

Need For Protocols (continued)

- Need mechanisms to distinguish among
 - Multiple computers on a network
 - Multiple applications on a computer
 - Multiple copies of a single application on a computer

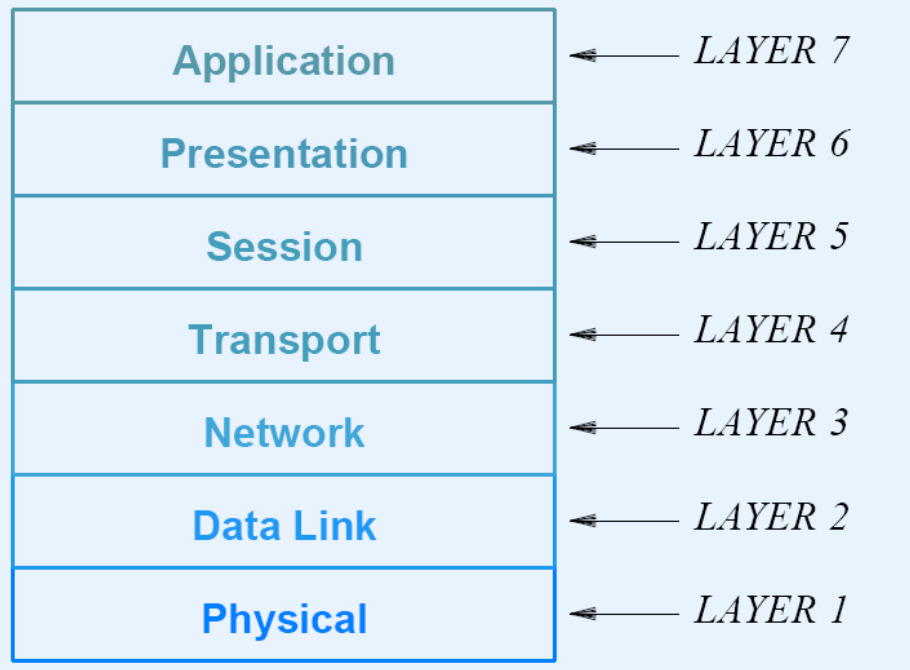
Set Of Protocols

- Work together
- Each protocol solves part of communication problem
- Known as
 - Protocol suite
 - Protocol family
- Designed in layers

Plan For Protocol Design

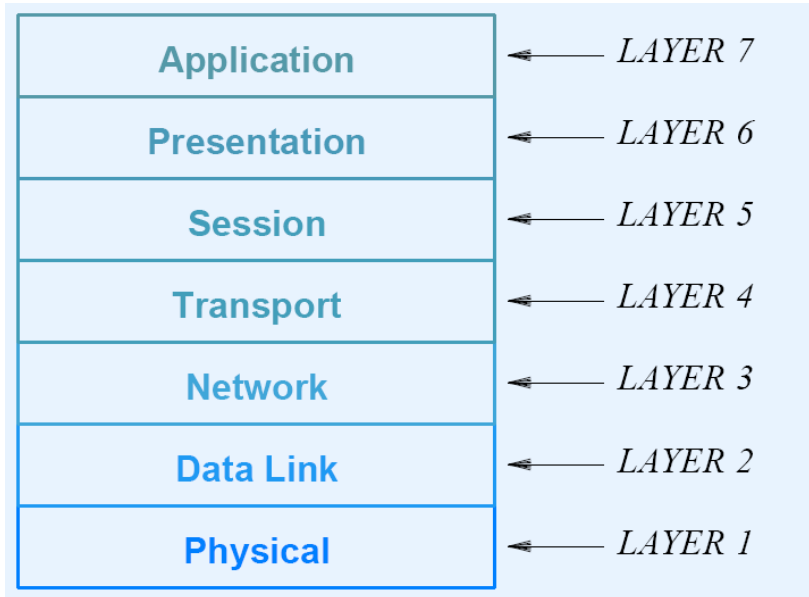
- Intended for protocol designers
- Divides protocols into layers
- Each layer devoted to one subproblem
- Example: ISO 7-layer reference model

Illustration Of The 7-Layer Model



- Defined early
- Now somewhat dated

Illustration Of The 7-Layer Model



- Defined early
- Now somewhat dated
- Does not include Internet layer!

