DES232 / Lecture 2 : Protocol Architecture

▶ A communication Protocol is a system of rules that allow entites of communication to transmit info via variation of physical quantity. It defines rules/methods/schematics/ error recovery. It can be implemented on hardware and/or software.

▶ Simple Architecture.

3 layers are involved.
- Network Access
  Concerned w/ the exchange of data blw computer & network
- Transport
  "Construct Package"/collects mechanisms in common layer
- Application
  Logic support for application

- each computer must have an unique address, so the network can find a path and connect.
- Port is used by application in order to communicate wl transportlayer.

▶ TCP/IP (Transmission Control Protocol / Internet Protocol)

- a large collection of protocols that are internet standard.

"5 layers"
- Application : Provide access to environment, distribution services, user.
- Transport : Provide data transfer blw end point wl error control, flow control etc
- Internet : Routing/finding path/Quality of Services congestion control
- Network Access : Logical interface/stream or packet oriented
- Physical : Bit stream transmission / Physical Connector. via medium

- Network Access Layer (Data Link) : how to use the network to transmit an IP address datagram defined details of how data should be sent using the network
- Internet / Network Layer : "Logical transmission of data packets over internet"
  Ex IP → speed over accuracy & best traffic/rate
  ARP/RARP/ICMP/IGMP
  - route each packet independently, reassemble out-of-order packets / handle error and fragmentation
- Transport Layer : how data should be sent, ensure delivery wl error free & correct sequence, control reliability, offers acknowledgement.
  Ex
  TCP (reliable/connection-oriented) / UDP (message-oriented & simple unreliable) / SCTP

- Application Layer : interact w/ software, provides services
  ex HTTP/HTTPS/FTP/SMTP/DNS/TELNET/SNMP etc.

TCP/IP Requirements

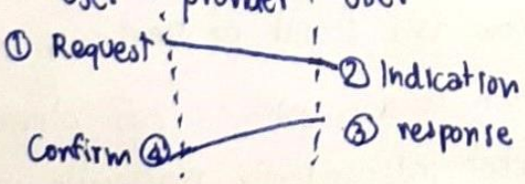
- each host on subnetwork must have a unique global internet address.
- each process must have an unique port within the host

- **TCP (Transmission control protocol)**
  - provides reliable connection to transfer data
  - tracks segment b/w entities for connection duration
  - Headers w/ 20 octets // added in transport layer
  - connection-oriented
- **UDP (User datagram protocol)**
  - doesn't guarantee delivery, preservation of sequence, protection against duplication.
  - message-oriented, unreliable connection, speed over accuracy
  - used w/ SNMP, operate w/ minimum of protocol mechanism
  - checksum to check no error in data
  - Headers w/ 8 octets. // added in transport layer
- **IP**
  - IPV4 has 20 octets headers, IPV6 w/ 40 octets
  - added header in the internet layer
  - IPV6 capable for more device in larger expanding network.

Service Primitives and Parameters

- **Primitives**: functions to be performed
- **Parameters**: pass data & control information

	Issued by	to
Request	User	invoke service + pass parameter
Indication	provider	indicate invoked
Response	user	acknowledge or
Confirm	provider	complete prev. invoked by req



