Network Protocols

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Introduction

Outline

- Introduction
- Internet Layers
- Internet Data Packet transmission and Addressing
- Network Protocols
- A glimpse at the OSI model and Internet protocol suite

Introduction 1/2

- What is a network? Set of nodes connected by communication links
  - Components
    - ✓(Network edge) Computing devices (end hosts, PDAs, …) connected to the network
    - ✓(Network core) Routers/switches that move data through the network
    - ✓(Media) Physical links that carry information (fiber, copper, radio, and satellite)
    - ✓Applications that communicate with each other to provide services (Email, file transfer, and Web browsing).
- What is an internetwork? A network of networks (an internet)
  - Specific example is the ***Internet***

Introduction 2/2

- Network physical topology
  - ➢ Geometric representation of the relationship of all the links and nodes to one another
  - ➢ Categories: *mesh*, *star*, *bus*, and *ring*
- Network Categories
  - Local-Area Network (LAN)
  - Metropolitan-Area Network (MAN)
  - Wide-Area Network (WAN)
  - Personal-Area Network (PAN)

The Internet 1/2

- ARPA (Advanced Research Projects Agency) in DoD wanted to find a way to connect computers that were stand-alone in mid 1960s
- In 1967, ARPA presented idea for ARPANET (an ACM meeting)
- In 1969, ARPANET was a reality (4 nodes → UCLA, UCSB, Stanford Research Institute SRI, and Univ. of Utah)
- In 1973, landmark paper (by Vint Cerf and Bob Khan) outlined protocols to achieve end-to-end delivery of packets (TCP)
- Split TCP into 2 protocols: IP to handle datagram routing, and TCP higher-level functions such as segmentation, reassembly, and error detection
- For Internet pioneers, see http://www.ibiblio.org/pioneers/

The Internet 2/2

- Not a simple hierarchical structure (For a host count, see https://www.isc.org/solutions/survey/history)
- Internet Service Providers
  - ➢ International/National/Regional service providers versus Local service providers (direct service to end-users)
- Internet Standards → RFCs (Request For Comments) by IETF (Internet Engineering Task Force)
- Internet Protocols: control sending and receiving of messages (TCP, IP, HTTP, FTP, …)
- Communication Services → Connectionless or Connection-oriented

Connection-oriented versus Connectionless 1/2

- Connection-oriented
  - ➢ Setup data transfer ahead of time (through *handshaking*)
  - ➢ Internet's connection-oriented service is TCP (Transmission Control Protocol) [RFC 793]. It provides
    - ✓ reliable, in-order byte delivery
    - ✓ flow control
    - ✓ congestion control.
  - ➢ Applications using TCP: Email (SMTP), web browsing (HTTP), and file transfer (FTP)

Connection-oriented versus Connectionless 2/2

- Connectionless
  - Internet's connectionless service is UDP (User Datagram Protocol) [RFC 768] . It provides
    - ✓unreliable data transfer
    - ✓no flow control
    - ✓no congestion control
  - Applications using UDP: streaming media, video conferencing, and IP telephony

Network Protocols

- Applications to communicate across a computer network
  - ➢ Invent a *protocol* (an agreement how will communicate)
  - ➢ Which application is expected to initiate communicate and when responses are expected
    - ✓ Syntax: format of data
    - ✓ Semantics: meaning of each section of bits (How it is interpreted and what action (s) to be taken)
    - ✓ Timing: when data should be sent and how fast?
- Example: Web Server and Web client
- Other examples? Other modes of communication?

Protocol "Layers" 1/2

•Used in daily life! → 2 friends communicating through the mail (sender, receiver, and a carrier)

•Sender side

- ➢Layer 1: Write letter, insert letter in envelope, write sender and receiver address, drop letter in mailbox
- ➢Layer 2: letter picked up by carrier and delivered to post office
- ➢Layer 3: letter stored at post office, a carrier transports the letter

