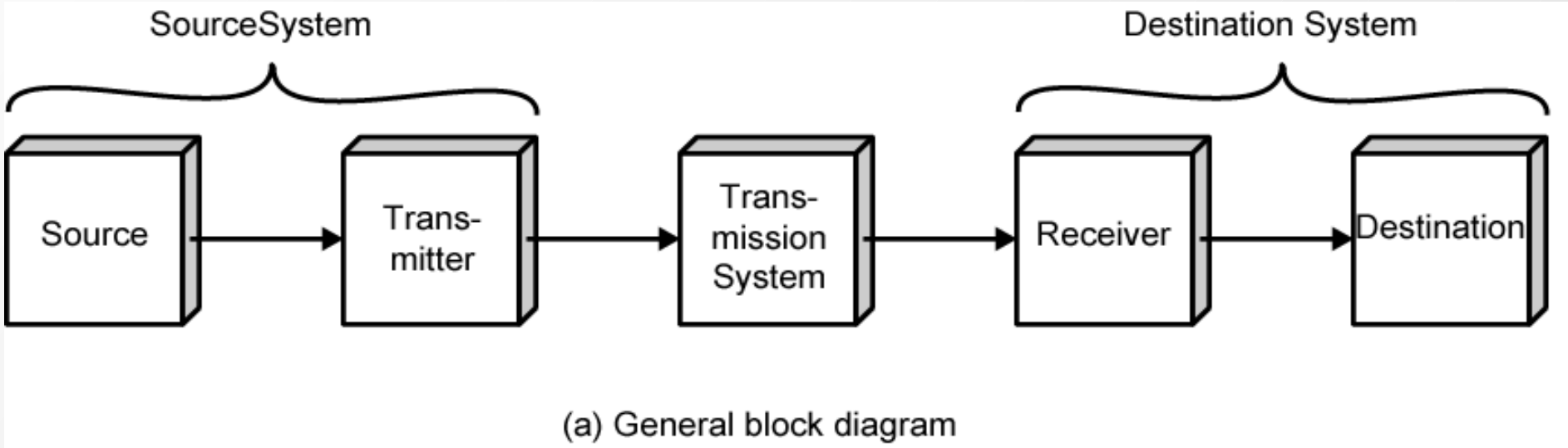
ET4254 – Communications and Networking 1

Topic 2

Aims:-

- Communications System Model and Concepts
- Protocols and Architecture
- Analog and Digital Signal Concepts
- Frequency Spectrum and Bandwidth

A Communications Model



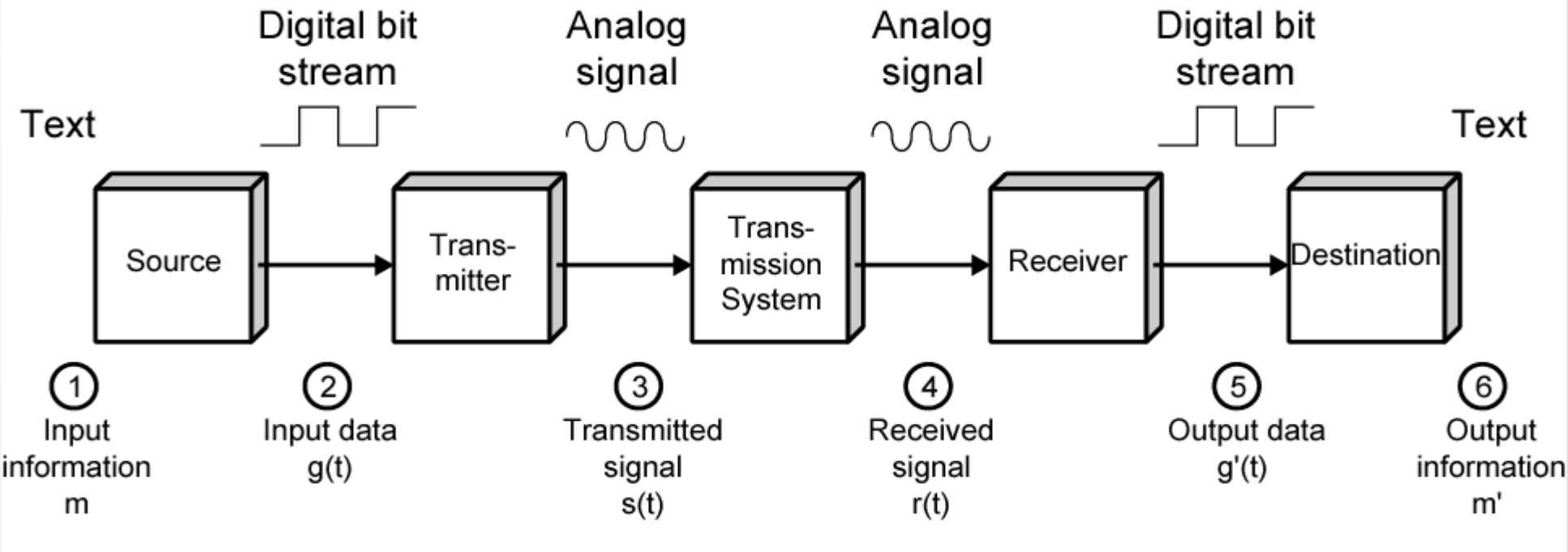
(a) General block diagram

(b) Example

Communications Tasks

Transmission System Utilization	Addressing
Interfacing	Routing
Signal Generation	Recovery
Synchronization	Message Formatting
Exchange Management	Security
Error detection and correction	Network Management
Flow Control	

Data Communications Model



Protocol Architecture, TCP/IP, and Internet-Based Applications

To destroy communication completely, there must be no rules in

common between transmitter and receiver

- neither of alphabet nor of syntax -

On Human Communication, Colin Cherry

Need For Protocol Architecture

- data exchange can involve complex procedures, cf. file transfer example
- better if task broken into subtasks
- implemented separately in layers in stack
  - each layer provides functions needed to perform comms for layers above
  - using functions provided by layers below
- peer layers communicate with a protocol

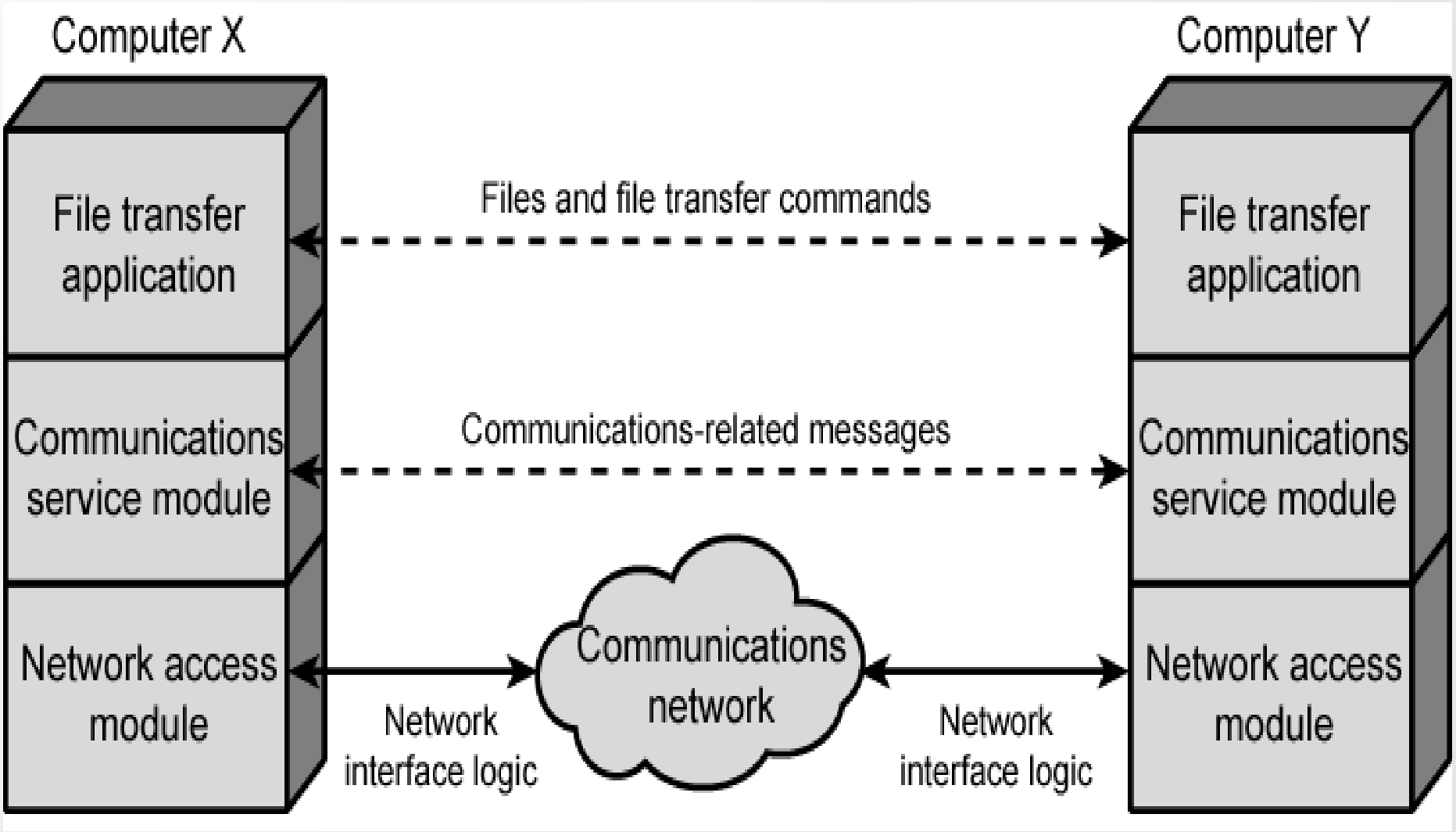
Key Elements of a Protocol

- syntax - data format
- semantics - control info & error handling
- timing - speed matching & sequencing

TCP/IP Protocol Architecture

- developed by US Defense Advanced Research Project Agency (DARPA)
- for ARPANET packet switched network
- used by the global Internet
- protocol suite comprises a large collection of standardized protocols

Simplified Network Architecture



TCP/IP Layers

- no official model but a working one
  - Application layer
  - Host-to-host, or transport layer
  - Internet layer
  - Network access layer
  - Physical layer

Physical Layer

- concerned with physical interface between computer and network
- concerned with issues like:
  - characteristics of transmission medium
  - signal levels
  - data rates
  - other related matters

Network Access Layer

- exchange of data between an end system and attached network
- concerned with issues like :
  - destination address provision
  - invoking specific services like priority
  - access to & routing data across a network link between two attached systems
- allows layers above to ignore link specifics

Internet Layer (IP)

- routing functions across multiple networks
- for systems attached to different networks
- using IP protocol
- implemented in end systems and routers
- routers connect two networks and relays data between them

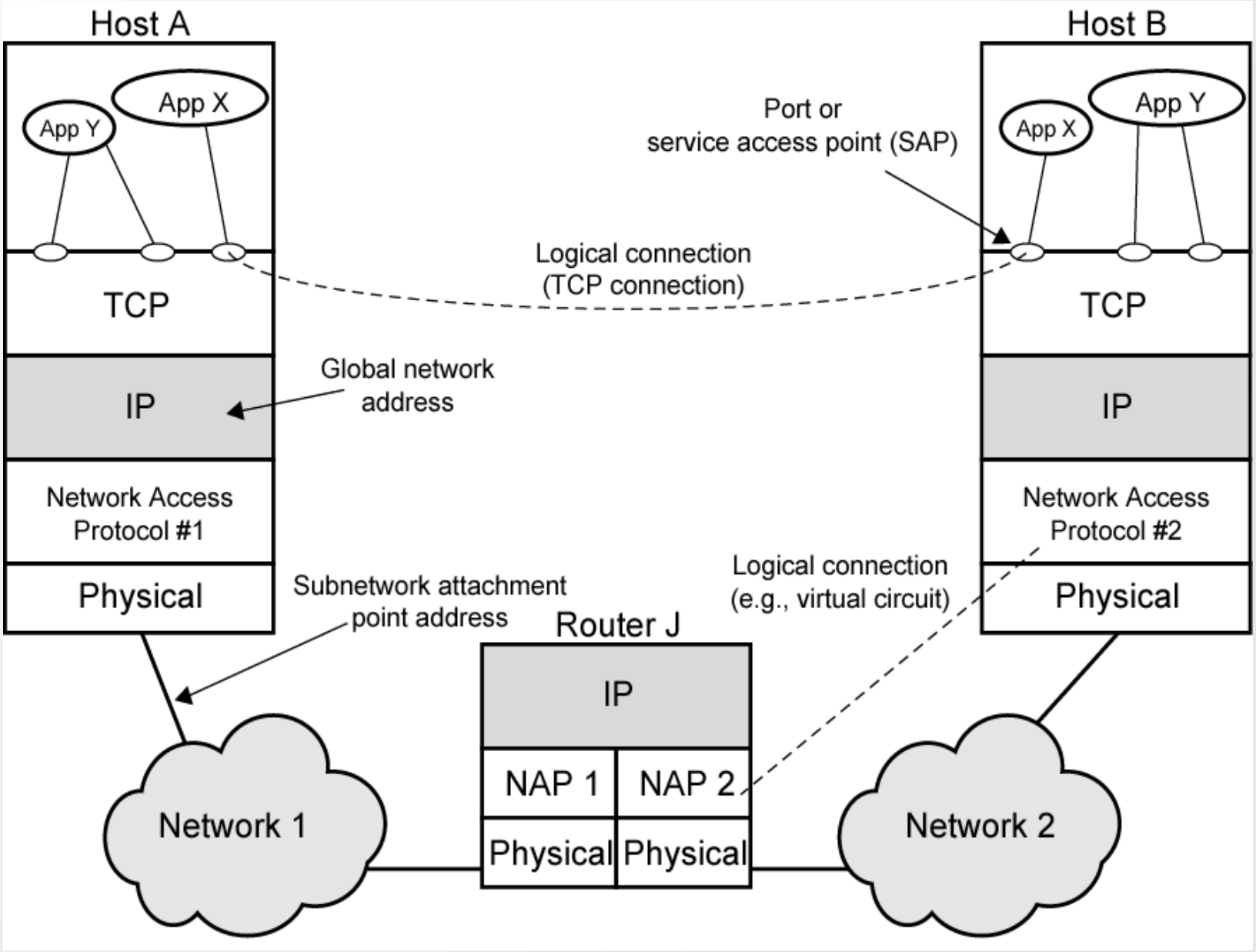
Transport Layer (TCP)

