CIS 551 / TCOM 401

Computer and Network Security

Spring 2007

Lecture 8

Announcements

- Reminder:
  - Project 1 is due on tonight by midnight.

- Midterm 1 will be held next Thursday, Feb. 8th.
  - Example midterms from last year will be put on the web pages.

Open Systems Interconnection (OSI)

Reference model – not actual implementation.

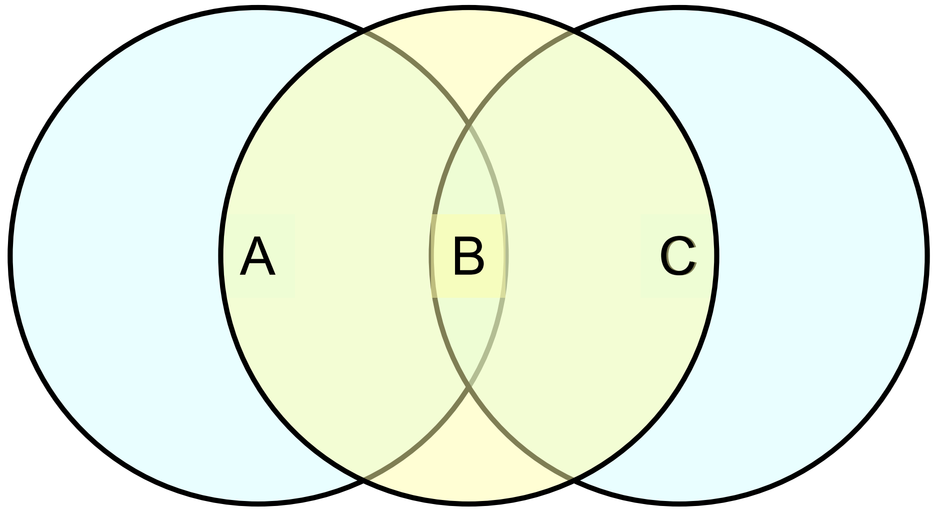
End Host	
Application	Transmits *messages* (e.g. FTP or HTTP)
Presentation	Data format issues (e.g. big- vs. little-endian)
Session	Manages multiple streams of data
Transport	Process to process protocols
Network	Routes *packets* among nodes in network
Data Link	Packages bit streams into *frames*
Physical	Transmits raw bits over link

Wireless (802.11)

- Spread spectrum radio
  - 2.4GHz frequency band
- Bandwidth ranges 1, 2, 5.5, 11, 22, … Mbps

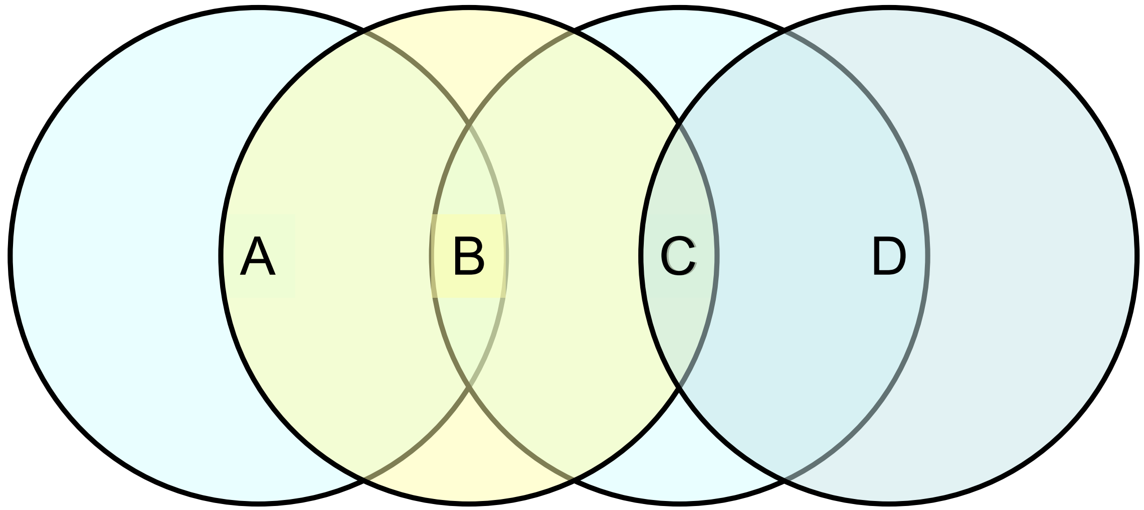
- Like Ethernet, 802.11 has shared medium
  - Need MAC (uses exponential backoff)
- Unlike Ethernet, in 802.11
  - No support for collision detection
  - Not all senders and receivers are directly connected

Hidden nodes



- A and C are *hidden* with respect to each other
  - Frames sent from A to B and C to B simultaneously may collide, but A and C can't detect the collision.

