Mobile/Wireless Networks, Internet, and Multimedia: Enabling Technologies for Collaborative Systems

S.R. Subramanya
University of Missouri – Rolla

CTS – 2004
January 18, 2004

Tutorial Objectives

Present the underlying
- Technologies
- Principles and Techniques
- Issues and Challenges

Of
- Mobile/wireless networks
- Internet
- Multimedia

As
- Enabling technologies of collaborative systems

Collaborative Systems

Definition

Collaboration is the integration of many different technologies into a single application or environment to facilitate information sharing and information management.

Collaborative Systems

Shared space: core element of typical collaborative system

- facilitates coordination of cooperative design activities
- Activities: synchronous or asynchronous
- Intelligent engines and agents support activities of the participants
  - detect design changes
  - automatic notification of changes
  - activity scheduling

Collaborative Systems Types

- Closed Collaborative System
  - A collaborative system where central authority exists and can act
    - Example: military defense systems.
- Open Collaborative System
  - Central authority exists but does not have coercive power to run the system.
    - Example: Standards Organization.
- Virtual Collaborative System
  - No central authority or agreed-upon purposes; large scale behavior emerges.
    - Example: the web, economics.

Collaborative System Applications

- Science
- Engineering
- Manufacturing
- Health Care
- Education / Learning

Example Tasks

- Computation of Large Primes
- Breaking Codes
- SETI (Search for Extra-Terrestrial Intelligence)

Enabling Technologies

- Mobile/Wireless Networks
  - Provide Pervasiveness
- Internet
  - Provides (Logical) Proximity
- Web
  - Provides Shared Data / Services
- Multimedia
  - Provides Expressiveness

Mobile / Wireless Communications and Networks

Outline of Topics

- Background
- Mobile Communications and Networks
- Wireless Communications and Networks
- Issues in Mobile / Wireless Networks

Background

Wireless Communications

- Origin : Radio Communications by Marconi, over 100 years ago (1896).
- Initially : Telegraph, Radio.
- More recently : Telephony, Data.
- Future : Multimedia (Voice, Images, Video, Text,)
- Three basic steps in communications:
  - Information piggybacked on RF waves – Modulation
    - RF waves : small portion of Electromagnetic Spectrum.
  - RF waves transmitted
    - Few feet, Few miles, thousands of miles.
  - Information recovered from modulated RF waves- Demodulation

Wireless Devices/Applications

- Radio, TV (broadcasts/Satellites)
- Remote Controls
  - TV, Toys, Stereos, Appliances
- Cell Phones
- Pagers
- Wireless Networks: PCs, Laptops, PDAs on:
  - Wireless LANs.
  - Wireless connection to the Internet.
  - Peer-to-Peer networks.

Broadband Wireless Technology

- Higher data rates obtainable with broadband wireless technology
  - Supports Multimedia (video, audio, graphics)
- Shares same advantages of all wireless services
  - convenience and reduced cost
  - Service can be deployed faster than fixed service
  - No cost of cable plant
  - Service is mobile, deployed almost anywhere

Limitations and Difficulties of Wireless Technologies

- Communication channel limitations
  - Higher error rates
  - Lower bandwidth
  - Smaller coverage
- Device limitations
  - Display. (small LCD on a mobile telephone can only displaying a few lines of text)
  - Processor (limited capability)
- Power limitations
  - Dependent on battery (limited power)
- Lack of an industry-wide standard

Radio Frequency (RF) Spectrum

- RF: Occupies a small portion of Electromagnetic Spectrum.
- Range : 9KHz – 30 GHz.
- LF, HF, VHF, UHF, Microwaves.
- Lower frequencies – Farther range.
- Higher frequencies – Shorter range.

Radio Frequency Bands

Extremely Low Frequency (ELF)	below 3 KHz (submarine communications)
Very Low Frequency (VLF)	3KHz – 30 KHz (maritime communications)
Low Frequency (LF)	20 KHz – 300 KHz (AM radio broadcast)
Medium Frequency (MF)	300KHz – 3MHz (AM radio broadcast)
High Frequency (HF)	3MHz – 30MHz (AM broadcast, amateur radio)
Very High Frequency (VHF)	30 MHz – 300MHz (FM radio, TV)
Ultra High Frequency (UHF)	300 MHz – 3GHz (TV broadcast, Cellular phones)
Super High frequency (SHF)	3GHz-30GHz (fixed wireless, Satellite)
Extremely High Frequency (EHF)	30 GHz-300GHz (satellites, radar)

Transmission Fundamentals

Data Communication Terms

- Data – Entities that convey meaning, or information
- Signals – Electric or electromagnetic representations of data
- Transmission – Communication of data by the propagation and processing of signals
- Data rate – Rate at which data can be communicated (bps)
- Bandwidth – Data carrying capacity of the medium
  - Constrained by transmitter
  - Constrained by the nature of the medium
- Noise – Average level of noise over communications path
- Error rate – Rate at which errors occur

Data Rate and Bandwidth

- The higher the bandwidth, the higher the information-carrying capacity
- Increase in data rate increases bit error rate
- Any digital waveform will have infinite bandwidth
- Any transmission system has limited bandwidth
- Limited bandwidth (sometimes) creates distortions
- The higher the bandwidth, the higher the cost

Types of Signals

- Analog
  - Continuously varying electromagnetic wave
  - Propagation over a variety of media (twisted pair, coaxial cable, fiber optic cable, wireless), depending on frequency
- Digital
  - Sequence of voltage pulses
  - Propagation (usually) over a copper wire medium
  - Generally cheaper than analog signaling
  - Less susceptible to noise interference

Data and Signal Combinations

- Digital data, digital signal
  - Equipment for encoding is less expensive than digital-to-analog equipment
- Analog data, digital signal
  - Conversion permits use of modern digital transmission and switching equipment
- Digital data, analog signal
  - Some transmission media will only propagate analog signals
    - Examples include optical fiber and satellite
- Analog data, analog signal
  - Analog data easily converted to analog signal

Signal-to-Noise Ratio

- Ratio of the power in a signal to the power in the noise present at a particular point in the transmission
- Typically measured at a receiver
- Signal-to-noise ratio (SNR, or S/N)

- A high SNR means a high-quality signal
  - less number of required intermediate repeaters
- SNR sets upper bound on achievable data rate

Multiplexing

- Capacity of transmission medium usually exceeds capacity required for transmission of a single signal
- Multiplexing: carrying multiple signals on a single medium
  - More efficient use of transmission medium

Multiplexing Techniques

- Frequency-division multiplexing (FDM)
  - Multiple data items transmitted using different frequencies
  - Takes advantage of the fact that the useful bandwidth of the medium exceeds the required bandwidth of a given signal
- Time-division multiplexing (TDM)
  - Data items transmitted in different time slots
  - Takes advantage of the fact that the achievable bit rate of the medium exceeds the required data rate of a digital signal

Signal Encoding Techniques

Carrier Signal Modulation

- Amplitude Modulation (AM) : The amplitude of the carrier wave (signal) is changed (modulated) based on the information signal.
  - AM radio broadcasts.
  - Prone to interference/noise.
- Frequency Modulation (FM) : The frequency of the carrier signal is changed based on the information signal.
  - FM radio broadcasts.
  - More robust to noise.
- Phase Modulation (PM) : The phase of the carrier is changed based on the information.
  - Well suited for digital information.
  - Variants used in many cellular technologies.

Analog Carrier Modulation With Digital Data

- Binary Amplitude-shift keying (BASK)
  - Amplitude difference of carrier frequency
- Binary Frequency-shift keying (BFSK)
  - Frequency difference of carrier frequency
- Binary Phase-shift keying (BPSK)
  - Phase of carrier signal shifted

Analog Carrier Modulation With Digital Data

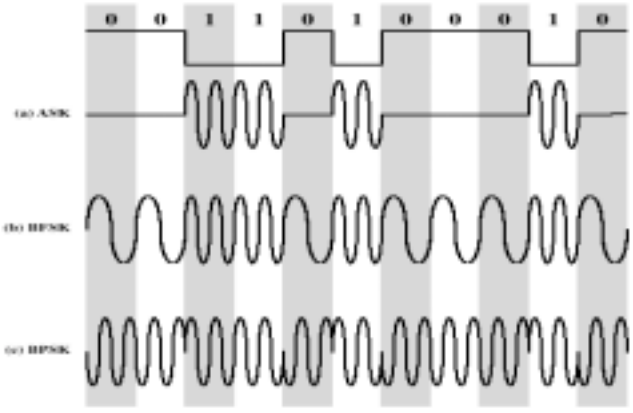


Figure 6.2 Modulation of Analog Signals for Digital Data

Source: Stallings

Spread Spectrum

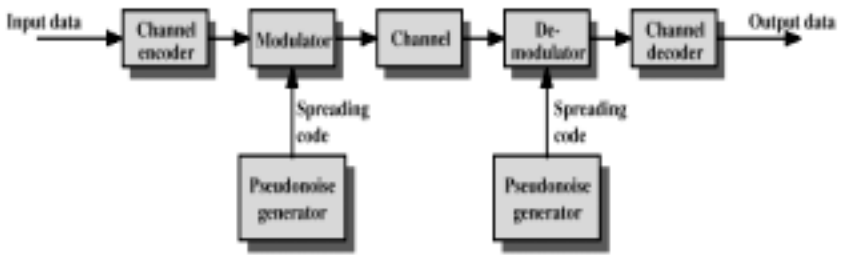


Figure 7.1 General Model of Spread Spectrum Digital Communication System

Source: Stallings

Spread Spectrum

- Immunity from various kinds of noise and multipath distortion
- Can be used for hiding and encrypting signals
- Several users can independently use the same higher bandwidth with very little interference
- Two major types:
  - Frequency Hopping Spread Spectrum
  - Direct Sequence Spread Spectrum