- common layer shared by all applications
- provides reliable delivery of data
- in same order as sent
- commonly uses TCP

Application Layer

- provide support for user applications
- need a separate module for each type of application

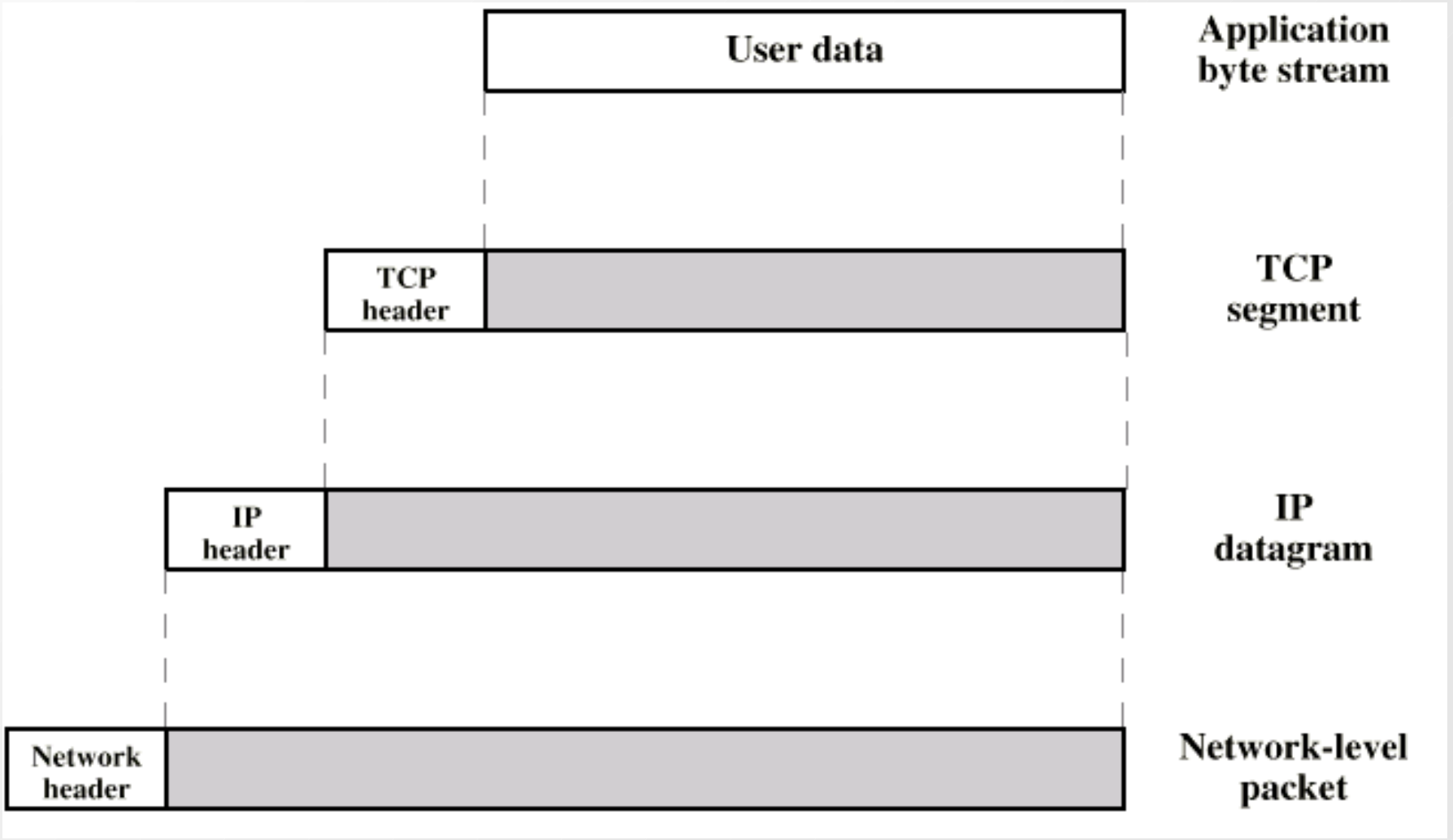
Operation of TCP and IP



Addressing Requirements

- two levels of addressing required
- each host on a subnet needs a unique global network address
  - its IP address
- each application on a (multi-tasking) host needs a unique address within the host
  - known as a port

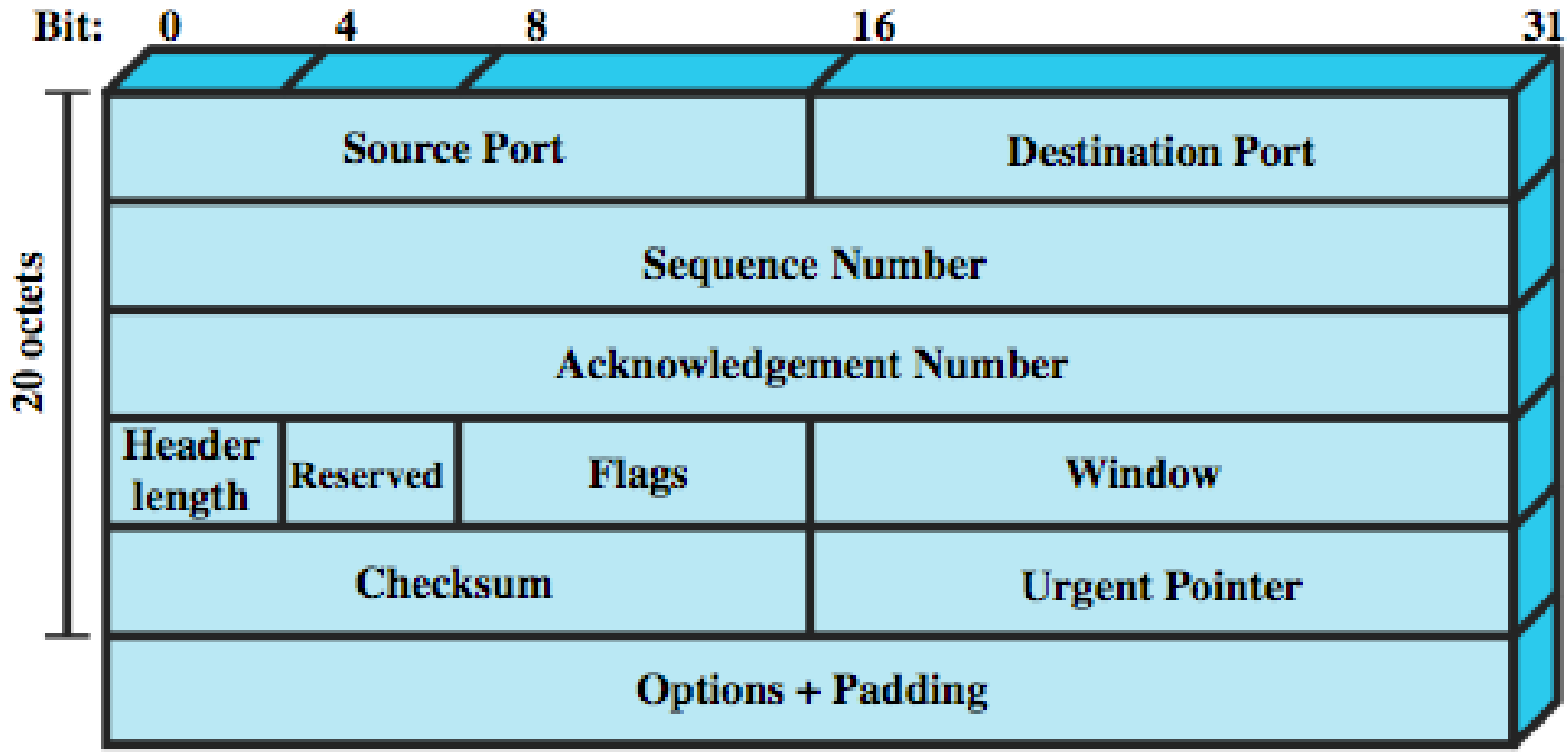
Operation of TCP/IP



Transmission Control Protocol (TCP)

- usual transport layer is (TCP)
- provides a reliable connection for transfer of data between applications
- a TCP segment is the basic protocol unit
- TCP tracks segments between entities for duration of each connection

TCP Header

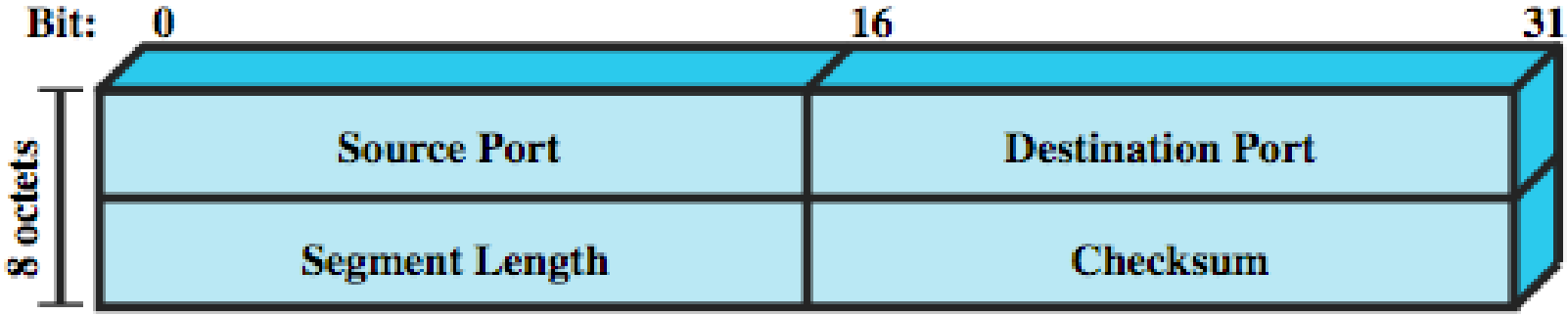


(a) TCP Header

User Datagram Protocol (UDP)

