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Introduction

Evaluation /Assessment

- Midterm Exam (November 12, 2002) 25%
- Homeworks 10%
- Quizzes 15%
- Project 15%
- Final Exam 35%

Course Objective

- To Learn
  - » Short-term memory
  - » Long-term memory
    - – reinforcement
- Surface Learning
- Deep Learning

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Historical glimpses

- The past several decades have witnessed a phenomenal growth in the computer industry:
  - » Dramatic drop in the cost/performance
  - » Advanced and complex computer applications, e.g. Image processing, speech recognition,..
- As computer proliferated, so did the need for data communication
  - » People became more and more interested in connecting several computers together.

Historical glimpses

- **Computer Network:**
  Interconnected collection of autonomous computers and computer resources
- **Expected return!**
  - *Resource Sharing (information, software, printers, …)*
  - *High reliability*
  - *Saving money*
  - *Powerful communication medium*

Historical glimpses (contd.)

- In early years of networking, each computer manufacturer developed its own communication solution
  - Structured Network Architecture (SNA) of IBM
  - DEC Network Architecture (DNA) of DEC
  - ARPANET of ARPA
  - etc.

Historical glimpses (contd.)

- 1977 -- ISO established a subcommittee to develop an architecture/structure that defines communication tasks and which would:
  - Serve as a reference model for international standards
  - would facilitate efficient internetworking among systems from different technologies, manufacturers, administrations, nationalities, and enterprises.

Historical glimpses (contd.)

- 1978 -- Meeting of 40 experts in Washington, D. C. started work that yielded 6 years later the OSI Reference Model.
  - *Paper by Louis Pouzin and Hubert Zimmermann, Proc. Of the IEEE November 1978, pp. 1346 - 1370.*
- 1975 -- ARPANET transitioned to Defense commercial agency.
- 1978-80 -- ARPANET protocol were upgraded with TCP/IP.
  - Paper by Cerf and Khann, IEEE Trans. Comm., May 1974.

Historical glimpses (contd.)

- February 1980 -- The IEEE started Project 802 to develop standards for the LAN market.
- 1981 -- A new host added to ARPANET every 20 days.
- 1983 -- TCP/IP switchover complete.
  - TCP/IP adopted as standard by DOD
  - ARPANET had over 300 hosts.
  - Over 1200 nodes by 1985.
  - ARPANET split
    - ARPANET: Academic (Educational, Research)
    - MILNET: Military

Historical glimpses (contd.)

- 1984 -- The OSI-RM came out.
  - Defines a strategic outline/vision
  - Reduces degrees of freedom of standards developers
  - Centered around the hierarchical decomposition of communication functions
- 1986 -- NSFnet backbone created.
- 1990 -- ARPANET put to rest
  - 1987 -- over 25000 nodes
  - 1989 -- 3000 networks for over 200000 users

Historical glimpses (contd.)

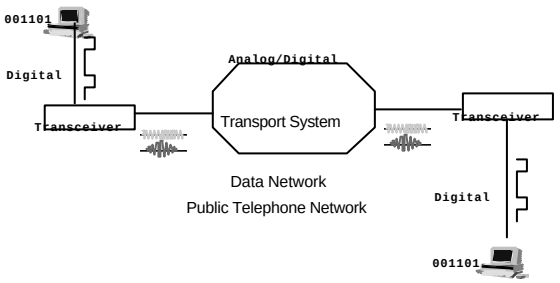
- 1991-- WWW invented & Gopher introduced
- 1995
  - » Internet backbone privatized
  - » Over 7 million networks around the world
  - » 150000 users join the network every month
- July, 1998 -- over 36 million networks
- Jan, 1999 -- 157 million users
- Projected to be 327 million by year 2000

Historical glimpses (contd.)

- The Internet is an Information Highway
  - » Dedicated communication links (copper, fiber, satellite) functioning as the concrete/asphalt
  - » Usually T/E leased lines serve as the on-ramp connecting to regional networks
    - – Capacity of T1 highways is 1.544 Mbps
    - – that of T3 is 45 Mbps
- The Internet is becoming a platform for most computer needs.

