CIS 551 / TCOM 401

Computer and Network Security

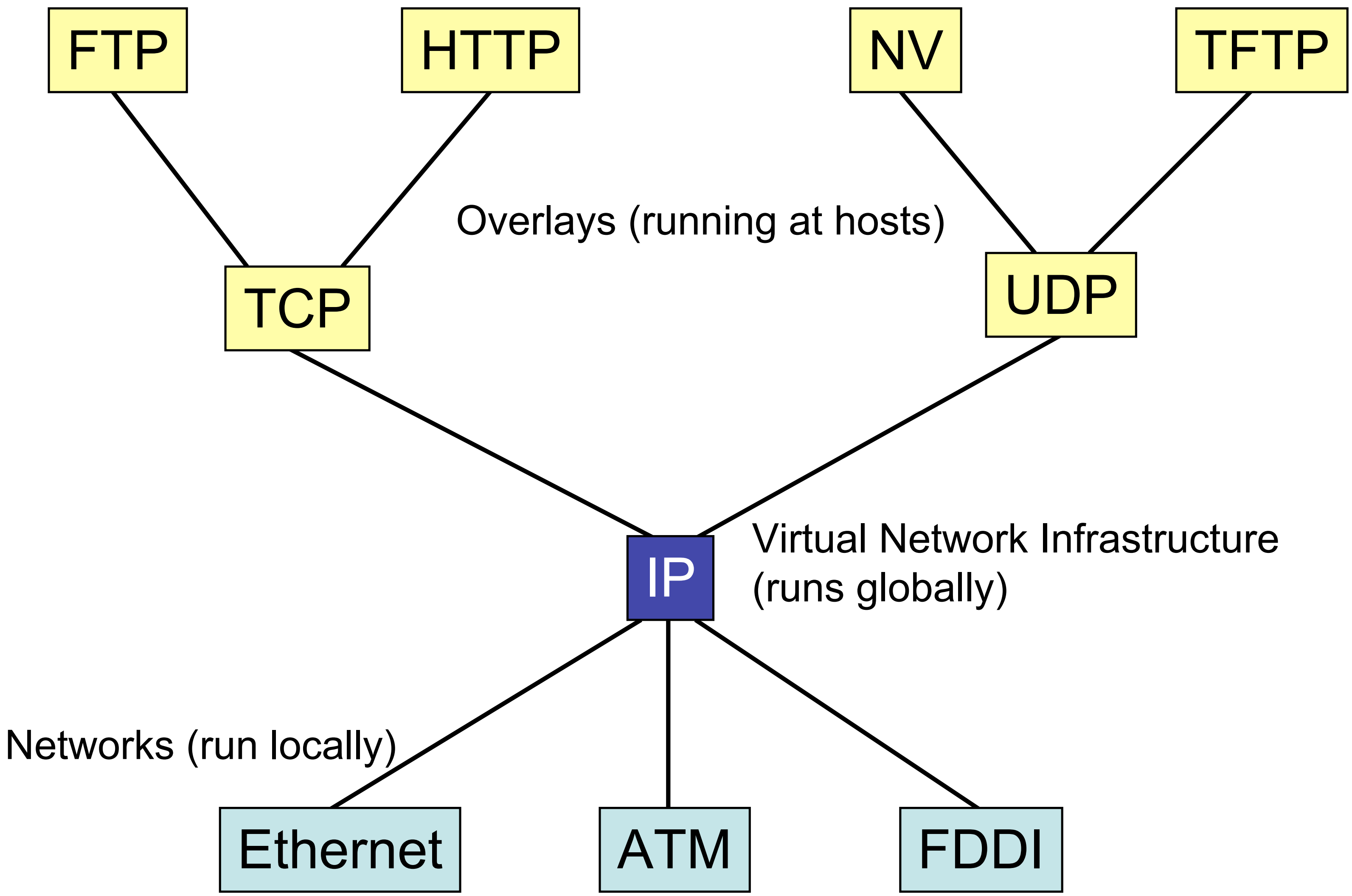
Spring 2006

Lecture 16

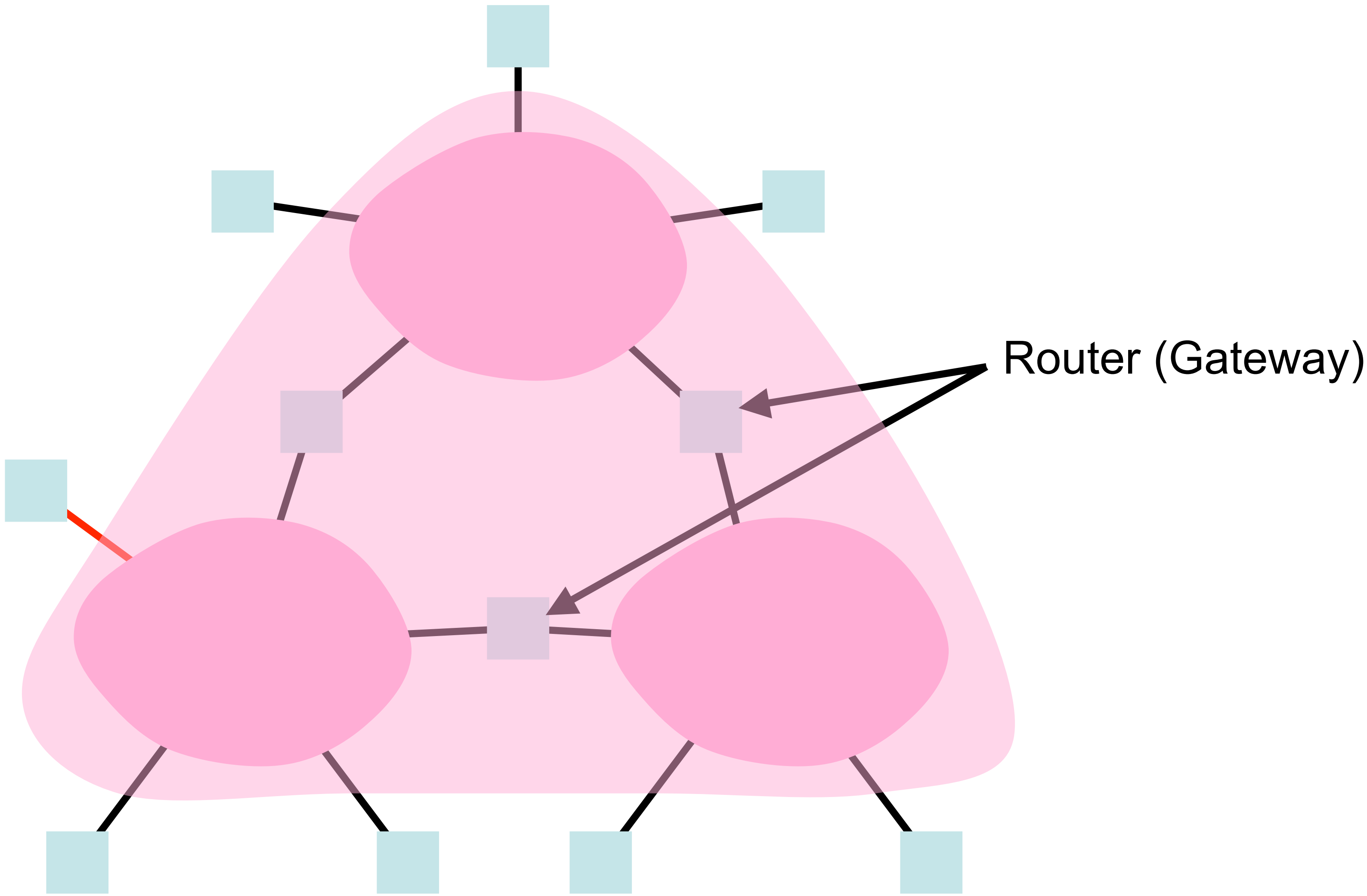
Announcements

- Midterm II
  - March 21st (One week from today)
  - In class
  - Same format as last time
  - Will cover all material since Midterm I
- Talk: "Analyzing Intrusions Using Operating System Level Information Flow"
  - Sam King, University of Michigan, Ann Arbor

