

**PART X**  
**PROTOCOL LAYERING**

## Motivation For Layering

- Communication is difficult to understand
- Many subproblems
  - Hardware failure
  - Network congestion
  - Packet delay or loss
  - Data corruption
  - Data duplication or inverted arrivals

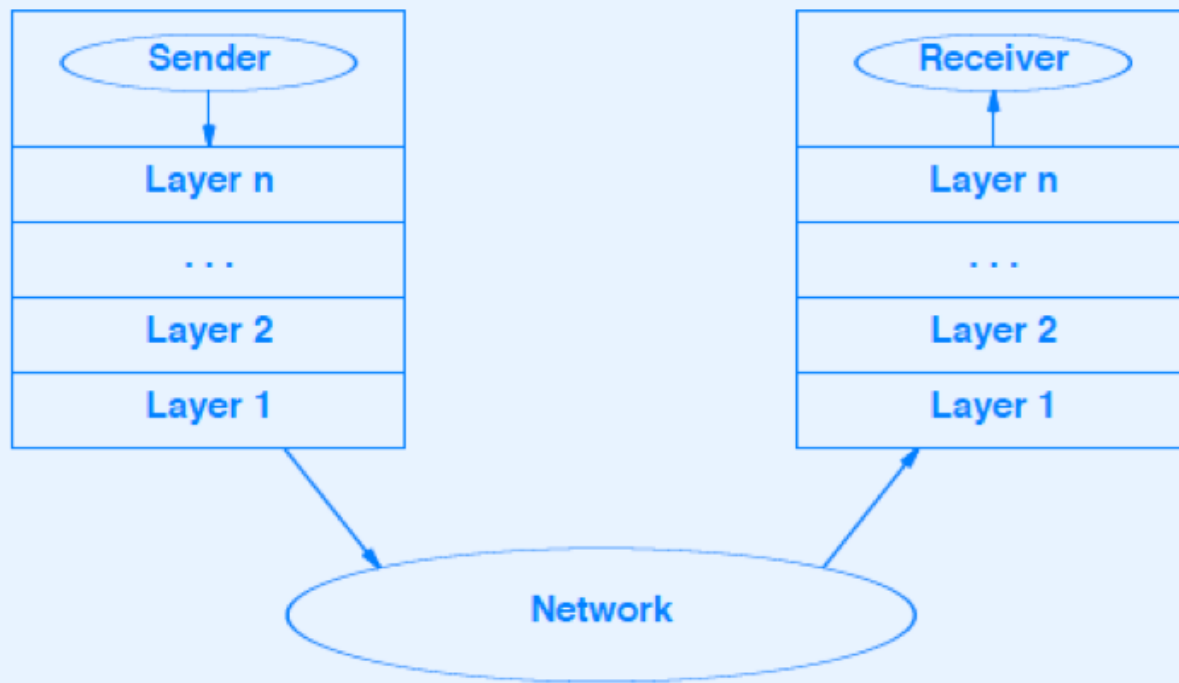
## Solving The Problem

- Divide the problem into pieces
- Solve subproblems separately
- Combine into integrated whole
- Result is *layered protocols*

## Protocol Layering

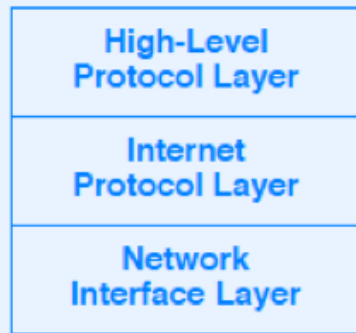
- Separates protocol functionality
- Each layer solves one part of the communication problem
- Intended primarily for protocol designers
- Set of layers is called a *protocol stack*

