Internetworking

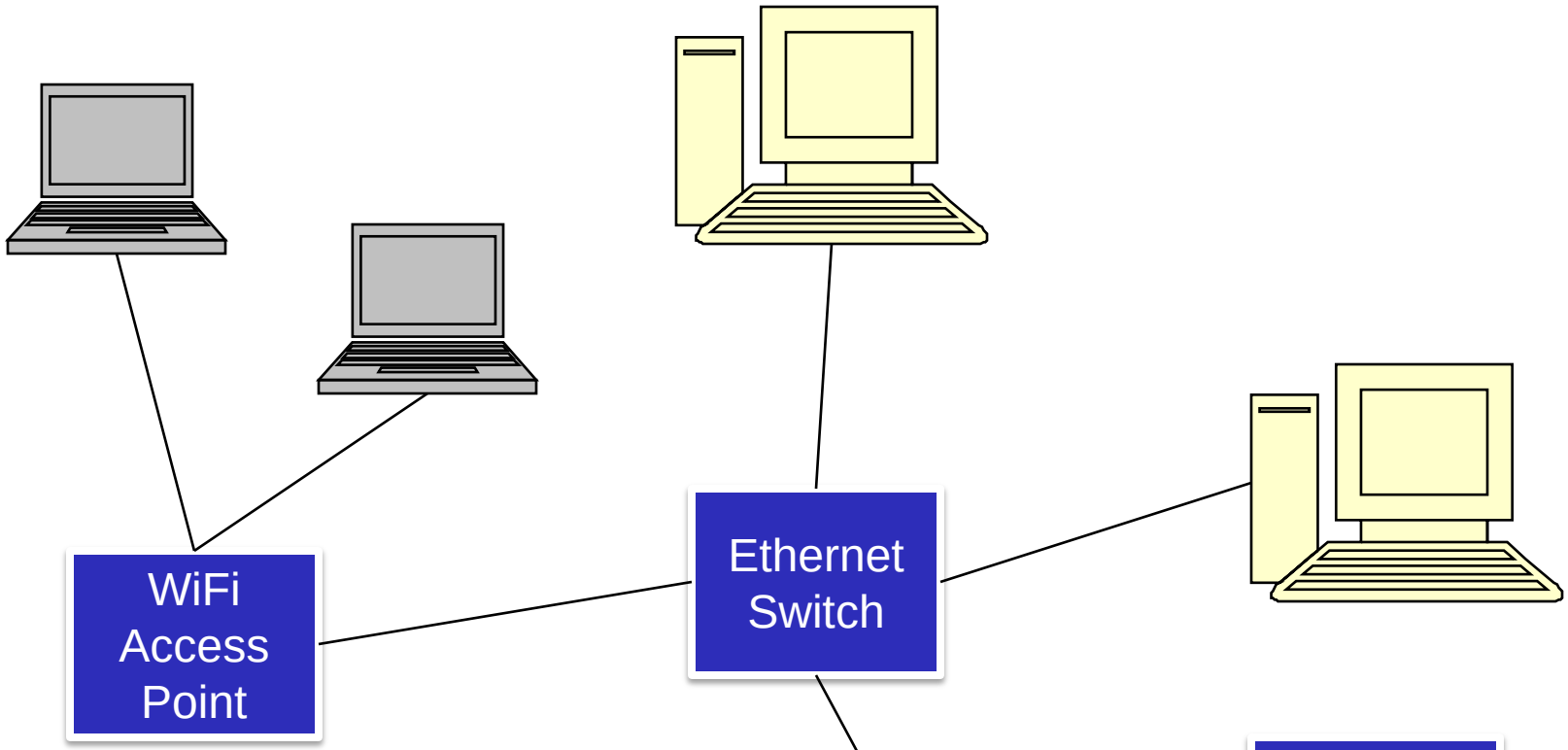
Class so far…

- Covered individual networks
  - PHY
  - MAC / Data Link
    - Point-to-point networks
    - Point-to-multipoint networks
    - Multipoint-to-multipoint networks
- Internetworking
  - Networks of networks
  - Rest of the semester focuses on L3/L4 issues with networks

Connecting networks

- Switches connect together components of a single network
  - Components can have different PHY but must have same MAC
- Routers connect together independent networks
  - Components can have different PHY/MAC but must have same network layer (L3)
- Internet Protocol (IP) is common L3 across the entire Internet, and most private networks today

Internetworking Example: Home Router



WiFi has compatible MAC with Ethernet
Both CSMA
WiFi AP can bridge the two networks
Without using the Router directly