Frequency Hopping Spread Spectrum

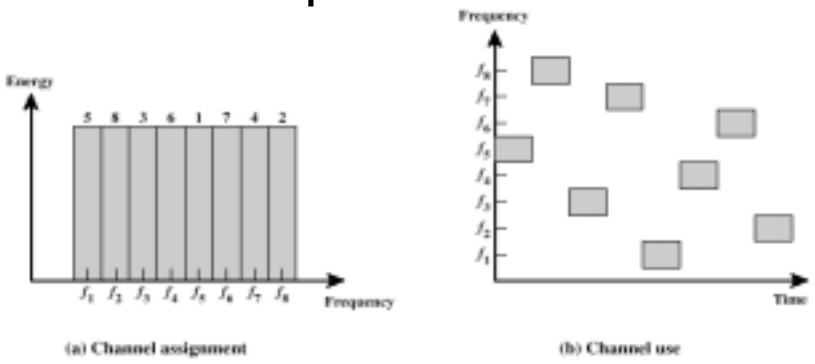


Figure 7.2 Frequency Hopping Example

Source: Stallings

Frequency Hopping Spread Spectrum (FHSS)

- Signal is broadcast over seemingly random series of frequencies
  - A number of channels allocated for the FH signal
  - Width of each channel corresponds to bandwidth of input signal
- Signal hops from frequency to frequency at fixed intervals
  - Transmitter operates in one channel at a time
  - Bits are transmitted using some encoding scheme
  - At each successive interval, a new carrier frequency is selected
- Channel sequence dictated by spreading code
- Receiver hops between frequencies in synchronization with transmitter
- Advantages:
  - Eavesdroppers hear only unintelligible blips
  - Attempts to jam signal on one frequency succeed only at knocking out a few bits

Direct Sequence Spread Spectrum (DSSS)

- Each bit in original signal is represented by multiple bits in the transmitted signal
- Spreading code spreads signal across a wider frequency band
  - Spread is in direct proportion to number of bits used
- One technique combines digital information stream with the spreading code bit stream using exclusive-OR

Direct Sequence Spread Spectrum (DSSS)

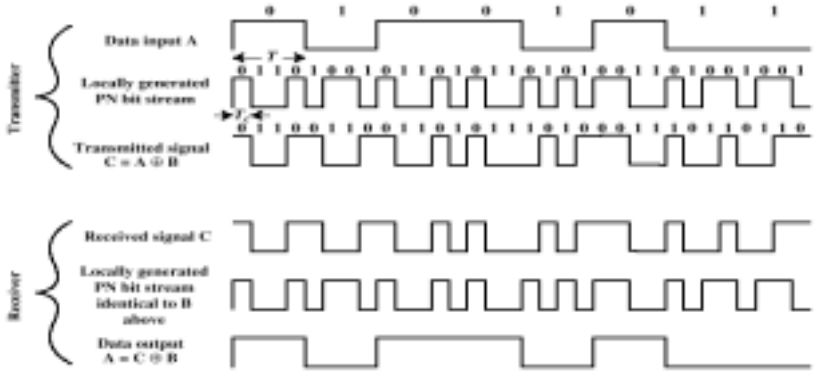


Figure 7.6 Example of Direct Sequence Spread Spectrum

Source: Stallings

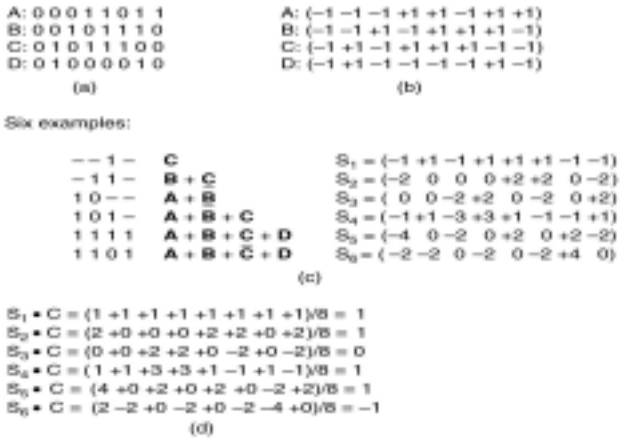
CDMA: Code Division Multiple Access – Extension of DSSS

- Basic Principles of CDMA
  - *D* = rate of data signal
  - Break each bit into *k chips* (c_i)
    - Chips are a user-specific fixed pattern
    - Each chip c_i is a 1 or a –1
  - Chip data rate of new channel = *kD*

CDMA Coding/Decoding

- If *k*=6 and code is a sequence of 1s and -1s
  - For a '1' bit, A sends code as chip pattern
    - <c1, c2, c3, c4, c5, c6>
  - For a '0' bit, A sends complement of code
    - <-c1, -c2, -c3, -c4, -c5, -c6>
- Receiver knows sender's code and performs electronic decode function
  - <d1, d2, d3, d4, d5, d6> = received chip pattern
  - <c1, c2, c3, c4, c5, c6> = sender's code

CDMA Example



Source: Tanenbaum

(a) Binary chip sequences for four stations
(b) Bipolar chip sequences
(c) Six examples of transmissions
(d) Recovery of station C's signal

Cellular / Mobile Networks

The Mobile Telephone System

- First-Generation Mobile Phones
  - Analog / Voice
  - Advanced Mobile Phone Service (AMPS): two 25-MHz bands
    - One for transmission from base to mobile unit
    - One for transmission from mobile unit to base
- Second-Generation Mobile Phones
  - Digital / Voice
- Third-Generation Mobile Phones
  - Digital / Voice and Data

Differences Between First and Second Generation Systems

- Digital traffic channels – first-generation systems are almost purely analog; second-generation systems are digital
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception
- Channel access – second-generation systems allow channels to be dynamically shared by a number of users

Third-Generation Mobile Phones: Digital Voice and Data

- High-quality voice transmission
- Messaging (replace e-mail, fax, SMS, chat, etc.)
- Multimedia (music, videos, films, TV, etc.)
- Internet access (web surfing, w/multimedia.)

Cell Phone Components

- Each cell phone has in its internal memory (NAM : Number Assignment Module) :
  - Mobile Identification Number (MIN) : [Phone Number]
  - System ID (SID): [Number identifying the cell phone system it works with].
  - Electronic Serial Number (ESN) : [Identifies phone and guards against fraud].
  - Information about subscribed features.
- Microprocessor
  - Digital and intelligence in the phone.
- Digital Signal Processor (DSP)
  - Compression/Decompression of signals
  - Modulation/Demodulation
  - Error correction
- A/D and D/A chips
- ROM and Flash memory
  - Storage for Telephone Operating System
  - Storage for data
- Amplifier, Microphone, Speaker, Keyboard, Display, Battery.

Cellular Network - Entities

- Made up of many “cells”.
- Each cell has a Base Station (BS) (also called Base Transceiver Station (BTS))
  - includes an antenna, a controller, and a number of receivers
- Cell Phones – Mobile Subscriber Units (MSU).
- Mobile Switching Center (MSC) (Also called Mobile Telephone Exchange (MTX), Mobile Telephone Switching office (MTSO))
  - Brains of Cellular networks
  - Connects calls between mobile units
- Gateway Mobile Switching Center (GMSC)
  - Route calls from MSCs to find destinations.

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks
  - Controls handoffs between cells in different BSSs
  - Authenticates users and validates accounts
  - Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching center (MSC)

Mobile Switching Center (MSC) Databases

- Home location register (HLR) – stores information about each subscriber that belongs to it
- Visitor location register (VLR) – maintains information about subscribers currently physically in the region
- Authentication center (AuC) – used for authentication activities (holds encryption keys)
- Equipment identity register (EIR) – keeps track of the type of equipment that exists at the mobile station

Cellular Network Organization

- Use multiple low-power transmitters (100 W or less)
- Cell phone network made up of many overlapping cells.
- Each cell has a base station.
- Each cell is (approximately) a circle, but represented as a hexagon (to avoid overlaps).

