Address Resolution Protocol (ARP)

- Question: how do packets actually get to their destination?
- IP routing tables: based on network addresses
- Ethernet physical interfaces only understand ethernet addresses
- So, how do packets actually reach their destination?
Address Mappings

- Each host keeps a mapping table:
  - IP address <-> physical network address

- When a machine on a physical network wants to reach another host on the same physical network (either first-hop router, or another host), it consults this table

- How is this table maintained?
When the table doesn’t have the required mapping, the host broadcasts a message (to the physical net) asking: who has this IP address?

- The appropriate host responds with its physical address (and inserts the requester in its table)

- All others listening who have either host in their table refresh their entries
Assumptions in ARP

- Assumes that physical network can broadcast

- Not always true: e.g., ATM

- Must find methods for these networks
  - (e.g., ATMARP)
Host Configuration

- How does a host know its IP address?

- Manually configured:
  - time consuming
  - doesn’t work for transient hosts

- Dynamic Host Configuration Protocol (DHCP)
  - much easier to administer
  - allows transient hosts to automatically configure themselves
DHCP

- New host broadcasts DHCPDiscover message
  - Using IP broadcast

- If DHCP server is local, it responds

- If no DHCP server is local, there is a DHCP relay agent which forwards DHCPDiscover messages to DHCP server

- DHCP server gives IP address (and other info)
Methods of Address Assignment

- Have DHCP database that matches MAC address with IP address

- Freely assign IP addresses from pool
Internet Control Message Protocol

- ICMP provides for a variety of control messages
  - host unreachable
  - reassembly process failed
  - TTL reached 0
  - IP header checksum failed
  - ICMP redirect
Final exam logistics

- Final exam: 12/21, 10:30-12:30AM
- Calculator, 1 page of notes allowed
- No computers
- Early exam: 12/20, please contact me
Course Summary

What have we learned: a huge amount!
- principles
- practice
….. using Internet to motivate examples
What did we do?

Introduction
- What is the Internet, protocol?
- network edge, core, access nets
- physical media
- delay, loss
- layers, service models
- Internet backbones, NAPs, ISPs
- history

Application Layer
- application-layer protocols
- the WWW: HTTP
- FTP
- email: SMTP, POP3, IMAP
- DNS
- Socket programming
What did we do?

**Transport Layer**
- services, principles
- multiplexing, demultiplexing
- UDP
- Principles of reliable of data transfer
- TCP
- Principles of congestion control
- TCP congestion control

**Network Layer**
- service model(s)
- routing principles
- hierarchical Routing
- IP protocol
- routing in the Internet
- what’s inside a router?
What did we do?

**Link Layer, LANs**
- introduction, services
- error detection, correction
- multiple access protocols
- LAN addresses, ARP
- Ethernet
- hubs, bridges and switches
- wireless: IEEE 802.11
- PPP
- ATM

**Network Security**
- introduction
- cryptography
- authentication
- integrity
- key distribution, certificates
- Firewalls
- secure email
- secure sockets
- IP sec
- 802.11 WEP

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Course Overview:

Network Management
- network management framework
- SNMP
- ASN.1

Multimedia Networking
- application requirements
- making the best of best-effort service
- scheduling, policing
- Integrated Services
- RSVP
- Differentiated Services
Q: Whither goest networking?

A: nobody knows!

General tends:

- **ubiquity** of communications
  - IP dialtone, IP: like electricity: it’s everywhere!
  - network-capable appliances (e.g., IP thermostat)
  - issues of scale important: 100's of millions of network-connected devices

- **mobility** important:
  - people move, need to communicate

- **multimedia** important:
  - it is how people communicate
Q: Whither goest networking?

- increasing link rates, but bandwidth not free in near future
  - increased # "users"
  - increased bandwidth requirements of enabled apps
- high bandwidth to home (ADSL, cable modems) a major driver for future
  - games, VR, education, information, entertainment
  - merger of networking and telephony
  - broadcast entertainment (TV) and WWW
- security, management: critical concerns
- agents: processing “in” or “on” the network in support of end users
The Future: a broader CS view

1980 - 1995

computing
communications

1995-2005

computing
communications

2005 - ?

computing
communications

information processing
Our Very Last Note Page!

- **networking**: will play a central role in computing, information processing

- **this course**:
  - specific architectures, protocols
  - fundamental issues: APIs, reliable data transfer, flow/congestion control, routing, multiple access, addressing, security, management

- **remember**: you learned it HERE!
What is on the final exam?

- Comprehensive
  - Including midterm 1 and midterm 2 material
  - Remember new material after midterm 2
    - Wireless networks, network security, sensor networks, network management