CSc 450/550
Computer Networks
Interworking

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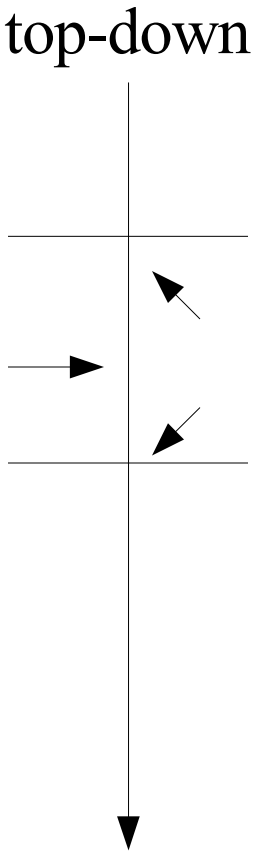
Review: protocols

- Application layer
  - HTTP, DNS
- Transport layer
  - TCP, UDP
- Network layer
  - IP/ICMP; RIP, OSPF, BGP
- Link layer
  - IEEE 802.3, IEEE 802.11



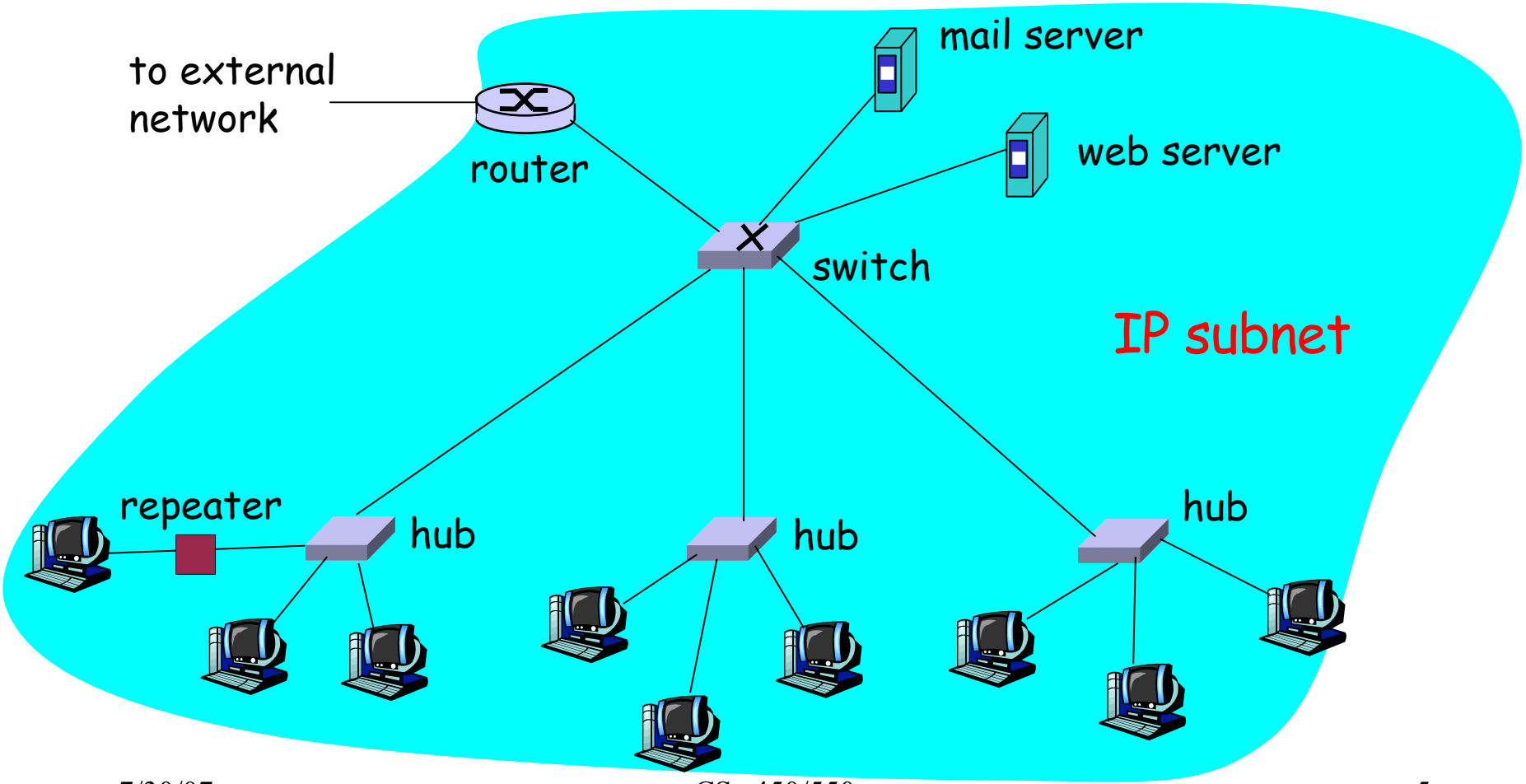
Review: mechanisms, algorithms

- HTTP, DNS
  - client-server, request/reply, (non)persistence, pipelining
  - domain hierarchy, recursive/iterative queries
- TCP, UDP, IP, DLC
  - connection management, flow/error/congestion control
- Routing
  - distance vector, link state, path vector
- Media access control
  - Aloha, slotted Aloha, 1/p/non-persistent CSMA, CSMA/CD, CSMA/CA, RTS/CTS

Today's topics

- Interworking
  - now a “bottom-up” approach
  - devices
    - repeater, hub, switch, router, gateway
  - protocols
    - ARP: address resolution protocol