ISO Layers

- Layer 1: Physical
 - Underlying hardware
- Layer 2: Data Link (media access)
 - Hardware frame definitions
- Layer 3: Network
 - Packet forwarding
- Layer 4: Transport
 - Reliability

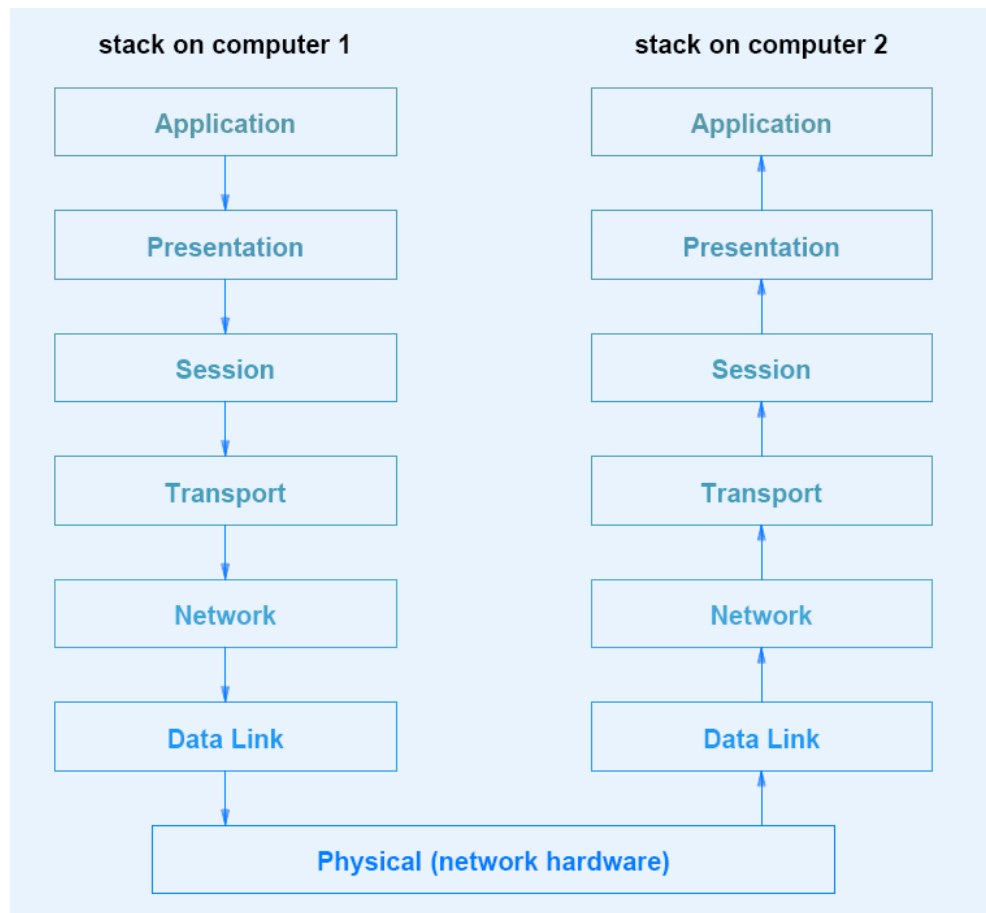
ISO Layers (continued)

- Layer 5: Session
 - Login and passwords
- Layer 6: Presentation
 - Data representation
- Layer 7: Application
 - Individual application program