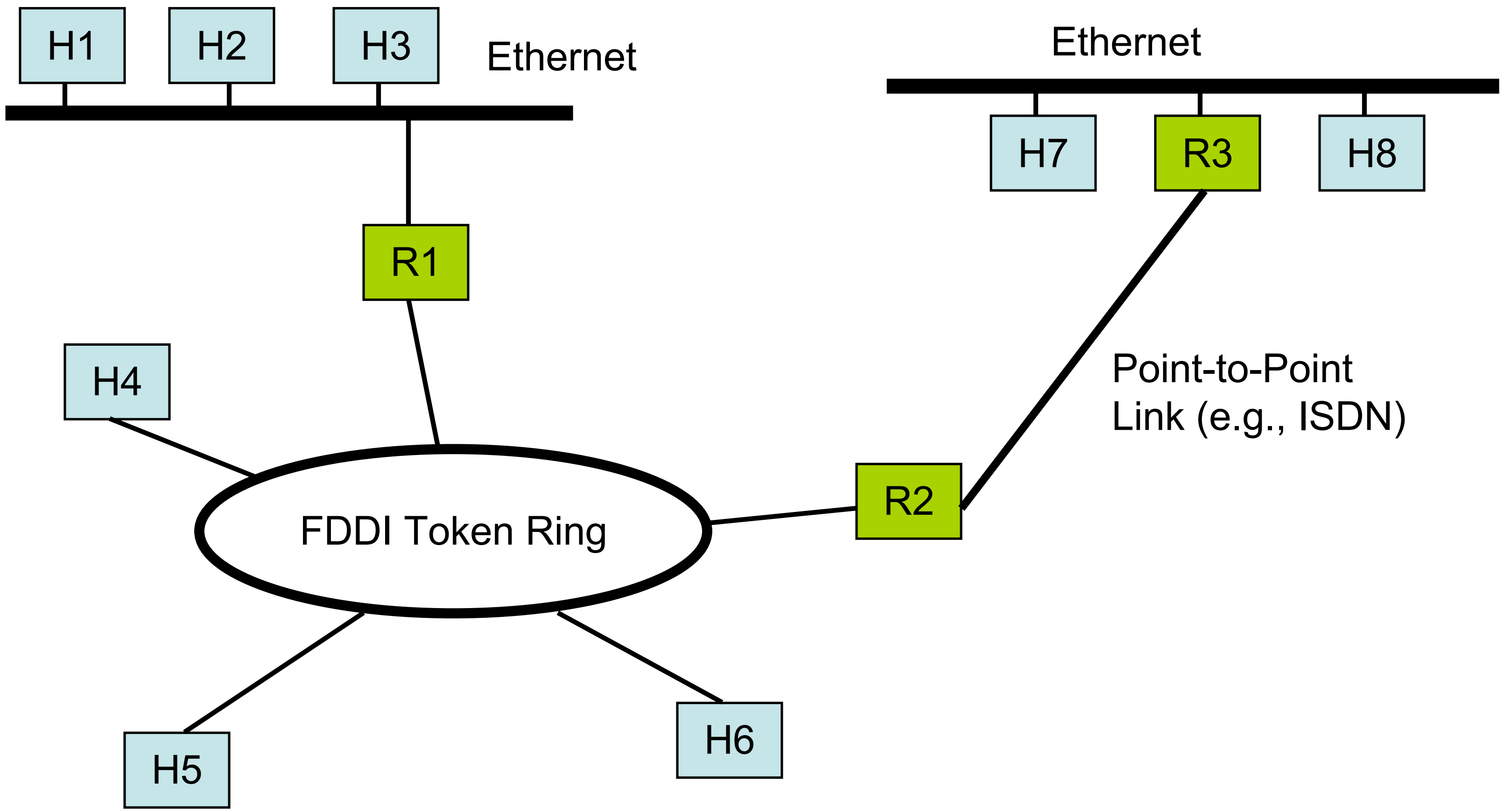
Internet Protocol Interoperability



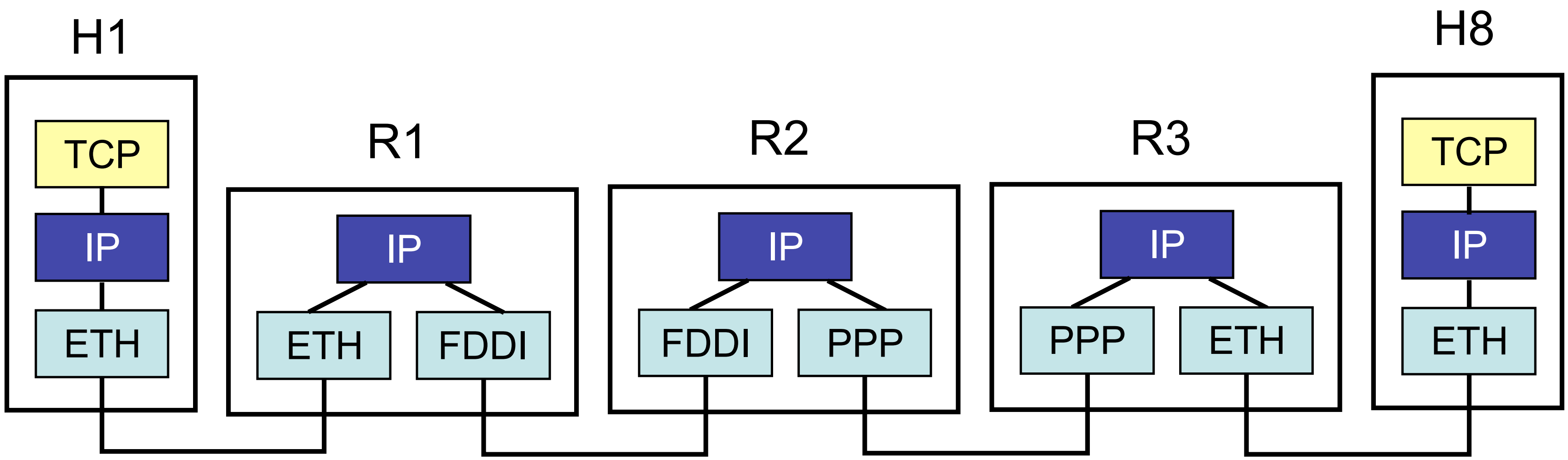
Internetworks



Internetworks



IP Encapsulation

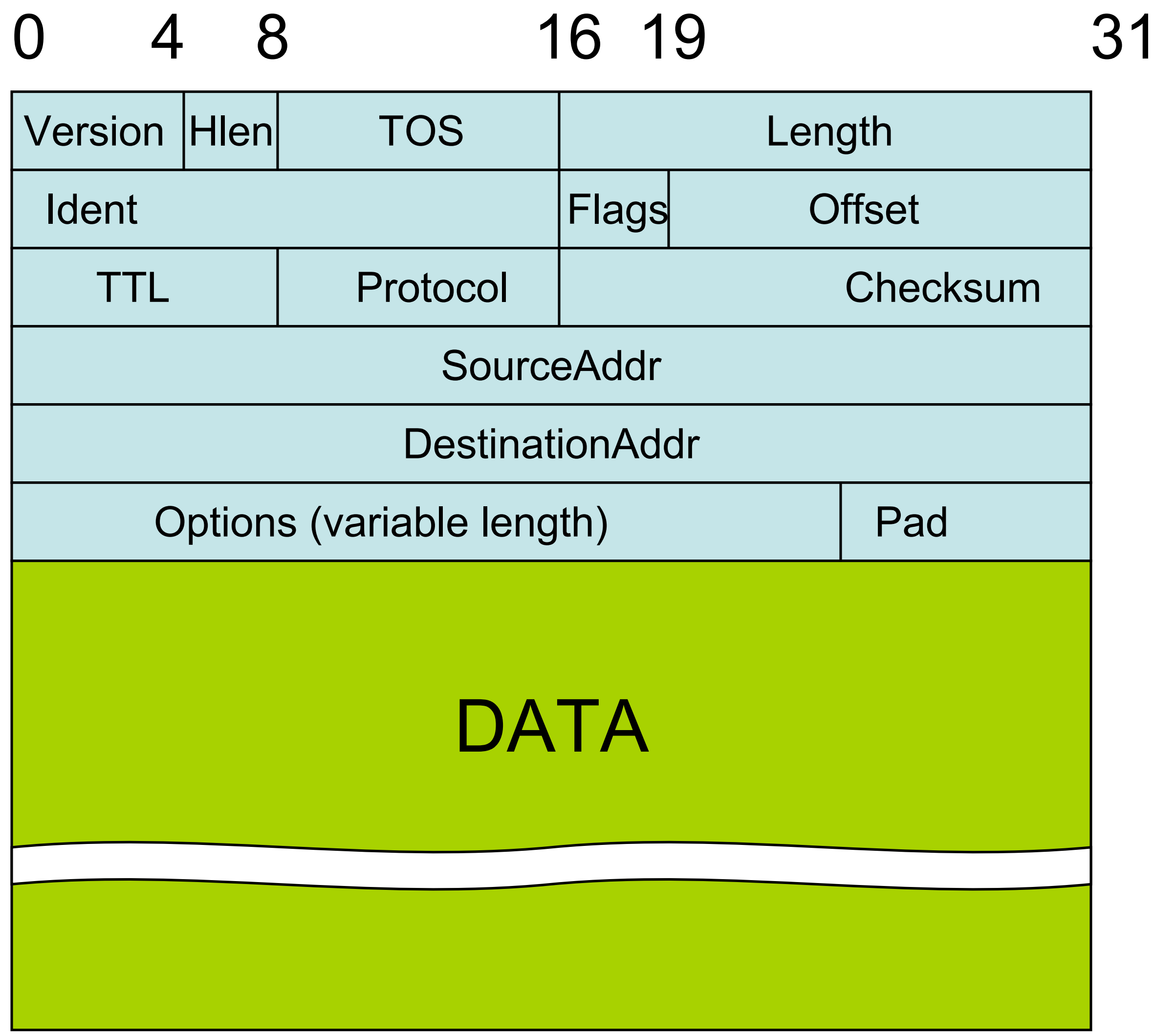


Example of protocol layers used to transmit