Overview

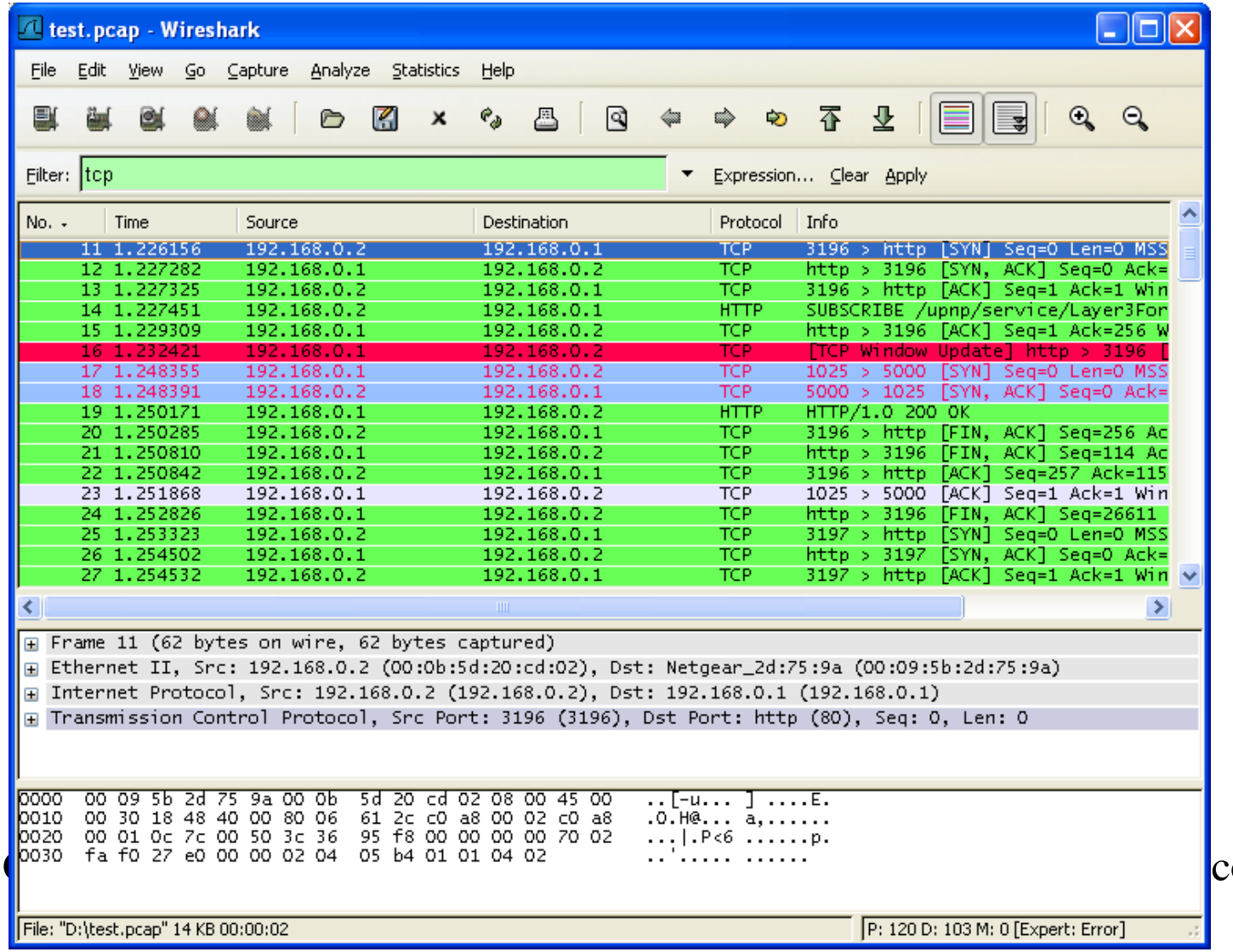
- Last Lecture
  - Introduction
- This Lecture
  - Network Hardware and Protocols
  - Reference:
- Next Lecture
  - IPv6 Bootcamp

OSI model

- OSI model
  - Seven layers: physical, data link, network, transport, session, presentation, application
  - Protocol encapsulation
  - Five layers in Internet: physical, data link, network, transport, application (including presentation and session layers of OSI model),
- A guideline for writing network software and understanding the principle of internetworking
- You can't see the layers as a network user

Wireshark

- The best way to understand the OSI model



COS cols

Twisted-pair cables

- Network cables: physical layer
- Twisted-pair categories
  - Cat 1 and 2, Cat 3, Cat 4, Cat 5 and 5e, Cat 6
- Crosstalk
  - Signal crosstalk occurs when the signals in one wire are eletromagnetically coupled (or cross over) into another wire. This happens because wires in close proximity to one another can pick up each other's signal.
  - Problem: phantom collisions can be detected.

