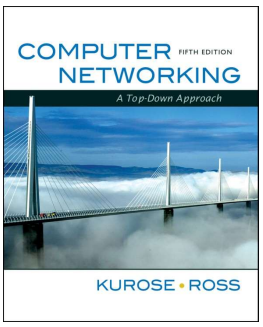
RSC
Part II: Network Layer
4. IPv4 in operation



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These slides are, mainly, part of the companion slides to the book "Computer Networking: A Top Down Approach" generously made available by their authors (see copyright below). The slides have been adapted, where required, to the teaching needs of the subject above.

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Computer Networking: A Top Down Approach 5th edition. Jim Kurose, Keith Ross Addison-Wesley, April 2009.

RSC Part II: Network Layer

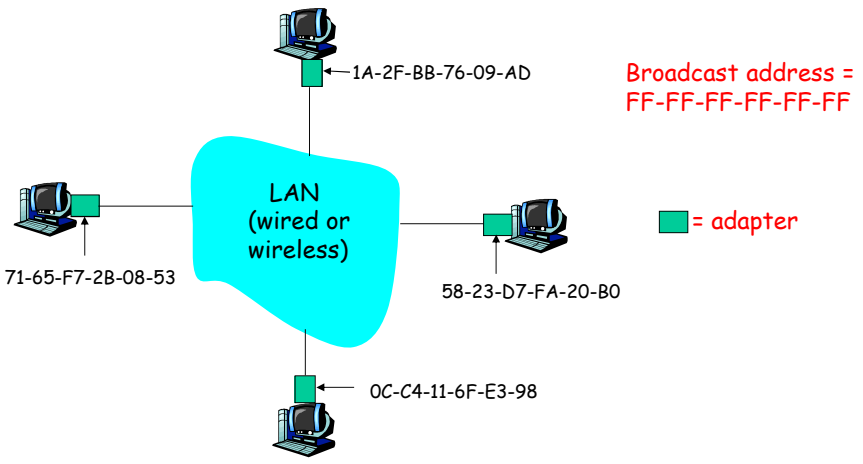
- II. 1 Basic Network layer concepts
- II.2 Introduction to IPv4
- II.3 IPv4 addressing
- II.4 IPv4 in operation
  - ARP
- II.5 IPv6
- II.6 Network routing
  - Link state
  - Distance Vector
  - Hierarchical routing
- II.7 Routing in the Internet
  - RIP

MAC Addresses and ARP

- 32-bit IPv4 address:
  - *network-layer* address
  - used to get datagram to destination IP subnet
- MAC (or LAN or physical or Ethernet) address:
  - function: *get frame from one interface to another physically-connected interface (same network)*
  - 48 bit MAC address (for most LANs)
    - burned in NIC ROM, also sometimes software settable

LAN Addresses and ARP

Each adapter on LAN has unique LAN address

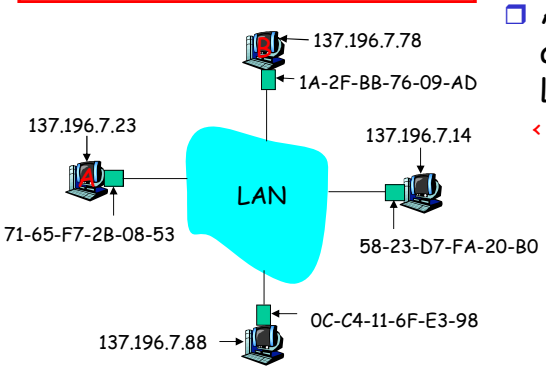


LAN Address (more)

- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- analogy:
  - (a) MAC address: like Social Security Number
  - (b) IP address: like postal address
- MAC flat address ➜ portability
  - can move LAN card from one LAN to another
- IP hierarchical address NOT portable
  - address depends on IP subnet to which node is attached

ARP: Address Resolution Protocol

Question: how to determine MAC address of B knowing B's IPv4 address?



- Each IPv4 node (host, router) on LAN has ARP table
- ARP table: IPv4/MAC address mappings for some LAN nodes

  < IPv4 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: 193.196.7.23; B: 193.196.7.78; Subnet: 193.196.7.0
- A wants to send a datagram to B, B is in the same IP sub-network as A (as learned in A's routing table), 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

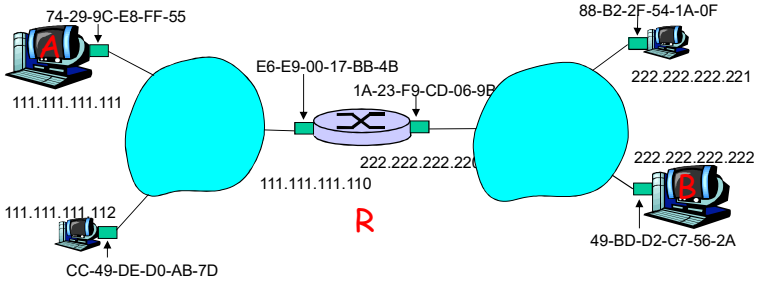
Forwarding table in A:

Network	Mask	Gateway	Interface
193.196.7.0	255.255.255.0		193.196.7.23

Addressing: routing to another LAN

walkthrough: send datagram from A to B via R

assume A knows B's IPv4 address

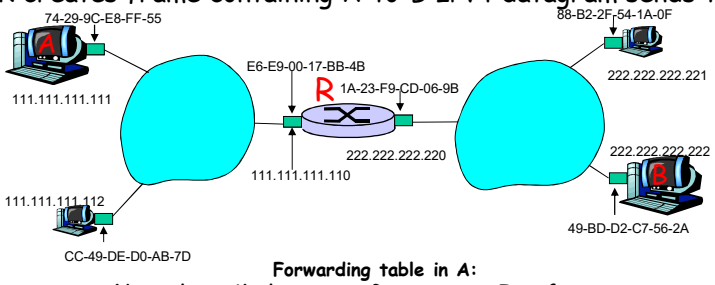


- two ARP tables in router R, one for each IPv4 network (LAN)
- Forwarding table in A:

Network	Mask	Gateway	Interface
111.111.111.0	255.255.255.0		111.111.111.111
0.0.0.0	0.0.0.0	111.111.111.110	111.111.111.111

- A creates IPv4 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 IPv4 datagram
- A's NIC sends frame
- R's NIC receives frame
- R removes IPv4 datagram from Ethernet frame, sees its destined to B
- R uses ARP to get B's MAC address
- R creates frame containing A-to-B IPv4 datagram sends to B

This is a really important example – make sure you understand!



Forwarding table in A:

Network	Mask	Gateway	Interface
111.111.111.0	255.255.255.0		111.111.111.111
0.0.0.0	0.0.0.0	111.111.111.110	111.111.111.111