from H1 to H8 in network shown on previous slide.

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

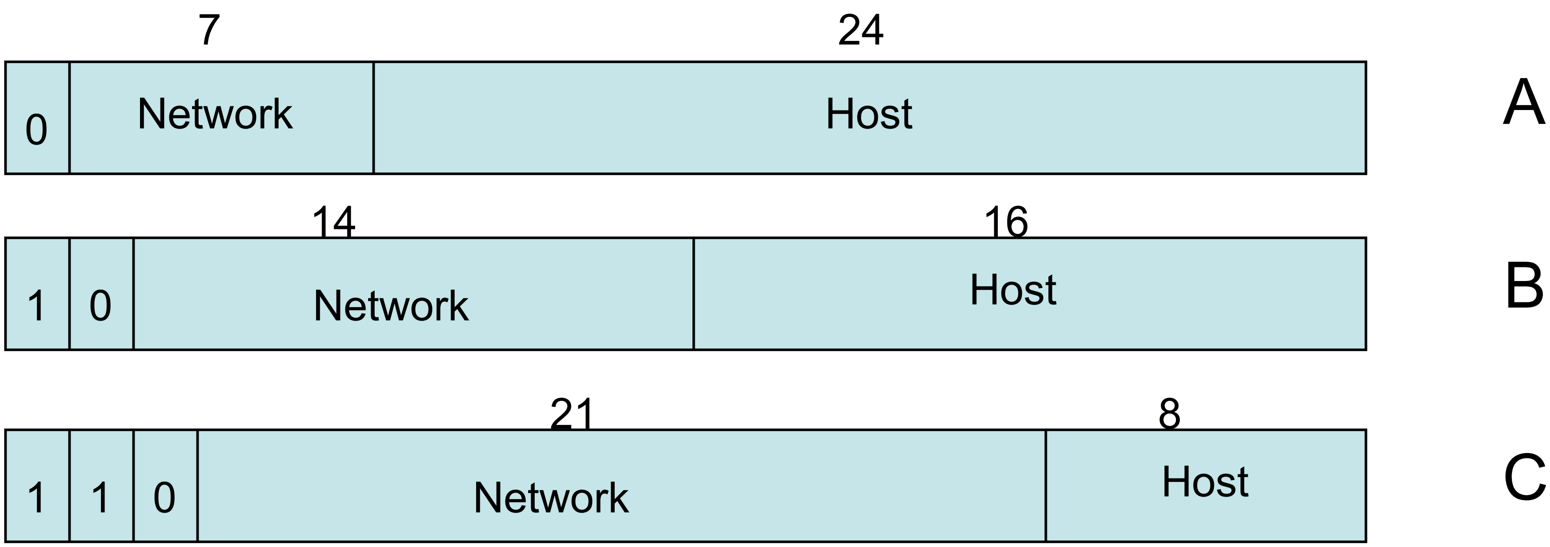
- TTL
  - Time to live (in reality, hop count)
  - 64 is the current default (128 also used)
- Protocol
  - e.g., TCP (6), UDP(17), etc.
- Checksum
  - Checksum of header (not CRC)
  - If header fails checksum, discard the whole packet
- SourceAddr, DestinationAddr
  - 32 bit IP addresses - global, IP-defined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