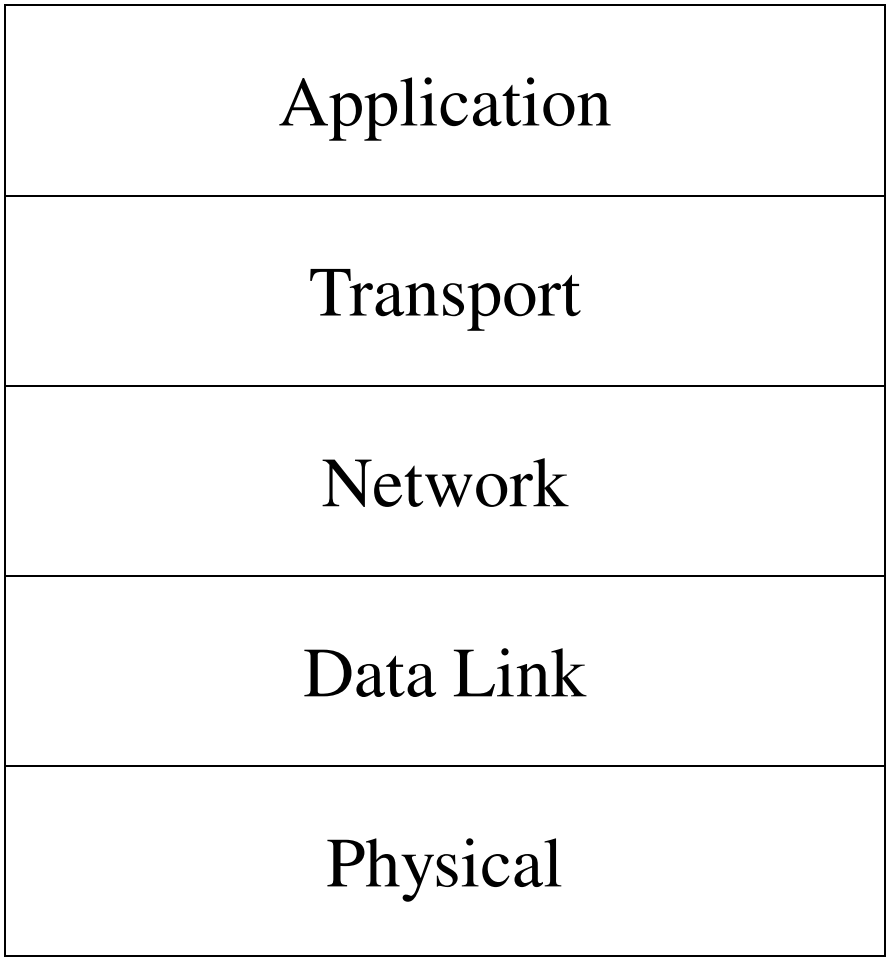
•On the way → Letter on the way to recipient's local post office (maybe through a central office), transported by truck, train, airplane, boat, or a mix

•Receiver Side → Layer3, then Layer 2, then Layer 1

Protocol "Layers" 2/2

- Characteristics
  - Each layer implements a service
  - Via its own internal-layer actions (a layer is a *black-box*)
  - Relying on services provided by layer below
- Why layering?
  - explicit structure allows identification, relationship of complex system's pieces (modular approach)
    - ✓ layered reference model for discussion
  - modularization eases maintenance, updating of system
    - ✓ change of implementation of layer's service transparent to rest of system
  - layering considered harmful?
    - ✓ Different layers may duplicate functionality
    - ✓ Different layers may need access to same information

Internet Layers



Supporting network applications (HTTP, FTP, DNS, …)

