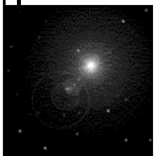
CS 4/54201 Computer Communication Network

Kent State University

Dept. of Computer Science

www.mcs.kent.edu/~javed/class-NET06F/



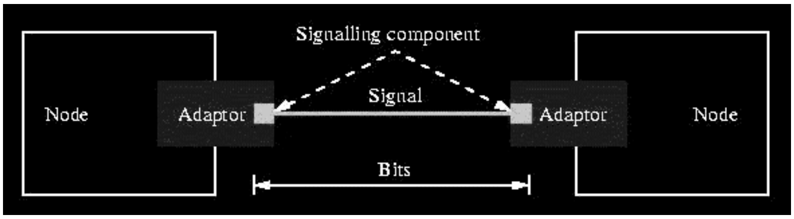
A Course on Networking and Computer Communication

RELIABLE TRANSMISSION
ENCODING & FRAMING ON SIGNALS

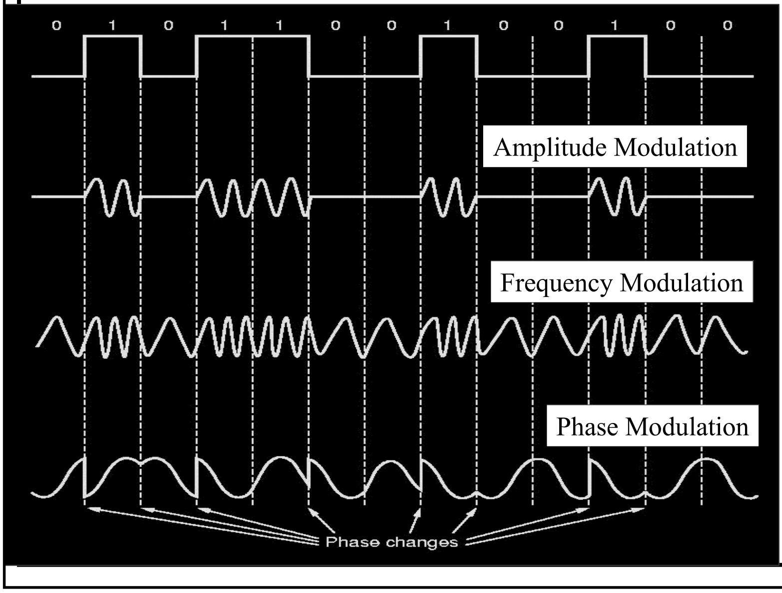
Topics

- Encoding Analog Signals on a Link
- Encoding Digital Bits on a Link
- Framing of Bits
- Coding bits for Error Correction and Detection

Signal Transmission

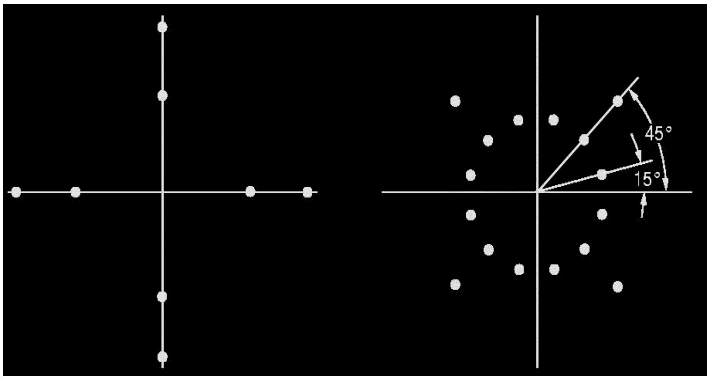


Modulation



- Square waves have a wide spectrum, and thus are subject to strong attenuation, delay distortion and noise.
- Thus DC signals are unsuitable.
- To get around this problem some form of AC is used.

Advanced Modems use Constellation Code



8 points (3 bits)

16 points (4 bits)

With 4 bit per baud 9600 bps can be sent over 2400-baud line

V.32 bis use 6 bits per sample at 2400 baud. Its constellation pattern has 64 points.

After v.32 comes V.34 which runs at 28,800 bps.

