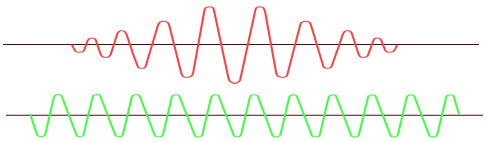
Chapter 1: Data Communications vs. Telecommunications



- **DATA COMMUNICATIONS:**
  - concerned with the transformation of digital information
- **TELECOMMUNICATIONS:**
  - deals with transmission of multiple forms of communication, whether it is voice, video, or graphics (e.g. Movie signal used in cable TV).

Essential Features of Communications

- Message
- Sender
- Receiver
- Medium
- Understandability
- Error detection

Data Communications Applications

1. Inquiry/response application
2. Interactive applications
3. Batch applications
4. Data entry applications
5. Distributed applications
6. Sensor based applications
7. Combined applications

- **Batch applications:** typically, large data transfers in two directions
- **Data entry applications:** consists of lengthy inputs with short responses
- **Distributed applications:** the data or/and processing are distributed among processing units.

Requirements of an Online System

1. Performance:
   - response time: differences in transaction
   - throughput
   - turnaround time
2. Consistency
3. Flexibility
4. Availability & Reliability
   - MTBF (Mean Time Between Failure)
   - MTTR (Mean Time to Repair)
5. Recovery
   - backups
   - fault tolerance
6. Security
   - data
   - access
   - physical
   - encryption

OSI Reference Model Example

1. Application:
2. Presentation:
3. Session:
4. Transport:
5. Network:
6. Data Link:
7. Physical:

Chapter 2: Transmission Media

2 Major Classes:

1. Conducted Media:
   - uses a conductor such as wire or fiber optic cable
2. Radiated Media:
   - Uses radio waves or infrared light to transmit through the air.
   - Wireless

Conducted Media:

1. Wires
2. Coaxial Cable
3. Fiber Optic Cables

Wires

Oldest & most common

Advantages:

- low cost & availability

Disadvantages:

- error potential & slow transmission rates

Can be used in both Private & Public lines

Transmission speed factors:

- thickness of wire
- no. of wire conductors used
- distance covered

Types of wires ()

- single conductor wire
- twisted-pair wires
- shielded multiconductor wire bundle

Twisted-Pair:

- bundle of color-coded wires
- solid color twisted with same solid color & striped wire
  - ex. blue solid twisted with blue and white striped wire.
- Twisted pair minimizes electromagnetic field
- ***2 basic types:***
  - 1. UTP (Unshielded twisted-pair)
  - 2. STP (Shielded twisted-pair)

Switched vs. Leased lines

Gauge and types of wires

Categories of twisted-pair wires:

- **Category 1 Wire:** traditional telephone wire
- **Category 2 Wire:** certified for speeds up to 4Mbps
- **Category 3 Wire:** in LANs operating at 10Mbps
- **Category 4 Wire:** used in 16Mbps LANs
- **Category 5 Wire:** up to 1 Gbps

Coaxial Cable

Used primarily in LANs less than 10 miles and terminal connections with terminal controller units

Data transmissions rates of up to 100Mbps are common

Coaxial Cable

Advantages:

- High data transmission rates
- Immunity to noise and signal distortion (as compared to twisted-pair)
- Capacity for adding stations
- Reasonable cost over short distances

Disadvantages:

- security (can be both advantage & disadvantage)
- attenuation
- cost

Composition of a Single-conductor coaxial cable:

- Outer insulation
- Mesh shielding
- Insulation
- Conductor

Baseband: One data carrying channel

Broadband: Multiple data carrying channels

Fiber Optic Cable

Composed of glass or plastic fibers as core of cable.

Cladding of glass or plastic

covering of plastic or other material

Use guided light pulses instead of sound as in wires.

3 varieties of fiber optic cables:

1. Multimode step-index fiber

2. Multimode graded-index fiber

3. Single-mode transmission

1. Multimode step-index fiber

- light pulses are reflected off the walls of fiber optic cable

2. Multimode graded-index fiber

- Light is refracted toward the center by variations in the density of the core

3. Single-mode fiber optic

- Light is guided down the center of an extremely narrow core.

Advantages:

- high speed
- low noise
- light weight
- high capacity

Disadvantages:

- high cost for short distances
- inability to add new nodes while other nodes are active

Radiated Media (Wireless)

1. Broadcast Radio
2. Microwave Radio
3. Satellite Radio
4. Spread-Spectrum Radio
6. Infrared Transmissions
7. Other

1. Broadcast Radio

- AlohaNet is early use of radio broadcast for data communication
- lower speeds
- congestion for bands
- noise
- mobile applications
- Cellular radio are most common media for mobile computing communications, but have high error rates and suitable for transfers of small amounts of data, I.e. e-mail.

