PART X

PROTOCOL LAYERING

Motivation For Layering

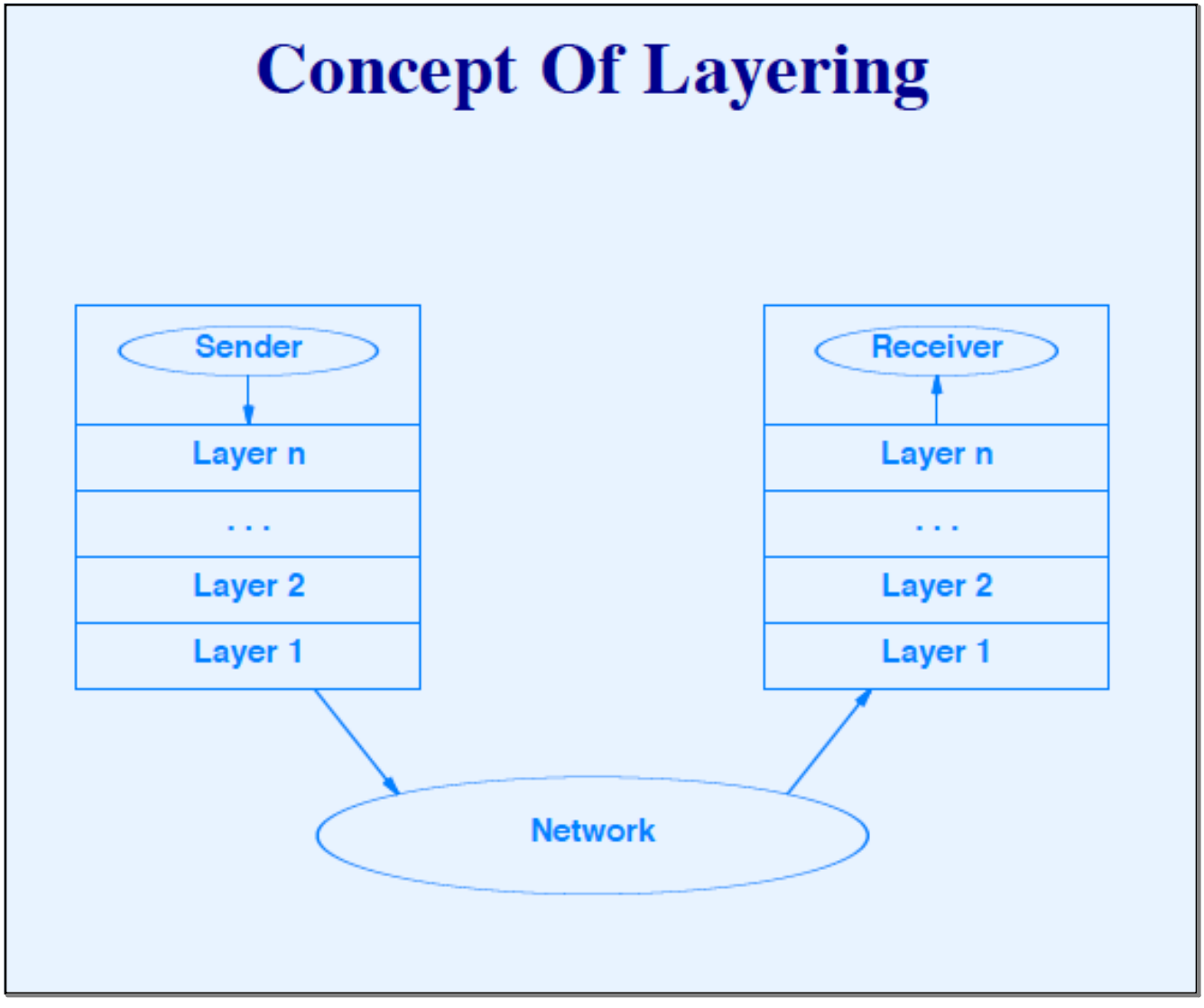
- Communication is difficult to understand
- Many subproblems
  - Hardware failure
  - Network congestion
  - Packet delay or loss
  - Data corruption
  - Data duplication or inverted arrivals

