Internetworking: Concepts, Architecture, and Protocols

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Motivation

- There are many different LAN and WAN technologies
- In real world, computers are connected by many different technologies
- Any system that spans a large organization must accommodate multiple technologies

Universal service

- Telephones are useful because any telephone can reach any other telephone
- *Universal service* among computers greatly increases the usefulness of each computer
- Providing universal service requires interconnecting networks employing different technologies

Universal Service - 2

- allows any pair of computers talk to each other.
- However, bridging cannot be used to connect heterogeneous network technologies (eg. Token-ring & Ethernet) due to incompatible network, hardware, packet formats, and physical addressing scheme.
- providing universal service among heterogeneous networks.
- The resulting system is known as an internetwork or internet.
- Router is a special-purpose computer dedicated to interconnecting at least two networks that use different technologies, such as differing media, physical addressing schemes, or frame formats.
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Internetworking

- *Internetworking* is a scheme for interconnecting multiple networks of dissimilar technologies
- Uses both hardware and software
  - Extra hardware positioned between networks
  - Software on each attached computer
- System of interconnected networks is called an *internetwork* or an *internet*

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*

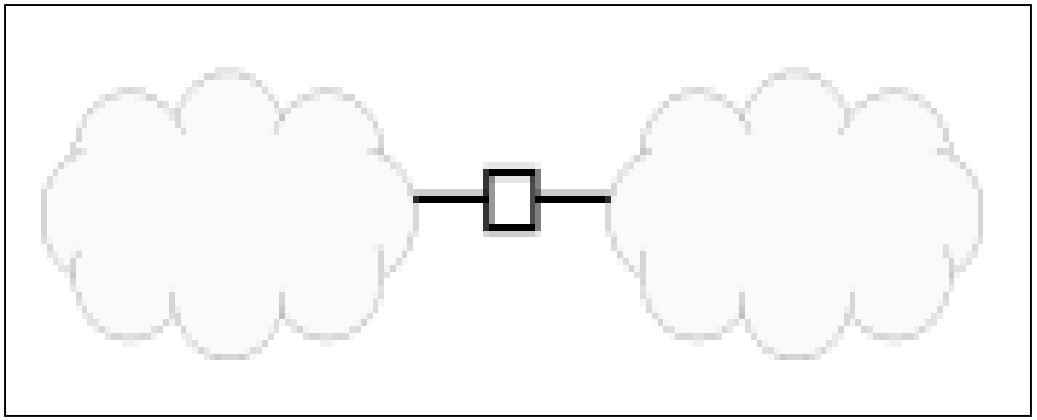
Connecting Heterogeneous Networks

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

Routers

- A *router* is a hardware component used to interconnect networks
- A router has interfaces on multiple networks
- Networks can use different technologies
- Router forwards packets between networks
- Transforms packets as necessary to meet standards for each network

Illustration Of An Internet Router



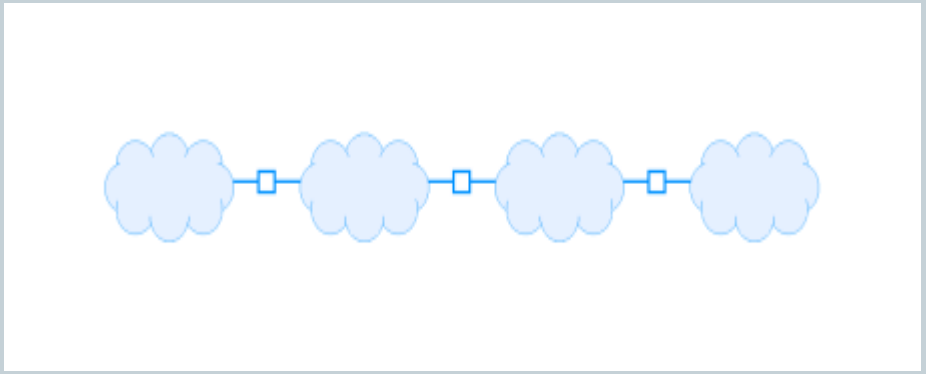
- Cloud denotes arbitrary network technology
- One interface per network

