Network Programming
Game 311

Chapter 2

The Internet

Lecture 5 / Chapter 2
Objectives

- **Review Basic Networking Concepts**

- **Origins**
  - What precursors made the Internet possible?

- **The TCP/IP layer cake**
  - The hierarchy of standards and protocols that drive the Internet

ARPANET

- The Advanced Research Projects Agency Network
- US Department of Defense funded
- December 1969
- Four nodes
  - UCLA
  - UCSB
  - University of Utah
  - Stanford Research Institute

- To provide geographically dispersed scientists with access to geographically dispersed computing power
  - Computers were expensive and rare!
- Used new technology: packet switching

Circuit Switching

- Previous data exchange technology
- Each circuit dedicated to communication between the endpoints using it.
  - Could not be shared with other endpoints until communication complete

Packet Switching

- Breaks communication into **packets**.
- Packets can be sent on shared circuits, interleaved with packets travelling between other endpoints.
- Allows much more efficient use of circuits.

The Layer Cakes

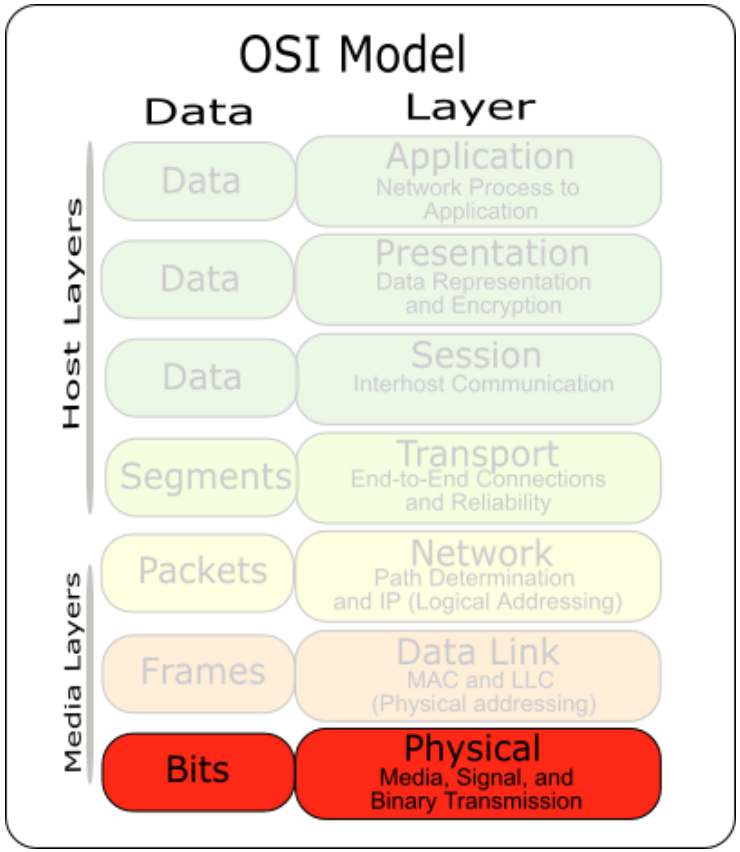
- **OSI**
  - *Open Systems Interconnection*
    - Application
    - Presentation
    - Session
    - Transport
    - Network
    - Data link
    - Physical
- **TCP/IP**
  - Application
  - Transport
  - IP
  - Link
- **Book**
  - Application
  - Transport
  - Network
  - Link
  - Physical

Layer Cake Responsibilities

- Each layer wraps and attempts to deliver data for the layer above it.

