Data Communications

1

Course Curricula

- *Introduction*
- *Channels: bandwidth, transmission impairments.*
- *Digital signals encoding: RZ, NRZ, Manchester, AMI, HDB3, B8ZS. Scramblers.*
- *Baseband transmissions. Inter-Symbol Interference (ISI). Nyquist's first theorem. Partial-response systems. Performance improvement: adaptive filtering, eye-diagram, equalization (ZF-zero-forcing). BER-curves. Symbol synchronization.*
- *Linear modulation : modulation and demodulation description, errors, ASK modems.*
- *Frequency modulation : modulation and demodulation description, errors, FSK modems.*
- *Phase modulation : modulation and demodulation description, errors, PSK modems.*
- *Orthogonal Frequency Division Multiplexing*
- *DTE/DCE interfaces : V24/RS232C, USB, X21*

2

Applications (laboratory works)

- *Baseband transmissions (BB)*
  1. Digital encoding of the baseband signals.
  2. Baseband transmissions (BB), without Inter-Symbol Interference ISI.
  3. Baseband transmissions (BB), with controlled Inter-Symbol Interference ISI.
- *Modulations*
  1. Amplitude modulation.
  2. Angle modulation.
  3. Orthogonal Frequency Division Multiplexing.

Applications (exercises)

- Channel capacity
- Scramblers
- Nyquist filters (square root raised cosine) and their implementation
- Frequency modulation
- Phase modulation

References

- The course materials can be downloaded from:

http://shannon.etc.upt.ro/teaching/dc-pi/

- Further references

1. W.Stallings, “Data and Computer Communications”, Edit. Prentice-Hall, 1997.
2. M. Nafornita, C. Munteanu, ’’Comunicatii de date’’, Edit. Gh. Asachi, 1996.
3. B. A. Forouzan, “Data communications and networking –fourth edition”, Mc. Graw-Hill, 2007.

Course 1: Basic Concepts of Data Communications

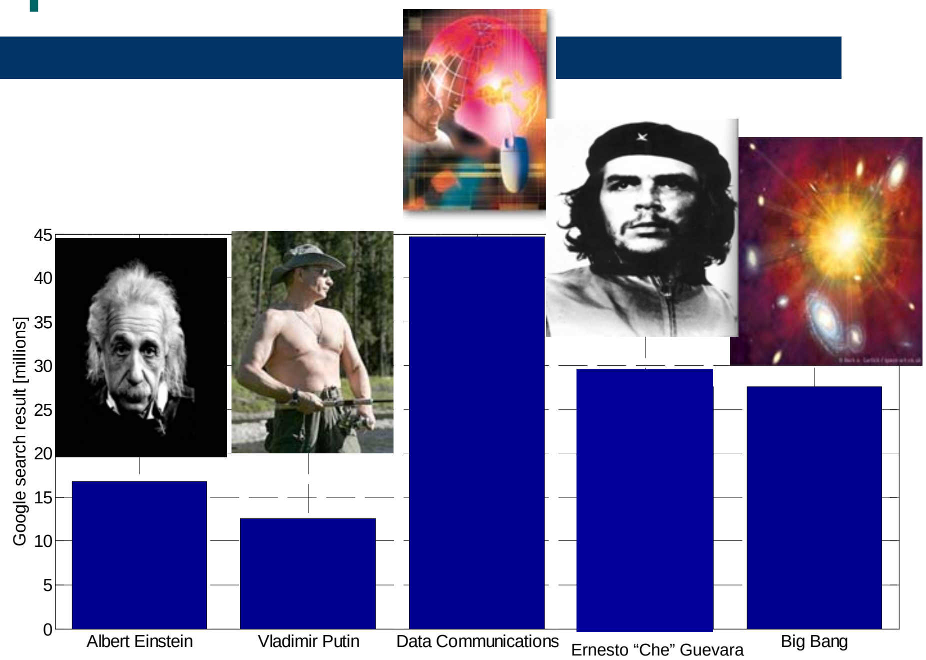
“I'm a great believer that any tool that enhances communication has profound effects in terms of how people can learn from each other, and how they can achieve the kind of freedoms that they're interested in”

Bill Gates

Course content

- Impact
- Definition
- Data communications versus networking
- Processes involved in communication
- Basic parameters of a communication system
- Elements of a communication system
- Basics of network architectures

Impact



Definitions for Data Communications

- Definition 1: the transfer of data and information from one location to another (Source: http://www.techweb.com/encyclopedia)
- Definition 2: process which takes place between two devices which are directly connected by some form of point-to-point transmission medium (Source: W.Stallings, "Data and Computer Communications", Edit. Prentice-Hall, 1997).