# Concept Of Layering



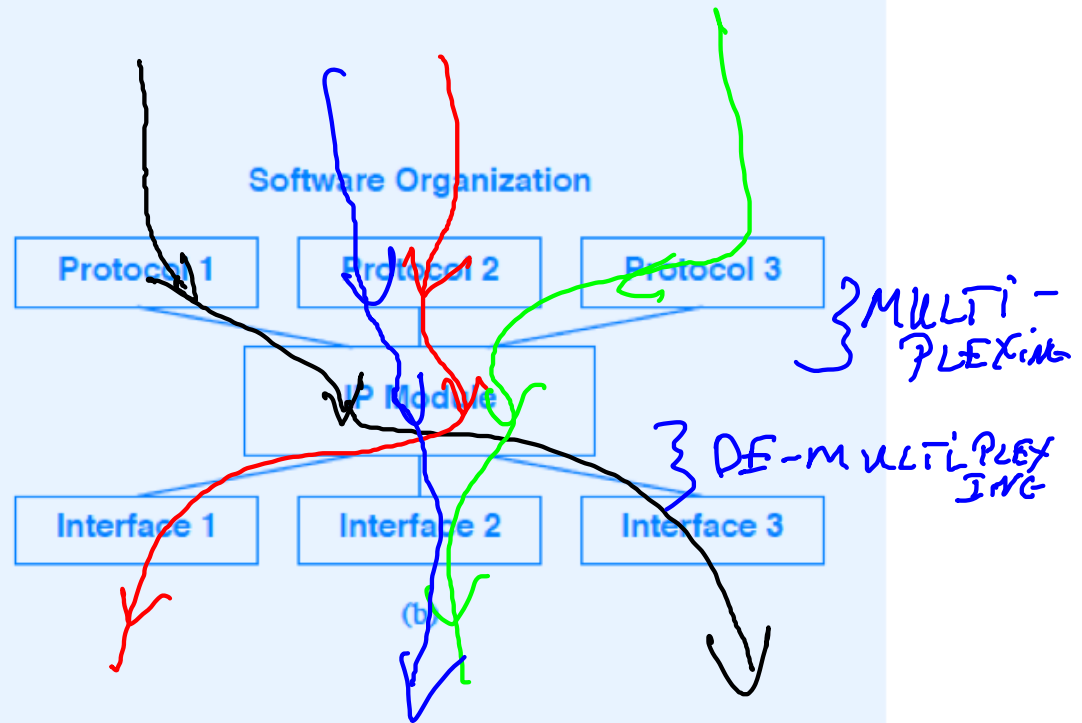
# More Realistic Layering

## Conceptual Layers



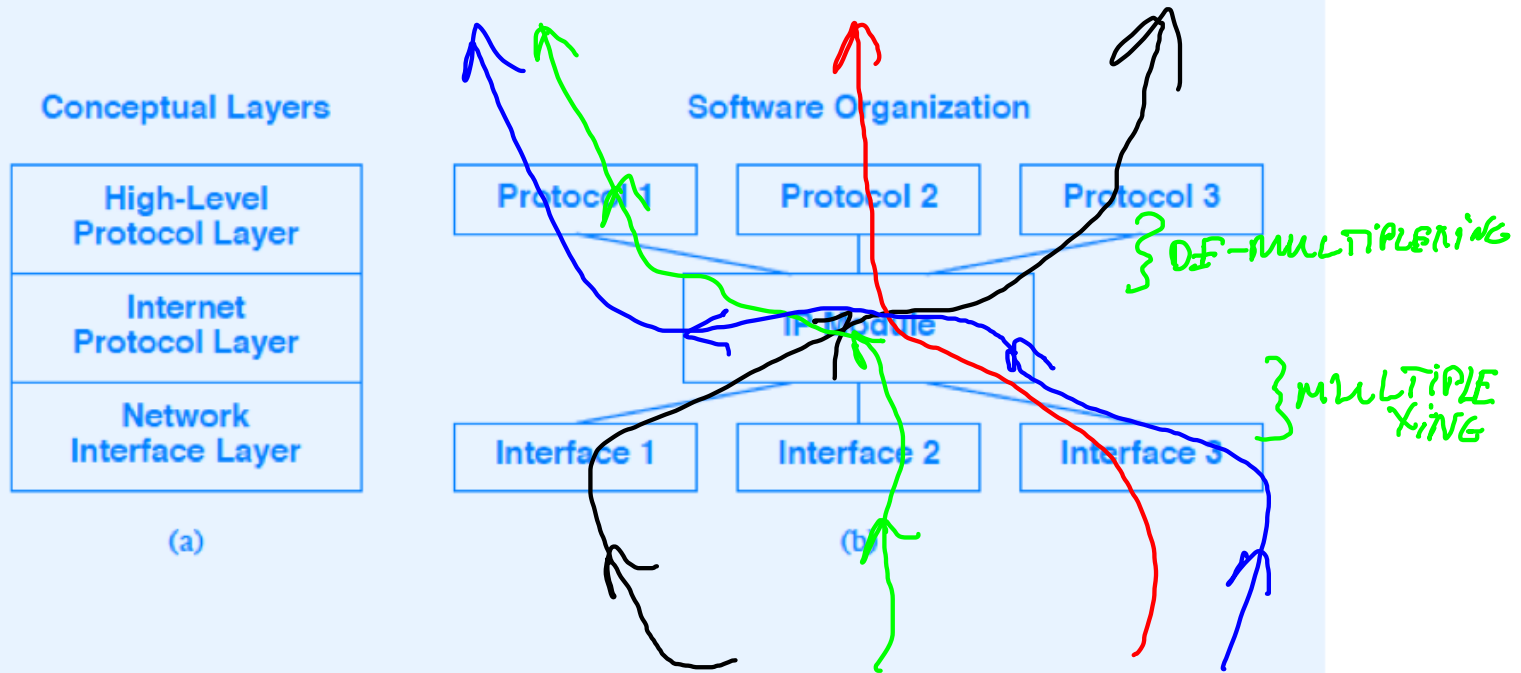
(a)