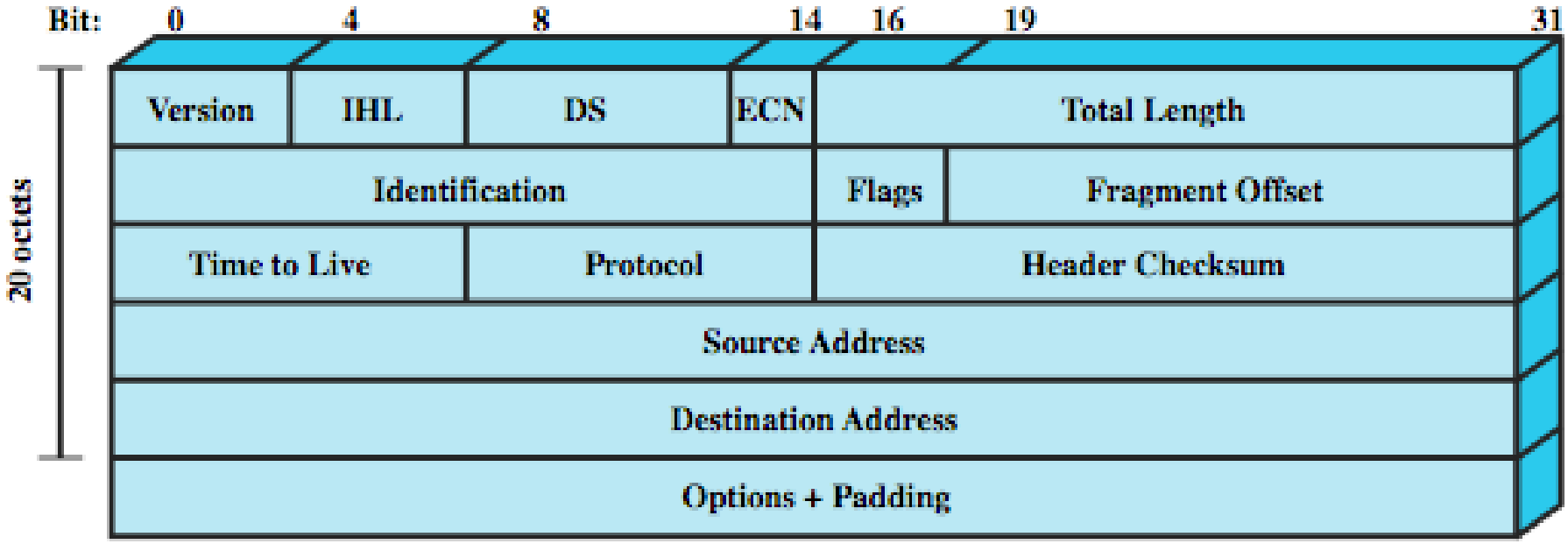
- an alternative to TCP
- no guaranteed delivery
- no preservation of sequence
- no protection against duplication
- minimum overhead
- adds port addressing to IP

UDP Header



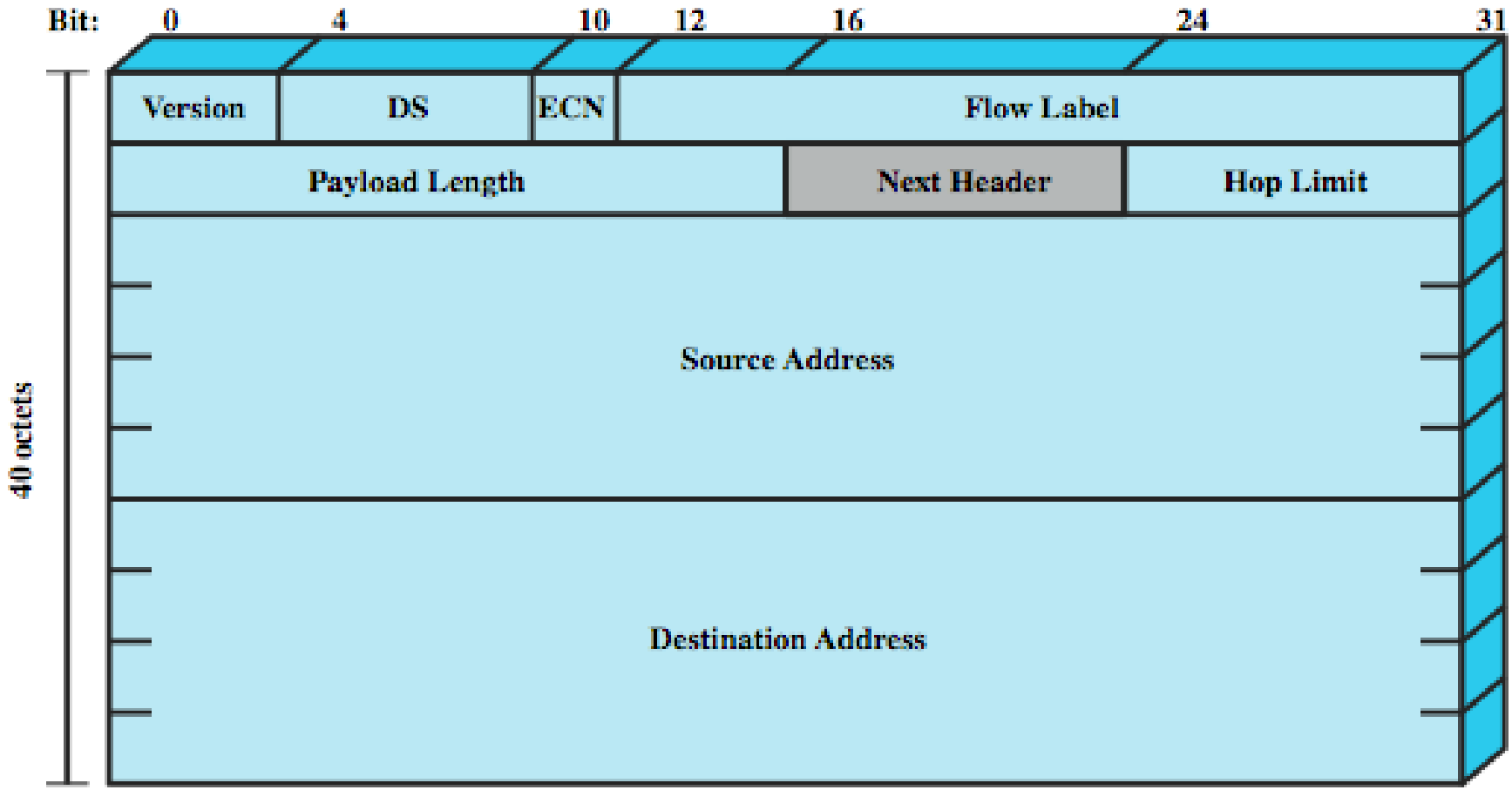
(b) UDP Header

IP Header



(a) IPv4 Header

IPv6 Header

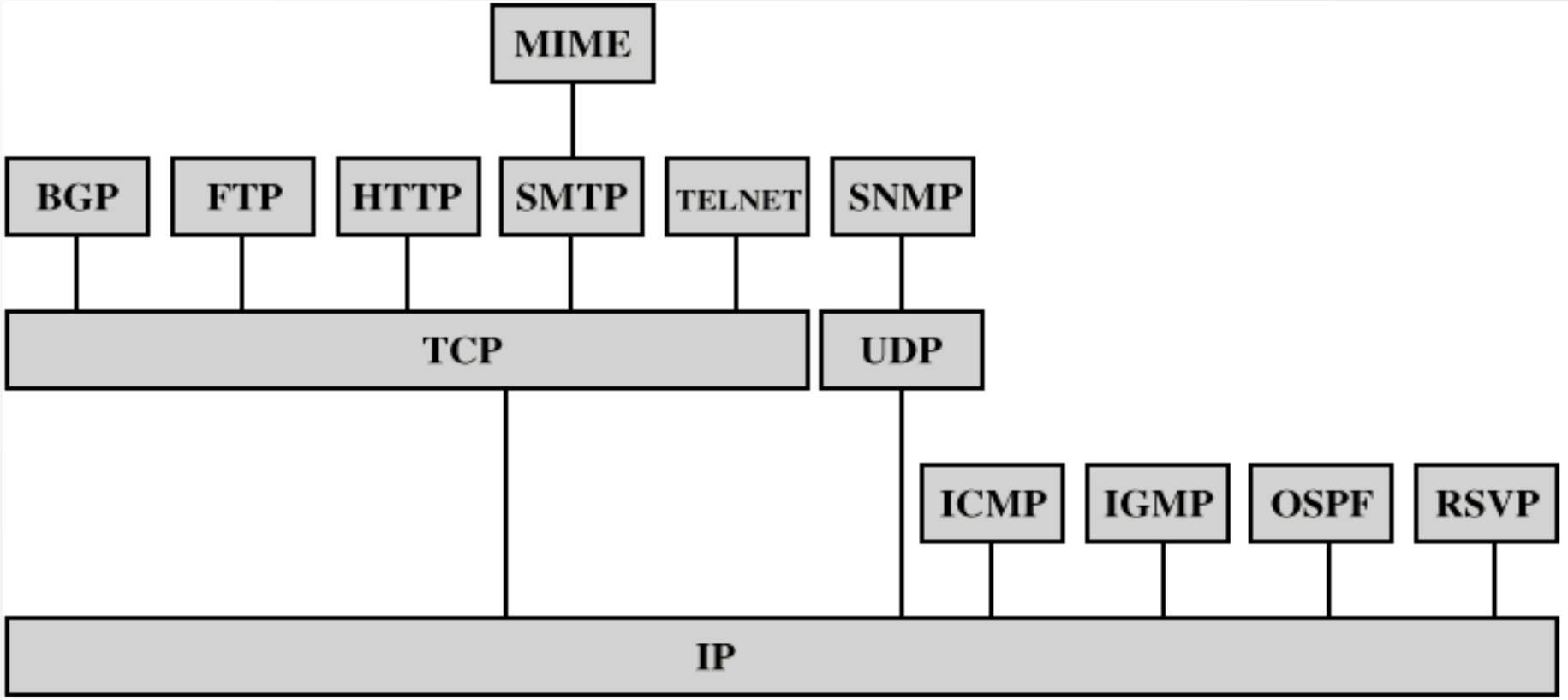


(b) IPv6 Header

TCP/IP Applications

- have a number of standard TCP/IP applications such as
  - Simple Mail Transfer Protocol (SMTP)
  - File Transfer Protocol (FTP)
  - Telnet

Some TCP/IP Protocols



BGP = Border Gateway Protocol
FTP = File Transfer Protocol
HTTP = Hypertext Transfer Protocol
ICMP = Internet Control Message Protocol
IGMP = Internet Group Management Protocol
IP = Internet Protocol
MIME = Multi-Purpose Internet Mail Extension
OSPF = Open Shortest Path First
RSVP = Resource ReSerVation Protocol
SMTP = Simple Mail Transfer Protocol
SNMP = Simple Network Management Protocol
TCP = Transmission Control Protocol
UDP = User Datagram Protocol

OSI

- Open Systems Interconnection
- developed by the International Organization for Standardization (ISO)
- has seven layers
- is a theoretical system delivered too late!
- TCP/IP is the de facto standard