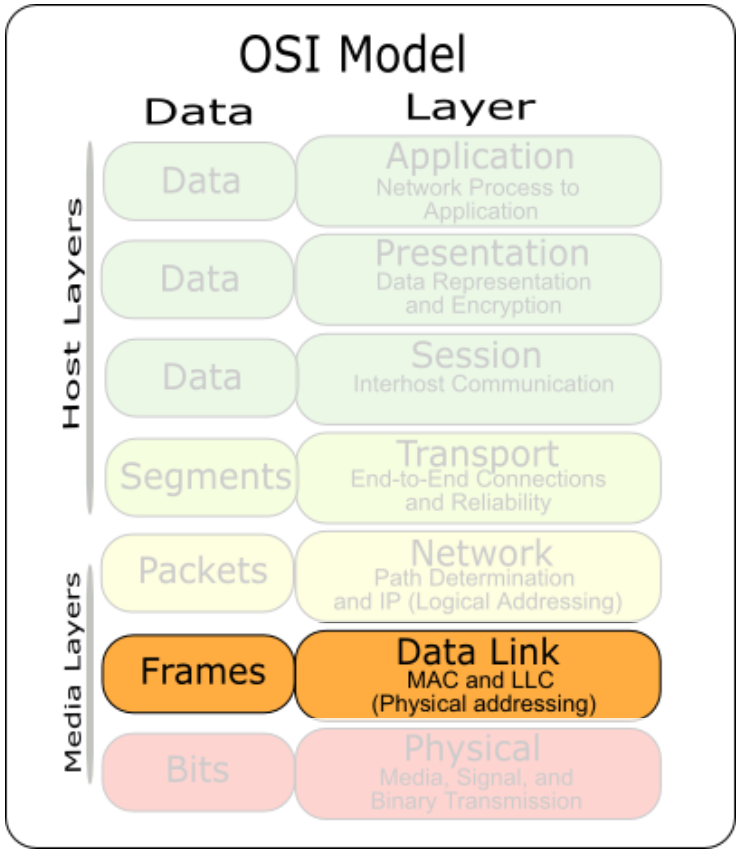
Physical Layer

- Provides path for electrons
  - Ethernet cable (four pairs of copper wire)
  - Fiber
  - Radio transmission / wifi
- Unreliable
  - No guaranteed delivery or ordering



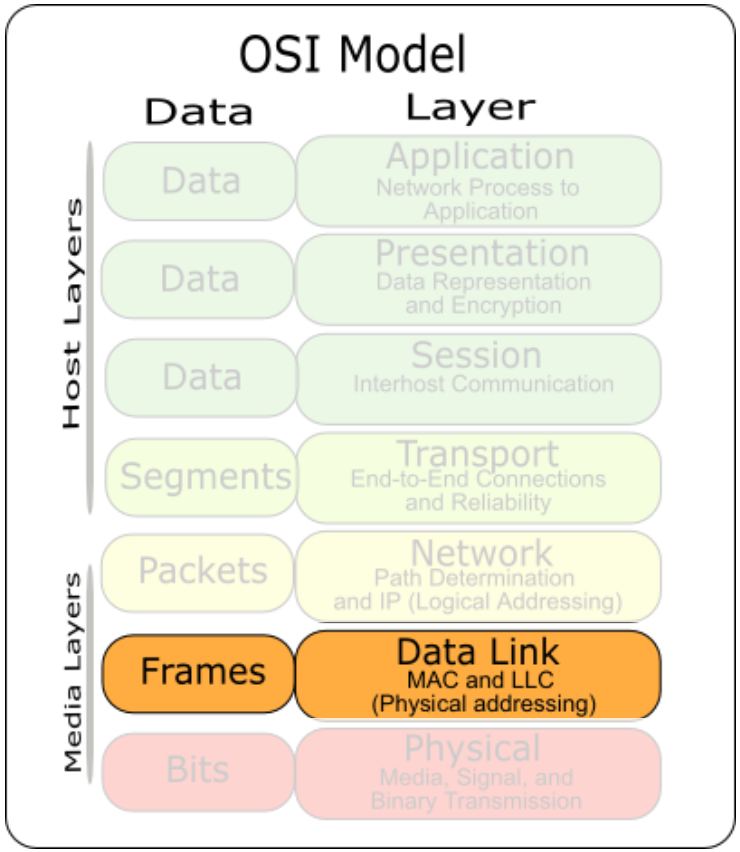
Link Layer

- Provides a transmission channel along the physical layer
  - Ethernet
  - 802.11a/b/g/n/ac (wireless)
  - FDDI (fibre)
- Data unit = Frame
- Unreliable



