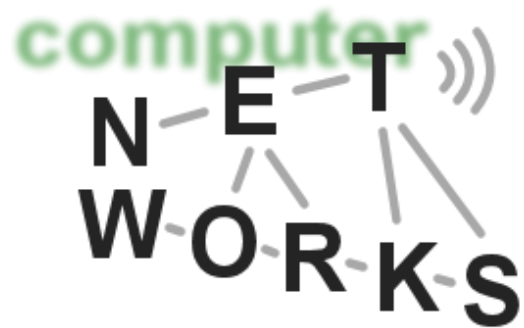# Network Layer – Part III
Multicast and Mobility

Computer Networks, Winter 2012/2013
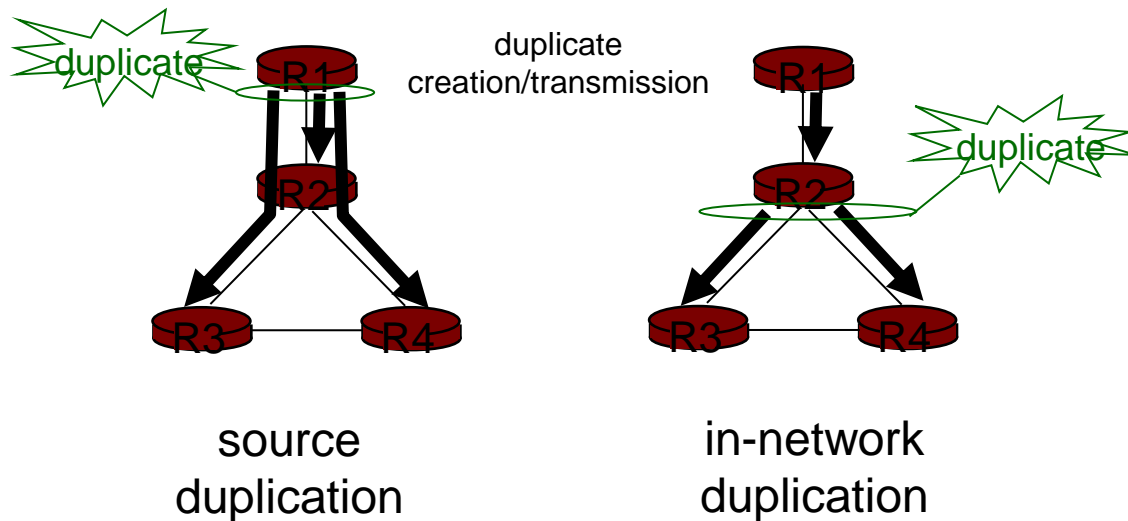
Network Layer III

o 4.6 Multicast

    o Broadcast routing

    o Multicast routing

    o Multicast routing protocols

o 4.7 Mobility

    o What is Mobility?

    o Network layer mobility concepts and principles

    o Mobile IP

Broadcast Routing

o Deliver packets from source to all other nodes

o Source duplication is inefficient:

duplicate

duplicate
creation/transmission

R1

R2

R3   R4

duplicate

R1

R2

R3   R4

source
duplication

in-network
duplication

o Source duplication: how does source determine recipient addresses?

In-network duplication

o Flooding: when node receives broadcast packets, sends copy to all neighbors

  o Problems: cycles & broadcast storm

o Controlled flooding: node only broadcast pkt if it hasn't broadcasted same pkt before

  o Node keeps track of pkt ids already broadcasted

  o Reverse path forwarding (RPF): only forward pkt if it arrived on shortest path between node and source

o Spanning tree

  o No redundant packets received by any node

Spanning Tree

o First construct a spanning tree

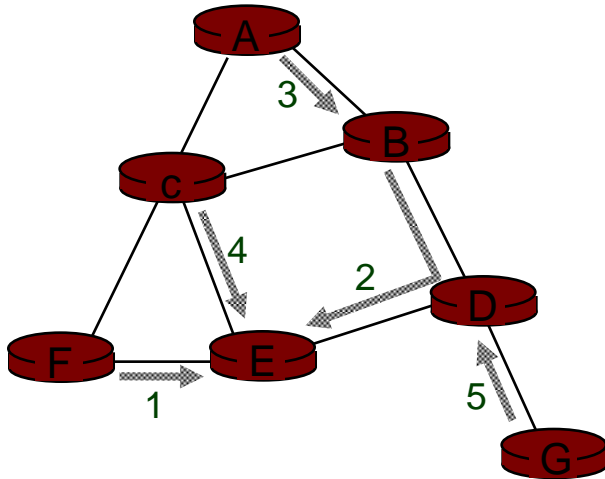o Nodes forward copies only along spanning tree
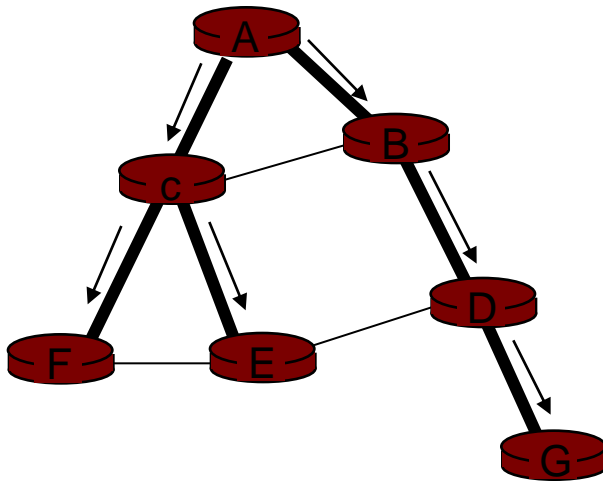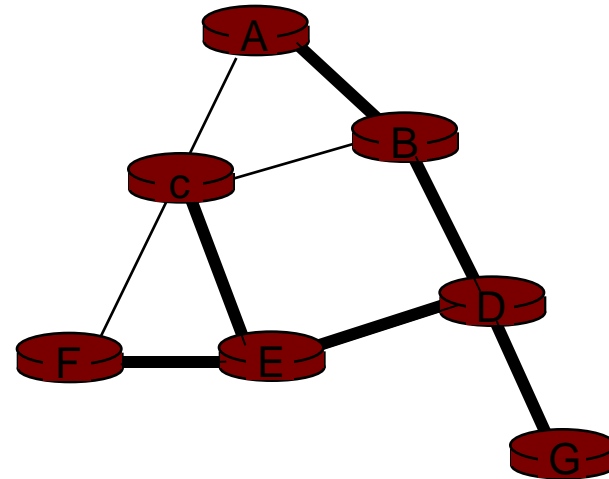

(a) Broadcast initiated at A
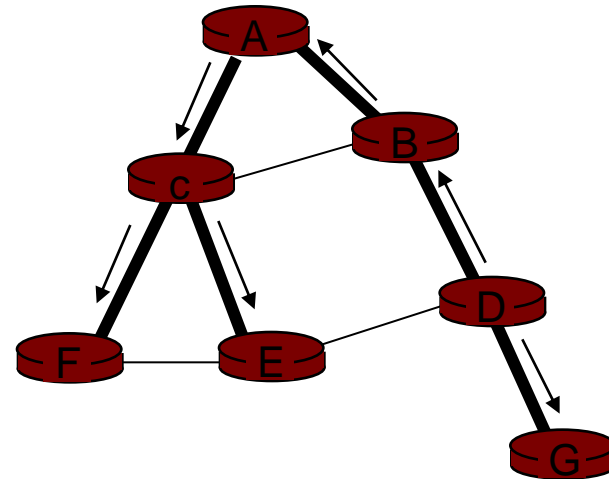
(b) Broadcast initiated at D

Spanning Tree: Creation

o Center node

o Each node sends unicast join message to center node 'E'

    o Message forwarded until it arrives at a node already belonging to spanning tree


(a) Stepwise construction of spanning tree

(b) Constructed spanning tree

Network Layer II

- ○ 4.6 Multicast
  - ○ Broadcast routing
  - ○ Multicast routing
  - ○ Multicast routing protocols
- ○ 4.7 Mobility
  - ○ What is Mobility?
  - ○ Network layer mobility concepts and principles
  - ○ Mobile IP