## Software Organization

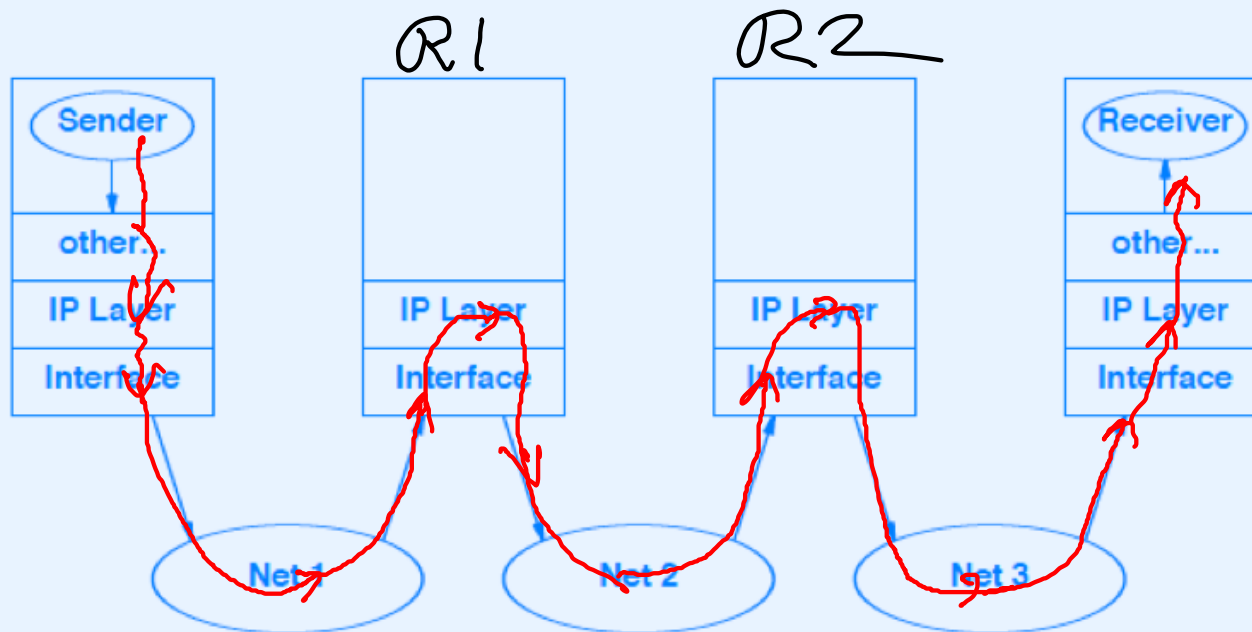


(b)