Structured cabling

- High-quality cabling is essential to network performance
- Structured cabling provides a reliable and manageable cabling system
- TIA/EIA cabling standards
  - Telecommunications Industries Association (TIA)
  - Electronic Industries Association (EIA)
  - Refer to *Ethernet: The Definitive Guide*

Structured cabling

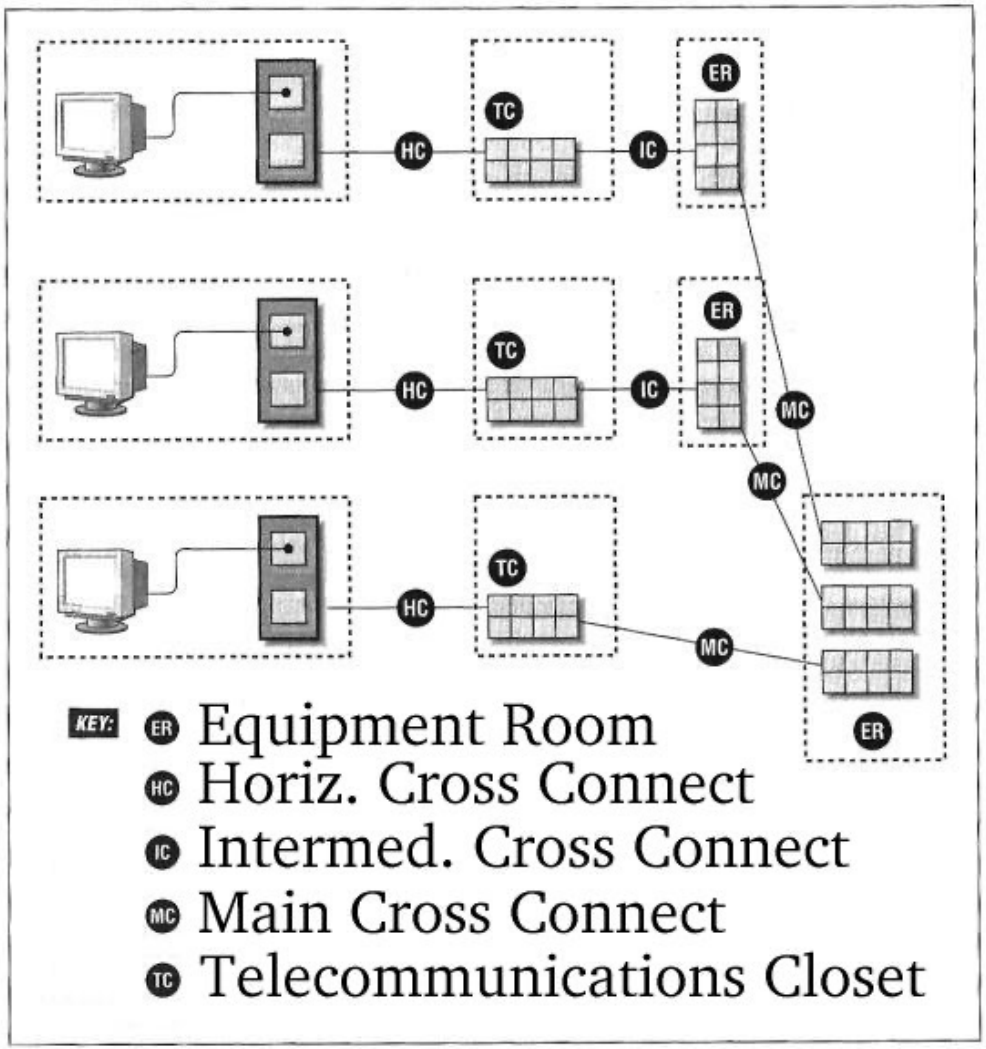


Figure 14-1. Elements of a structured cabling system

Switches

- Switches:
  - involves physical layer and data link layer
  - mainly work at Medium Access Control (MAC) sublayer of the data link layer.

Autonegotiation and flow control

- How can a NIC work with different cables with different speed?
- How can a slow NIC handle fast traffic from a fast NIC?
- Autonegotiation is defined in IEEE 802.3
  - Two connected devices can choose common transmission parameters such as speed
  - Media Independent Interface (MII) defined by IEEE 802.3u
  - Implemented in NICs and switches.

Key components

- Router (up to layer 3)
  - Route and forward network packets (up to OSI layer 3)
  - called gateway in Linux network config, but different from the gateway below
- Firewall (up to layer 3 or 4)
  - a dedicated software (maybe with hardware support), which inspects network traffic passing through it, and denies or permits passage based on a set of rules.
- Gateway (up to application layer)
  - a device that serves as an entrance for an application like email in an organization.
  - similar to a firewall, but has more knowledge of application protocols and better security.