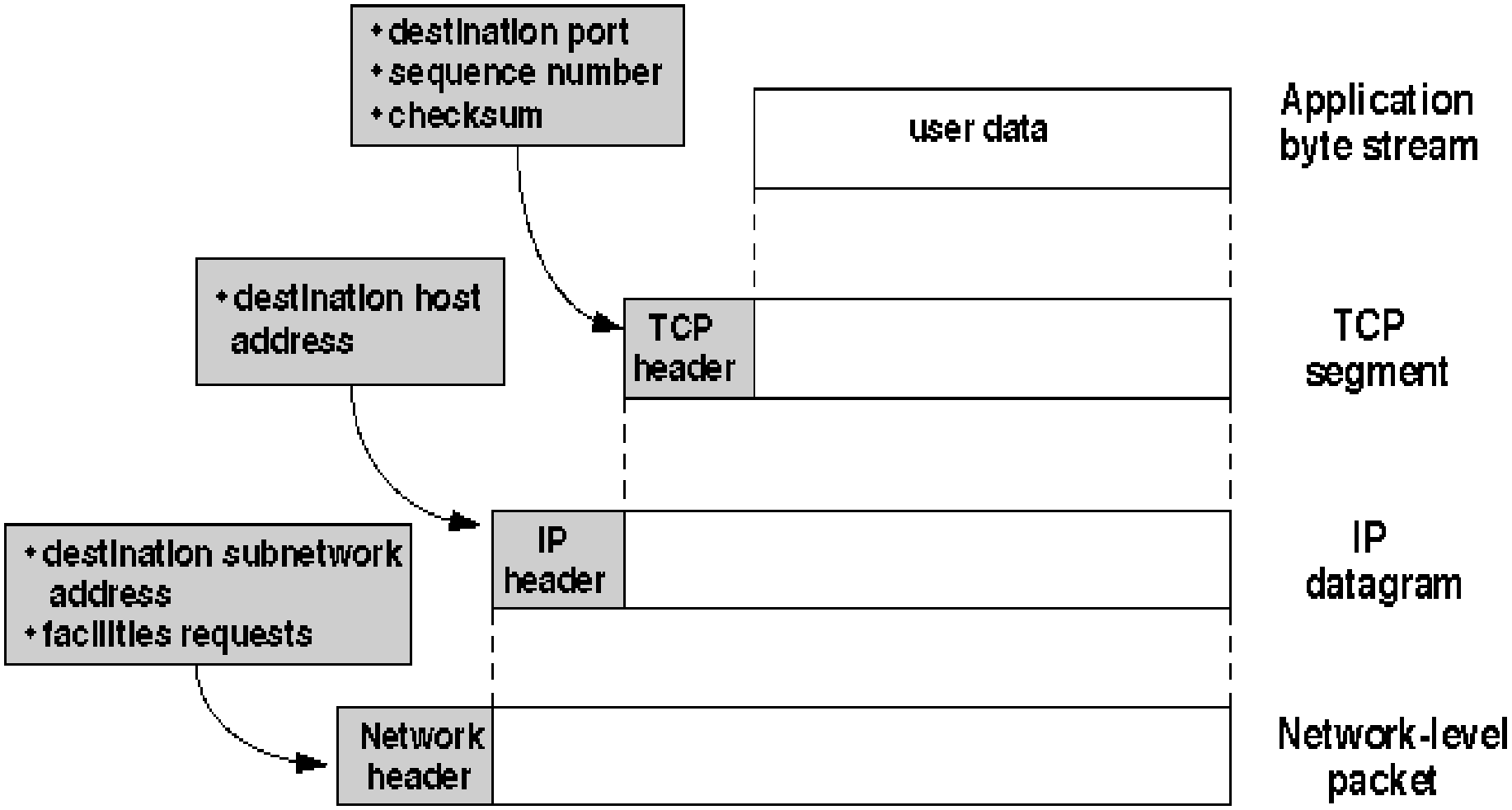
Transporting application-layer ***messages*** between client and server sides of an application (TCP and UDP)

Routing ***datagrams*** from one host to another (IP protocol: IPv4 and IPv6)

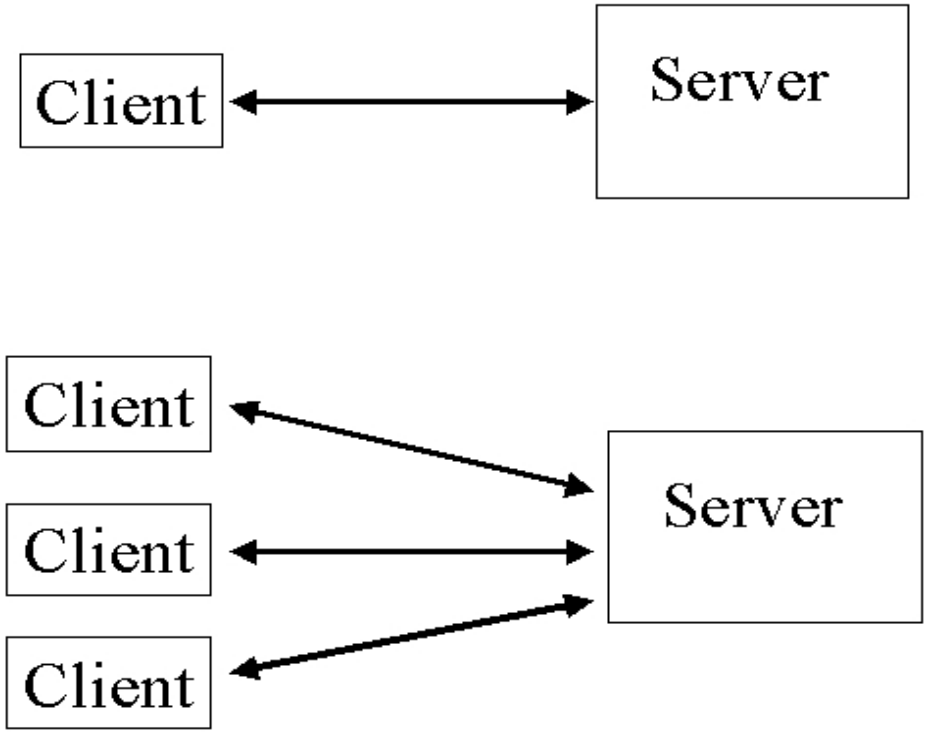
Move entire ***frames*** from one network element to an adjacent network element (Ethernet, PPP, …)