# More Realistic Layering



# Layering In An Internet

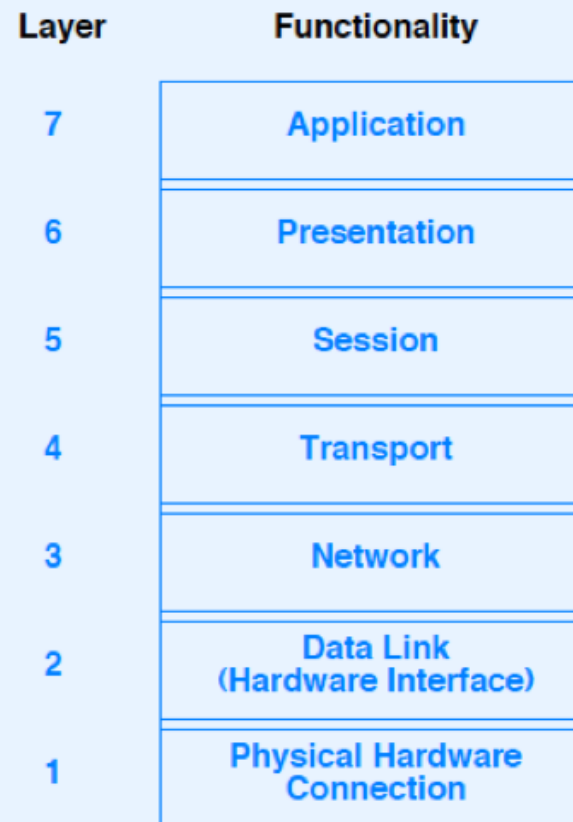




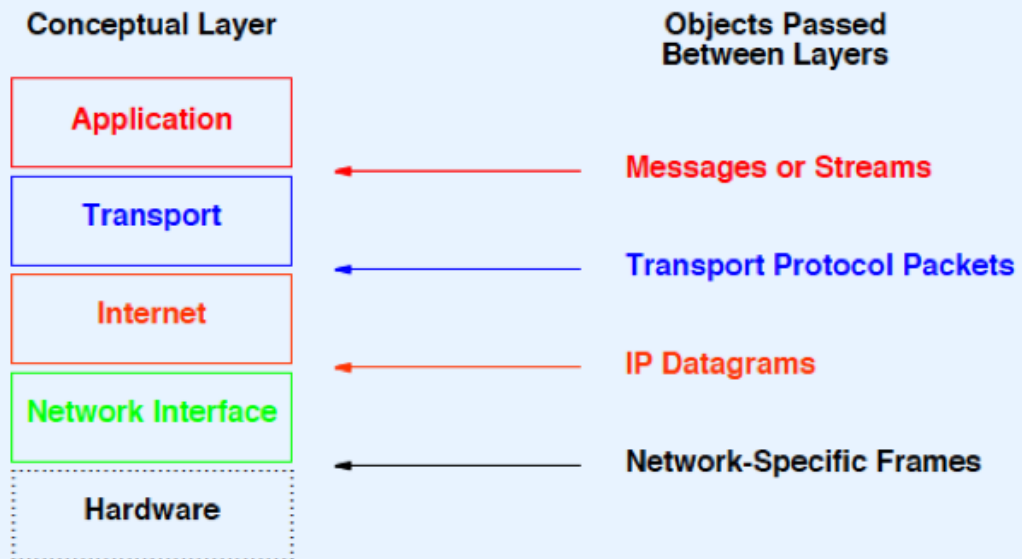
## Examples Of Layering

- Two models exist
- ISO 7-layer reference model for *Open System Interconnection (OSI)*
  - Predates TCP/IP
  - Does not include an Internet layer
  - Prescriptive (designed before protocols)
- Internet 5-layer reference model
  - Designed for TCP/IP
  - Descriptive (designed along with actual protocols)

# ISO 7-Layer Reference Model



# TCP/IP 5-Layer Reference Model



- Only four layers above hardware

## **TCP/IP Layer 1: Physical Hardware**

- Defines electrical signals used in communication (e.g., voltages on wires between two computers)
- Uninteresting except to electrical engineers

## TCP/IP Layer 2: Network Interface

- Defines communication between computer and network hardware
- Isolates details of hardware (MAC) addressing
- Example protocol: ARP
- Code is usually in the operating system

## TCP/IP Layer 3: Internet

- Protocol is IP
- Provides machine to machine communication
- Defines best-effort, connectionless datagram delivery service for the Internet
- Code is usually in the operating system

## TCP/IP Layer 4: Transport

- Provides end-to-end connection from application program to application program
- Often handles reliability, flow control
- Protocols are TCP and UDP
- Code is usually in the operating system

## **TCP/IP Layer 5: Application**

- Implemented by application programs
- Many application-specific protocols in the Internet
- Built on top of transport layer