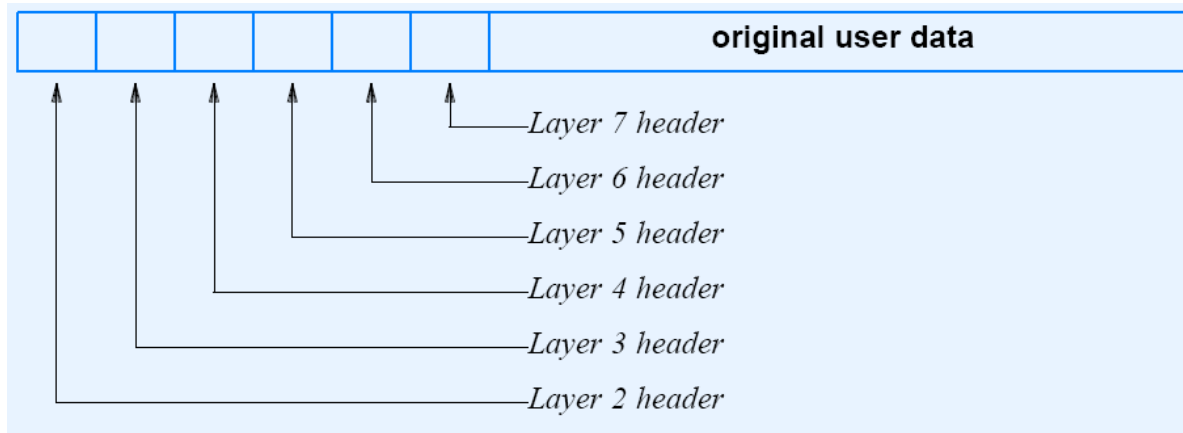
Layers And Protocol Software

- Protocol software follows layering model
 - One software module per layer
 - Modules cooperate
 - Incoming or outgoing data passes from one module to another
- Entire set of modules known as stack

Illustration Of Stacks



Layers And Packet Headers

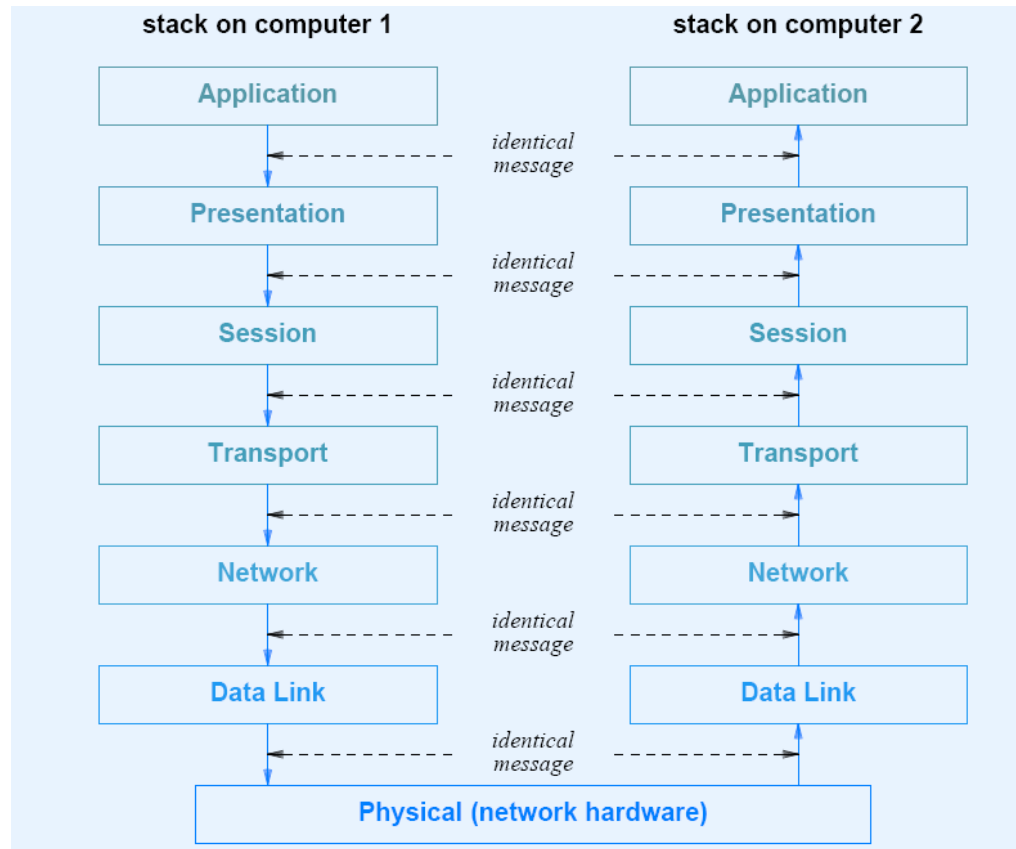


- Each layer
 - Prepends header to outgoing packet
 - Removes header from incoming packet