Network Interface Card (NIC)

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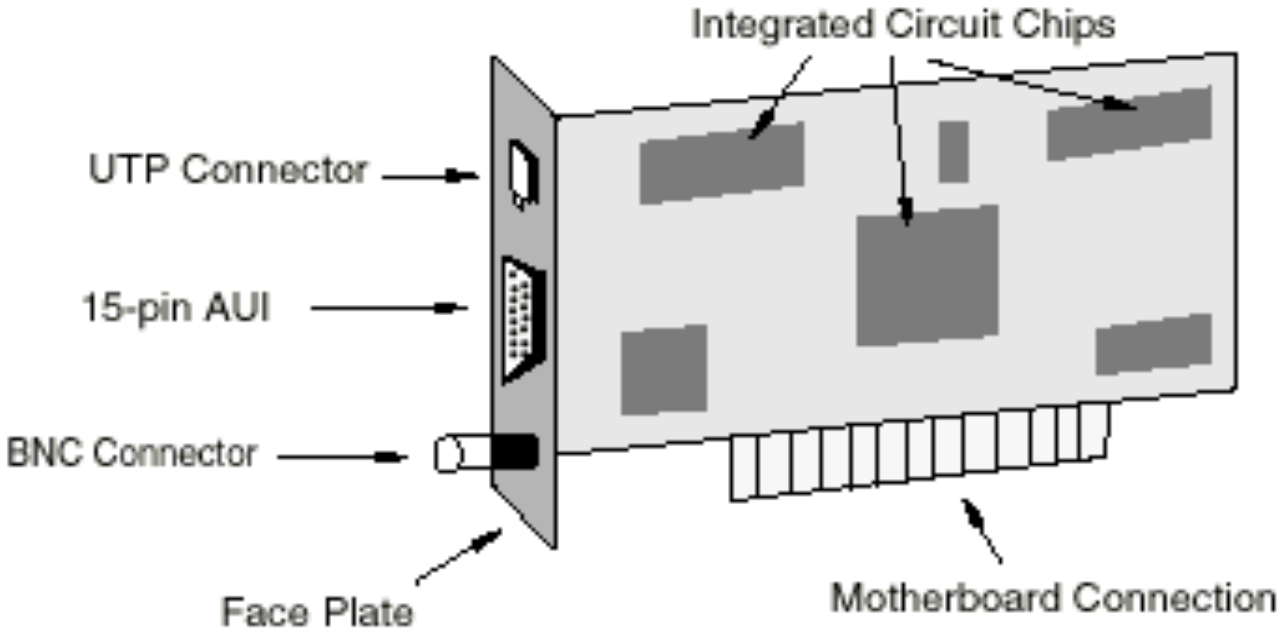
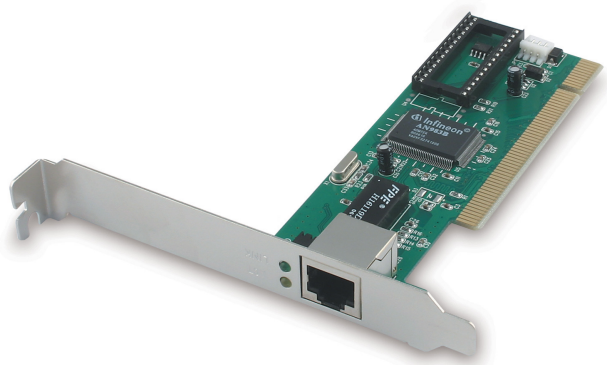
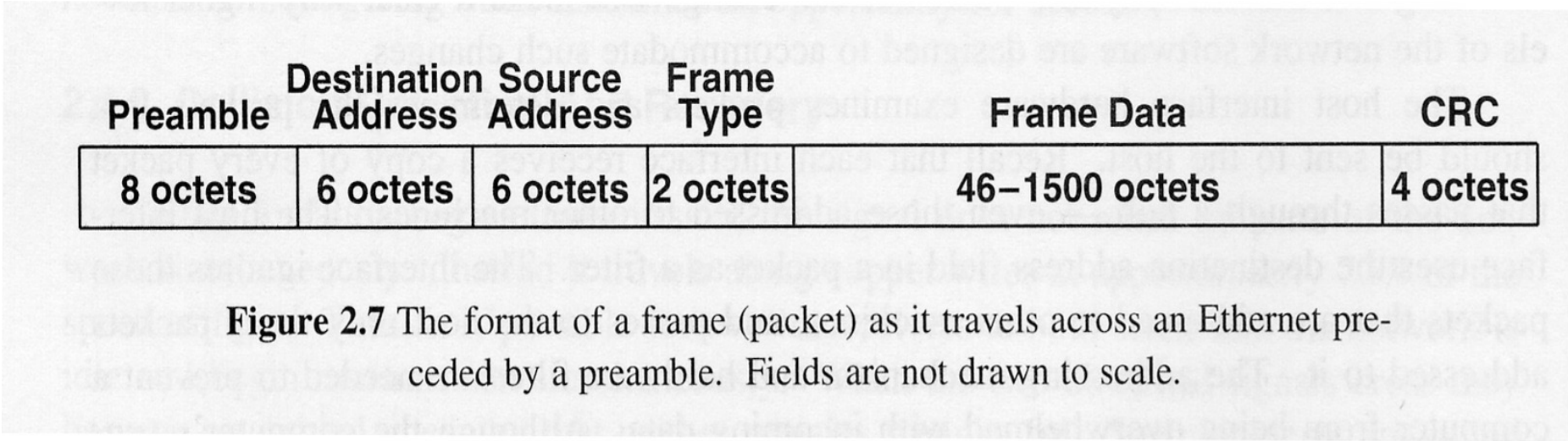