Exposed nodes

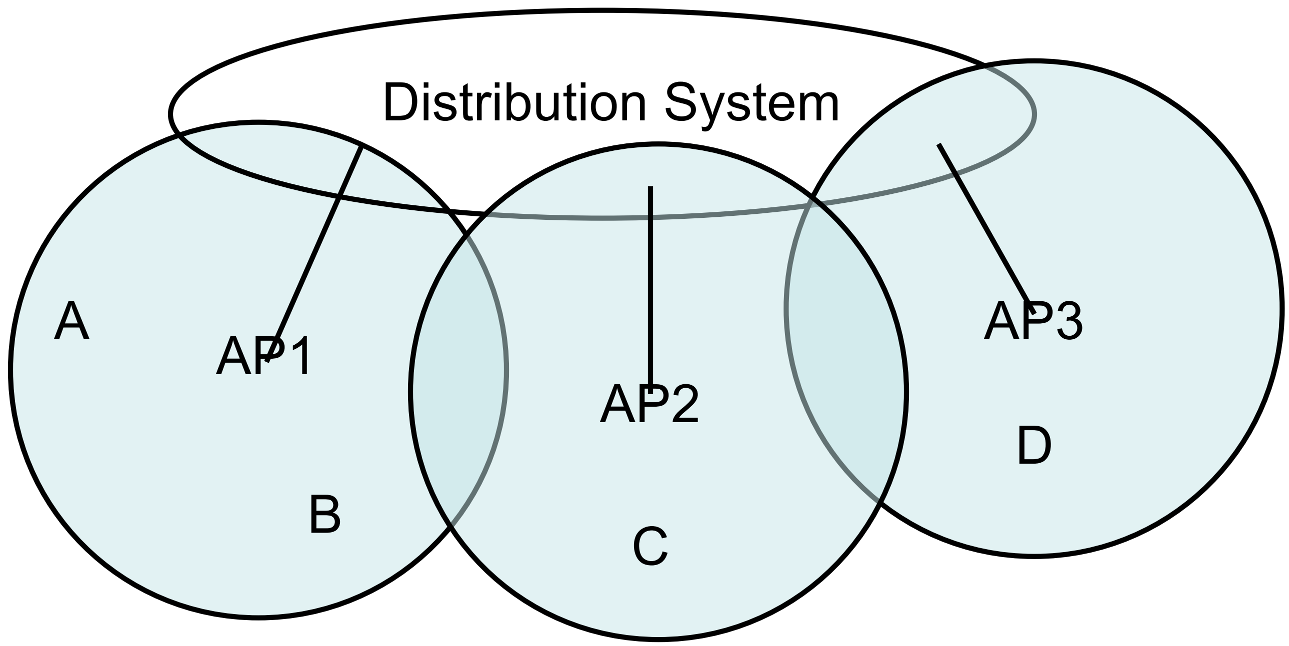


- B is exposed to C
  - Suppose B is sending to A
  - C should still be allowed to transmit to D
  - Even though C—B transmission would collide
  - (Note A to B transmission would cause collision)

Multiple Access Collision Avoidance

- Sender transmits Request To Send (RTS)
  - Includes length of data to be transmitted
  - Timeout leads to exponential backoff (like Ethernet)
- Receiver replies with Clear To Send (CTS)
  - Echoes the length field
- Receiver sends ACK of frame to sender
- Any node that sees CTS cannot transmit for durations specified by length
- Any node that sees RTS but not CTS is not close enough to the receiver to interfere
  - It's free to transmit

Wireless Access Points

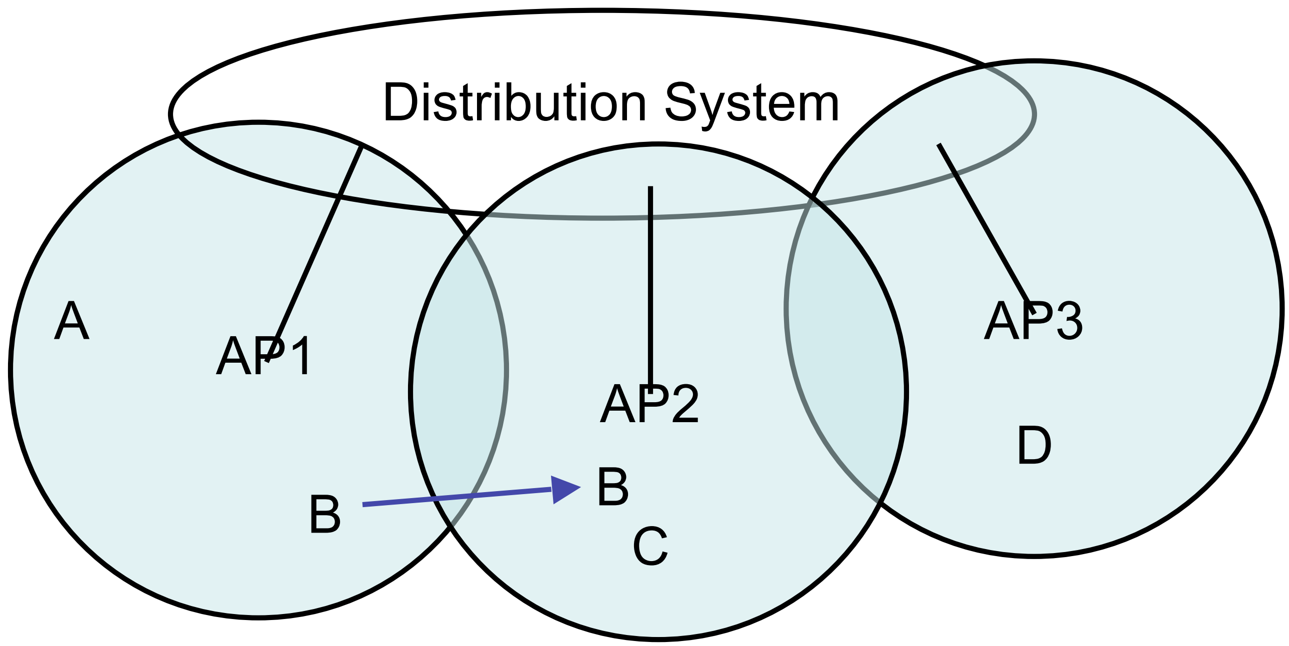


- Distribution System – wired network infrastructure
- Access points – stationary wireless device
- Roaming wireless