Scientific 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



Protocol Techniques

- For bit corruption
 - Parity
 - Checksum
 - CRC
- For out-of-order delivery
 - Sequence numbers
- Duplication
 - Sequence numbers

Protocol Techniques (continued)

- For lost packets
 - Positive acknowledge and retransmission
- For replay (excessive delay)
 - Unique message ID
- For data overrun
 - Flow control

Flow Control

- Needed because
 - Sending computer faster than receiving computer
 - Sending application faster than receiving application
- Related to buffering
- Two forms
 - Stop-and-go
 - Sliding window

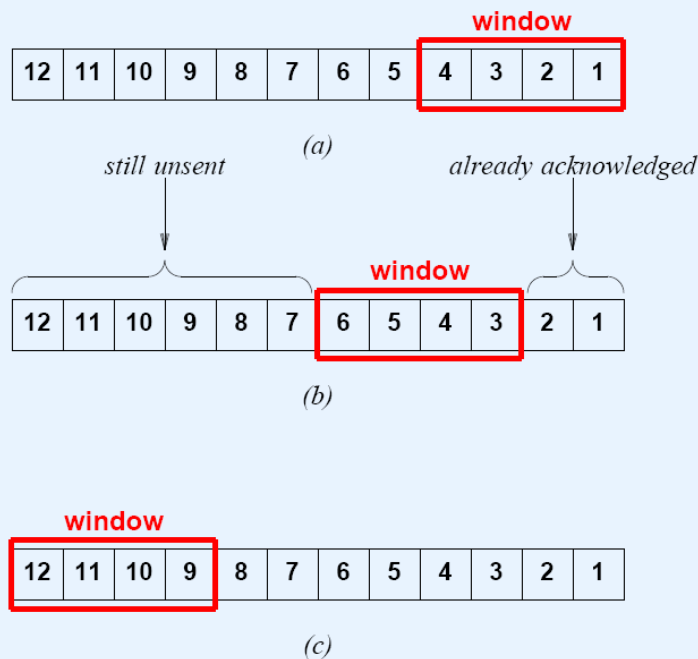
Stop-And-Go Flow Control

- Sending side
 - Transmits one packet
 - Waits for signal from receiver
- Receiving side
 - Receives and consumes packet
 - Transmits signal to sender
- Inefficient

Sliding Window Flow Control

- Receiving side
 - Establishes multiple buffers and informs sender
- Sending side
 - Transmits packets for all available buffers
 - Only waits if no signal arrives before transmission completes
- Receiving side
 - Sends signals as packets arrive

Illustration Of Sliding Window On Sending Side

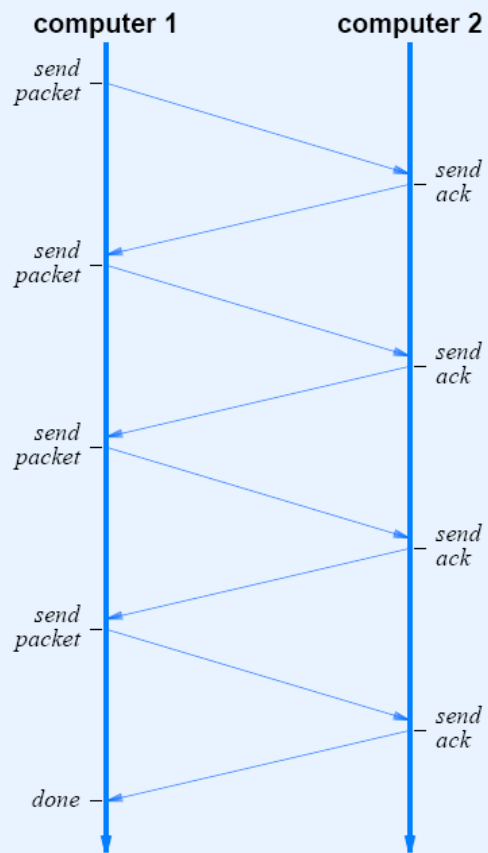


- Window tells how many packets can be sent
- Window moves as acknowledgements arrive

