INTEGRATED TECHNICAL EDUCATION CLUSTER
AT ALAMEERIA

E-626-A
Data Communication and Industrial Networks (DC-IN)

Lecture #5
Modulation, Signal Encoding and Errors

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SPRING 2015

Agenda

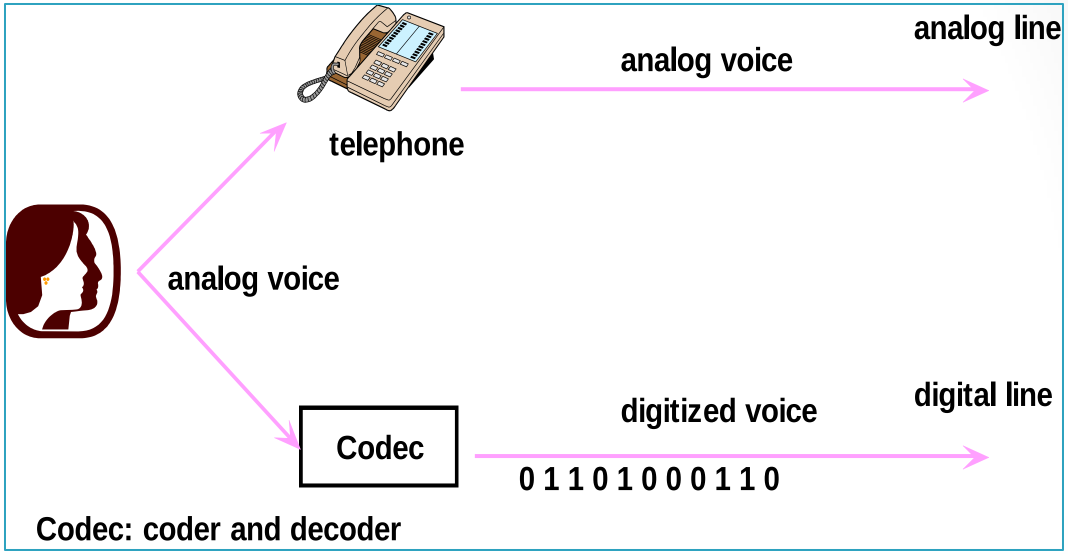
- Modulation
- Signal Encoding
- Error Detection
- Error Control