Move individual ***bits*** within the frame from one network element to an adjacent network element (coaxial cable, fiber optic, …)

TCP/IP Data Packet Transmission and Addressing

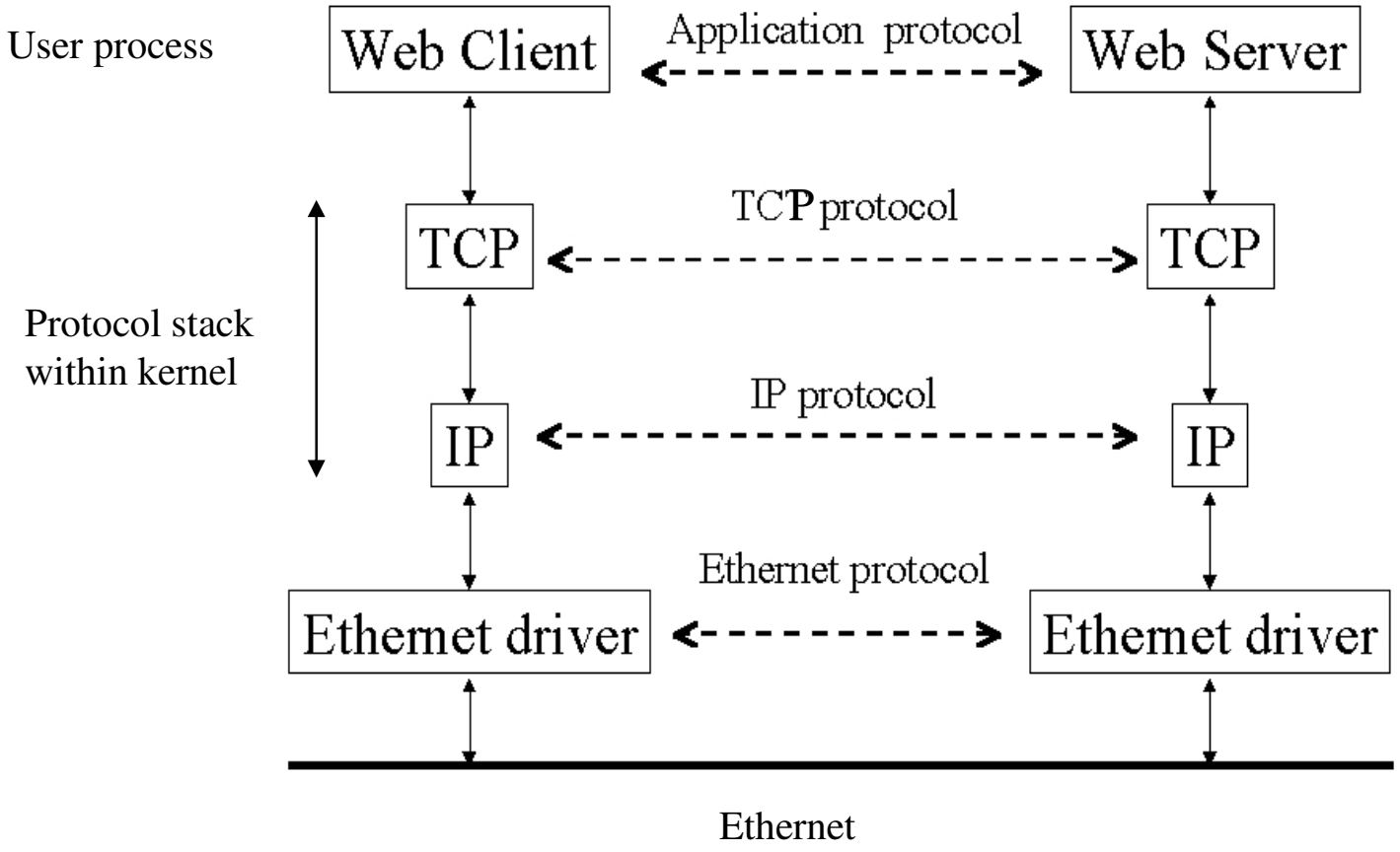


Servers and Clients