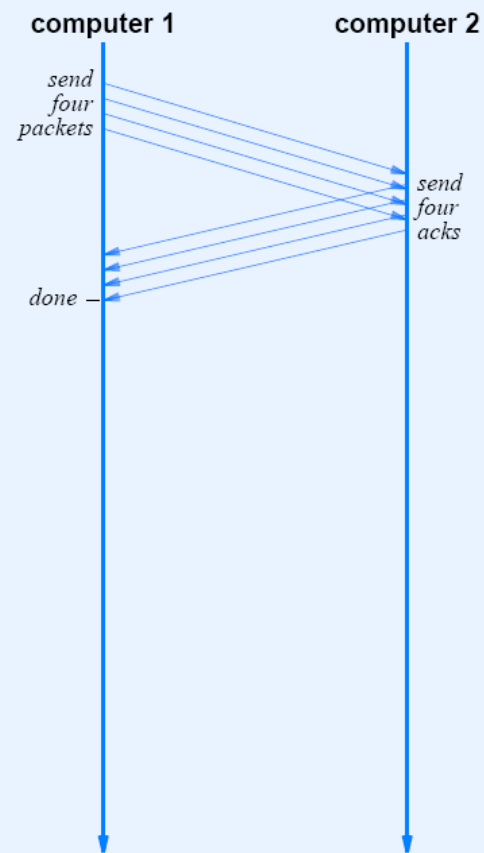
Performance

- Stop-and-go
 - Slow
 - Useful only in special cases
- Sliding window
 - Fast
 - Needed in high-speed network

Comparison Of Flow Control



(a)



(b)

Why Sliding Window?

- Simultaneously
 - Increase throughput
 - Control flow
- Speedup

$$T_w = \min (B, T_g \times W)$$

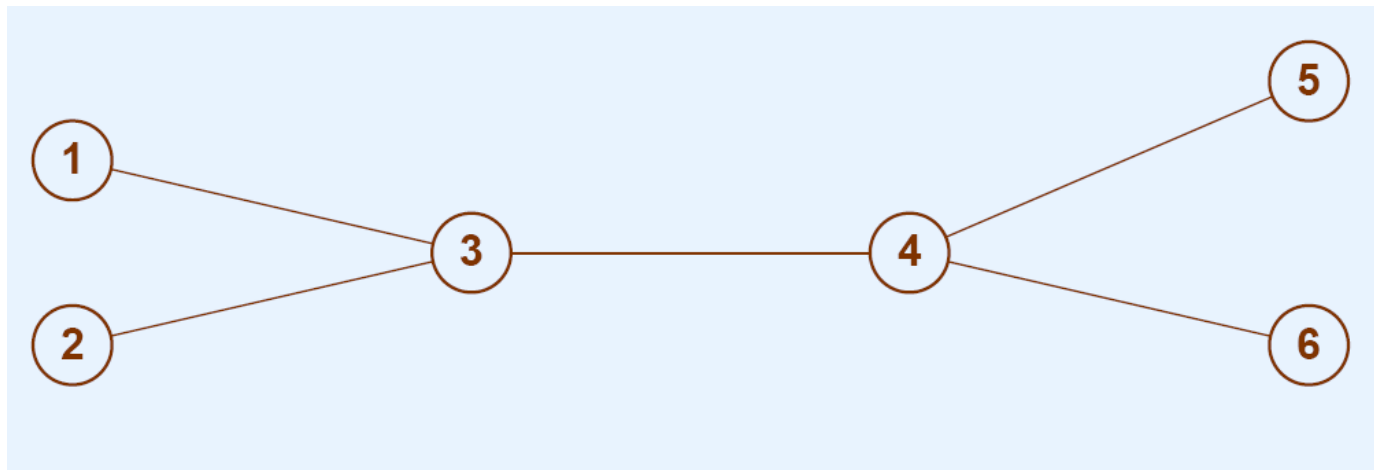
where

- * T_w is sliding window throughput
- * B is underlying hardware bandwidth
- * T_g is stop-and-go throughput
- * W is window size.