Network Interface Card (NIC)

- Network Interface Card (NIC)
  - CSMA/CD
  - Network device driver is used by OS to interact with NIC. An interrupt is used when a request is completed or when a packet arrives.
  - DMA: Direct Memory Access is used to copy data from NIC (device) memory to main memory (RAM)
  - Protocol stack: layer 1, layer 1.5 (MAC)

Ethernet frame



Preamble	Destination Address	Source Address	Frame Type	Frame Data	CRC
8 octets	6 octets	6 octets	2 octets	46–1500 octets	4 octets

Figure 2.7 The format of a frame (packet) as it travels across an Ethernet preceded by a preamble. Fields are not drawn to scale.

- MAC address: six octets for Ethernet NIC
  - 3b-00-65-fa-4a-68
- Frame type serves two purposes
  - Length (<=1500)
  - Frame type (>= 1536 or 0x0600), 0x0800 for IPv4 packet, 0x86dd for IPv6

Internet Protocol

- IPv4 and IPv6
- IP address (IPv4)
  - 4 bytes (octets), e.g. 132.65.33.24
  - Traditionally addresses are divided into class A, B and C
  - Classless Inter-Domain Routing (CIDR)
    - Use netmask to decide the network address such as 255.255.255.0

IP packet

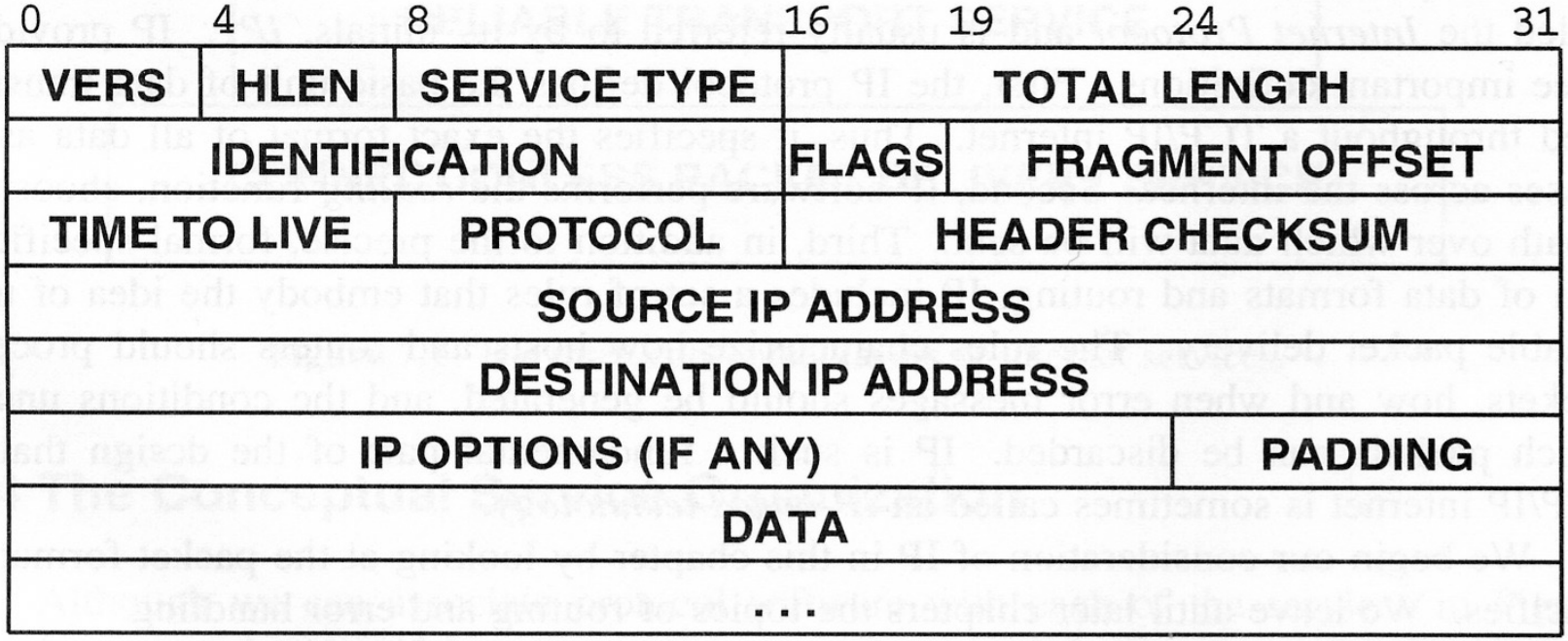


Figure 7.3 Format of an Internet datagram, the basic unit of transfer in a TCP/IP internet.