Basic Networking concepts

Simple Data Communication Model



Terminology

- Networks are classified on the basis of geographic span.
  - » **Local Area Networks (LANs)**
  - » **Metropolitan Area Networks (MANs)**
  - » **Wide Area Networks (WANs)**
- The difference in geographical extent between WANs and LANs account for significant differences in their respective design issues.

LAN Characteristics

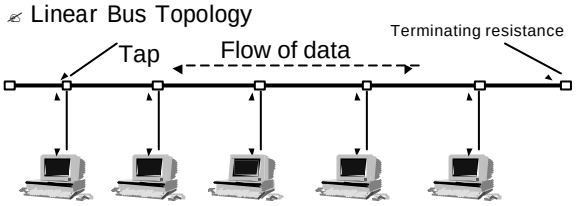
- LANs are designed to:
  - » Operate within a limited geographic area
  - » Allow multiaccess to high-bandwidth media
  - » Control the network privately under local administration
  - » Provide full-time connectivity to local services
  - » Connect physically adjacent devices

LAN Characteristics

» All nodes are connected by a single high speed shared channel.
» Data is packetized and packets are carried past all nodes in the network.
» Addressing is required but routing is not needed.
» Congestion control and network architecture are among design issues.
» Several topologies can be used but the choice of topology is not a major issue.

LAN Topologies

- Linear Bus Topology

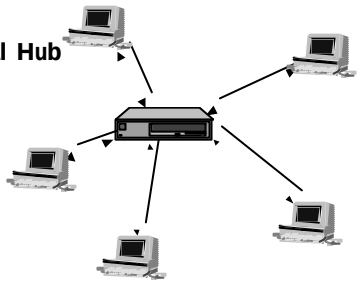


Bus Topology

- Characteristics:
  - Broadcasting (all station are listening)
  - Full-duplex link between Tap and station
- Problems:
  - A mechanism is needed to identify the destination
  - A mechanism is needed to regulating the flow of traffic
- Solution:
  - Addressing each station
  - Multiple access technique

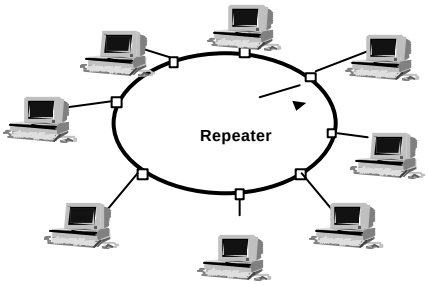
Star Topology

- **Functions of central Hub**
  - Store-and-Forward



LAN Topologies (Contd.)

- **Ring**.



LAN Components

A LAN has the following basic components:

- Transmission Medium
  - » Cable or Cable-less. It connects the various stations. E.g. twisted pair, coaxial cable, CATV cable, fiber optics, radio waves.
- Stations
  - » Intelligent workstations which attach to the medium. E.g. PC or workstation.

LAN Components (Cont.)

- » Non-intelligent which attach to a station. E.g. Printers, Modems, Hard disks, etc.
- File server
  - » The main unit in the network that offers various services to the network users.
  - » It refers to a computer, its hard disk, its network operating system, and the file server software that manages the network resources.

LAN Components (Cont.)

- Network Interface Card (NIC)
  - » Network adapter to send and receive messages. It is a circuit board with the components necessary for handling communication tasks
  - » The NIC is plugged onto one of the available slots on the PC expansion bus.
  - » Installed in each workstation and file server such as Ethernet NIC.

LAN Components (Cont.)

- Network Operating System (NOS)
  - » Installed on the hard disk of the file sever station. Its function is to control the access to the common shared resources, such as printers, hard disks, database applications, etc.
- Workstation Operating System
  - » Consists of a network shell installed on any one of the popular operating systems such as DOS, Unix, Linux, MAC-OS, etc.

LAN Characteristics

- What distinguishes one LAN from another:
  - » Transmission Medium
    - – Twisted pair, Coax, CATV, Fiber Optic, or Wireless.
  - » Topology: Star, Bus, Ring
  - » Transmission method: Base/Broadband
  - » Medium Access Technique
    - – Random Access (CSMA/CD)
    - – Controlled Access (Token Passing)

Server-Based LANs

- Server-based: A server-based network consists of a group of user-oriented PCs called *clients* that request and receive network services from specialized computers called *servers*.