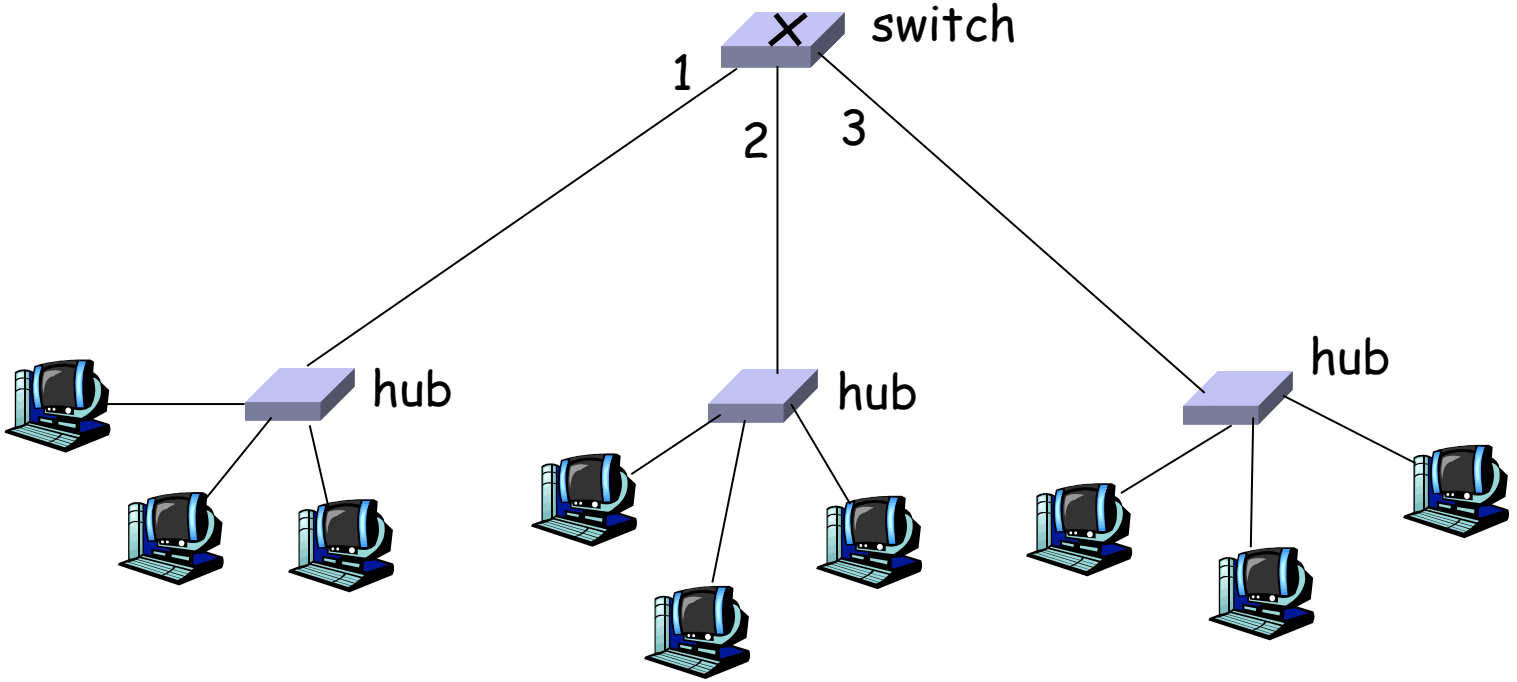
Example network



Interworking

- Repeater: signal regenerators
- Hub
  - Layer 1 device: forward from one link to all others
  - larger collision domain
- Switch
  - Layer 2 device, selective forward, self-learning
  - transparent to end hosts
- Router: Layer 3 device, routing involved
- Gateway: higher-layer protocol specific

Forwarding



- How do determine onto which LAN segment to forward a frame?
- Looks like a routing problem...

Self learning