OSI Layers

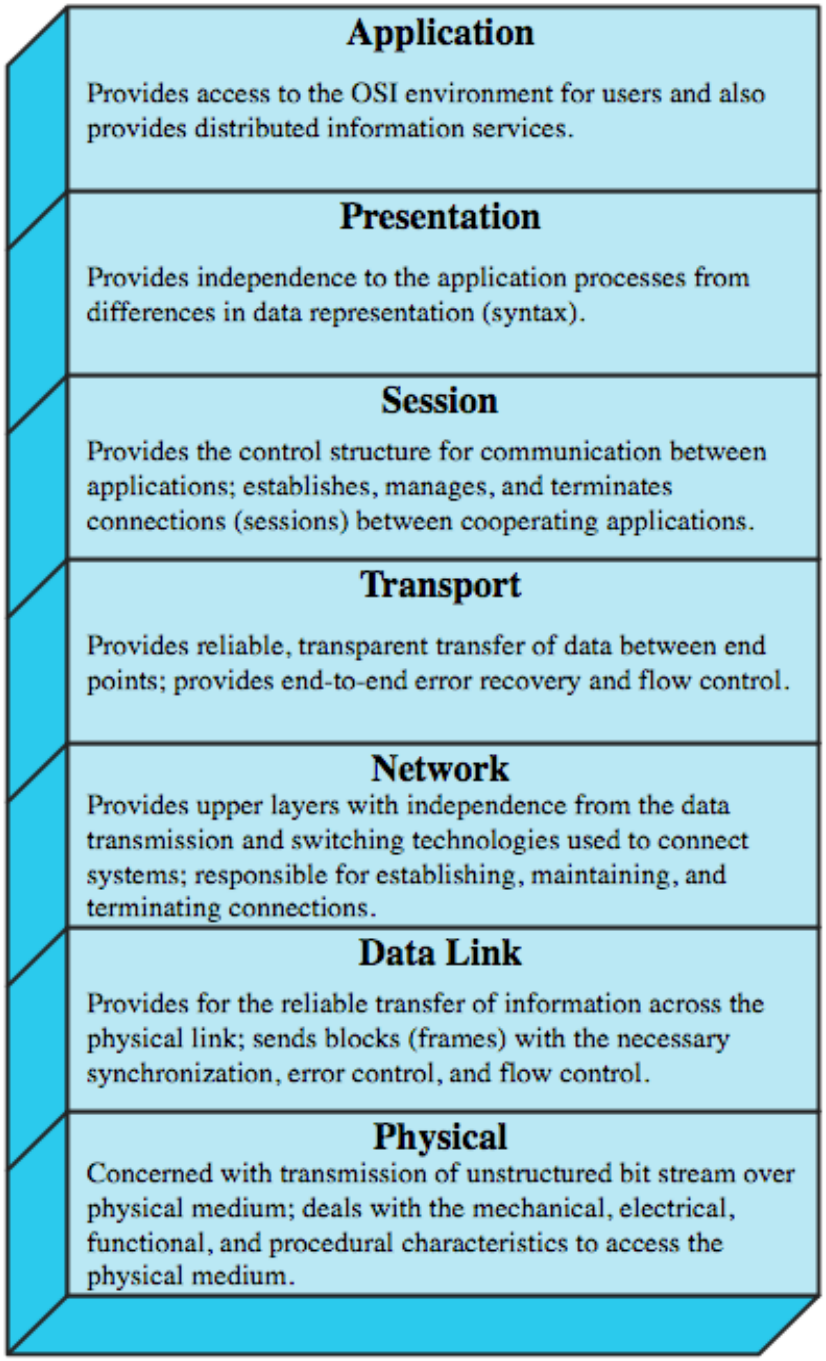
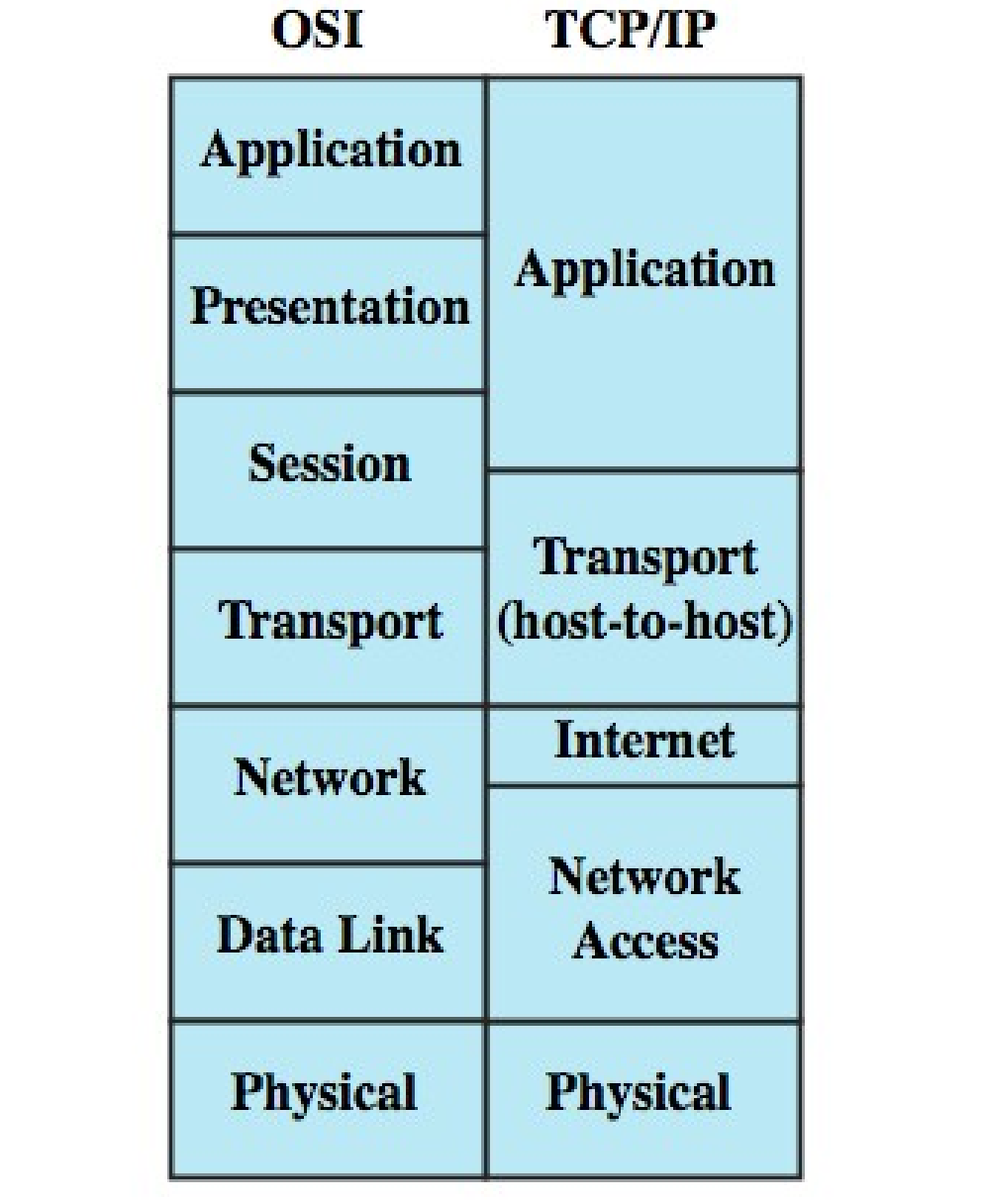
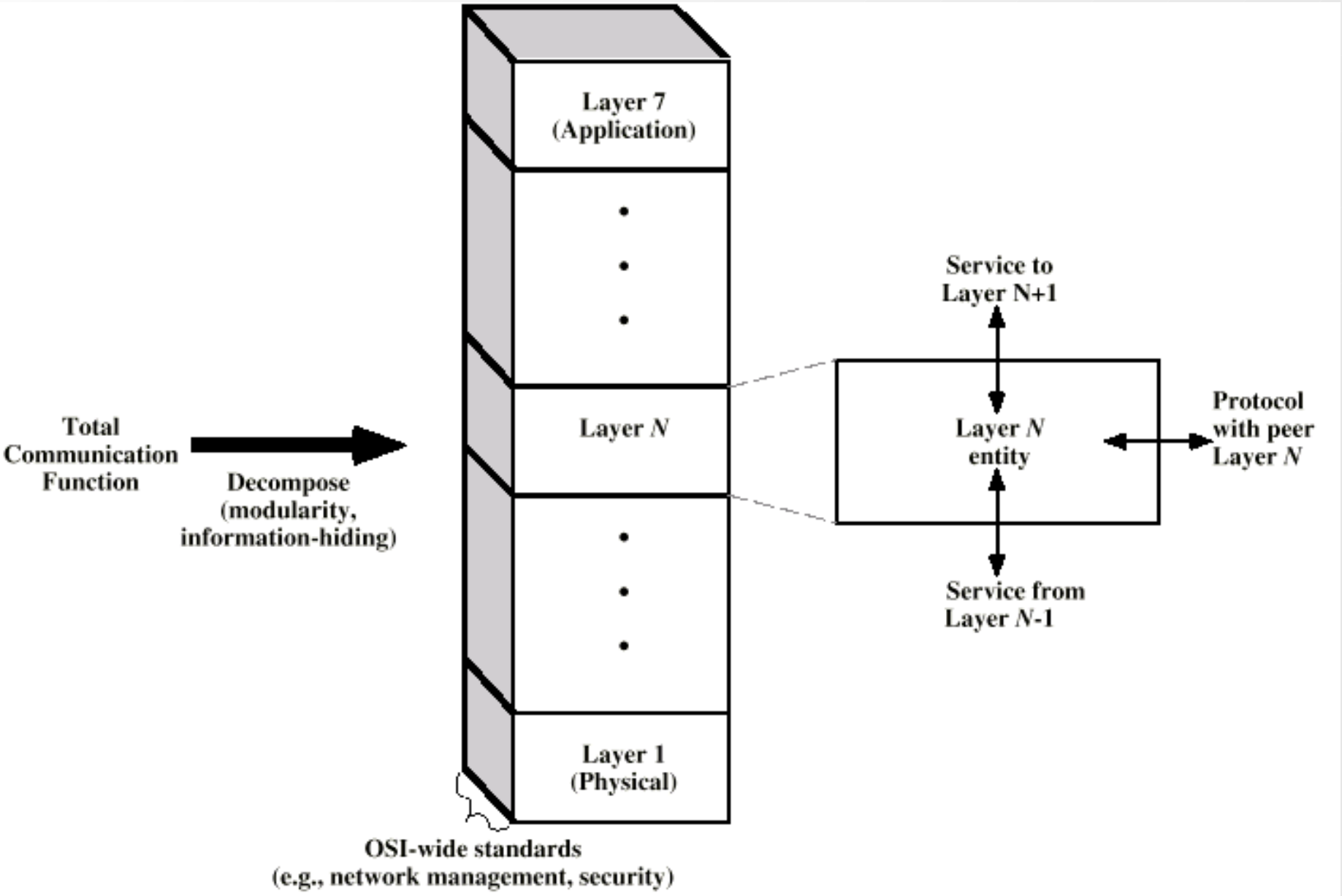


Figure 2.6 The OSI Layers

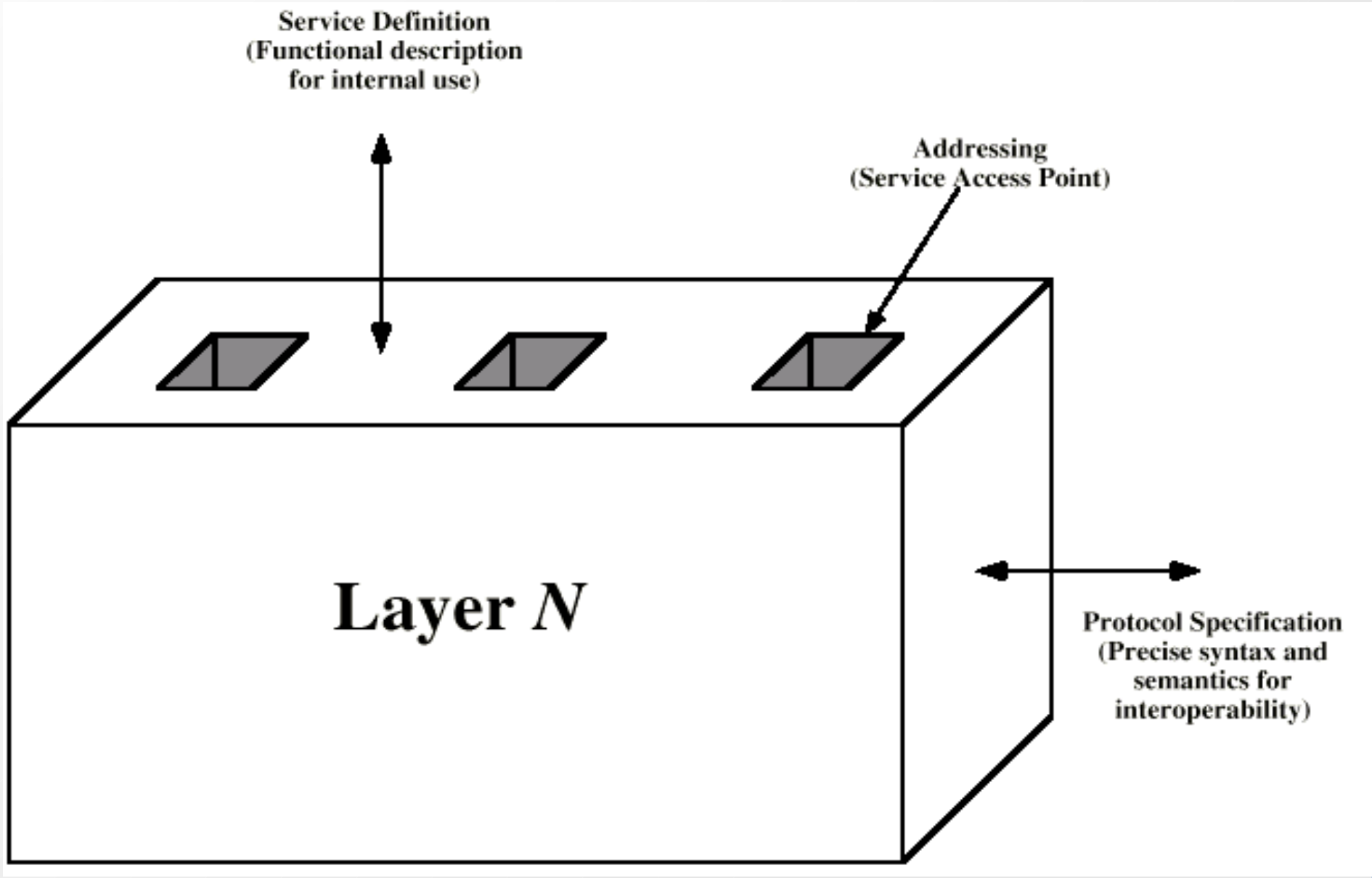
OSI v TCP/IP


OSI
TCP/IP
Application
Presentation
Session
Transport
Network
Data Link
Physical
Application
Transport (host-to-host)
Internet
Network Access
Physical

