King Fahd University of Petroleum & Minerals
College of Computer Sciences and Engineering
Computer Engineering Department

COE 444 - Internetwork Design and Management

Spring 2006 (Term 052)

Lecture Notes

Prepared by:
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Course Topics:

1. *Overview of Computer Networks* **1 week**
Types of computer networks. LANs and WANs. Protocols and protocol families. The OSI reference model. The TCP/IP protocol.

2. *Internetworking* **3 weeks**
Basic terminology. Principles of internetworking. Types of internetworking devices. Repeaters, hubs, bridges, routers, switches and gateways. Transparent and source-routing bridges. Multilayer switches. VLANs. Routing strategies. Addressing.

3. *The Network Development Life Cycle* **1 week**
Network analysis. Network design methodology. Writing of a Request For Proposal (RFP) and quotation analysis. Prototyping/simulation. Implementation.

4. *Enterprise Network Design* **4 weeks**
Enterprise Network Design Model. Backbone design concepts. Network security and firewalls. Structured cabling systems. Case studies.

5. *Topology design and analysis* **3 weeks**
Topology design. Network design algorithms. Terminal assignment. Concentrator location. Traffic flow analysis and performance evaluation. Network reliability.

6. *Network Management* **2 weeks**
Network management standards & models. ISO Functional areas of management. Network management tools and systems. SNMP architecture & operations. Network administration.

7. *Project Presentations* **1 week**
More details will be posted on the course web site about the project.

Chapter 1 Overview of Computer Networks

Topics covered:
Types of computer networks. LANs and WANs. Protocols and protocol families. The OSI reference model. The TCP/IP protocol.

1.1 Terminology

- **Internetwork**: A collection of interconnected networks. It is also called "internet". The worldwide "Internet" is one specific internet. Examples are: LAN-to-LAN, LAN-to-WAN. These networks can be of different types: underlying hardware, protocols used, etc. One known application that runs on top of the Internet is the web which is a distributed system.

- **Design**: a preliminary sketch or outline showing the main features of something to be executed. The arrangement of elements or details in a product or work of art. ***[Merriam-Webster Dictionary]***

- **Network Design**: involves decisions on several issues including topology, architecture, flexibility and other cost and vendor related issues. The final product is a plan to be implemented including cabling, routing strategies, protocols to use.

- **Management:** the act or art of managing: the conducting or supervising of something. ***[Merriam-Webster Dictionary]***

- **Network Management**: The process of controlling a network so as to maximize its efficiency and productivity. ISO model defines 5 functional areas of network management: Configuration Management, Fault Management, Performance Management, Accounting Management, and Security Management.

1.2 Uses of computer networks

A distributed system is a software system built on top of a network.

1.2.1 Business Applications

- Issue of resource sharing
    - Physical resources (e.g., a high-volume networked printer)
    - Information: instant access to relevant documents
- Use of Client/Server model

- Networks provide a communication medium among employees
    - e-mail
    - Writing reports with a group of people located in different areas
    - Videoconferencing to organize meeting between employees at different locations.
    - e-business (e.g., suppliers and customers)
    - e-commerce: to do business with customers over the Internet (buying and selling)

1.2.2 Home Applications

The biggest reason for home computers is the Internet access.

The most popular uses of the Internet for home users are:

- Access to remote information: involves interactions between a person and a remote database. Examples: web, on-line newspapers, on-line digital library (e.g., www.acm.org)

- Person-to-person communication. Examples: email, instant messaging, chat rooms, newsgroups, telephone calls, videophone.

    - Peer-to-peer communication: eliminate the central database (different from the client/server model). Example: Napster.

- Interactive entertainment. Examples: video on demand, game playing.

- Electronic commerce: Examples: Home shopping, access to financial institutions (security issues), B2C (e.g., buying online), B2B (manufacturer orders from suppliers), G2C (Tax forms), C2C (Auctions), P2P (File sharing).

  B: Business, C: Client, G: Government, P: Peer.

1.2.3 Mobile users

- Mobile computers. Examples: notebook computers, personal digital assistants (PDAs)

- Portable office: portable electronic equipment used on the road. Examples: send and receive telephone calls, faxes, email, web, etc.