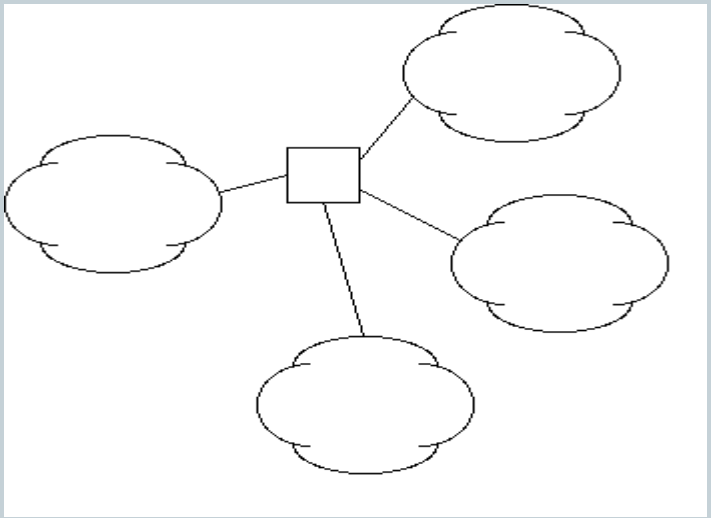
Important Idea

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

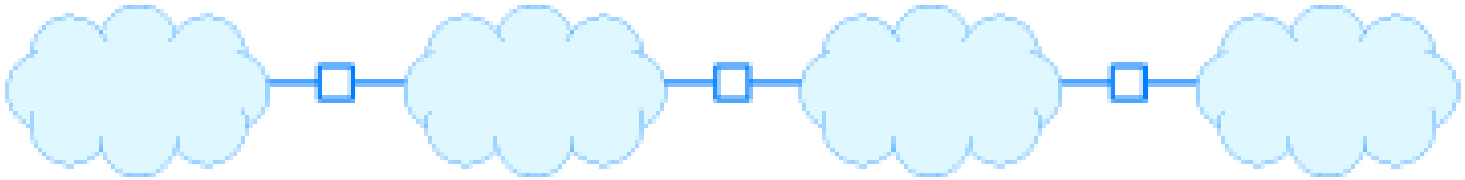
Internetwork

- An internetwork is composed of arbitrarily many networks interconnected by routers
- Routers can have more than two interfaces





Internet Architecture



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

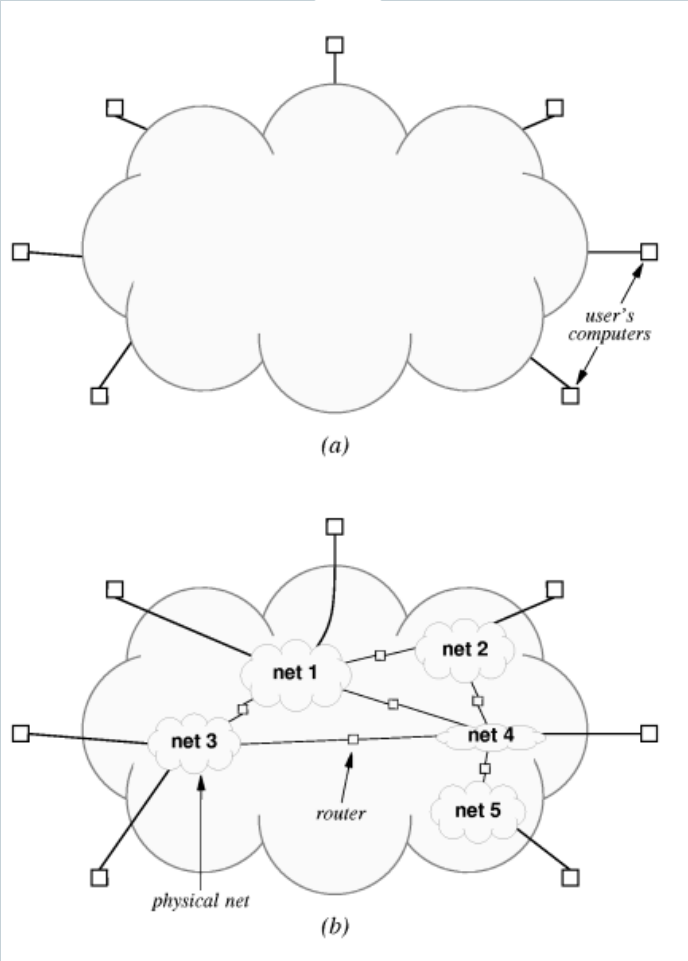
Internetworking 2

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

Routers in an organization

- Would be possible to interconnect all networks in an organization with a single router
- Most organizations use multiple routers
  - Each router has finite capacity; single router would have to handle *all* traffic across entire organization
  - Because internetworking technology can automatically route around failed components, using multiple routers increases reliability

The Internet Concept



A virtual network

- Internetworking software builds a single, seamless *virtual network* out of multiple physical networks
  - Universal addressing scheme
  - Universal service
- All details of physical networks hidden from users and application programs

Virtual Network

- an internet that provides universal service and the appearance of a single, seamless communication system to which many computers attach.
- Users and application programs are not aware of the underlying physical networks or the routers that connect them since the internet protocol software hides the details of physical network connections, physical address, and routing information.