Multicast Routing: Problem Statement

o Goal: find a tree (or trees) connecting routers that have local multicast group members

  o Tree: not all paths between routers used
  o Source-based: different tree from each sender to receiver
  o Shared-tree: same tree used by all group members
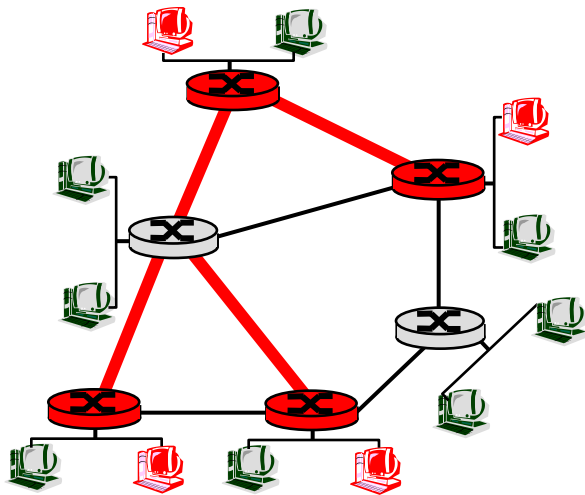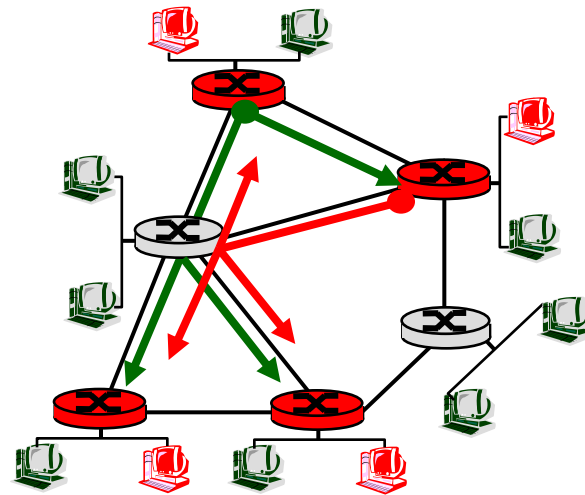
Shared tree   Source-based trees

Approaches for building mcast trees

o Source-based tree: one tree per source

  o shortest path trees

  o reverse path forwarding

o Group-shared tree: group uses one tree

  o minimal spanning (Steiner)

  o center-based trees

Shortest Path Tree

○ Multicast forwarding tree: tree of shortest path routes from source to all receivers

  ○ Dijkstra's algorithm

S: source

LEGEND

router with attached group member

router with no attached group member

i — link used for forwarding, i indicates order link added by algorithm
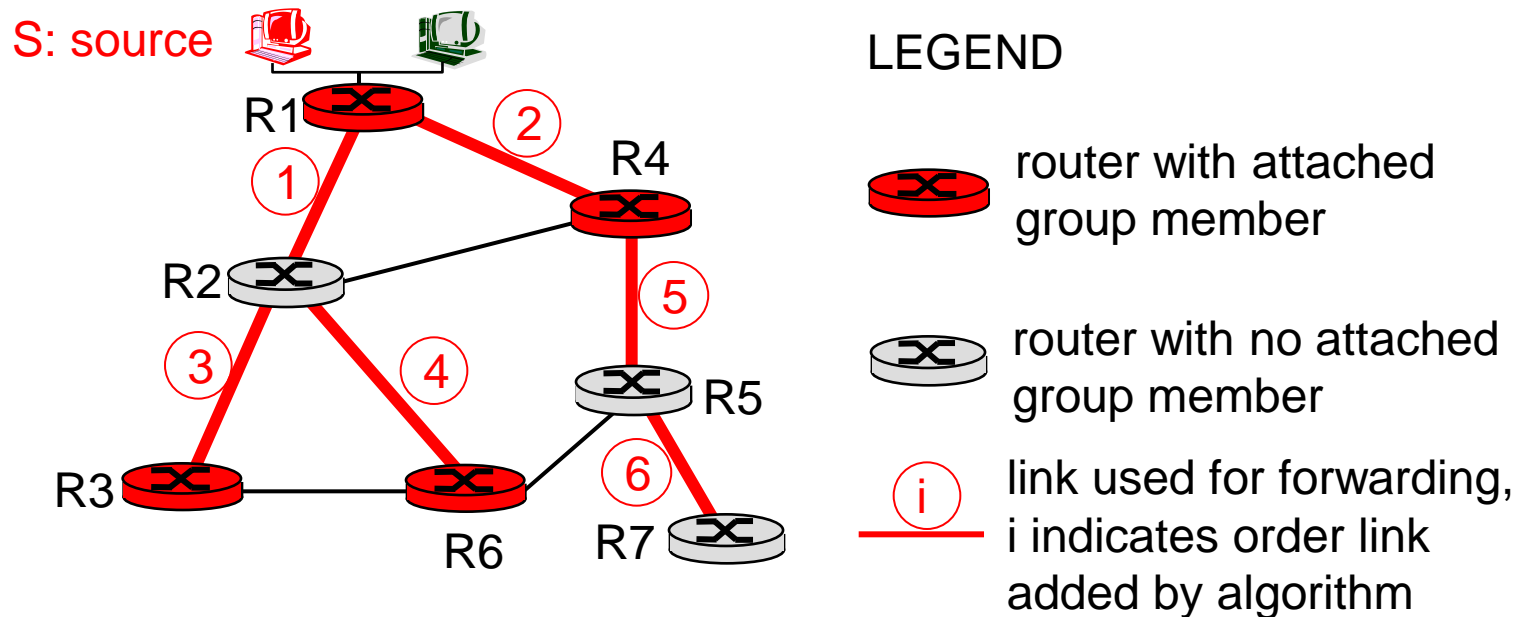
Reverse Path Forwarding

o Relies on router's knowledge of unicast shortest path from it to sender

o Each router has simple forwarding behavior:

if (multicast 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
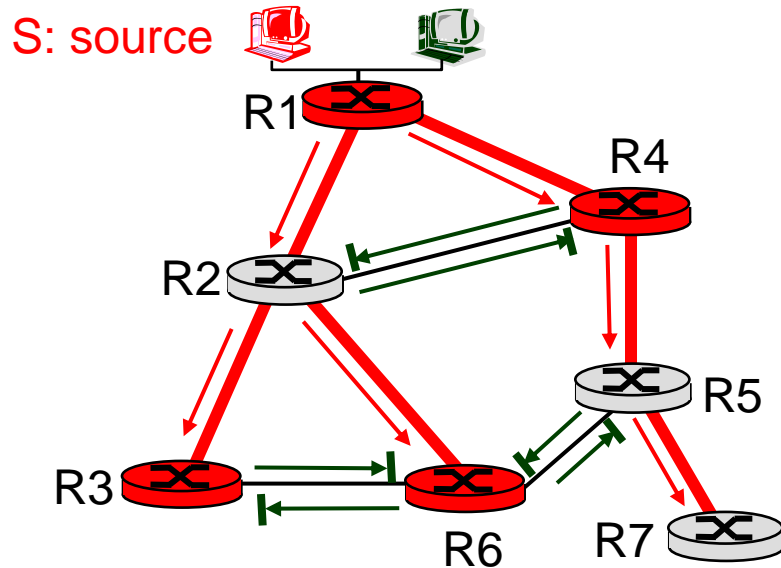
S: source

LEGEND

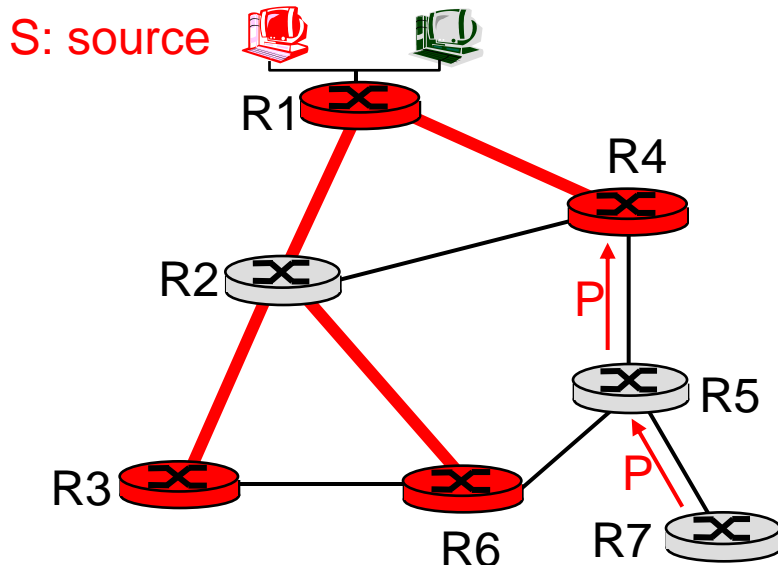router with attached group member

router with no attached group member

→ datagram will be forwarded

→| datagram will not be forwarded

R1
R4
R2
R3
R5
R6
R7

- result is a source-specific *reverse* SPT
  – may be a bad choice with asymmetric links

Reverse Path Forwarding: pruning

o forwarding tree contains subtrees with no multicast group members

- o no need to forward datagrams down subtree
- o "prune" msgs sent upstream by router with no downstream group members

S: source

LEGEND

router with attached group member

router with no attached group member

P → prune message

links with multicast forwarding

R1
R4
R2
R5
R3
R6
R7
P
P

Center-based trees

o Single delivery tree shared by all

o One router identified as "center" of tree

o To join:

- o edge router sends unicast join-msg addressed to center router

- o join-msg "processed" by intermediate routers and forwarded towards center

- o join-msg either hits existing tree branch for this center, or arrives at center

