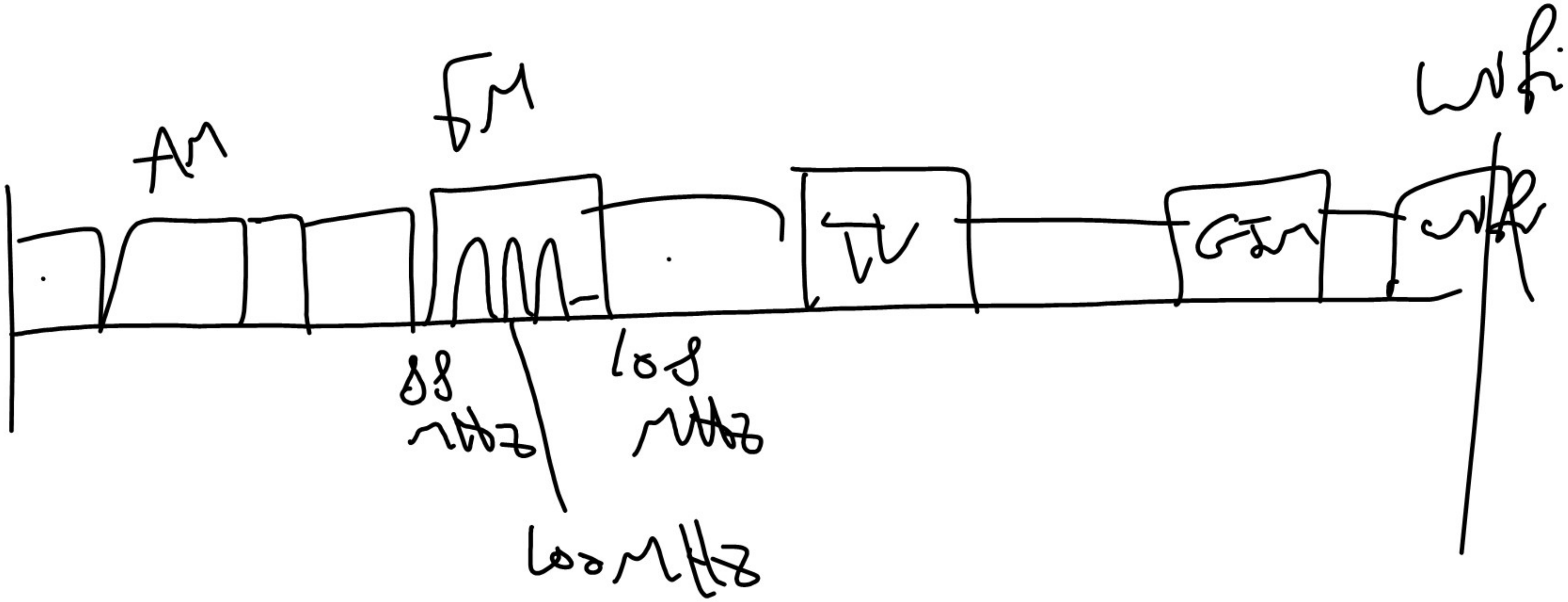
GSM
2G
- Voice
- 50kbps

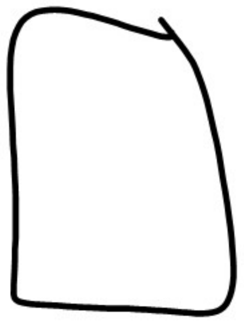
3G UMTS
- Voic
- 2Mbps

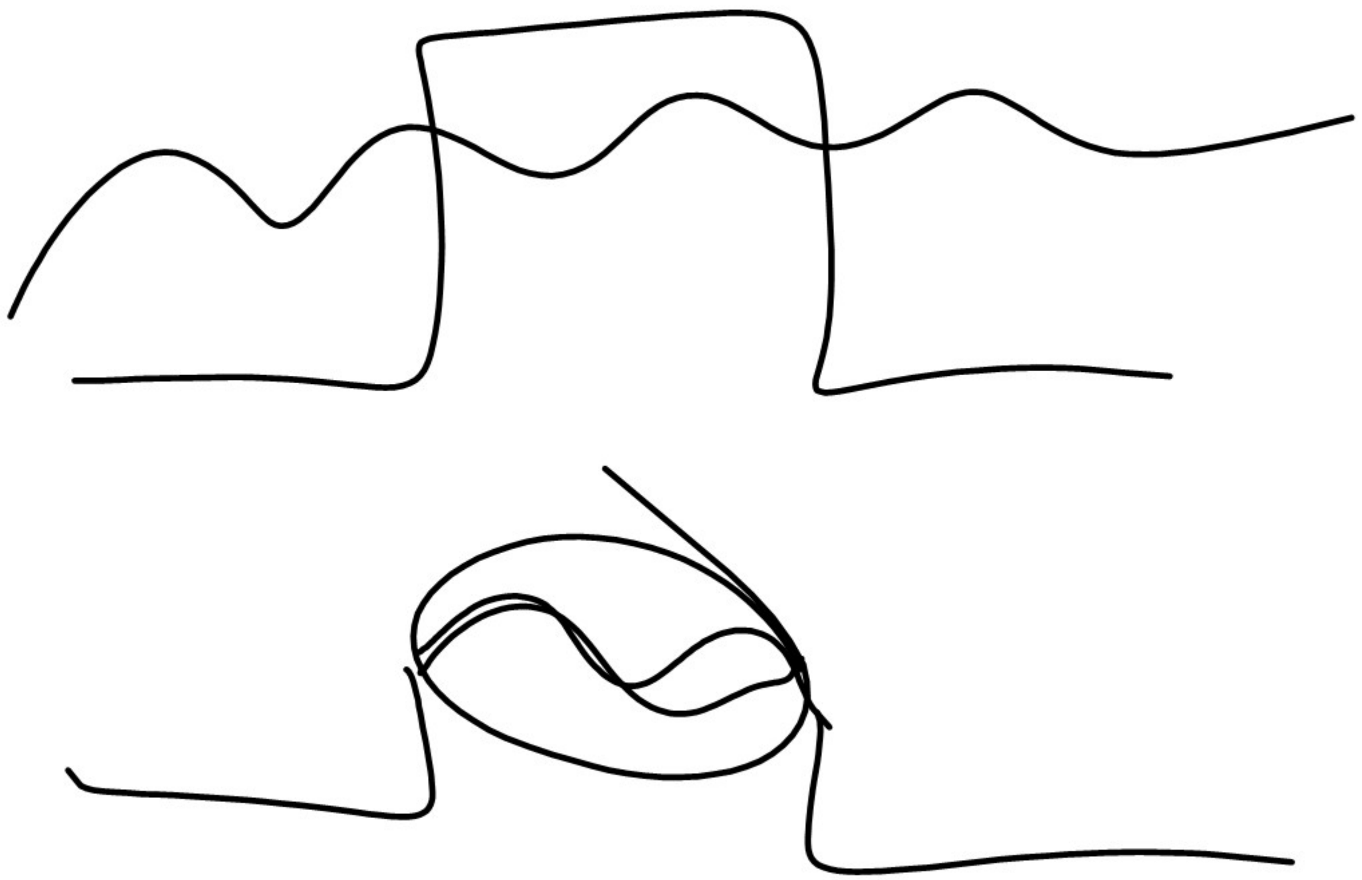
4G LTE
- ~~Voice~~
- 1Gbps DL 250Mbps UL

Voice over ip



Cognitive Radio.





Communications and Signals Processing

Dr. Ahmed Masri

Department of Communication
An Najah University

2014/2015

Introduction

- What this course is about
- Brief overview of the Course
- General Info
- Chapter 1：Introduction to communications

WHAT THIS COURSE IS ABOUT?

Textbook and/or References

- An Introduction to Analog and Digital Communications, Simon Haykin, 2nd Edition, 2007
- Communication System Engineering, J.G. Proakis and M. Salehi, 2nd Edition
- Modern Digital and Analog Communication Systems, B.P. Lathi, Oxford University Press,1998, Third Edition
- Digital and Analog Communication Systems, Leon coach, 2001 ,6th edition
- Communication system, S.Haykin,John Wily & Sons, 2001,Fourth edition
- Principles of Communications, Rodger Ziemer, William Tranter, 2008, 6th edition

What this course is about?