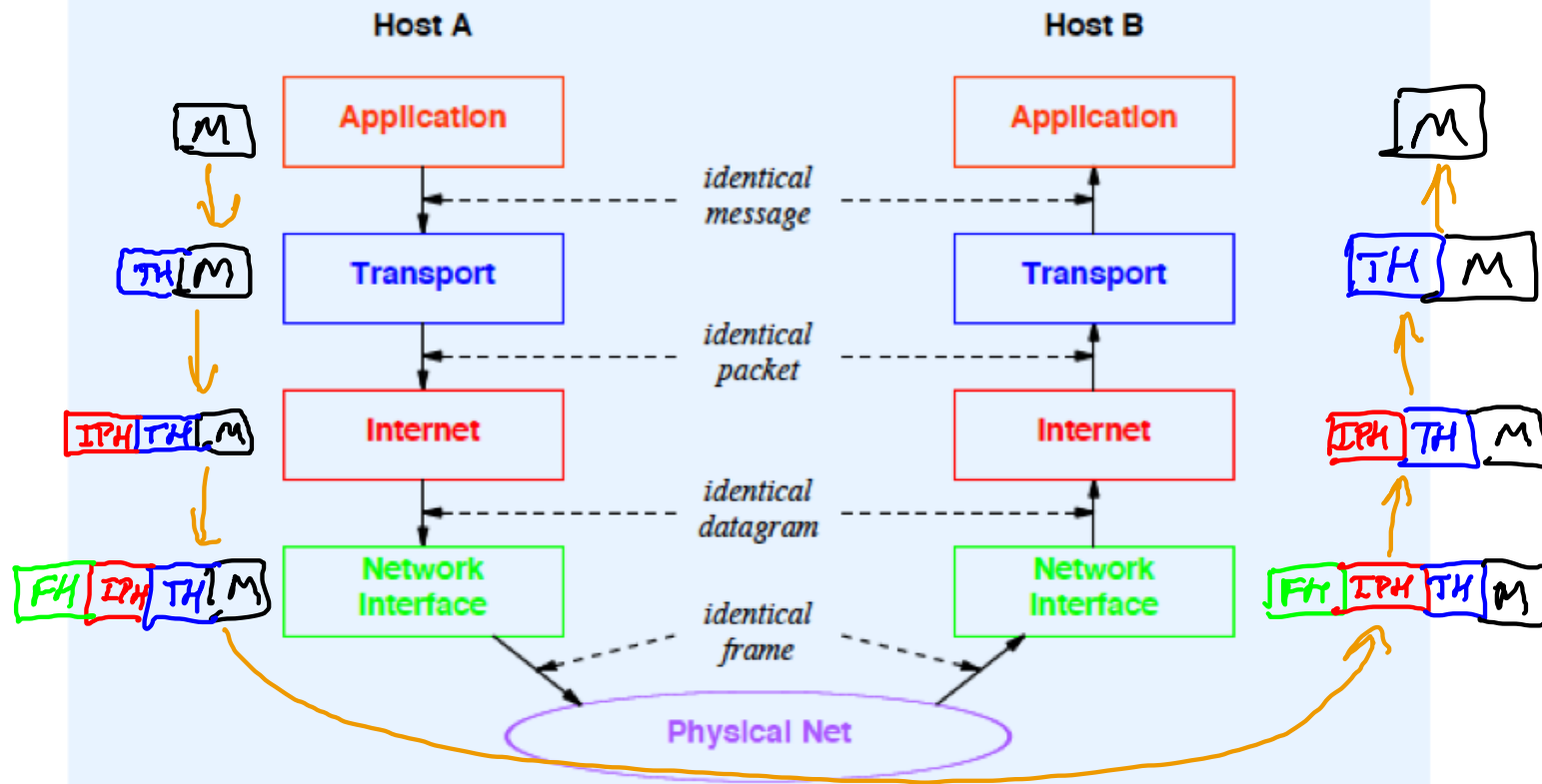
## **Two Differences Between TCP/IP And Other Layered Protocols**

- TCP/IP uses end-to-end reliability instead of link-level reliability
- TCP/IP places the locus of intelligence and decision making at the edge of the network instead of the core

## The Layering Principle

*Software implementing layer  $n$  at the destination receives exactly the message sent by software implementing layer  $n$  at the source.*