Client Server Model

- Client-Server paradigm is the primary pattern of interactions among cooperating applications.
- This model constitutes the foundation on which distributed algorithms are built.

What is the Client-Server Paradigm?

- The paradigm divides communicating applications into 2 broad categories, depending on whether the application waits for communication or initiates it.
  - » An application that initiates a communication is called a ***client***.
  - » End users usually invoke a client software when they use a network service.

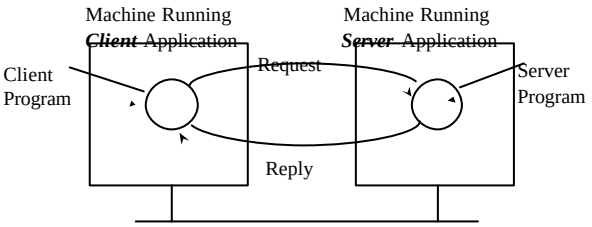
Client Server Model (cont.)

- Server: Any program that offers a service reachable over the network
  - » If a machine's primary purpose is to support a particular server program, the term server is usually applied to both, the machine and the server program
- Client: An executing program becomes a client when it sends a request to a server and waits for a response

Client Server Model (cont.)

- A ***server*** is any program that waits for incoming communication requests from a client.
  - » Each time a client application needs to contact a server, it sends a request and awaits a response.
  - » The server receives a client's request, performs the necessary computation, and returns the result to the client.
  - » When the response arrives at the client, the client continues processing.

Client Server Model (cont.)



Client Server Model (cont.)

- **A Misconception**:
  - » Technically, a ***server*** is a program and not a piece of hardware.
  - » However, computer users frequently (mis)apply the term to the computer responsible for running a particular server program.
    - – For example, ***Web Server***, is usually a computer running the ***http*** server program.

MANs

- A bigger version of a LAN (e.g. group of buildings, city, ..)
- No switching is used
- MAN supports both data and voice
- IEEE 802.6 standard

WANs

- To make optimum use of expensive communication links, WANs are structured with irregular placement of the nodes. Store-and-Forward packet switching is used to deliver packets to their destination.

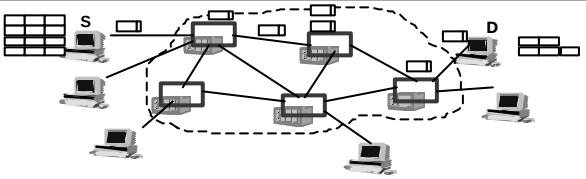
WAN Characteristics

- » Span a large geographical area
- » Data is packetized and packets are carried past all nodes in the network.
- » Addressing routing are required

Wide-Area Networks and Devices

- WANs are designed to:
  - » Allow access over serial interfaces operating at lower speeds
  - » Control the network subject to regulated public services
  - » Connect devices separated over wide, even global areas

WANs



Design Issues:

- Capacity assignment
- Network topology
- Routing algorithm
- Congestion control
- Network architecture

Enterprise Developments

- The enterprise is a corporation, agency, service, or other organization that will tie together its data, communication, computing, and storage resources.
- Developments on the enterprise network include:
  - » LANs interconnected to provide client/server applications integrated with the traditional legacy applications from mainframe data centers
  - » End-user needs for higher bandwidth on the LAN, which can be consolidated at a switch and delivered on dedicated media
  - » Integration of formerly separate networks so that the nonbursty traffic from voice and video applications coexist on a single network
  - » Relaying technologies for WAN service, with very rapid growth in Frame Relay and cell relay (ATM)

Network Architecture

Communications Protocol

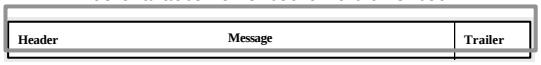
- A set of rules and conventions
  - » To provide error-free and maximally convenient information transfers
  - » Protocol define connectors, cables, signals, data formats, error control
  - » techniques and algorithms for message preparation, analysis and transfer

Communication Protocols (Contd.)