2. Microwave Radio

- speeds up to 45 Mbps
- travel in a straight line so sender & receiver must be in each other's line of sight
- possible atmospheric and obstacle interference
- low security
- used in wireless LANs

3. Satellite Radio

- very high frequency (VHF) waves
- *geosynchronous orbit* (stationary relative to a fixed seledted point on earth)
- *Uplink*: transmission from earth to satellite.
- *Downlink:* transmission from from satellite to receiving earth station.
- *Transponder:* changes frequency, amplitude from uplink and retransmits as downlink.
- *Propagation delay:* amount of time takes for a signal to travel from its source to its destination.

4. Spread-Spectrum Radio (SSR)

- primary use is for wireless LANs
- distance of about 1000 feet for LANs
- lower speeds in LANs than conducted media
- military use for radio communication in battlefield environments
- 2 methods for providing SSR signals:
    1. *Frequency hopping*: frequency is changed with each re-transmission.
    2. *Direct sequencing*: several different frequencies are transmitted simultaneously.

5. Infrared Transmission

- uses EM radiation of wavelengths between those of visible light and radio waves.
- used to provide connections between buildings
- used in some wireless LANs
- transmission rates of 4Mbps or less
- interference from obstacles
- lower speed in LANs than conducted media

Signal Representation and Modulation

Bit Rate: measure of transmission rate in bps (bits per second).

- bps is the best metric for data transmission

Bandwidth=difference maximum and minimum frequencies allowed.

- Example: for AM Radio, Bandwidth = 1600-540=1060
- The higher the bandwidth the higher the data carrying potential.

Baud Rate: the signaling rate, i.e. the number of discrete signals that can be observed per unit of time.

- Baud rate and bit rate are NOT usually the same, as one signal can carry multiple bits.

Signal Representation and Modulation (cont.)

Dibits: a transmission mode in which each signal conveys 2 bits of data

Tribits: 3 bits to be represented by each signal

Quadbits: 4 bits to represented by each signal

Phase Shift Keying (PSK): most common method of achieving dibit and tribit transfer.

Quadrature Amplitude Modulation (QAM): most common method for quadbit transfer.

Digital versus Analogue Representation:

- **Digital transmission: 0 or 1 digits only!**
- **Analogue transmission: continuous wave form of data transmission.**

Data Conversion to bps

Example: Convert 20,000 characters per minute to bits per second (bps)

Solution: 20,000 char per minute/60 seconds per minute = 333.33 char per second

CONVERSION FACTOR: Assume 10 bits per character! See page 79, 5th line from bottom of "Line Speed" paragraph!

Solution Continued: Then 333.33 characters per second X 10 bits/character = 3333.33 bps = ANSWER!!!

MODEMS

Modem stands for "modulator-demodulator"

- Accepting modem converts digital signals to analog signals.
- Sending modem converts converts analog signals back to digital signals.
- *"Short-Haul" Modems* for short distances up to about 20 miles at varying speeds.
- *"Modem Eliminator"* allows data transmissions over short distances without a modem.

Chapter 3: Data Flow

2 Levels of Data Flow

1.) Contention control ()

- which determines which stations may transmit
- conditions under which transmission of data is allowed
- pacing of data transmission

2.) Basic level which relates to transmission equipment used:

- lines
- modems
- devices

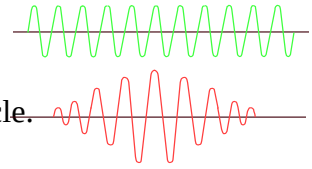
3 basic types:

1. **SIMPLEX TRANSMISSION**:
   - Data may flow in one direction only.
     - One station is sender.
     - One station is receiver.
     - Examples: Radio, TV, devices such as optical character recognition (OCR).
2. **HALF-DUPLEX TRANSMISSION**:
   - Data may flow in both directions, but ONLY in one direction at a time.
     - Example: CB Radio, common method of flow control in LANs.

3. **FULL-DUPLEX TRANSMISSION**:
   - Data can be transmitted in both directions SIMULTANEOUSLY.
     - Example: Switched telephone connections.

Error Sources

1. **Attenuation:** weakening of a signal as a result of distance and characteristics of medium
2. **Impulse Noise:** a noise characterized by signal spikes.
3. **Crosstalk:** when the signals from one channel distort or interfere with the signals of a different channel.