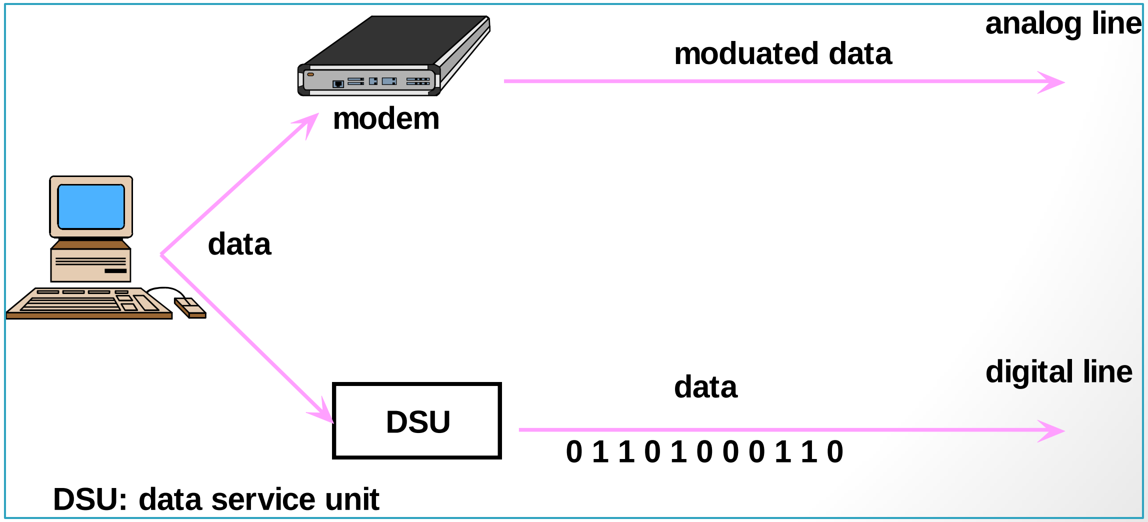
MODULATION

Data Communication Basics

- Analog or Digital
- Three Components
  - Data
  - Signal
  - Transmission

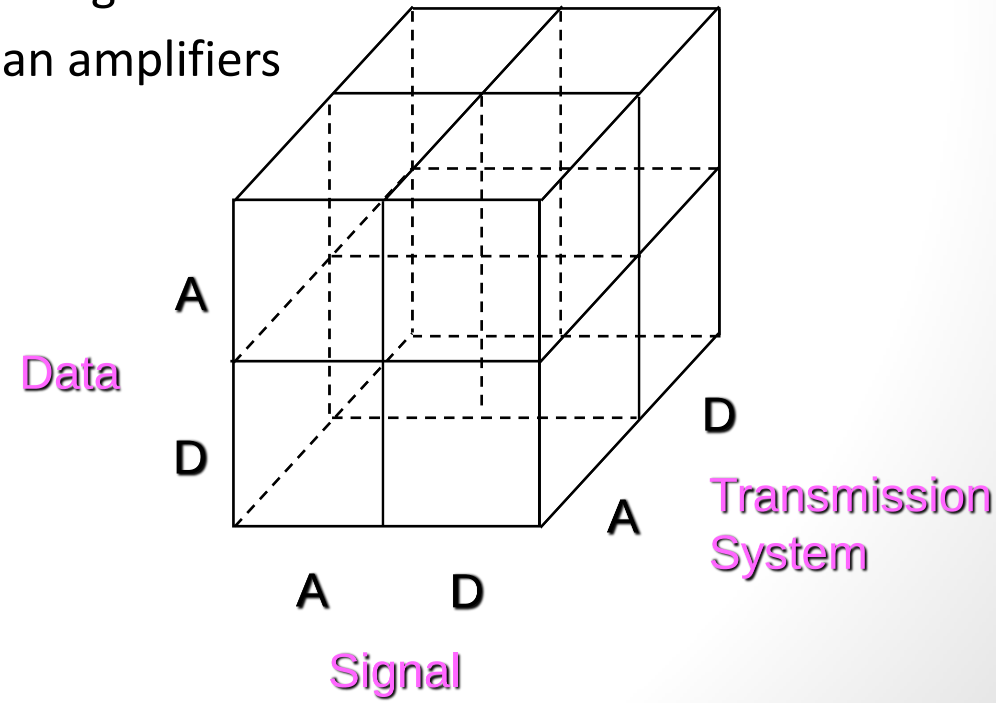
- Analog Data Choices
- Digital Data Choices





Transmission Choices

- Analog transmission
  - only transmits analog signals, without regard for data content
  - attenuation overcome with amplifiers
- Digital transmission
  - transmits analog or digital signals
  - uses repeaters rather than amplifiers



Digital Transmission Advantages

- The signal is exact
- Signals can be checked for errors
- Noise/interference are easily filtered out
- A variety of services can be offered over one line
- Higher bandwidth is possible with data compression

Analog Encoding of Digital Data

- data encoding and decoding to represent data using the properties of analog waves
- modulation: the conversion of digital signals to analog form
- demodulation: the conversion of analog data signals back to digital form