- A switch has a switch table, which is built automatically, dynamically, and autonomously—without any intervention from a network admin
- entry in switch table:
  - (MAC Address, Interface, Time Stamp)--Interface leads to the MAC Address
  - stale entries in table dropped (TTL can be 60 min)
- switch *learns* which hosts can be reached through which interfaces
  - when a frame is received, switch "learns" location of sender/source: incoming LAN segment
  - records sender/location pair in switch table

Filtering/Forwarding

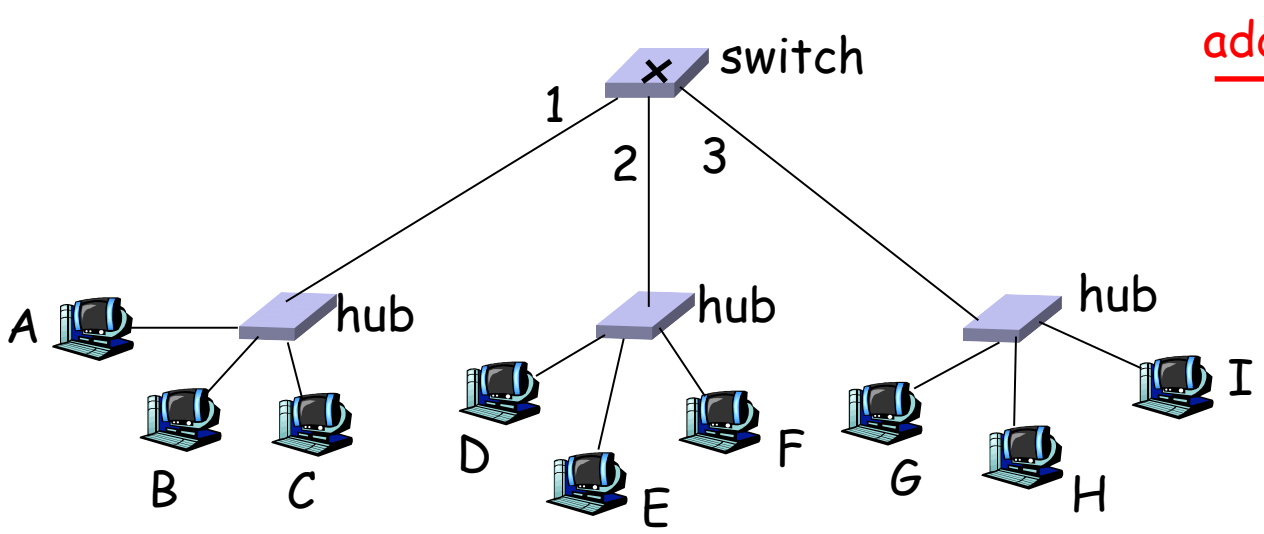
When switch receives a frame:

index switch table using MAC dest address
if entry found for MAC destination
then{
    if dest on segment is where the frame is from
    then drop the frame -- filtering
    else forward the frame on interface indicated
}
else flood

forward on all but the interface on which the frame arrived

Switch example

Suppose C sends a frame to D

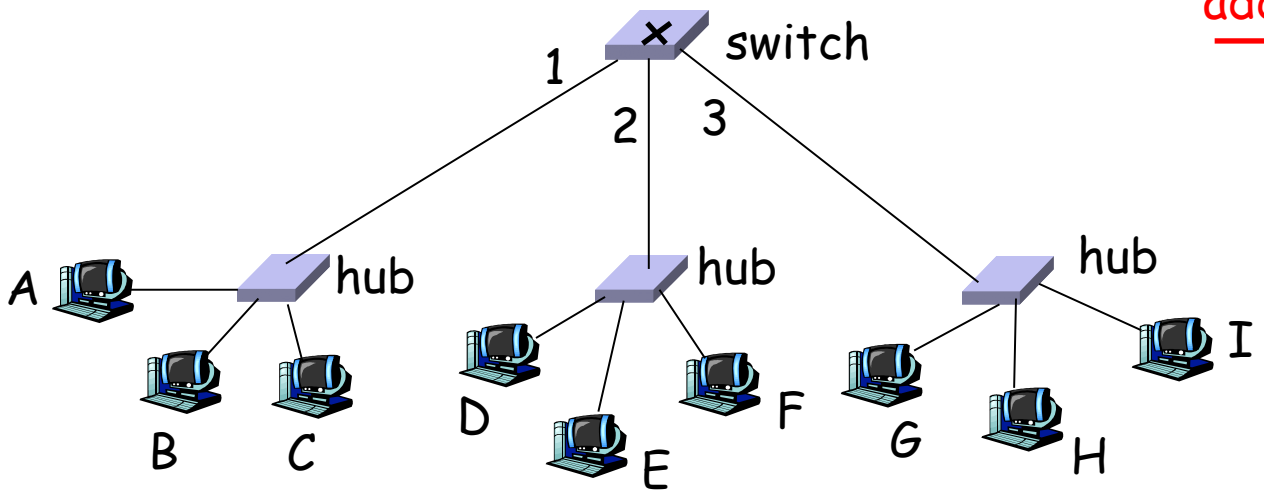


address	interface
A	1
B	1
E	2
G	3

- Switch receives frame from C
  - notes in switch table that C is on interface 1
  - because D is not in table, switch forwards frame into interfaces 2 and 3--flooding
- frame received by D

Switch example

Suppose D replies back with frame to C.