Selecting an Access Point

- *Active scanning*
  - Node sends a Probe frame
  - All AP’s within reach reply with a Probe Response frame
  - Node selects an AP and sends Association Request frame
  - AP replies with Association Response frame
- *Passive scanning*
  - AP periodically broadcasts Beacon frame
  - Node sends Association Request

Node Mobility



- B moves from AP1 to AP2
- B sends Probes, eventually prefers AP2 to AP1
- Sends Association Request

802.11 Security Issues

- Packet Sniffing is *worse*
  - No physical connection needed
  - Long range (6 blocks)
  - Current encryption standards (WEP, WEP2) not that good
- Denial of service
  - Association (and Disassociation) Requests are not authenticated

Wired Equivalent Privacy (WEP)

- Designed to provide same security standards as wired LANs (like Ethernet)
  - WEP uses 40 bit keys
  - WEP2 uses 128 bit keys
- Uses shared key authentication
  - Key is configured manually at the access point
  - Key is configured manually at the wireless device
- WEP frame transmission format:

$$802.11\text{Hdr}, IV, K_{S+IV}\{DATA, ICV\}$$

  - S = shared key
  - IV = 24 bit "initialization vector"
  - ICV = "integrity checksum" uses the CRC checksum algorithm
  - Encryption algorithm is RC4

Problem with WEP

- RC4 generates a keystream
  - Shared key S plus IV generates a long sequence of pseudorandom bytes RC4(IV,S)
  - Encryption is: $C = P \oplus RC4(IV,S)$ $\oplus$ = "xor"

- IV's are public -- so it's easy to detect their reuse
- Problem: if IV ever repeats, then we have
  - $C1 = P1 \oplus RC4(IV,S)$
  - $C2 = P2 \oplus RC4(IV,S)$
  - So $C1 \oplus C2 = P1 \oplus P2$
  - Statistical analysis or known plaintext can disentangle P1 and P2

Finding IV Collisions

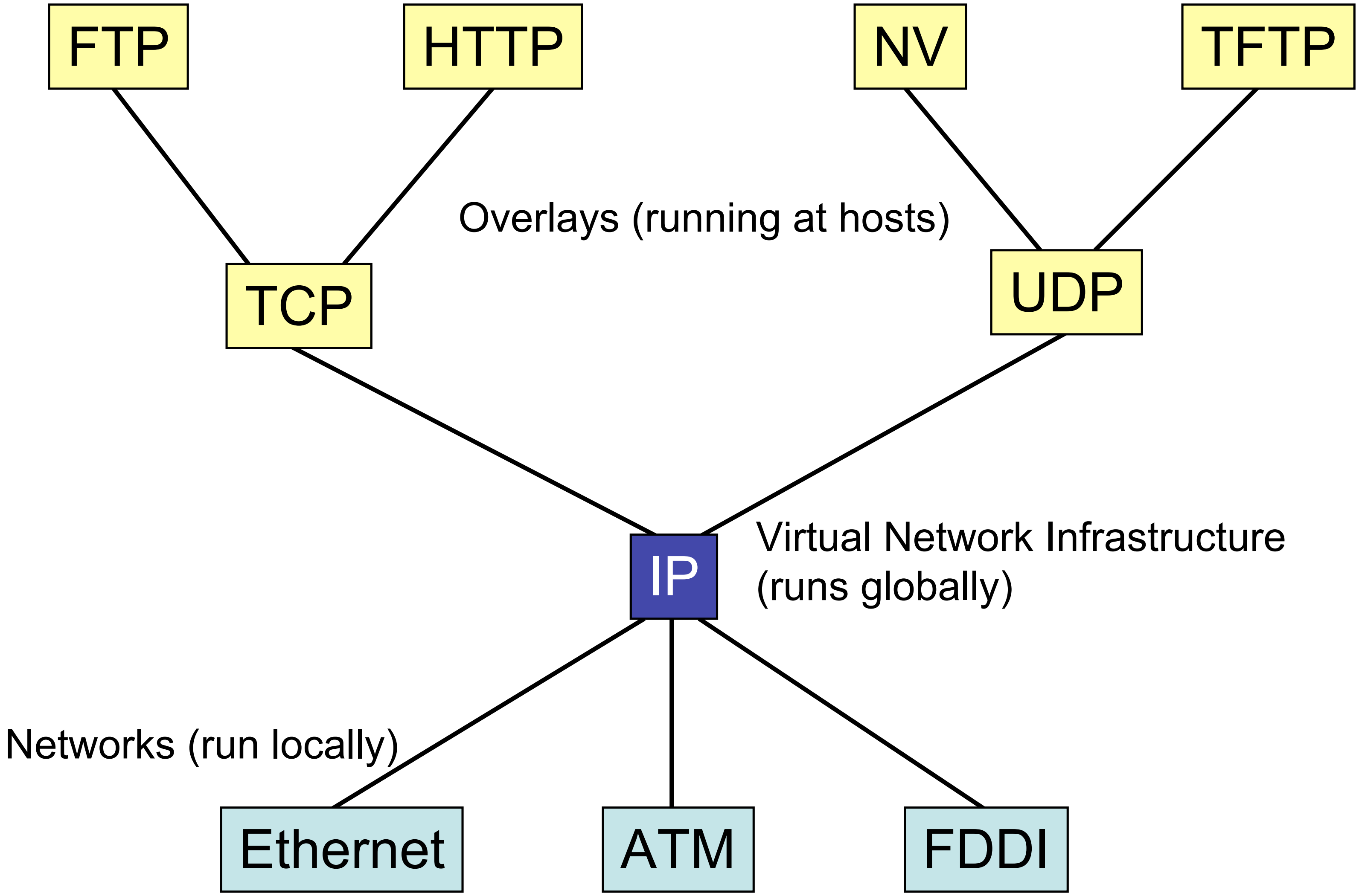
- How IV is picked is not specified in the standard:
  - Standard "recommends" (but does not require) that IV be changed for every packet
  - Some vendors initialize to 0 on reset and then increment
  - Some vendors generate IV randomly per packet
- Very active links send ~1000 packets/sec
  - Exhaust 24 bit keyspace in < 1/2 day
- If IV is chosen randomly, probability is > 50% that there will be a collision after only 4823 packets