UDP datagram

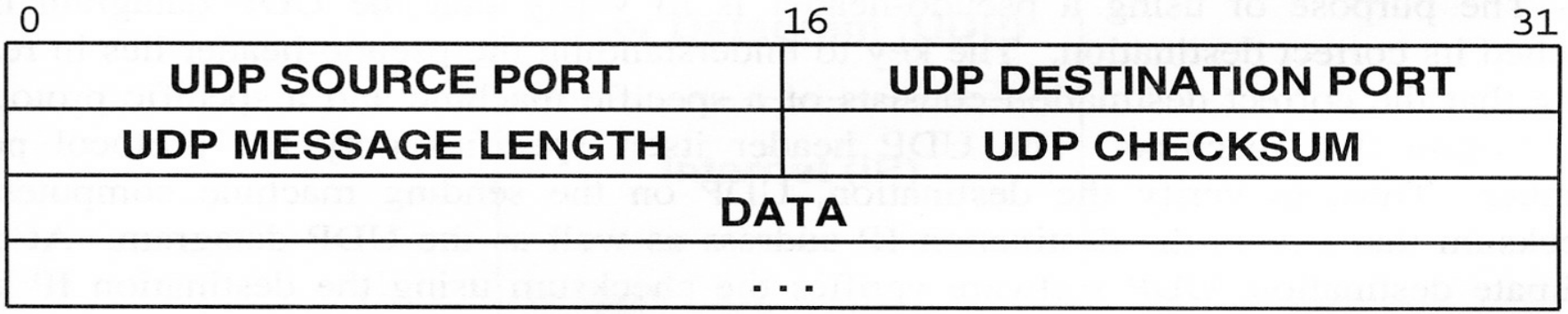


Figure 12.1 The format of fields in a UDP datagram.

- Port number is used to distinguish different applications such as email (25) and www (80).