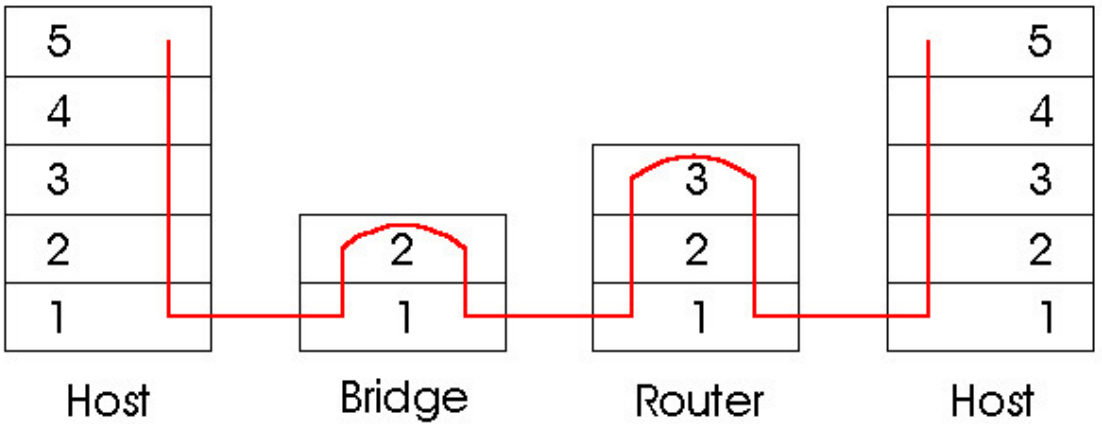


address	interface
A	1
B	1
E	2
G	3
C	1

- Switch receives frame from D
  - notes in switch table that D is on interface 2
  - because C is in table, switch forwards frame only to interface 1
- frame received by C

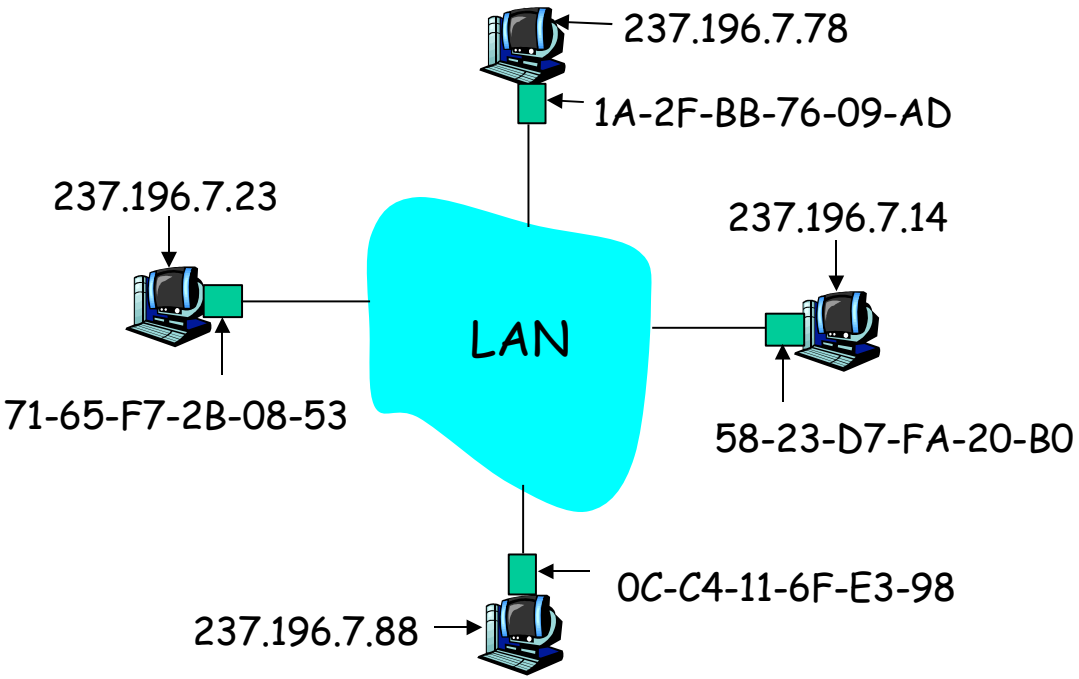
Switches vs. Routers

- both store-and-forward devices
  - routers: network layer devices (examine network layer headers)
  - switches are link layer devices
- routers maintain forwarding/routing tables, implement routing algorithms
- switches maintain switch tables, implement filtering, learning algorithms



ARP: Address Resolution Protocol

Question: how to determine MAC address of B knowing B's IP address?



- Each IP node (Host, Router) on LAN has ARP table
- ARP Table: IP/MAC address mappings for some LAN nodes

  < IP address; MAC address; TTL>

  - TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

ARP protocol: Same LAN (network)