4. **Echo:** the reflection or reversal of the signal being transmitted.
5. **Phase Jitter:** a variation in the phase of a continuous signal from cycle to cycle.
6. **Envelope Delay Distortion:**
   - occurs when signals that have been weakened or subjected to outside interference by transmission over long distances are enhanced by being passed through filters.
7. **White Noise:**
   - Also known as termal noise or Gaussian noise. The amount of white noise is directly proportional to the temperature of the medium. White Noise results from the normal movements of electrons and is present in all transmission media at temperatures above absolute zero.

Error Detection

1. **Parity Check**
2. **Longitudinal Redundancy Check (LRC)**
3. **Cyclic Redundancy Check (CRC)**
4. **Sequence CHECKS**
5. **Message Sequence Numbers**
6. **Packet Sequence Numbers**
7. **Error Correction Codes**

Error Correction

1. ***Message Acknowledgement:***

- When station receives message, it computes the number of error detection bits or characters and compares the results with the check number received.
- If the two are equal, the message is assumed to be error-free and the receiver returns a positive acknowledgment to the sender.
- If the two are unequal, a negative acknowledgement is returned and the sending station retransmits the message.

2. *Retry Limit:*

- Upper limit on number of continual retransmissions of a message.

Digital Data Transmission

Advantages of Digital Transmission

1. Lower Error Rates

2. Higher Transmission Rates

3. No Digital-Analog Conversion

- Theoretically digital transmission avoids the need for conversion.
- Unfortunately, not all locations are digital networks.
- Hence need for "codec" which is short for "coder-decoder."

4. Security

- One method is "encryption".
- Examples of "encryption" are: voice scramblers used on secure telephone lines, digital encryption algorithms, etc.

Chapter 4: Packet Distribution Networks (PDN)

Sometimes called:

- a "X.25 network",
- a "packet switching network" (PSN),
- a "valued-added network" (VAN), or
- a "public data network".

1st introduced in 1964 at Rand Corporation.

Process of:

- segmenting a message into specific-size packets,
- routing the packets to their destination, and
- reassembling the packets to re-create the message.

"Arpanet" :

- 1st packet distribution network planned" in 1967 which became operational in 1969 with 4 nodes.

This led to *"NSFNet"*

- several other regional networks which became integrated into one "supernetwork" called the *Internet*.

Name of *"X.25"* stems from:

- *"ITU X.25"* standard which defines the interface between *"data terminal equipment"* (DTE) and *"data circuit-terminating equipment"* (DCE) for terminals operating in the packet mode on public data networks.

Most common packet sizes are 128, 356, 512 and 1024 bytes.

All packets transmitted must conform to one of the available packet lengths.

1. PDNs and the OSI Layers

- Only 3 layers of OSI are described for PDNs because a PDN is only responsible for message delivery.
- These 3 layers of OSI are:
  - ***physical***
  - ***data link, and***
  - ***network layers.***
- The 4 other layers of OSI are implemented in the user's segment of the network.

2. Current PDN Implementation

- **Private Network:**
  - NSFNet
- **Public Networks:**
  - those offered by AT & T, CompuServe, GE Information Services, Infonet Services, MCI, & Sprint.
- **Foreign Networks:**
  - those offered by Datapac in Canada, Transpac in France, Britain's Packet Switching Service (PSS), and Japan's Nippon Telephone & Telegraph (NTT).

3. Connection Options

- **PDN provides up to 3 types of connection options:**

1. Switched Virtual Circuit (SVC)

- similar to a *"switched communication link"* in that both are established when needed by a session and dissolved when the session ends.
- end-to-end circuit allocated for duration of session that is accomplished by a call setup request tht is initiated by the user.
- SVC is dissolved at end of session by process known as ***"clearing."***

2. Permanent Virtual Circuit (PVC)

- A circuit is permanently allocated between two nodes, so no call setup is required.

3. Connection Options (Continued)

3. Datagram Service

- Message that fits completely into the data field of one packet.
- *"Connectionless"* because a dedicated connection is not established.
- Potential of fast service for short, unrelated messages.
- undesirable features of datagram's:
  1. **Arrival order of datagram's is not guaranteed, as each datagram sent by a particular node may take a different route.**
  2. **Arrival is itself into guaranteed because the PDN establishes datagram arrival queue depths.**

Chapter 5: Tiered LANs

Cost of attachment to a LAN tends to increase with data rate

Alternative to connecting all devices is to have multiple tiers

Bottom-up strategy: individual departments create LANs independently, eventually a backbone brings them together

Top-down strategy: management develops an organization-wide networking plan

BASIC LAN Topologies

Ring: See also Figure 7-3 on page 187.