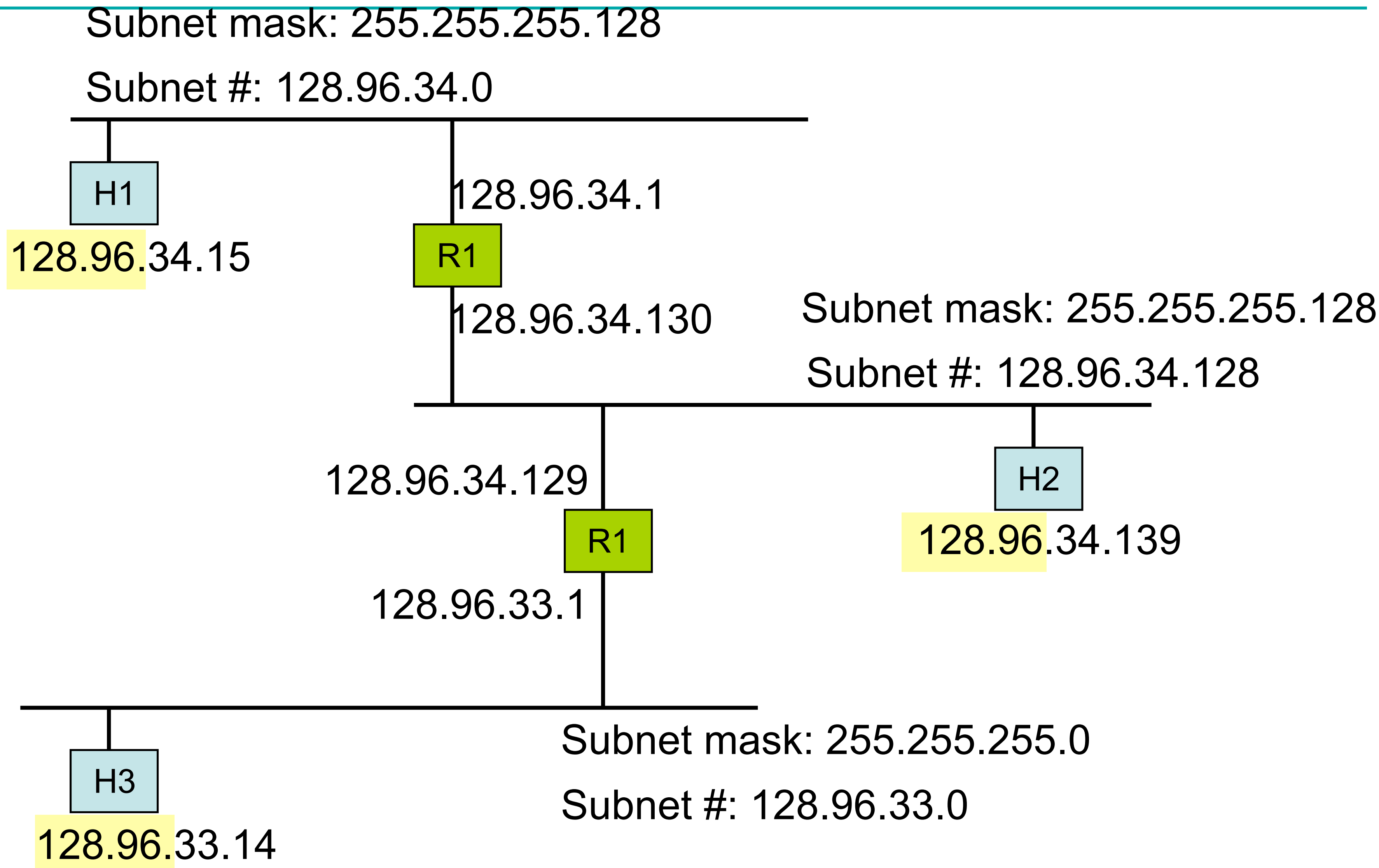
Subnet Mask (255.255.255.0)