- Network Protocol:
  - » A set of rules defining the syntax (form) and semantics (meaning) in order to regulate communication between network nodes.
  - » Protocols can be implemented in either hardware or software
  - » The EIA-232-D is a physical layer protocol implemented in hardware.
  - » TCP/IP are implemented in software.

Protocol Data Units (PDU)

- Each PDU must contain two major parts:
  - » Header:
    - – Identifies how the following parts are to be handled and routed.
  - » Message:
    - – This is the message body itself.
    - – This is where the protocol is determined to be character oriented or bit oriented.



Communication Standards

- The goal of the ISO subcommittee developing the OSI model was to provide a framework for network standards acceptable to all manufacturers

ISO OSI Reference Architecture

- The architecture is layered to reduce complexity.
  - » Each layer offers certain services to the layer immediately above it.
  - » Each layer shields the higher layer from the details of implementation of how the services are offered.
  - » Layer "n" on one station carries on a conversation with layer "n" on another network station.

OSI Reference Model

- The ISO OSI Layered Model
  - » Application: File transfer, mail, rlogin, etc.
  - » Presentation: Data formatting.
  - » Session: Negotiation and connection.
  - » Transport: End-to-end delivery.
  - » Network: Routing of packets.
  - » Data link: Transfer of frames.
  - » Physical: Cabling system.

Why a Layered Model

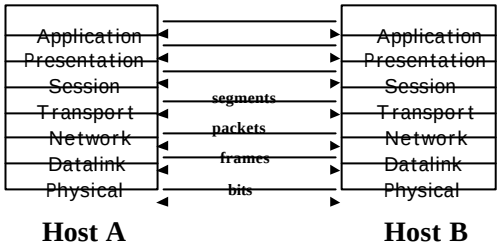
7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Datalink
1	Physical

- Reduces complexity
- Standardizes interfaces
- Facilitates modular engineering
- Ensures interoperable technology
- Accelerates evolution
- Simplifies teaching and learning

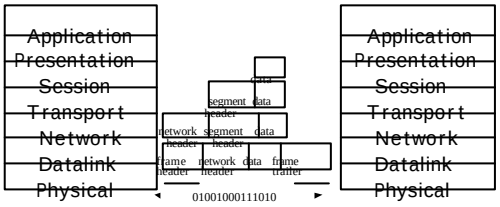
Layer Functions

7	Application	Network processes to applications
6	Presentation	Data representation
5	Session	Inter-host communication
4	Transport	End-to-end connections
3	Network	Addresses and best path
2	Datalink	Access to media
1	Physical	Binary transmission