Modem

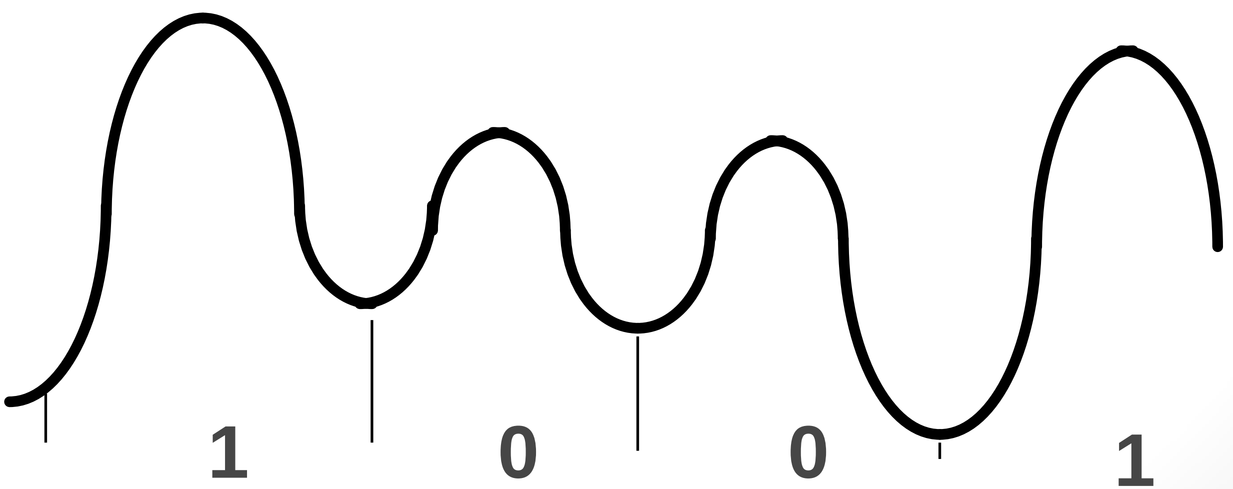
- an acronym for modulator-demodulator
- uses a constant-frequency signal known as a carrier signal
- converts a series of binary voltage pulses into an analog signal by modulating the carrier signal
- the receiving modem translates the analog signal back into digital data

Methods of Modulation

- amplitude modulation (AM) or amplitude shift keying (ASK)
- frequency modulation (FM) or frequency shift keying (FSK)
- phase modulation or phase shift keying (PSK)

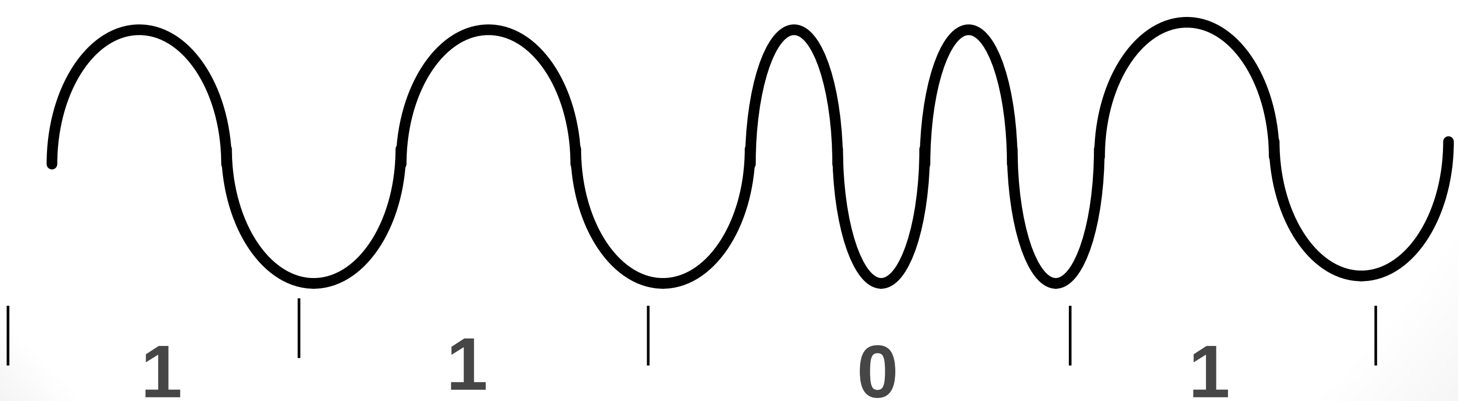
Amplitude Shift Keying (ASK)

- In radio transmission, known as amplitude modulation (AM)
- the amplitude (or height) of the sine wave varies to transmit the ones and zeros
- Up to 1200 bps over voice-grade lines
- major disadvantage
  - telephone lines are very susceptible to variations in transmission quality that affect amplitude