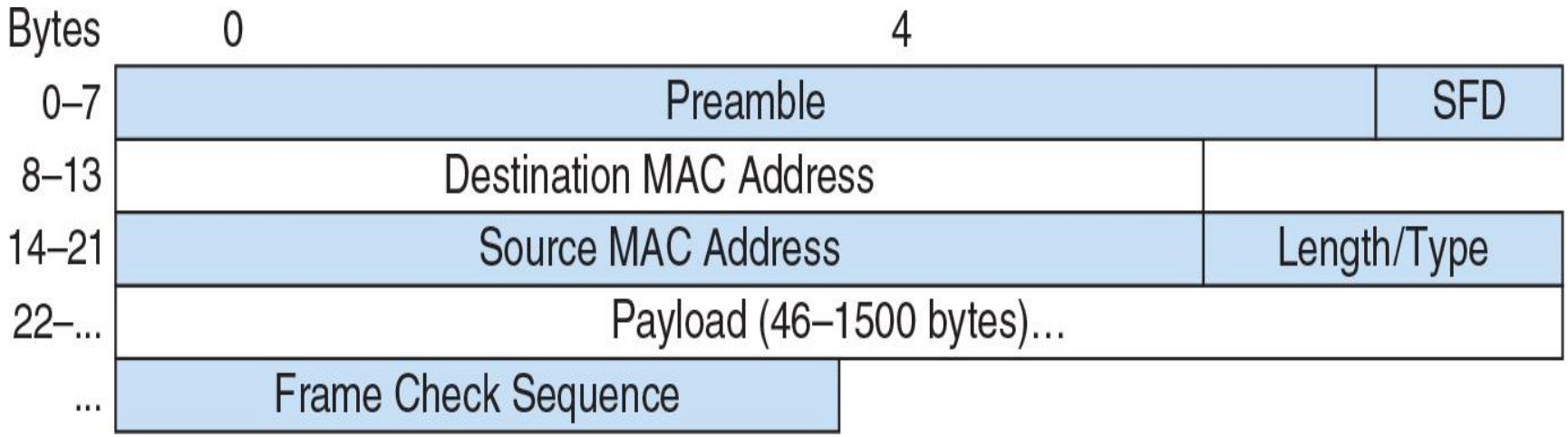
Link Layer

- Maximum transmission unit (MTU)
  - Maximum amount of payload the link layer can send as a unit
    - Not including link layer header
  - IPv4 standard requires >= 68
  - Ethernet v2 1500 bytes (most common Ethernet)
  - FDDI 4352
    - *(Fiber Distributed Data Interface)*
  - 802.11 7981 bytes



Ethernet

- Most commonly used link layer protocol
- Multiple speeds on various physical media, including 100 Mbps, 1 Gbps, 10 Gbps