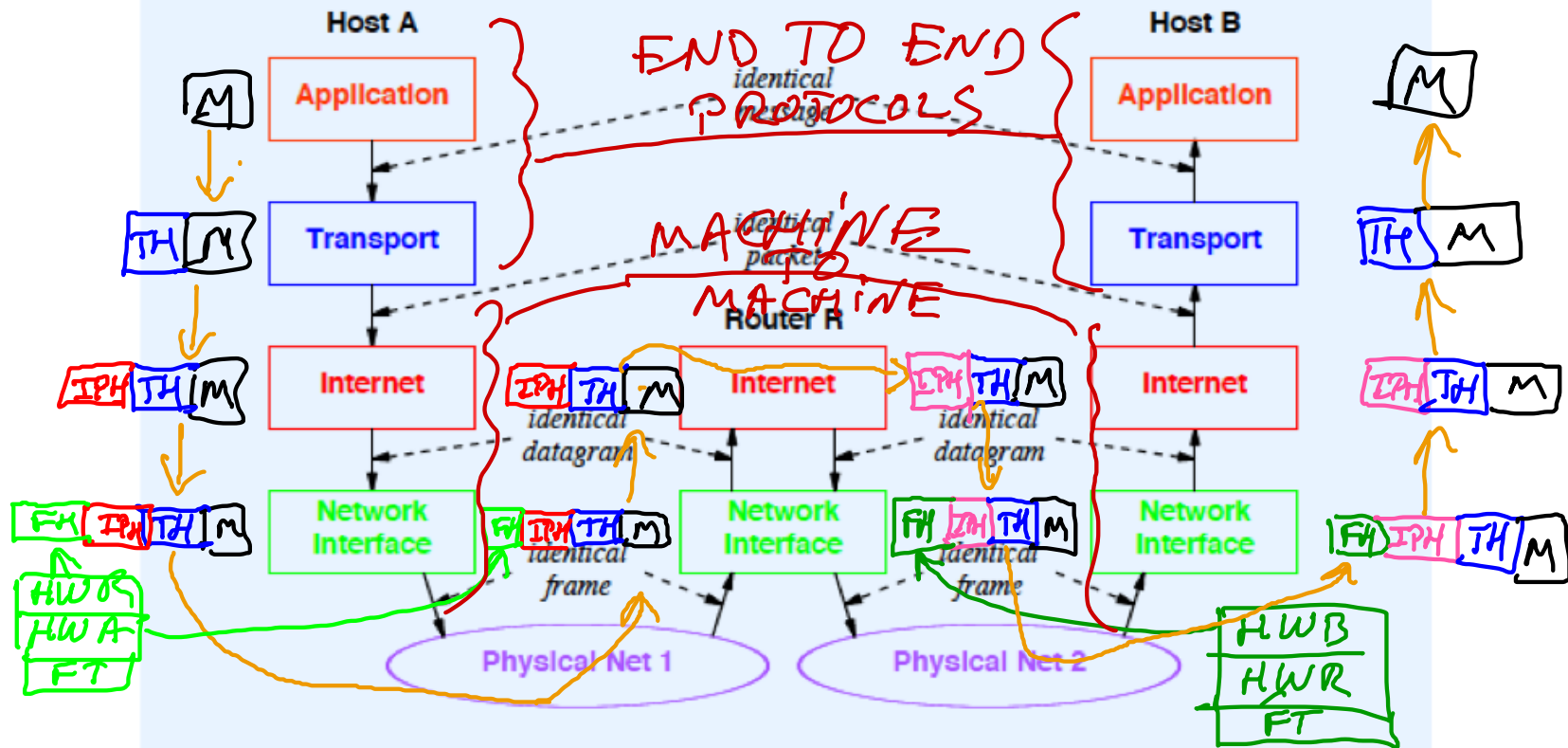
# Illustration Of Layering Principle



## When A Datagram Traverses The Internet

- All layers involved at
  - Original source
  - Ultimate destination
- Only up through IP layer involved at
  - Intermediate routers

# Illustration Of Layering In An Internet



## A Key Definition

- A protocol is classified as *end-to-end* if the layering principle applies from one end of the Internet to the other
- Examples
  - IP is *machine-to-machine* because layering principle only applies across one hop
  - TCP is *end-to-end* because layering principle from original source to ultimate destination