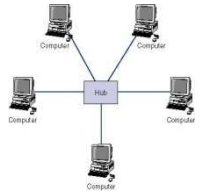
- IEEE 802.5

- token passing
- IBM
- FDDI/CDDI
- speeds

Bus: See also Figure 7-2 on page 186.

- IEEE 802.3
- CSMA/CD*
- Ethernet
- token pasing - IEEE 802.4
- speeds
- ARCnet
- *Carrier Sense with Multiple Access & Collision Detection

Star: See also Figure 7-5 on page 190.

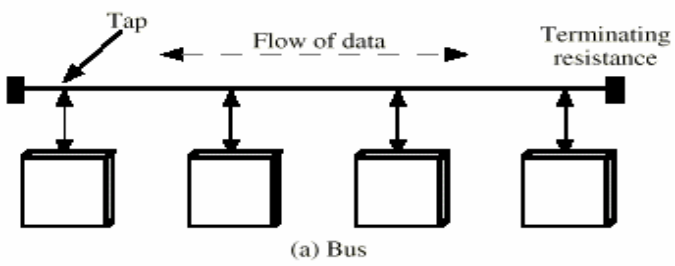
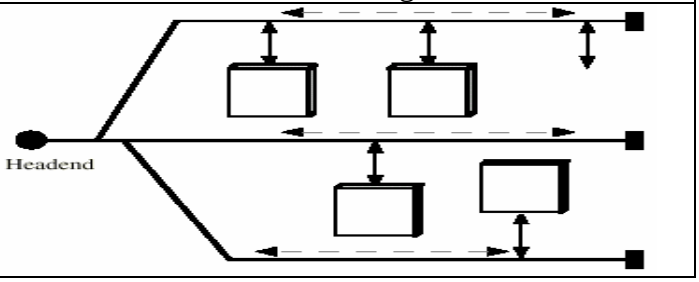


StarLan

ArcNet configuration NOT used much today.

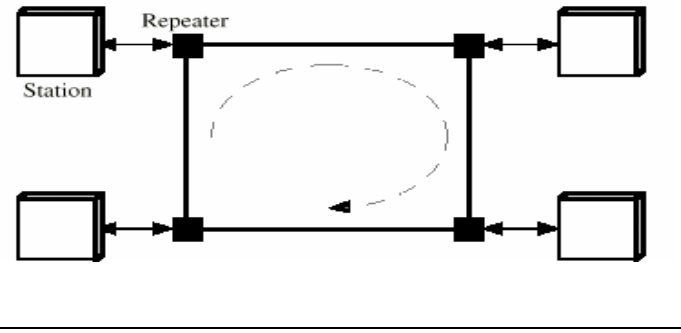
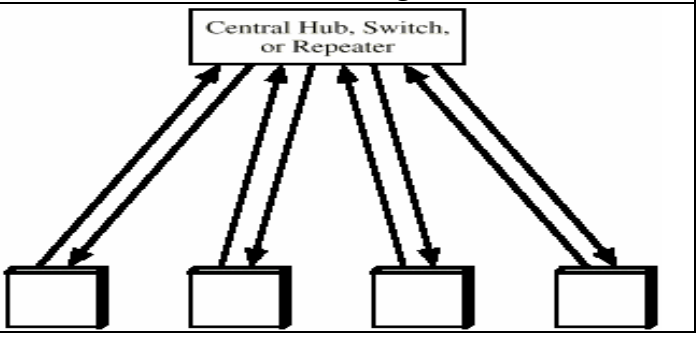
(Reference: p.188)

LANs with hubs

Bus LAN Diagram	Tree LAN Diagram
	

LAN Topologies: Ring

- Repeaters are joined by unidirectional point-to-point links in a ring
- As a frame circulates past a receiver, the receiver checks its address, and copies those intended for it into a local buffer
- Frame circulates until it returns to source, which removes it from network
- Active vs. Inactive Nodes on page 187.

Ring LAN Diagram	Star LAN Diagram
	

LAN Topologies: Star

- Each station connected directly to central node, usually with two unidirectional links
- Central node can broadcast info, or can switch frames among stations
- Star-wired LAN: similar to ARCnet configuration in Figure 7-6.

Choosing a Topology

- Factors to consider include reliability, flexibility/expandability, and performance
- **Bus/tree** is most flexible
- **Tree** topology easy to lay out

- **Ring** provides high throughput, but reliability problems.
- **Star** can be high speed for short distances, but has limited expandability

Chapter 6: LAN Software

2 Classes of LAN Software:

1. Workstation System Software
2. Server System Software

Purpose of System Software:

1-to insulate applications from hardware details .
2-Provides an interface through which the applications can request hardware services.