① - ④ ⇒ w/ acknowledgement
① - ② ⇒ w/o acknowledgement

Traditional Internet-based Application

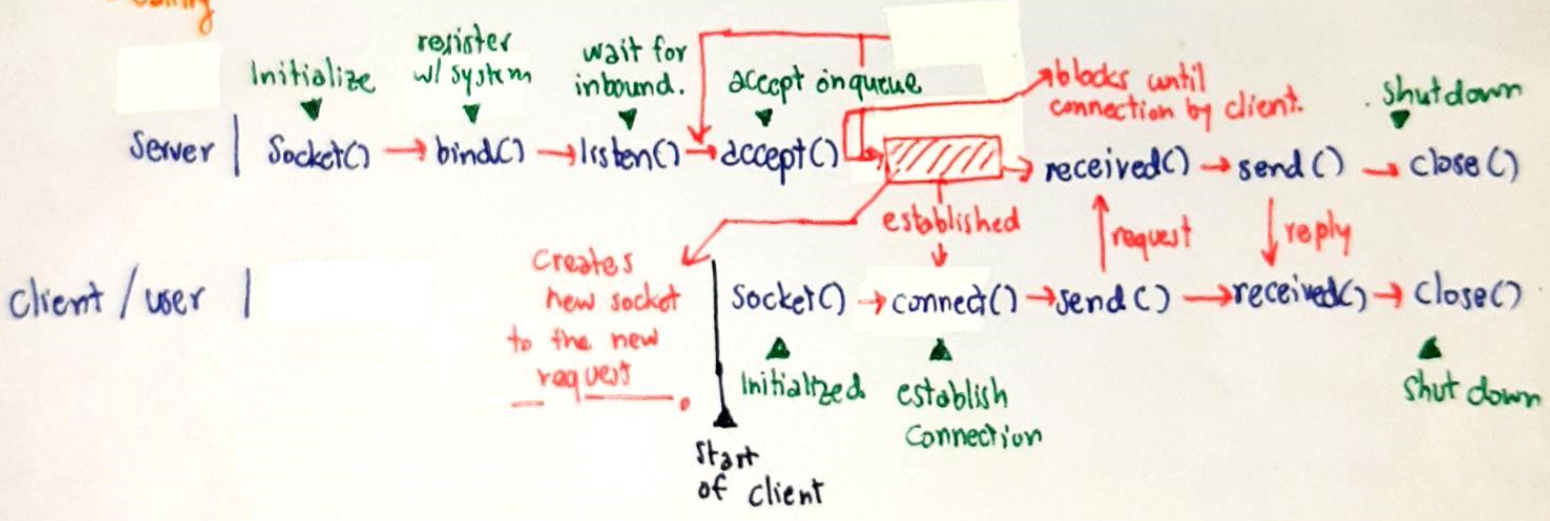
- **SMTP (simple-mail transfer)**
  - provide mechanism for transferring message among hosts
- **FTP**
  - send file from one to another, both text and bin
- **SSH**
  - provide secure remote logon

Socket Programming.

- enables communication b/w client & server process.
- maybe connection-oriented or connectionless
- unique throughout the internet (concat. port value and IP address)
- defined API (interface for writing program that use TCP or UPP

• Types
1) Stream Sockets
   - all blocks of data sent b/w pair of sockets are guaranteed for delivery and arrive in the order they were sent.
2) Datagram Sockets
   - delivery is not guarantee, order is not necessarily preserved.
3) Raw Sockets
   - Allow direct access to lower-layer protocols.

• Calling



DES232 / Lecture 3 Data Transmission

- deals w/ transmission of signal in a reliable and efficient manner.

- **Communication.**
  - the act of disseminating information
  - Required properties : modulation / signal compatibility / signal strength / data rate / protocol / demodulation

- **Terminology (1)**
  - Guided : waves are guided along physical path. (only directed by cable)
  - Unguided : transmitting by electromagnatic waves (any direction)

- **Cables**
  - **Twisted Pair**
    - electric form over metal conducting wire
    - low noise immunity / low bandwidth / high attenuation / can disrupted by external magnetic field
    - cheapest / easy to install
  - **Coaxial Cable**
    - electric form over inner conductor of cable
    - moderate bandwidth / moderate noise immunity / lower attenuation
    - can get disrupted by magnetic field.
  - **Optic Fiber**
    - optical form over glass fiber
    - highest noise immunity / bandwith / cost / efficiency
    - lowest attenuation / immune to magnetic field.