## **Practical Aspect Of Layering**

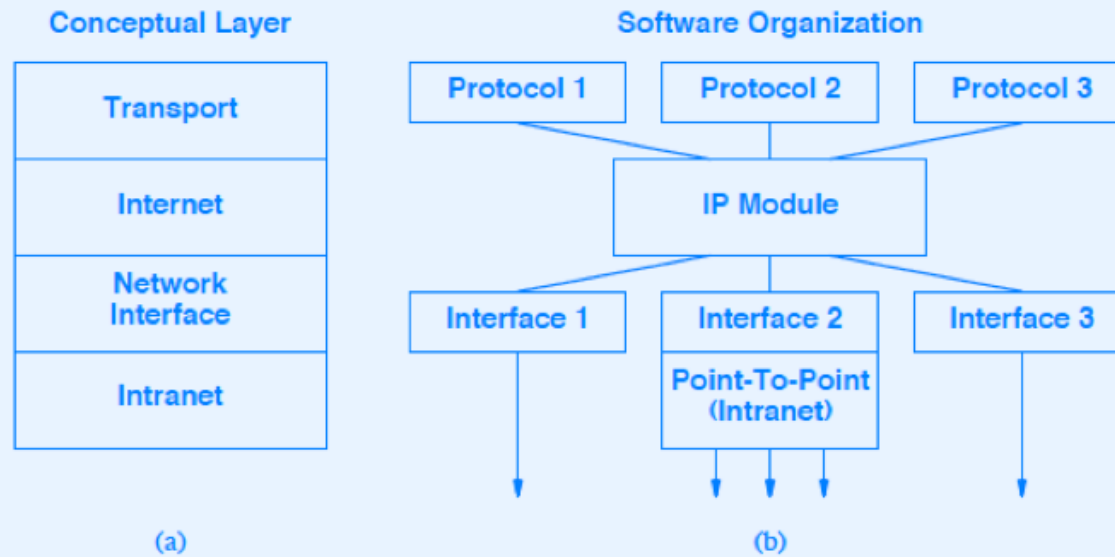
- Multiple protocols at each layer
- One protocol used at each layer for given datagram

## **Example Of Two Protocols At Network Interface Layer: SLIP And PPP**

- Both used to send IP across
  - Serial data circuit
  - Dialup connection
- Each defines standards for
  - Framing (encapsulation)
  - Addressing
- Incompatible



# Notion Of Multiple Interfaces And Layering



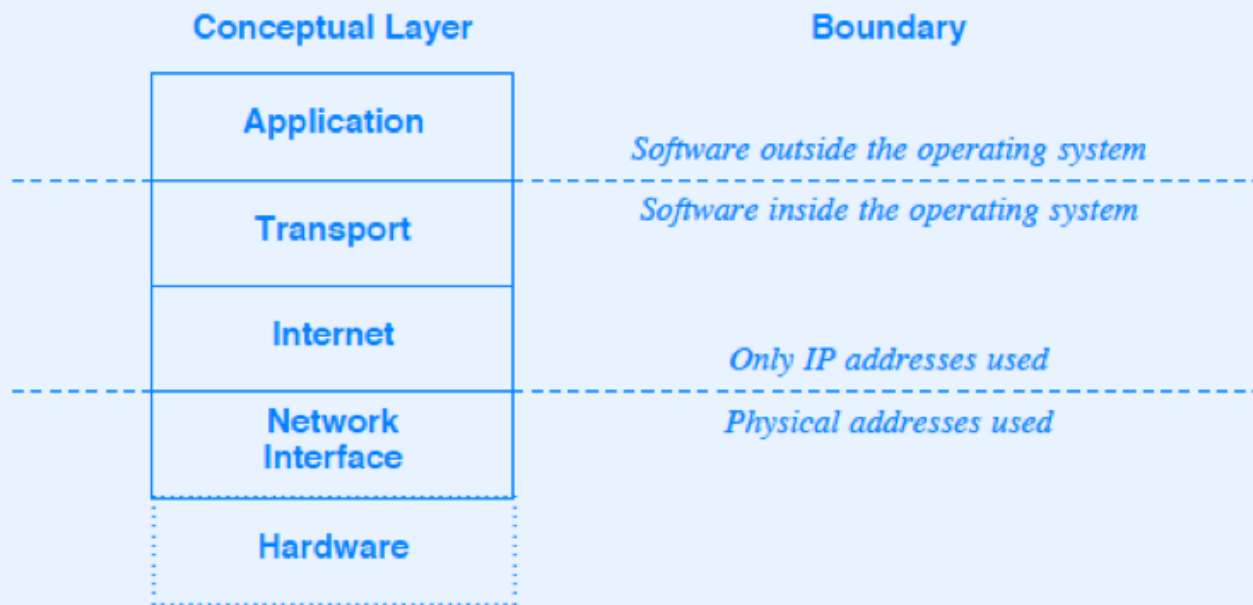
## Boundaries In The TCP/IP Layering Model

