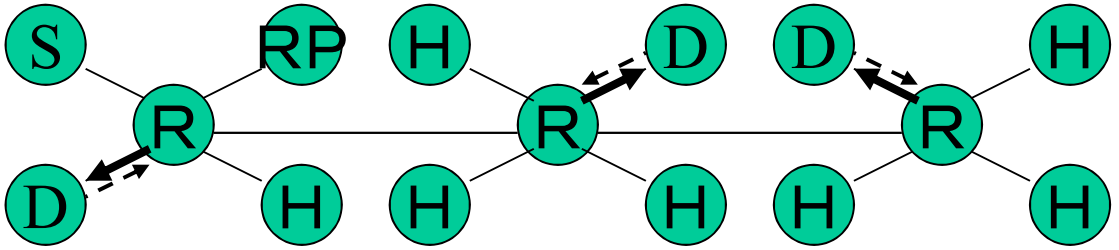
: data flow

: control flow

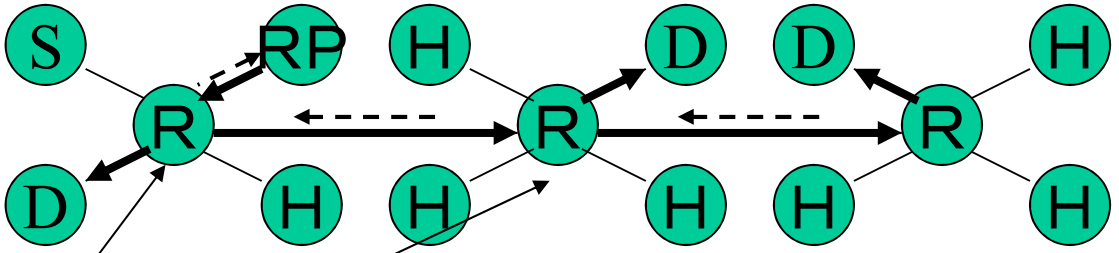
operation of CBT

PIM (Protocol Independent Multicast) SM (Sparse Mode)

- routers around destinations send registration message toward RP (Rendez-vous Point)
  - multiple registration messages are merged
  - uni-directional tree rooted by formed
- packets from (router adjacent to) source is unicast to RP
  - packets arriving RP is copied over the tree
- RP represent group management host
  - can control dataflow



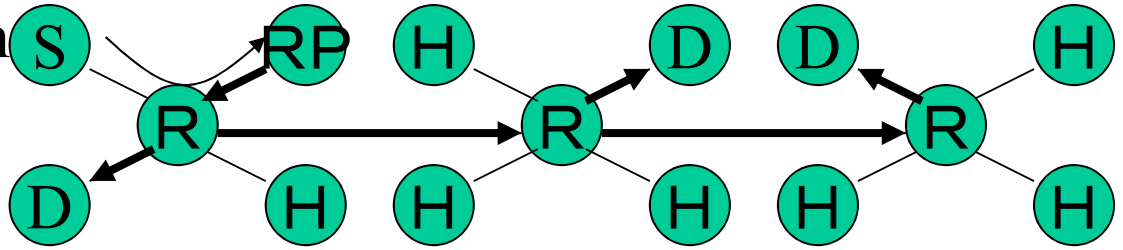
a) registration of destinations



b) propagation of registration requests

merge registration requests

→: multicast tree



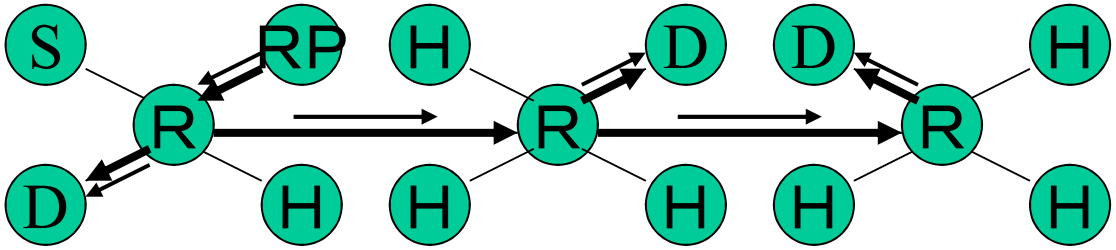
c) packets unitcast to RP (using IP tunneling)

H: host R: router S: source D: destination

→: data flow

- - →: control flow

operation of PIM-SM



d) relay by RP (multicast)

: multicast tree

H: host R: router S: source D: destination

: data flow

: control flow

operation of PIM-SM

Core and RP

- how to know Core and RP of a group?
  - broadcast?
  - delivered by application along with multicast address?
    - what if, a router receives inconsistent information?
  - give up many to many and make source RP
  - static multicast!
    - Core and RP registered to reverse DNS domain