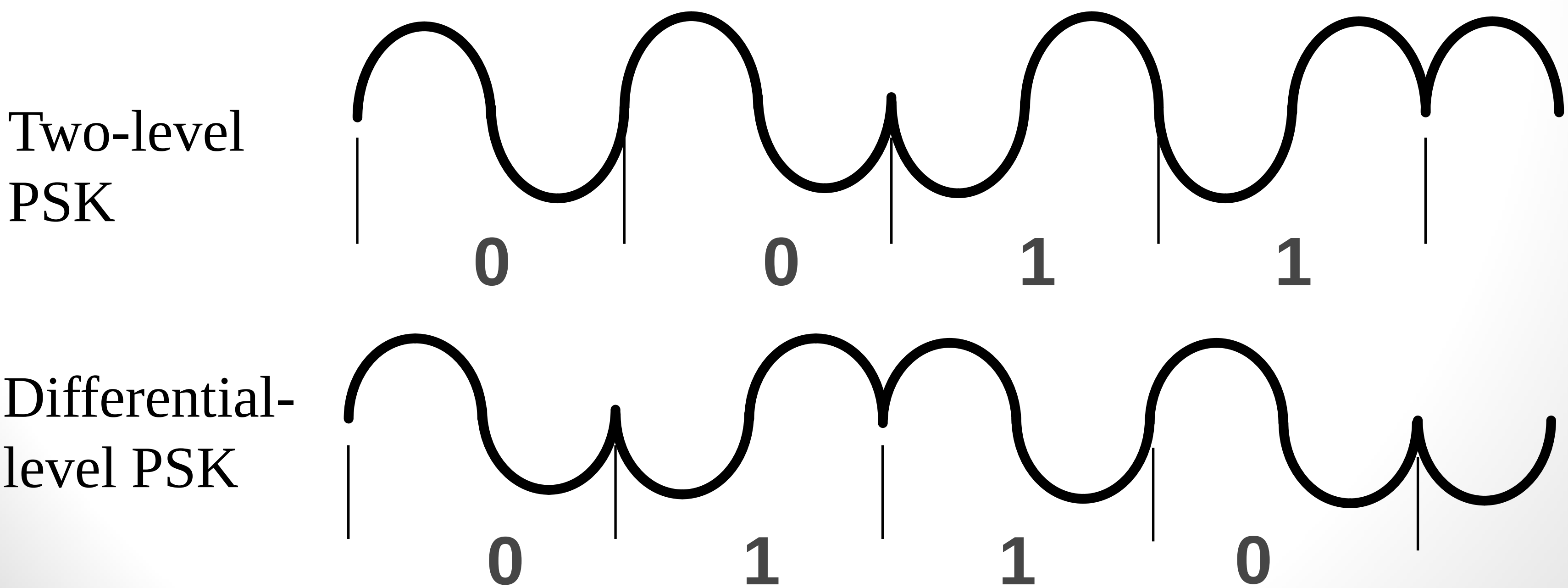
Frequency Shift Keying (FSK)

- in radio transmission, known as frequency modulation (FM)
- the frequency of the carrier wave varies in accordance with the signal to be sent
- signal is transmitted at constant amplitude
- more immune to noise than ASK
- requires more analog bandwidth than ASK
- still up to 1200 bps on voice-grade lines



Phase Shift Keying (PSK)

- also known as phase modulation (PM)
- frequency and amplitude of the carrier signal are kept constant
- the carrier is shifted in phase according to the input data stream
- each phase can have a constant value, or value can be based on whether or not phase changes (differential keying)



Complex Modulations

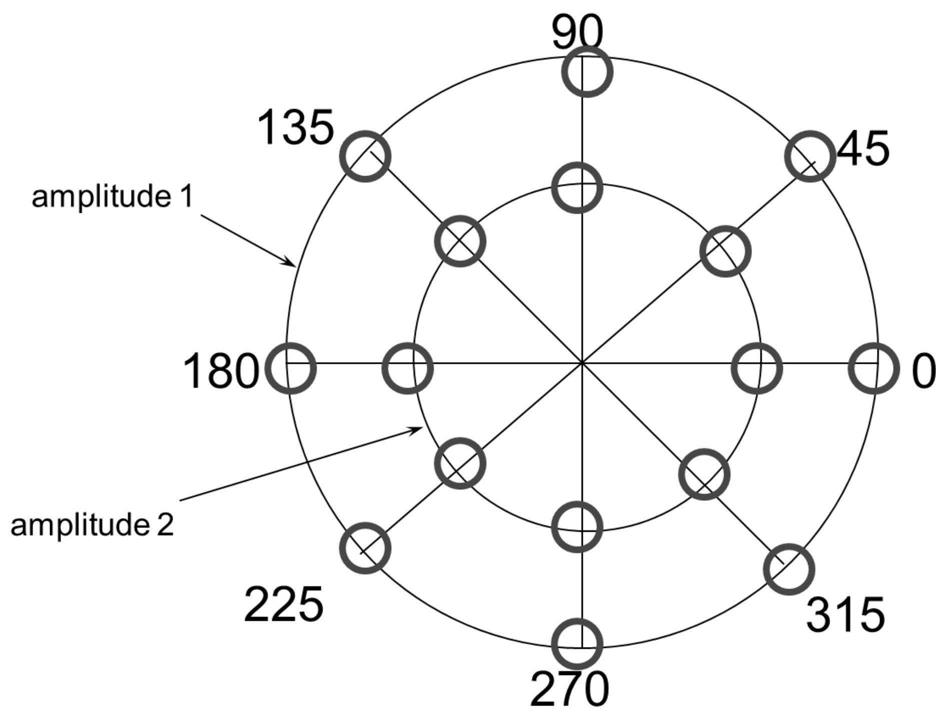
- Combining modulation techniques allows us to transmit multiple bit values per signal change (baud)
- Increases information-carrying capacity of a channel without increasing bandwidth
- Increased combinations also leads to increased likelihood of errors
- Typically, combine amplitude and phase