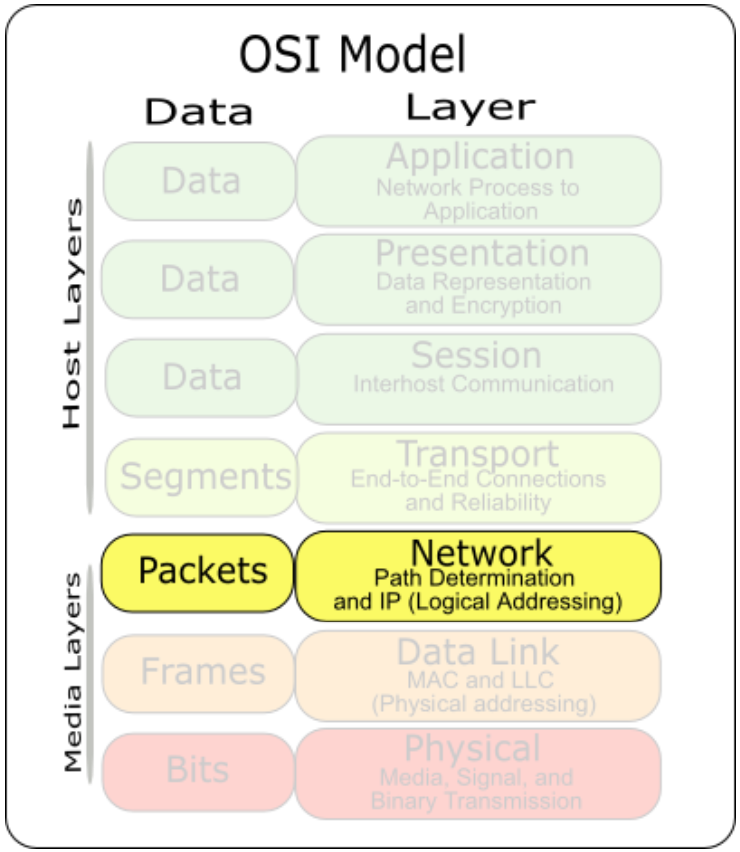


MAC Address

- Also known as Physical Address.
- 48-bit unique address
- Assigned by manufacturer
  - First 24 identify manufacturer
  - Next 24 unique within manufacturer
- Identifies Ethernet device for sending and receiving at the link layer

Network Layer

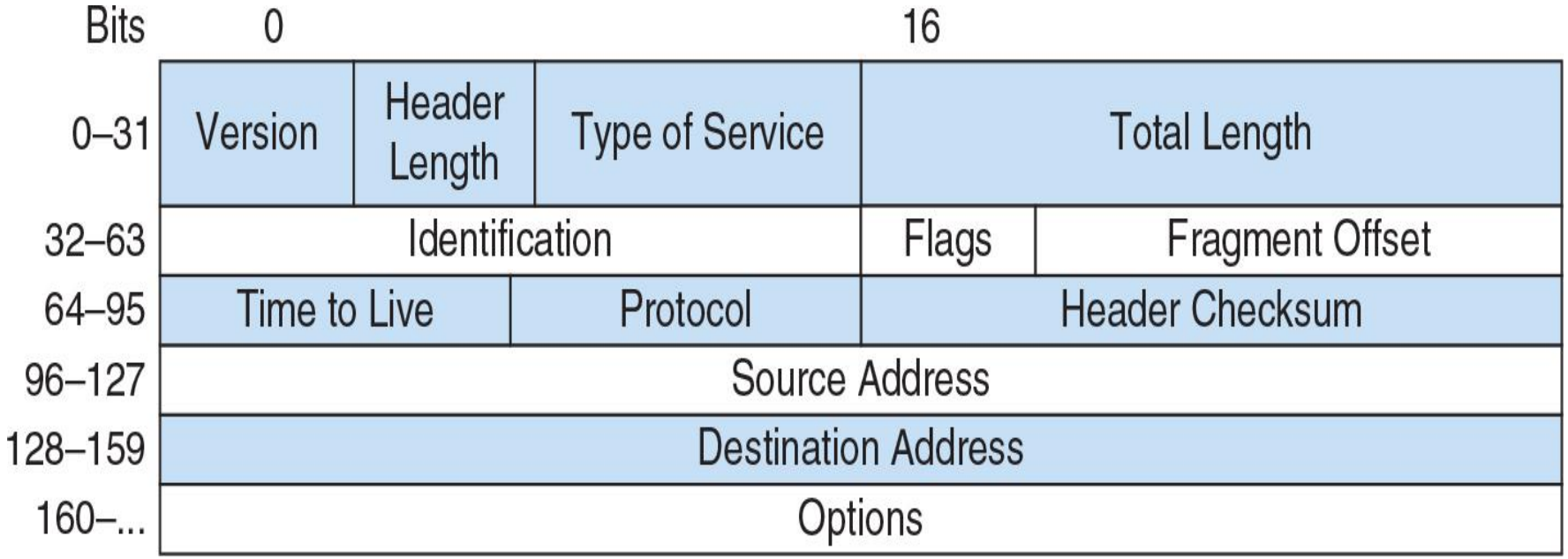
- Routes data from host to host
  - Across networks and even link layer protocols
- Data units = **packets**
- IP (IPv4 / IPv6), ICMP, et al.
- Unreliable
- Each host has
  - IP address
    - 128.125.253.146 is www.usc.edu in IPv4
  - Gateway address (router address)
  - Subnet mask (local network IP section)