Data Communications model

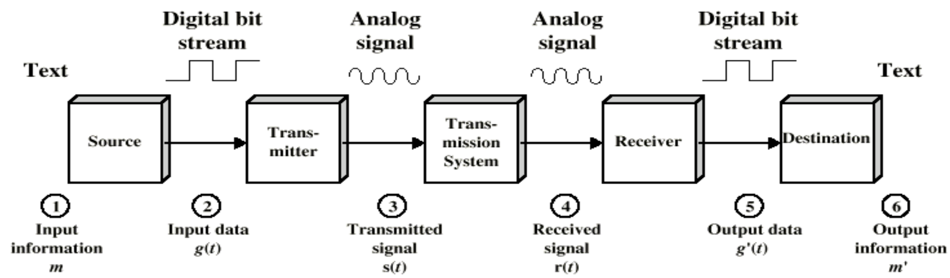


Fig. 1: A simplified data communications model .

- One source, one receiver
- The link is point-to-point

Networking model

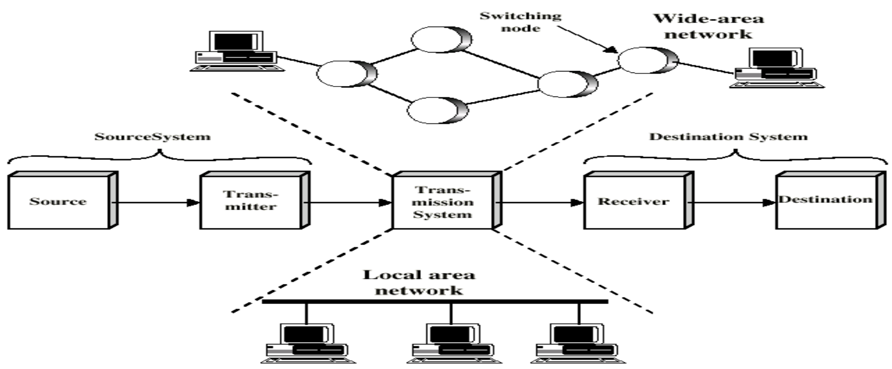


Fig. 2: A simplified networking model.

- Because point-to-point is oftentimes impractical
- Networking allows to efficiently connect remote devices

Processes involved in Data Communications

- Generation of a signal message: voice, music, images, computer data
- Symbols are generated to represent the data to be transmitted
- Information encoding: process used to adapt the symbols to be transmitted to the transmission environment (channel)
- Transmission: the symbols are transmitted towards the desired destination, using a certain physical medium (cable, optical fiber, radio)
- Decoding: from the received signal, the symbols are somehow extracted (the complementary operation of encoding)
- Recreation of the original message (prone to various types of distortions during its transmission)

Broadcasting versus Point-to-Point

- Broadcasting: one transmitter, multiple receivers (e.g.: broadcasted radio & TV)
- Point-to-Point: one transmitter, one receiver (e.g.: “backhauling” links for high capacity communications, point-to-point link between two PCs, classic telephone calls)
- Most of the data communication systems nowadays are a combination of the two modes: broadcasting at physical layer and point-to-point at data link layer (e.g Ehernet, WiFi, GSM)

Basic parameters of a communication system

- Transmitted power: the transmission power of the message signal [Watts]
- Frequency bandwidth: the physical spectrum available for a certain transmission [Hz, bps]
- Noises: undesired signals distorting the useful signal (channel noise, receiver noise, interferences)
- Shannon used these terms in its famous "capacity theorem"

Examples

- Bandwidth:
  - 300 – 3400 Hz for PSTN networks (adapted to the human hear's spectrum): restricted by regulations;
  - 1.1 MHz for twisted pairs cables (such as in PSTN): restricted by physical features;
  - 10 Mbps: total bandwidth available for an Ethernet transmission (100 Mbps for Fast Ethernet): restricted by regulations and physical features;

Power and noises

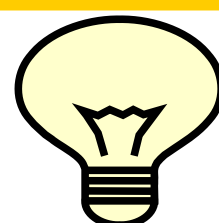
- SNR (signal-to-noise ratio):