Standardized Protocol Architectures

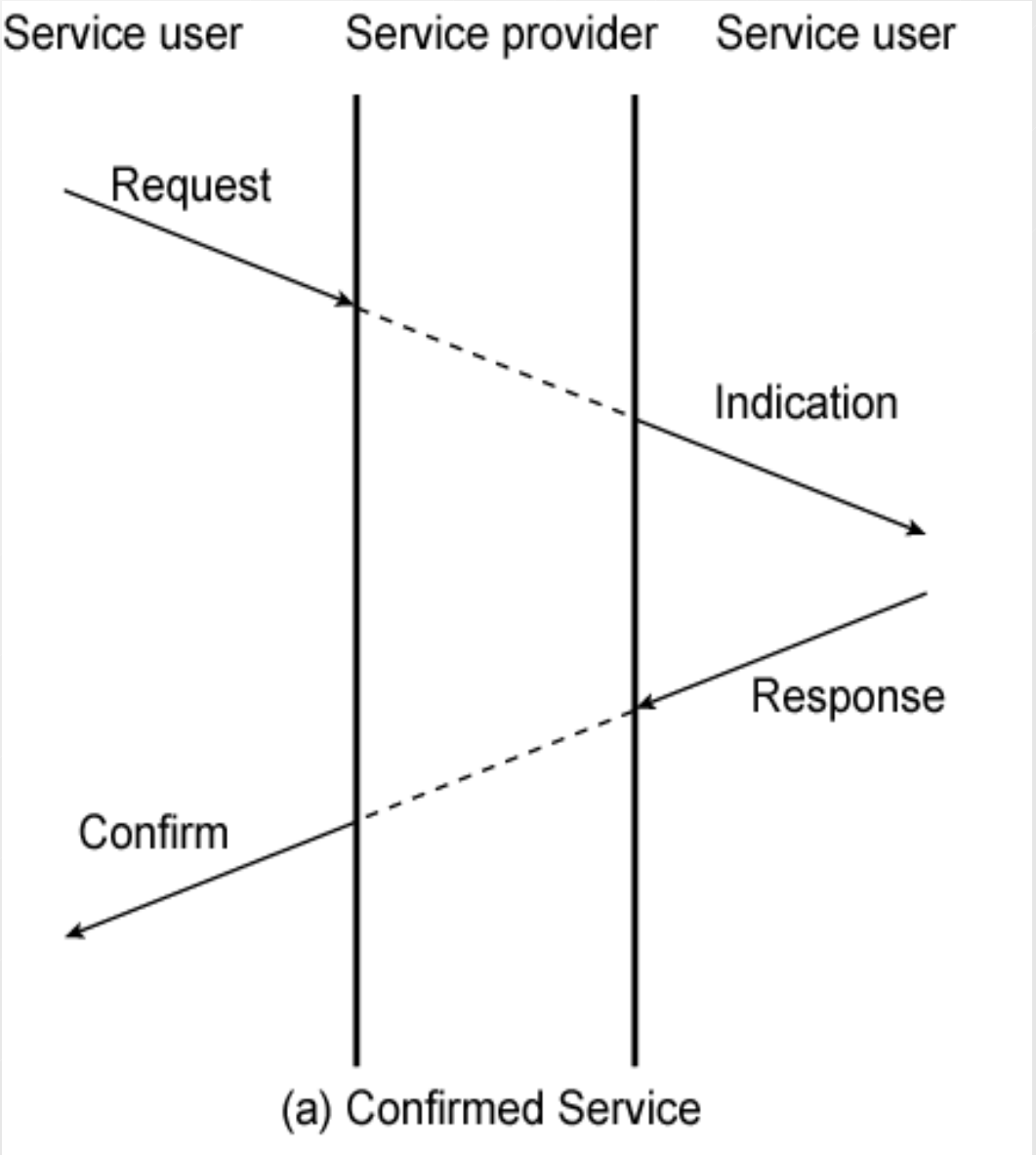


Layer Specific Standards



Service Primitives and Parameters

- define services between adjacent layers using:
  - primitives to specify function performed
  - parameters to pass data and control info



Primitive Types

REQUEST	A primitive issued by a service user to invoke some service and to pass the parameters needed to specify fully the requested service
INDICATION	A primitive issued by a service provider either to: indicate that a procedure has been invoked by the peer service user on the connection and to provide the associated parameters, or notify the service user of a provider-initiated action
RESPONSE	A primitive issued by a service user to acknowledge or complete some procedure previously invoked by an indication to that user
CONFIRM	A primitive issued by a service provider to acknowledge or complete some procedure previously invoked by a request by the service user

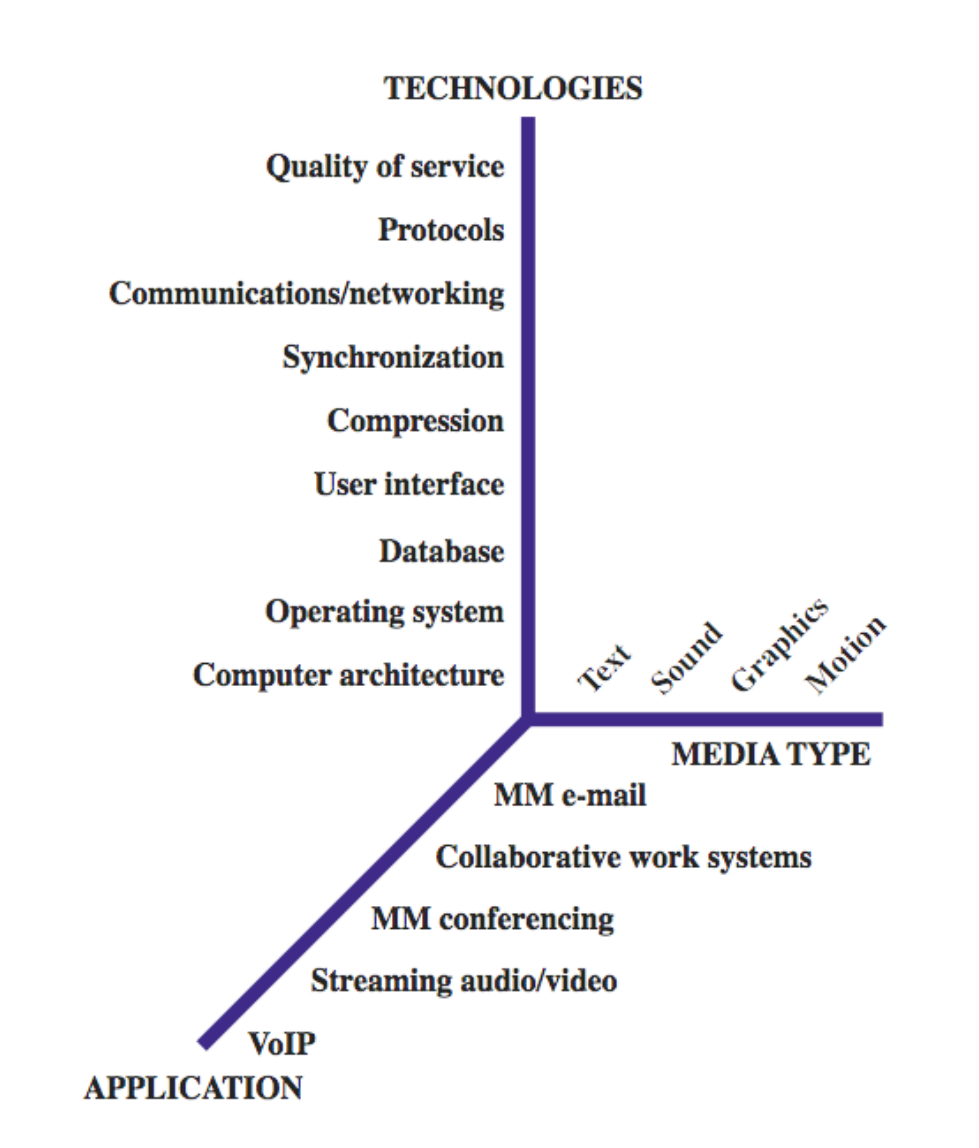
Traditional vs Multimedia Applications

- traditionally Internet dominated by info retrieval applications
  - typically using text and image transfer
  - eg. email, file transfer, web
- see increasing growth in multimedia applications
  - involving massive amounts of data
  - such as streaming audio and video

Elastic and Inelastic Traffic

- elastic traffic
  - can adjust to delay & throughput changes over a wide range
  - eg. traditional “data” style TCP/IP traffic
  - some applications more sensitive though
- inelastic traffic
  - does not adapt to such changes
  - eg. “real-time” voice & video traffic
  - need minimum requirements on net arch

Multimedia Technologies



Transmission Terminology

- data transmission occurs between a transmitter & receiver via some medium
- guided medium
  - *eg. twisted pair, coaxial cable, optical fiber*
- unguided / wireless medium
  - *eg. air, water, vacuum*

Transmission Terminology

- direct link
  - no intermediate devices
- point-to-point
  - direct link
  - only 2 devices share link
- multi-point
  - more than two devices share the link

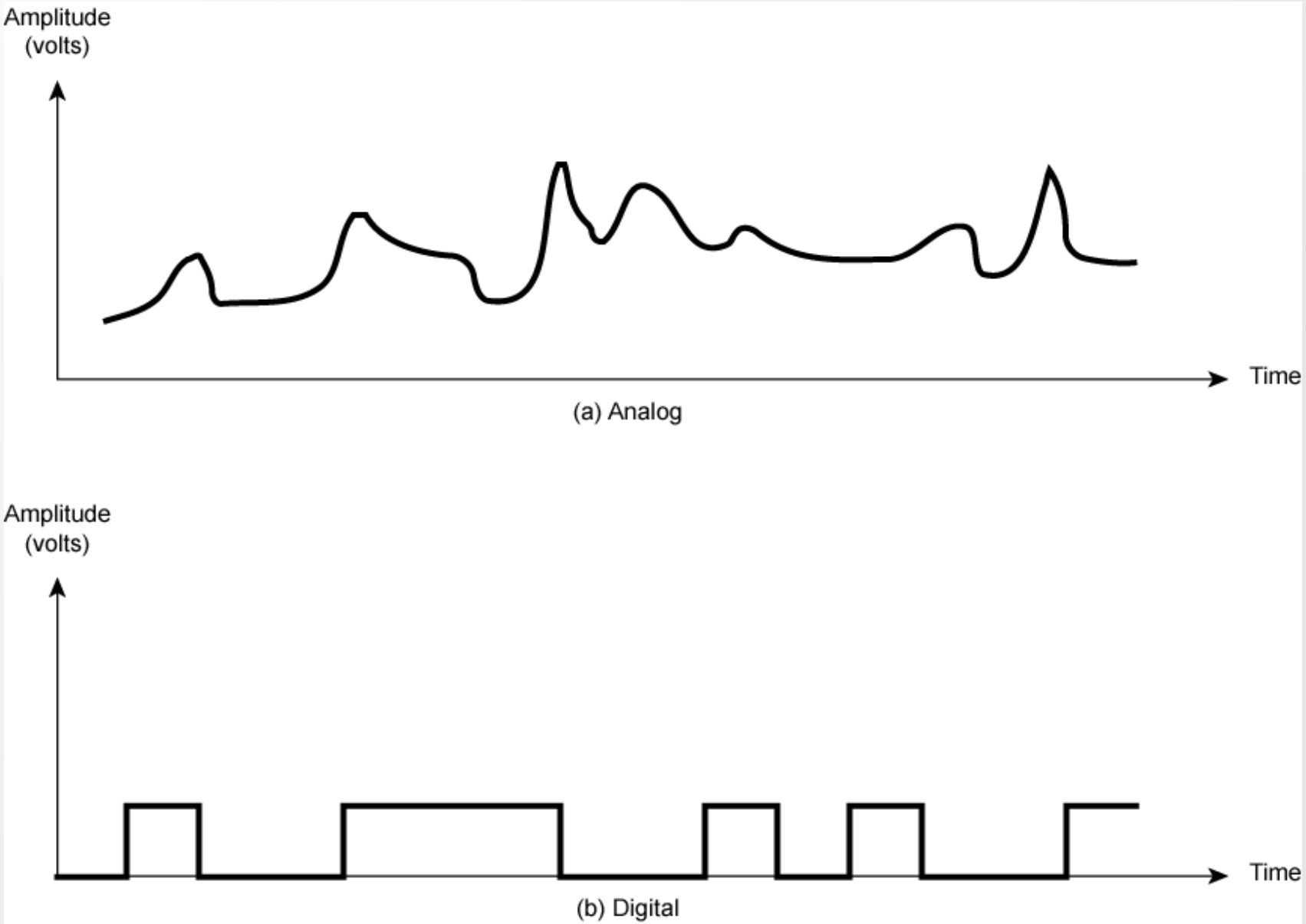
Transmission Terminology

- simplex
  - one direction
    - *eg. television*
- half duplex
  - either direction, but only one way at a time
    - *eg. police radio*
- full duplex
  - both directions at the same time
    - *eg. telephone*