- Wireless networks: used in taxis, delivery vehicles, military, etc.
    - Fixed wireless
    - Mobile wireless

- Applications:
    - WAP (Wireless Application Protocol) to merge cell phones and PDAs
    - m-commerce
    - Location dependent services (e.g., nearby restaurant requested from network operator)

1.2.4 Social, Political, Ethical, and Moral Issues

- Newsgroups: topics discussed are controversial (may be offensive to some)
- The exchange of information (text, audio, video) may be inappropriate and unacceptable by some people
- Employer check e-mails sent by employees: find out if anything harmful for the company
- Government snoop all incoming & outgoing e-mail: spy on people to find specific information (e.g., illegal activities)
- Cookies on web browsers allow companies to track users' activities in cyberspace. May allow confidential info (e.g., credit card numbers) to leak all over the Internet.
- Anonymous messages
- Information on the Internet can be ill-informed, misleading, or wrong.
- Electronic junk mail (spam)
- Viruses can easily be sent contained in e-mails.

→ Security can solve a lot of these problems. Messages can be encrypted and authenticated (i.e,. right user). This can be costly.

1.3 Types of Computer Networks

Computer networks are frequently classified by:

- Transmission technology: broadcast and point-to-point.
- Geographical area they encompass: LAN, WAN.
- Type of communications path they use and the manner in which data are transmitted across this path: circuit-switched, packet-switched.

1.3.1 Transmission Technology

1.3.1.1 Broadcast Networks

A broadcast network consists of nodes that share a single communications channel. Short messages, e.g., packets, sent by one machine are received by all other nodes connected to the shared channel.

An address field (i.e., destination address) within the packet specifies the intended recipient. Upon receiving a packet, each node checks the address field. If the packet is intended for the receiving node, that node processes the packet; otherwise it ignores it.

- **Analogy:** shouting in a corridor, airport announcement, asking one student a question
- **Broadcasting:** Broadcast systems allow the possibility of addressing a packet to all destinations by using a special code in the address field.
- **Multicasting:** support transmission to a subset of the nodes in a network.

Broadcast networks employ several topologies such as Bus (e.g., Ethernet) and Ring (e.g., Token Ring). Satellite can also be classified as a broadcast system (downlink transmission).

1.3.1.2 Point-to-Point Networks

Point-to-point networks consist of many connections between individual pairs of nodes. For a packet to go from the source to the destination, it may have to visit one or more intermediate nodes. The connection to or from an intermediate node on the path from the source to the destination is called a "hop". One hop implies two directly connected nodes.

Often multiple routes, of different lengths, are possible. There are different routing algorithms to find a good route.

Large networks are usually point-to-point.

Three very common point-to-point topologies are:

- Star
- Loop
  - Complete loop
  - Fully meshed
- Tree

1.3.2 Geographical Area

- PAN (1-10m): computer for one person (e.g., wireless network connecting computer, mouse, keyboard, and printer)
- LAN (10m-10km): room, building, campus
- MAN (10-100km): city (e.g., cableTV)
- WAN (100-1000km): country, continent
- Internet (10000km): planet

1.3.2.1 Local Area Networks

A LAN has the following characteristics:

- LANs are restricted in size (in general < 10km) and have smaller scope (within a single building or campus). This implies that the worst-case transmission time is bounded and known in advance. This makes it possible to use certain kinds of designs and to simplify network management (e.g., configuration, fault, performance, security, and accounting).
- LANs run at speeds ranging from 10 Mbps to 10 Gbps.
- LANs are usually privately-owned networks (i.e., owned by the same organization)

- LANs are usually broadcast systems. They may use a transmission technology consisting of a cable to which all the machines are attached (e.g., Ethernet, Token ring).
- Two of the main topologies used in broadcast LANs are: Bus and Ring.
- Switched LANs and ATM LANs have appeared as well.

1.3.2.2 Wide Area Networks

A WAN has the following characteristics:

- Covers a large geographical area (100-1000 km)
- Rely in part on common carrier circuits (e.g., telephone company, ISP)
- Consists of a number of interconnected switching nodes

1.3.3 Type of Communication Path

1.3.3.1 Circuit switching

A dedicated communications path is established between two stations through the nodes of the network for the duration of a connection.

Example:

Problem:

1.3.3.2 Packet switching

Data are sent out in a sequence of small chunks, called packets. Each packet travels through the network from node to node.

Example:

Problem:

1.3.3.3 Frame relay

Takes advantage of high data rates and low error rates in the modern high-speed telecommunications systems by stripping out most of the overhead involved with error control.