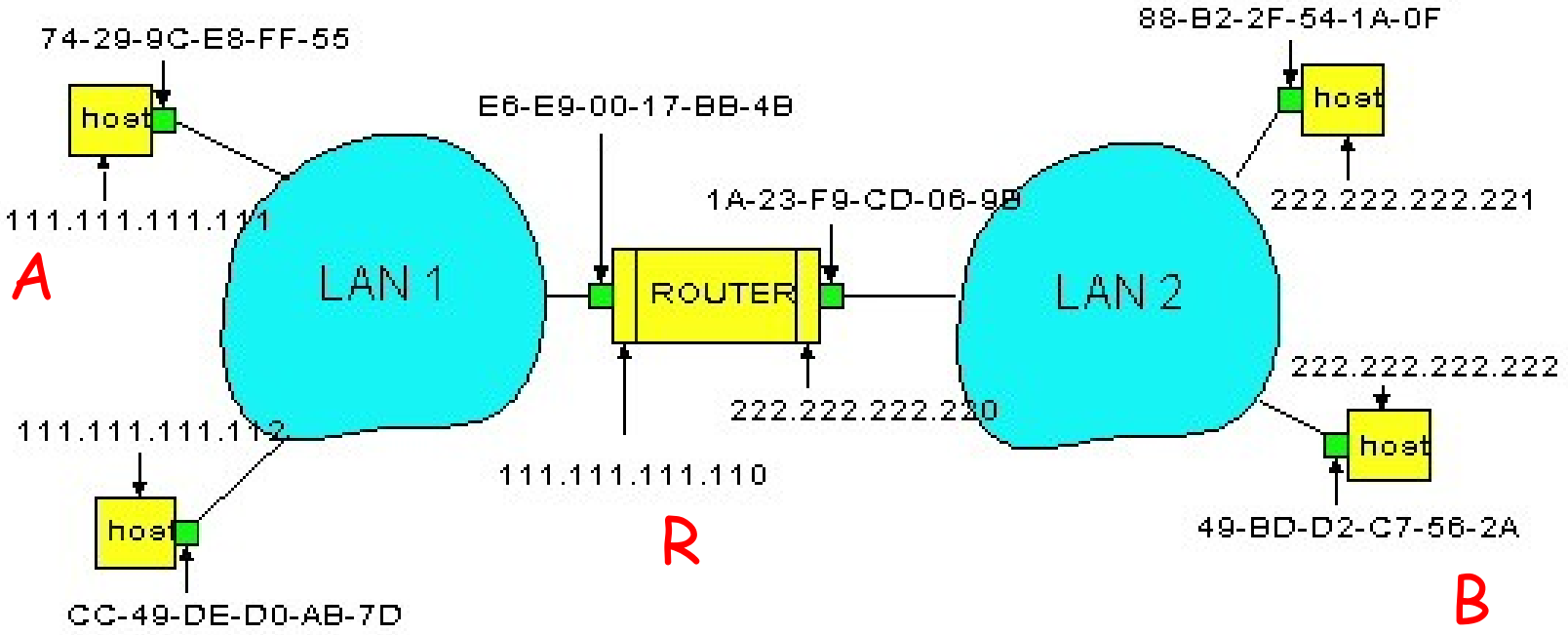
- **A** wants to send datagram to **B**, and **B**'s MAC address not in A's ARP table.
- **A** broadcasts ARP query packet, containing **B**'s IP address
  - Dest MAC address = FF-FF-FF-FF-FF-FF
  - all machines on LAN receive ARP query
- **B** receives ARP packet, replies to **A** with its (**B**'s) MAC address
  - frame sent to A's MAC address (**unicast**)

- **A** caches (saves) IP-to-MAC address pair in its ARP table until information becomes old (times out)
  - soft state: information that times out (goes away) unless refreshed
- ARP is "plug-and-play":
  - nodes create their ARP tables without intervention from net administrator