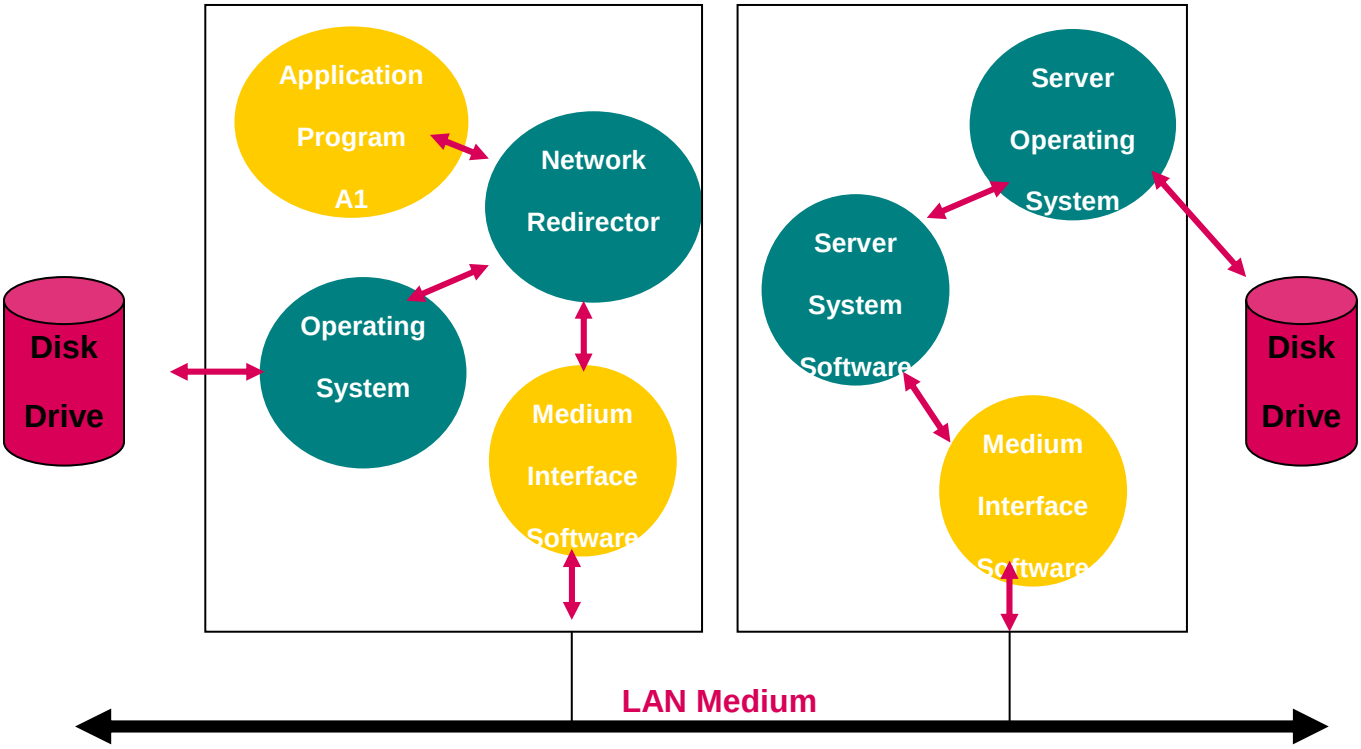
LAN System Software

1.Components for Workstation:

Application Programs
Operating System
Network Redirector
Medium Interface Software

2. Components for Server:

Server Operating System
Server System Software
Medium Interface Software



LAN System Software in Server and Workstation

System Software Functions

Hardware:provides the PHYSICAL connection between workstation and server.
Software:provides the LOGICAL connection between workstation and server.
Redirector: The software that reroutes I/O requests before they get to the workstation's OS.
Multithreading:the capacity of a server to work on MULTIPLE request at once.
Client/Server Protocol

LAN Workstation Software

3 Classes of LAN Workstation Software:
1. Application Software
2. Workstation System Software

3. LAN System Software

Workstation System Software
2 Parts of Interface: 1. With the applications and OS.
2. With the network hardware.
Medium-interface portion of LAN workstation software has 2 basic functions:
1. Placing data onto the network.
2. Receiving data from the network.

SPECIFICATIONS OF SERVER SOFTWARE
1. *Server OS*
Server software is more complex than ***workstation*** software because:
-Server software is usually multithreaded
-Server software must work well with the hardware.