Problem:

1.3.3.4 Asynchronous Transfer Mode (ATM)

ATM is an evolution of frame relay. ATM, in contrast to frame relay, uses fixed-length packets called cells (ATM is sometimes referred to as cell relay). A cell consists of 53 bytes. This reduces the overhead even further. Data rates in the range of 10s and 100s Mbps, and even in the Gbps range.

ATM also extends circuit switching to allow multiple channels with the data rate on each channel dynamically set on demand. ATM can offer constant-data-rate channels.

1.4 Protocols

- A protocol is an agreement between the communicating parties on how communication is to proceed (i.e., set of rules).
- A network architecture is a set of layers and protocols, e.g., OSI reference model and TCP/IP.
- Standards are needed to promote interoperability among vendors.

1.4.1 OSI Reference Model

The OSI (Open Systems Interconnection) reference model is an ISO (International Standards Organization) standard.

The OSI model is an architecture/structure that defines communication tasks and which would:

- serve as a reference model for international standards, and
- facilitate efficient internetworking among systems from different technologies, manufacturers, nationalities, and enterprises.

The OSI model 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.

Layer functions:

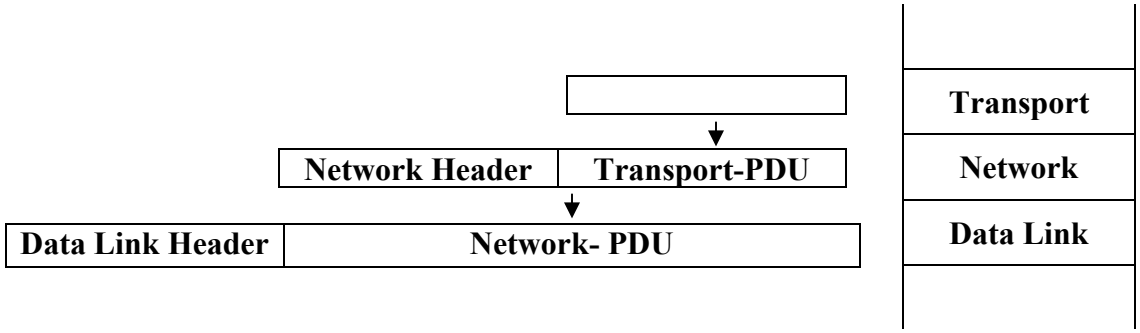
Application	ftp, telnet, email, web
Presentation	Data representation (ASCII, EBCDIC)
Session	Negotiation & connection (e.g., NFS)
Transport	End-to-end delivery → **Segments**
Network	Routing: addresses and best path → **Packets**
Data Link	Access to media → **Frames**
Physical	Binary transmission and cabling → **Bits**

Protocol entities exchange Protocol Data Units (PDUs). Each PDU contains:

- Header: contains control information to be used by the protocol at the peer layer.
- Message: Data from the upper layer.
- Trailer: is defined for some protocols

Header	Message	Trailer

The addition of control information to data is referred to as "Data Encapsulation"



1.4.2 TCP/IP Reference Model

(Referred to as TCP/IP protocol suite)

TCP/IP is a result of protocol research and development conducted on the experimental packet-switched network, ARPANET sponsored by DoD (U.S. Department of Defense).

Application
Transport
Internet
Host-to-Network

1.4.2.1 Transport Layer

Two end-to-end transport protocols have been defined: TCP and UDP.

- TCP (Transmission Control Protocol):
  - is a connection-oriented protocol
  - ensures end-to-end data reliability
  - uses segmentation and reassembly
  - handles flow control

- UDP (User Datagram Protocol):
  - is a connectionless protocol
  - unreliable (no sequencing or flow control)

1.4.2.2 Internet Layer (or Network Layer)

The internet protocol (IP) is used at this layer to provide the routing function across multiple networks.

This protocol is implemented in the end systems and in routers. A router primary function is to relay data from one network to the other.

1.4.2.3 Host-to-Network Layer

The TCP/IP reference model does not define explicitly what happens in this layer except that the host has to connect to the network using some protocol.

LAN protocols occupy the bottom two layers of the OSI reference model: the physical layer and the data link layer.

- The data link layer provides data transport across a physical link. It includes:
  - LLC: Logical Link Control sub-layer
  - MAC: Media Access Control sub-layer
- The physical layer specifies the electrical, mechanical, procedural and functional characteristics of the physical link between end systems.

1.5 References:

Chapter I of "Computer Networks" by Andrew S. Tanenbaum, Fourth Edition