To Hide Heterogeneity

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

A protocol suite for internetworking

- The *TCP/IP Internet Protocols* or, simply, *TCP/IP* is the mostly widely used internetworking protocol suite
- First internetworking protocol suite
- Internet concept (originally called *catenet* developed in conjunction with TCP/IP
- Initially funded through ARPA
- Picked up by NSF
- Described in *Where Wizards Stay Up Late*

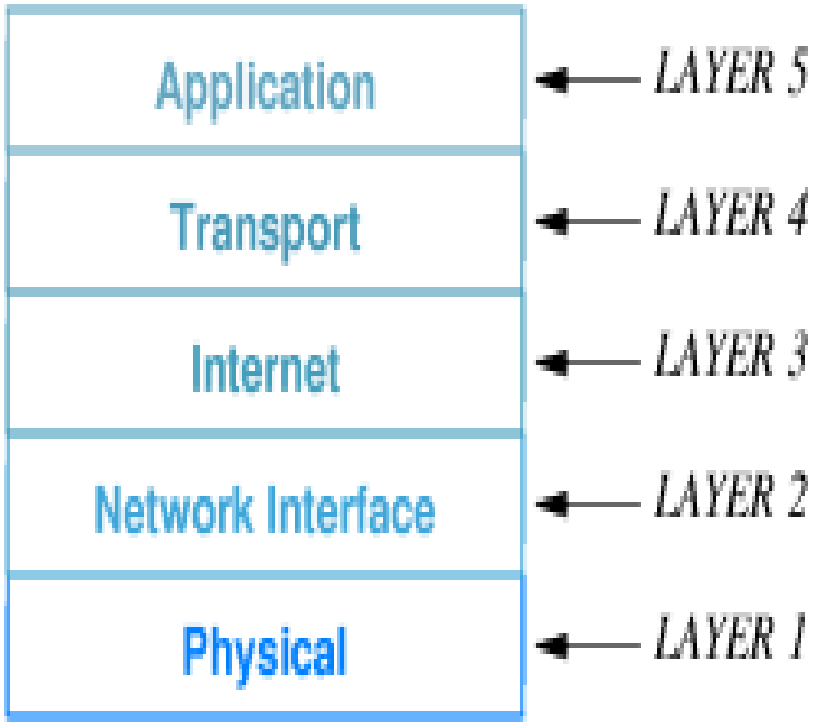
Internetworking protocols

- Others include IPX, VINES, AppleTalk
- TCP/IP is by far the most widely used
- Vendor and platform independent
- Used in the *Internet* - 20 million computers in 82 countries

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
- OSI 7-layer model does not include internetworking
- TCP/IP layering model includes five layers

TCP/IP Layers

- Layer 5: Application Corresponds to ISO model layers 6 and 7; used for communication among applications
- Layer 4: Transport Corresponds to layer 4 in the ISO model; provides reliable delivery of data
- Layer 3: Internet Defines uniform format of packets forwarded across networks of different technologies and rules for forwarding packets in routers

TCP/IP Layers (continued)

- Layer 2: Network Corresponds to layer 2 in the ISO model; defines formats for carrying packets in hardware frames
- Layer 1: Hardware Corresponds to layer 1 in the ISO model; defines basic networking hardware

Hosts, routers and protocol layers

- A *host computer* or *host* is any system attached to an internet that runs applications
- Hosts may be supercomputers or toasters
- TCP/IP allows any pair of hosts on an internet communicate directly
- Both hosts and routers have TCP/IP stacks
  - Hosts typically have one interface and don't forward packets
  - Routers don't need layers 4 and 5 for packet forwarding

Summary

- An *internet* is a collection of physical networks interconnected into a single *virtual network*
- *Routers* provide the physical interconnection and forward packets between networks
- *Hosts* communicate across multiple network through packets forwarded by routers
- TCP/IP is the most widely used internetworking protocol suite