- o path taken by join-msg becomes new branch of tree for this router

Center-based trees: an example

Suppose R6 chosen as center:
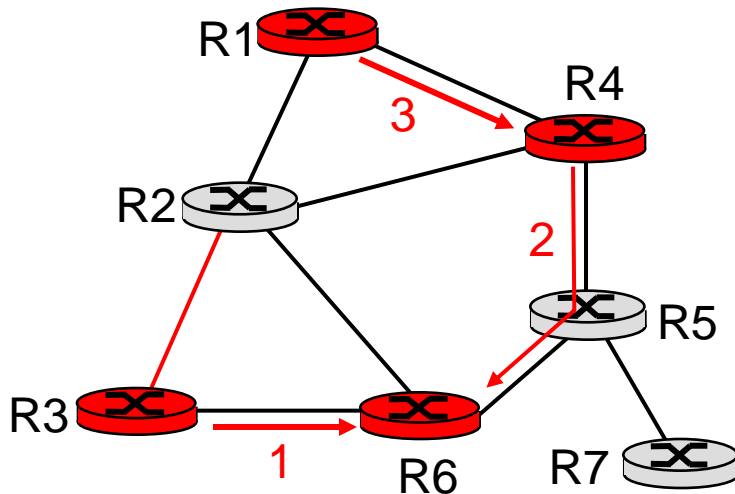
LEGEND

router with attached group member

router with no attached group member

1 ⟶ path order in which join messages generated

Network Layer II

○ 4.6 Multicast

  ○ Broadcast routing

  ○ Multicast routing

  ○ Multicast routing protocols

○ 4.7 Mobility

  ○ What is Mobility?

  ○ Network layer mobility concepts and principles

  ○ Mobile IP

Internet Multicast Service Model

128.59.16.12

128.119.40.186

multicast group 226.17.30.197

128.34.108.63

128.34.108.60
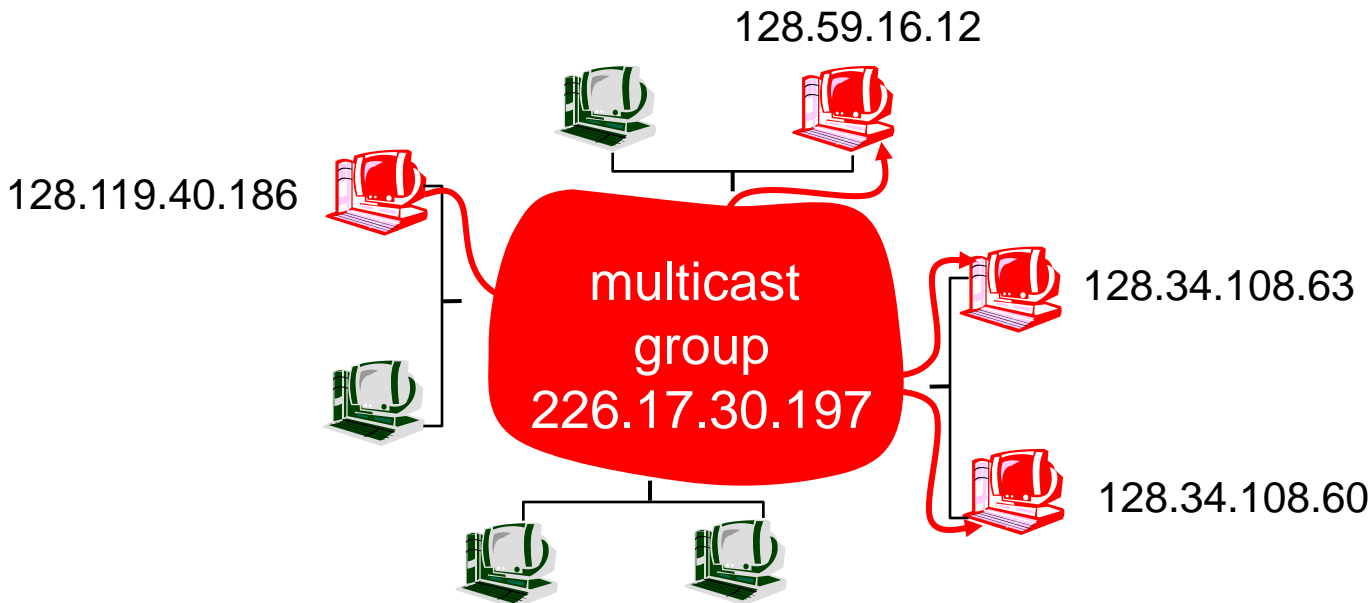
Multicast group concept: use of indirection

- o hosts addresses IP datagram to multicast group
- o routers forward multicast datagrams to hosts that have "joined" that multicast group

Multicast Groups

o Class D Internet addresses reserved for multicast:

1110	Multicast Group ID

←——— 28 bits ———→
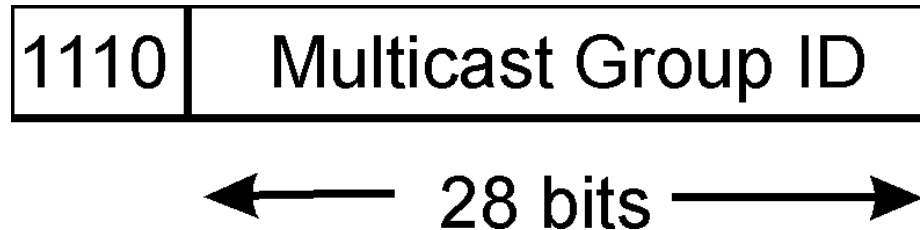
o Host group semantics:

- o anyone can "join" (receive pkts) multicast group
- o anyone can send pkts to multicast group
- o no network-layer identification to hosts of the members

o Needed: infrastructure to deliver mcast-addressed datagrams to all hosts that have joined that multicast group

Joining a mcast group: two-step process

o Local: host informs local mcast router of a desire to join group:

  o IGMP (Internet Group Management Protocol)

o Wide area: local router interacts with other routers to receive mcast datagram flow

  o many protocols (e.g., DVMRP, MOSPF, PIM)
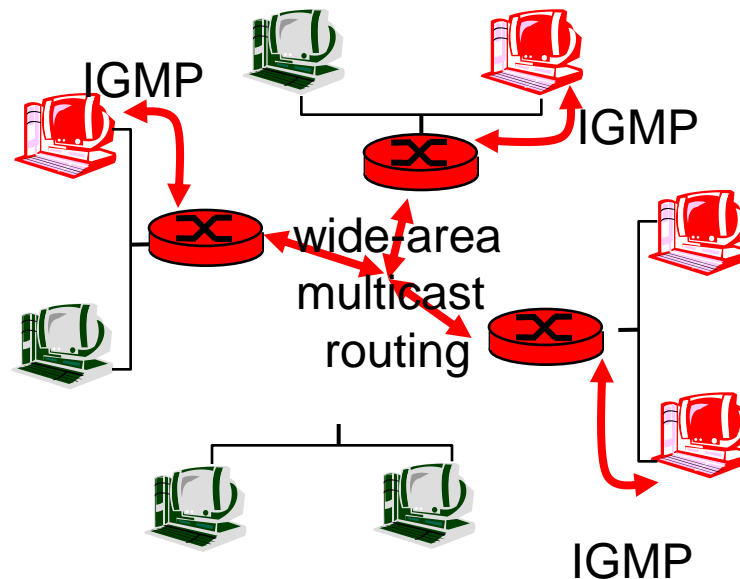
IGMP: Internet Group Management Protocol

o Host: sends IGMP report when application joins mcast group

  o IP_ADD_MEMBERSHIP socket option

  o host needs not explicitly "disjoin" group when leaving

o Router: sends IGMP query at regular intervals

  o host belonging to a mcast group must reply to query

query   report
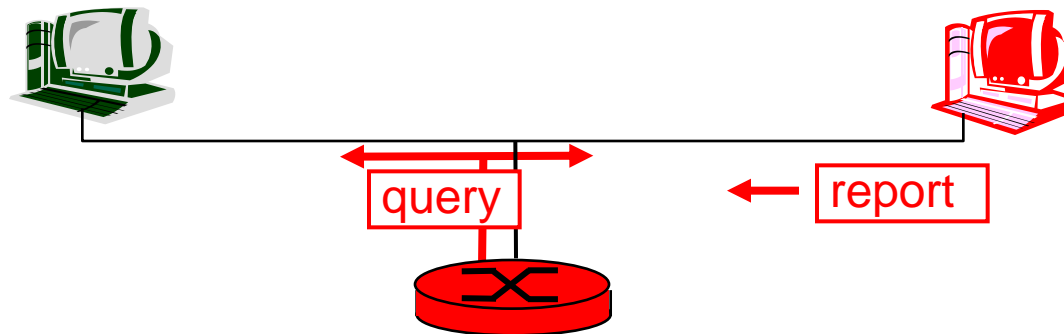
Internet Multicasting Routing: DVMRP

o DVMRP: distance vector multicast routing protocol, RFC1075

o flood and prune: reverse path forwarding, source-based tree

- o RPF tree based on DVMRP's own routing tables constructed by communicating DVMRP routers