Congestion

- Fundamental problem in networks
- Caused by traffic, not hardware failure
- Analogous to congestion on a highway
- Principle cause of delay

Illustration Of Architecture That Can Experience Congestion



- Multiple sources
- Bottleneck

Congestion And Loss

Modern network hardware works well; most packet loss results from congestion, not from hardware failure.

Avoiding Congestion

- Rate control
 - Limit rate of data transmission
 - Performed by sending computer
 - Performed by network
- Network rate control
 - Monitor incoming traffic
 - Drop or reject packets over rate
 - Called traffic shaping

Summary

- Protocols
 - Rules for communication
 - Specify syntax and semantics
 - Complex
- Protocol layering
 - Intended for protocol designers
 - Helps organize set of protocols
 - Each layer handles one problem

Summary (continued)

- Problems and techniques
 - Corruption: parity, checksums, CRCs
 - Duplication, out-of-order delivery: sequence numbers
 - Loss: acknowledgement and retransmission
 - Replay: unique ID
 - Congestion: rate control
 - Data overrun: flow control

Summary (continued)

- Two types of flow control
 - Stop-and-go
 - Sliding window
- Sliding window
 - Receiver advertises buffer
 - Sender can fill entire buffer
 - Produces higher performance

PART X

Internetworking Part 1
(Concept, IP Addressing, IP Routing, IP
Datagrams, Address Resolution)

Motivation For Internetworking

- LANs
 - Low cost
 - Limited distance
- WANs
 - High cost
 - Unlimited distance

Heterogeneity Is Inevitable

No single networking technology best for all needs.

Universal Service

- Fundamental concept in networking
- Pioneered by telephone system
- Arbitrary pair of computers can communicate
- Desirable
- Difficult in a heterogeneous world

Heterogeneity And Universal Service

- Incompatibilities among networks
 - Electrical properties
 - Signaling and data encoding
 - Packet formats
 - Addresses

The Bottom Line

Although universal service is highly desirable, incompatibilities among network hardware and physical addressing prevent an organization from building a bridged network that includes arbitrary technologies.

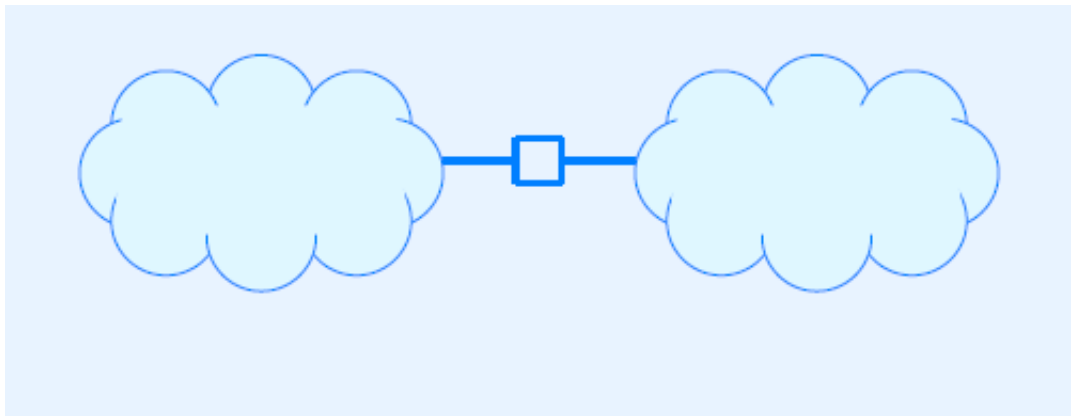
An Internetwork

- Begin with heterogeneous network technologies
- Connect the physical networks
- Create software to make resulting system appear homogeneous
- Called an internetwork or internet

Connecting Heterogeneous Networks

- Computer system used
 - Special-purpose
 - Dedicated
 - Works with LAN or WAN technologies
 - Known as
 - * Internet router
 - * Internet gateway