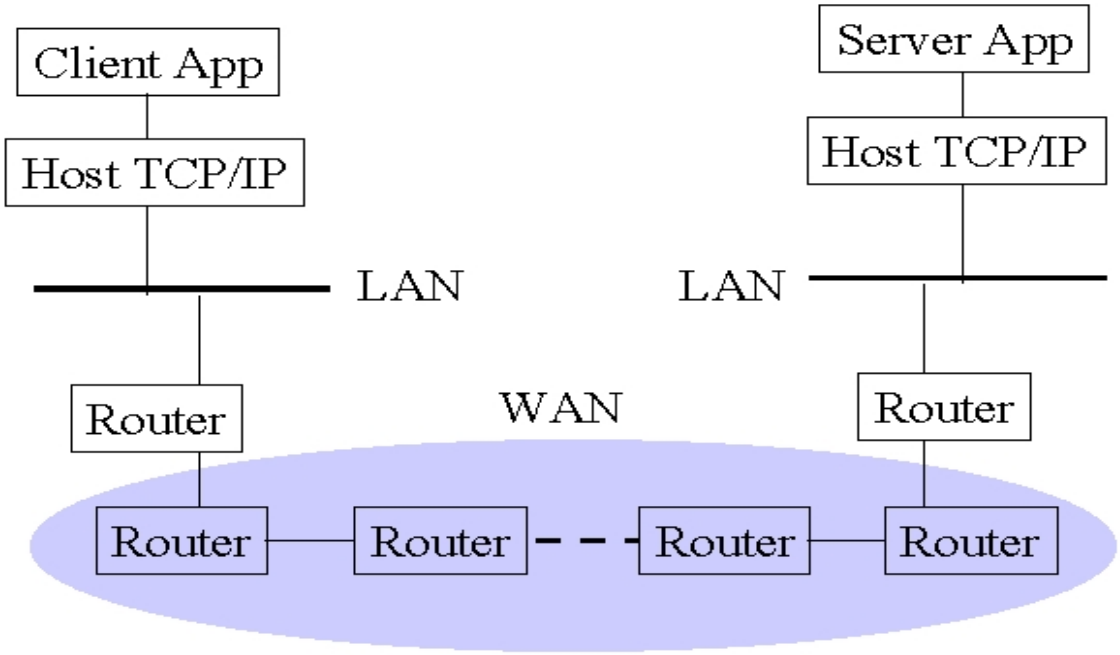
Multiple Layers of Network Protocols

Client and Server on same Ethernet



Multiple Layers of Network Protocols

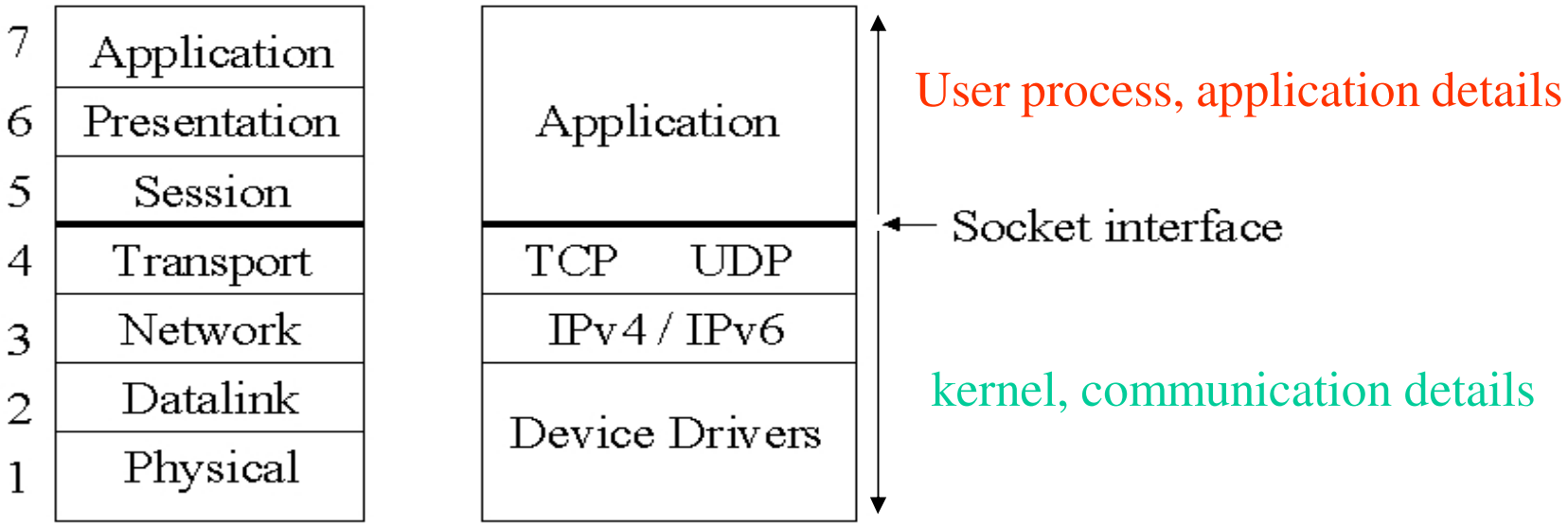
Client and server on different LANs connected through a WAN