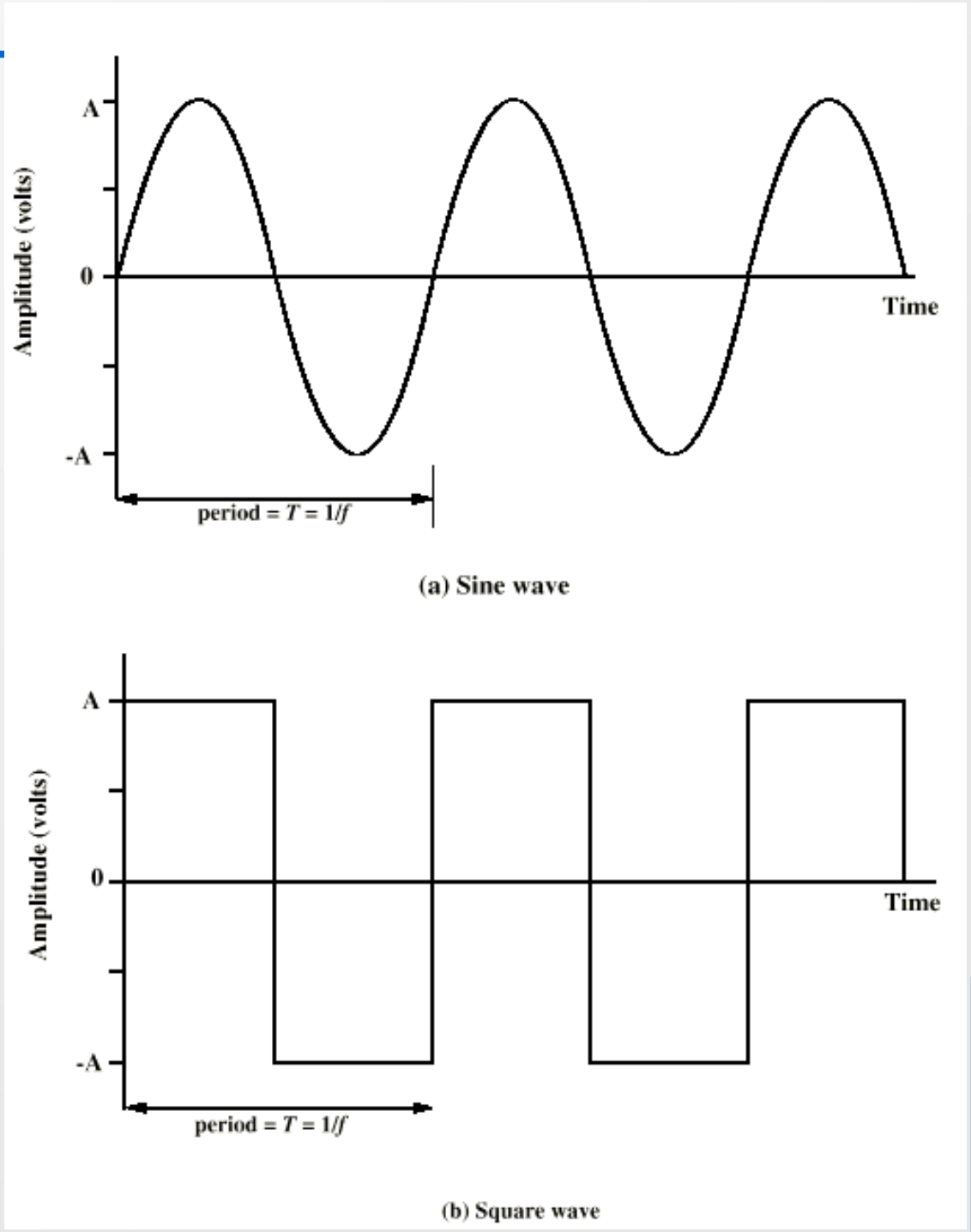
Frequency, Spectrum and Bandwidth

- time domain concepts
  - analog signal
    - *various in a smooth way over time*
  - digital signal
    - *maintains a constant level then changes to another constant level*
  - periodic signal
    - *pattern repeated over time*
  - aperiodic signal
    - *pattern not repeated over time*

Analogue & Digital Signals



Periodic Signals

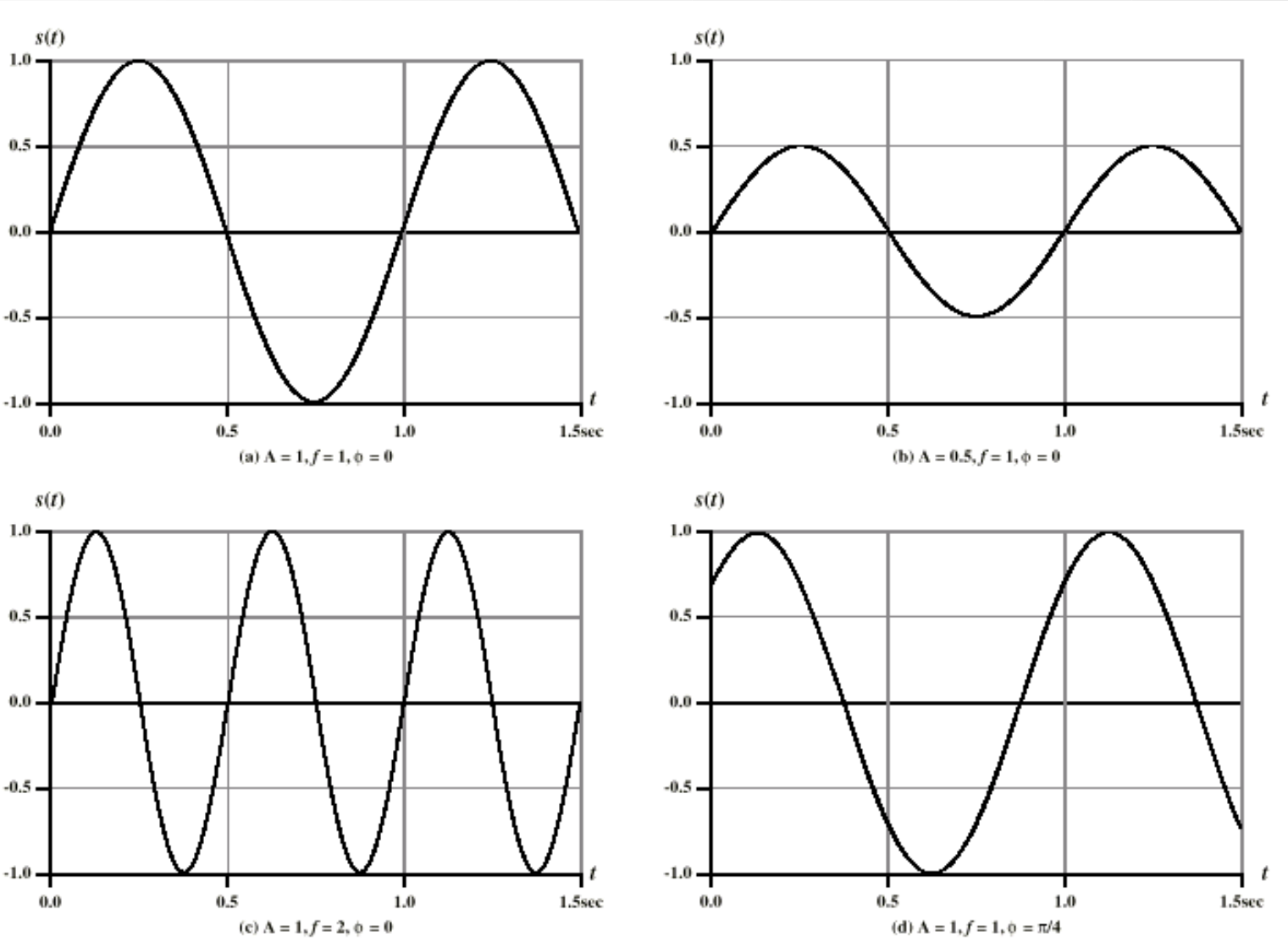


Sine Wave

- peak amplitude (A)
  - maximum strength of signal
  - volts
- frequency (f)
  - rate of change of signal
  - Hertz (Hz) or cycles per second
  - period = time for one repetition (T)
  - T = 1/f
- phase (ϕ)
  - relative position in time

Varying Sine Waves

$$s(t) = A \sin(2\pi ft + \Phi)$$



Wavelength (λ)

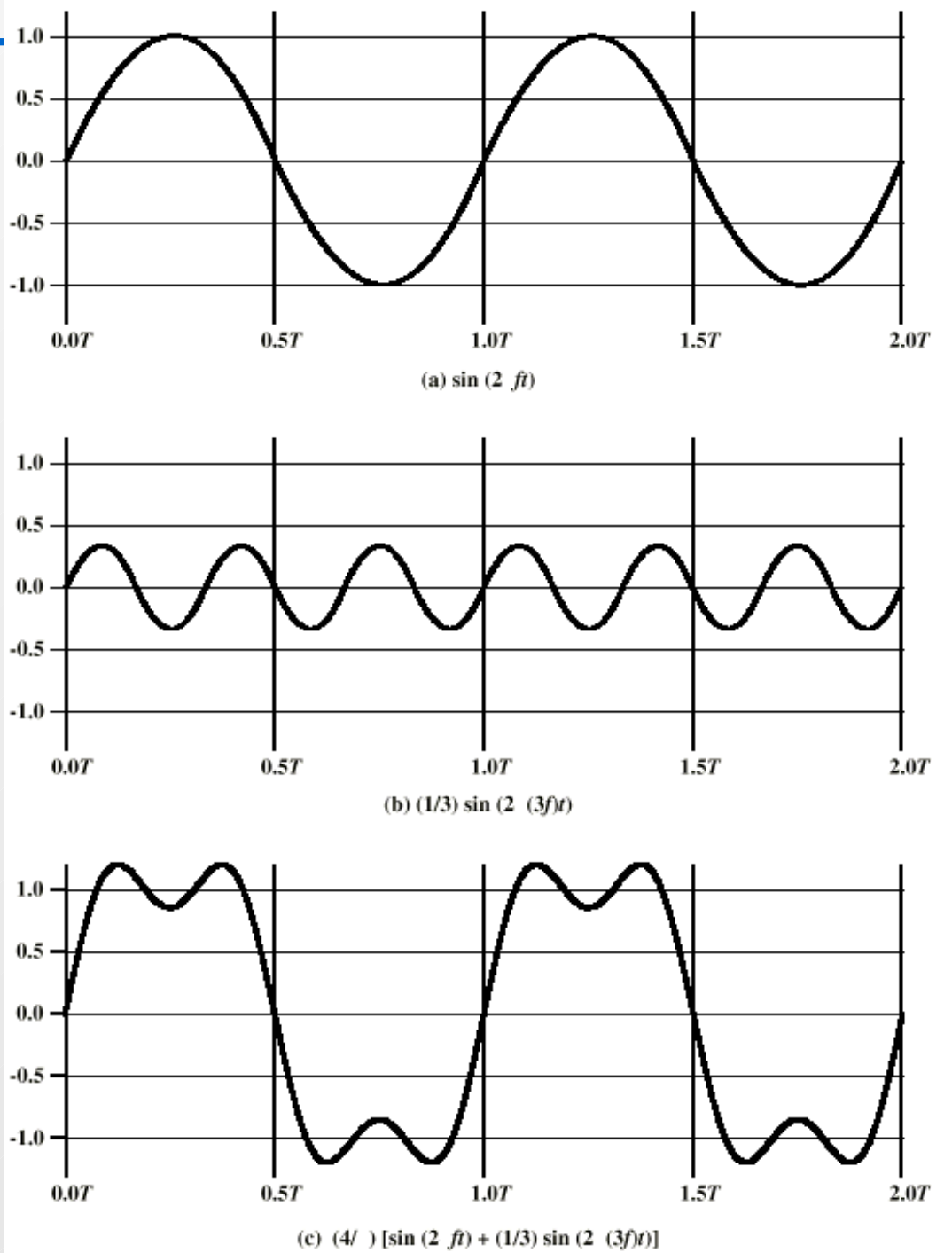
- is distance occupied by one cycle
- between two points of corresponding phase in two consecutive cycles
- assuming signal velocity v have $\lambda = vT$
- or equivalently $\lambda f = v$
- *especially when v=c*
  - $c = 3*10^8\ ms^{-1}$ (speed of light in free space)

Frequency Domain Concepts

- signal are made up of many frequencies
- components are sine waves
- Fourier analysis can shown that any signal is made up of component sine waves
- can plot frequency domain functions