- A Cellular network has a limited number of frequencies allotted : channels.
- Frequencies are reused in cells that are farther apart (signal from one cell completely fades before it reaches the other cell).
- When cell phone moves from one cell to another, the handoff procedure ensures continuous communication of cell phone with base station.
- Mobile Switching Center (MSC) continuously monitors power levels of cell phone and base station and determines the handoff suitably.

Cells and Microcells

Source: Tanenbaum

(a) Frequencies are not reused in adjacent cells.

(b) To add more users, smaller cells can be used.

Frequency Reuse

- Adjacent cells assigned different frequencies to avoid interference or crosstalk
- Objective is to reuse frequency in nearby cells
  - 10 to 50 frequencies assigned to each cell
  - Transmission power controlled to limit power at that frequency escaping to adjacent cells
  - The issue is to determine how many cells must intervene between two cells using the same frequency

Channel Categories

- *Control* (base to mobile) to manage the system
- *Paging* (base to mobile) to alert users to calls for them
- *Access* (bidirectional) for call setup and channel assignment
- *Data* (bidirectional) for voice, fax, or data

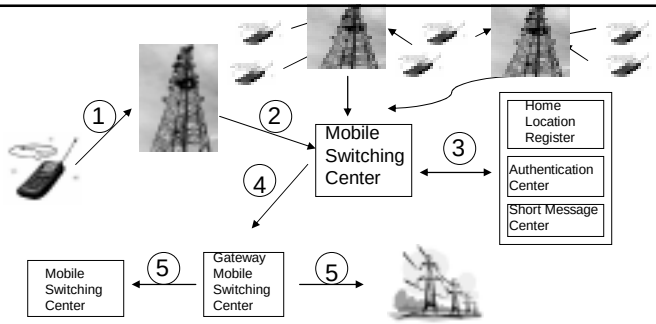
Basic Operations in Cellular Networks

Steps in an MSC Controlled Call between Mobile Users

- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- Handoff

Additional Functions in an MSC Controlled Call

- Call blocking
- Call termination
- Call drop
- Calls to/from fixed and remote mobile subscriber

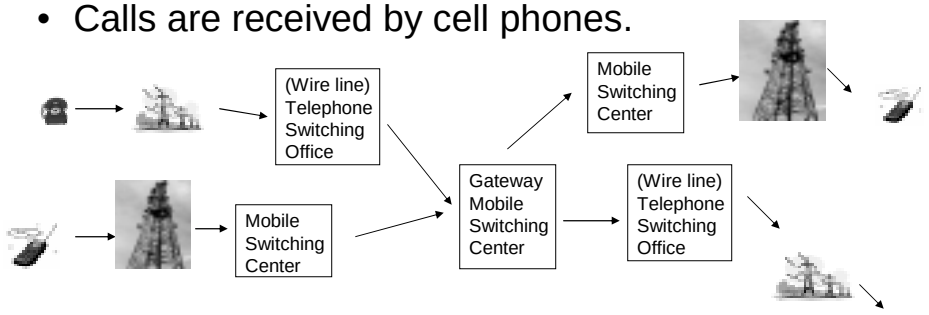


Cellular Networks – Outline Of Operations

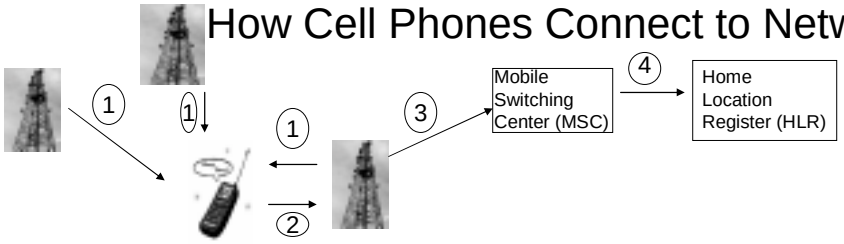
- Cell phone communicates wirelessly with Base station.
- Base station communicates with MSC on fiber-optic cables or microwave links (1.544 Mbps).
- MSC consults one or more of databases for relevant information.
- MSC routes calls to GMSC
- GMSC routes calls to final destinations (could be mobile or land line phone).

Basic Operations in Cell Phone Communications

- Cell phones connect to Cellular Networks.
- Cell phones make calls.
- Calls are routed in Cellular networks.
- Calls are received by cell phones.



How Cell Phones Connect to Network



1. When Cell phone is turned on, it listens to *overhead signals* from base station (s) which contain SIDs.
2. (a) Cell phone tunes to the base station with the strongest signal
   1 and 2 are repeated every few minutes. If SID stored in cell phone matches the SID in the strongest overhead signal, then cell phone is in home network; otherwise it goes into roaming mode.
2. (b) Cell phone sends its MIN and ESN to Base Station.
3. Base Station sends the above information to Mobile Switching Center (MSC)
4. MSC stores this information in Home Location Register (HLR).
   - MSC knows the location of cell phone and the base station it is communicating with
   - MSC uses this information to route calls

How Cell Phone Make Calls

- Destination number is dialed and SEND key is pressed.
- MSC determines that strongest channel the cell phone needs to be tuned it.
- The above information is sent to cell phone through the base station.
- Cell phone tuner to the ‘best’ channel, and sends its MIN, its ESN, and the destination number to base station.
- The above information is relayed by base station to Mobile Switching Center (MSC).
- MSC verifies authenticity of cell phone and routes the information to Gateway Mobile Switching Center (GMSC).
- GMSC routes the call request to destination phone (wireline or cellular).
- GMSC and ‘destination’ phone network exchange signaling tones and ensure the connection is in order.
- Ringing sound sent to calling phone.

How Cell Phones Receive Calls

- Call request sent from the caller to Gateway Mobile Switching Center (GMSC) on the destination network.
- The GMSC routes the call request to Mobile Switching center (MSC).
- MSC looks up Home Location Registry (HLR) and determines the location of the (destination) Cell phone and the appropriate base station.
- MSC sends call request to base station (BS).
- BS sends request to cell phone using the overhead signal.
- Cell phone receives call request; Informs BS to send the call.
- Base station conveys this to the MSC.
- MSC in turn conveys this to the GMSC.
- GMSC exchanges signaling tones with phone network of the caller to ensure connection is in order, and then call goes through.
- Cell phone rings.

Handoff Outline

- Mobile unit physically leaving a cell.
- Base station notices fading signal.
- Base station communicate with surrounding base stations to determine the signal power from mobile unit.
- Transfers ownership to cell getting strongest signal.
- Informs mobile unit of the new base station.
- Process takes about 300 msec.

Handoff Types

- Soft Handoff – Mobile unit acquired by new base station before the current one signs off.
  - No loss of continuity
  - Mobile unit must be capable of tuning to two different frequencies at the same time
  - Not available in first/second generation devices.
- Hard Handoff – Current (old) base station drops the mobile unit before the new base station acquires it.
  - If new one unable to acquire (due to unavailability of channels), call gets disconnected.

Handoff Performance Metrics

- Cell blocking probability – probability of a new call being blocked
- Call dropping probability – probability that a call is terminated due to a handoff
- Call completion probability – probability that an admitted call is not dropped before it terminates
- Probability of unsuccessful handoff – probability that a handoff is executed while the reception conditions are inadequate

Handoff Performance Metrics (2)

- Handoff blocking probability – probability that a handoff cannot be successfully completed
- Handoff probability – probability that a handoff occurs before call termination
- Rate of handoff – number of handoffs per unit time
- Interruption duration – duration of time during a handoff in which a mobile is not connected to either base station
- Handoff delay – distance the mobile moves from the point at which the handoff should occur to the point at which it does occur

Types of Mobile Systems

Global System for Mobile Communications (GSM)

- Standard for digital cellular Communications.
- Developed in Europe, adopted in 1992.
- Most popular (over half billion using some variant of GSM).
- Uses 124 frequency channels in each direction
  - each channel uses an eight-slot TDM system
- Operates in different frequency bands (450, 900, 1800, 1900 MHz).
- PCS System based on GSM operates at 1900 MHz.
- Subscriber Identity Module (SIM) card contains:
  - Cell phone number.
  - Mobile Electronic Identity Number (MEIN) (serial number).
  - Other identifying information.
  - Can be taken out of phone and carried around.

CDMA Cellular Systems

- Cell phones share the same channel simultaneously.
- A cell phone is assigned to a coded channel.
- Voice, data and control of many phones sent simultaneously on a wideband channel.
- Cell phones are able to pick information from the coded channel on the wideband channel.

Personal Communications Service (PCS)

- General name for newer cellular systems offering many services.
- Use 1900 MHz spectrum band.
- All digital systems
- Use a variety of standards and technologies:
  - TDMA, CDMA, GSM.
- Example services:
  - Short Message Service (SMS).
  - Internet access.