TCP segment

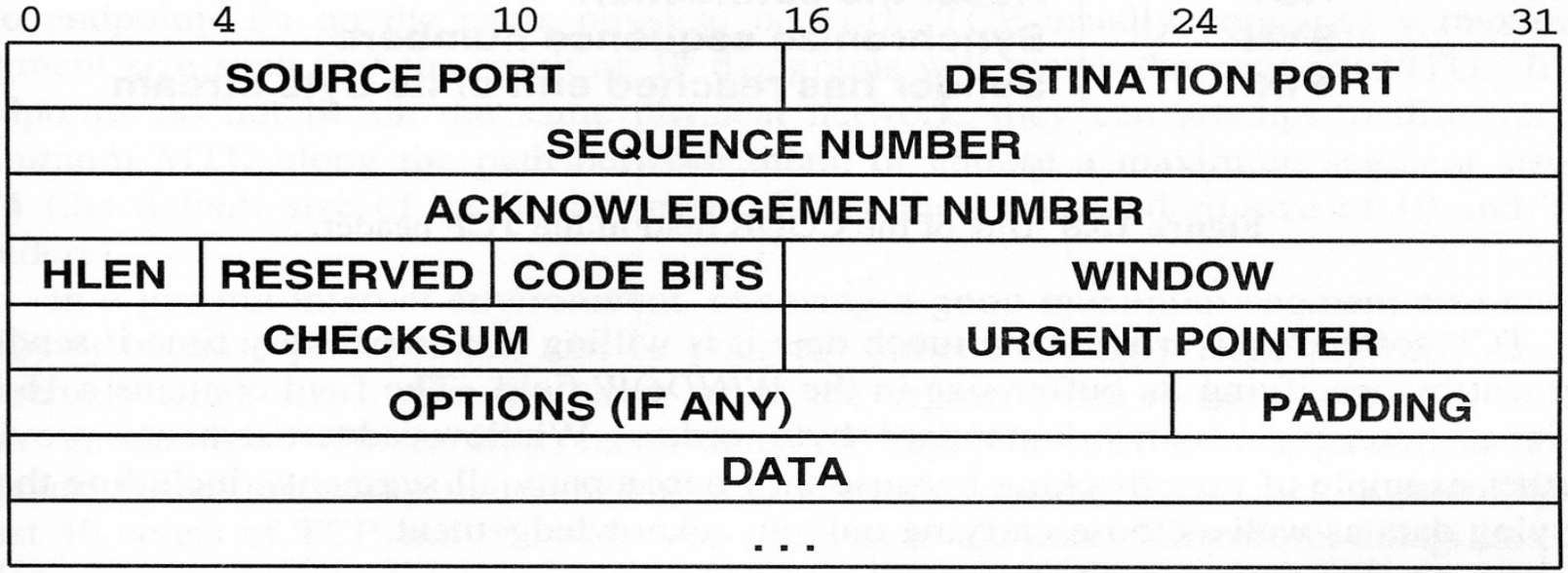
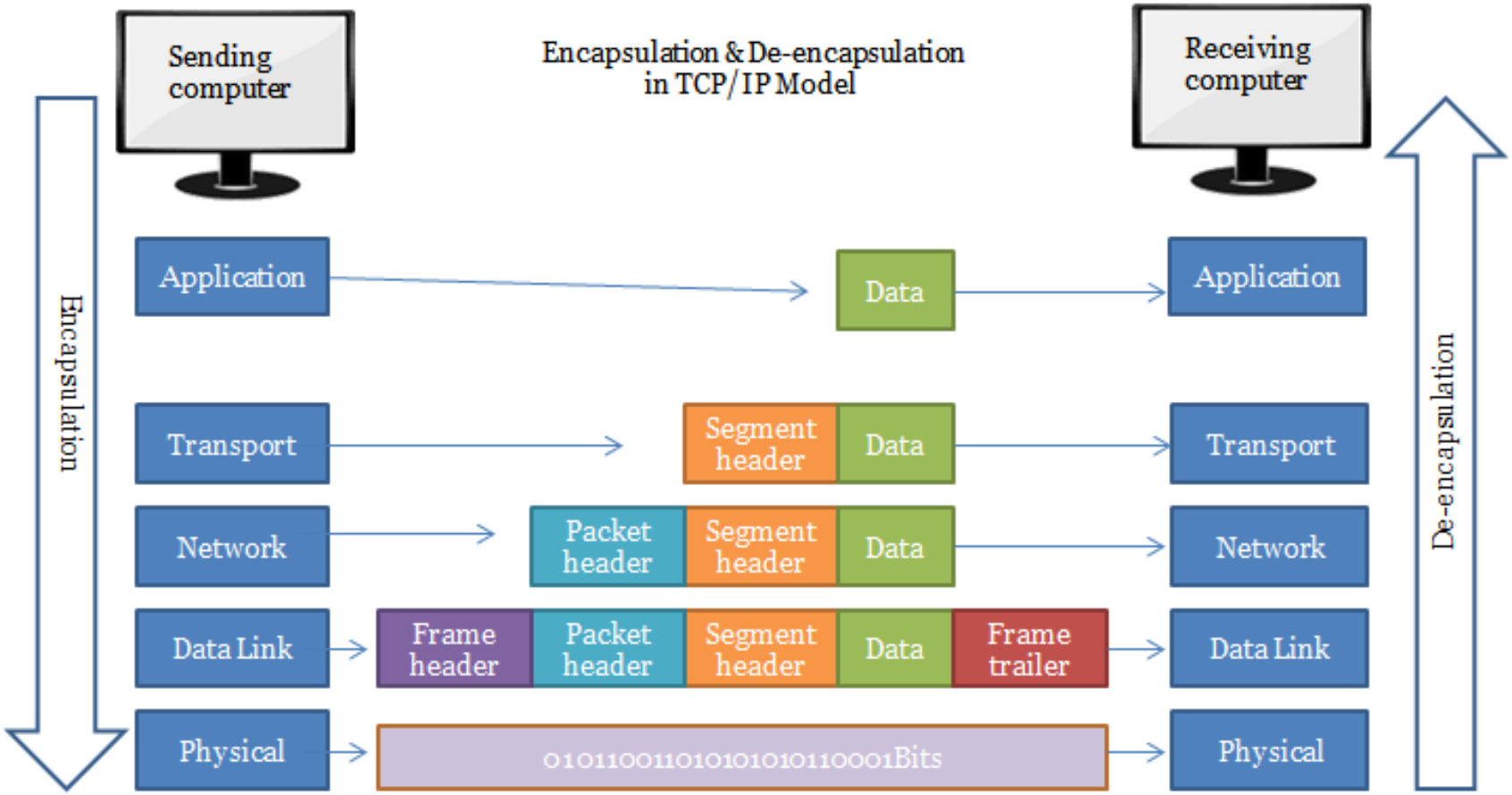


Figure 13.7 The format of a TCP segment with a TCP header followed by data. Segments are used to establish connections as well as to carry data and acknowledgements.

