Chapter 1 Introduction and Overview

- Motivation for Internetworking:
  - Computer users want to communicate with each other,
    BUT network technology chosen or used by different
    groups of users is different.

- What is internetworking (internet) technology?
  - Technology that makes it possible to:
    * interconnect many disparate physical networks
    * make them function as a coordinated unit

- What does internet technology achieve?
  - Hiding details of network hardware
  - Permitting computers to communicate independent of
    their physical network connections

Internetworking

- OSI (Open System Interconnection)
  - Example: the Internet
    * Specifications are publicly available
      → anyone can build the software needed to
      communicate across an internet
    * designed to foster communication between machines
      with diverse HW architectures
    * supported by using almost any packet switched network
      hardware
    * accommodate multiple computer OSs

- TCP/IP
  - TCP/IP Internet Protocol Suite
    * is more than just TCP (Transmission Control Protocol)
      and IP (Internet Protocol)
  - Resulted from ARPA (Advanced Research Projects
    Agency)
    * ARPA technology includes
      + Specification of how computers communicate
      + Conventions for interconnecting networks and routing
        traffic

- internet and the Internet
  - internet = internetworking
    * Making two networks work together
    * Not necessarily TCP/IP
  - Internet = world wide internet using TCP/IP
    * AKA: TCP/IP Internet
    * AKA: Global Internet

- Intranet: Internet technology inside a corporation
  - Internal corporate internet using TCP/IP protocols
  - Might not (necessarily) connect to the outside world
Protocols

- Protocols: Syntactic and semantic rules for communication
  - i.e. message formats, message processing, error handling
  - allow discussion computer communication independent of specific hardware.

- Protocol :: Communication
  (is to)
  as
  Algorithm :: Computation

⇒ low level hardware details are hidden
⇒ 1. New programs can be created quickly
  2. Programs do not need to be changed when machines and networks are reconfigured
  3. Programs can provide direct communication for an arbitrary pair of machines.

Internet Services

- Application level Internet Services
  - High degree of interoperability
  * ability of diverse computing systems to cooperate in solving computational problems
  - Examples: WWW, e-mail, file transfer, remote login, etc.

- Network level Internet Services
  - Connectionless packet delivery service
    * small messages forwarded separately
    * unreliable, but extremely efficient
  - Reliable stream transport service
    * connection-oriented
    * acknowledgement

What Make TCP/IP Internet Different

- Distinctions between TCP/IP and others:
  - Network technology independence
    * packet switching independent of any particular HW
    * TCP/IP protocols
      + define the unit of data transmission – datagram
      + specify how to transmit datagrams on a particular network
  - UNIVERSAL interconnection
    * Any pair of computers attached to the Internet can communicate with each other
    * Each computer is assigned a universally recognized address
    * Each datagram carries a source and a destination addresses
    * Routing is based on the destination address
  - End-to-end acknowledgements
  - Application protocol standards: e.g. FTP, E-Mail

Internet Architecture Board and RFCs

- IAB (Internet Architecture Board)
  - Sets policy and direction for TCP/IP and the Internet
    * IETF (Internet Engineering Task Force): www.ietf.org
    * IRTF (Internet Research Task Force)

- Internet RFC (Internet Request For Comments)
  - A series of documents that contains
    * surveys, measurements, ideas, techniques, and observations
    * proposed and accepted TCP/IP protocol standards
  - Available on-line at www.ietf.org

- Exponential growth of Internet:

<table>
<thead>
<tr>
<th>Year</th>
<th>#networks</th>
<th>#computers</th>
<th>#users</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>$10^3$</td>
<td>$10^2$</td>
<td>$10^2$</td>
</tr>
<tr>
<td>1990</td>
<td>$10^5$</td>
<td>$10^5$</td>
<td>$10^6$</td>
</tr>
<tr>
<td>2000</td>
<td>$10^6$</td>
<td>$10^7$</td>
<td>$10^8$</td>
</tr>
<tr>
<td>2005</td>
<td>$10^6$</td>
<td>$10^8$</td>
<td>$10^9$</td>
</tr>
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(Also: http://navigators.com/stats.html)
Chapter 2 Review Of Underlying Network Technologies

- Two approaches to network communication
  - Circuit-Switched Network
    * connected-oriented
    * dedicated connection
  - Packet-Switched Networks
    * data divided into "packets"
    * packets carry ID

  ➔ network knows how to deliver it to destination.

- Pros and Cons
<table>
<thead>
<tr>
<th>Circuit Switched</th>
<th>Packet Switched</th>
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</thead>
<tbody>
<tr>
<td>Pros</td>
<td>Cons</td>
</tr>
<tr>
<td>guaranteed BW</td>
<td>fixed-cost</td>
</tr>
<tr>
<td>inter-machine</td>
<td>independent of traffic</td>
</tr>
<tr>
<td>connection sharing</td>
<td>less capacity as traffic heavier</td>
</tr>
</tbody>
</table>

- For cost and performance, packet switching has advantage and is widely used.