Layers in OSI Model and Internet Protocol Suite

OSI: Open Systems Interconnection model for computer communications

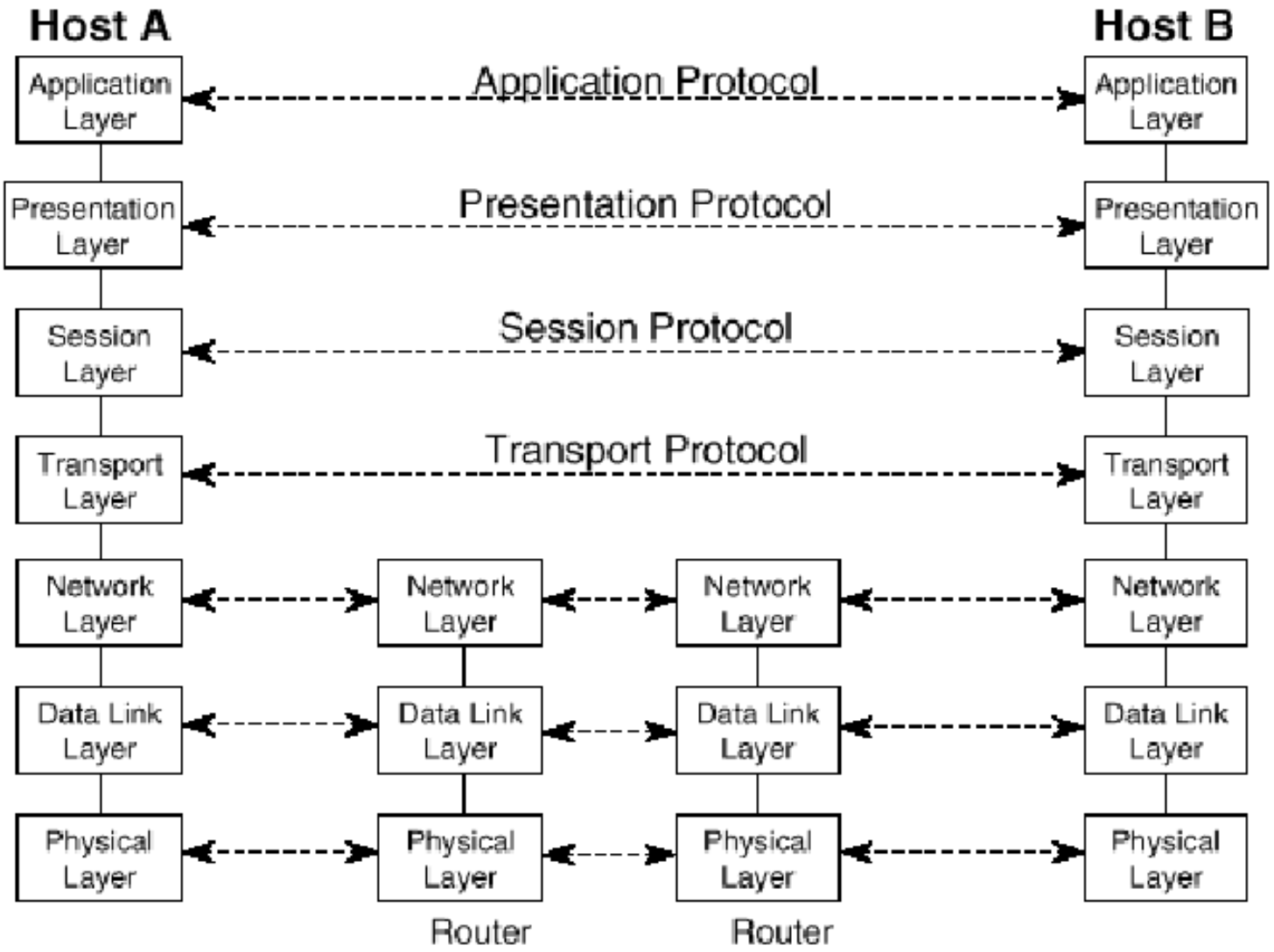
ISO: International Organization for Standardization



Outline

- OSI Layering Architecture
- TCP/IP Layers

OSI Layers


Host A
Host B
Application Layer
Application Protocol
Application Layer
Presentation Layer
Presentation Protocol
Presentation Layer
Session Layer
Session Protocol
Session Layer
Transport Layer
Transport Protocol
Transport Layer
Network Layer
Network Layer
Network Layer
Network Layer
Data Link Layer
Data Link Layer
Data Link Layer
Data Link Layer
Physical Layer
Physical Layer
Physical Layer
Physical Layer
Router
Router