Subnet

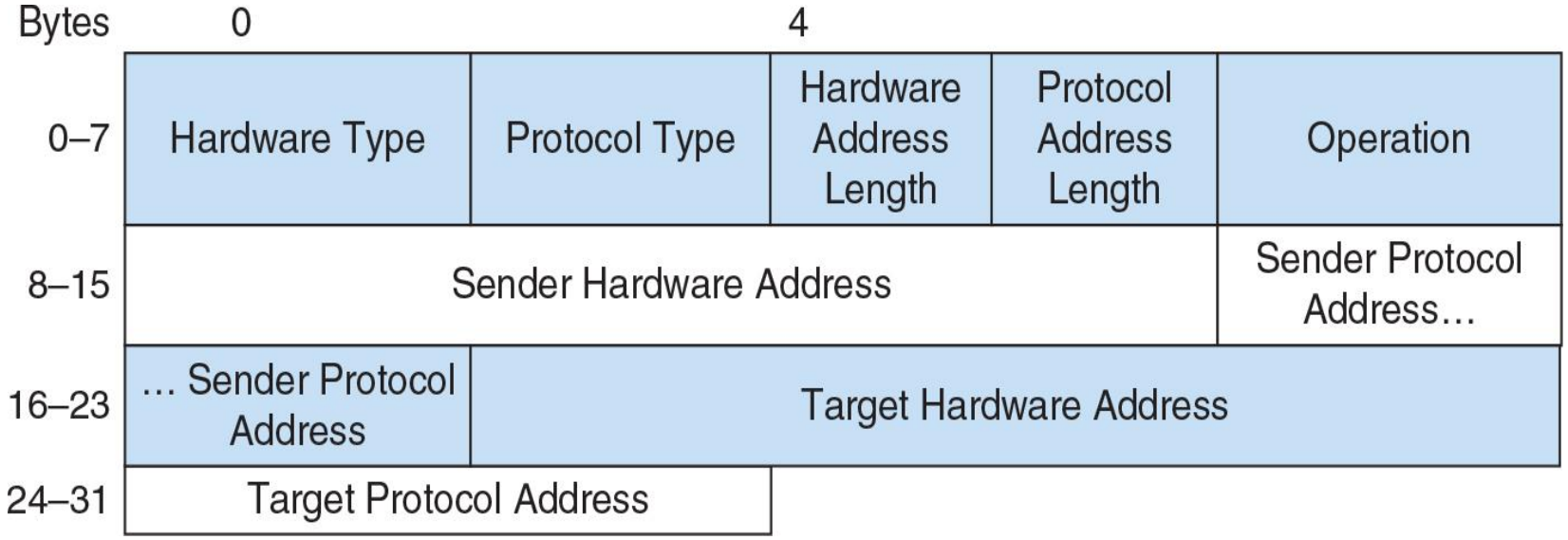
- A group of hosts on a network that communicate without an external router.
- **Subnet mask** defines subnet:
  - 255.255.0.0 = 11111111 11111111 00000000 00000000
  - isSameSubnet = ((ip1 & netmask) == (ip2 & netmask))
  - 192.168.1.10, 192.168.2.20 same subnet, 192.169.1.10 is not
  - Classless interdomain routing notation (CIDR)
    - IP/X, where X is number of significant bits in IP address that match