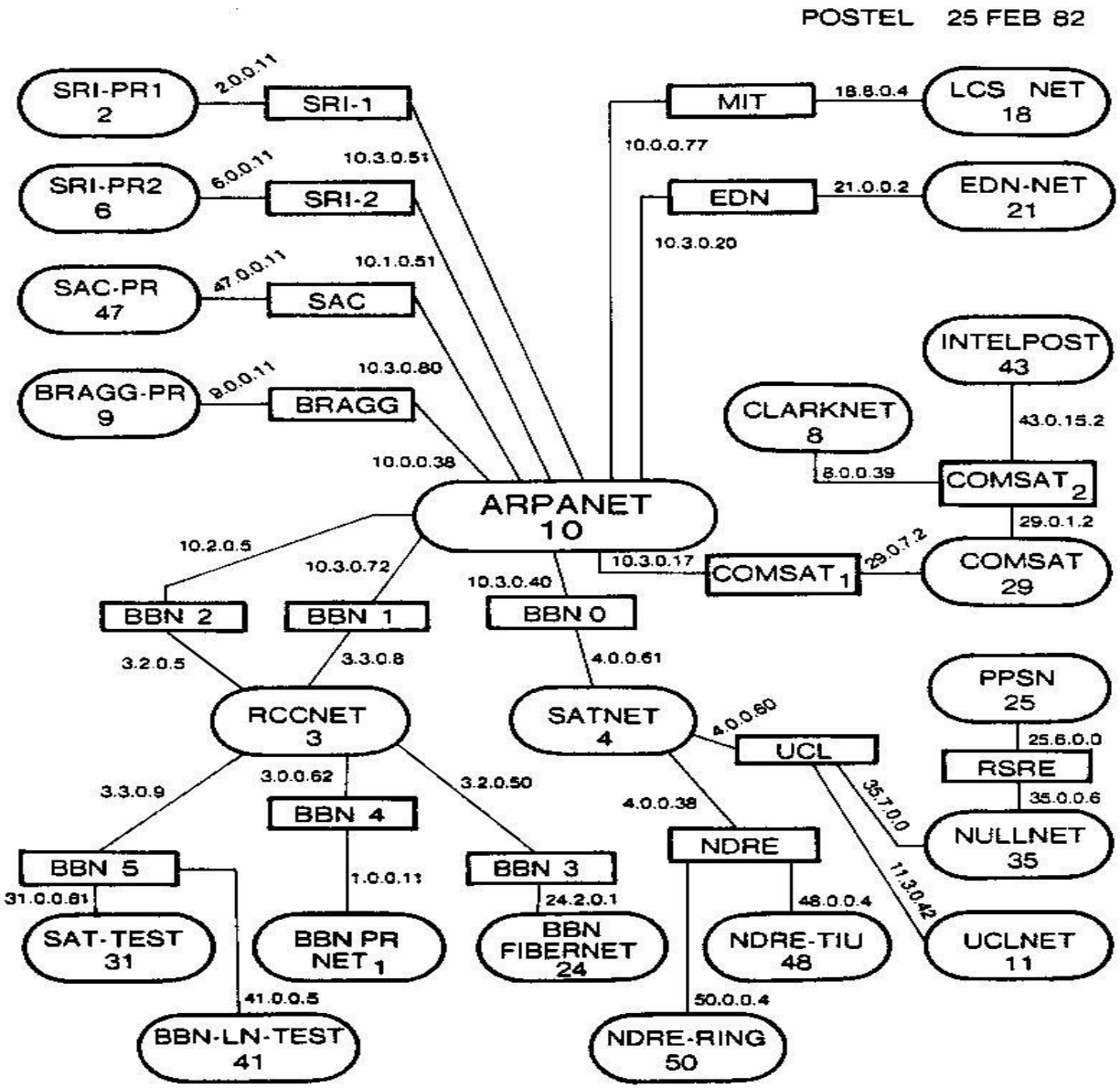
Internet Protocol (IP)

- IP version 4
  - Global addressing
  - Best effort traffic
  - Fragmentation and reassembly
- IP version 6
  - Larger address space (2^128 versus 2^32)
  - Built-in device auto-configuration
  - IPsec built-in (L3 security)
  - Larger MTUs
  - Multicast built-in
  - Mobility built-in

Global Addressing

- IP address: 4 bytes = 32 bits
- Typically represented in “dotted-decimal notation” with each byte as a decimal integer, separated by dots
  - aaa.bbb.ccc.ddd where aaa, bbb, ccc, ddd are [0, 255]
  - First portion of the address represents the network
  - Last portion of the address represents the individual host