Prerequisites

- Maths
  - Engineering mathematics, such as:

    Trigonometry, series, integration/ differentiation, etc.
  - Probability, random variables and statistics , such as:

    Gaussian and uniform distributions, noise, autocorrelation, power spectrum, etc.

- Primary Prerequisites courses
  - Systems & signal analysis

    Fourier series/transform, transfer function, sampling, filtering, etc.

WHAT THIS COURSE IS ABOUT?

Course Contents

- Mathematical representation of message signals (Review)
- Amplitude and angle modulation techniques:
  - Amplitude modulation
  - Double sideband, single sideband modulation
  - Vestigial sideband modulation
  - Frequency modulation
- Super heterodyne receivers and Phase locked loops
- Noise in amplitude and frequency modulation system
- Introduction to digital communication techniques
- Frequency division multiplexing, sampling theorem

What this course is about?

Course Objectives

- Understanding the mathematical representation of massage signals
- To learn the analysis and synthesis of amplitude and angle modulation systems
- Learning the concepts of time and frequency division multiplexing
- Ability to implement some communication systems

WHAT THIS COURSE IS ABOUT?

Learning Outcomes and Competences

- Ability to use mathematics (Fourier transform, calculus, special mathematical functions) to analyze analog communication systems
- Ability to design simple analog AM, FM transmitters and receivers
- Study the performance of various AM and FM modulation schemes under noise
- Ability to use simulation tools such as MATLAB and workbench to simulate analog modulation techniques

General Info

Contact information and office hours

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Office hours: Check the table infront of my office

“To understand a science it is necessary to know its history” —Auguste Comte (1798–1857)

Historical review

- Early history of communication – 1
  - 1799 Alessandro Volta invented electric battery
  - 1837 Samuel Morse demonstrated telegraph and 1844 first telegraph line (Washington-Baltimore) became operational

INTRODUCTION TO COMMUNICATIONS

- Early history of wireless communication – 2
  - 1831 Faraday demonstrates electromagnetic induction
  - J. Maxwell (1831-79): theory of electromagnetic Fields, wave equations (1864)
  - H. Hertz (1857-94): demonstrates with an experiment the wave character of electrical transmission through space (1888, in Karlsruhe, Germany, at the location of today's University of Karlsruhe)

INTRODUCTION TO COMMUNICATIONS

- Early history of wireless communication – 3
  - 1895: Guglielmo Marconi
    - first demonstration of wireless telegraphy (digital!)
    - long wave transmission, high transmission power necessary (> 200kw)
  - 1907: Commercial transatlantic connections
    - huge base stations (30 100m high antennas)

Introduction to communications

- Early history of wireless communication – 4
  - 1915: Wireless voice transmission (New York - San Francisco)
  - 1920: Discovery of short waves by Marconi
    - reflection at the ionosphere
    - smaller sender and receiver, possible due to the invention of the vacuum tube (1906, Lee DeForest and Robert von Lieben)
  - 1926: Train-phone on the line Hamburg - Berlin
    - wires parallel to the train track

Early history of wireless communication – 5

- 1928 many TV broadcast trials (across Atlantic, color TV, TV news)
- 1933 Frequency modulation (E. H. Armstrong)
- 1958 A-Netz in Germany
  - analog, 160MHz, connection setup only from the mobile station, no handover, 80% coverage, 1971 11000 customers
- 1972 B-Netz in Germany
  - analog, 160MHz, connection setup from the fixed network too (but location of the mobile station has to be known)

Introduction to communications

- Early history of wireless communication – 6
  - 1979 NMT at 450MHz (Scandinavian countries)
  - 1982 Start of GSM-specification
    - goal: pan-European digital mobile phone system with roaming
  - 1983 Start of the American AMPS (Advanced Mobile Phone System, analog)
  - 1984 CT-1 standard (Europe) for cordless telephones

- Early history of wireless communication – 7
  - 1986 C-Netz in Germany
    - analog voice transmission, 450MHz, hand-over possible, digital signaling, automatic location of mobile device
    - Was in use until 2000, services: FAX, modem, X.25, e-mail, 98% coverage
  - 1991 Specification of DECT
    - Digital European Cordless Telephone (today: Digital Enhanced Cordless Telecommunications)
    - 1880-1900MHz, ~100-500m range, 120 duplex channels, 1.2Mbit/s data transmission, voice encryption, authentication, up to several 10000 user/km2, used in more than 50 countries

Introduction to communications

- Early history of wireless communication – 8
  - 1992 Start of GSM
    - in D as D1 and D2, fully digital, 900MHz, 124 channels
    - automatic location, hand-over, cellular
    - roaming in Europe - now worldwide in more than 170 countries
    - services: data with 9.6kbit/s, FAX, voice, ...

Introduction to communications

- Early history of wireless communication – 9
  - 1994 E-Netz in Germany
    - GSM with 1800MHz, smaller cells
    - As Eplus in D (1997 98% coverage of the *population*)
  - 1996 HiperLAN (High Performance Radio Local Area Network)
    - ETSI, standardization of type 1: 5.15 - 5.30GHz, 23.5Mbit/s
    - recommendations for type 2 and 3 (both 5GHz) and 4 (17GHz) as wireless ATM-networks (up to 155Mbit/s)

INTRODUCTION TO COMMUNICATIONS

- Early history of wireless communication – 10
  - 1997 Wireless LAN - IEEE802.11
    - IEEE standard, 2.4 - 2.5GHz and infrared, 2Mbit/s
    - already many (proprietary) products available in the beginning
  - 1998 Specification of GSM successors
    - for UMTS (Universal Mobile Telecommunication System) as European proposals for IMT-2000
    - 66 satellites (+6 spare), 1.6GHz to the mobile phone

INTRODUCTION TO COMMUNICATIONS

- Early history of wireless communication – 11
  - 1999 Standardization of additional wireless LANs
    - IEEE standard 802.11b, 2.4-2.5GHz, 11Mbit/s
    - Bluetooth for piconets, 2.4Ghz, <1Mbit/s
  - Decision about IMT-2000
    - Several "members" of a "family": UMTS, cdma2000, DECT, …
  - Start of WAP (Wireless Application Protocol) and i-mode
    - First step towards a unified Internet/mobile communication system
    - Access to many services via the mobile phone

Introduction to communications

- Early history of wireless communication – 12
  - 2000 GSM with higher data rates
    - HSCSD offers up to 57,6kbit/s
    - First GPRS trials with up to 50 kbit/s (packet oriented!)
  - UMTS auctions/beauty contests
  - 2001 Start of 3G systems
    - Cdma2000 in Korea, UMTS in Europe, Foma (almost UMTS) in Japan

Introduction to communications

- Early history of wireless communication – 13
  - 2007
    - Commercial deployment of 3G becomes widespread
  - 2008
    - 4G/LTE widely talked
  - 2009
    - Cognitive Radio Network (CRN) widely talked
    - Advanced LTE
  - 2013+ ???

