

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

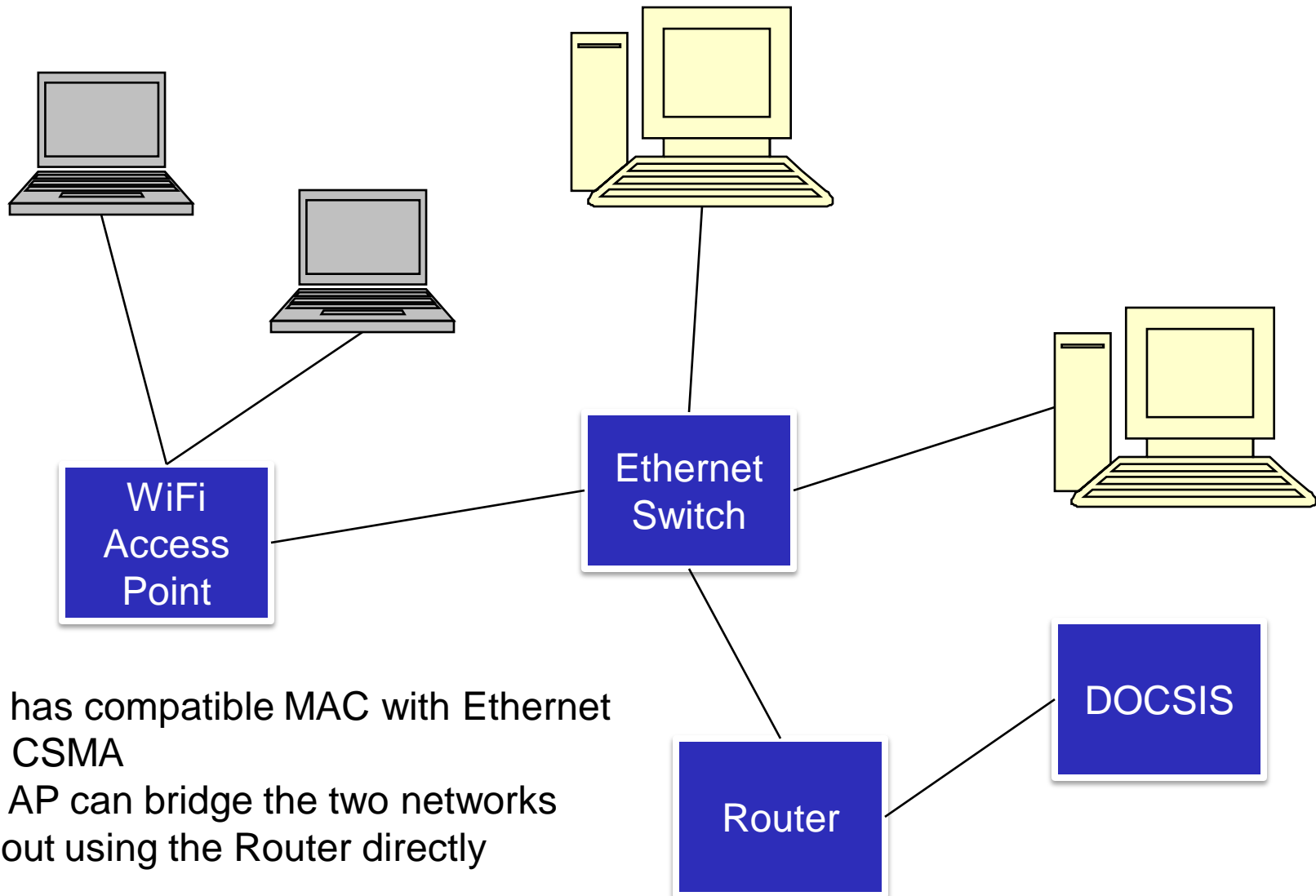


Connecting networks

- 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)