Short Message Service (SMS)

- Allows text message to be sent from cell phone to cell phone.
- Message from cell phone sent to Mobile Switching Center (MSC).
- MSC routes message to Messaging Center for storage.
  - Specific mailbox associated with a cell phone
- Signal sent to base station of closest cell about message over control channel.
- Base station relays this to cell phone.
- Cell phone tunes to the channel where message will be sent.
- MSC sends message to cell phone via base station (over the control channel).
- Receiving cell phone acknowledges receipt of message.
- Message deleted from message center.
- Common limit on message size : 160 bytes.

System Performance Parameters

- Probability that call request is blocked
- Capacity needed to achieve a certain upper bound on probability of blocking
- Average delay
- Capacity needed to achieve a certain average delay

ITU's View of 3G Capabilities

- Voice quality comparable to the public switched telephone network
- 144 kbps data rate available to users in high-speed motor vehicles over large areas
- 384 kbps available to pedestrians standing or moving slowly over small areas
- Support for 2.048 Mbps for office use
- Symmetrical / asymmetrical data transmission rates
- Support for both packet switched and circuit switched data services
- An adaptive interface to the Internet to reflect efficiently the common asymmetry between inbound and outbound traffic
- More efficient use of the available spectrum in general
- Support for a wide variety of mobile equipment
- Flexibility to allow the introduction of new services and technologies

Communication Networks

Switching Techniques

- Circuit switching
  - –Dedicated communications path between two stations
  - –E.g., public telephone network
- Packet switching
  - –Message is broken into a series of packets
  - –Each node determines next leg of transmission for each packet
  - –E.g., Data networks, Internet.

Phases of Circuit Switching

- Circuit establishment
  - An end to end circuit is established through switching nodes
- Information Transfer
  - Information transmitted through the network
  - Data may be analog voice, digitized voice, or binary data
- Circuit disconnect
  - Circuit is terminated
  - Each node deallocates dedicated resources

Characteristics of Circuit Switching

- Can be inefficient
  - Channel capacity dedicated for duration of connection
  - Utilization not 100%
  - Delay prior to signal transfer for establishment
- Once established, network is transparent to users
- Information transmitted at fixed data rate with only propagation delay

Packet Switching

- Data is transmitted in blocks, called packets
- Before sending, the message is broken into a series of packets
  - Typical packet length is 1000 octets (bytes)
  - Packets consists of a portion of data plus a packet header that includes control information
- At each node en route, packet is received, stored briefly and passed to the next node
- Packets don't necessarily follow same route and may arrive out of sequence
- Exit node restores packets to original order
- Responsibility of exit node or destination to detect loss of packet and how to recover

Packet Switching Advantages

- Line efficiency is greater
  - Many packets over time can dynamically share the same node to node link
- Packet-switching networks can carry out data-rate conversion
  - Two stations with different data rates can exchange information
- Unlike circuit-switching networks that block calls when traffic is heavy, packet-switching still accepts packets, but with increased delivery delay
- Priorities can be used

Disadvantages of Packet Switching

- Each packet switching node introduces a delay
- Overall packet delay can vary substantially
  - This is referred to as jitter
  - Caused by differing packet sizes, routes taken and varying delay in the switches
- Each packet requires overhead information
  - Includes destination and sequencing information
  - Reduces communication capacity
- More processing required at each node

Virtual Circuit

- Route is established before packets are sent
- Route is fixed for the duration of logical connection
- All packets follow the same route during the logical connection
- No elaborate routing decisions needed
- More than one virtual circuit between a pair of stations
- A station can have virtual circuit to more than one station

Wireless LAN Technology

Wireless LAN Applications

- LAN Extension
  - Wireless LAN linked into a wired LAN on same premises
- Cross-building interconnect
  - Connect LANs (typically bridges or routers) in nearby buildings using point-to-point wireless link
- Nomadic Access
  - Wireless link between LAN hub and mobile data terminal (ex. Transfer data from portable computer to office server)
- Ad hoc networking
  - Temporary peer-to-peer network set up to meet immediate need (ex. Group of employees with laptops setting up a meeting)

802.11 Protocol Layers

- Functions of physical layer:
  - Encoding/decoding of signals
  - Preamble generation/removal (for synchronization)
  - Bit transmission/reception
- Functions of medium access control (MAC) layer:
  - Assemble data into a frame with address and error detection fields (transmission)
  - Disassemble frame and perform address recognition and error detection (reception)
  - Govern access to the LAN transmission medium
- Functions of logical link control (LLC) Layer:
  - Provide interface to higher layers
  - perform flow and error control

IEEE 802.11 Architecture

- Distribution system (DS)
- Access point (AP)
- Basic service set (BSS)
  - Stations competing for access to shared wireless medium
  - Isolated or connected to backbone DS through AP
- Extended service set (ESS)
  - Two or more basic service sets interconnected by DS

IEEE 802.11 Services

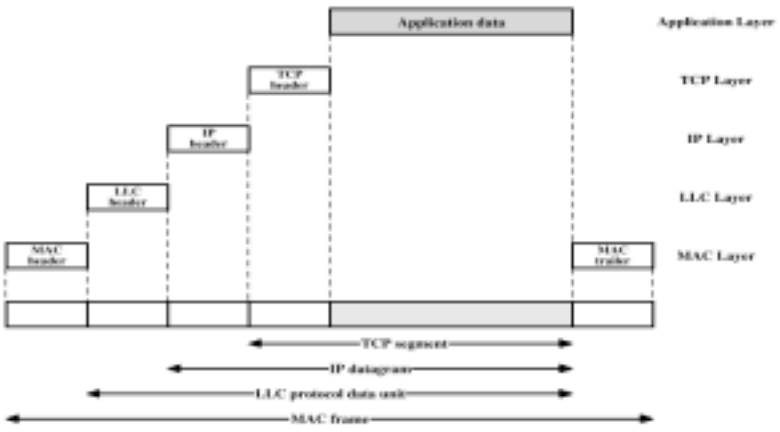


Figure 14.2 IEEE 802 Protocols in Context

Source: Stallings

Association-Related Services

- Association
  - Establishes initial association between station and AP
- Reassociation
  - Enables transfer of association from one AP to another, allowing station to move from one BSS to another
- Disassociation
  - Association termination notice from station or AP

Access and Privacy Services

- Authentication
  - Establishes identity of stations to each other
- Deauthentication
  - Invoked when existing authentication is terminated
- Privacy
  - Prevents message contents from being read by unintended recipient

Mobile IP and Wireless Application Protocol

Mobile IP Uses

- Enable computers to maintain Internet connectivity while moving from one Internet attachment point to another
- Mobile – user's point of attachment changes dynamically and all connections are automatically maintained despite the change
- Nomadic - user's Internet connection is terminated each time the user moves and a new connection is initiated when the user dials back in
  - New, temporary IP address is assigned

Operation of Mobile IP

- Mobile node is assigned to a particular network
  - home network
- IP address on home network is static
  - home address
- Mobile node can move to another network
  - foreign network
- Mobile node registers with network node on foreign network
  - foreign agent
- Mobile node gives care-of address to agent on home network
  - home agent

Capabilities of Mobile IP

- Discovery – mobile node uses discovery procedure to identify prospective home and foreign agents
- Registration – mobile node uses an authenticated registration procedure to inform home agent of its care-of address
- Tunneling – used to forward IP datagrams from a home address to a care-of address

Discovery

- Mobile node is responsible for ongoing discovery process
  - Must determine if it is attached to its home network or a foreign network
- Transition from home network to foreign network can occur at any time without notification to the network layer
- Mobile node listens for agent advertisement messages
  - Compares network portion of the router's IP address with the network portion of home address

Registration Process

- Mobile node sends registration request to foreign agent requesting forwarding service
- Foreign agent relays request to home agent
- Home agent accepts or denies request and sends registration reply to foreign agent
- Foreign agent relays reply to mobile node

Tunneling

- Home agent intercepts IP datagrams sent to mobile node's home address
  - Home agent informs other nodes on home network that datagrams to mobile node should be delivered to home agent
- Datagrams forwarded to care-of address via tunneling
  - Datagram encapsulated in outer IP datagram

Wireless Application Protocol (WAP)

- Open standard providing mobile users of wireless terminals access to telephony and information services
  - Wireless terminals include wireless phones, pagers and personal digital assistants (PDAs)
  - Designed to work with all wireless network technologies such as GSM, CDMA, and TDMA
  - Based on existing Internet standards such as IP, XML, HTML, and HTTP
  - Includes security facilities

Wireless Markup Language (WML) Features

- Text and image support – formatting and layout commands
- Deck/card organizational metaphor – WML documents subdivided into cards, which specify one or more units of interaction
- Support for navigation among cards and decks – includes provisions for event handling; used for navigation or executing scripts

Wireless Application Environment (WAE)

- WAE specifies an application framework for wireless devices
- WAE elements:
  - WAE User agents – software that executes in the wireless device
  - Content generators – applications that produce standard content formats in response to requests from user agents in the mobile terminal
  - Standard content encoding – defined to allow a WAE user agent to navigate Web content
  - Wireless telephony applications (WTA) – collection of telephony-specific extensions for call and feature control mechanisms