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)
```

ARP - Address Resolution Protocol

- Problem:
  - Need mapping between IP and link layer addresses.

- Solution: ARP
  - Every host maintains IP–Link layer mapping table (cache)
  - Timeout associated with cached info (15 min.)
- Sender
  - Broadcasts “Who is IP addr X?”
  - Broadcast message includes sender’s IP & Link Layer address
- Receivers
  - Any host with sender in cache “refreshes” time-out
  - Host with IP address X replies “IP X is Link Layer Y”
  - Target host adds sender (if not already in cache)

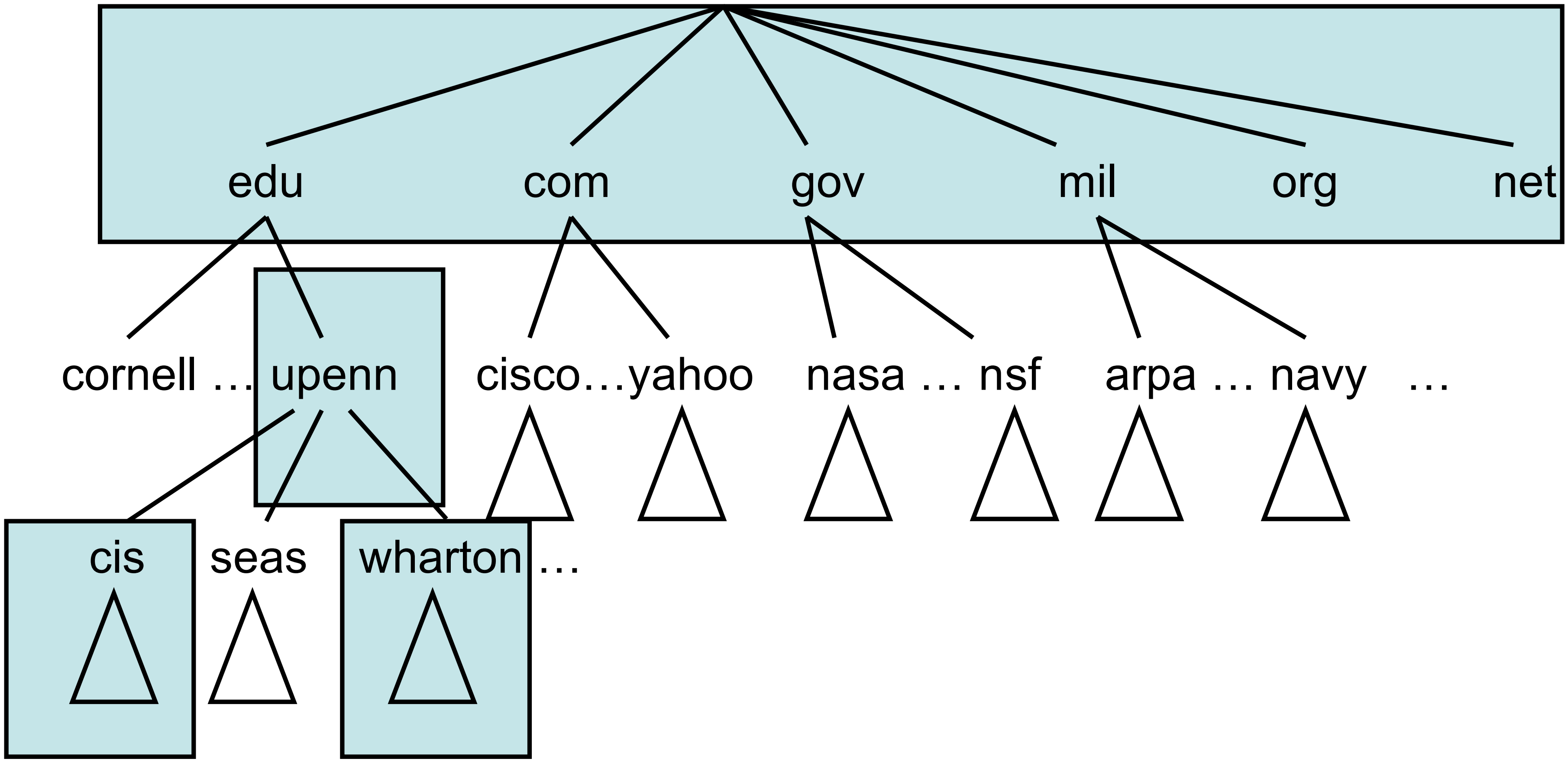
ICMP: Internet Control Message Protocol

- Collection of error & control messages