Illustration Of An Internet Router

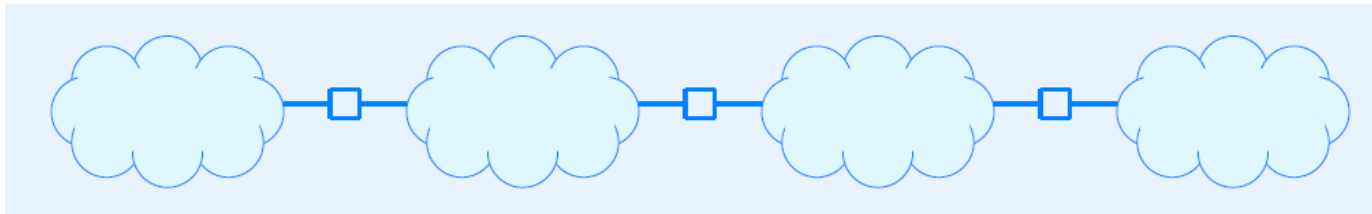


- Cloud denotes arbitrary network technology
- One interface per network

Important Idea

A router can interconnect networks that use different technologies, including different media and media access techniques, physical addressing schemes, or frame formats.

Internet Architecture

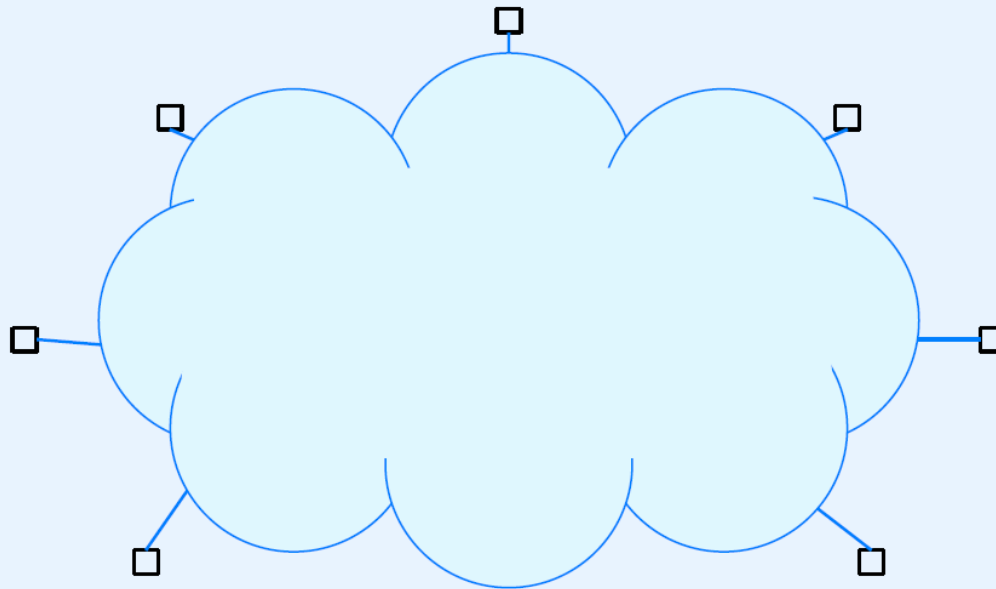


- Multiple
 - Networks
 - Routers interconnecting networks
- Host computer connects to a network
- Single router has insufficient
 - CPU power and memory
 - I/O capability

Internetworking

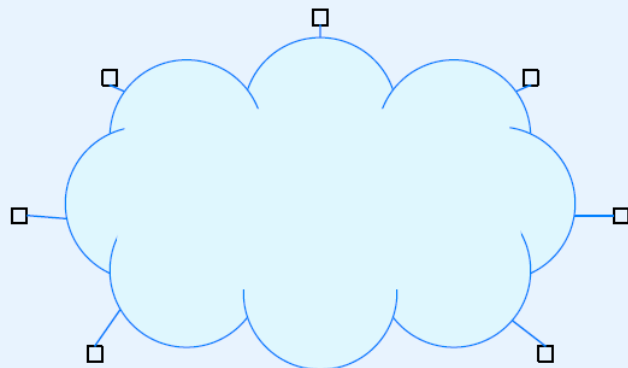
- Goal: communication system
 - Seamless
 - Uniform
 - General-purpose
 - Universal
 - Hides heterogeneity from user