Solving The Problem

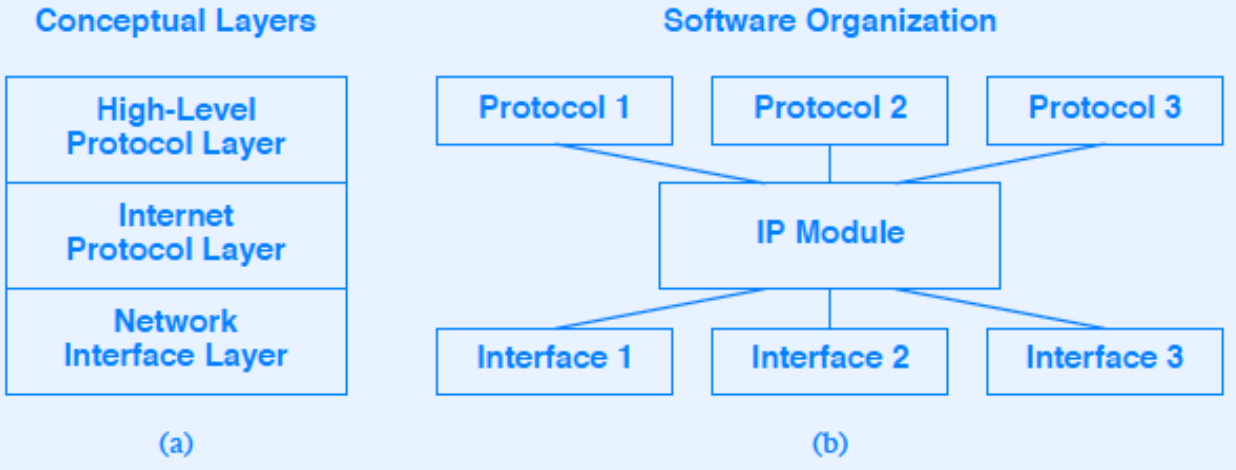
- Divide the problem into pieces
- Solve subproblems separately
- Combine into integrated whole
- Result is *layered protocols*