- **Terminology (2)**

Config.
- **Direct link** : no intermediate devices
- **Point-to-point** : only 2 shared link
- **multilink** : more than 2 shared link

- **amplifier**
  = expanding signal devices / maybe appeared / depend on distance blw node

Data flow
- **Simplex** : one-way / one direction only
- **Half duplex** : two-way / one direction at a time
- **Full duplex** : two-way / simutaneously

b = bits, B = bytes

Frequency, Spectrum, Bandwidth

Time-domain Concept: as a function over time

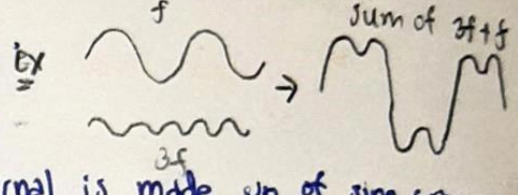
- Analog (smooth, no discontinuity, ∿)
- Digital (0/1)
- Periodic (repeat pattern)
- Aperiodic (no repeat pattern)

sine-wave as fundamental waveform $s(t) = A \sin(\phi + 2\pi f t)$

- A: Peak Amplitude / maximum signal strength
- f/T: frequency / Period | T = 1/f, (hertz, cycle per seconds)
- ϕ: Phase / relative position over time.
- λ: wavelength / distance used by 1 cycle ($c = f\lambda$, c = light speed)

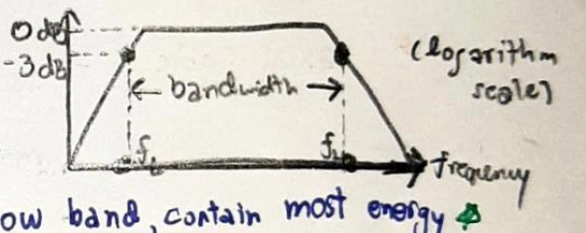
Frequency-domain concept: as a frequency function

- components are sine-wave
- lowest frequency = fundamental frequency
- use fourier analysis to show that any signal is made up of sine waves.



Spectrum & Bandwidth

- spectrum: range of frequency
- absolute bandwidth: width of spectrum
- bandwidth (effective bandwidth): narrow band, contain most energy
- direct current (DC / constant): component of zero frequency



- Bandwidth: maximum data rate / (digital as bps or Bps / analog as Hz)
- Half-power or -3dB: output power at this frequency will be half of maximum 0dB

Data Rate / Bit Rate

- the amount of data being transfered through a connection w/ in a second.
- measured as bits per second or bytes per seconds

more limited bandwidth, greater distortion, greater for potential error by receiver

higher data rate, greater required effective bandwidth

- signal/signaling: electric/electromagnetic representation of data, propagates along medium.
- Transmission: propagation and processing of signals

Analog / Dytal Transmission

Audio Signal

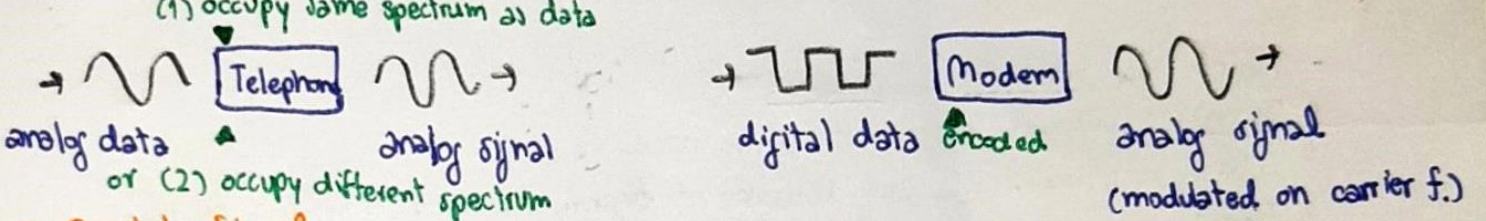
- 20 - 20,000 Hz - easily converted into electromagnetic signal
- varying volume converted to varying voltage
- standard spectrum is 300 - 3400 Hz