ELEMENTS OF A COMMUNICATION SYSTEM

Introduction to communications

- Elements of a communication system
  - Basic concepts
    - Sources (information inputs)

      voice (audio), text, image/video and data
    - Signals

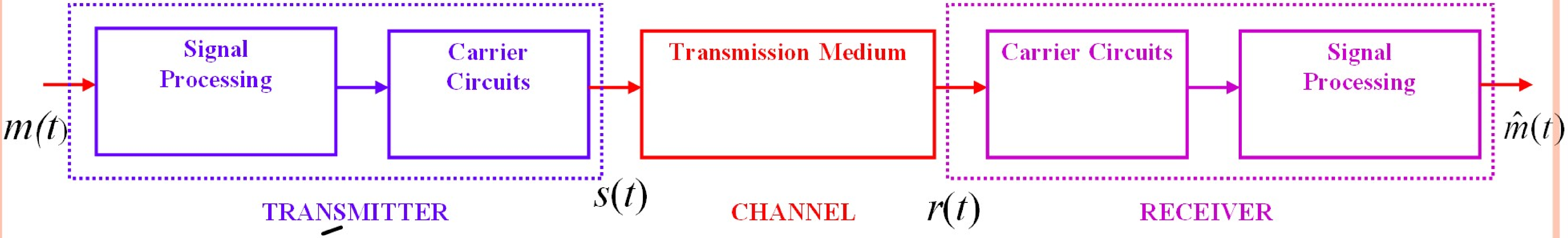
      Analogue signals, Digital signals
    - Noises

      Thermal noise, man-made noise, atmospheric noise, etc
    - Sinks (information output devices)

      Computer screens, speakers, TV screens, etc

INTRODUCTION TO COMMUNICATIONS

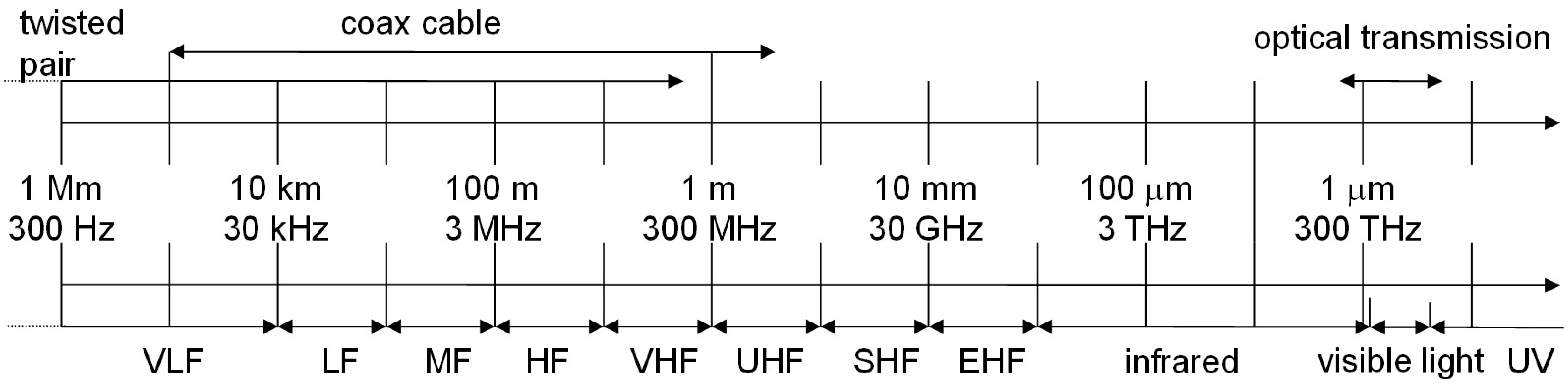
Elements of a communication system (cont)



- Basic components
  - **Transmitter**
    - Convert Source (information) to signals
    - Send converted signals to the channel (by antenna if applicable)
  - **Channel**
    - Wireless: atmosphere (free space)
    - Wired: coaxial cables, twisted wires, optical fibre
  - **Receiver**
    - Reconvert received signals to original information
    - Output the original information

INTRODUCTION TO COMMUNICATIONS

- Elements of a communication system (cont)
  - Frequencies for communication



- VLF = Very Low Frequency
- LF = Low Frequency
- MF = Medium Frequency
- HF = High Frequency
- VHF = Very High Frequency
- Frequency and wave length:

UHF = Ultra High Frequency
SHF = Super High Frequency
EHF = Extra High Frequency
UV = Ultraviolet Light

$\lambda = c/f$

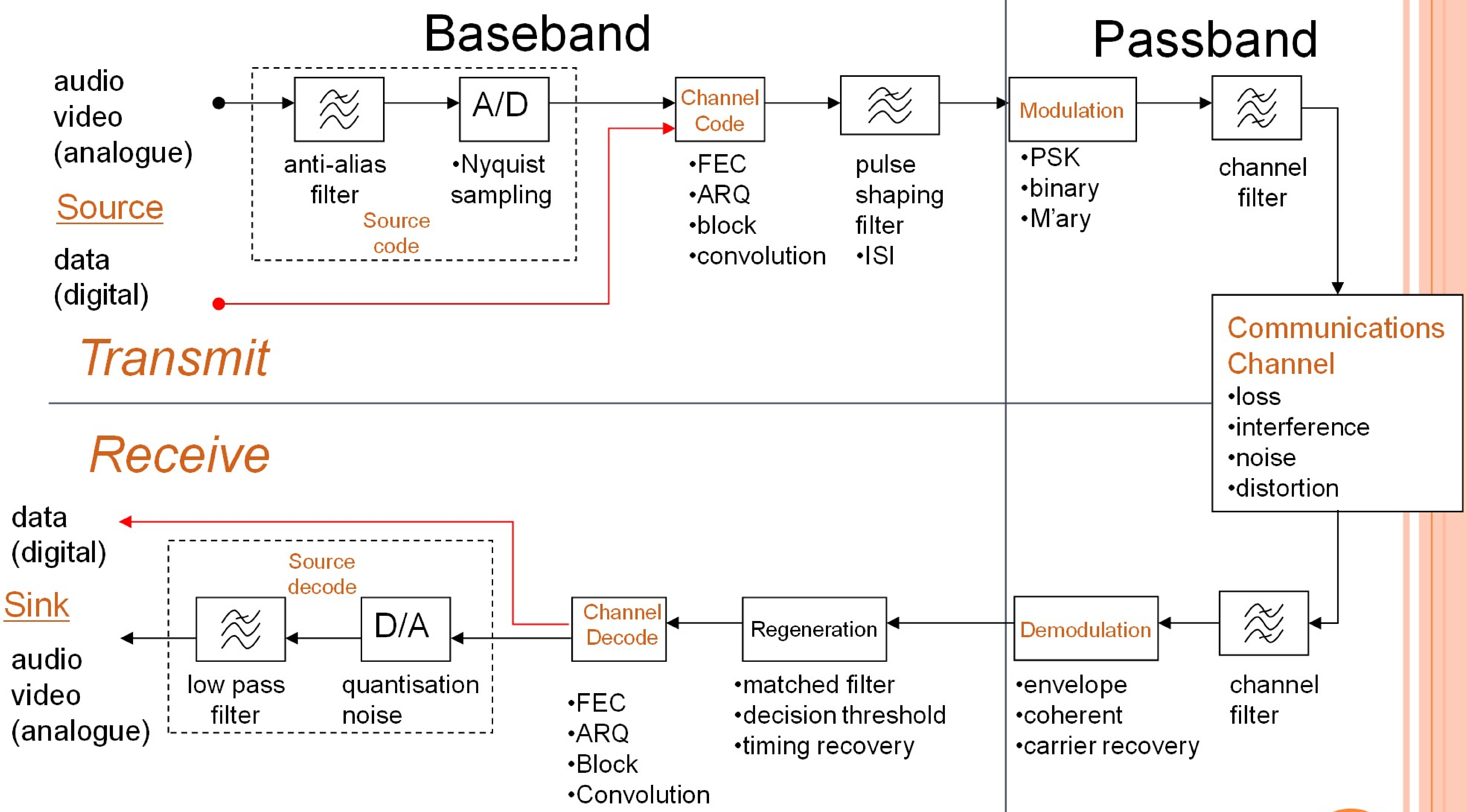
wave length λ, speed of light $c \cong 3 \times 10^8$ m/s, frequency f

Introduction to communications

- Basic digital communications system

  Signals processing:
  - Source encoding/decoding
    - Reduction of redundancy
  - Encryption /decryption
    - Security and privacy
  - Channel encoding/decoding
    - Anti-interferences
  - Modulation/demodulations
    - Channel adaptation and sharing