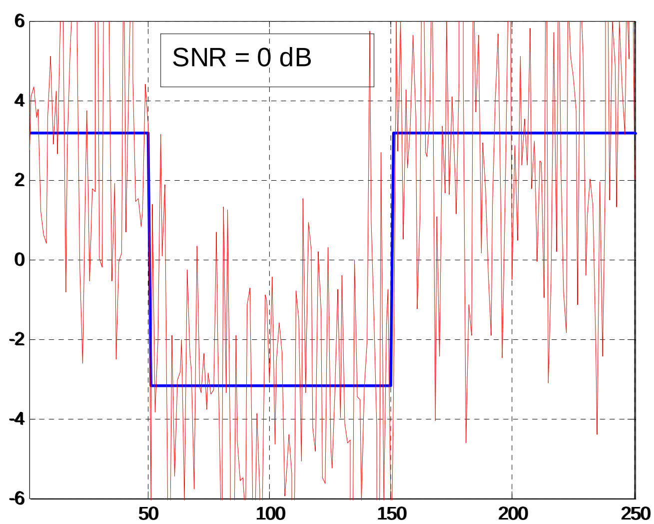
$$SNR = \frac{P_{signal}}{P_{noise}} \qquad (1)$$

$$SNR[dB] = 10\lg\frac{P_{signal}}{P_{noise}} \qquad (2)$$

- Examples: 0dB means unitary SNR, 10 dB means that the signal is ten times stronger, 20 dB means 100 times more signal power than noise power etc.

How good is a good SNR?





Data sources

- 1D data sources: audio signals (speech, music)
- 2D data sources: pictures
- 3D data sources (video sequences: a sequence of pictures automatically changing during the time)
- PC-generated data: the broader class (the PC can transmit all the above type of data)
- Sources can be, at their origin, digital or analog

Audio signals

- Audio signals propagate by means of audio waves (speed of 340 m/s)
- Speech:
  - its power spectral density (PSD) has significant components below 1KHz
  - This explains the bandwidth allocated for the analog telephony
- Music: much more extended spectrum (up to 20 KHz)
- These sources are analog, so conversion is needed for digital transmission

Pictures

- More technically they are referred to as "static images"
- They are considered as 2-D signals
- Example: a black and white picture can be represented as a matrix of values, every value being a level of intensity

Moving images

- Generally referred to as "video sequences"
- A scanning procedure is performed by the camera, which converts the intensity of an image into a1-D signal
- The scanning is made on two interlaced fields (composed of image rows)
- 25 (or 30) images/s are displayed on the screen, being perceived as a real time video sequence
- Bandwidth higher than 4MHz (4.2, 5, 5.5, 6) MHz

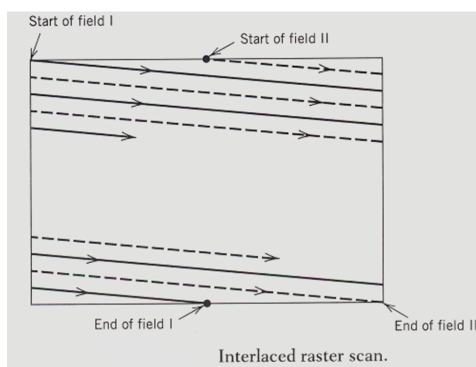


Fig. 3: Interlaced raster scan.

Personal Computers

- They generate digital data
- Example: the ASCII (American Standard Code for Information Exchanges) code
- 7 bits represent a character, 1 bit is for parity
- Example: “black” in the PC’s language will be {1100010 1101100 1100001 1100011 1101011} (parity ignored)
- Generally, the PC generated data requires a large amount of bandwidth
- To reduce it, compression algorithms must be applied

Compression

- Signal processing process which reduces the size of the data to be transmitted or stored
- Part of a process referred to as source coding
- Compression can be lossless or lossy
- Lossless algorithms exploit the statistical dependency (correlation) which exists in the data stream

Lossless Compression

- The data is reconstructed (uncompressed) exactly in its original form
- Mostly used to compress texts
- Huffman Code: the most widely used characters are encoded with fewer bits, the rare ones with a longer combination
- It is a fixed-to-variable size encoder
- Lempel-Ziv algorithm: groups of characters are encoded using a dictionary
- The algorithm replaces groups of characters with indexes in the dictionary
- Resource saving between 35% and 80%, depending on the data