Digital Data

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

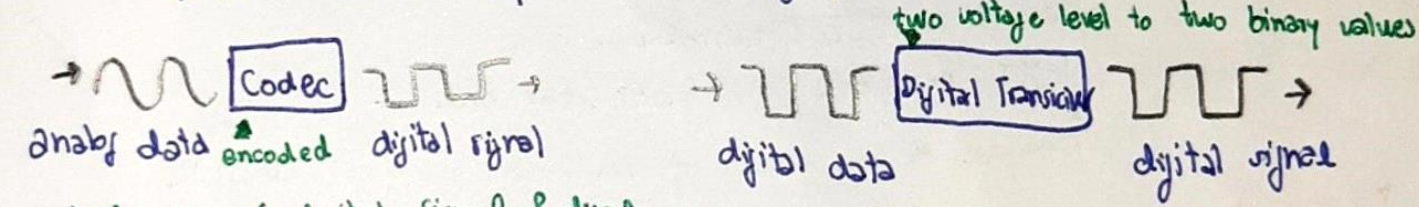
Analog Signal

- Represent data w/ continuously varying electromagnetic wave



Digital Signal

- Represent data w/ sequence of voltage pulse



* advantage of digital signal & disadvantage
  - Cheaper / less susceptible to noise interference / greater attenuation (gradual loss in intensity of flux)

Transmission

- analog signal by analog transmission : propagates through amplifiers.
- analog signal by digital transmission : propagates through repeaters
  at repeater; recov. from inbound to generate new analog outbo
- digital signal by digital transmission : propagates through repeaters:
  at repeater; recov. from inbound to generate new digital outbo

* no digital signal by analog transmission

Transmission Impairments

- received signal may differ from signal transmitted causing "degradation of signal quality" in analog / "bit error" in digital.

Attenuation

- any reduction in the strength of a signal where strength fall off w/ distance
- depends on medium
- equalize attenuation across band of froquency used / increasing f^n of frequency / increase strength using amplifiers / repeaters.
- receivd signal strenjth must strong enough to be detected | sufficiently higher than noise to receive w/o error

Delay Distortion

- only in guided transmission where network data signal are transmitted via medium at a certain froquency and speed.
- occurs when signal velocity & frequency vary hence arrive at different times.
- critical for digital and causing inter-symbol interference.

Noise

- inserted blw transmitter & receiver.
- Thermal : uniformly distributed / white noise.
- Intermodulation : sum and difference of original frequency sharing a medium.
- Impulse : short duration / high amplitude / irregular spike / minor to analog, major to digital
- Crosstalk. : one line pick up by another signal.
  - occured on PCB & twisted-pair cable

NEXT : near end FEXT : far end.

▲ measure of the ability of the cabling to reject crosstalk.

Capacity

- maximum possible data rate on communication channel.
- function of data rate, bandwidth, noise, error rate
- limit due to physical properties

Nyquist Formula

- no noise included in formular
- increase rate by increasing signal at cost of receiver complexity
- band width B, highest data rate is 2B

$$C = 2B \log_2 M$$

C = capacity (bps / Bps)
B = channel bandwidth (Hz)
M = signal level.

Shanon Capacity Formula

- faster data rate, shorten bits, burst noise affects more bits
- included noise in formula
- noise calculated as decibel (dB)
- SNR = signal to noise ratio

$$SNR_{dB} = 10 \log_{10}(SNR)$$ (SNR: unitless)

SNR_{dB} = in decible

$$C = B \log_2 (1 + SNR)$$

C = capacity
B = bandwidth

- spectrum width = bandwidth

DES232 / Lecture 4 : Transmission Media

Data Rate & Distance Factors

- Bandwidth : Higher bandwidth gives higher data rate.
- Transmission impairments : attenuation, other impairments limit the distance
- Interference : Overlapping frequency bands ; distort or wipe out a signal
- Number of Receivers : more receivers = more attenuation.