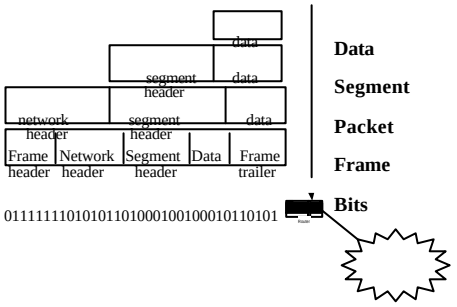
Layer Functions



Data Encapsulation

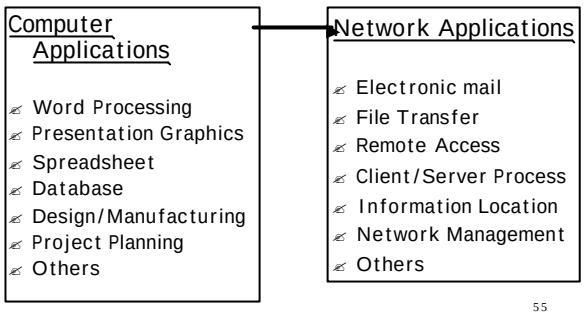


Data Encapsulation Example

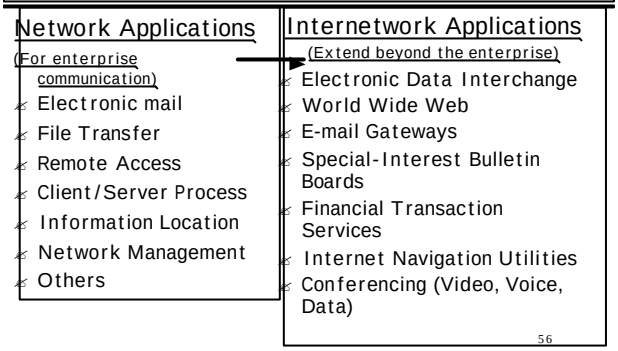


Application,
Presentation,
and Session Layers

Application Layer



Application Layer (cont.)



Presentation Layer

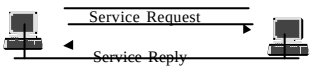
- Text
- Data
  - » ASCII, EBCDIC
  - » Encrypted
- Sound
- Video
  - » MIDI (Musical Instrument Digital Interface)
  - » MPEG (Motion Picture Experts Group)
  - » QuickTime

Presentation Layer

- Graphics
- Visual Images
  - » PICT(format to transfer QuickDraw graphics between Macintosh or PowerPC programs)
  - » TIFF (Tagged Image File Format)
  - » JPEG (Joint Photographic Experts Group)
  - » GIF
- Provides code formatting and conversion for applications

Session Layer

- Coordinates applications as they interact on different hosts



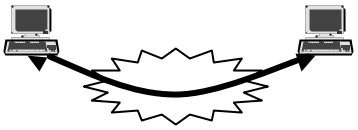
Session Layer (contd.)

- Network File System (NFS)
  - – Allows trasnparent access to remote network resources
- Structured Query Language (SQL)
- Remote-Procedure Call (RPC)
  - – RPC procedures are built on clients and executed on servers
- X Window System
  - – Allows intelligent terminals to communicate with remote UNIX machines
- AppleTalk Session Protocol (ASP)
  - – Establishes and maintains sessions between an AppleTalk client and server
- DNA Session Control Protocol (SCP)

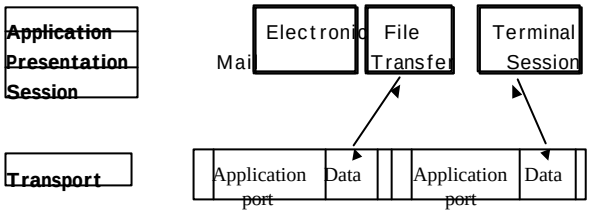
Transport Layer

Transport Layer Overview

- Segments upper-layer applications
- Establishes an end-to-end connection
- Sends segments from one end host to another
- Ensures end-to-end data reliability

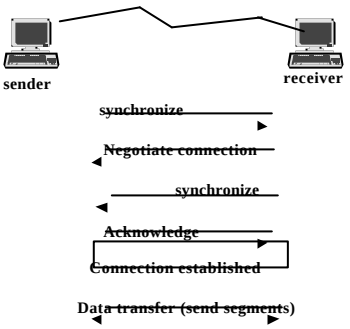


Segment Upper-Layer Applications

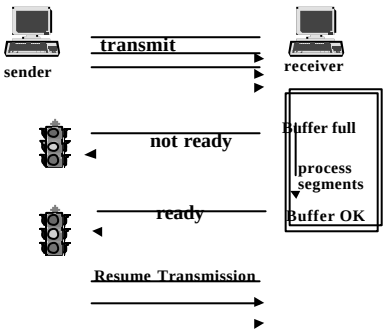


- **Transport segments share traffic stream**

Establishes Connection



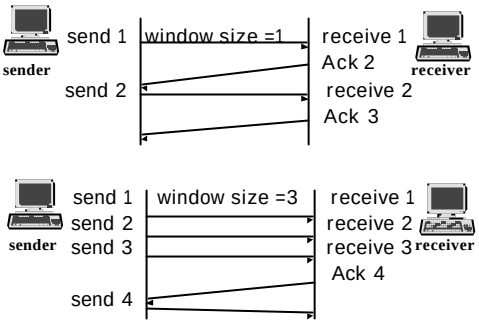
Establishes Connection



Reliability with Windowing

- In the most basic form of reliable connection-oriented transfer, data segments must be delivered to the recipient in the same sequence that they were transmitted.
- *Windowing* is a method to control the amount of information transferred end-to-end. Some protocols measure information in terms of number of packets