- Sent back to the source when Router or Host cannot process packet correctly
- Error Examples:
  - Destination host unreachable
  - Reassembly process failed
  - TTL reached 0
  - IP Header Checksum failed
- Control Example:
  - Redirect – tells source about a better route

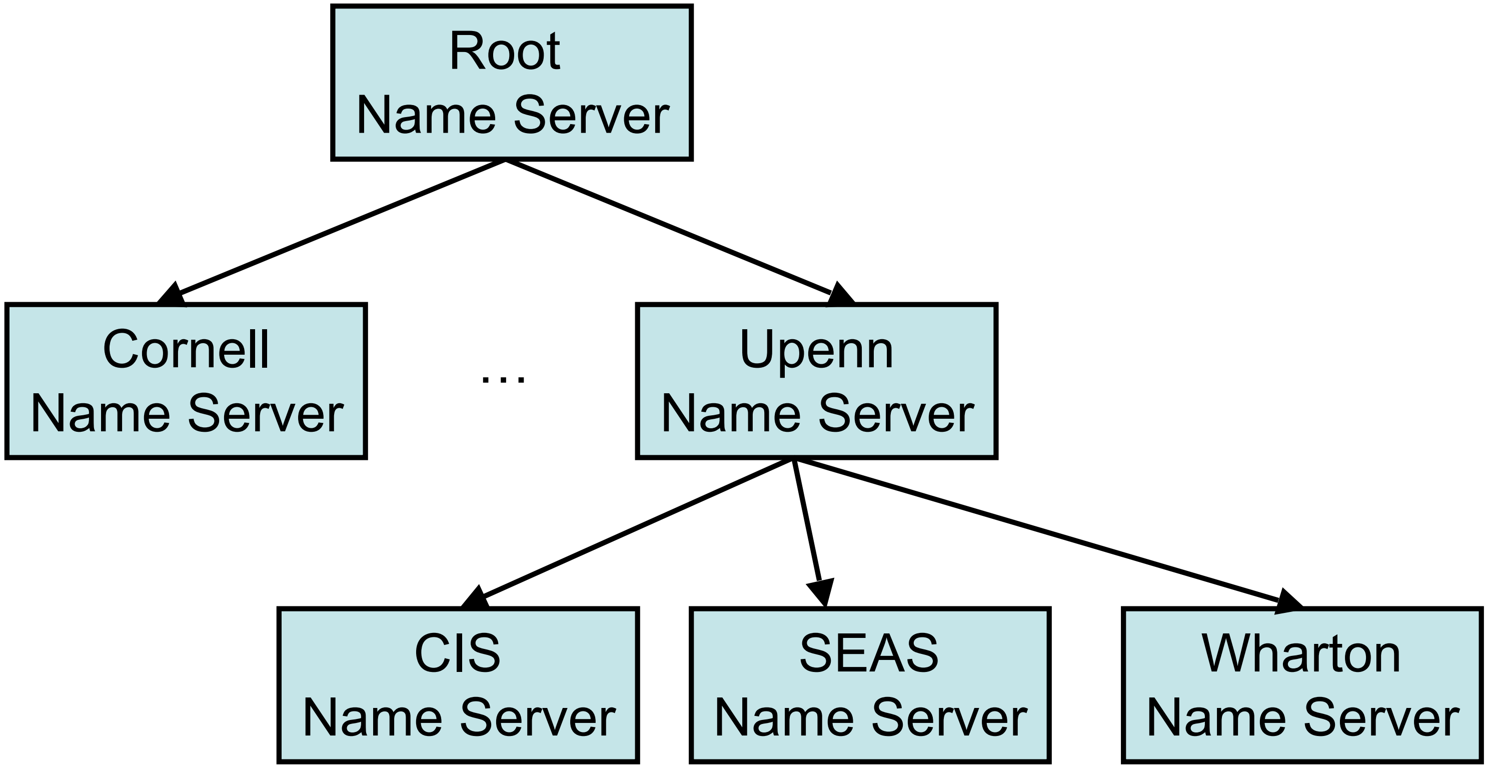
Domain Name System

- System for mapping mnemonic names for computers into IP addresses.
  zeta.cis.upenn.edu → 158.130.12.244
- Domain Hierarchy
- Name Servers
- Name Resolution

Domain Name Hierarchy



Hierarchy of Name Servers



Records on Name Servers

- < Name, Value, Type, Class >
- Types
  - A Host to address mappings
  - NS Name server address mappings
  - CNAME   Aliases
  - MX Mail server mappings
- Class IN for IP addresses

Name resolution