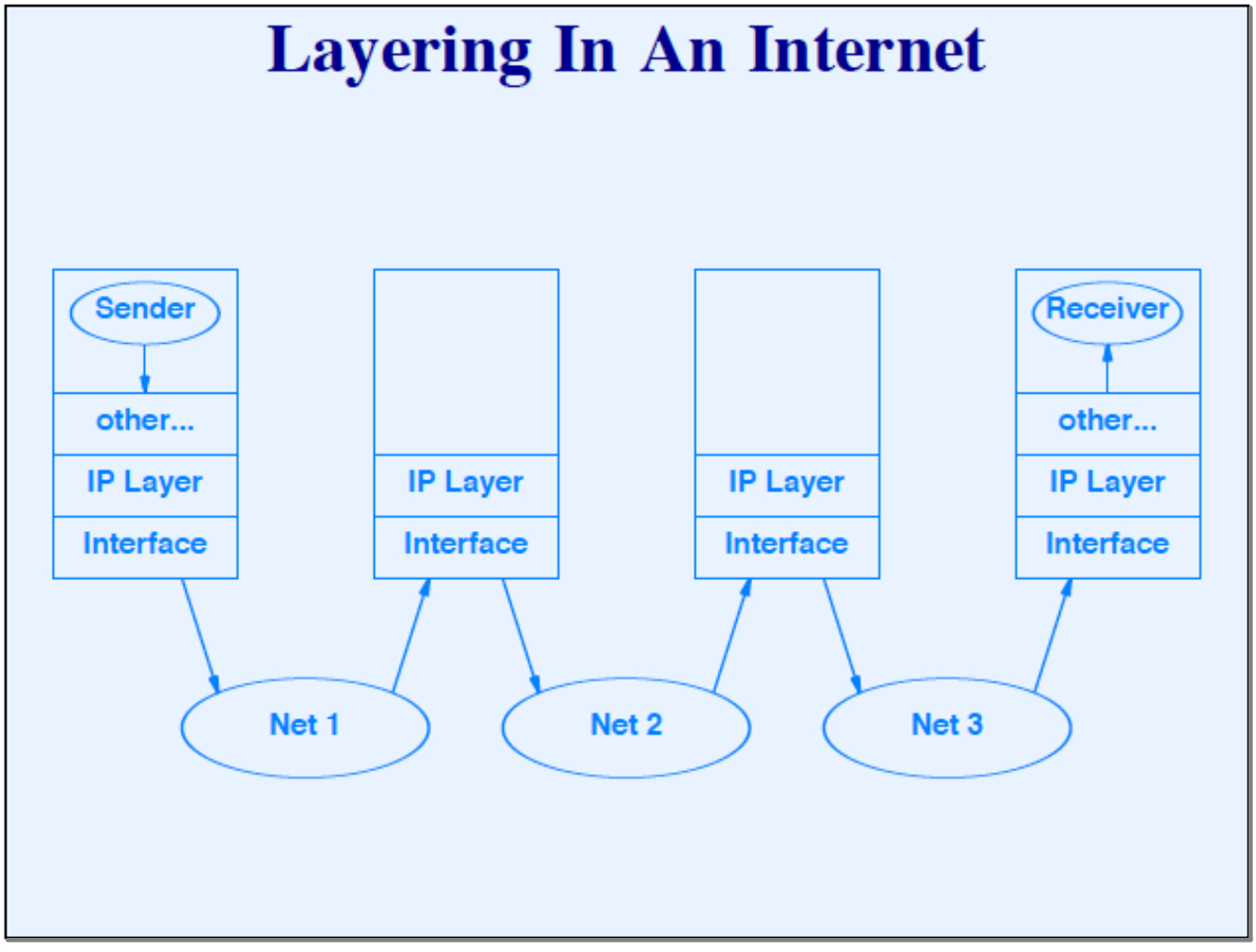
Protocol Layering

- 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
Sender
Layer n
. . .
Layer 2
Layer 1
Receiver
Layer n
. . .
Layer 2
Layer 1
Network

More Realistic Layering



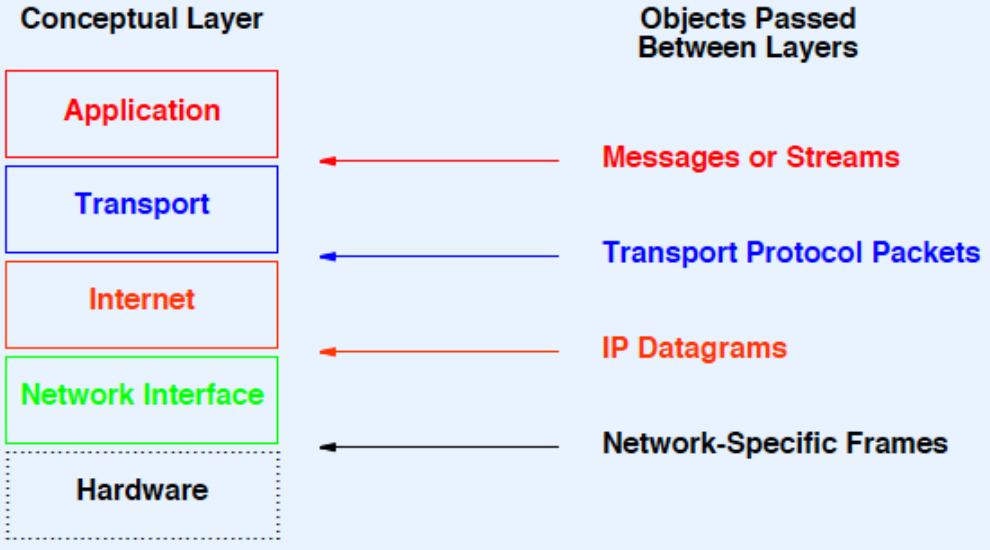

Layering In An Internet
Sender
other...
IP Layer
Interface
IP Layer
Interface
IP Layer
Interface
Receiver
other...
IP Layer
Interface
Net 1
Net 2
Net 3

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.