Introduction to communications

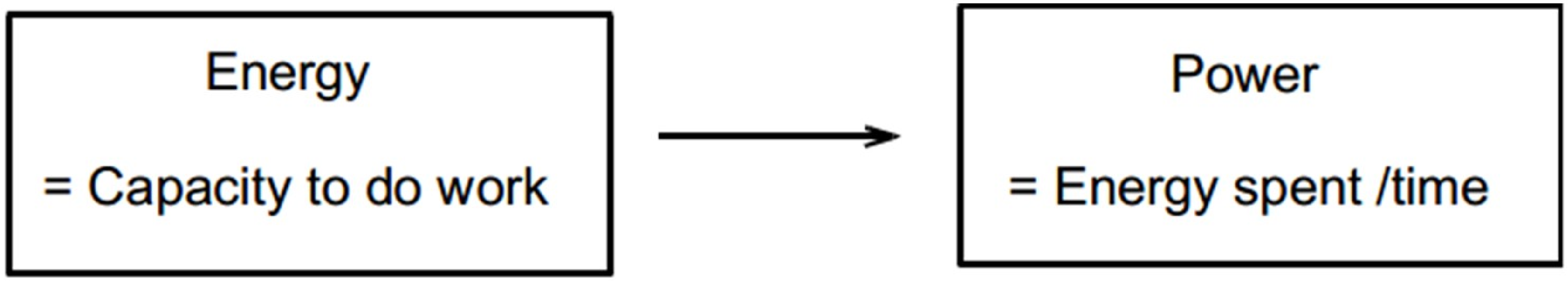


Basic Digital Communications System

Introduction to communications

- Energy vs Power:

  The energy is the capacity to do work and the energy expended per time is called power



- Energy vs Power:
  - The average power is the energy per unit time and
  - The bit rate is the number of bits per unit time.
  - The division removes the units of time leaving Energy per bit (E_b)

Pavg = Energy per unit time = E/T_b

Where T_b is the unit time (Bit time)

$P_{avg} / R_b = (E/T_b)/(1/T_b) = E_b$

To compute E_b, we divide the average signal power by its bit rate

$$E_b = \frac{P_{avg.}}{R_b}$$

Applications

Applications

- Broadcasting
  - Which involves the use of a single powerful transmitter and numerous receivers that are relatively inexpensive to build
- point-to-point communications
  - In which the communication process takes place over a link between a single transmitter and a single receiver

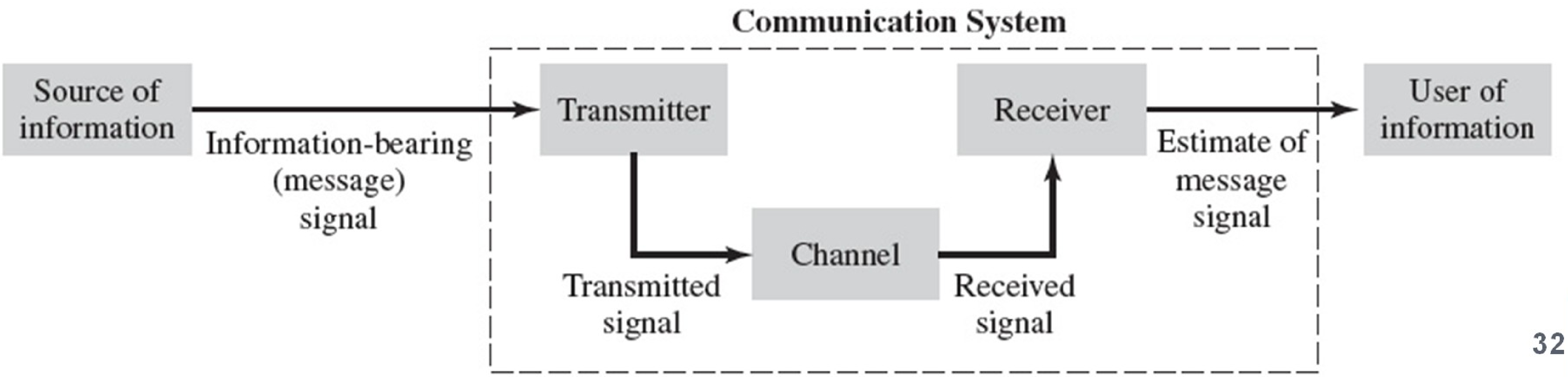


Figure 1.1 Elements of a communication system.

Applications

- Radio
  1. Broadcasting
     - AM and FM radio
       - The voices are transmitted from broadcasting stations that operate in our neighborhood
     - Television
       - Transmits visual images and voice
  2. Point-to-point communication
     - Satellite communication
       - Built around a satellite in geostationary orbit, relies on line-of-sight radio propagation for the operation of an uplink and a downlink

APPLICATIONS

- Satellite Communication System

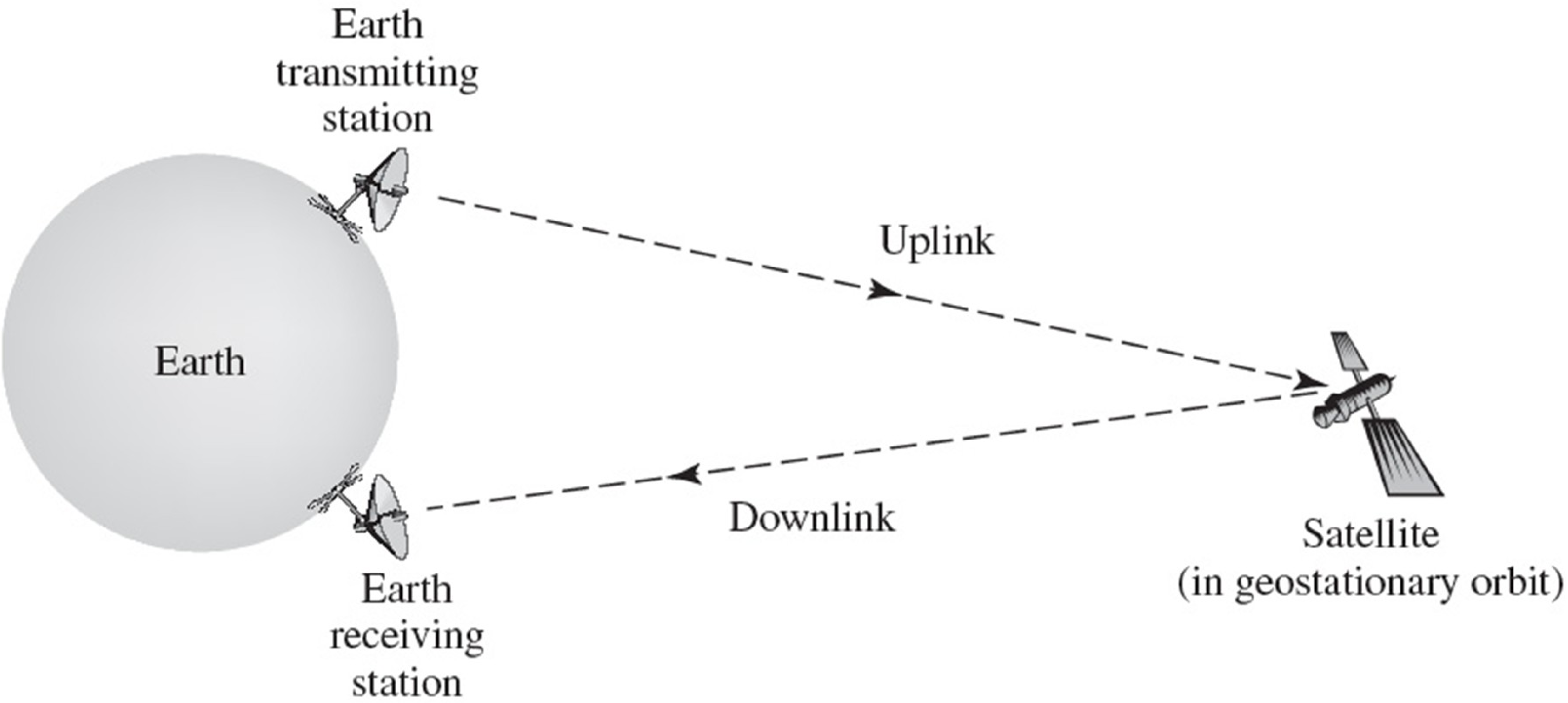


FIGURE 1.2 Satellite communication system.