- o no assumptions about underlying unicast

- o initial datagram to mcast group flooded everywhere via RPF

- o routers not wanting group: send upstream prune msgs

DVMRP: continued…

o soft state: DVMRP router periodically (1 min.) "forgets" branches are pruned:

  o mcast data again flows down unpruned branch

  o downstream router: reprune or else continue to receive data

o routers can quickly regraft to tree

  o following IGMP join at leaf

o odds and ends

  o commonly implemented in commercial routers

  o Mbone routing done using DVMRP

Tunneling

○ Q: How to connect "islands" of multicast routers in a "sea" of unicast routers?
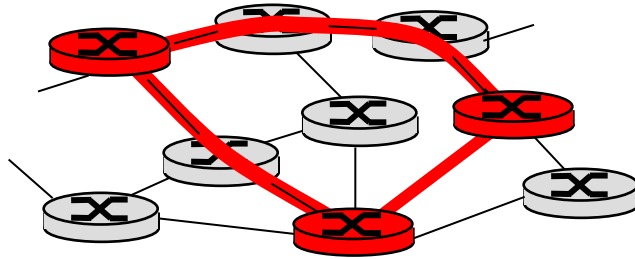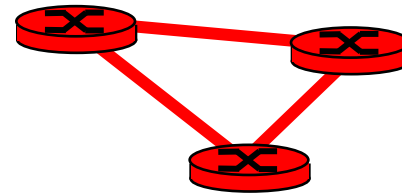
physical topology   logical topology

○ mcast datagram encapsulated inside "normal" (non-multicast-addressed) datagram

○ normal IP datagram sent through "tunnel" via regular IP unicast to receiving mcast router

○ receiving mcast router de-capsulates pkt to get mcast datagram

PIM: Protocol Independent Multicast

○ not dependent on any specific underlying unicast routing algorithm (works with all)

○ two different multicast distribution scenarios :

  ○ Dense:

    • group members densely packed, in "close" proximity.
    • bandwidth more plentiful

  ○ Sparse:

    • # networks with group members small wrt # interconnected networks
    • group members "widely dispersed"
    • bandwidth not plentiful

Consequences of Sparse-Dense Dichotomy

o Dense

- o group membership by routers assumed until routers explicitly prune
- o data-driven construction on mcast tree (e.g., RPF)
- o bandwidth and non-group-router processing profligate

o Sparse

- o no membership until routers explicitly join
- o receiver- driven construction of mcast tree (e.g., center-based)
- o bandwidth and non-group-router processing conservative

PIM- Dense Mode

o Flood-and-prune RPF, similar to DVMRP but

  o underlying unicast protocol provides RPF info for incoming datagram

  o less complicated (less efficient) downstream flood than DVMRP reduces reliance on underlying routing algorithm

  o has protocol mechanism for router to detect it is a leaf-node router

PIM - Sparse Mode

o center-based approach

o router sends *join* msg to rendezvous point (RP)

   o intermediate routers update state and forward *join*

o after joining via RP, router can switch to source-specific tree

   o increased performance: less concentration, shorter paths

all data multicast from rendezvous point

rendezvous point
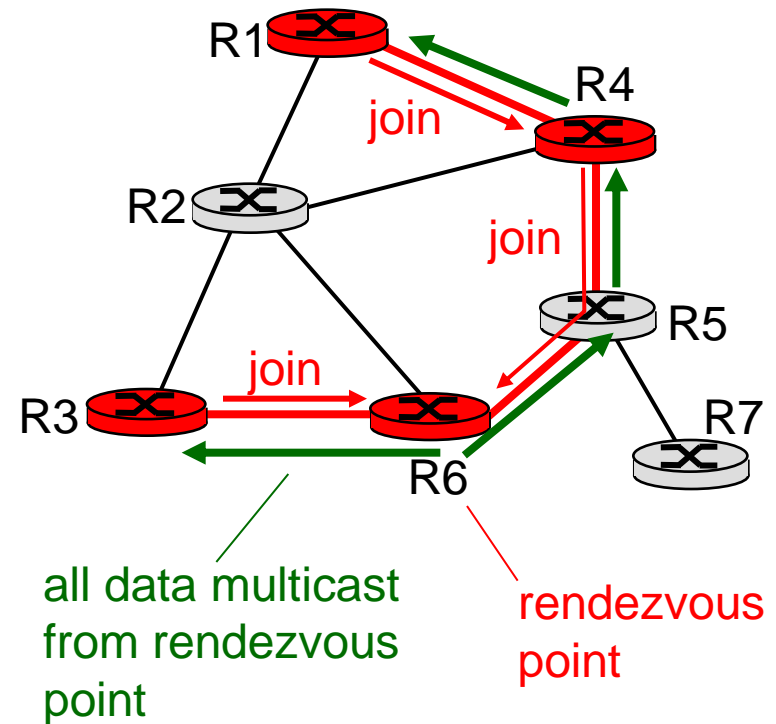
PIM - Sparse Mode

sender(s):

- unicast data to RP, which distributes down RP-rooted tree

- RP can extend mcast tree upstream to source

- RP can send *stop* msg if no attached receivers
  - "no one is listening!"
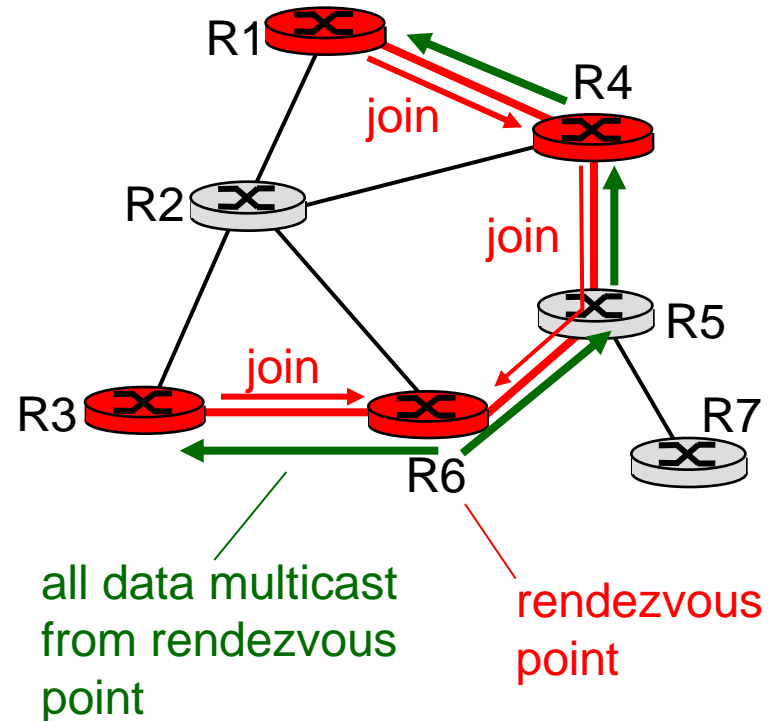
R1

R4

join

R2

join

R5

R3   join

R7

R6

all data multicast from rendezvous point

rendezvous point

Network Layer II

o 4.6 Multicast

   o Broadcast routing

   o Multicast routing

   o Multicast routing protocols

o 4.7 Mobility

   o What is Mobility?

   o Network layer mobility concepts and principles

   o Mobile IP

What is mobility?

o spectrum of mobility, from the *network* perspective:

no mobility   high mobility

mobile wireless user, using same access point

mobile user, connecting/ disconnecting from network using DHCP.

mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

Mobility: Vocabulary

home network: permanent "home" of mobile
(e.g., 128.119.40/24)

home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote

Permanent address: address in home network, *can always* be used to reach mobile
e.g., 128.119.40.186

wide area network
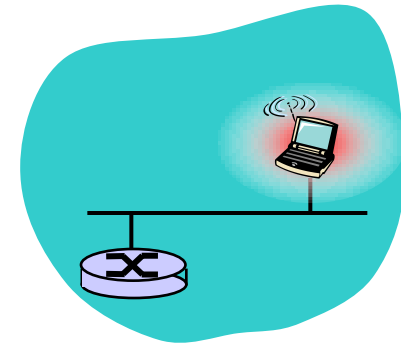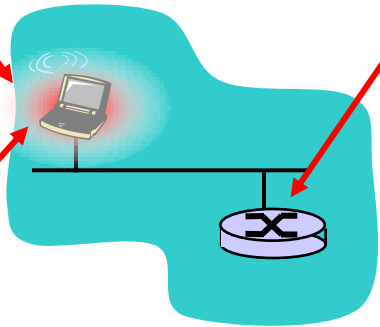
correspondent

Mobility: more vocabulary

visited network: network in which mobile currently resides (e.g., 79.129.13/24)

Permanent address: remains constant (e.g., 128.119.40.186)

Care-of-address: address in visited network.
(e.g., 79,129.13.2)

wide area network

foreign agent: entity in visited network that performs mobility functions on behalf of mobile.
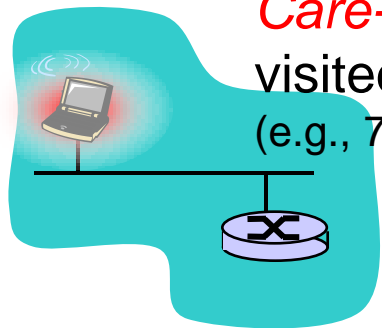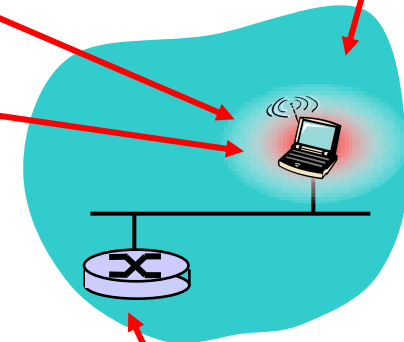
correspondent: wants to communicate with mobile

How do *you* contact a mobile friend:

Consider friend frequently changing addresses, how do you find her?