Issues in Mobile / Wireless Networks

Issues in Mobile / Wireless Networks

- Coding and Error Control
- Routing
- Quality of Service
- Security, Authentication, Privacy

Techniques for Achieving Good QoS

- Overprovisioning
  - Adequate router capacity, buffer space, bw
- Buffering
  - Smooths delay (but increases delay)
- Traffic Shaping
  - Smoothing traffic on server side
- Leaky Bucket Algorithm
  - Provides regulated flow out of the interface
- Resource Reservation
  - Bandwidth, buffer, CPU cycles for flow in a route
- Admission Control
  - Server / router decides about accepting/rejecting a flow

Summary

- Mobile Systems
  - Cell Phones, Base Stations, Mobile Switching Centers, Gateway Mobile Switching Centers
  - GSM, CDMA
- Wireless Systems
  - Laptops, PDA's, Access Points
  - 802.11b, WAP

Internet and Web

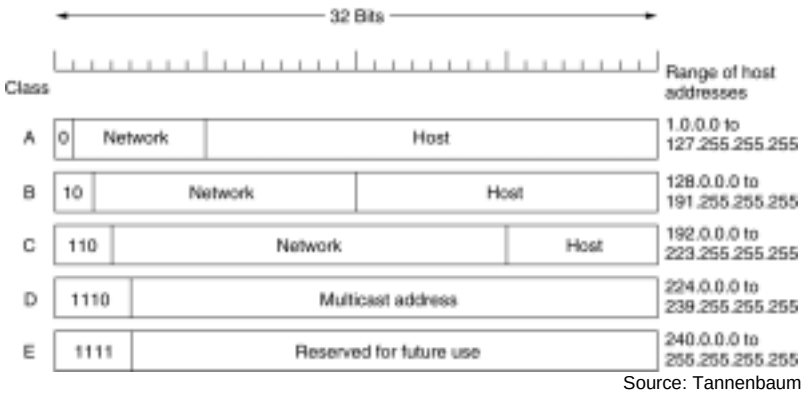
Network Categories

Network Category	***Coverage***
Personal Area Networks	1 m
Local Area Networks	10m – 1Km
Metropolitan Area Networks	1Km – 10 Km
Wide Area Networks	~ 1000 Km
Internet	~ 10,000 Km

Internet

- Origins: ARPANet (mid 70's)
- Network of (numerous) heterogeneous networks
- The component networks consist of heterogeneous hosts and operating systems
  - Held together by TCP/IP protocol
- Component networks: 3 classes
  - Class A, B, C

IP Addresses



Source: Tannenbaum

IP address formats.

Design Principles for Internet

- Make sure it works.
- Keep it simple.
- Make clear choices.
- Exploit modularity.
- Expect heterogeneity.
- Avoid static options and parameters.
- Look for a good design; it need not be perfect.
- Be strict when sending and tolerant when receiving.
- Think about scalability.
- Consider performance and cost.

Internet and Web

Web
Tools: Markup Languages (HTML), Browsers, Scripting languages (CGI).
Services: Directory, Search, Transactions, etc.

Internet
Hardware: Host Computers, Communication Links, Bridges, Routers, Gateways.
Protocols: TCP/IP, FTP, RTP, SNMP, HTTP, etc.

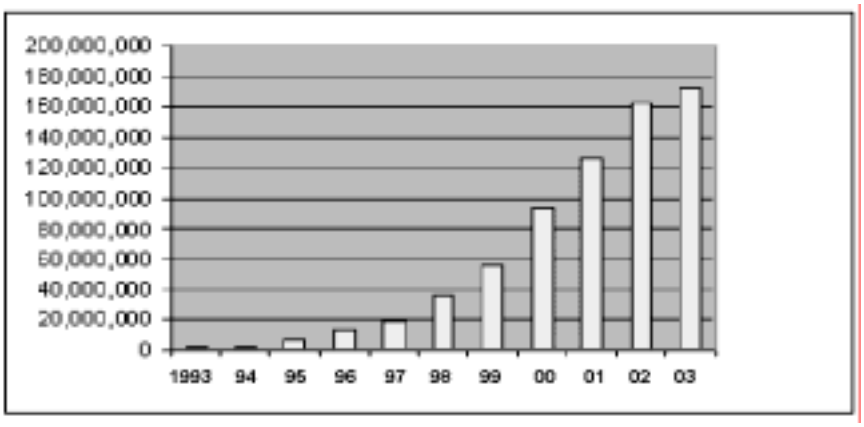
Internet and Web

- Internet provides:
  - Basic communication infrastructure
  - Communication protocols
  - Network functions
    - Routing
    - Admission control
    - Congestion control
    - Error recovery
- Web provides:
  - Data/information authoring and publishing
  - Shared access to data/information
  - Data/information services

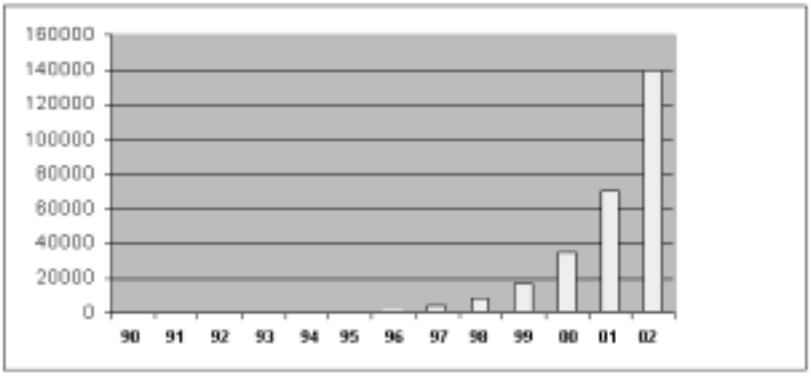
Internet Traffic Growth

- Overall traffic growth:
  - around 20% to 30% per year in the 1980's
  - 30 to 40% per year in 1990 through 1998
  - Closer to 100% per year
- Internet traffic doubles each year

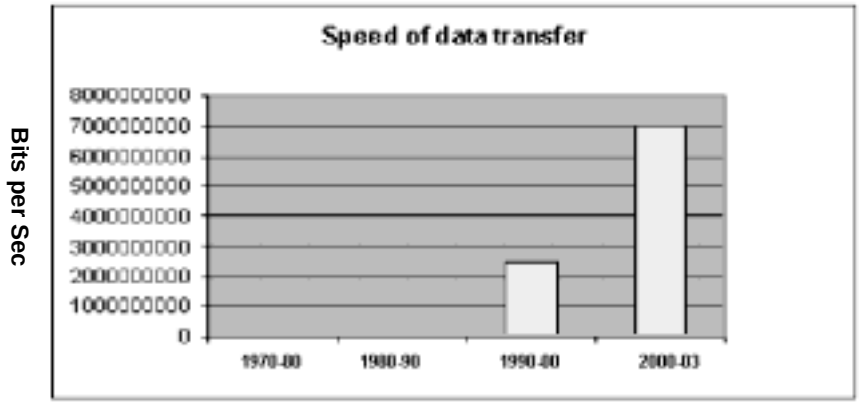
Growth of Internet Hosts



Internet Traffic Growth



Speed of Data Transfer



S.R. Subramanya 111

Protocols and the TCP/IP Suite

Key Features of a Protocol

- Syntax
  - Concerns the format of the data blocks
- Semantics
  - Includes control information for coordination and error handling
- Timing
  - Includes speed matching and sequencing

Agents Involved in Communication

- Applications
  - Exchange data between computers (e.g., electronic mail)
- Computers
  - Connected to networks
- Networks
  - Transfers data from one computer to another

TCP/IP Layers

- Physical layer
- Network access layer
- Internet layer
- Host-to-host, or transport layer
- Application layer

TCP/IP Physical Layer

- Covers the physical interface between a data transmission device and a transmission medium or network
- Physical layer specifies:
  - Characteristics of the transmission medium
  - The nature of the signals
  - The data rate
  - Other related matters

TCP/IP Network Access Layer

- Concerned with the exchange of data between an end system and the network to which it's attached
- Software used depends on type of network
  - Circuit switching
  - Packet switching (e.g., X.25)
  - LANs (e.g., Ethernet)
  - Others

TCP/IP Internet Layer

- Uses internet protocol (IP)
- Provides routing functions to allow data to traverse multiple interconnected networks
- Implemented in end systems and routers

TCP/IP Host-to-Host, or Transport Layer

- Commonly uses transmission control protocol (TCP)
- Provides reliability during data exchange
  - Completeness
  - Order

Common TCP/IP Applications

- Simple mail transfer protocol (SMTP)
  - Provides a basic electronic mail facility
- File Transfer Protocol (FTP)
  - Allows files to be sent from one system to another
- TELNET
  - Provides a remote logon capability

Quality of Service (QoS) Parameters

- Reliability (Error Rate)
- Delay (Latency)
- Jitter (Delay Variance)
- Throughput