Routing to another LAN

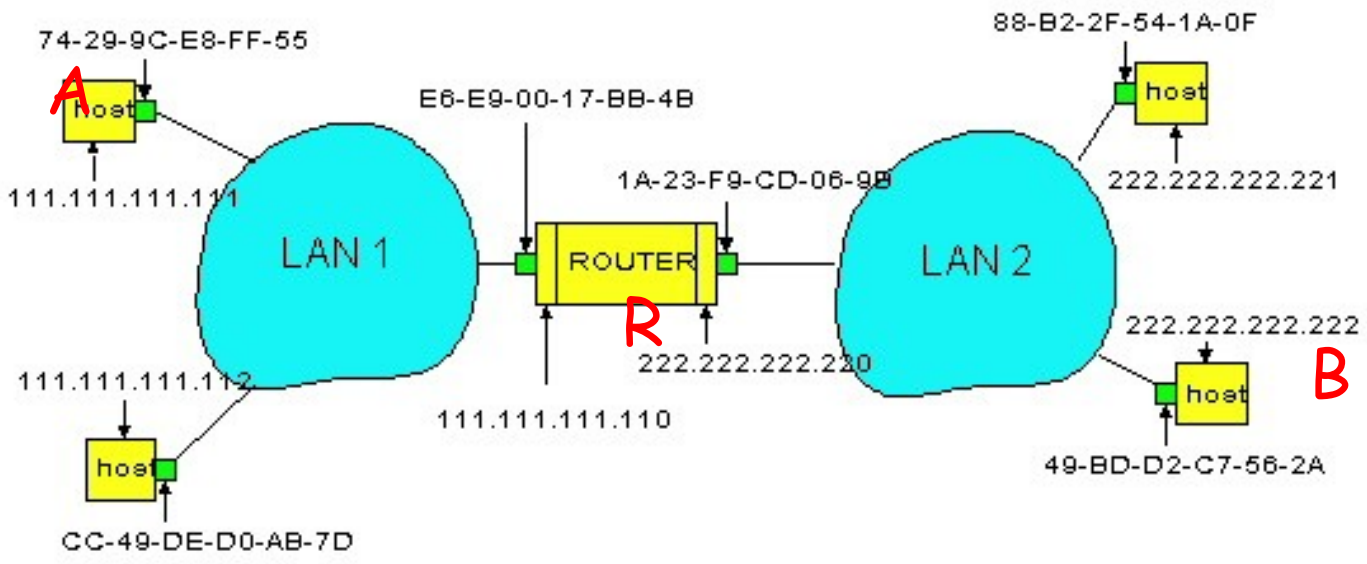
walkthrough: send datagram from A to B via R

assume **A** knows **B** IP address



- Two ARP tables in router **R**, one for each IP network (LAN)

- A creates datagram with source A, destination B
- A uses ARP to get R's MAC address for 111.111.111.110
- A creates link-layer frame with R's MAC address as dest, frame contains A-to-B IP datagram
- A's adapter sends frame
- R's adapter receives frame
- R removes IP datagram from Ethernet frame, sees its destined to B, and then forward the datagram from 111.111.111.110 to 222.222.222.220 (forwarding table).
- R uses ARP to get B's MAC address
- R creates frame containing A-to-B IP datagram sends to B



This lecture

- Interworking
  - devices
    - repeater, hub, switch, router, gateway
  - protocols
    - ARP
- Explore further
  - *new*! CSC463: Wireless and Mobile Networks
  - *new*! CSC466: Advanced Computer Networks
  - *new*! CSC467: Advanced Communications Networks

One more message...

- Research opportunities for undergraduates
  - NSERC USRA
  - MITACS internship, on-campus coop
  - directed studies, technical projects
- Graduate study at UVic
  - UVic CS: systems, theory, applications
  - UVic ECE: communications networks, ...
  - financial support
    - NSERC CGS/PGS, BC Pacific Century, UVic Fellowship
    - research and teaching assistantship, coop

Thanks to our TAs

- TAs done a good job?
  - Deer (Dale) Li: lead lab instructor (afternoon)
  - Ming Lu: lab instructor (morning), marker
- Nominate them for the TA award!
  - Andy Farquharson Award for Excellence in Graduate Student Teaching
  - http://ltc.uvic.ca/servicesprograms/tacorner/taawards/TA_awards.php
- Also thanks to our lab support staff
  - Tomas Bednar, Victoria Li, Bill Gorman

Next lecture

- August 2: 3rd in-class midterm exam
  - extra before-exam office hours: August 1
  - regular office hours: MR 10:30-11:30am