IPv4

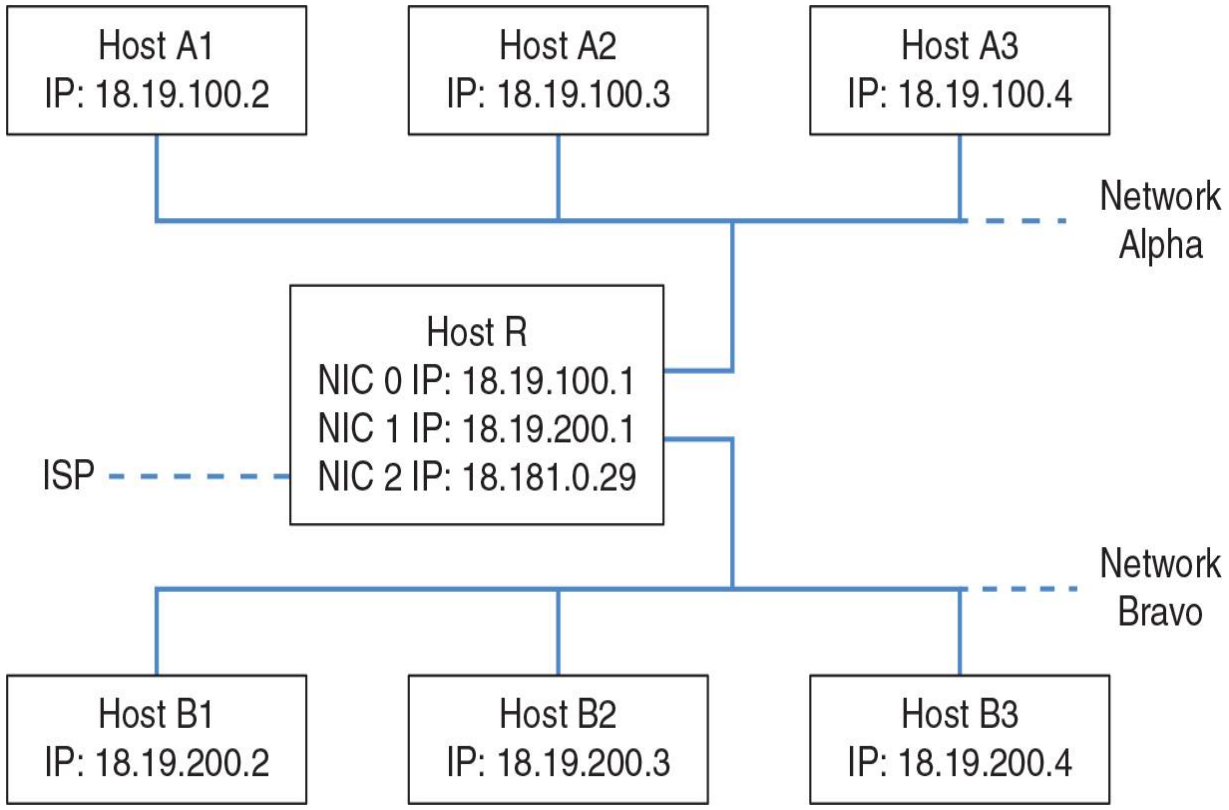

Bits
0
16
0–31
Version
Header Length
Type of Service
Total Length
32–63
Identification
Flags
Fragment Offset
64–95
Time to Live
Protocol
Header Checksum
96–127
Source Address
128–159
Destination Address
160–...
Options

ARP: Address Resolution Protocol

- Provides way for hosts to determine MAC address of host with a given IP address.
- Each host on local network maintains a map.
  - Can send frames directly to desired MAC address