QoS Requirements of Typical Applications

Application	Reliability	Delay	Jitter	Bandwidth
E-mail	High	Low	Low	Low
File transfer	High	Low	Low	Medium
Web access	High	Medium	Low	Medium
Remote login	High	Medium	Medium	Low
Audio on demand	Low	Low	High	Medium
Video on demand	Low	Low	High	High
Telephony	Low	High	High	Low
Videoconferencing	Low	High	High	High

Source: Tannenbaum

Internet / Web Challenges

- More effective and efficient search schemes
- Real-time support for time-sensitive data (audio, video)
- Powerful interfaces
- Multilingual support
- Trusted systems (controlled sharing of information)
- Security

Summary

- Growth of Internet / Web have been phenomenal
- No central control
- Powerful communications medium
- Several novel services
- Newer tools and techniques needed to support emerging applications

Multimedia

Technologies, Techniques, Systems

Topics

- Introduction to Multimedia
- Data Acquisition and Processing
- Data Compression Techniques/Standards
- Data Analysis
- Storage, Indexing, and Retrieval
- Communications and Networking
- Media Protection
- Applications

Introduction to Multimedia

Multimedia Computing and Information Systems

- Kinds of data stored and manipulated by computers have changed drastically over the years:
- Early generation: mid-40's to mid-60's
  - Numeric data (numbers)
- Second/Third generation: mid-60's to late 80's
  - Media Symbolic data (alphanumeric)
- Fourth/Fifth generation: Early 90's to Present
  - Media data (audio, images, video)
- Need for design of systems to consider the paradigm shift

What is Multimedia Data ?

- Combination of different kinds of Semantically related
  - Text
  - Audio
  - Images
  - Videos
  - Graphics
  - Animation

Why Multimedia Data?

- Power of Expression
- Richness of content
- Support for Interactivity
- Ease of Comprehension
- Attract Attention

Benefits of Multimedia

Some empirical results have shown the following:

- more than 80 % by sight - of which 20 % is remembered
- 11 % by hearing - of which 30 % is remembered
- 3.5 % by smell
- 1.5 % by touch and taste.
- 50 % of what is both seen and heard is remembered
- 80 % of what is seen, heard and done, is remembered

Thus, multiple and interactive media is very effective

What is a Multimedia System?

A Multimedia system is any system which performs any subset of the major operations on multimedia data:

- Generation / acquisition
- Processing
- Storage
- Query and retrieval
- Transmission (and Synchronization)
- Presentation

System Implications of Multimedia

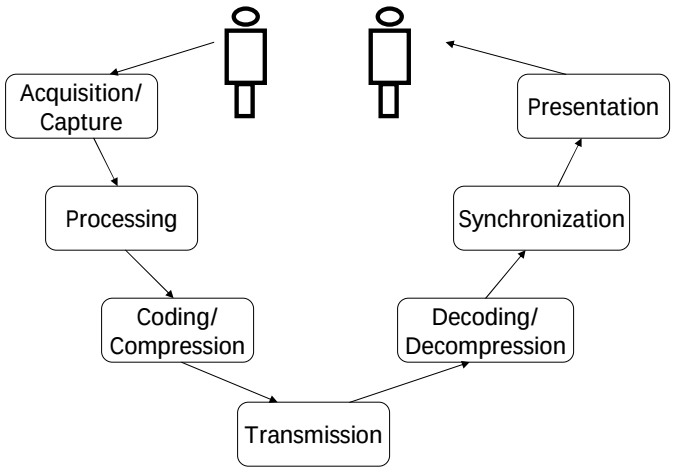
Acquisition / Generation	Newer devices, pre-processing
Production	More complex authoring and user interface software
Representation / Coding	Coping with lossy compression
Storage	Huge volumes and new access patterns
Protection	Encryption, watermarking
Processing	OS, scheduling, indexing, searching
Analysis / Understanding	Speech/object recognition, content analysis, feature extraction
Indexing	Multidimensional index structures
Query, Search, and Retrieval	Content-based queries, similarity searches
Communication	Transmission over networks, QoS management
Synchronization and Presentation	User perception and user friendliness
Distribution	Media delivery and broadcast

Broad Categories

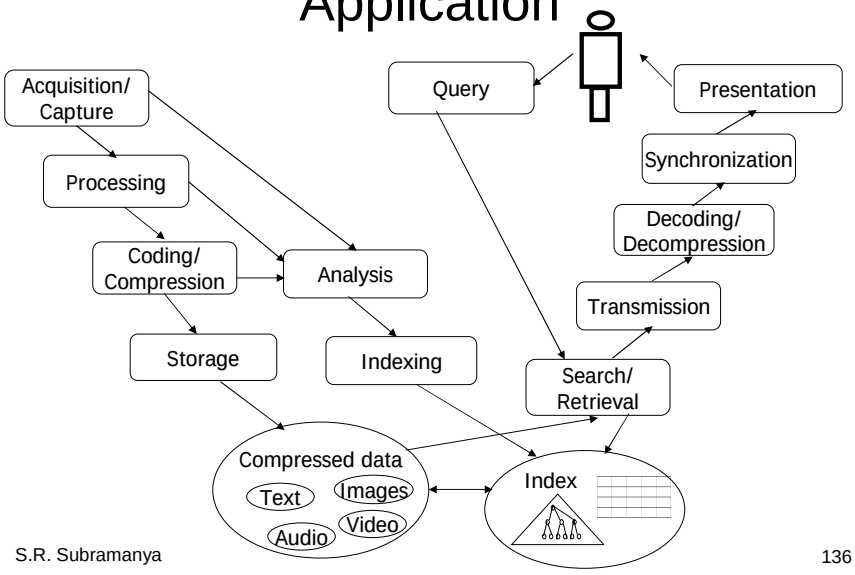
- Stand-alone systems
- Distributed systems

- Live systems
- Orchestrated systems

Major steps in a Live Application



Major steps in an Orchestrated Application



Coding/ Compression

Primarily information is subjected to two kinds of coding

- *Source Coding*: Coding for efficient representation of information. (Also called Compression)
- *Channel Coding*: Coding for error free transmission of information through a noisy medium

Multimedia Storage/Bandwidth Requirements

Media type	Duration/Size	Bandwidth	Storage
Audio Speech quality CD-DA quality	60 mins	64Kbits/sec. 1.412 Mbits/lsec.	28.8MB. 635MB.
Image Gray scale (8-bit) Color (24-bit)	640× 480		~307KB. ~922KB.
Video NTSC HDTV	60 mins.	221 Mbits/sec.	99.45 GB. ~922 GB.

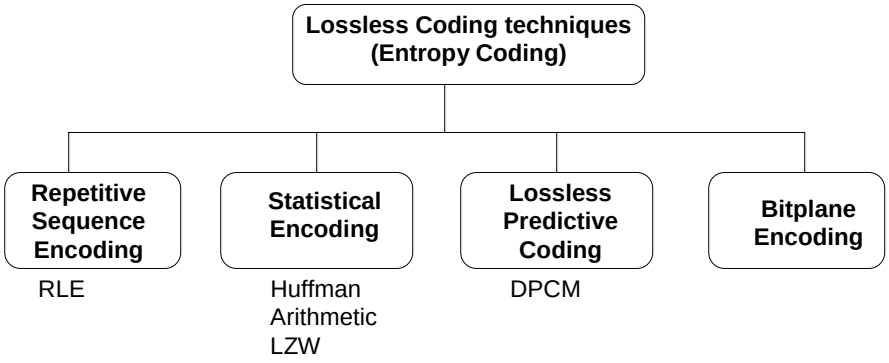
Compression

- Multimedia data need
  - Huge Storage Space
  - Large Transmission Bandwidth
- Storage, Bandwidth Requirements are usually much greater than Availability
- Compression is a viable technique
- Compression techniques make use of various kinds of redundancies in data
- Major types:
  - Lossless or Lossy

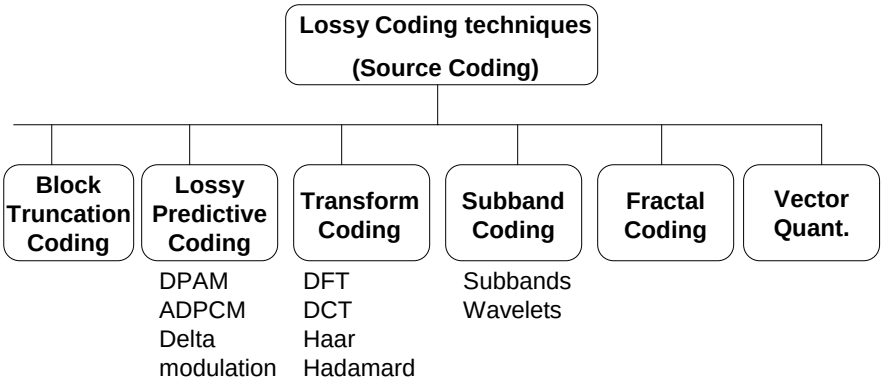
Types of Redundancies

- Spatial Redundancy
  - Due to the correlation between neighboring pixel values
- Spectral Redundancy
  - Due to the correlation between different color planes or spectral bands
- Temporal Redundancy
  - Due to the correlation between successive frames in video
- Psycho-visual redundancy
  - Due to Human Visual Systems (HVS) properties