Twisted Pair

- least expensive
- most widely used guided medium
- separately insulated / twisted together
- mostly used w/in buildings & LAN

Each Pair Cable / Type of twisted pair

S : Shield F : Foiled U : Unshielded

ex SF/UTP : Shield & foiled w/ unshielded TP

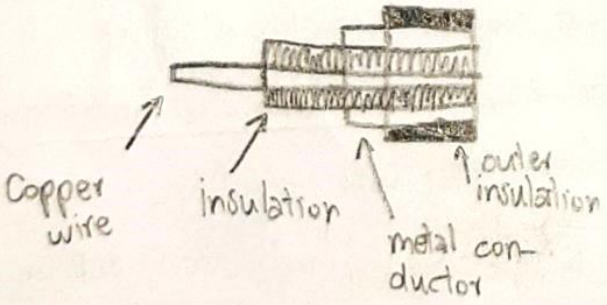
* Shielded = metal braid.

S & F provide protection ex EMI / RFI

- Cat 5e : UTP / 100 MHz , Cat 6 : UTP, FTP / 250 MHz
- Insertion loss = loss of signal when traveling in & out of circuit / component (dB)
- NEXT loss = near-end crosstalk (dB) / Greater NEXT loss magnitude = less crosstalk noise
- ACR = attenuation to crosstalk ratio = received strength of signal over amount of crosstalk
- mostly telephone line (voice & data channel) / DSL (digital subscriber line)

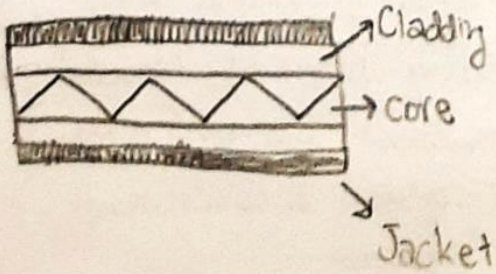
Coaxial Cable

- can be used over long distances & supported more station on shared line

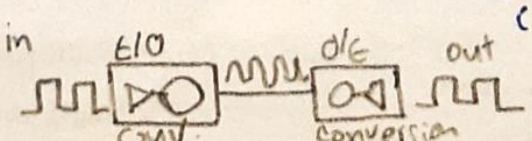


- transmission characteristic.
  - Analog : Amplifer every few km, spectrum upto 500 MHz
  - Digital : Repeater every 1km
  - frequency superior than TP / performance limit by attenuation.
- mostly used in LAN, short distance / TV distribution

Optical Fiber Cable



- used over long distance communication / VDO / Broadband
- greater capacity / smaller size / lighter weight / lower attenuation / electromagnetic isolation / greater repeater spacing (less is needed)



Wireless Transmission

Microwave Frequency (1 GHz ~ 40 GHz)

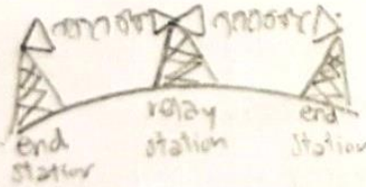
- Antenna :- made up of metal conductor, convert electric to electromagnetic
  - electrical energy from transmitter is converted into electromagnetic energy by antenna & radiated to surrounding
  - reception occurs when signal intersects the antenna
  - types: Monopole / Dipole / Yagi / Loop / Bowtie / Dish
  - Radiation Pattern - 1) Directional & Omnidirectional
    2) Parabolic antenna: use parabolic reflector.
    3) Isotropic Antenna: sphere, all direction equally.
  - Antenna Performance? (criteria)
    1) Ability to convert w/ little loss as possible
    2) Ability to transmit as much as possible in direction →

$$G_{dB} = 10 \log \left(P_2/P_1\right)$$

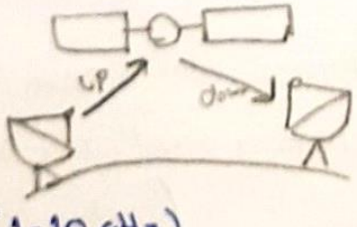
(gain; power antenna interest out; power antenna reference ant)