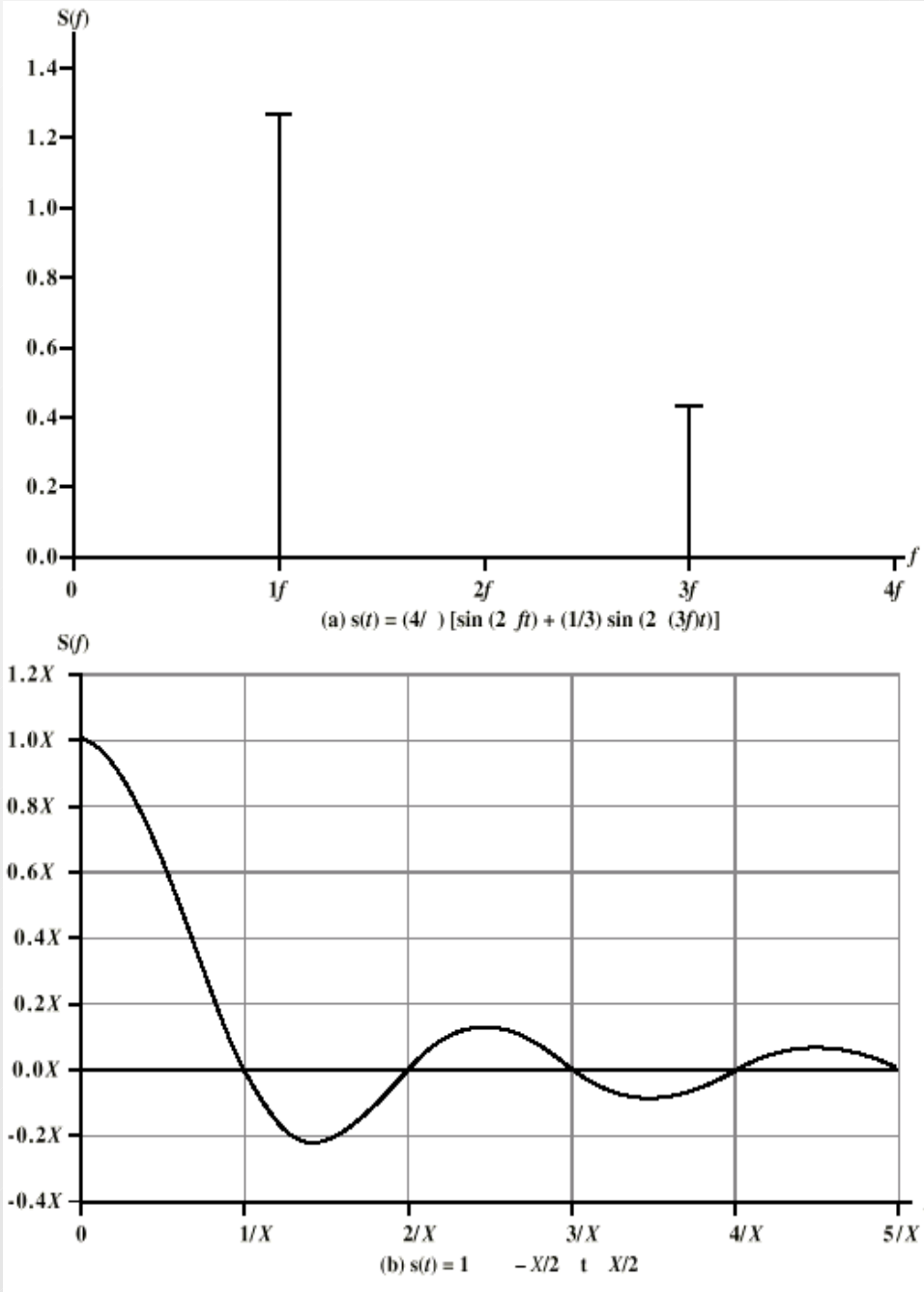
Addition of Frequency Components (T=1/f)

- (c) is sum of *f* & *3f*



Frequency Domain Representations

- frequency-domain function for the signal on the previous slide
- freq domain function of single square pulse



Spectrum & Bandwidth

- spectrum
  - range of frequencies contained in signal
- absolute bandwidth
  - width of spectrum
- effective bandwidth
  - often just *bandwidth*
  - narrow band of frequencies containing most energy
- DC Component
  - component of zero frequency

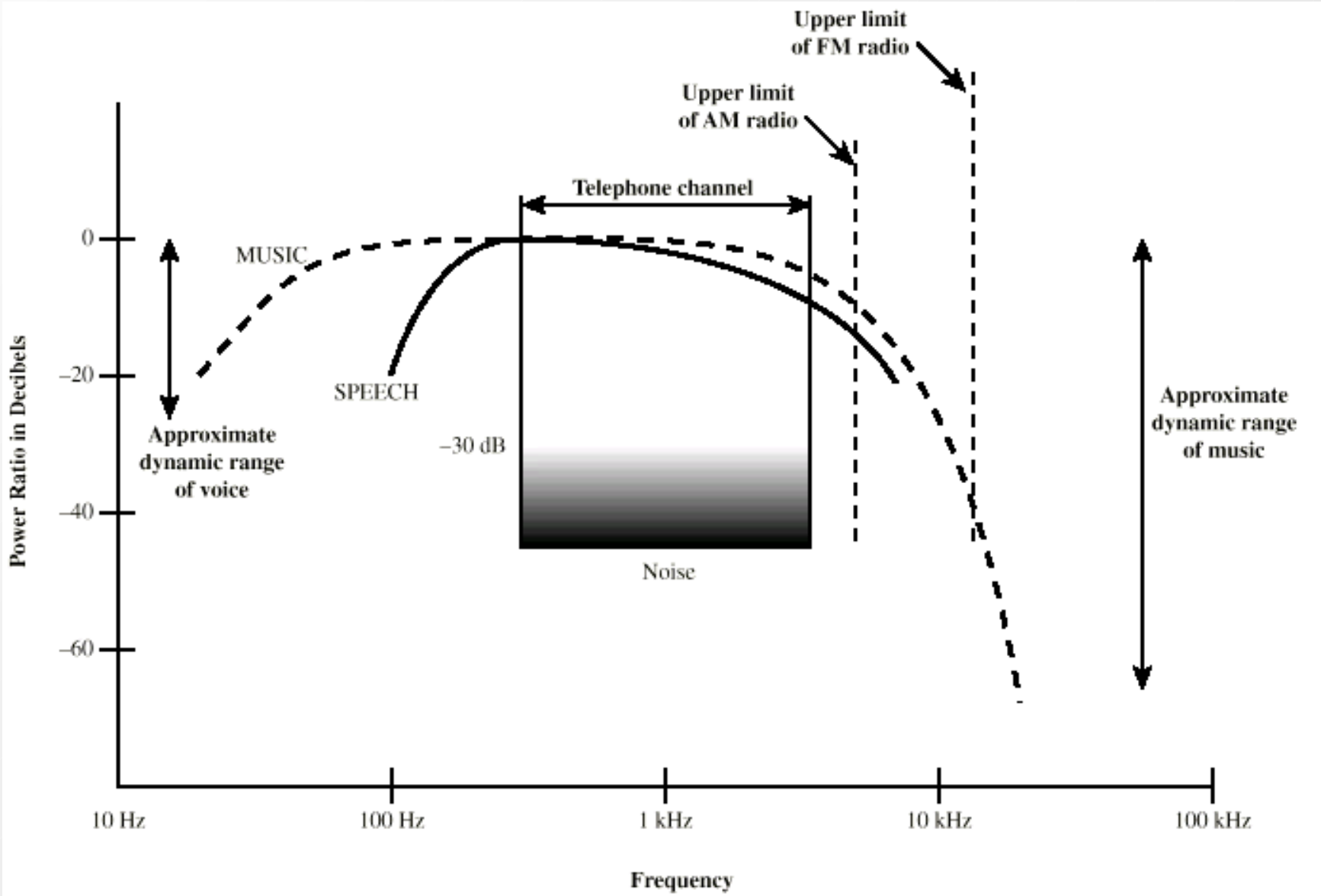
Data Rate and Bandwidth

- any transmission system has a limited band of frequencies
- this limits the data rate that can be carried
- square have infinite components and hence bandwidth
- but most energy in first few components
- limited bandwidth increases distortion
- have a direct relationship between data rate & bandwidth

Analog and Digital Data Transmission

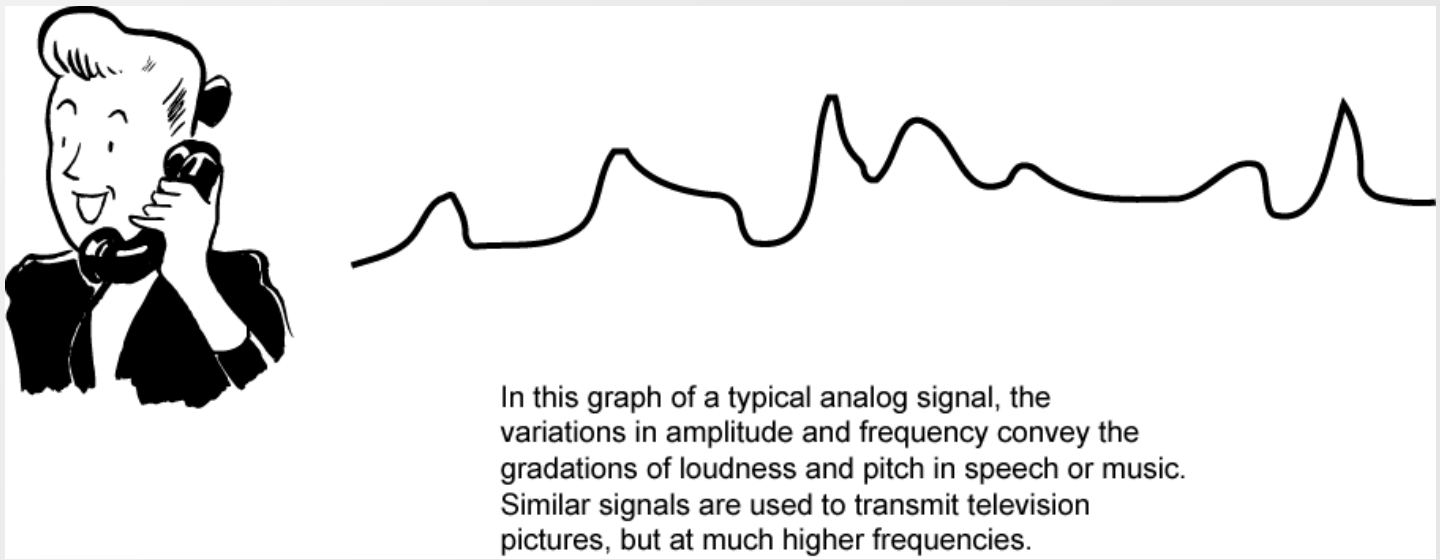
- data
  - entities that convey meaning
- signals & signalling
  - electric or electromagnetic representations of data, physically propagates along medium
- transmission
  - communication of data by propagation and processing of signals

Acoustic Spectrum (Analog)



Audio Signals

- freq range 20Hz-20kHz (speech 100Hz-7kHz)
- easily converted into electromagnetic signals
- varying volume converted to varying voltage
- can limit frequency range for voice channel to 300-3400Hz



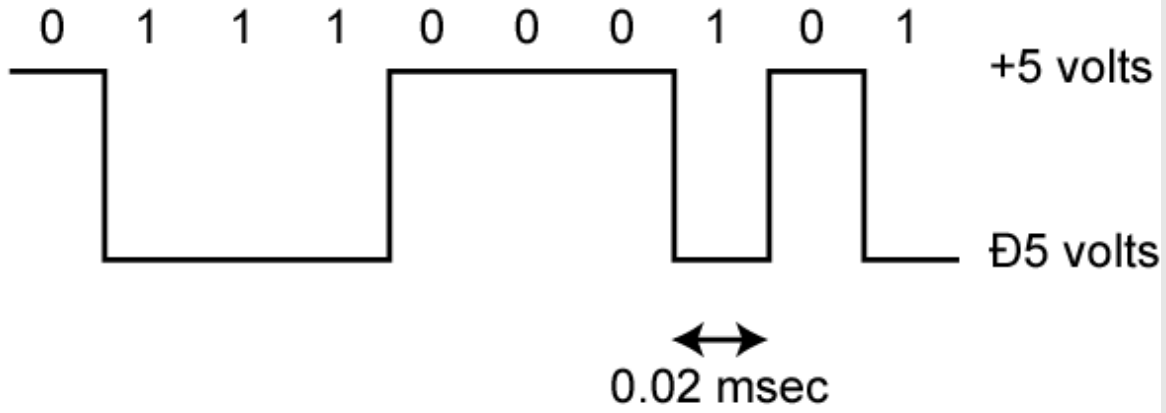
In this graph of a typical analog signal, the variations in amplitude and frequency convey the gradations of loudness and pitch in speech or music. Similar signals are used to transmit television pictures, but at much higher frequencies.