Multilevel PSK

- Can extend levels beyond one bit at a time
- 9600 bps modem
  - 12 different phase angles
  - 4 of them use two different amplitude values (ASK)
  - 16 different signal types – 4 bits per signal type
  - 9600 bps modem / 4 bits per signal type
  - 2400 baud modem (signaling speed)

Quadrature Amplitude Modulation (QAM)

- the most common method for quadbit transfer
- combination of 8 different angles in phase modulation and two amplitudes of signal
- provides 16 different signals, each of which can represent 4 bits



SIGNAL ENCODING

Digital Encoding of Analog Data

- Uses pulse-code modulation (PCM)
- The sampling theorem:
  - If a signal *f*(*t*) is sampled at regular intervals of time and at a rate higher than twice the highest signal frequency, the samples contain all the information of the original signal.
- 8000 samples/sec sufficient for 4000 Hz

Converting Samples to Bits

- Quantizing (similar concept to pixelization)
- Breaks wave into pieces, samples it, and assigns a value in a particular range
- More bits per sample means greater detail, fewer bits means less detail
- 8-bit range allows for 256 possible sample levels
  - Quality of recovered voice comparable to analog
- 8000 samples/sec * 8 bits/sample = 64 kbps

Codec

- Coder/Decoder
- converts analog signals into a digital form and converts it back to analog signals
- e.g. television
  - 4.6 MHz bandwidth signal (9.2 M samples per sec)
  - 10-bit codes
  - 92 Mbps data
- Repeaters instead of amplifiers
  - No cumulative noise

Digital Encoding of Digital Data

- Most common, easiest method is different voltage levels for the two binary digits
- Typically, negative=1 and positive=0
- Known as NRZ-L, or non-return-to-zero level
  - signal never returns to zero, and the voltage during a bit transmission is level (constant)

Differential NRZ

- Differential version is NRZI (NRZ, invert on ones)
- Change=1, no change=0
- Advantage of differential encoding is that it is more reliable to detect a change in polarity than it is to accurately detect a specific level

Problems With NRZ:

- Difficult to determine where one bit ends and the next begins
- In NRZ-L, long strings of ones and zeroes would appear as constant voltage pulses
- Timing is critical, because any drift results in lack of synchronization and incorrect bit values being transmitted

Biphase Alternatives to NRZ

- Require at least one transition per bit time, and may even have two
- Modulation rate is greater, so bandwidth requirements are higher
- Advantages
  - Synchronization due to predictable transitions
  - Error detection based on absence of a transition