Other WEP problems

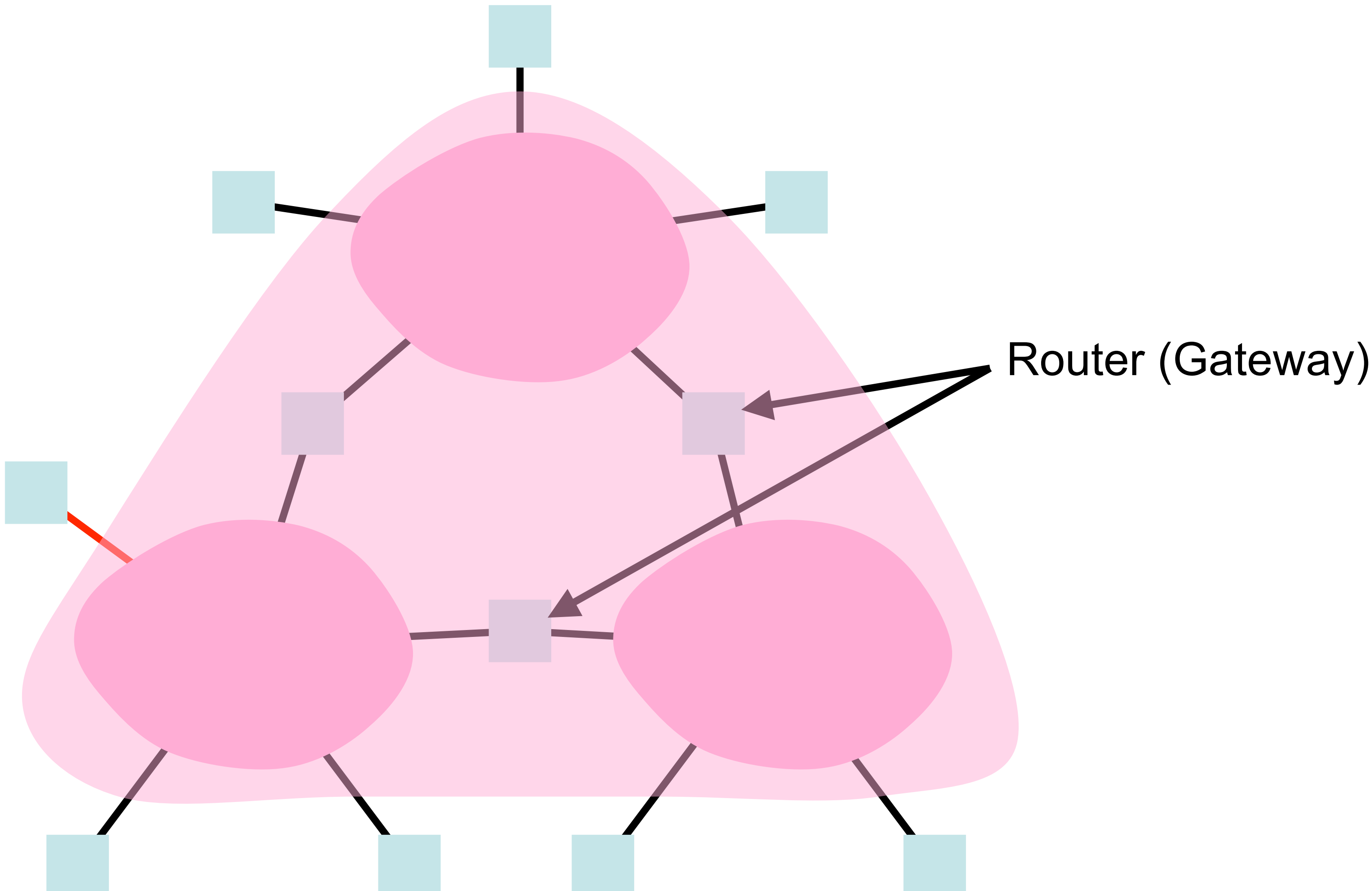
- Replay attacks
  – Standard requires the protocol to be stateless
  – Not possible to rule out replay attacks. (The sender and receiver can't keep track of expected sequence numbers)