INTEGRATED SOFTWARE:
Examples: Novell Netware and MS Windows NT
Advantage: can optimize the software for LAN operation
Disadvantage: requires writing more complex software.
LAN software that can run under existing OS:
Examples: Banyan Vines which runs under UNIX and
IBM Warp Server which runs under OS/2.

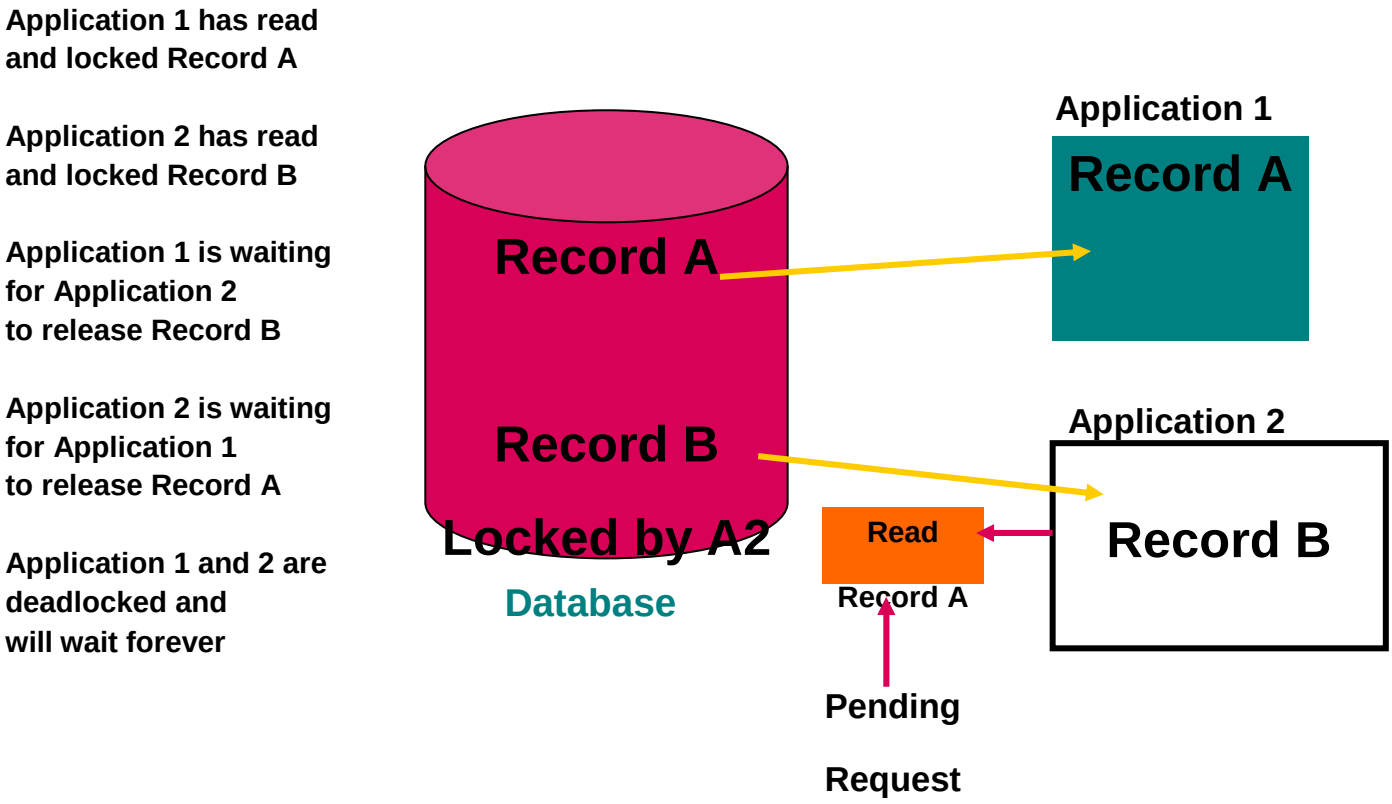
2. *LAN OS Functions:*
I. I/O Optimization:
1. *Disk caching*
2. *Disk seek enhancement*
II. Fault Tolerance Techniques:
1. *Read-after-write*
2. *Mirrored Disks*
3. *Redundant Arrays of Independent Disks (RAID)*
4. *Duplex Servers*
5. *Clustering*

PRINT SPOOLER : *"SPOOL"* stands for Simultaneous Peripheral Operation Online.
Allows several users to logically write to one printer at the same time.