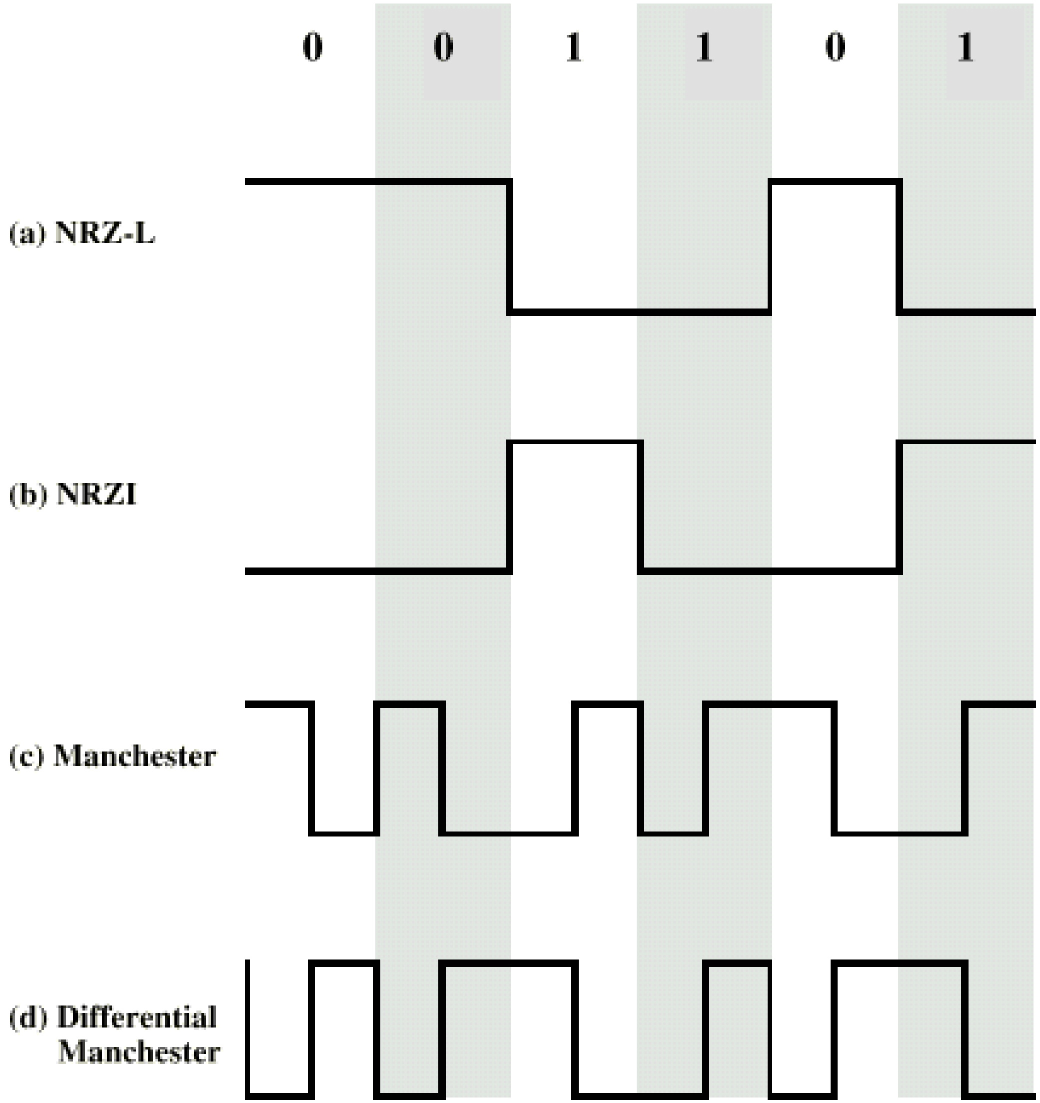
Manchester Code

- Transition in the middle of each bit period
- Transition provides clocking and data
- Low-to-high=1 , high-to-low=0
- Used in Ethernet

<u>Differential Manchester:</u>

- Midbit transition is only for clocking
- Transition at beginning of bit period=0
- Transition absent at beginning=1
- Used in token-ring