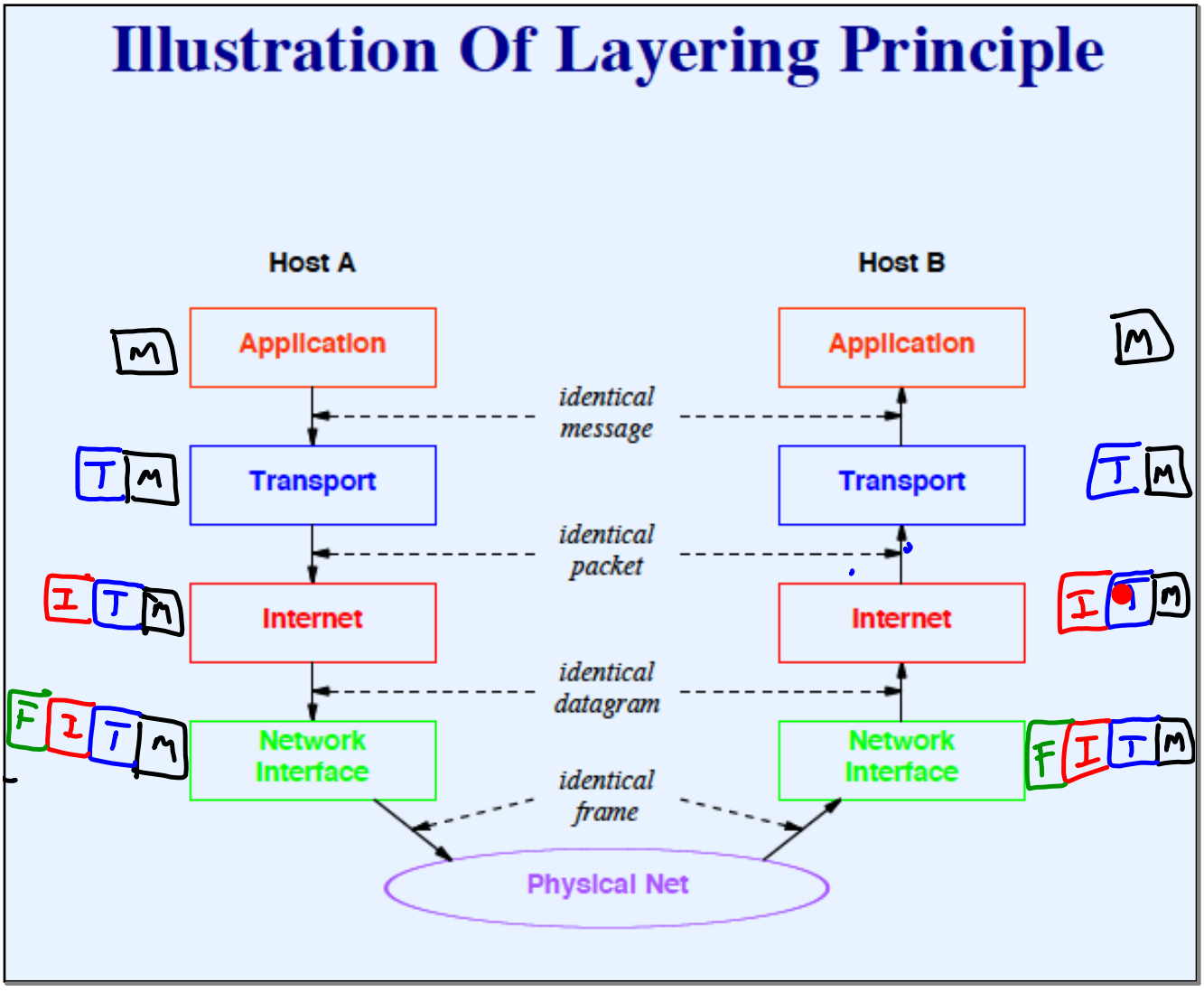


Illustration Of Layering Principle
Host A
Host B
Application
Application
identical message
Transport
Transport
identical packet
Internet
Internet
identical datagram
Network Interface
Network Interface
identical frame
Physical Net