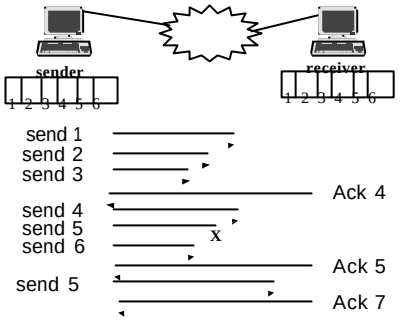
Reliability with Windowing



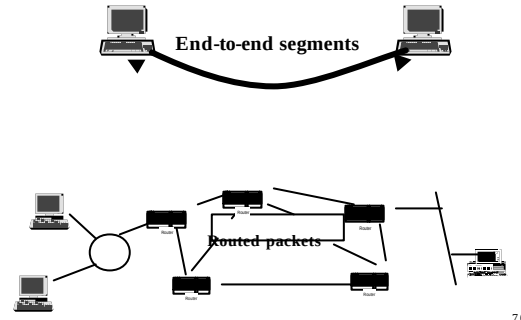
An Acknowledgement Technique

- Reliable delivery guarantees that a stream of data sent from one machine will be delivered through a functioning data link to another machine without duplication or data loss. Positive acknowledgement with retransmission is one technique that guarantees reliable delivery of data streams.
- The sender keeps the record of each segment it sends and waits for an acknowledgement.
- The sender also starts a timer when it sends a segment, and it retransmits a segment it the timer expires before an acknowledgement arrives.

An Acknowledgement Technique



Transport to Network Layer



Summary

- Presentation layer formats and converts network application data to represent text, graphics, images, video, and audio.
- Session-layer functions coordinate communication interactions between applications.
- Reliable transport-layer functions include
  - » Multiplexing
  - » Connection synchronization
  - » Flow control
  - » Error recovery
  - » Reliability through windowing

Important Concepts

- **Circuit Switching**
  - » A dedicated communication path between two stations
    - a path is a sequence links between nodes
  - » Circuit switching connection phases:
    - Circuit Establishment (TDM or FDM)
    - Data transfer
    - Circuit disconnect
  - » Channel capacity is dedicated for the duration of a connection
  - » Fixed data (digital or analog) transfer rate (streaming)
  - » No delay other than Call establishment delay and propagation delay
  - » **Main Application: Telephone networks**

Important Concepts

- **Circuit Switching Drawbacks:**
  - » Low channel utilization
  - » The interconnecting devices must receive and transmit at the same rate
- **Packet Switching**
  - » Data is transmitted in blocks, called packets
  - » Each packet has two main components:
    - – data (payload)
    - – header (control information)

Important Concepts

- **How Network handles the Packet Streams:**
  - » Datagram Approach
  - » Virtual Circuit Approach
- **Datagram Approach**
  - » Each packet is treated independently
  - » Packets may not follow the same route and therefore arrive out of sequence
- **Virtual Circuit Approach**
  - » A logical connection is established before any packets are sent
  - » A fixed route is preplanned
  - » Each packet contains a virtual circuit identifier and data

TCP/IP Key Differences From OSI

- Connectionless Service: TCP/IP is pro-connectionless
- Simple Management
- Hierarchy vs layering
- Internetworking: Not in original OSI

Layering

- Each layer has to perform a set of functions
- All alternatives for a row have the same interfaces
- Choice at each layer is independent of other layers.
- Need one component of each layer
- Null components
- Nth layer control info is passed as N-1th layer data.