- Integrity violations
  – Attacker can inject or corrupt WEP encrypted packets
  – CRC (Cyclic Redundancy Check) is an error detection code commonly used in internet protocols
  – CRC is good at detecting random errors (introduced by environmental noise)
  – But, CRC is not a hash function -- it is easy to find collisions
  – Attacker can arbitrarily pass off bogus WEP packets as legitimate ones

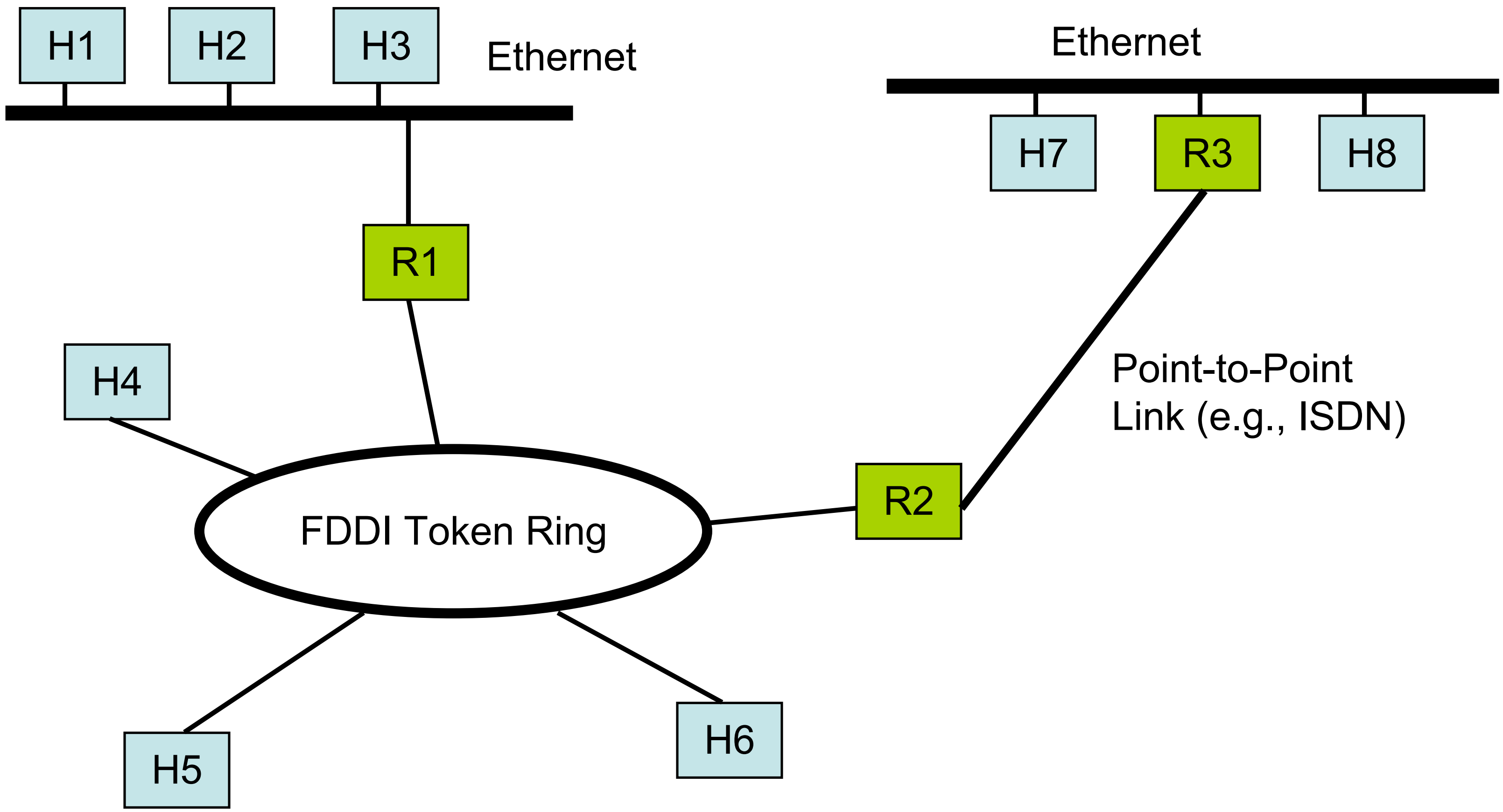
Internet Protocol Interoperability



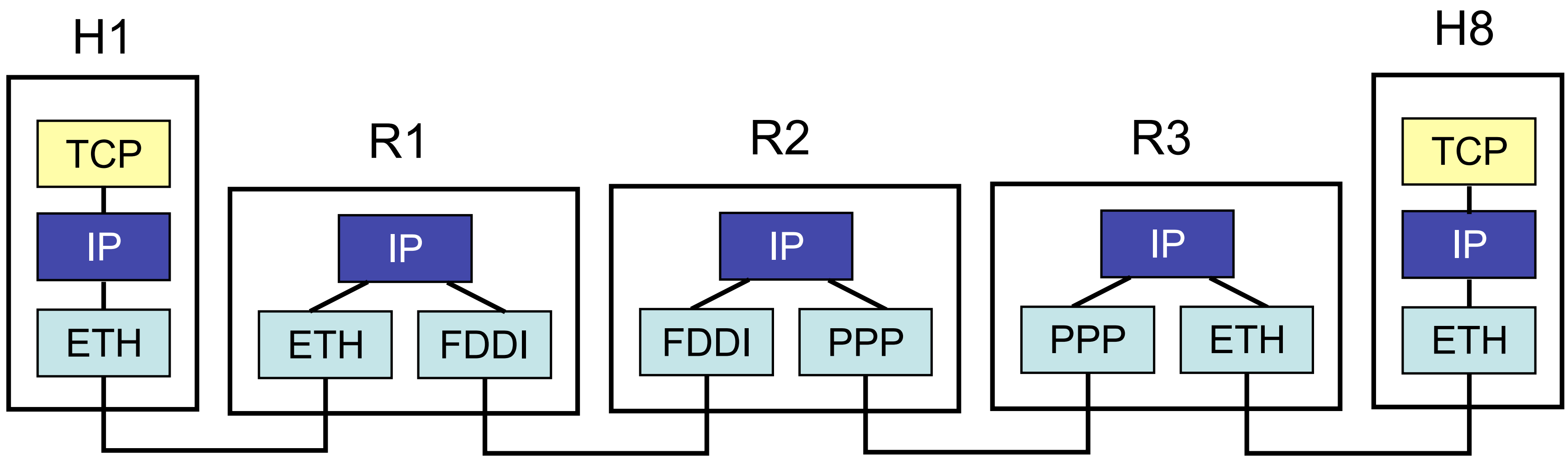
Internetworks



Internetworks



IP Encapsulation

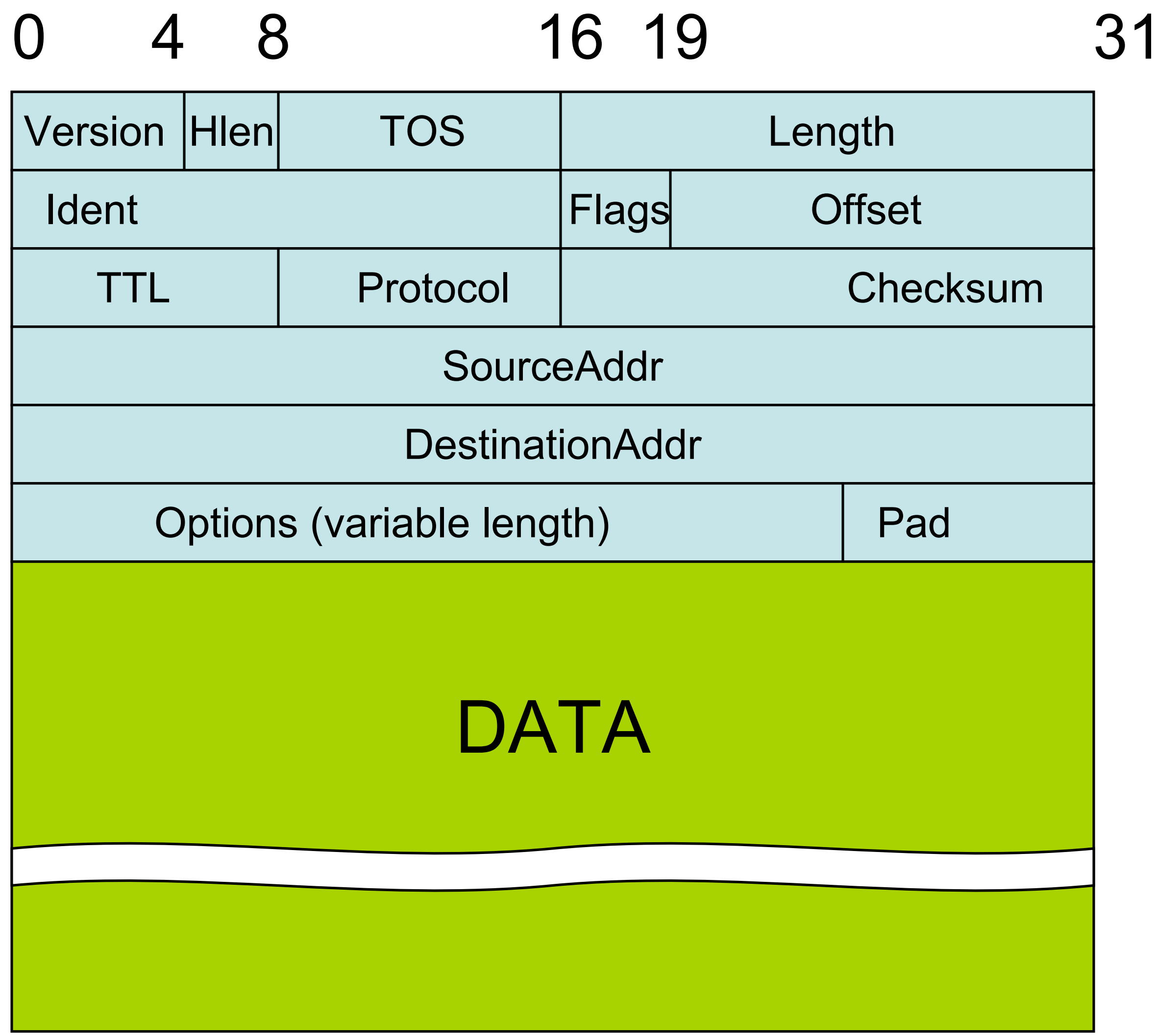


Example of protocol layers used to transmit from H1 to H8 in network shown on previous slide.