APPLICATIONS

- Communication Networks
  - Consists of the interconnection of a number of ***routers*** that are made up of intelligent processors
  - **Circuit switching**
    - Is usually controlled by a centralized hierarchical control mechanism ***with knowledge of the network's entire organization***

Applications

- Communication Networks
  - **Packet switching**
    - Store and forward
    - Any message longer than a specified size is subdivided prior to transmission into segments
    - The original message is reassembled at the destination on a packet-by-packet basis
      - Advantage: when a link has traffic to sent, the link tends to be more fully utilized

Applications

- Communication Networks

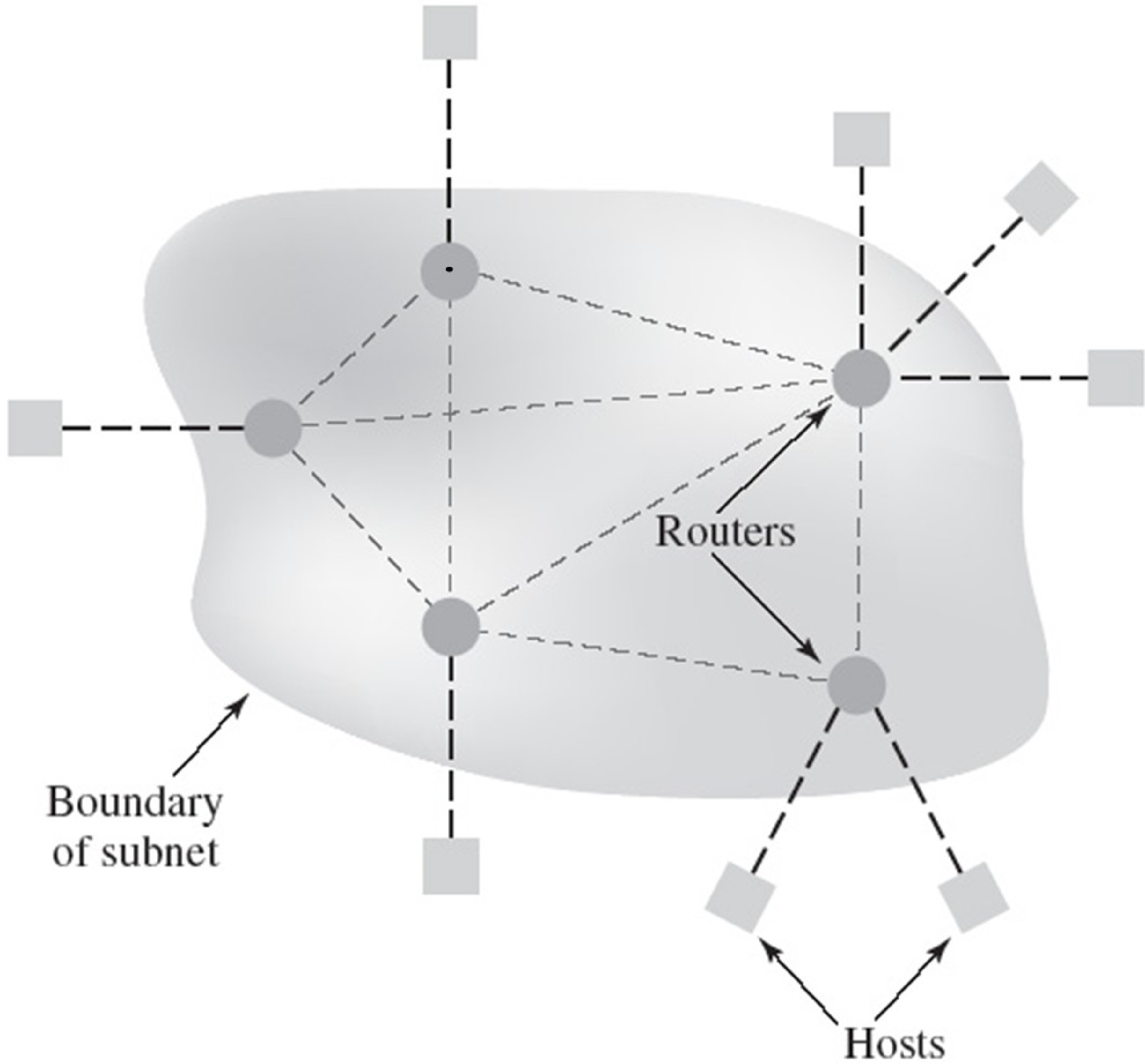


Figure 1.3 Communication network.

APPLICATIONS

- Data Networks
  - ***Layer***
    - A process or device inside a computer system that is designed to perform a specific function
  - ***Open systems interconnection (OSI)*** reference model
    - The communications and related-connection functions are organized as a series of layers with well-defined interfaces
    - Composed of seven layers

Applications

- Data Networks

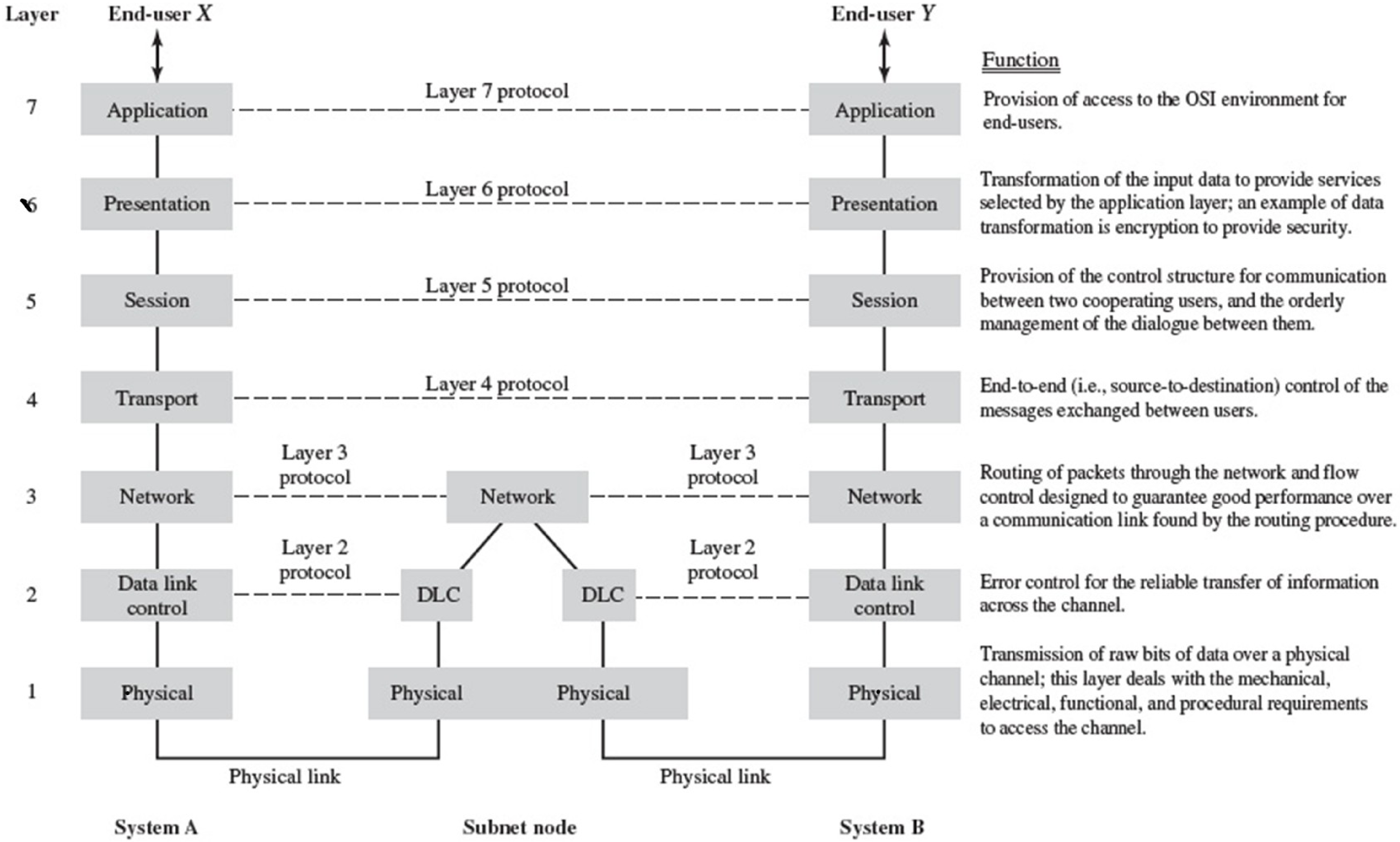


Figure 1.4 OSI model; the acronym DLC in the middle of the figure stands for *data link control*.