Taxonomy of Lossless Image Compression



Taxonomy of Lossy Image Compression



Performance Metrics for Lossy Techniques

- Compression Ratio (CR)

$$CR = \frac{size\ of\ original\ data}{size\ of\ compressed\ data}$$

- Peak Signal to Noise Ratio (PSNR)

$$PSNR = 20\log_{10}\frac{peak\ data\ value}{RMSE}$$

RMSE is the Root Mean Square Error between the original and reconstructed data

- Speed (Complexity) of encoding and decoding

JPEG Image Compression Standard

- JPEG : Joint Photographic Experts Group
- Standard for continuous-tone still images
- Widely used standard
- New Standard : JPEG 2000

JPEG Features

- Hybrid scheme: Uses
  - DCT
  - Run Length Encoding
  - Huffman Coding
- Four Different Modes
  - Lossless
  - Sequential (Baseline)
  - Progressive
  - Hierarchical

JPEG-2000 Image Coding System

- Handles different types of images :
  - bi-level, gray-level, color, multi-component.
- Handles images with different characteristics :
  - Natural images, Scientific, medical, Remote Sensing, Rendered graphics, etc.
- Region-of-Interest coding
  - Some parts of an image which are more important to be coded with better quality and lower distortion
- Provides low bit-rate (< 0.25 bpp) operation with lower distortion
- Content-based description
  - Metadata information
  - Image archival, indexing and searching applications
- Protective image Security
  - Watermarking , stamping, labeling encryption
- Intended to compliment (not replace) existing JPEG standards.

Standards for Video

	HDTV	CCIR 601 NTSC	CCIR 601 PAL	CIF	QCIF
Luminance Resolution	**1920 x 1080**	**720 x 486**	**720 x 576**	**352 x 288**	**176 x 144**
Chrominance Resolution	**960 x 540**	**360 x 486**	**360 x 576**	**176 x 144**	**88 x 72**
Color Subsampling	**4:2:2**	**4:2:2**	**4:2:2**	**4:2:0**	**4:2:0**
Fields/sec	**120**	**60**	**50**	**30**	**30**
Aspect Ratio	**16:9**	**4:3**	**4:3**	**4:3**	**4:3**
Interlacing	**Yes**	**Yes**	**Yes**	**No**	**No**

CCIR – Consultative Committee for International Radio
CIF – Common Intermediate Format (approximately VHS quality)
QCIF – Quarter CIF

Video Compression

- Video : Sequence of frames
- Each Frame : 2-D Array of Pixels
- Video: 3-D data
  - 2-D Spatial, 1-D Temporal
- Video has both :
  - Spatial Redundancy (within each frame – Intra-Frame)
  - Temporal Redundancy (between Frames – Inter-Frame)

Major Video Coding Techniques

- Several Proprietary Schemes.
- Motion JPEG
- H.261/H.263
- MPEG (Motion Pictures Expert Group)
  - MPEG-1
  - MPEG-2
  - MPEG-4
  - MPEG-7
  - MPEG-21

Overview of MPEG Standards

- MPEG-1 (1992)
  - Coding of video and audio for storage media (CD-ROM, 1.5Mbps)
  - VCD, MP3
- MPEG-2 (1994)
  - Coding of video and audio for transport and storage (15 Mbps)
  - Digital TV (HDTV) and DVD
- MPEG-4 (v1:1999, v2: 2000, v3: 2001)
  - Coding of natural and synthetic media objects for web and mobile applications
- MPEG-7 (2001)
  - Multimedia content description for AV materials
  - Media searching and filtering
- MPEG-21 (started from 2000)
  - Multimedia framework for integration of multimedia technologies
  - Transparent and augmented use of multimedia resources

MPEG-1 Video Layer

- Intra-frame encoding: DCT-based compression for the reduction of spatial redundancy (similar to JPEG)
- Inter-frame encoding: block-based *bidirectional* motion compensation for the reduction of temporal redundancy
- The difference signal, the prediction error, is further compressed using the discrete cosine transform (DCT) to remove spatial correlation and is then quantized.
- Finally, the motion vectors are combined with the DCT information, and coded using variable length codes
- MPEG-1 syntax has a hierarchy of six layers:
  - Sequence Layer
  - GOP (Group of Pictures) Layer
  - Picture Layer
  - Slice Layer
  - Macro block Layer
  - Block Layer

MPEG-2

- MPEG-2 is a standard for digital TV (HDTV and DVD)

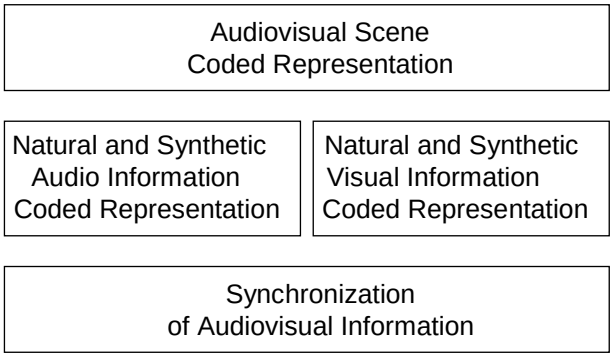
Level	Size	Pixels/sec	Bit-rate (Mb/s)	Application
Low	352 x 288 x 30	3 M	4	VHS, TV
Main	720 x 576 x 30	12 M	15	Studio TV
High 1440	1440 x 1152 x 60	96 M	60	Consumer HDTV
High	1920 x 1152 x 60	128 M	80	HDTV, Film

Object-Based Coding of Video

- Content-Based Coding
- Increases compression efficiency
- Allows access to arbitrarily-shaped objects in a coded scene
- Enables high interaction with scene content
- Facilitates manipulation of scene content on bitstream level

Overview of MPEG-4

- The coded representation of the combination of streamed elementary audiovisual information
- 1) Compression, 2) content-based interactivity, 3) universal access
- To provide a bridge between the www and conventional AV media
- To deliver streaming AV media on the Internet and wireless networks



MPEG-4 Baseline Coding

- Support both progressive and interlaced scanning
- Arbitrary size from 8x8 to 2048x2048
- Y, Cr, Cb: 4:0:0, 4:2:0, 4:2:2 and 4:4:4
- Bit rates: 5Kbps ~ 1Gbps from very small TV to Studio TV
  - low (<64Kbps), intermediate (64~484kbps)
  - high (384K~4Mbps) and very high (>4Mbps)
- Better coding efficiency than MPEG-1/2 and H.263

MPEG-7 Features

- Not a compression standard like MPEG-1, -2, -4.
- Support for advanced query
- Fast and accurate access
- Personalized content production and consumption
- Content management
- Main Elements
  - Descriptors (D)
    - Syntax and Semantics of each feature representation
  - Description Schemas (DS)
    - Structure and Semantics of relationships between components
  - Description Definition Language (DDL)
    - Creation of new DS's
    - Extension / Modification of existing DS's

MPEG-21

- Capable of supporting delivery and use
  - of all content types
  - by different categories of users
  - in multiple application domains
- MPEG-21 digital item
  - A structured digital object with a standard representation, identification and metadata
  - Fundamental unit for distribution and transaction within this framework.
- Major functionalities:
  - Digital Item Declaration
  - Digital Item Representation
  - Digital Item Identification and Description
  - Digital Item Management and Usage
  - Intellectual Property Management and Protection
  - Terminals and Networks
  - Event Reporting

Video Conferencing Standard: H.261/H.263

- Uses 2-D DCT for Intraframe
- Uses simple Motion Estimation for Inter-Frame
- Provides Real-Time coding/decoding

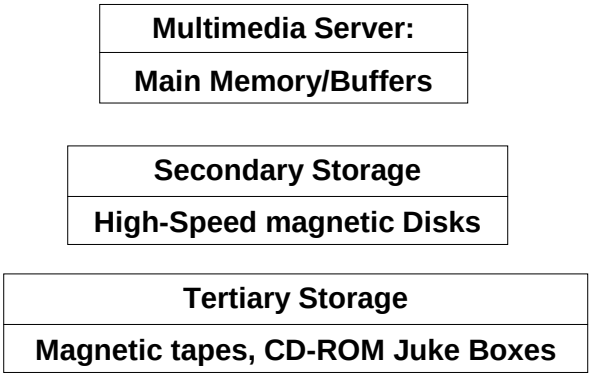
Multimedia Storage and Retrieval

Multimedia Storage and Retrieval

Requirements:

- Simultaneous Access to Multiple Media Objects
- Support for Continuous media (Audio, Video)
- Concurrent Accesses by Different Users
- Guarantee Data Rates
- Support Several QoS Requirements