Lossy Compression

- After reconstruction, there are some differences between the original and the retrieved data, but unperceivable (hopefully)
- Mostly employed for media compression (speech, music, video)
- Transform-based compression: a unitary transform is applied, some data is removed
- The applied transform concentrates most of the energy in a small number of relevant coefficients
- Examples: Discrete Cosine Transform (DCT), Wavelet Transfolrm
- Prediction-based compression: previous and/or subsequent decoded data is used to predict the current sample
- Focus on the idiosyncrasies of human physiology (the human eye can see only certain wavelengths of light, some frequencies in the sound can be seamlessly suppressed)

Standards

- JPEG- Joint Photografic Experts Group – photo compression
- Compression ratios of 10:1 (versus bitmap) are common
- DCT is applied, relevant coefficients are cuantified and a Hoffman coding takes place
- MPEG-1 (Motion Photografic Experts Group): allows image transmission at 1.5 Mbps
- Redundancy is extensively exploited: inter-frame redundancy (in time), in frame redundancy (pixels of the same frame), psycho-visual redundancy and entropic redundancy
- MP3 (MPEG-1 audio layer 3): audio compression
- Based on DCT, allows transmission at 128kbps
- Compression rates of 10:1 versus the original CDA format

Basics of network architectures

- Point-to-Point communication is oftentimes impractical
- Netwotks must be designed to achieve a higher degree of connectivity
- Networks are traditionally classified according to the geographic area they cover (WAN, MAN, LAN and PAN)
- Wide Area Network: covers a large area, requiring routers and switches to interconnect the nodes. Example: Internet
- Metropolitan Area Network: covers smaller areas than WAN. Example: WiMAX (IEEE 802.16)
- Local Area Network: they cover smaller areas, but achieve higher bit rates. Examples: Ethernet (IEEE 802.3), WiFi(IEEE 802.11)
- Personal Area Networks: communication between computer devices within a range of a few meters. Example: Bluetooth, ZigBee.

WAN

- Four technologies used to transport data between nodes: circuit switching, packet switching, ATM and frame relay
- Circuit switching: dedicated communication path is established between two nodes
- The path is a connected sequence of physical links between nodes
- Example: the telephone network
- Packet switching: data is split in packets
- Packets are indexed and sent one by one
- Each node checks the destination and tries to route the packet optimally
- No need for dedicated paths in this scenario
- Example: computer-related communications, VoIP

Circuit vs. Packet Switching

- Circuit switching is expensive, because requires dedicated lines
- Packet switching allows to share the physical medium: several callers can simultaneously use the same link
- The shared medium in Packet Switching allows great cost reduction
- Circuit-switching is more reliable than packet-switching, guaranteeing some QoS: bit delay, jitter, data-rate
- In Packet Switching, congestion in the network can degrade the performance
  - The biggest enemy of VoIp is the jitter delay

Frame Relay

- Viewed as an “encapsulation technique” employed to interconnect LANs composing a WAN
- Data to be transmitted is encapsulated in variable size packets
- Issued from the need for an error-free and effective transmission
- Important overhead required in Packet Switching to deal with the bit errors
- Unnecessary correcting information is suppressed
- Frame relay provides an efficient mechanism to “deliver” data, transparent to the end users
- Frame relay allows user data rates of 2Mbps

ATM

- ATM stands for Asynchronous Transfer Mode
- Sometimes referred to as Cell Relay, represents an evolution of Frame Relay
- The size of the packet is fixed and the packets are called “cells”
- Fixed packet size allows reducing the overhead
- Adapts circuits switching to packet based transmission: the term of “virtual circuit” is defined
- Multiple virtual channels can be created, with data rate on each channel set on demand

LAN

- Local Area Networks are dedicated to small geographic areas (buildings, clusters of buildings)
- Usually, one LAN is usually owned by a single organization
- The achievable data rates are higher than in the case of WANs
- Example of LAN: Ethernet (802.3), WiFi (802.11)