IP Service Model

- Choose minimal service model
  - All nets can implement
  - “Tin cans and a string” extremum
- Features:
  - Best-effort datagram delivery
  - Reliability, etc. as *overlays*
  - Packet format standardized

IPv4 Packet Format



Fields of IPv4 Header

- Version
  - Version of IP, example header is IPv4
  - First field so easy to implement case statement
- Hlen
  - Header length, in 32-bit *words*
- TOS
  - Type of Service (rarely used)
  - Priorities, delay, throughput, reliability
- Length
  - Length of datagram, in *bytes*
  - 16 bits, hence max. of 65,536 bytes
- Fields for *fragmentation* and *reassembly*
  - Identifier
  - Flags
  - Offset

Header fields, continued

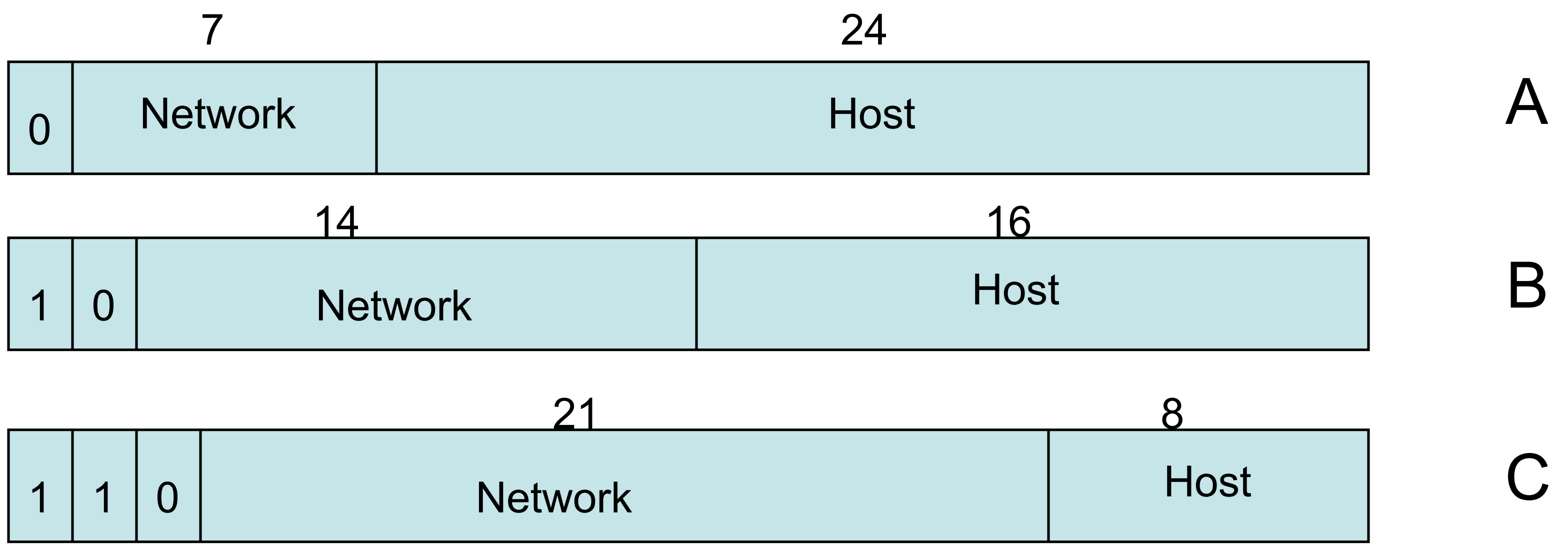
- TTL
  - Time to live (in reality, hop count)
  - 64 is the current default (128 also used)
- Protocol
  - e.g., TCP (6), UDP(17), etc.
- Checksum
  - Checksum of header (not CRC)
  - If header fails checksum, discard the whole packet
- SourceAddr, DestinationAddr
  - 32 bit IP addresses - global, IP-defined
- Options
  - length can be computed using Hlen

IP Datagram Delivery

- Every IP packet (datagram) contains the destination IP address
- The network part of the address uniquely identifies a single network that is part of the larger Internet.
- All hosts and routers that share the same network part of their address are connected to the same physical network.
- Routers can exchange packets on any network they're attached to.

IP addresses

- Hierarchical, not flat as in Ethernet



- Written as four decimal numbers separated by dots: 158.130.14.2

Network Classes

Class	*# of nets*	*# of hosts per net*
A	126	~16 million
B	8192	65534
C	~2 million	254

IP Forwarding algorithm

- If (Network # dest == Network # interface) then deliver to destination over interface
- else if (Network # dest in forwarding table) deliver packet to NextHop router
- else deliver packet to default router

- Forwarding tables
  - Contain (Network #, NextHop) pairs
  - Additional information
  - Built by routing protocol that learns the network topology, adapts to changes

Subnetting

- Problem: IP addressing scheme leads to fragmentation
  - A class B network with only 300 machines on it wastes > 65,000 addresses
  - Need a way to divide up a single network address space into multiple smaller subnetworks.