Applications

- Internet
  - The applications are carried out independently of the technology employed to construct the network
  - By the same token, the network technology is capable of evolving without affecting the applications.
  - Internal operation of a subnet is organized in two different ways:
    1. **Connected manner** : where the connections are called virtual circuits, in analogy with physical circuits set up in a telephone system.
    2. **Connectionless manner** : where the independent packets are called datagrams, in analogy with telegrams

Applications

- Internet

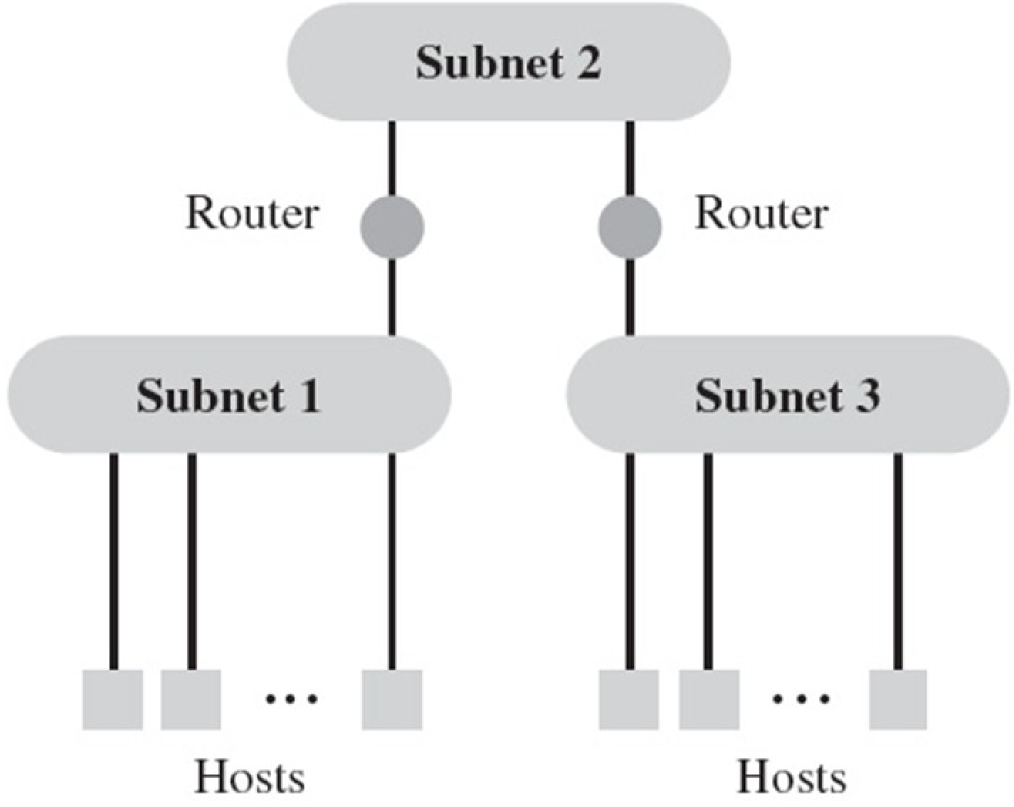


Figure 1.5 An interconnected network of subnets.

APPLICATIONS

❖ Internet

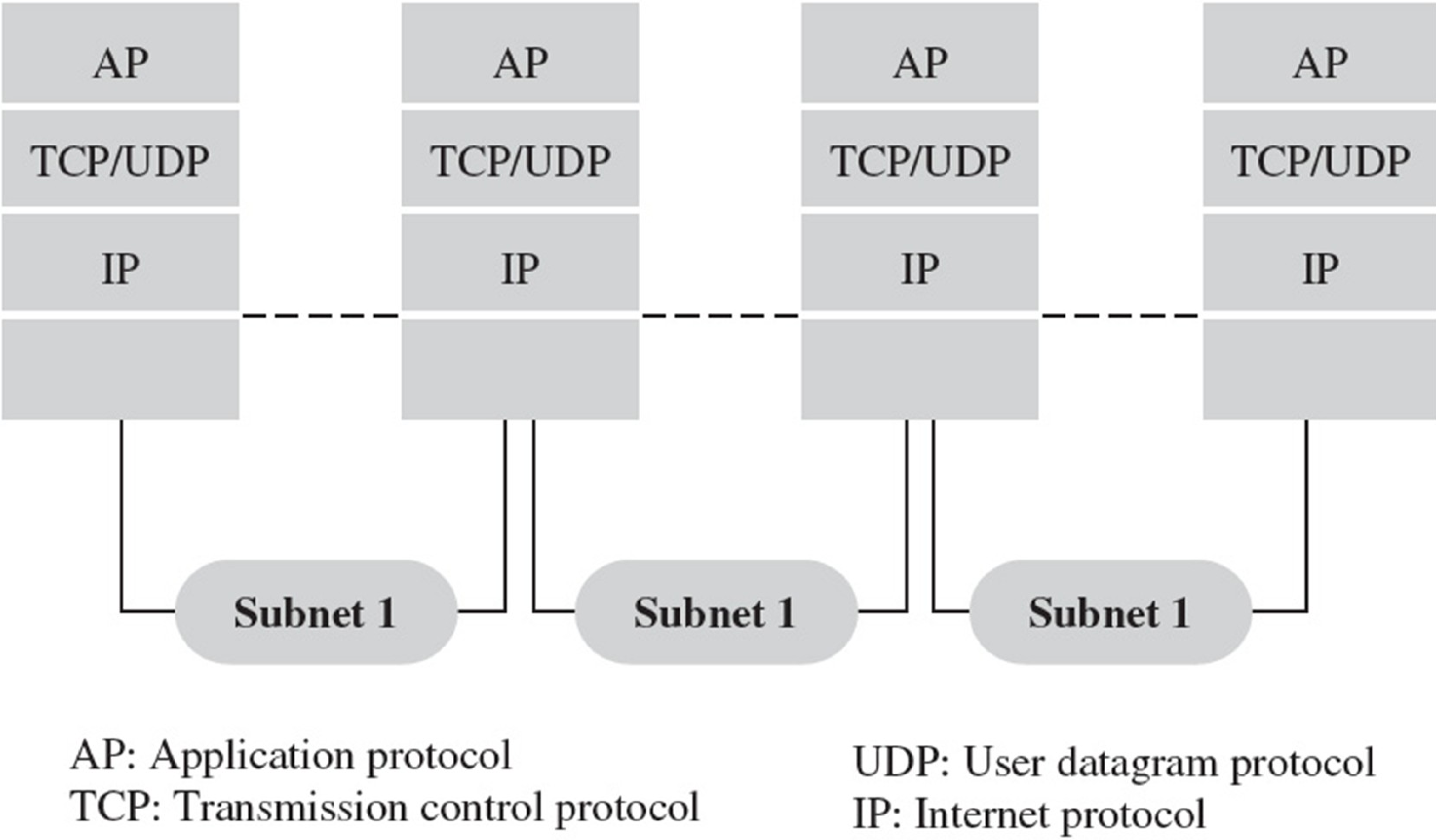


FIGURE 1.6 Illustrating the network architecture of the Internet.