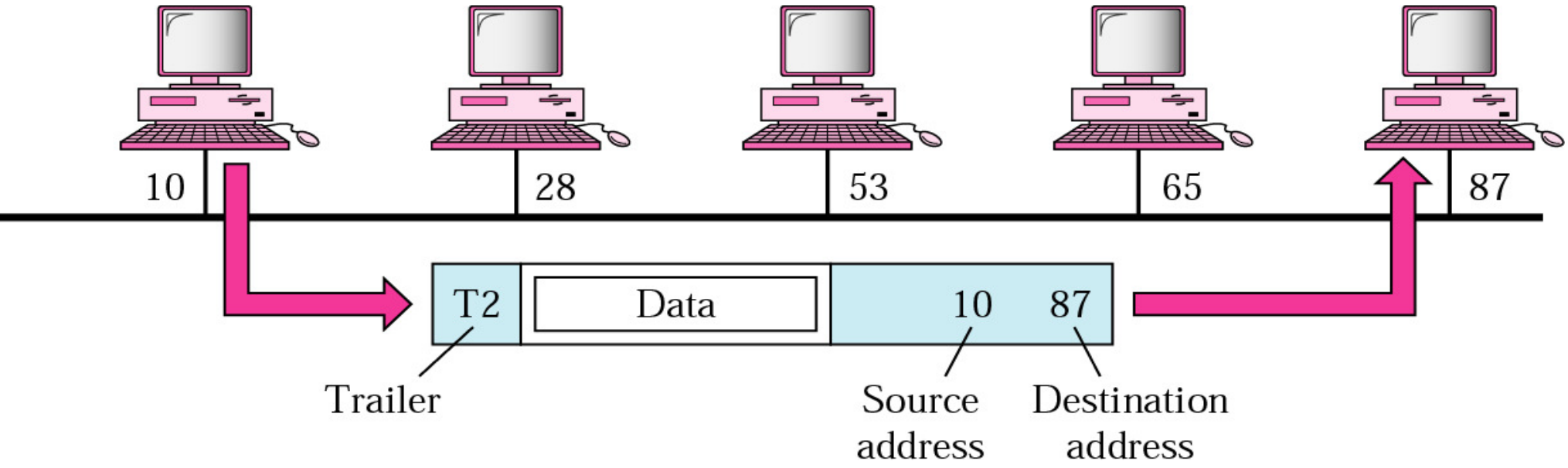
Physical Layer 1/2

- Functions
  - Transmission of a raw bit stream
  - Forms the physical interface between devices
- Issues
  - Which modulation technique (bits to pulse (analog signal))?
  - Which Line Coding technique (bits to digital signal?)
  - How long will a bit last? (*bit interval vs bit rate*)
  - Bit- serial or parallel transmission?
  - Half- or Full- duplex transmission?
  - How many pins does the network connector have?
  - How is a connection set up or torn down?

Data Link Layer 1/2

- Functions
  - Provides *reliable transfer* of information between two adjacent nodes (*physical link is a raw transmission facility*)
  - Creates frames (manageable data units) from bits and vice versa
  - Physical addressing (identify frame sender and/or receiver)
  - Provides frame- level error control (normally through a trailer added at end of frame)
  - Provides flow control
  - Access Control (through a MAC sub layer)
- In summary, the data link layer provides the network layer with what appears to be an error- free link for packets