Digital Encoding Schemes

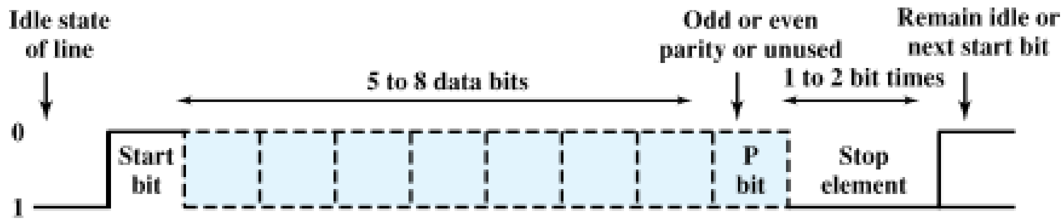


Asynchronous & Synchronous Transmission

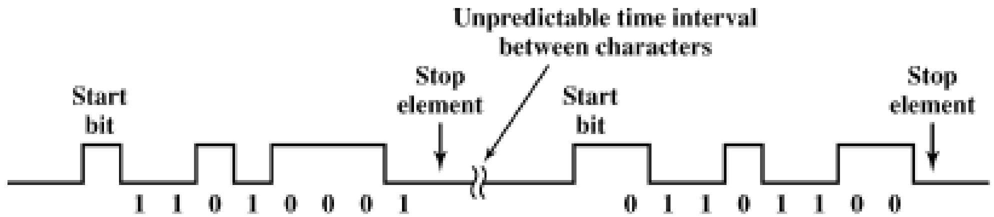
- Concerned with timing issues
- How does the receiver know when the bit period begins and ends?
- Small timing difference become more significant over time if no synchronization takes place between sender and receiver

Asynchronous Transmission

- Data transmitted
  1 character at a time
- Character format is
  1 start & 1+ stop bit, plus data
  (typically between 5 and 8 bits)
- Character may include parity bit
- Timing needed only within each character
- Resynchronization with each start bit
- Uses simple, cheap technology
- Wastes 20-30% of bandwidth
- Low-speed terminals and PCs commonly use asynchronous transmission



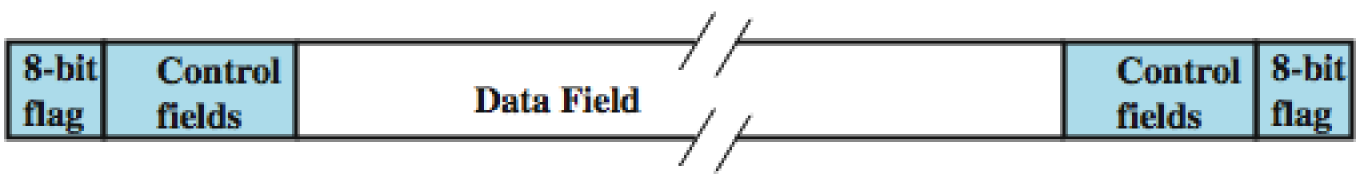
(a) Character format



(b) 8-bit asynchronous character stream

Synchronous Transmission

- Large blocks of bits transmitted without start/stop codes
- Synchronized by clock signal or clocking data
- Data framed by preamble and postamble bit patterns to establish timing
- More efficient than asynchronous
- Overhead typically below 5%
- Used at higher speeds than asynchronous
- Requires error checking



•Large systems and networks commonly use synchronous transmission

ERROR DETECTION & CONTROL

Errors

- An error occurs when a bit is altered between transmission and reception
  - binary 1 is transmitted and binary 0 is received or binary 0 is transmitted and binary 1 is received
- Single bit error
  - isolated error that alters one bit but not nearby bits
  - caused by white noise
- Burst error
  - contiguous sequence of *B* bits where first and last bits and any number of intermediate bits are received in error
  - caused by impulse noise or by fading in wireless
  - effects greater at higher data rates

Error Detection

- regardless of design you will have errors
- can detect errors by using an error-detecting code added by the transmitter
    - code is also referred to as "*check bits*"
- recalculated and checked by receiver
- still chance of undetected error

Parity Check

- parity
  - parity bit set so character has even or odd # of ones
    - even parity – used in synchronous transmission
    - odd parity – used in asynchronous transmission
  - even number of bit errors goes undetected
- problem
  - noise impulses often long enough to destroy more than one bit, especially at high data rates

Cyclic Redundancy Check (CRC)

- one of most common and powerful checks
- for a block of *k* bits, transmitter generates an *n*-bit frame by adding an (*n*-*k*)-bit frame check sequence (FCS)
- Transmits *n* bits which is exactly divisible by some predetermined number
- receiver divides frame by that number
  - if no remainder, assume no error

Error Control

- Two types of errors
  - Lost frame - never arrives or too error filled
  - Damaged frame - error in bits but recognizable
- Techniques involve
  - Error detection (e.g. CRC)
  - Positive acknowledgement – if error free
  - Retransmission after timeout – no ACK received
  - Negative acknowledgement and retransmission