SOFTWARE REQUIREMENTS FOR SHARED USAGE
1. Hardware Configuration
2. Application Settings
User sets own application settings to meet personal preferences.
3. Contention
Devices compete for control of network medium.
LAN Software can prevent contention
One method of preventing contention is the way application program opens a file.
3 Basic file open modes:

- Exclusive open mode: only one user has exclusive right to open file
- Protected open mode: user has secure entry procedure to access file
- Shared open mode: allows multiple users to have file open concurrently.

4. Access Security
LAN Software must provide protection through security.



Deadlock Situation

SOFTWARE LICENSE AGREEMENTS

License agreement:

an agreement that covers the rules under which you are allowed to use a product.

Types of License Agreements:

1. Single-user, single-workstation licenses
2. Single-user, multiple-workstation licenses
3. Restricted number of concurrent users licenses
4. Server licenses
5. Site licenses
6. Corporate licenses

NOVELL OPERATING SYSTEMS (NOS)

Three Basic Systems:

1. NetWare 3.x

Formerly known as NetWare 386

Uses Sever-oriented bindery

2. NetWare 4.x

Uses Network-oriented Directory

3. Personal NetWare (PNW): for small networks

BANYAN VINES

LAN Software that runs on UNIX-based servers.

Advantage because many WANs contain nodes running the UNIX OS.

This makes it easier for Banyan Vines systems to connect to the WAN nodes.

INTEROPERABILITY OF SERVER SOFTWARE

"Interoperability": means the ability of all network components to connect to the network and to communicate with shared network resources.

Chapter 7: LAN Considerations

Dedicated vs. Non-Dedicated Server

Dedicated Server:
One or more computers that operate **ONLY** as designated file, database.

Non-dedicated Server:
A computer that can operate as **BOTH** a server and a workstation.
Non-Dedicated Servers

Advantages:

1. Allows more effective use of resources.

Disadvantages:

1. Divide between its application work and its server work.
2. Increased likelihood of server failures.

Other Implementations

1. Large, Central Computer Systems
2. Service Bureaus
3. Zero-Slot LANs
4. Sub-LANs

Traditional Approach:

Central Host Computer

* Primary means for:
1-processing large volumes of data
2-producing big reports
3-Supporting special-purpose hardware devices.

Modern Approach:

1-Microcomputers argument large central computer systems.
2-Downsizing to LANs is more common than replacing LANs with large systems.

Zero-Slot LANs

1-Low-speed LANs
2-Lower Cost of Implementation.
3-Do ***not*** require an additional slot on the motherboard for a LAN adapter.
4-If LAN adapter is used:

Sub-LANs

1-Provides a subset of LAN capabilities in:

1. Peripheral sharing
2. File transfer

2-Differences from LAN:

1. Transfer rates & Costs are lower for a Sub-LAN than for a LAN.

2. File transfer capabilities are typically less transparent than on a LAN.

Sub-LANs

1- Are inexpensive.

2- Implemented with "Data ***Switches***."

"Data Switches"

To connect peripherals devices such as printers & plotters.

Manual switching using a "switch selection knob. &" Keyboard command switching.

ADVANTAGES:

1. Effective, low cost
2. Accomplish infrequent transfers of small files.

DISADVANTAGES:

1. Low speed of communication link
2. Lack of user transparency &Expandability

Comparison of LAN Alternatives

1. Large, centralized computer system
2. use of a service bureau
3. sub-LANs
4. Zero-slot and low-cost LANs
5. Conventional LAN (such as Ethernet or token ring)

LAN Selection Criteria:

1. **Immediate Cost**
   -Example: installing a LAN
2. **Recurring Cost**
   -Operating cost
   -Updating cost
   -Training cost for LAN users and administrators.
3. **NUMBER OF WORKSTATIONS**:
   1-Maximum number of workstations can support
   2-Methods for extension of maximum number
   3-Upgrade existing workstations to maintain current number
4. **TYPE OF WORKSTATIONS**:
   -Compatibility of LAN hardware & software with workstations used.
5. **NUMBER OF CONCURRENT USERS**:
   -Limits on number of concurrent users.
   -Increases on system resulting in:
   1. Slower system responsiveness
   2. Higher costs incurred as needed to increase the work potential of system.

   Overlay Module:
   -Computer memory management technique

   Word Processing:
   -Infrequent LAN
   -Amount of data transfers can be large.
   -Class in lab with multiple concurrent users **Data Base**
6. **Number & Type of Printers**:

-LAN must be able to support both the printers you plan to use
-E.g. printing text and printing graphics.