Hierarchy

- **Can directly use the services of a lower entity even if it is not in an adjacent layer**
- **Control and data can be separate connections.**
- **Control connections may have different reliability requirements than data.**
- **Lower layer control information can be used for higher layer control, e.g., lower layer close may close all higher layers**

Internetworking Terms

- **End-system: Host**
- **Network: Provides data transfer between end-systems**
- **Internet: A collection of networks**
- **Subnetwork: Each component of an internet**
- **Intermediate System: Connects two subnetworks**
- **Port: Application processes in the host**

Operation of TCP/IP

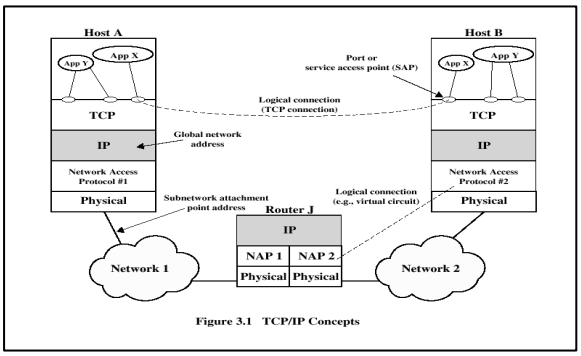


Figure 3.1 TCP/IP Concepts

Operation of TCP/IP

- Two levels of addressing are needed:
  - Each host on a subnet must have a unique global internet address
  - Each process with a host must have a unique address within the host (port)
- Host address on a network
- IP deals only with host addresses = Subnet + Host #
- Application messages are broken into TCP segments

Operation of TCP/IP (Cont.)

- **TCP Header**
  - Source port (16 bits)
  - Destination port (16 bits)
  - Uses segment sequence number (32 bits) for ordering and lost segment detection
  - Uses checksum for error detection
- Passes the segment to IP with instructions to deliver it to the destination host
- Delivers the data to appropriate port in the destination host

IP Operation

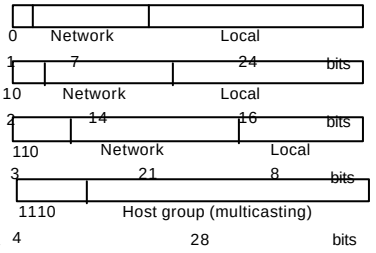
- **IP Protocol**
  - **Deals only with host addresses**
- **Services:**
  - **Send: user to IP**
  - **Deliver: IP to user**
  - **Error (optional): IP to user**

IP Operation

- **IP Header**
  - Source host address (32 bits)
  - Destination host address (32 bits)
  - Type of service (reliability, precedence, priority)
  - Time-to-live (TTL)
  - Uses checksum for error detection

IP Address

- Class A: 16,774,214
- Class B: 65,534
- Class C: 254
- Class D:
- Local : Subnet + Host



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  - » Source port (16 bits)
  - » Destination port (16 bits)
  - » Uses segment sequence number (32 bits) for ordering and lost segment detection
  - » Uses checksum for error detection
  - » Passes the segment to IP with instructions to deliver it to the destination host
  - » Delivers the data to appropriate port in the destination host

IP Operation

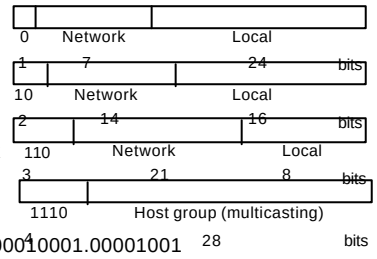
- **IP Protocol**
  - » **Deals only with host addresses**
- **Services:**
  - » **Send: user to IP**
  - » **Deliver: IP to user**
  - » **Error (optional): IP to user**

IP Operation

- **IP Header**
  - » Source host address (32 bits)
  - » Destination host address (16 bits)
  - » Type of service (reliability, precedence, priority)
  - » Time-to-live (TTL)
  - » Uses checksum for error detection

IP Address

- Class A: 16,774,214
- Class B: 65,534
- Class C: 254
- Class D:
- Local : Subnet + Host
- Example 1:
  150.215.17.9
  10010110.11010111.00010001.00001001
- Example 2:
  150.215.255.255 (broadcasting)



IP Address

- Class A - supports 16 million hosts on each of 127 networks
- Class B - supports 65,000 hosts on each of 16,000 networks
- Class C - supports 254 hosts on each of 2 million networks