Class	Leading	Net bits	Host bits	Net count	Host count	Net
A	0	7	24	126	16,777,214	0-127
B	10	14	16	16,382	65,534	128-191
C	110	21	8	2,097,150	254	192-223
D	1110	Multicast				224-239
E	1111	Reserved				240-255


POSTEL 25 FEB 82
SRI-PR1 2
20.0.11
SRI-1
SRI-PR2 6
6.0.0.11
SRI-2
SAC-PR 47
47.0.0.11
SAC
BRAGG-PR 9
9.0.0.11
BRAGG
10.3.0.51
10.1.0.51
10.3.0.80
10.0.0.38
ARPANET 10
MIT
18.8.0.4
LCS NET 18
10.0.0.77
EDN
21.0.0.2
EDN-NET 21
10.3.0.20
INTELPOST 43
43.0.15.2
CLARKNET 8
8.0.0.39
COMSAT 2
29.0.1.2
COMSAT 29
29.0.7.2
COMSAT 1
10.3.0.17
10.2.0.5
10.3.0.72
10.3.0.40
BBN 2
BBN 1
BBN 0
3.2.0.5
3.3.0.8
4.0.0.61
RCCNET 3
SATNET 4
4.0.0.60
UCL
PPSN 25
25.6.0.0
RSRE
35.0.0.6
NULLNET 35
35.7.0.0
11.3.0.42
UCLNET 11
3.3.0.9
3.0.0.62
3.2.0.50
BBN 4
4.0.0.38
NDRE
BBN 5
BBN 3
1.0.0.11
31.0.0.61
24.2.0.1
46.0.0.4
SAT-TEST 31
BBN PR NET 1
BBN FIBERNET 24
NDRE-TIU 48
41.0.0.5
50.0.0.4
BBN-LN-TEST 41
NDRE-RING 50

Classful Addressing

- Improvement over original scheme with 1-byte network, 3-byte host
  - Limits Internet to 256 networks
- Allowed for many different sizes and scales of networks to be deployed
- Around 1993 again an IP address shortage began
- Also Class A networks with 2^24 hosts became unmanageable

Solution: CIDR

- Classless Inter-Domain Routing
- Concept of “subnets”
  - Break large networks up in to smaller ones
  - Since address can be arbitrary, you need a mask to tell you what part of the IP address represents the network, and what part represents the host
  - Result: subnet mask
- Useful for routing (get to that next week)
  - Telescoping address, with bits further down in the address representing further sub-networks

IP Supporting Protocols

Internet Control Messaging Protocol

- ICMP
- Diagnostic protocol
- Major Messages
  - Echo request/response (ping)
  - Destination unreachable
  - Time Exceeded (TTL expiration)

Address Resolution Protocol

- ARP
- Given an IP address, determine MAC address
- Broadcast Ethernet message (destination address ff:ff:ff:ff:ff:ff)
- Contains source/destionation IP address and src MAC address
- Requests for computer with matching IP address to respond back with their MAC address
- Information cached in ARP tables

ARP and Subnet Masks

- Devices configured with IP address, subnet mask, and router IP address
- A wants to talk to B
  - A computes (IP-A && Mask) and (IP-B && Mask)
  - If (IP-A && Mask) == (IP-B && Mask) then B is on the same network as A
    - Send packet to B's MAC and IP address (ARP for MAC if unknown)
  - If not equal, B is on a different network
    - Send packet to B's IP and Router's MAC (ARP for MAC if unknown)
    - On destination network, last-hop router will ARP for B's MAC to transmit the packet to B

Domain Name Service

- DNS
- IP addresses hard to remember
- Need easy to remember names for hosts on the Internet
- Fully Qualified Domain Name (FQDN)
- Example: www.umd.edu
  - edu is a “top level domain” or TLD
    - Fixed number of TLDs, maintained by ICANN
    - Generic vs Country-Specific
  - umd is domain name owned by UMD
  - www is the name of the server

Reverse DNS

- Given an IP address, what is the FQDN?
- IP address is a.b.c.d, perform lookup on d.c.b.a.arpa
- .arpa is a special TLD for reverse DNS
- ISPs maintain RDNS tables

Host Configuration

- Devices need to know a lot of information about the network in order to use it
  - IP address, Router, DNS Server, Subnet Mask
- Early Solution: Reverse ARP (RARP)
  - Send packet with source MAC of host to configure, broadcast destination
  - Requires RARP server on every network, and does not configure extended properties

Dynamic Host Configuration Protocol

- DHCP
- Allows hosts to be autoconfigured when they connect to the network
- Allows central administration of network connection information
- Static and dynamic IP address allocations
- Addresses from a pool, leased for specified amount of time