7. **Distance**:
   -Distance in LAN is measured in wiring length.
   -Most microcomputer LANs range from few 100's m to several 1000's m

8. **Medium:**
   -Coaxial cable and fiber optic cables are more noise-resistant mediums.

9. **Speed:**
   -Common LAN speeds for PC's are 1, 2.5, 4, 10, 16, 20 and 100 Mbps.
   -Trend is for higher speeds so can transmission greater volumes of data.
10. **Applications:**
    -***Application Program Interfaces*** (APIs) are used to interface with networks.
    -Some software is not LAN compatible.
11. **Expandability:**
    -Adding workstations.
    -Ease of expandability.
    -Adding nodes is more difficult for fiber optic cables
12. **Device Connectivity**:
    -Ability to attach devices
13. **Connectivity to Other Networks**:
    -Ability to connect to WANs and/or other LANs.
14. **LAN Software and Hardware**:
    Selecting software & hardware that is compatible with existing equipment.
15. **Adherence to established Standards**:
    We discussed some of these Standards in Chapter 7.
16. **Vendor and Support**:
    -You can be more successful with a good vendor, and a less capable LAN than with a poor vendor and a superior LAN.
    -Vendor speed of resolving problems, obtaining needed equipment, etc.
17. **Manageability:**
    -Do not underestimate the time and effort required to operate & manage a LAN.
    -LAN Management Tasks are listed.
18. **Security**:
    -LAN software must have ability to control access to data.

Chapter 8: WAN Hardware

Network Types

1. **Wide Area Network (WAN):**
   Cover large geographical areas, often crossing public right-of-ways
   Usually consists of several interconnected switching points.
2. **Local Area Network (LAN):**
   Small scope, usually a building or cluster
   Typically owned by the same organization that owns the equipment.

TERMINAL TYPES:

1. Microcomputers
2. Remote Job Entry (RJE) Stations
3. Data Entry and Display
4. Sensor Devices
5. Display-Only Devices
6. Point-of-Sale (PoS) Terminals
7. Portable Terminals.
8. Automatic Teller Machines (ATMs).

Terminal Capabilities:

Types of Terminals based on capability:

1. ***Dumb:***
   NO MEMORY!!! (e.g. Doesn't save data!)
   NO PROCESSING OF DATA!!!
2. ***Smart:***
   Can SAVE DATA entered by the operator
   Advantage over dumb terminals is independence between terminal operator & host.

3. Intelligent:

BOTH SAVES DATA & PROCESSES DATA !!!
Advantage over smart terminals is fact that control & processing are local.

2 Options for attaching Terminals:

1. ***Point-to-Point Connection:***
   Uses a communication line to connect one terminal to a host computer.
   Examples: Computer-to-computer communications
   "Contention" or when host and terminal compete for control of medium.

2. ***Multipoint Connection:***
   Several terminals share one communications line.
   Most common approaches with terminals are ***"polling"*** & ***"multiplexing."***

   Advantages of Multipoint Connections:
   1. Economical
   2. Only ONE communication link is required for a host to communicate with several terminals.
   3. If modems are required, FEWER modems are necessary.

   Disadvantages of Multipoint Connections:

1. Terminals more expensive than those in point-to-point connections, as not dumb terminals.
2. Waiting time for message or data transmission.

Multiplexers:

- Multiplexing is line-sharing technique that allows multiple signals to be transmitted over a single link.
- The multiplexer (mux) combines the data from all incoming lines and transmits it via one line to a mux at the receiving line.

Types of Multiplexers:

1. Time-Division Multiplexers (TDM)
2. Frequency Division Multiplexers (FDM)
3. Statistical TDM.

Concentrators:

- A concentrator is a computer that provides line-sharing capabilities including data editing, polling, error handling, code conversion, compression, and encryption.

Differences between Concentrators and Muxes:

1. Concentrators are used ONE at a time. Multiplexers are used in PAIRS.
2. (i)Concentrator may have number of incoming lines NOT equal to number of outgoing lines.
   (ii) Multiplexer merges a set of incoming lines into ONE LINE, and then converts back to the same number of outgoing lines.
3. Concentrator is a computer and may have auxiliary storage for use in support of an application.
4. Concentrator may perform some data processing functions, such as device polling and data validation.

Diagnostics and Miscellaneous Equipments:

1. Security Hardware
   - Call-Back Units
   - Encryption Equipment
2. Line Monitors
3. Breakout Boxes
4. Auto-Call Units (ACU)
5. Port Concentrators
6. Port Selector or Data Switch
7. Cluster Controllers
8. Private Branch Exchanges (PBXs)
9. Matrix Switches