- search all phone books?
- call her parents?
- expect her to let you know where he/she is?
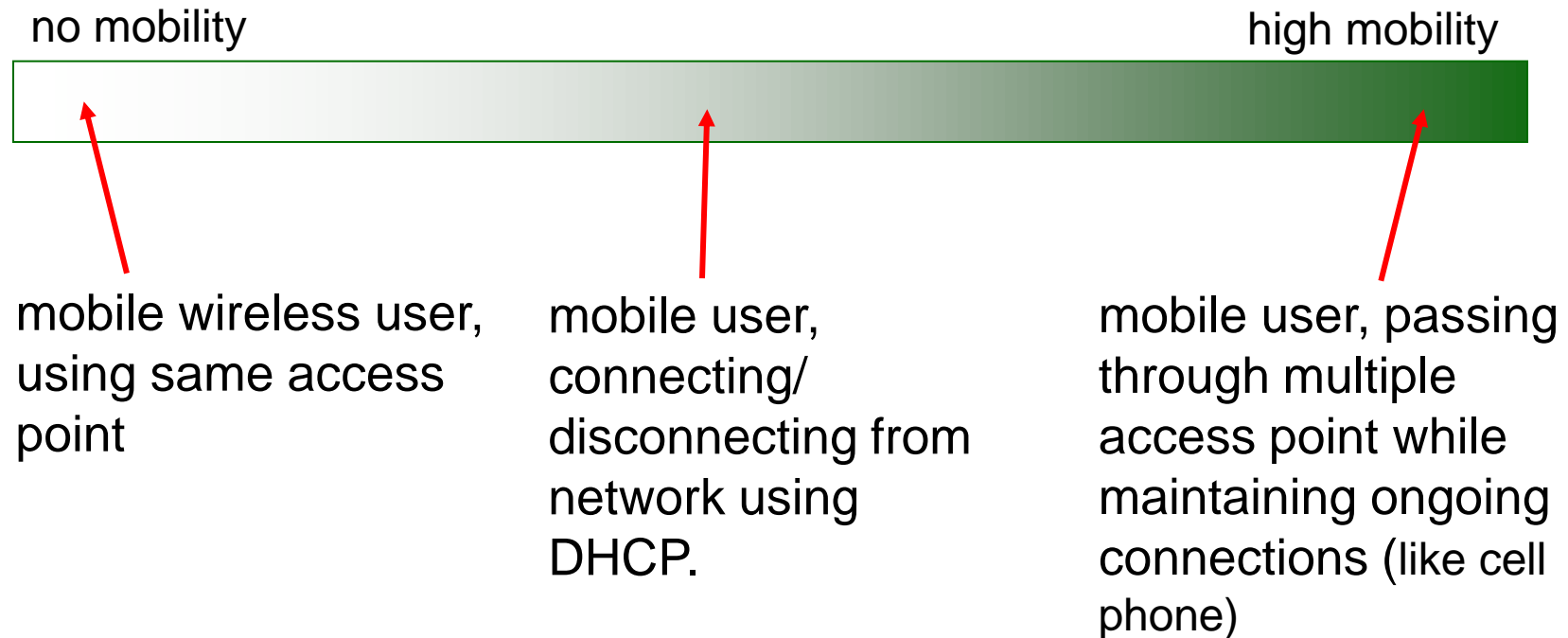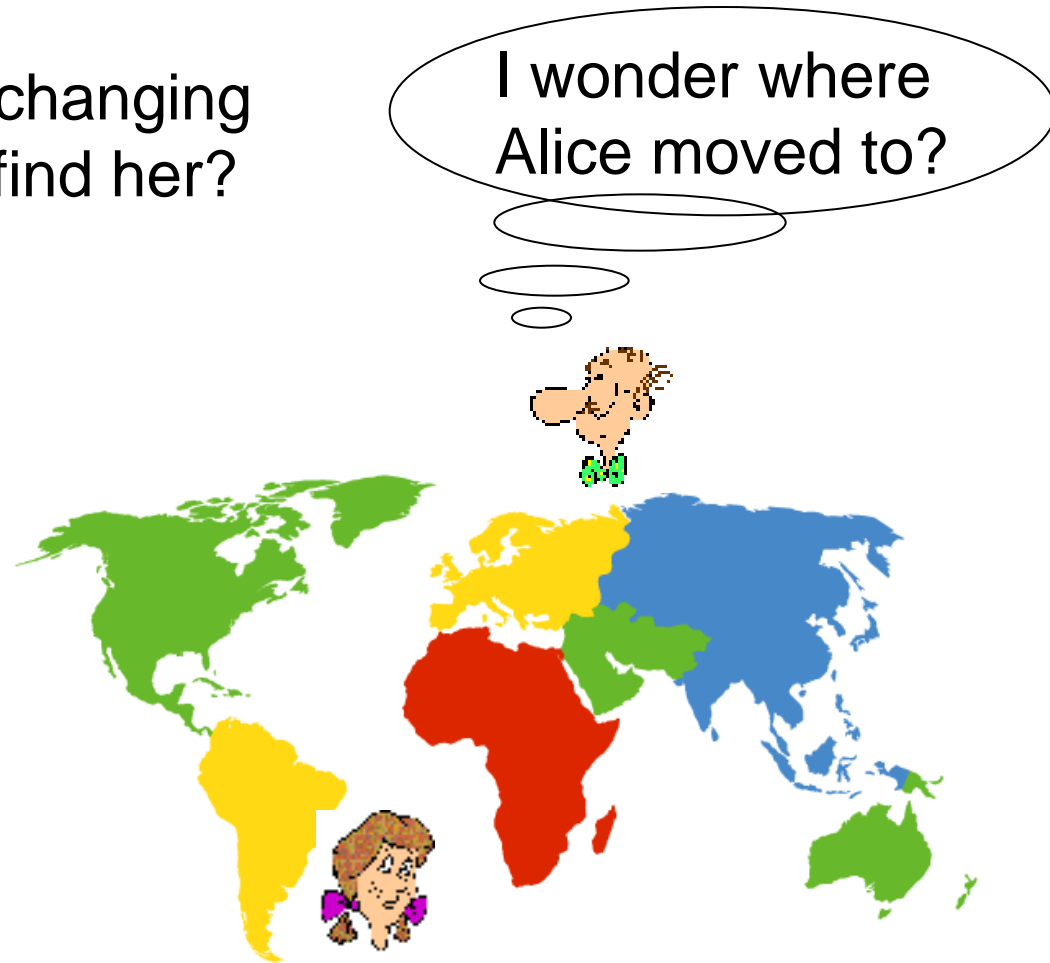
I wonder where Alice moved to?

Network Layer II

o 4.6 Multicast

- o Broadcast routing
- o Multicast routing
- o Multicast routing protocols

o 4.7 Mobility

- o What is Mobility?
- o Network layer mobility concepts and principles
- o Mobile IP

Mobility: approaches

o Let routing handle it

- o routers advertise permanent address of mobile-nodes via usual routing table exchange.

- o routing tables indicate where each mobile located

- o no changes to end-systems

- o does not scale well!