Interdomain Multicast

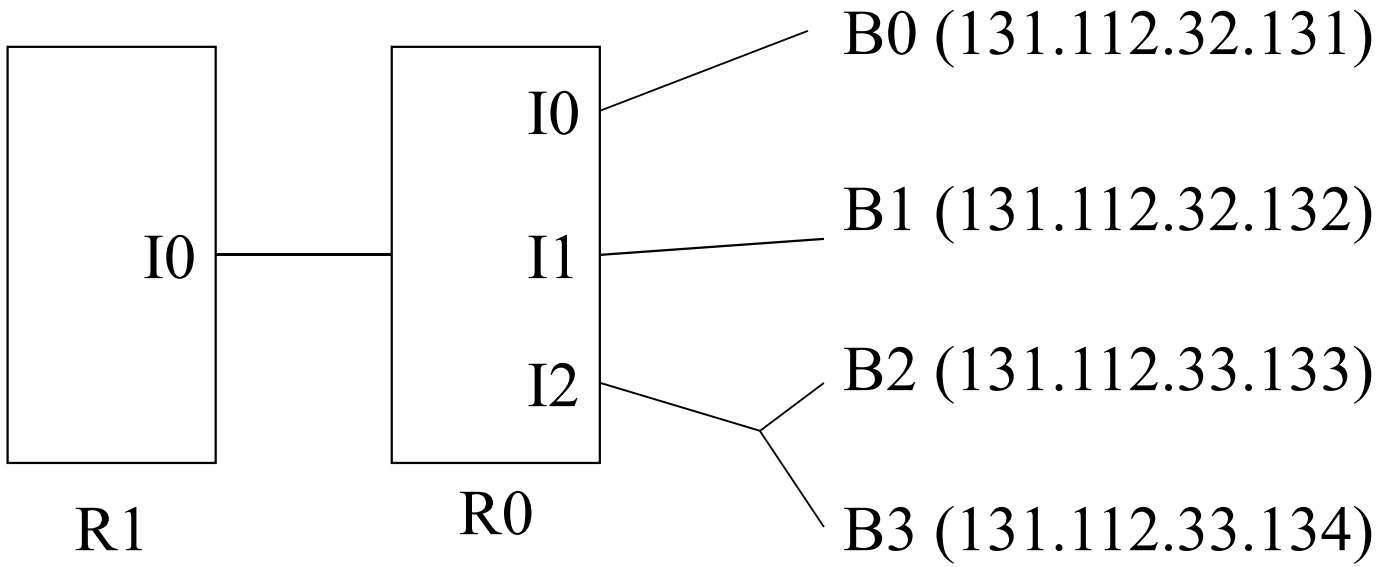
- existing multicast protocols needs separate routing table entry for each group
  - does not scale over the Internet?
- existing protocols should be used in small domain
- provide other protocol for interdomain routing
  - BGMP (Border Gateway Multicast Protocol, rfc3913, something like Interdomain CBT)
- each domain has block of multicast address and aggregate routing table entry between domains

Aggregation of Multicast Routing Table Entries

- impossible
- multicast address does not designate location
- distribution of destinations is different group by group (even with similar address)
- if multicast has a center (center domain of BGMP)
  - route from source to the center (essentially unicast) can be aggregated
  - route from the center to destinations cannot be aggregated

Routing Table

- routers send packets to next hop routers based on look up results of routing table
  - key of the look up is destination address
- same entry may be shared if similar(?) addresses occur only in some remote region
  - route aggregation
    - 1 entry shared by many addresses
  - like phone numbers, may be hierarchical
    - +81-3-5734-3299



routing table at R0

destination	next hop
131.112.32.131	I0
131.112.32.132	I1
131.112.33.*	I2

routing table at R1

destination	next hop
131.112.*	I0

route aggregation

Cases When Route Aggregation Impossible

- aggregation possible, if route is shared by addresses sharing a pattern
- route not by destination address only
  - QoS routing depends on required QoS
- destination address not designate location
  - multicast address designate set of locations
- random IP addresses within a region
  - initial allocations for IPv4
  - multihoming by routing

Multicast Routing Table Entries Cannot be Aggregated

- interdomain multicast by BGMP is illusion
  - static CBT and PIM works Interdomain
- routing table of internet backbone is large
- multicast group is resource reserving communication occupying limited resource of routing table entries
  - should be charged proportional to duration of the communication

Multicast and Bandwidth

- congestion situation is different by each destination
  - BW management for which destination?
- source determines BW
  - destinations somehow (BW (QoS) guarantee?) receives or give up

Economic Incentive for Multicast

- with flat rate best effort
  - ISP want to collect extra money for multicast
    - destinations have no merit to use multicast
      - easy to insist on unicast
    - source do not want to use multicast with no destinations
- with proportional charge (with QoS)
  - ISP prefer unicast
    - source/destinations want to reduce charge by multicast

Example of Multicast Cost (8k broadcast in a prefecture)

- assume 10Gbps prefecture backbone (excluding access)
  - ISP charge 5000Yen/month, 2.5 person for each subscriber, 30% for prefecture backbone
    - backbone cost: 600Yen/(person･month)
    - occupying 100Mbps costs 72Yen/(person･year)
      - 72MYen/year with 1M populations
- multicast is
  - less expensive than radio-wave broadcast or CDN
  - costs 1/10 if backbone is 100Gbps

Wrap-up

- multicast is function of network
  - impossible by ends
- IGMP is against E2E principle
- end systems managing group is essential
- broadcast must be avoided in multicast routing protocols
- multicast route cannot be aggregated
- multicast congestion control impossible
  - multicast is resource reserving