Indirect Routing



Fragmentation

- MTU at the link layer for Ethernet v2 is 1500 bytes.
- Max packet size is 65535 bytes
  - If we go beyond the size, we have to fragment the data into multiple packets.
- Each fragment gets
  - Identification: Unique ID for packet
  - More Fragments flag (0x4) (except the last)
  - Fragment Offset into packet

Fragmentation

- Why is fragmentation bad?
  - Must buffer incoming fragments to reassemble.
  - Must spend time reassembling.
  - If one fragment is lost, whole packet is lost.
  - Must spend bandwidth on one header per fragment.
- Why is fragmentation good?
  - Higher layers can send more data at once and not worry about underlying MTUs.

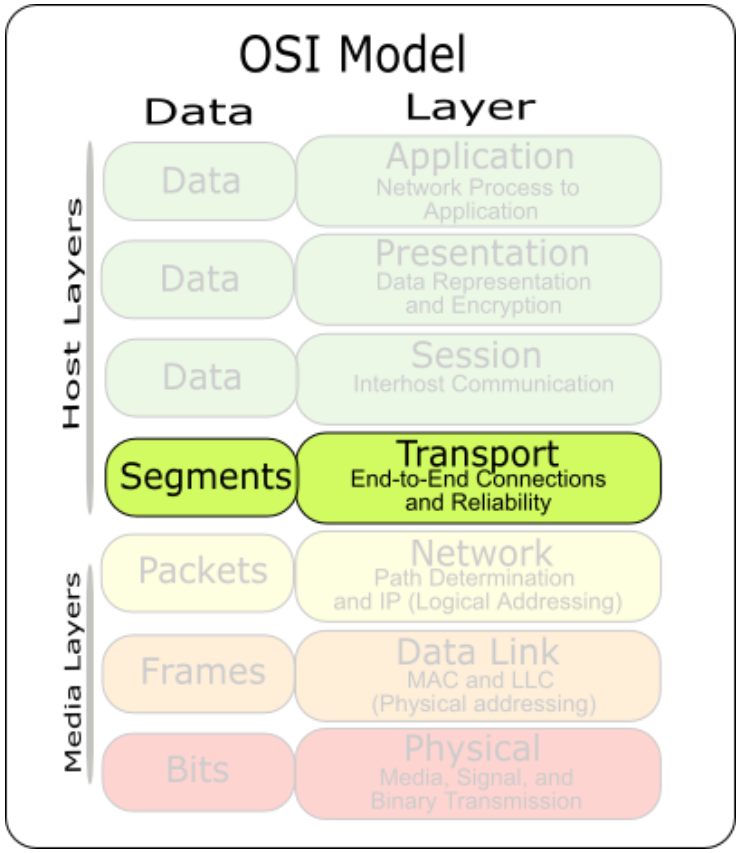
More Header Fields

- Time To Live (TTL)
  - Decremented by one each time packet goes through a router
  - Prevents Internet clogging up due to bad routing

- Protocol
  - Tells host which protocol to use at the the transport layer to interpret the packet

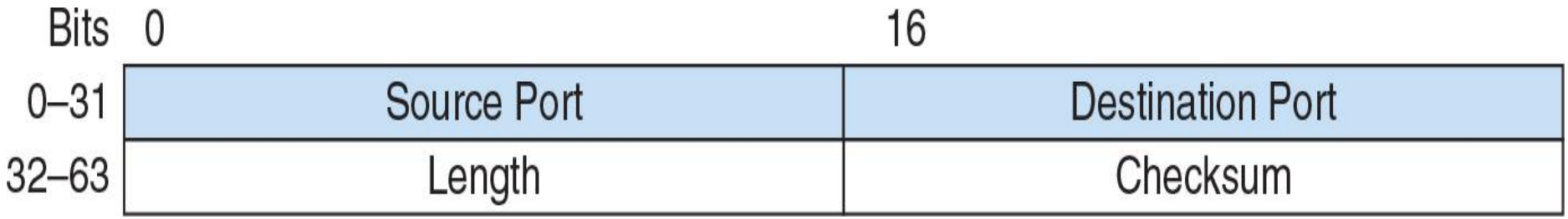
Transport Layer

- Implements end-to-end communication between two processes
- Data units = **datagrams** or **segments**
- **Ip Protocol Numbers:**
  - TCP (6)
  - UDP (17)
  - SCTP(132)
  - Etc…