When A Datagram Traverses The Internet

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

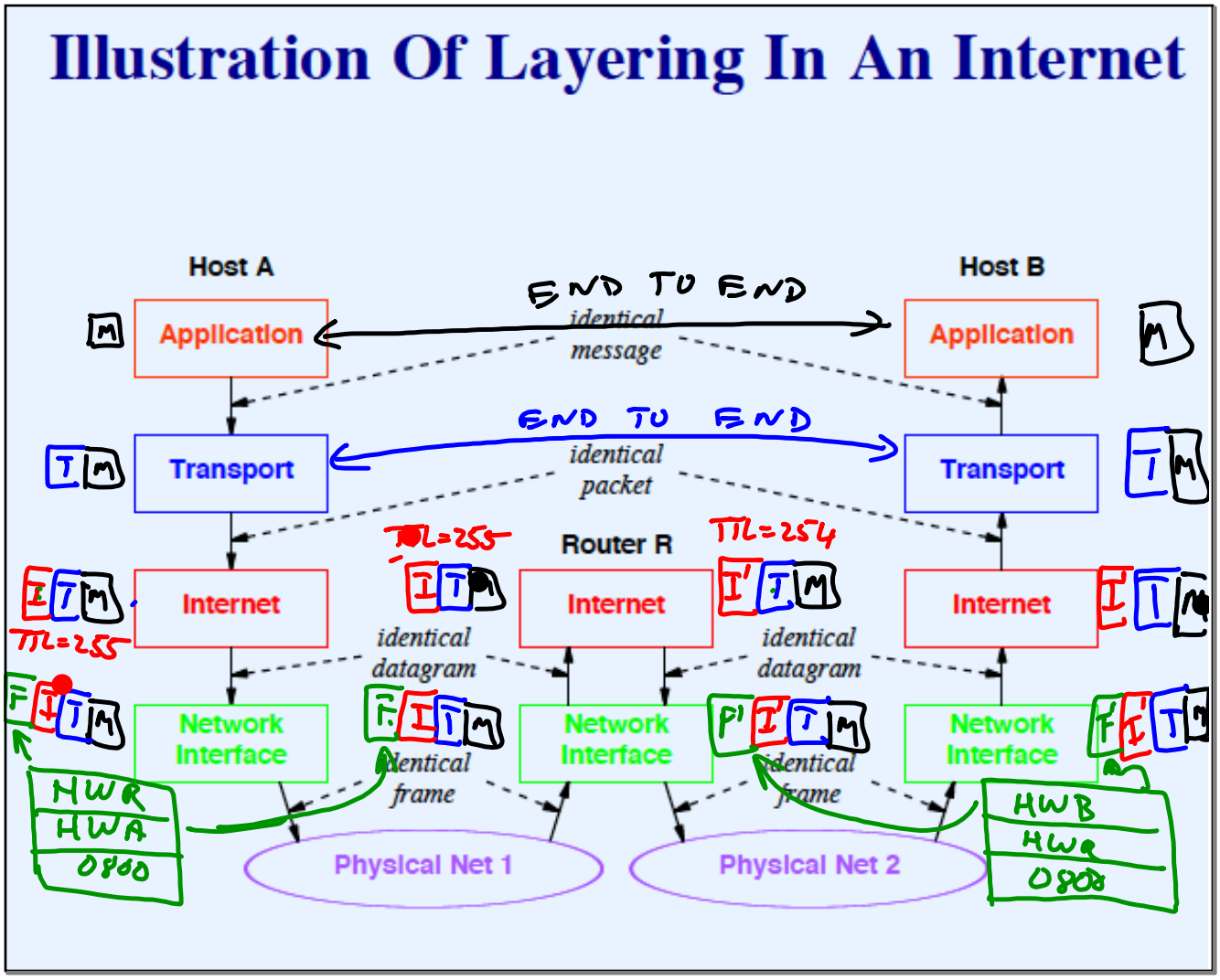


Illustration Of Layering In An Internet
Host A
Host B
Application
Application
END TO END
identical
message
Transport
Transport
END TO END
identical
packet
Router R
Internet
Internet
Internet
identical
datagram
identical
datagram
Network
Interface
Network
Interface
Network
Interface
identical
frame
identical
frame
Physical Net 1
Physical Net 2
TTL=255
TTL=254
TTL=255
HWR
HWA
0800
HWB
HWR
0800