Data Communications Concepts

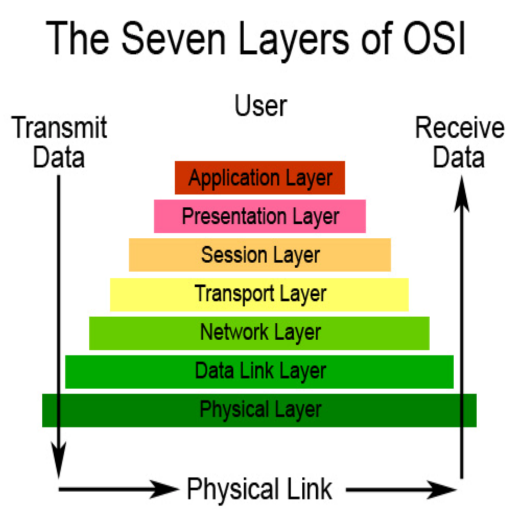
- Two concepts are crucial: protocols and protocol (layered) architecture
- Protocol: a set of rules which helps two devices to “talk” with each other
- The key elements of a protocol are:
  - Syntax: data formats, signal levels
  - Semantics: control information for coordination and error handling
  - Timing: includes spedd matching and sequenving

Layered architectures

- Two models are widely used: OSI and TCP/IP
- The term “layered” highlights the fact that each layer uses the services provided by the layers below it
- OSI is a generic frame for the architecture, but TCP/IP comes to dominate the practical implementations

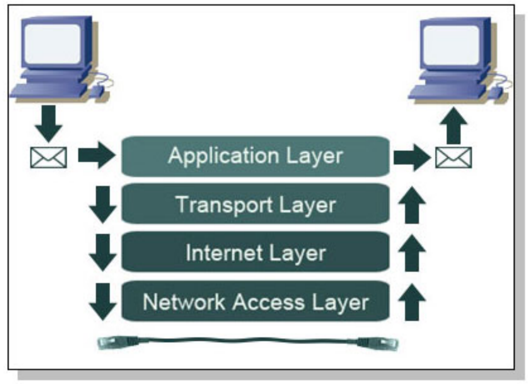
OSI model

- **Application:** the layer at which applications (file transfer, e-mails, database access) access network services.
- **Presentation:** translates data from the Application layer into a network format , performs data compression and encryption.
- **Session:** session setup, control and tear down
- **Transport:** reliable transfer data between the communicating end points. Error recovery and flow control.
- **Network:** addresses messages and translates logical addresses and names into physical addresses. It also determines the route from the source to the destination computer.
- **Data Link:** packages raw bits from the Physical layer into frames (logical, structured packets). It also implements acknowledgement mechanisms
- **Physical:** transmission over the physical medium. It addresses mechanical, electrical, physical connection issues (pin configurations, voltage levels, and cable requirements).

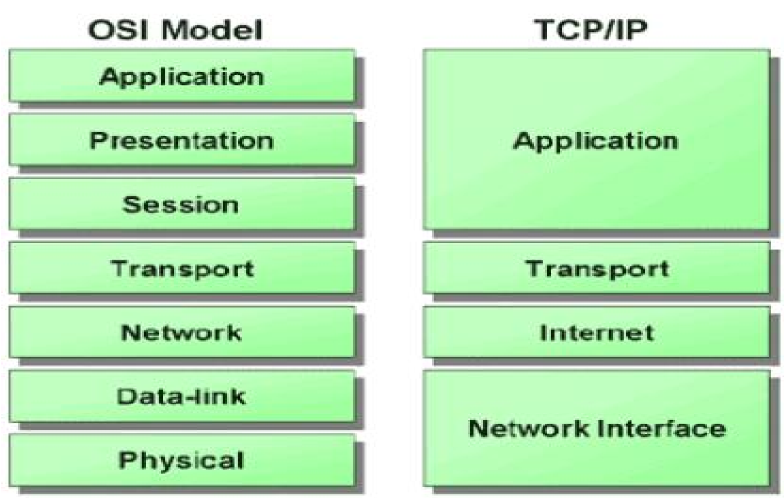


TCP/IP model

- **Application Layer** :all of the processes that involve user interaction. Examples:Simple Mail Transfer Protocol (SMTP) and Post Office Protocol (POP) for e-mail, Hyper Text Transfer Protocol (HTTP) for the World-Wide-Web, and File Transfer Protocol (FTP).
- **Transport Layer**: two Transport Layer protocols. The Transmission Control Protocol (TCP) is safer but slower . The User Datagram Protocol (UDP) performs no end-to-end reliability checks, but is more rapid.
- **Internet Layer:** the network layer of the TCP/IP model. Data is transmitted in variable size IP packets. Addresses the two ends of the communcation, routes the data between source and destination.
- **Network Access Layer:** TCP/IP makes use of the existing PHY and Data Link Layer standards.



OSI vs TCP/IP



TCP/IP and the OSI model