Storage Hierarchies



Storage Scheme Design Factors

- Number of Applications to be Supported
- Required Bandwidth of each Application
- Support for VCR-like Functions (Ex. FF, Rewind)
- Reliability Considerations
- Required Storage
- Affordable Cost

Data Analysis

Data Analysis and Feature Extraction

- Image processing and computer vision techniques
- Scene analysis and segmentation (video)
- Manual/semi-automatic annotation

Perceptual features (Image/Video)

- Color
- Texture
- Shape
- Objects
- Spatial Relationships
- Motion

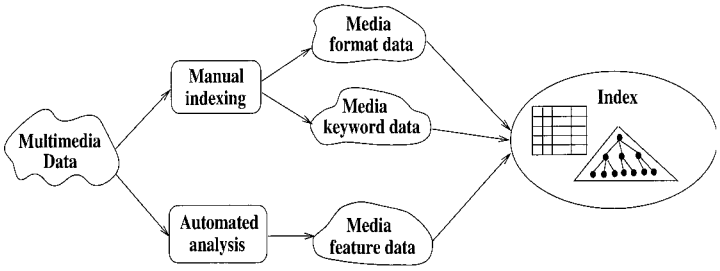
Video Scene Analysis and Scene Segmentation

- Identify significant video frames
- Derive content information (semantic interpretation)
  - require techniques from
    - Image Processing
    - Computer Vision
    - Artificial Intelligence

Indexing

Indexing

- Organizing features (and data) in suitable data structures:
- Building the index
  - Providing Similarity Search Scheme



Index Structures

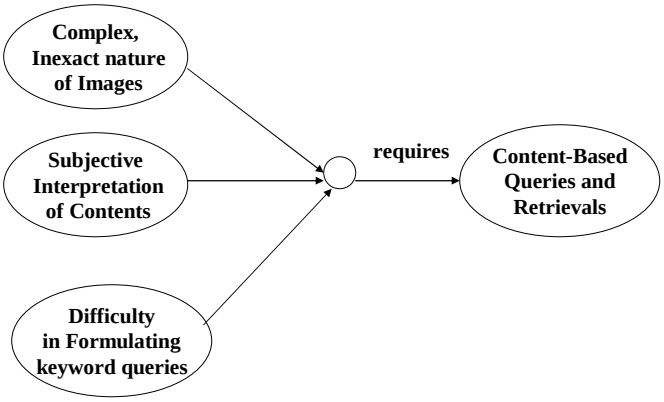
- String Attributes:
  - Hash Tables
  - Signature Files
- Visual Attributes:
  - Grid Files
  - K-D Trees
  - R, R^+, R* Trees
  - SS-Trees

Multimedia Data Query and Retrieval

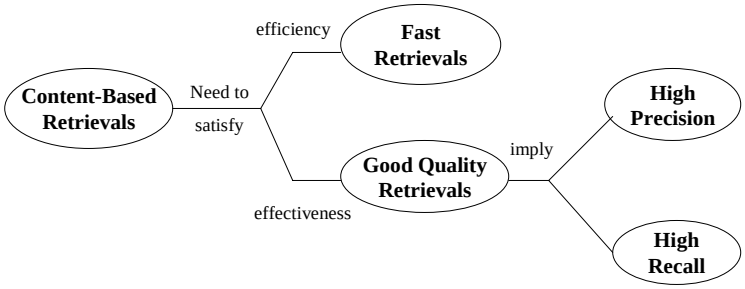
Multimedia Query/Retrieval Requirements

- Content Based Retrieval
- Browsing Facility
- GUI for user to formulate queries
- Similarity search
- Relevance feedback

Need for CBRs



Requirements of CBRs



Components of Multimedia Retrieval System

- Subsystem for extraction of perceptual features
- subsystem for extraction of high-level features (and semantics)
- Subsystem for (semi-automated) annotation
- graphical tool for composing queries
- Index structure for organizing metadata
- Retrieval engine for finding data similar to query
- Relevance feedback mechanism

Types of Metadata

(Image / Video Example)

- Content-Independent Metadata
  - Not related to content per se
  - Generally related to content creation
  - Ex. Author, date/time, location, etc
- Content-Dependent Metadata
  - Refer to low/intermediate level features
  - Related to perceptual factors
  - Ex. Color, texture, shape, motion
- Content-Descriptive Metadata
  - Refer to content semantics
  - Related to meanings objects/scenes
  - Ex. ‘buildings’, ‘aircraft’, ‘flower’

Retrieval Performance Metrics

	Relevant	Not Relevant
Retrieved	**A(correct retrieval)**	**B (false retrieval)**
Not Retrieved	**C(miss)**	**D (correct miss)**

- Recall = $\frac{\text{Relevant Correct Retrieval}}{\text{All Relevant}} = \frac{\text{A}}{\text{A + C}}$
- Precision = $\frac{\text{Relevant Correct Retrieval}}{\text{All Retrieved}} = \frac{\text{A}}{\text{A + } B}$

Multimedia Communication

Major Multimedia communication Issues

- Maintenance of Time Synchronization across Media
- Asynchrony introduced between Media Streams by the Network
  - Due to varying delays for different media
  - Due to varying delays at different parts of the Network
- Buffering can compensate for delays
- However, Delay is not constant
  - Due to bursty nature of data
  - Due to dynamic nature of network
- Variations in Delay: Jitter
- Packet Losses
  - Due to communication errors
  - Due to buffer overflows

Quality of Service (QoS)

- QoS is not fixed; varies with application
- QoS Spectrum:
  - Acceptable QoS: Minimum Acceptable
  - Preferred QoS: Ideal/Desirable Condition
  - Guaranteed QoS: Operating Point
- Normally QoS is negotiated between Application and Network Service Provider

QoS Parameters

- Traffic Throughput
  - Amount of Data sent through the Network in a given time
- Transmission Delay
  - Delay suffered by Data through the network
- Delay Jitter
  - Bound on the delay variation
- Transmission Reliability
  - Related to buffering and packet loss
- Synchronization
  - Sync. Of different media on different channels

Multimedia Networks

- Ethernet LANs
- Token ring LANs
- Gigabit Ethernet
- WANs
- ATM
- Internet

Media Protection

What is Media Protection?

- Media protection or digital rights management (DRM) is the set of techniques used to:
  - Control access to content:
    - Viewing rights
    - Reproduction (copying) rights
- Essentially, media protection is the management of the author's and publisher's intellectual property in the digital world.

Media Protection Principles

- Encryption of the content to disallow uncontrolled access.
- Decryption key management.
- Access control according to flexible usage rules
  - Number of times content can be accessed; times it can be accessed; trading of access rights.
- Copy control or copy prevention
  - Management of the number of copies that can be made of the content.
- Identification and tracing of multimedia data.

Underlying Technologies

- DRM is based on two fundamental underlying technologies:
  - Encryption
    - used to “lock” the content and deny access to it to those parties that do not possess the appropriate keys
    - enforces the restrictions placed on the content by the author/publisher
  - Digital Watermarking
    - used to “mark” the content so that a particular copy can be traced back to the original user
    - used as a deterrent to large-scale unauthorized copying of copyrighted material

Applications

Multimedia Databases
Mobile/Wireless Multimedia

Multimedia Databases

- Organize massive amounts of Multimedia data
- Provide Query and Retrieval for users
- Provide Browsing
- Support a variety of Applications:
  - Video-On-Demand
  - Manufacturing
  - e-shopping
  - Digital Libraries

Major Design Issues of MMDBS

- Manage different types of Data
- Handle a variety of compression and storage formats
- Support different computing platforms, OS
- Integrate different Data Models
- Offer a variety of Query Systems
- Use different Kinds of Indices
- Provide transparent view of geographically distributed data
- Support Real-Time delivery of data
- Provide Synchronization of different data (media) streams

Mobile / Wireless Multimedia Applications

Mobile Office	E-Commerce	Communications
File Services	Broker Services	Messaging
Real-time Support	Electronic Ticketing	Event notification
Corporate Applications	Online-banking	Email
Remote diagnostics/maintenance	E-retail & Auction	Voice Services
Collaboration	Interactive Shopping	Video Telephony

Entertainment	Travel	Telemetry
News, sports, weather updates	Scheduling/ Timetables	Monitoring & Control
E-magazines	Navigation Services	Data acquisition
Interactive gaming	Traffic Information	Health monitoring
Audio on demand	Directory Services	Surveillance
Video on demand	Tourist Services	
	Locator Services	

Summary

- Newer Multimedia technologies and techniques are on the horizon
- Multimedia provides:
  - High expressive power
  - Richness of content
  - Support for Interactivity
  - Ease of comprehension

In Conclusion

- Advancing technologies
- Enhancement of techniques
- Convergence

Of

- Mobile/wireless networks
- Internet
- Multimedia

Would impact the development and use of Collaborative Systems

Thank You