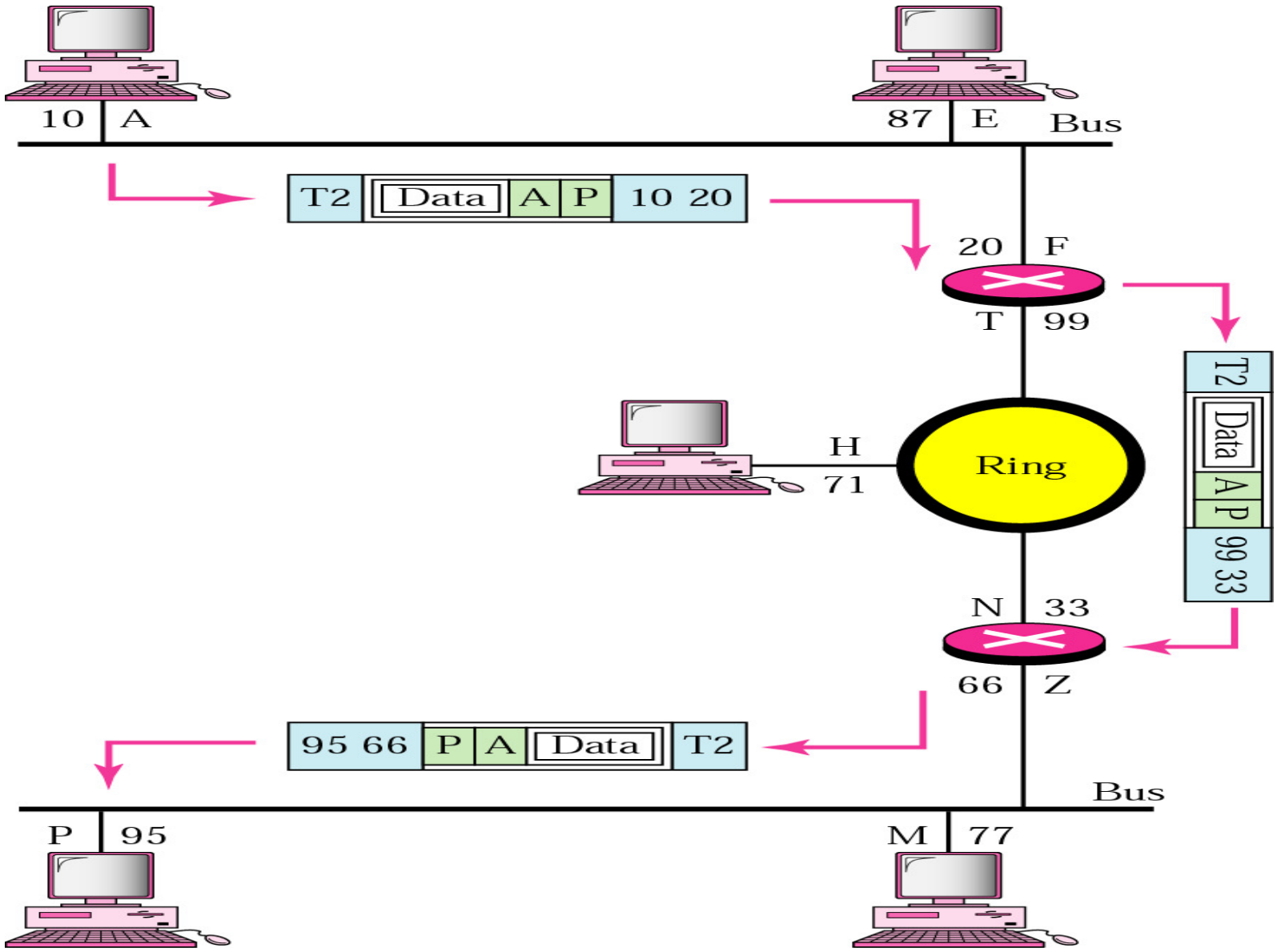
Data Link Layer 2/2



Network Layer 1/2

- Functions
  - Source-to-destination delivery of packets across multiple networks
  - Logical addressing
  - Responsible for routing decisions
    - ✓Dynamic routing
    - ✓Fixed routing
  - Performs congestion control
    - ✓In the Internet model, the network layer does not perform congestion control
    - ✓Congestion control at the network layer is a current area of research

Network Layer 2/2



Transport Layer

- Functions
  - Process-to-process delivery of entire message
  - Port addressing
  - Connection control
  - Provides reliable end-to-end communication
  - Perform end-to-end flow control
  - Perform packet retransmission when packets are lost by the network
  - In the Internet model, the transport layer also offers congestion control.

Session Layer

- Functions
  - Network dialog controller
    - ✓Establish, maintain, and synchronize interaction between communicating entities
  - May perform synchronization between several communicating applications
  - Groups several user- level connections into a single "session"

Presentation Layer

- Functions
  - ➢ Concerned with syntax and semantics of information exchanged between 2 systems
  - ➢ Performs specific functions that are requested regularly by applications
    - ✓ Encryption
    - ✓ Compression
    - ✓ Translation
      - ❑ ASCII to Unicode, Unicode to ASCII
      - ❑ LSB- first representations to MSB- first representations

Application Layer

- Functions
  - Application layer protocols are application-dependent
  - Implements communication between two applications of the same type
  - Examples
    - ✓FTP
    - ✓HTTP
    - ✓SMTP (email)

OSI Layering Problems

- Seven layers not widely accepted
- Standardized before implemented
- Top three layers fuzzy
- Internet or TCP/ IP layering widespread

Internet Design Principles

- Scale
  - Protocols should work in networks of all sizes and distances
- Incremental deployment
  - New protocols need to be deployed gradually
- Heterogeneity
  - Different technologies, autonomous organizations
- End-to-end argument
  - Networking functions should be delegated to the edges; application knows best
  - *"A function can only be completely and correctly implemented with the knowledge and help of the applications standing at the communication end points"*