Applications

- Integration of Telephone and Internet
  - VOIP's Quality of service
    - Packet loss ratio:
      - the number of packets lost in transport across the network to the total number of packets pumped into the network
    - Connection delay:
      - The time taken for a packet of a particular host-to-host connection to transmit across the network
  - In future
    - VOIP will replace private branch exchanges (PBXs)
    - If the loading is always low and response time is fast, VOIP telephony may become mainstream and widespread

Applications

- Data Storage
  - The digital domain is preferred over the analog domain for the storage of audio and video signals for the following compelling reasons
    1) The quality of a digitized audio/video signal, measured in terms of frequency response, linearity, and noise, is determined by the digital-to-analog conversion (DAC) process, the parameterization of which is under the designer's control.
    2) Once the audio/video signal is digitized, we can make use of well-developed and powerful encoding techniques for data compression to reduce bandwidth, and error-control coding to provide protection against the possibility of making errors in the course of storage.

APPLICATIONS

- Data Storage
  3) For most practical applications, the digital storage of audio and video signals does not degrade with time.
  4) Continued improvements in the fabrication of integrated circuits used to build CDs and DVDs ensure the ever-increasing cost-effectiveness of these digital storage devices.

PRIMARY RESOURCES AND OPERATIONAL REQUIREMENTS

Primary Resources and Operational Requirements

- The systems are designed to provide for the efficient utilization of the two primary communication resources
  - Transmitted power
    - The average power of the transmitted signal
  - Channel bandwidth
    - The width of the passband of the channel

Primary Resources and Operational Requirements

- Classify communication channel
  - Power-limited channel
    - Wireless channels
    - Satellite channels
    - Deep-space links
  - Band-limited channel
    - Telephone channels
    - Television channels

PRIMARY RESOURCES AND OPERATIONAL REQUIREMENTS

- The design of a communication system boils down to a tradeoff between signal-to-noise ratio and channel bandwidth
- Improve system performance method
  1. Signal-to-noise ratio is increased to accommodate a limitation imposed on channel bandwidth
  2. Channel bandwidth is increased to accommodate a limitation imposed on signal-to-noise ratio

Understanding Theories of Communication Systems

Modulation Theory

- Sinusoidal carrier wave
  - Whose amplitude, phase, or frequency is the parameter chosen for modification by the information-bearing signal
- Periodic sequence of pulses
  - Whose amplitude, width, or position is the parameter chosen for modification by the information-bearing signal
- The issues in modulation theory
  - Time-domain description of the modulation signal.
  - Frequency-domain description of the modulated signal
  - Detection of the original information-bearing signal and evaluation of the effect of noise on the receiver

Understanding Theories of Communication Systems

- Fourier Analysis
  - Fourier analysis provides the mathematical basis for evaluating the following issues
    - Frequency-domain description of a modulated signal, including its transmission bandwidth
    - Transmission of a signal through a linear system exemplified by a communication channel or filter
    - Correlation between a pair of signals
- Detection Theory
  - Signal-detection problem
    - The presence of noise
    - Factors such as the unknown phase-shift introduced into the carrier wave due to transmission of the sinusoidally modulated signal over the channel

UNDERSTANDING THEORIES OF COMMUNICATION SYSTEMS

- In digital communications, we look at
  - The average probability of symbol error at the receiver output
  - The issue of dealing with uncontrollable factors
  - Comparison of one digital modulation scheme against another

- Probability Theory and Random Processes
  - Probability theory for describing the behavior of randomly occurring events in mathematical terms
  - Statistical characterization of random signals and noise

Mathematical Models for Communication Channels

Mathematical Models for Communication Channels

- Physical channels
  - Wireless electromagnetic channel:
    - Atmosphere (free space)
    - ionospheric channel
  - Wireline channels
    - twisted-pair wirelines
    - coaxial cables
    - optical fiber cables
  - Underwater acoustic channels

Mathematical Models for Communication Channels

- Common feature for distinct physical channels
  - Noises, existing always and anywhere
  - Interferences ,from adjacent channels
  - Distortion of channel

- Model for communication channels
  - Reflect the most important characteristics of transmission medium, i.e., physical channels
  - Be able to conveniently use in design and analysis of communication system

Frequently used channel models

– Additive noise channel

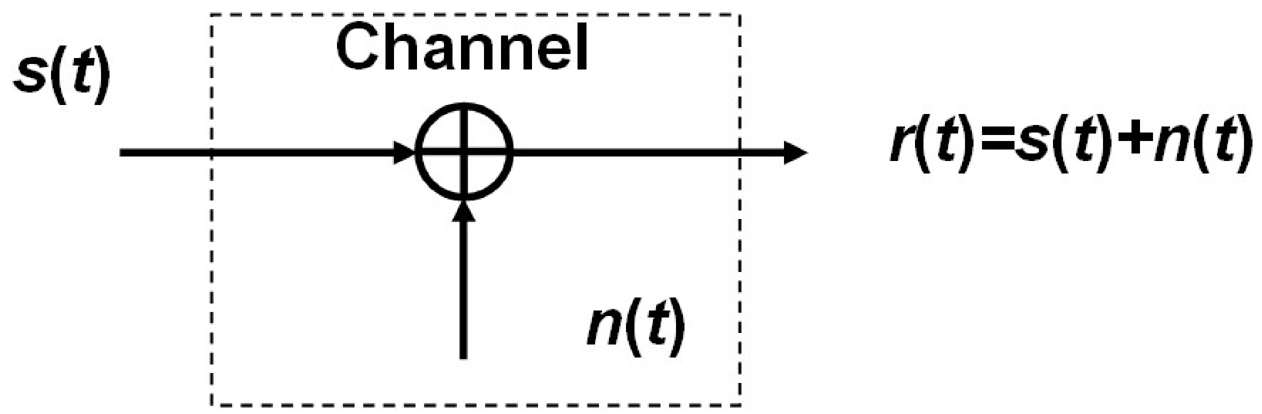


Fig.1. The additive noise channel

- *Physically*, $n(t)$ arising from electronic components and amplifiers, both at transmitter and receiver.
- *Statistically*, $n(t)$ is a random process.
- Gaussian noise: $n(t)$ follows Gaussian distribution.
- When propagation happened, signal attenuation occurred

$r(t)=as(t)+n(t)$, *Where a represents the attenuation factor*

✓ It is a predominant model due to its mathematical tractability

Mathematical Models for Communication Channels

– Linear filter channel

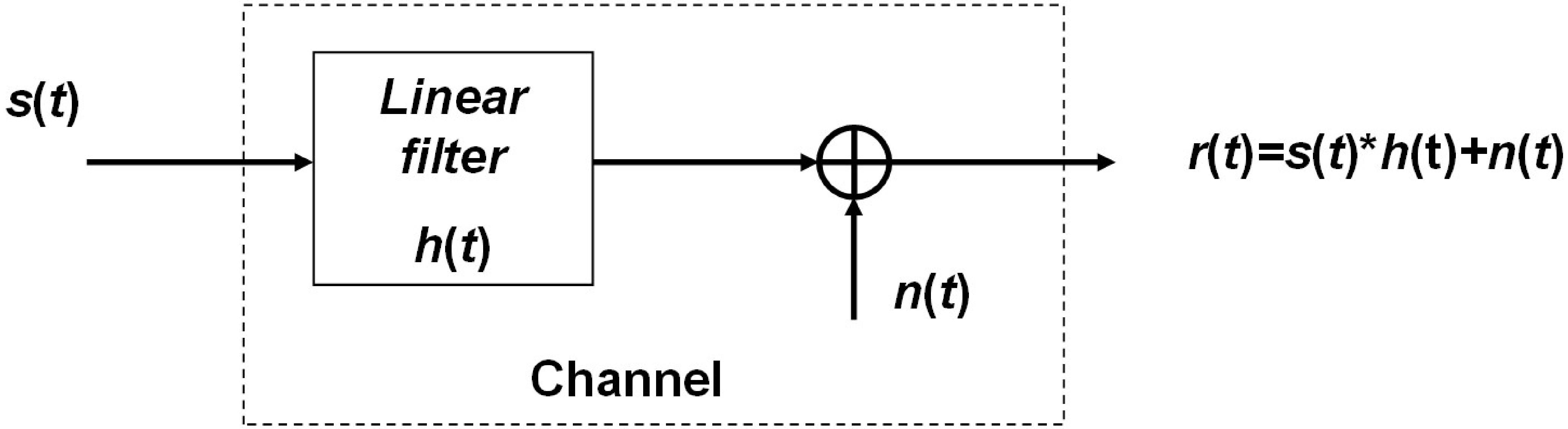


Fig.2. The linear time-invariant (LTI) filter channel with additive noise channel