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

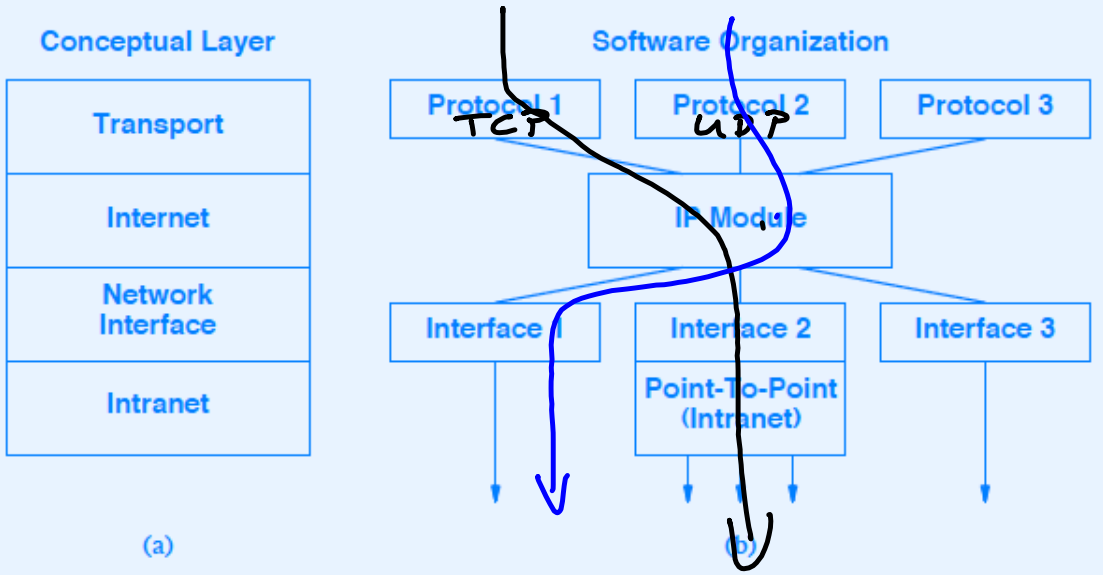
Practical Aspect Of Layering

- 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



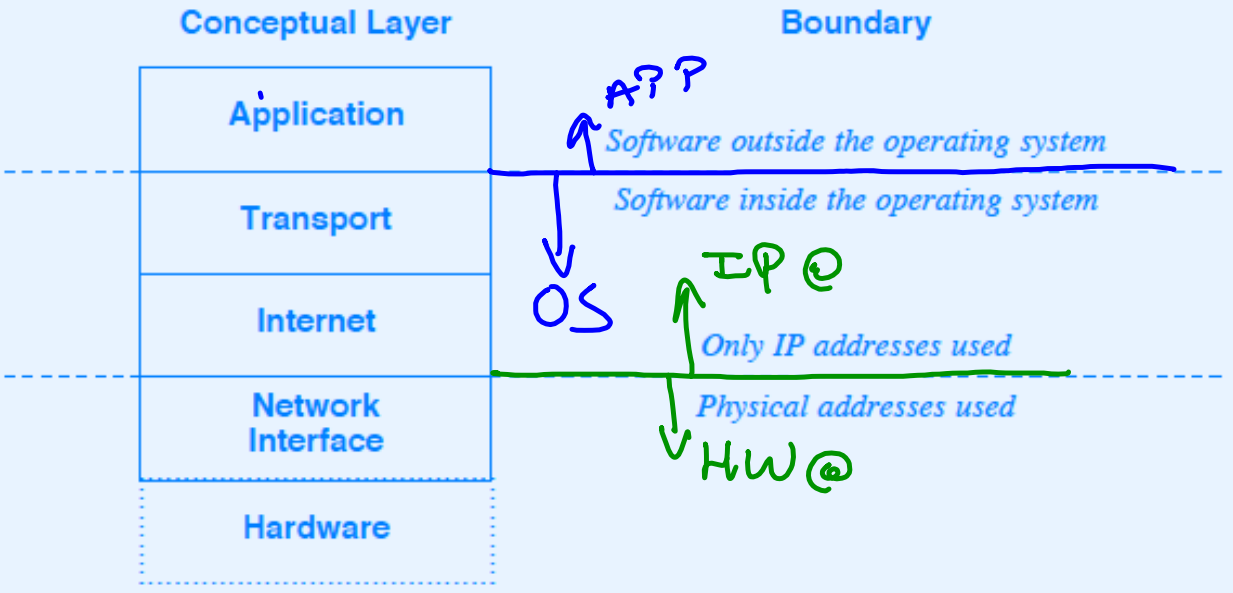
Boundaries In The TCP/IP Layering Model

- 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.

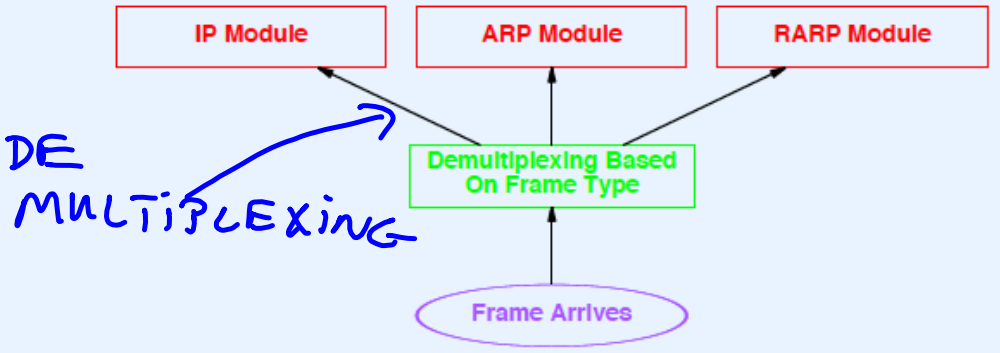