Mobility: approaches

○ Let end-systems handle it

 ○ Indirect routing: communication from correspondent to mobile goes through home agent, then forwarded to remote

 ○ Direct routing: correspondent gets foreign address of mobile, sends directly to mobile

Mobility: registration

visited network

home network

wide-area network

2

1

foreign agent contacts home agent home: "this mobile is resident in my network"

mobile contacts foreign agent on entering visited network
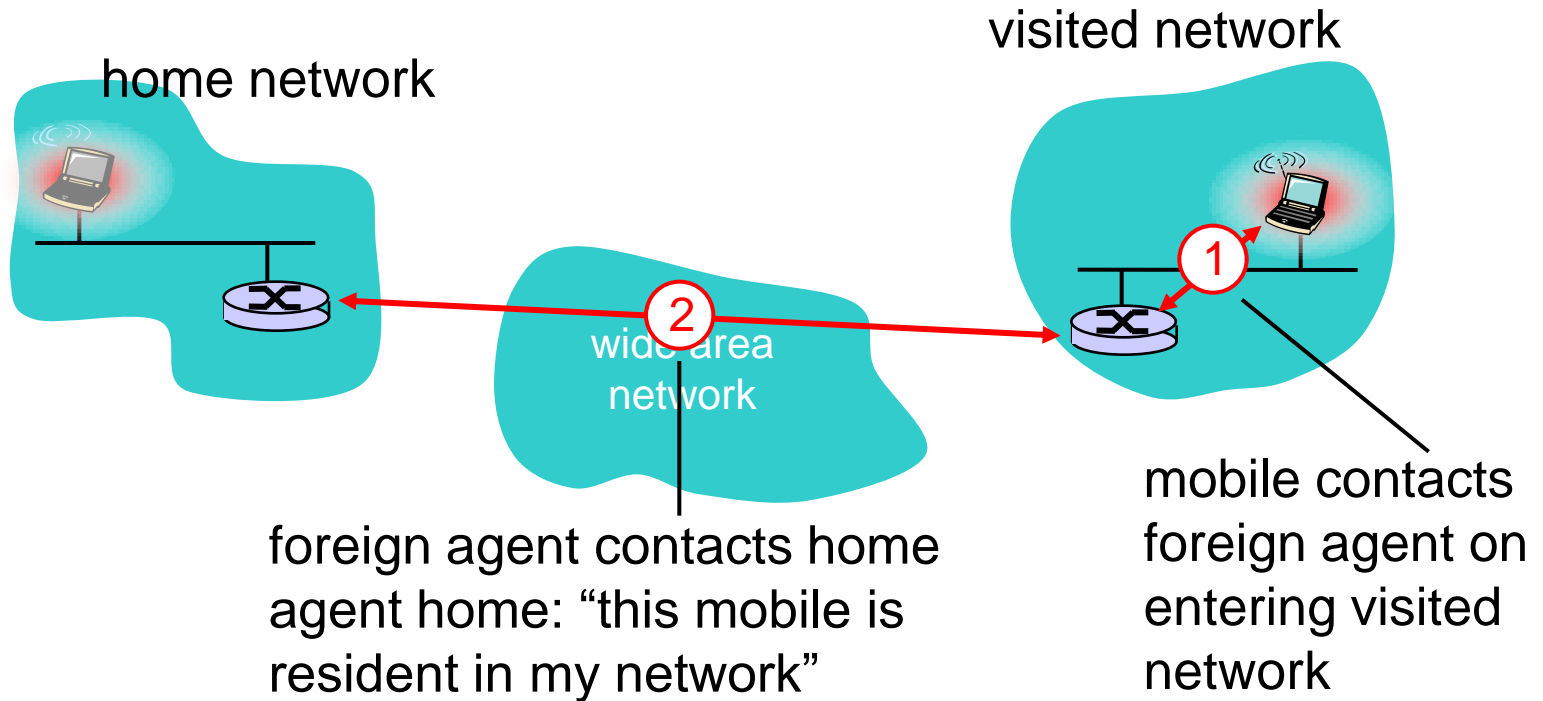
End result:

o Foreign agent knows about mobile

o Home agent knows location of mobile

Mobility via Indirect Routing

home agent intercepts packets, forwards to foreign agent

foreign agent receives packets, forwards to mobile

visited network

home network

wide area network

correspondent addresses packets using home address of mobile

mobile replies directly to correspondent

(1) (2) (3) (4)
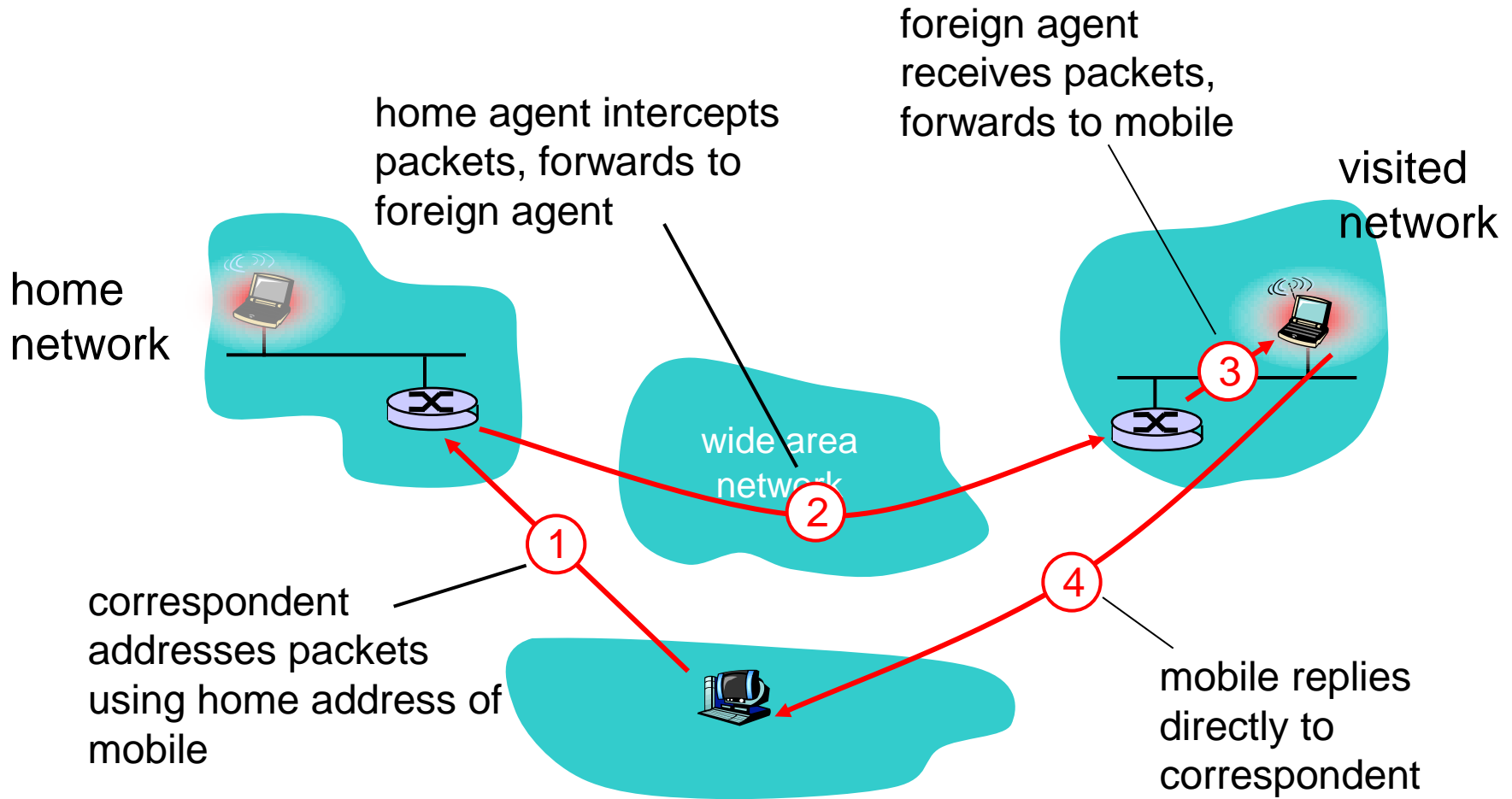
Indirect Routing: comments

o Mobile uses two addresses:

  o permanent address: used by correspondent (hence mobile location is *transparent* to correspondent)

  o care-of-address: used by home agent to forward datagrams to mobile

o foreign agent functions may be done by mobile itself

o triangle routing: correspondent-home-network-mobile

  o inefficient when correspondent, mobile are in same network
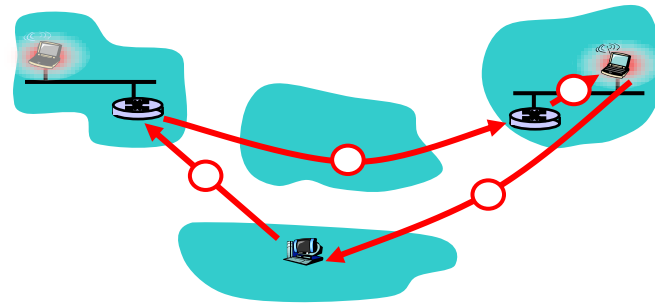
Indirect Routing: moving between networks

○ suppose mobile user moves to another network

○ registers with new foreign agent

○ new foreign agent registers with home agent

○ home agent update care-of-address for mobile

○ packets continue to be forwarded to mobile (but with new care-of-address)

○ mobility, changing foreign networks transparent: *ongoing connections can be maintained!*

Mobility via Direct Routing

foreign agent
receives packets,
forwards to mobile

correspondent forwards
to foreign agent

visited
network

home
network

wide area
network

(2)

(1)

(3)

(4)