Video Signals

- USA - 483 lines per frame, at frames per sec
  - have 525 lines but 42 lost during vertical retrace
- 525 lines x 30 scans = 15750 lines per sec
  - 63.5μs per line
  - 11μs for retrace, so 52.5 μs per video line
- max frequency if line alternates black and white
- horizontal resolution is about 450 lines giving 225 cycles of wave in 52.5 μs
- max frequency of 4.2MHz

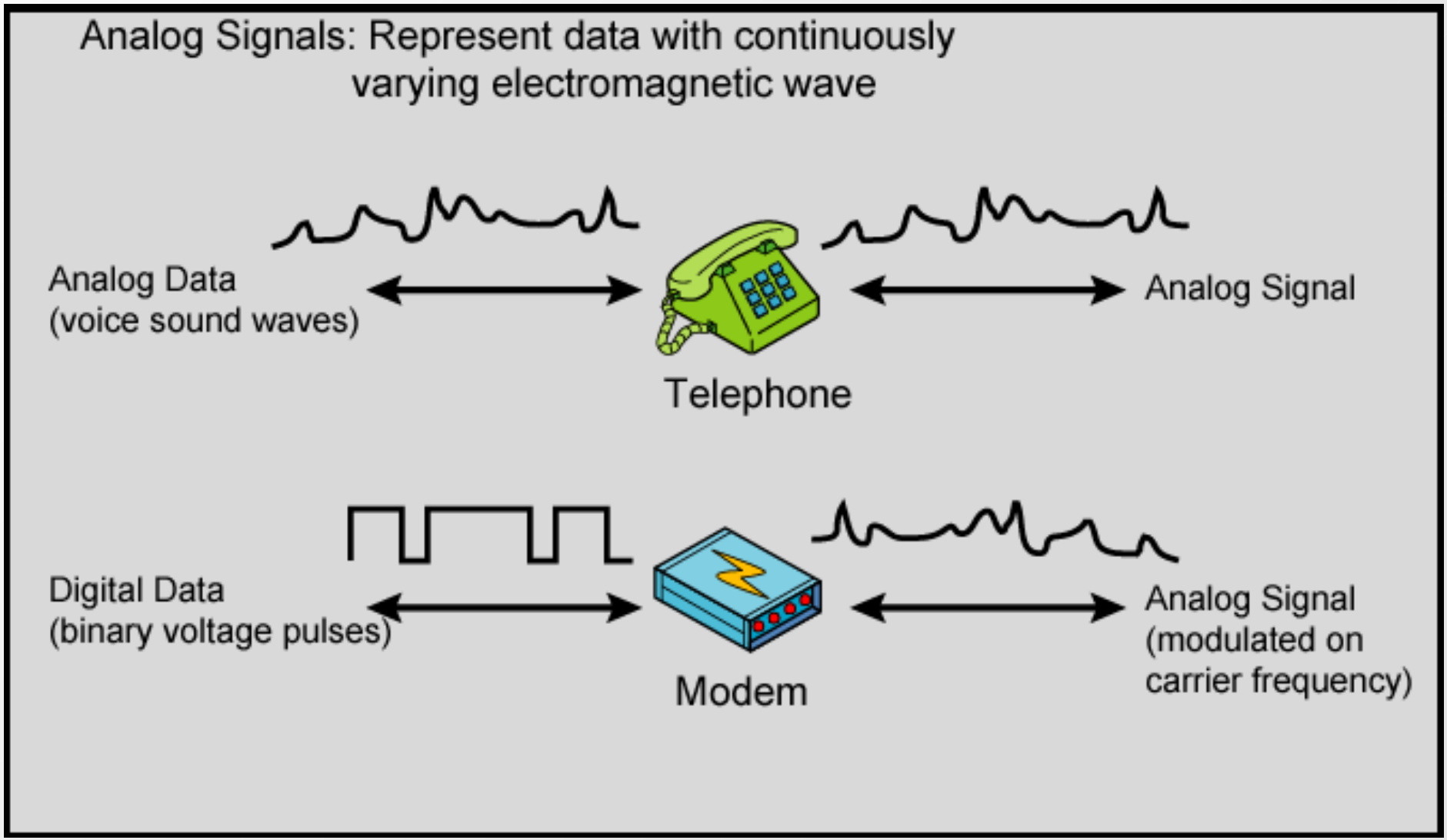
Digital Data

- as generated by computers etc.
- has two dc components
- bandwidth depends on data rate

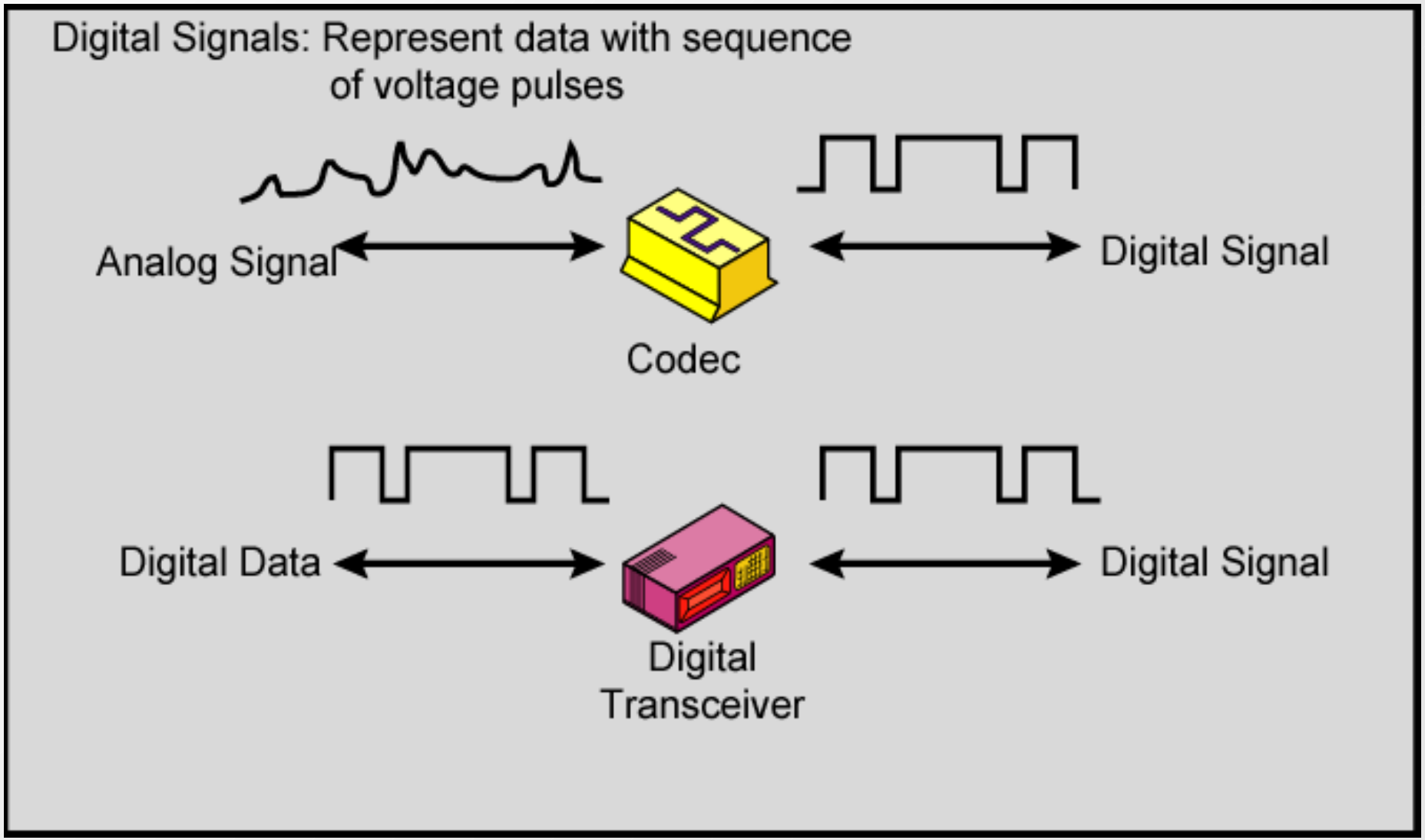


User input at a PC is converted into a stream of binary digits (1s and 0s). In this graph of a typical digital signal, binary one is represented by Ð5 volts and binary zero is represented by +5 volts. The signal for each bit has a duration of 0.02 msec, giving a data rate of 50,000 bits per second (50 kbps).

Analog Signals

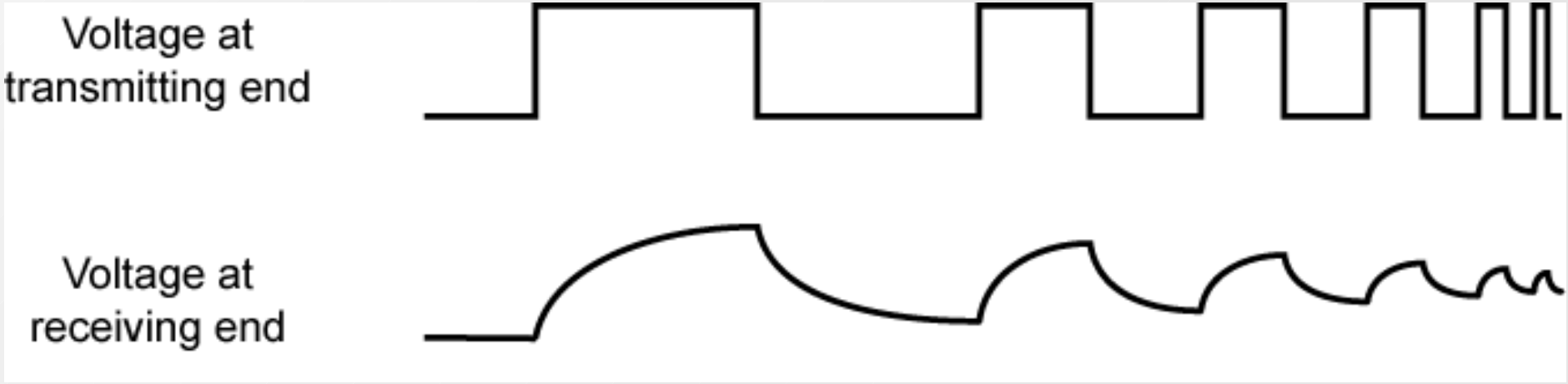


Digital Signals



Advantages & Disadvantages of Digital Signals

- cheaper
- less susceptible to noise
- but greater attenuation
- digital now preferred choice



Transmission Impairments

- signal received may differ from signal transmitted causing:
  - analog - degradation of signal quality
  - digital - bit errors
- most significant impairments are
  - attenuation and attenuation distortion
  - delay distortion
  - noise

Attenuation

- where signal strength falls off with distance
- depends on medium
- received signal strength must be:
  - strong enough to be detected
  - sufficiently higher than noise to receive without error
- so increase strength using amplifiers/repeaters
- is also an increasing function of frequency
- so equalize attenuation across band of frequencies used
  - eg. using loading coils or amplifiers

Delay Distortion

- only occurs in guided media
- propagation velocity varies with frequency
- hence various frequency components arrive at different times
- particularly critical for digital data
- since parts of one bit spill over into others
- causing intersymbol interference

Noise

- additional signals inserted between transmitter and receiver
- thermal
  - due to thermal agitation of electrons
  - uniformly distributed
  - white noise
- intermodulation
  - signals that are the sum and difference of original frequencies sharing a medium

Noise

- crosstalk
  - a signal from one line is picked up by another
- impulse
  - irregular pulses or spikes
    - *eg. external electromagnetic interference*
  - short duration
  - high amplitude
  - a minor annoyance for analog signals
  - but a major source of error in digital data
    - *a noise spike could corrupt many bits*

Channel Capacity

- max possible data rate on comms channel
- is a function of
  - data rate - in bits per second
  - bandwidth - in cycles per second or Hertz
  - noise - on comms link
  - error rate - of corrupted bits
- limitations due to physical properties
- want most efficient use of capacity

Nyquist Bandwidth

- consider noise free channels
- if rate of signal transmission is 2B then can carry signal with frequencies no greater than B
  - ie. given bandwidth B, highest signal rate is 2B
- for binary signals, 2B bps needs bandwidth B Hz
- can increase rate by using M signal levels
- Nyquist Formula is: $C = 2B \log_2 M$
- so increase rate by increasing signals
  - at cost of receiver complexity
  - limited by noise & other impairments

Shannon Capacity Formula

- consider relation of data rate, noise & error rate
  - faster data rate shortens each bit so bursts of noise affects more bits
  - given noise level, higher rates means higher errors
- Shannon developed formula relating these to signal to noise ratio (in decibels)
- $SNR_{db} = 10 \log_{10} (signal/noise)$
- Capacity $C = B \log_2(1+SNR)$
  - theoretical maximum capacity
  - get lower in practise

Summary

- communications model
- introduced need for protocol architecture
- TCP/IP protocol architecture
- OSI Model & protocol architecture standardization
- traditional vs multimedia application needs
- looked at data transmission issues
- frequency, spectrum & bandwidth
- analog vs digital signals