The Internet Concept

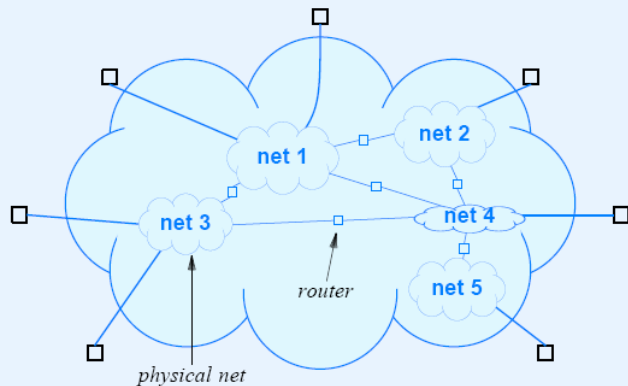


(a) The Goal

The Internet Concept



(a) *The Goal*



(b)

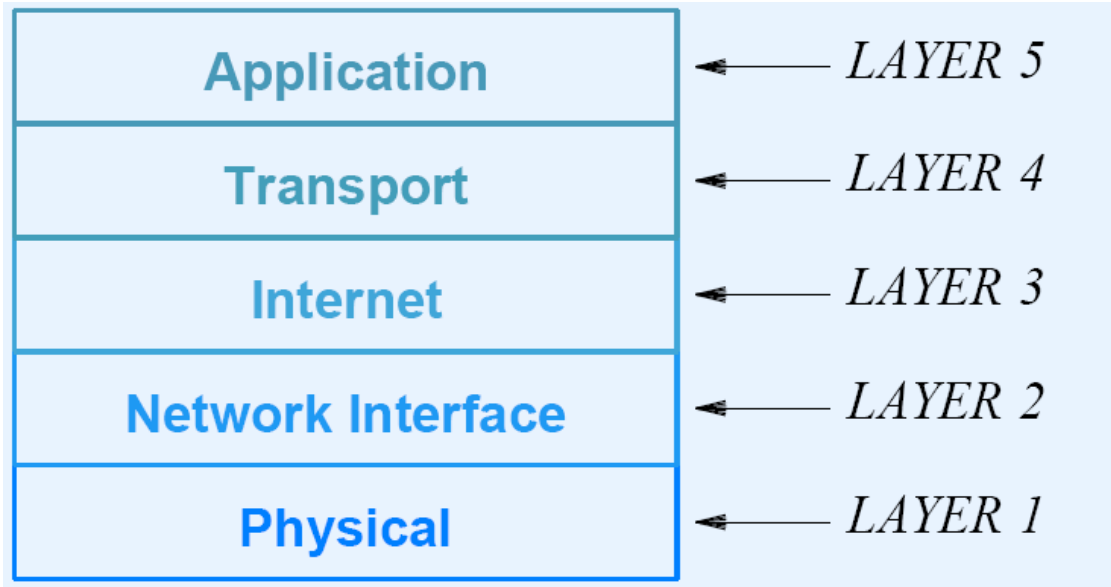
To Hide Heterogeneity

- Create “virtual” network
- Invent
 - Addressing scheme
 - Naming scheme
- Implement with
 - Protocol software
- Note: protocol software needed on both hosts and routers

Internet Protocols

- Known as TCP/IP
- Many protocols comprise suite
- Designed to work together
- Divided into five conceptual layers

Layering Used With TCP/IP



Note: TCP/IP layering model replaces the old ISO model

TCP/IP Layers

- Layer 1: Physical
 - Basic network hardware
- Layer 2: Network Interface
 - MAC frame format
 - MAC addressing
 - Interface between computer and network (NIC)
- Layer 3: Internet
 - Facilities to send packets across internet composed of multiple routers

TCP/IP Layers (continued)

- Layer 4: Transport
 - Transport from an application on one computer to application on another
- Layer 5: Application
 - Everything else

Internet Protocol (IP)

- Only protocol at Layer 3
- Fundamental in suite
- Defines
 - Internet addressing
 - Internet packet format
 - Internet routing

IP Addressing

- Abstraction
- Independent of hardware addressing
- Used by
 - Higher-layer protocols
 - Applications

IP Address

- Virtual
 - Only understood by software
- Used for all communication
- 32-bit integer
- Unique value for each host