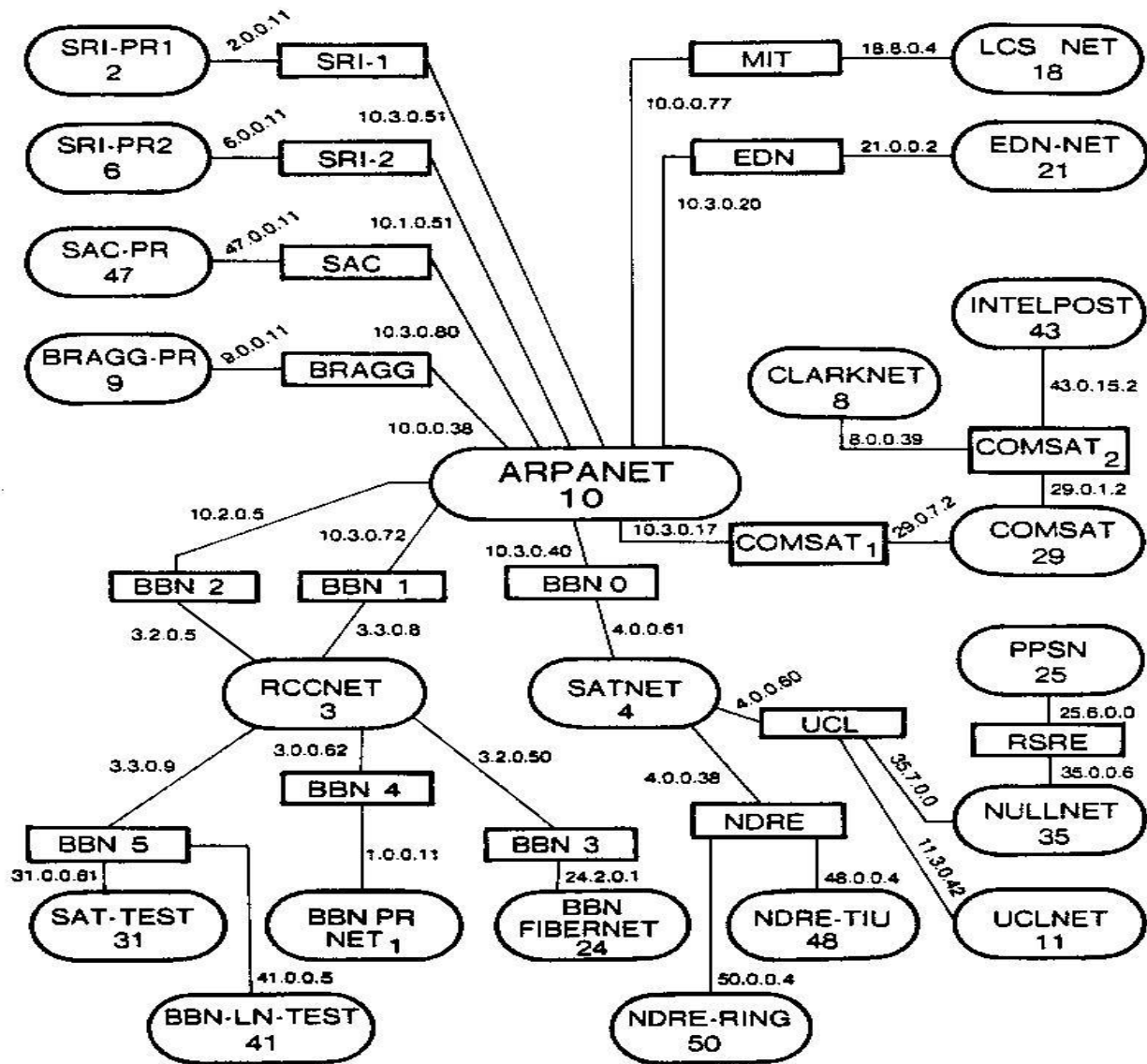
- IP version 4
 - Global addressing
 - Best effort traffic
 - Fragmentation and reassembly
- IP version 6
 - Larger address space (2^{128} versus 2^{32})
 - Built-in device auto-configuration
 - IPsec built-in (L3 security)
 - Larger MTUs
 - Multicast built-in
 - Mobility built-in



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



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/destination 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