(indicator)
1) Radiation Pattern
2) Total Radiated Power
3) Total Isotropic sensitivity (TIS / avg. sensitivity)
4) Antenna Gain (measured in dB)
   - measure of directionality
   - increase power in direction is expense of other

- Terrestrial Microwave Transmission System (TMTS)
  - long-hual communication / both voice & TV Transmission
  - fewer repeater but require LoS (line of sight)
  - main loss is attenuation by distance / weather / interference. (frequency & strength.)
  - higher band (GHz), higher Data rate (Mbps)
  - Relay tower as extend. signal.



- Satellite Microwave Transmission System (SMTS)
  - use satellite in geostationary orbit (GEO) 36k km over ea
  - operates w/ satellite as repeaters, receiving antenna, transponder / transmitte
  - receive on one frequency band, amplifies/repeat on to another
  - Uplink: ground-to-sat, downlink: sat-to-ground.
  - Application: GPS / Long-distance tel. / Starlink / Private co



(1-10 GHz)
- main loss is attenuation by frequency & power
- required proper alignment w/ earth station.
- use satelite as expansion

↳ 14 ~ 14.5 : Up (12/14 band)
11.7 ~ 12.2 : Down

Broadcast Radio. (30 MHz ~ 1GHz)

- electromagnetic radiation
- Covers FM Radio, Data Network, Television band (UHF/VHF)
- broadcast radio is omnidirectional, microwave is directional
- limited to LoS / suffered from multipath interference/Refraction

Infrared (IR)

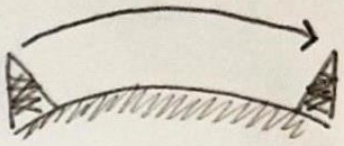
- transceiver must be w/in LoS by directly or reflection
- not penetrate wall / no licensing / no frequency allocation issue

Signal Propagation.

- Sky wave (SW) / Ground wave (GW) / Line of sight (LoS)

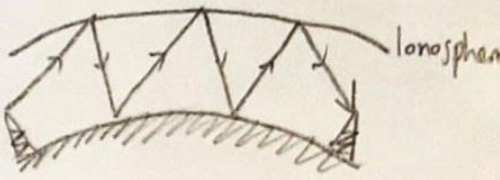
Ground wave propagation.

- follows earth contour line, over visual horizon
- frequency upto 2MHz, ex AM Radio.



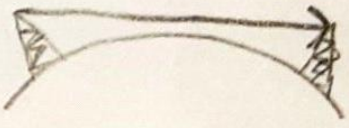
Sky wave propagation.

- from earth antenna to ionized layer in Ionosphere and back down to earth
- travel through a lot of hops & bouncing
- used for amateur radio & international broadcast



Line of sight (LoS)

- GW & SW don't operate above 30 MHz



- free space loss: loss signal w/ distance
- Atmospheric Absorption: from vapor & oxygen absorption.
- Multipath: Multiple interfering signal from reflections.
- Refraction: Bending signal away from receiver.

Refraction (change when medium change)

Reflection (bounce)

Diffraction (change when passed through opening ex. slit)

* Index of refraction.

$$n_1 \sin(\theta_1) = n_2 \sin\theta_2$$

- gradual bending; density of atmosphere decrease w/ height which toward the earth.

DES232 / Lecture 5: Signal Encoding Techniques.

Signal Interpretation

- timing of bits & signal level must be known
- SNR, data rate, bandwidth, encoding scheme affect interpretation.

conversion

from \ to	analog	digital
analog	modulate ana.	digitizing.
digital	modulate dig.	encoding.

Encoding

→ embedding clock into data stream

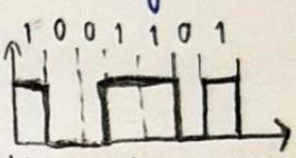
→ transmitter for encoding, receiver from decoding

* must encode data into signals to send them.