(4)

correspondent
requests, receives
foreign address of
mobile

mobile replies
directly to
correspondent
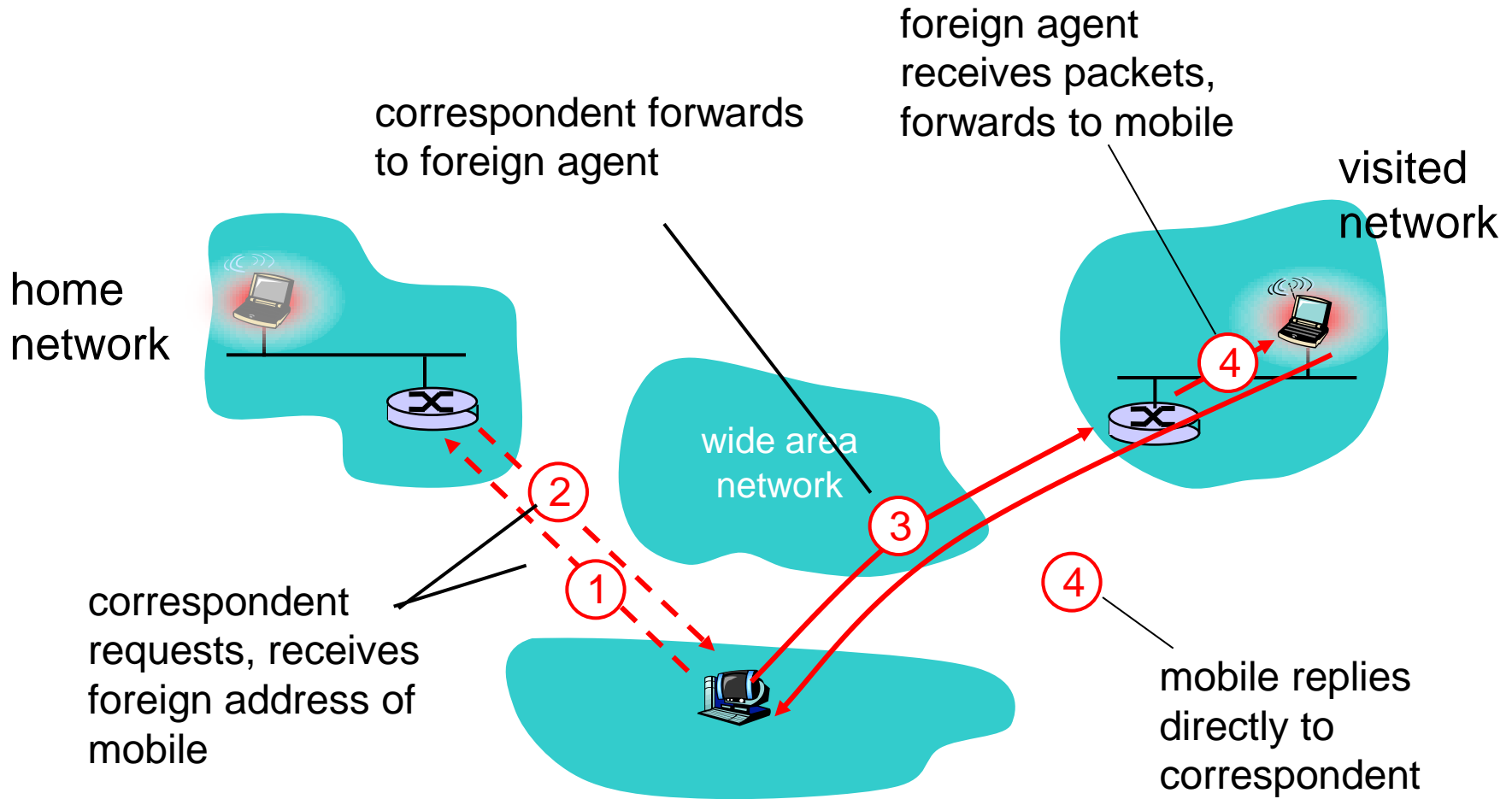
Mobility via Direct Routing: comments

o overcome triangle routing problem

o non-transparent to correspondent: correspondent must get care-of-address from home agent

   o what if mobile changes visited network?
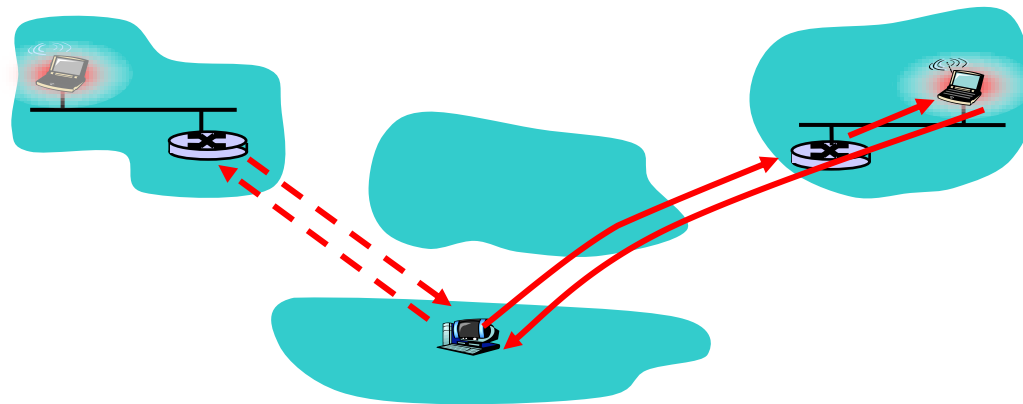
Accommodating mobility with direct routing

o anchor foreign agent: FA in first visited network

o data always routed first to anchor FA

o when mobile moves: new FA arranges to have data forwarded from old FA (chaining)
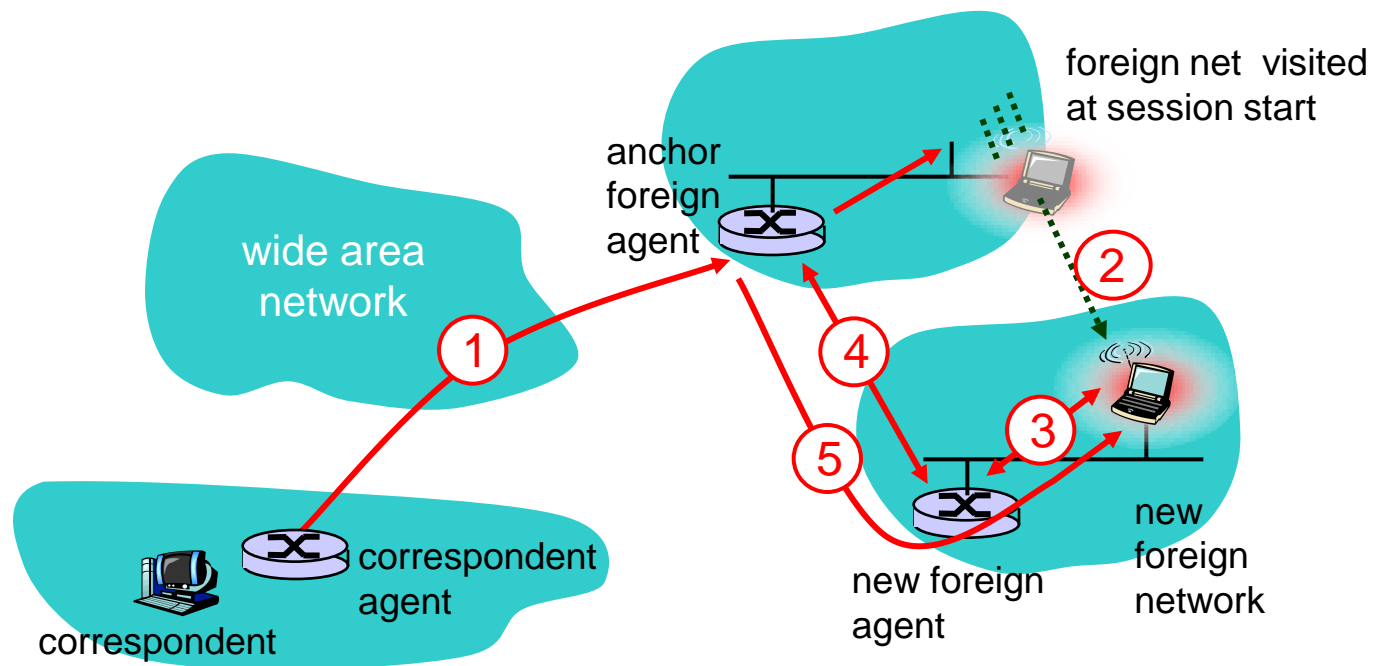
foreign net visited at session start

anchor foreign agent

wide area network

1

2

4

5

3

correspondent agent

correspondent

new foreign agent

new foreign network

Network Layer II

o 4.6 Multicast

- o Broadcast routing

- o Multicast routing

- o Multicast routing protocols

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Mobile IP

o RFC 3344

o has many features we've seen:

   o home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)

o three components to standard:

   o indirect routing of datagrams

   o agent discovery

   o registration with home agent

Mobile IP: indirect routing

foreign-agent-to-mobile packet

dest: 128.119.40.186	

packet sent by home agent to foreign agent: a *packet within a packet*

dest: 79.129.13.2	dest: 128.119.40.186	

Permanent address:
128.119.40.186

Care-of address:
79.129.13.2

dest: 128.119.40.186	

packet sent by correspondent
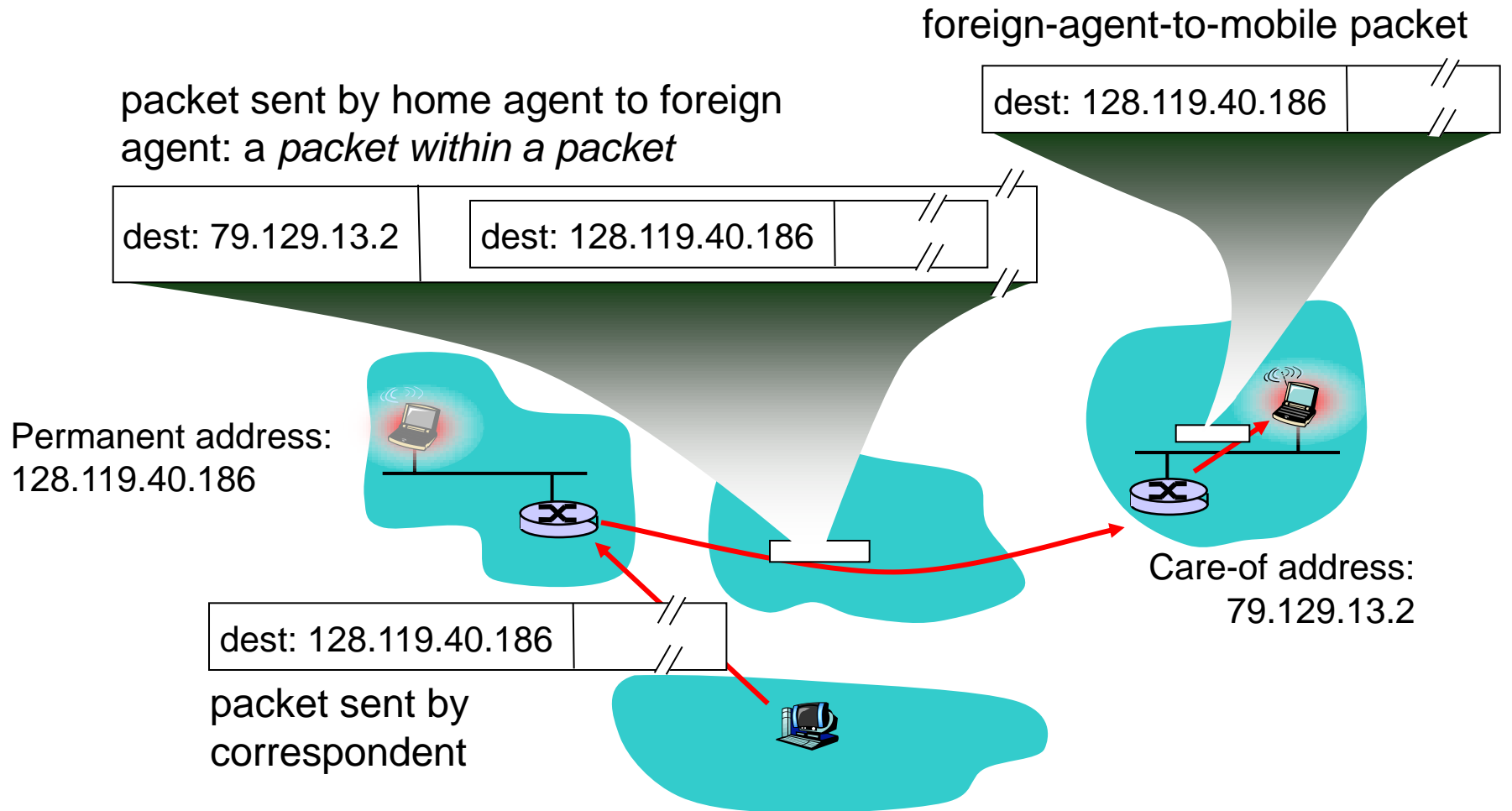
Mobile IP: agent discovery

o agent advertisement: foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9)

H,F bits: home and/or foreign agent

R bit: registration required

0	8	16	24
type = 9	code = 0	checksum	
router address			
type = 16	length	sequence #	
registration lifetime		RBHFMGV bits	reserved
0 or more care-of-addresses			

standard ICMP fields

mobility agent advertisement extension
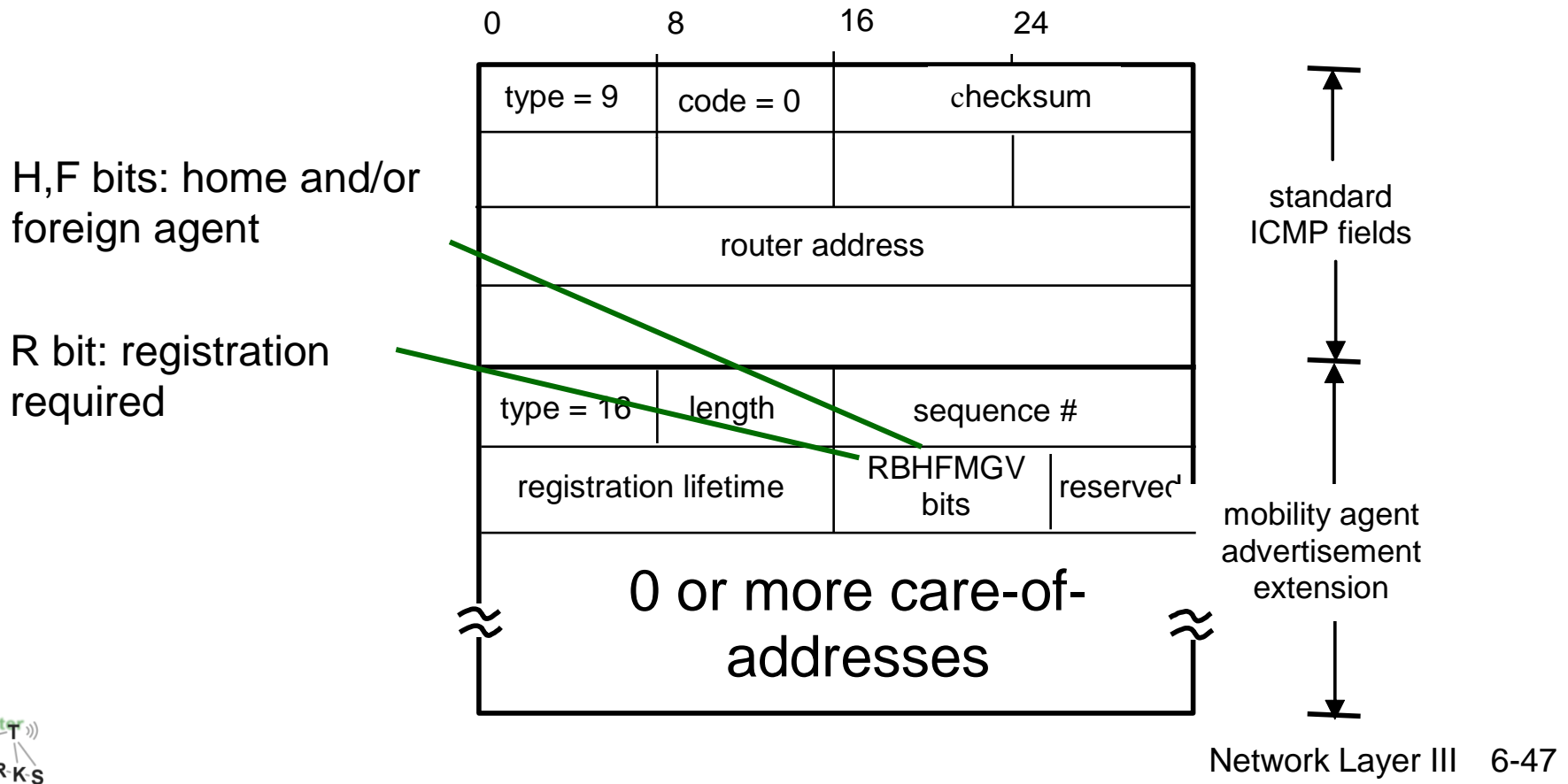
Mobile IP: registration example

visited network: 79.129.13/24

home agent
HA: 128.119.40.7

foreign agent
COA: 79.129.13.2

ICMP agent adv.

```
COA: 79.129.13.2
….
```

Mobile agent
MA: 128.119.40.186

registration req.

```
COA: 79.129.13.2
HA: 128.119.40.7
MA: 128.119.40.186
Lifetime: 9999
identification:714
….
```

registration req.

```
COA: 79.129.13.2
HA: 128.119.40.7
MA: 128.119.40.186
Lifetime: 9999
identification: 714
encapsulation format
….
```

time

registration reply

```
HA: 128.119.40.7
MA: 128.119.40.186
Lifetime: 4999
Identification: 714
encapsulation format
….
```

registration reply

```
HA: 128.119.40.7
MA: 128.119.40.186
Lifetime: 4999
Identification: 714
….
```