- High-level protocol address boundary
  - Division between software that uses hardware addresses and software that uses IP addresses
- Operating system boundary
  - Division between application program running outside the operating system and protocol software running inside the operating system

## The Consequence Of An Address Boundary

*Application programs as well as all protocol software from the Internet layer upward use only IP addresses; the network interface layer handles physical addresses.*

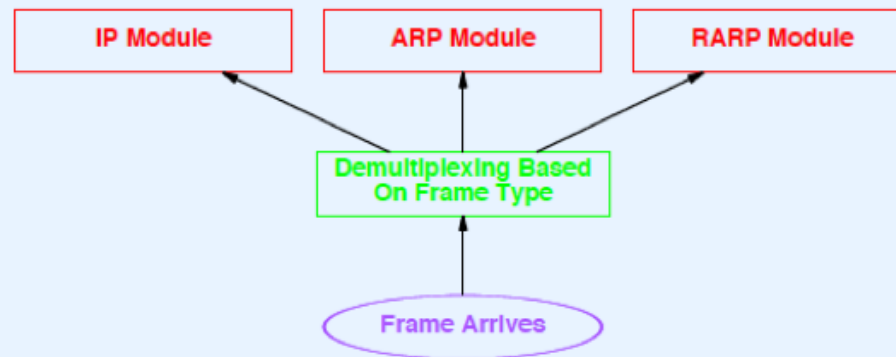
# Illustration Of The Two Boundaries



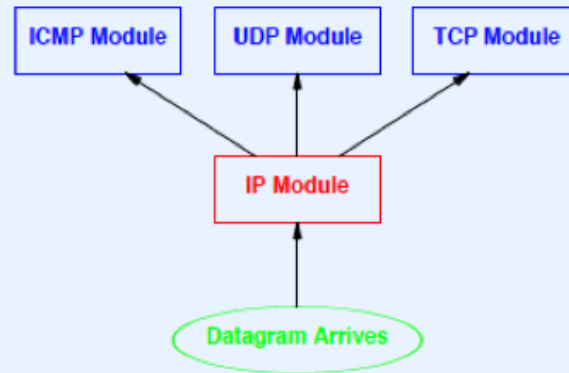
## Handling Multiple Protocols Per Layer

- Sender places field in header to say which protocol used at each layer
- Receiver uses field to determine which protocol at next layer receives the packet
- Known as *multiplexing* and *demultiplexing*

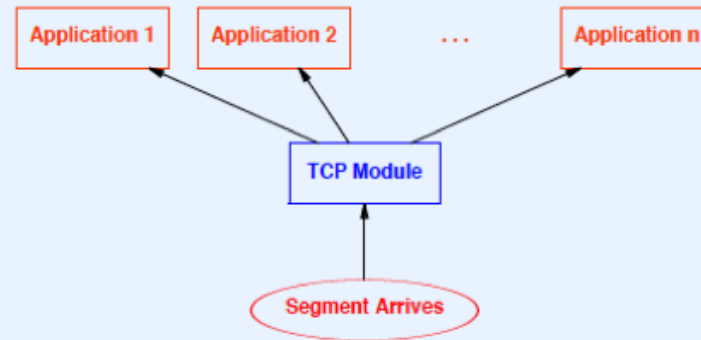
## Example Of Demultiplexing An Incoming Frame



## Example Of Demultiplexing Performed By IP



## Example Of Demultiplexing Performed By TCP



- TCP is part of operating system
- Transfer to application program must cross operating system boundary



## Discussion

- What are the key advantages and disadvantages of multiplexing / demultiplexing?
- Can you think of an alternative?

## Summary

- Layering
  - Intended for designers
  - Helps control complexity in protocol design
- TCP/IP uses 5-layer reference model
- Conceptually, a router only needs layers 2 and 3, and a host needs all layers
- IP is machine-to-machine protocol
- TCP is end-to-end protocol
- Demultiplexing used to handle multiple protocols at each layer