TCP/IP protocol layers

- Application layer like email (smtp), web (http, https)
- Transport layer: TCP and UDP
- Network layer: IPv4 and IPv6
- Data link layer: Ethernet, Token Ring
- Physical layer: Manchester encoding, WiFi radio signals

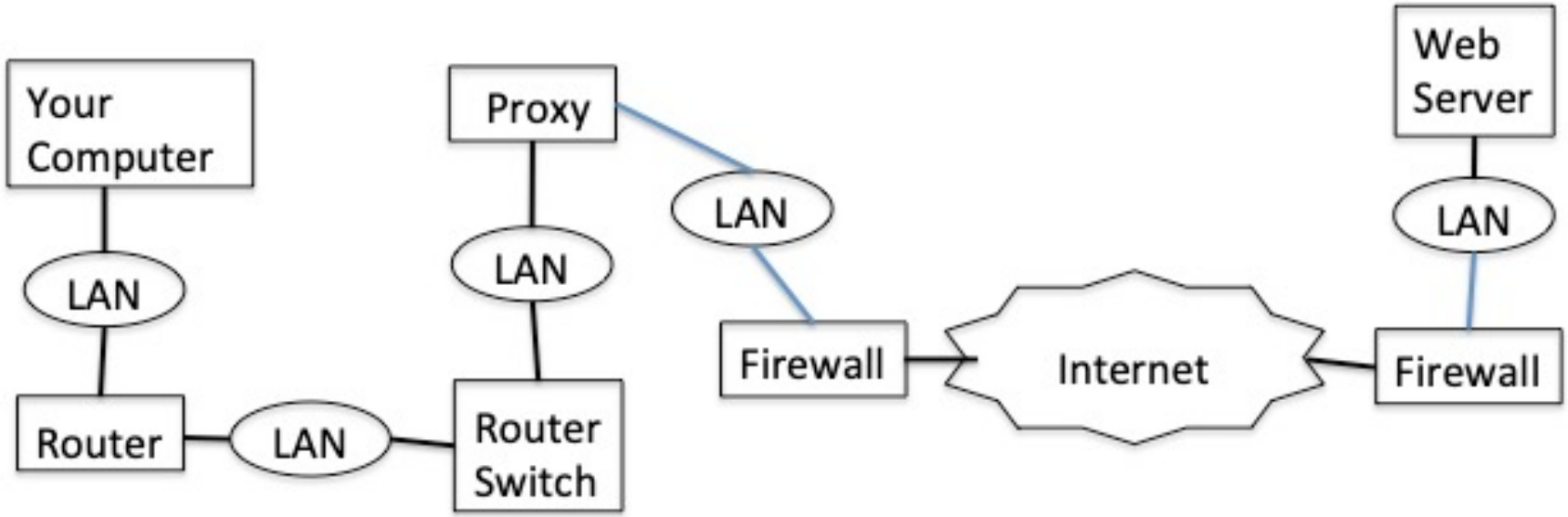
Packet Encapsulation

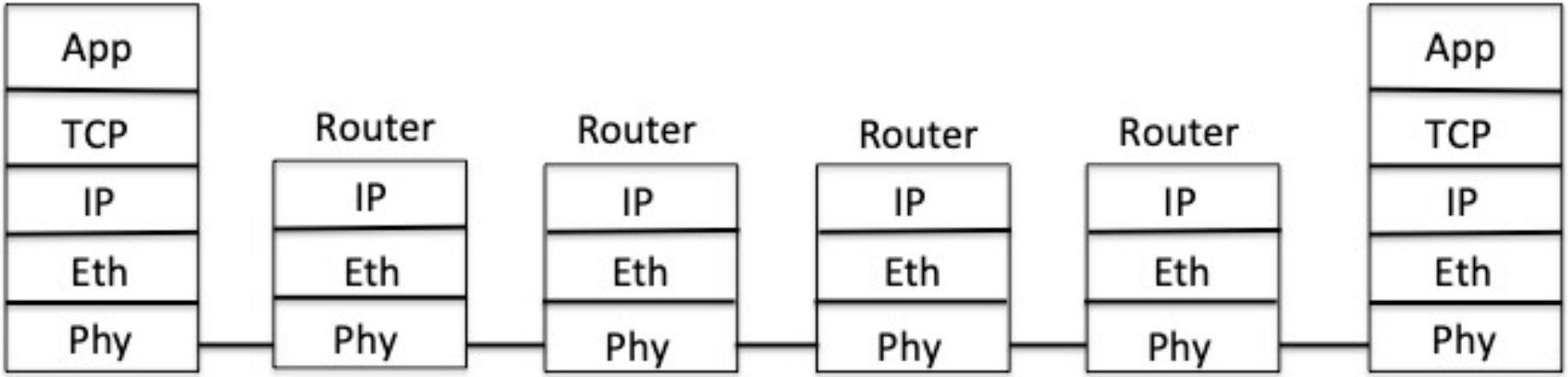


Client/server model

- Many network functions are implemented in client/server model at the application layer
  - Client: make a request
  - Server: process requests from clients and reply
- Clients and servers are programs.
  - Many servers are just installed on a single powerful machine for easy administration. Therefore that machine is normally called a “server” machine.
  - Port numbers/well-known port numbers are used to find the different services on the same server machine.