Digital-to-Digital Encoding

- as sequence of voltage pulse
- 2 parameters: amplitude & duration
- bit rate ↑, bit duration ↓
- 3 common methods: unipolar, polar, bipolar

→ Unipolar



- only [1] binary state will be encoded by only 1 voltage level.

* Problems

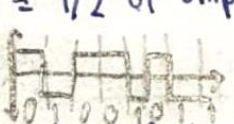
① DC comp. in Unipolar encoding
- avg. amplitude is nonzero → DC shifts thus cannot travel on medium.

② Synchronization → diff. timing/bit duration.
- may cause problems in error detection & recovery from long 0's & 1's w/o transit.

→ Polar. Encoding

- uses two levels amplitude (+ & -)
- eliminates DC residual problem.
- power to transmit signal = 1/2 of unipolar.

#1 → NRZ-L (level)



↳ dependent upon the state of the bit.

→ 0 = high level, 1 = low level

#2 → NRZ-I (invert on one)

↳ signal is inverted if 1 is encounter.

↳ provide more synchronization than NRZ-L

→ 0 = no transition at beginning of interval,
1 = transition at begining of interval.

#3 → RZ (return to zero)

- Positive Voltage = 1, Negative Voltage = 0
- return to zero halfway into the bit interval

→ Biphase Encoding

#4 → Manchester

- self-clocking, transition at middle of bit.

→ 0 = ⌐¬, 1 = ¬⌐

#5 → Differential Manchester

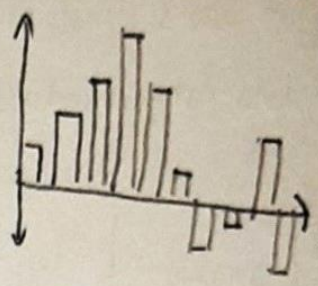
↳ if next bit = 0, transition at beginning

↳ if next bit = 1, no transition at beginning of a bit cell.

Analog-to-Digital Encoding

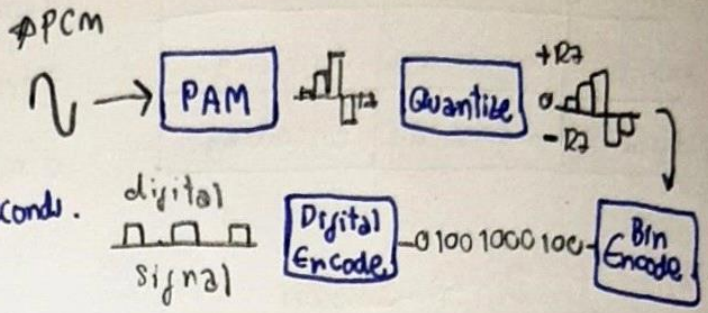
→ Pulse Amplitude Modulation (PAM)

- Sample analog & generate pulse based on sampling
- Sampling measures the amplitude at equal intervals.



→ Pulse Code Modulation (PCM)

- 3-4 processes to create digital signal.
- Sampling rate - 2x the highest frequency/seconds.



Digital-to-Analog Encoding

- modem converts digital-to-analog
- bit rate & baud rate. → container-like.
  - ↳ bits/seconds
  - ↳ signal unit/second.
- high frequency as a basis for info signal
- encoded by modulate signal A, f, ∅
- → Bits rate = baud rate * # of bit/baud.

→ ASK: Amplitude shift keying

- highly susceptible to noise. interference, lower A = 0
- bit rate = baud rate = minimum bandwidth, higher A = 1

→ FSK: frequency shift keying

- not problematic to noise b/c doesn't care about spike.
- lower f = 0, higher f = 1

+ Nyquist's theory's signal le
= number of bits in baud.