UDP: User Datagram Protocol

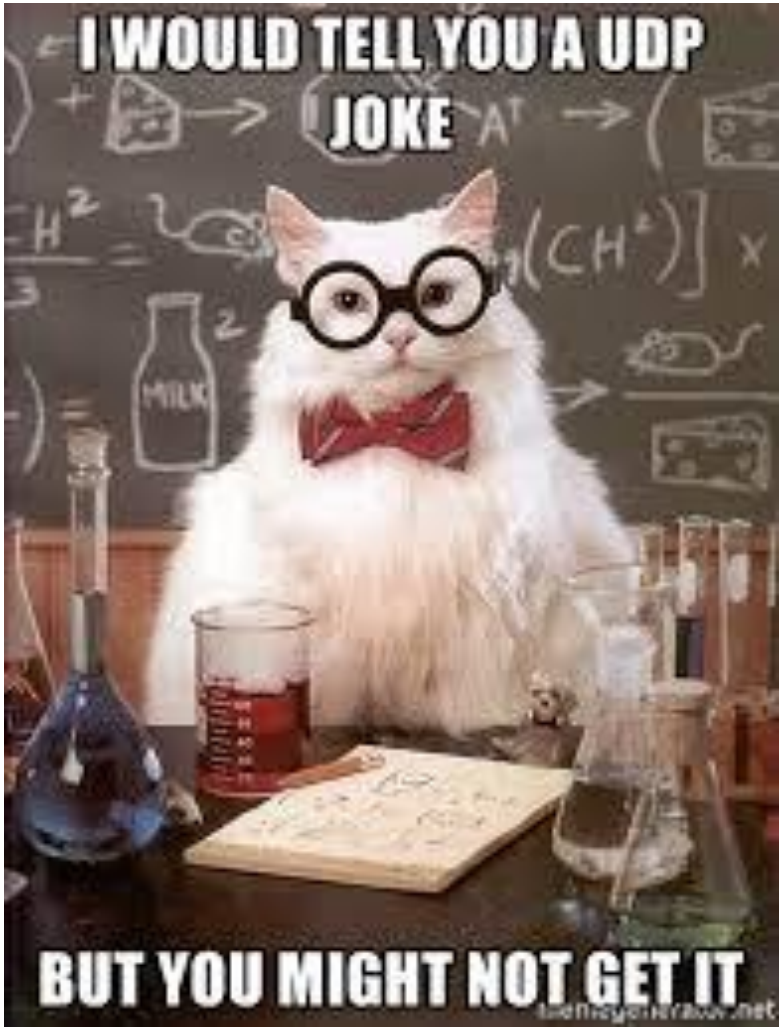
- Introduces **ports**
  - Solves problem of where data goes when it arrives
- Adds checksum to detect corruption of entire segment



Ports

- 0-1023 are **system ports** or **reserved ports**
  - Reserved with port authority for specific use
  - Sometimes require escalated privileges.
- 1024-49151 are **user ports** or **registered ports**
  - Reserved with port authority for specific use
- 49152-65535 are **dynamic ports**
  - Free for all

Problems with UDP



- Offers no guarantees over the underlying network layer, which means it too is Unreliable
  - Datagrams might arrive out of order
  - Datagrams might arrive twice
  - Datagrams are not guaranteed to arrive at all

Lecture / Chapter 2
Summary

- **Reviewed Basic Networking Concepts**

- **Origins**
  - What precursors made the Internet possible?

- **The TCP/IP layer cake**
  - The hierarchy of standards and protocols that drive the Internet