The journey of an IP packet – a holistic view





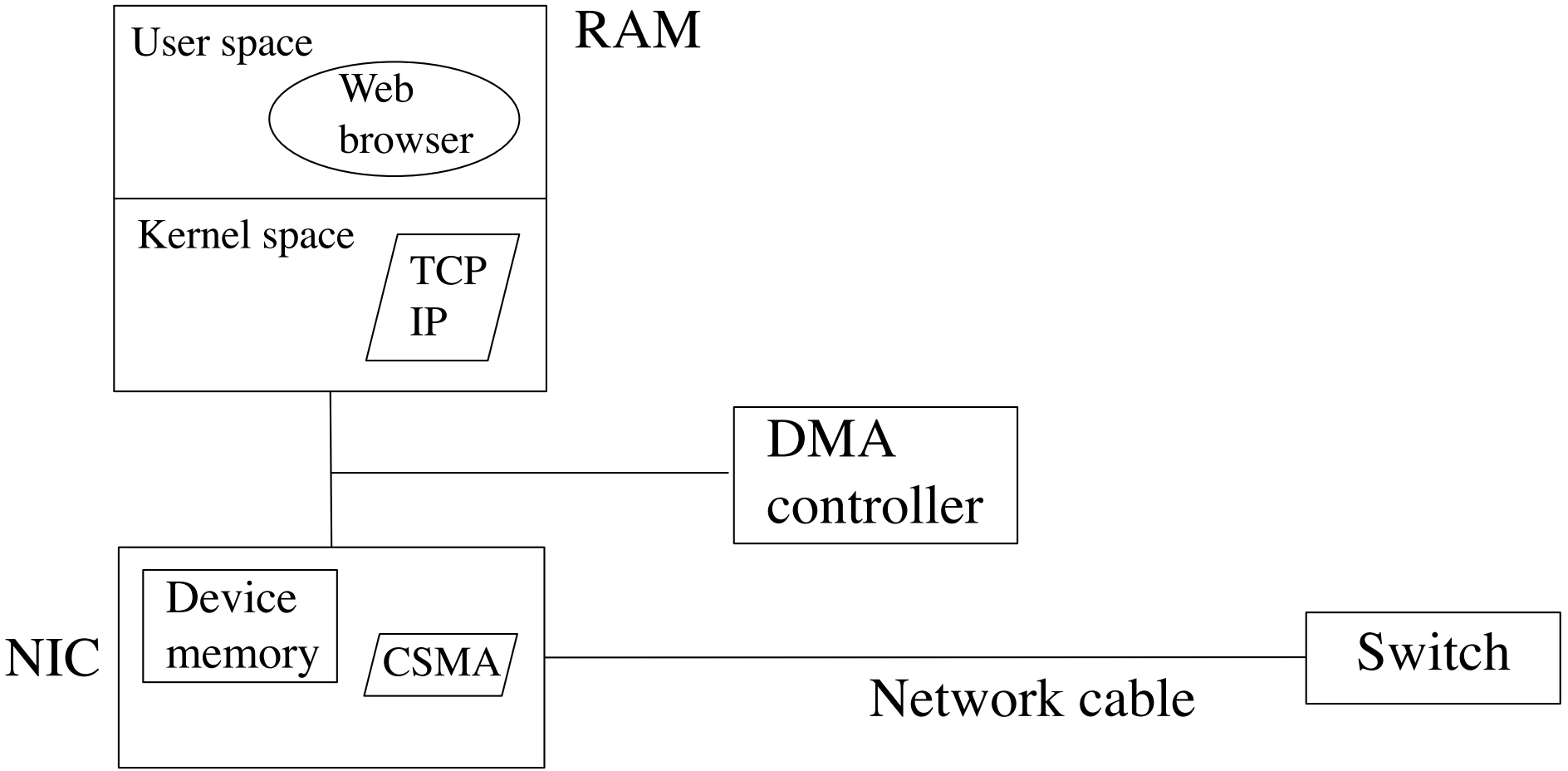
Kernel space and user space

- The memory of a computer system (like a client or server machine) is separated into kernel space and user space.
- User data like email or HTTP request are in user space but transferred to the kernel space for processing via system calls.
- Functions like TCP/UDP, IP are in the privileged kernel space and handle the encapsulation of packets like creating headers for the packets or frames and the sending/receiving of the packets.

Data path between client/server

- Copy data from the user process (user memory) to socket in OS kernel (kernel memory)
- Add headers to the data to make a frame
- Copy to NIC memory using DMA
- Send the frame by NIC to the/a router
- The IP packet travels from router to router, finally to the server
- Receive the frame by the NIC of the server
- NIC sends interrupts to CPU
- CPU invokes NIC driver to copy the frame to RAM (using DMA)
- Headers are processed by related protocols
- Copy data from the receiving socket (kernel memory) to the buffer of the user process (maybe a web server)

Data path inside a computer



Summary

- Which OSI layers are these devices involved?
  - switch, router, firewall, gateway.
- How is an email sent from a client machine to an email server like Google Gmail in Internet?