ARQ

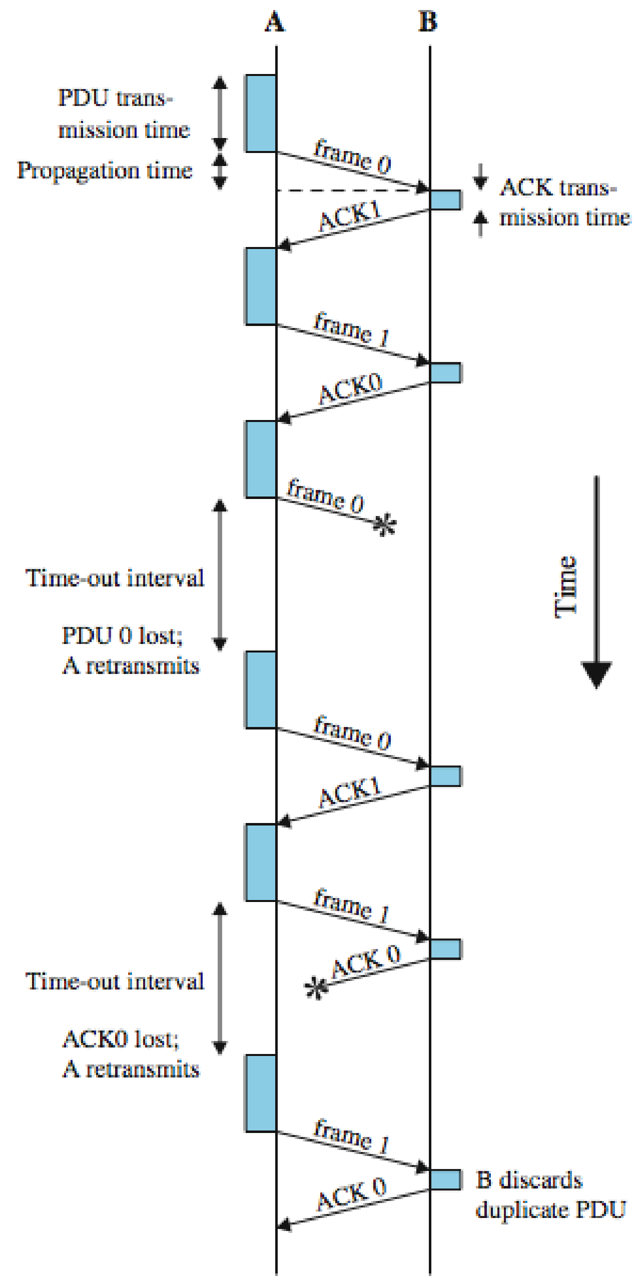
- Automatic Repeat reQuest (ARQ)
  - Collective name for error control techniques
  - Make potentially unreliable data link reliable
- Three versions
  - Stop-and-wait ARQ
  - Go-back-N ARQ
  - Selective-reject ARQ

Stop-and-Wait ARQ

- source transmits single frame
- waits for ACK
  - no other data can be sent until destination's reply arrives
- if frame received is damaged, discard it
  - transmitter has timeout
  - if no ACK within timeout, retransmit
- if ACK is damaged, transmitter will not recognize it
  - transmitter will retransmit after timeout
  - receiver will get two copies of same frame
  - use alternate frame numbering and ACK0 / ACK1 (one bit)

Stop and Wait ARQ

- Pros
  - Simplistic
- Cons
  - inefficient



Go-Back-N ARQ

- most commonly used error control
- based on sliding-window
  - use window size to control number of outstanding frames
- if no error, ACK as usual with frame number
- if error, reply with rejection REJ
  - destination will discard that frame and all future frames until frame in error is received correctly
  - transmitter must go back and retransmit that frame and all subsequent frames

Selective Reject ARQ

- also called selective retransmission
- only rejected frames are retransmitted
- subsequent frames are accepted by the receiver and buffered
- minimizes retransmission
- receiver must maintain large enough buffer
- more complex logic in transmitter
  - less widely used
- useful for satellite links with long propagation delays

- For more details, refer to:
  - Chapters 5,6 , W. Stallings, **Data and Computer Communications**, 8^{th} ed. .
- The lecture is available online at:
- Lecture notes are found at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12133
- For inquires, send to:
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