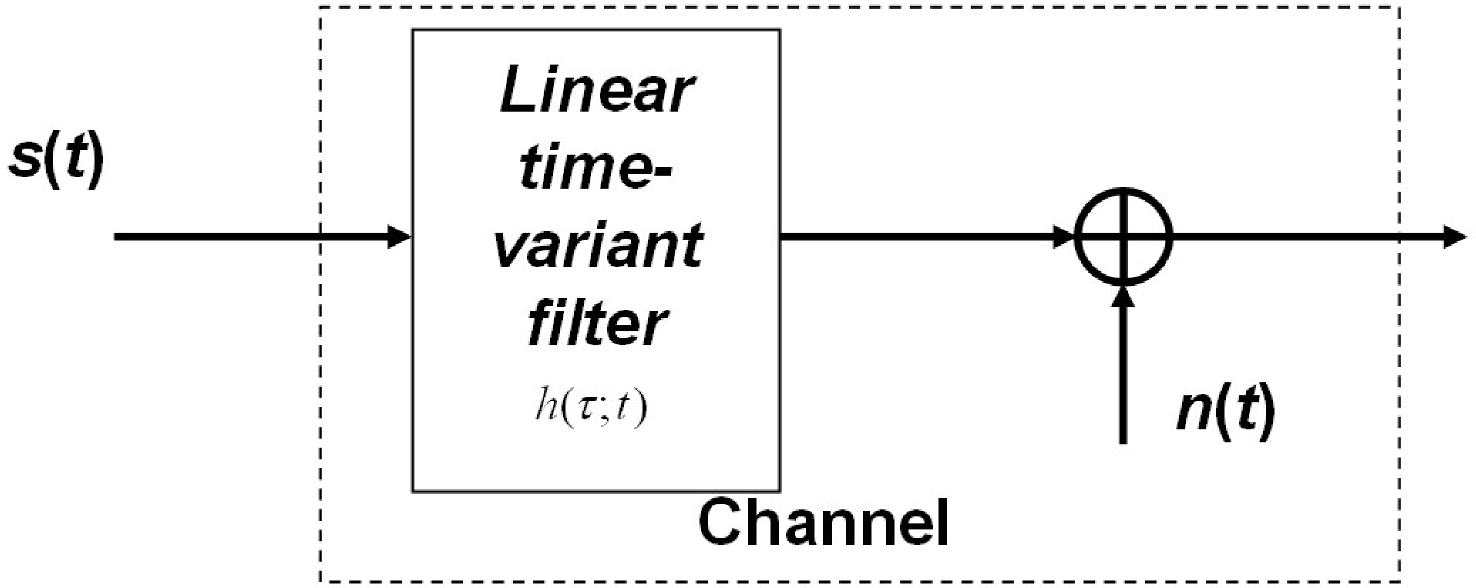
- *Filter, ensuring that transmitted signal do not exceed specified bandwidth limitation*
- *h(t) is the impulse response of the linear filter*

$$r(t) = s(t) * h(t) + n(t) = \int_{-\infty}^{\infty} h(\tau) s(t-\tau) d\tau + n(t)$$

✓ It is the most common used model in theory or practical applications

Mathematical Models for Communication Channels

– Linear time-variant filter channel



$$r(t) = s(t) * h(\tau;t) + n(t)$$
$$= \int_{-\infty}^{\infty} h(\tau;t)s(t-\tau)d\tau + n(t)$$

Fig.2. The linear time-variant (LTV) filter channel with additive noise channel

- *Suitable for the case of physical channels such as under water acoustic channel and ionospheric radio channels.*
- $h(\tau;t)$ *is the response of the channel at time t, due to an impulse applied at time* $t-\tau$
- τ *represents the "age" (elapsed time) variable*

✓ It is the most common used model in theory or practical applications

Mathematical Models for Communication Channels

– Multipath channel
  - It's a special case of LTV
  - Widely used in wireless communications

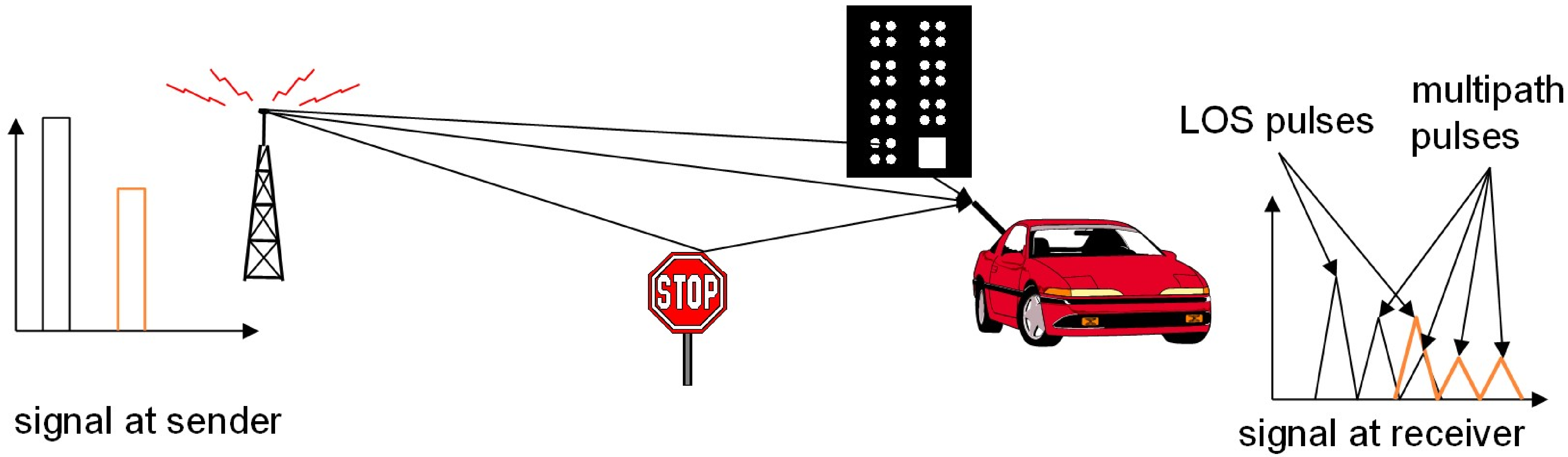


Fig.3. Multipath channel model

$$r(t) = \sum_{k=1}^{L} a_k(t) s(\tau - \tau_k) + n(t)$$

$$h(\tau;t) = \sum_{k=1}^{L} a_k(t) \delta(\tau - \tau_k)$$

L is the number of multipath propagation paths

$\{a_k(t)\}$ is the possibly time-variant attenuation factors

$\{\tau_k\}$ is the possibly delay attenuation factors

Let's summarize today's lecture !!!

WHAT WE HAVE LEARNT TODAY !!!

- An brief introduction to the course
- What we will learn in this course, *i.e.*, the roadmap of the course
- General pre-requirements for learning this course
- Block diagram of communication systems and its basic components, esp. for digital communication systems
- Brief history of communications
- Applications of communication
- Primary resources and operational requirements
- Understanding theories of communication systems
- Channel models for communication systems

WHAT IS THE NEXT ?

- Frequency domain analysis of signals and systems---Chapter 2 (totally, 2-3 lectures)

  We will learn and review:

  - Fourier series (Section 2.1)
  - Fourier transforms (Section 2.2)

WHAT YOU NEED TO DO AFTER LECTURE?

- Review and self-study

  Go through the Chapter 1 (at least 1 times)
- Homework
- Preparation

  pp.24-40, of textbook

Thank you for attention!!!