Illustration Of The Two Boundaries



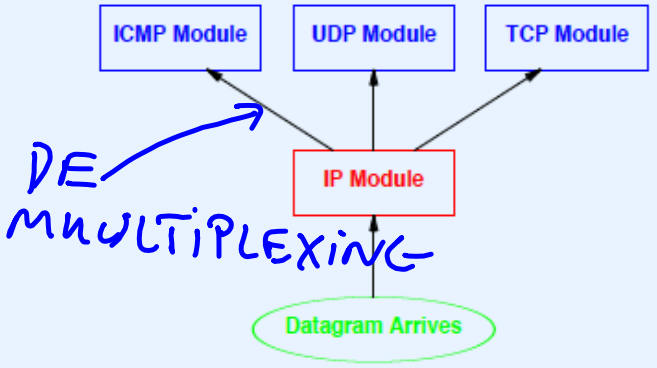
Handling Multiple Protocols Per Layer

- 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*

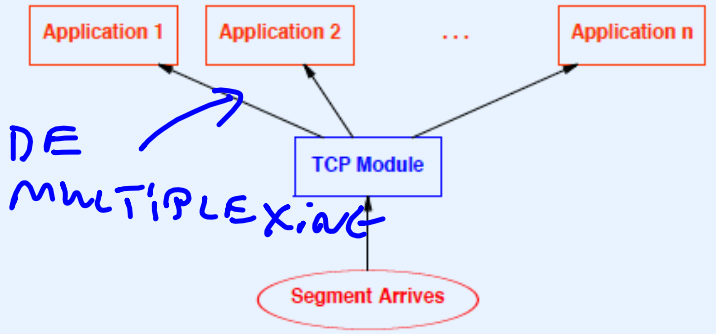
Example Of Demultiplexing An Incoming Frame



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

October 24, 2016