LANs and WANs

- LAN vs. WAN

<table>
<thead>
<tr>
<th>LAN (Local Area Network)</th>
<th>WAN (Wide Area Network)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Speed</td>
<td>Slower Speed</td>
</tr>
<tr>
<td>Shorter Delay</td>
<td>Longer Delay</td>
</tr>
<tr>
<td>Smaller Area</td>
<td>Larger Area</td>
</tr>
<tr>
<td>Each computer connects directly to the net medium using a Network Interface Card (NIC)</td>
<td>Network consists of packet switches (routers) interconnected by communication lines with modems and computers connected to switches</td>
</tr>
</tbody>
</table>

- Network Hardware Addresses

- Each network HW technology defines an addressing mechanism

- Every computer attached to a network is assigned a unique address

- Destination address is carried in each packet

- Each HW technology specifies how computers are assigned hardware addresses

Ethernet Technology

- Ethernet (IEEE 802.3)
  - Xerox PARC in early 1970s
  - Original wiring: coaxial cable, 1/2" in diameter (Thicknet)
  - Most popular LAN technology

- Twisted Pair Ethernet
  - Connects each computer to a hub/switch
  - Low cost and easy to install
  - Disconnect one computer won't affect others
  - "Tree" topology
  - First one: 10Base-T

- Hub
  * electronic device simulating signals on an Ethernet cable
  * power required
  * connection between a computer and a hub < 100 m
**Ethernet Hardware Address**

- Each computer attached to an Ethernet is assigned a unique 48 bit number (address).
  - Each Ethernet card has a unique address.
  - Hardware address = Physical Address
  - Associated with the Ethernet Interface Hardware
  - Changed when moving hardware interface to a new machine OR replacing an old card with a newer one

- Host interface hardware examines packets and determines if packets should be sent to the host.

- Addressing mechanism & HW filter needed to prevent a computer from being overwhelmed with incoming data. (CPU not involved, done by the hardware interface.)

- Three types of addresses:
  1. Unicast address
  2. Broadcast address
  3. Multicast address

- A host interface usually supports at least (1) and (2)

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**Ethernet Frame Format**

- Ethernet frame format:
  - Size: 64 to 1518 octets (bytes)
  - Fields:
    - Preamble 8 octets
    - Destination Address 6
    - Source Address 6
    - Frame Type 2 (self-identifying)
    - Frame Data 46 - 1500
    - CRC 4 (error detecting)

- Self-identification
  - Used by OS to determine which protocol software to use
  - Advantages:
    - Allowing multiple protocols to be used
    - 1. Used together on a single machine
    - 2. Intermixed on the same physical network without interference (IPX/SPX or TCP/IP for example)

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**Example Ethernet Frame In Memory**

- How do we interpret the content (preamble not shown)?

  02 07 01 00 27 ba 08 00 2b 0d 44 a7 08 00 45 00
  00 54 82 68 00 00 ff 01 35 21 80 0a 02 03 80 0a
  02 08 08 00 73 0b d4 6d 00 00 04 3b 8c 28 28 20
  0d 00 08 09 0a 0b 0c 0d 0e 0f 10 11 12 13 14 15
  16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 22 23 24 25
  26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 32 33 34 35
  36 37

- Destination is ____________________
- Source is ___________________
- Frame type is ________________

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**Extending Ethernet**

- Problem: Ethernet cable has a maximum length

- Solution:
  - Bridges (Data Link Layer)
    - Devices that connect LANs
    - 3 LANs connected by one bridge are like one LAN
    - Advantages
      - Noise and errors not replicated
      - Collisions and delays on one wire isolated from the other (yet virtually one big LAN)

- Details of interconnection are hidden
  - A set of bridged segments acts like a single Ethernet
Chapter 3
Internetworking Concept and Architectural Model

o Primary goal
  - A scheme that hides the details of underlying network hardware while providing universal communication services

o Primary result
  - A high-level abstraction that provides the framework for all design decisions

o Approaches
  - Application-level interconnection - NOT feasible
  - Network-level interconnection: internetworking

Network-Level Interconnection

o Internet Concept
  - notions of communication detached from the details of network technologies
  - low-level details hidden from the user
  - derivation of all software designs decisions
  - explanation how to handle physical addresses and routes

o Internet Scheme
  - a unified, cooperative interconnection of networks that support a universal communication service
  - computers within each network use underlying technology-dependent communication facilities
  - new software inserted between technology-dependent communication mechanisms and application programs
    * hide the low-level details
    * make the collection of network appear to be a single large network

Properties of Internet

o Universal service
o Hardware and network topology detail hidden
o All machines share a universal set of machine IDs (names or addresses)
o Network independence in the user interface

Internet Architecture

o How are networks interconnected to form an internet?
  - Two "clouds" interconnected by R

* R: router or IP gateway

* clouds: physical networks (as exact hardware unimportant)

o Example of multiple networks

- Networks can be heterogeneous
- No direct connection from network 1 to network 3
Internet Architecture

- Interconnection through IP routers
  - IP Routers (or IP Gateways)
    * computers responsible for
      - interconnecting two networks
      - passing packets from one network to others
    * small computers usually, but FAST.
  - destination NETWORK, not destination HOST is used when routing a packet
  - needs to know topology of the internet so routing can be done efficiently.
  - more than one routers might be involved in routing a packet

User's view

- Internet = one single VIRTUAL network
- All networks are treated equally by TCP/IP
- Conclusion:
  TCP/IP defines an abstract of "network" that hides the details of physical networks.

Architectural Terminology

- End-user system is called host computer
  - Connects to physical network
  - Possibly many hosts per network
  - Possibly more than one network connection per host
- Dedicated systems called IP gateways or IP routers interconnect networks
  - Router connects two or more networks

Many Unanswered Questions

- Addressing model and relationship to hardware addresses
- Format of packet as it travels through Internet
- How a host handles concurrent communication with several other hosts

Summary

- Internet is set of interconnected (possibly heterogeneous) networks
- Routers provide interconnection
- End-user systems are called host computers
- Internetworking introduces abstractions that hide details of underlying networks