- Idea: One IP network number allocated to several physical networks.
  - The multiple physical networks are called *subnets*
  - Should be close together (why?)
  - Useful when a large company (or university!) has many physical networks.

Subnet Numbers

- Solution: *Subnetting*
  - All nodes are configured with *subnet mask*
  - Allows definition of a *subnet number*
    - All hosts on a physical subnetwork share the same *subnet number*

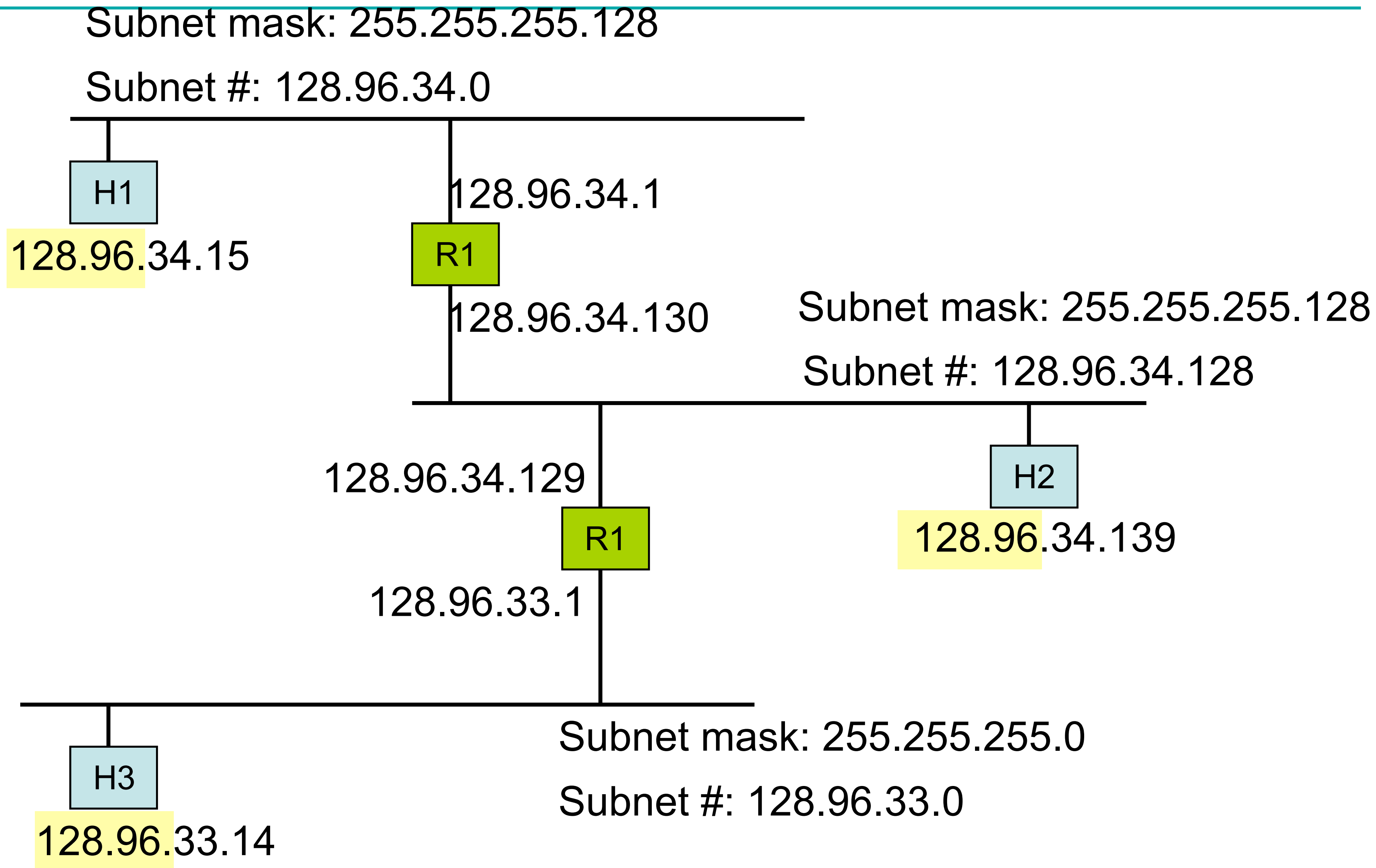
Subnet Mask (255.255.255.0)

111111111111111111111111	00000000

Subnetted Address:

Network number	Subnet ID	Host ID

Example of Subnetting



Subnets, continued

- Mask is bitwise-ANDed with address
- This is done at routers
- Router tables in this model:
  - <Subnet #, Subnet Mask, NextHop>
- Subnetting allows a set of physical networks to look like a single logical network from elsewhere

Forwarding Algorithm

D = destination IP address
for each forwarding table entry
(SubnetNumber, SubnetMask, NextHop)
    D1 = SubnetMask & D
    if D1 = SubnetNumber
        if NextHop is an interface
            deliver datagram directly to destination
        else
            deliver datagram to NextHop (router)

Deliver datagram to default router (if above fails)