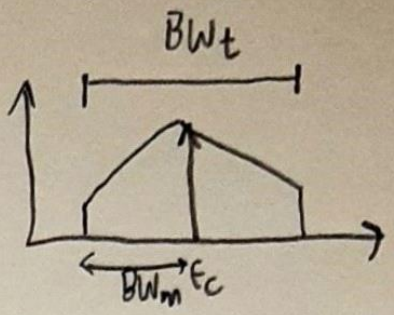
→ PSK: Phase-shift keying

- limit potential bit rates
- difference b/w 2 waves is the delay
- detect phase change

→ QAM: Quadrature Amplitude Modulation = ASK + PSK

- higher level signal & signaling of QAM, have longer symbol.
- allow higher-bit rate w/ same bandwidth; 64-QAM, 256 is common

Analog-to-Analog Encoding



1) AM: Amplitude Modulation

→ carrier signal is modulated, amplitude varies w/ changing amplitude

→ bandwidth = 2 × bandwidth of modulating signal, canter aroud carrier f.

→ minimum bandwidth = 10 kHz

2) Frequency Modulation: FM

*need buffer blw station

→ frequency of carrier signal is modulated, follows changing amplitude of signal

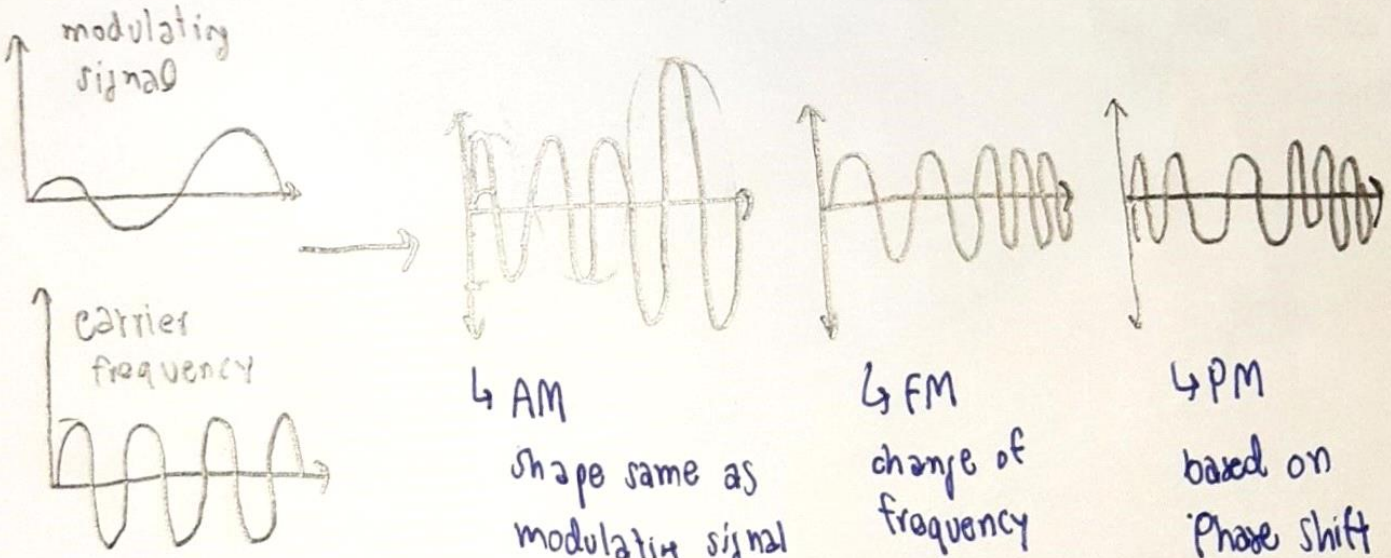
→ bandwidth = 10 × bandwidth of modulating signal. → min BW = 200 kHz

3) Phase Modulation (PM)

→ Phase is modulated by changing amplitude of modulating signal.

→ alternative to FM

→ use ful for many digital transmission coding schema.



↳ AM
shape same as modulating signal

↳ FM
change of frequency
(↑higher → ↑higher)
A f

↳ PM
based on phase shift