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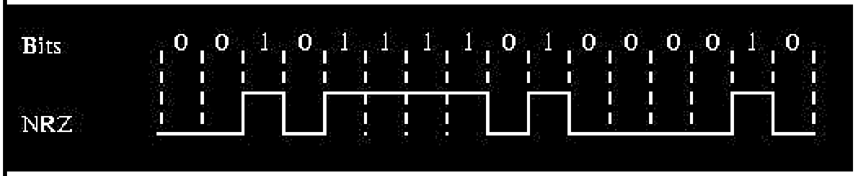
Binary Signal



<u>Problems with long sequence of 1's and 0s:</u>

- •Differentiate from long runs of 0s to deadline
- •Baseline signaling
- •Clock recovery

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NRZI and Manchester Encoding

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- NRZI
  - 0 => current level
  - 1=> change level
- Manchester
  - 0 => low to high
  - 1=> high to low
  - Ex-OR of NRZ and clock

NRZI and Manchester Encoding

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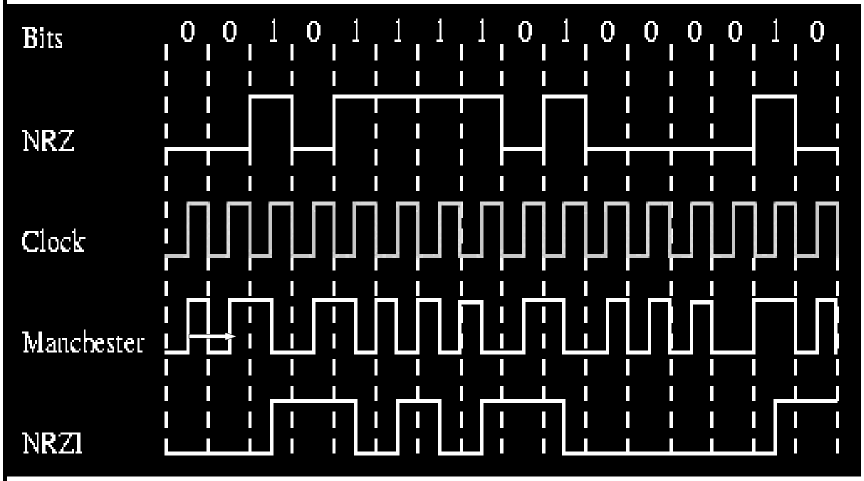

NRZI:

solves the problem of long 1’s

Manchester:

requires twice the baud rate.

4B/5B Encoding

4-bit Data	*5-bit Code*
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10011
1011	10110
1100	11010
1101	11011
1110	11100
1111	11101

- The code ensures that there is no more than one leading zero and no more than two trailing zeros. Thus there will never be more than three consecutive 0s.
- Of the possible 32 symbols, 16 are data, 7 are invalid, 11111 is idle, 00000 is dead and remaining 7 are other controls.

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Framing

- In computer networks data is not sent as a stream of bits rather they are further divided into blocks. Each block is known as Frame.
- Framing helps in
  - better utilization/sharing of links, and
  - efficient error handling.
- Recognizing what set of bits constitutes a Frame is the major computational task performed by Network Adapters.

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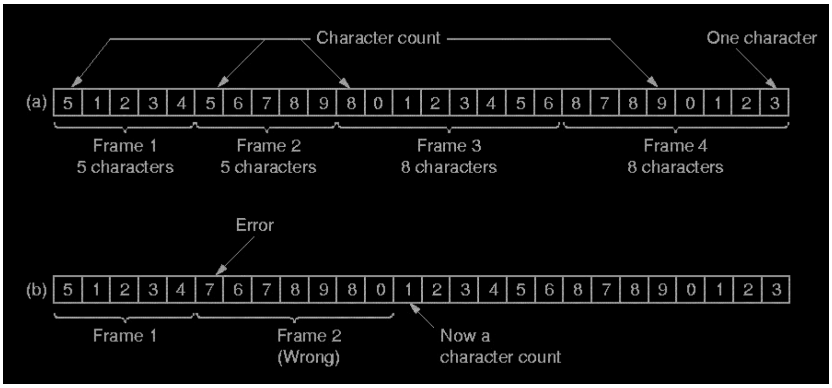
Byte-Counting Frames

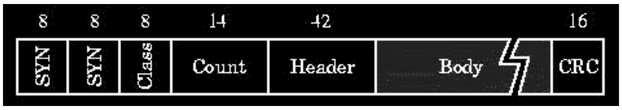
- A character stream without error and with one error



Sentinel Approach

- BISYNC (IBM 1960) Frame format

- IMP-IMP (ARPANET) Frame Format



- What if the Data itself has DLE or any special character?

Byte-Stuffing

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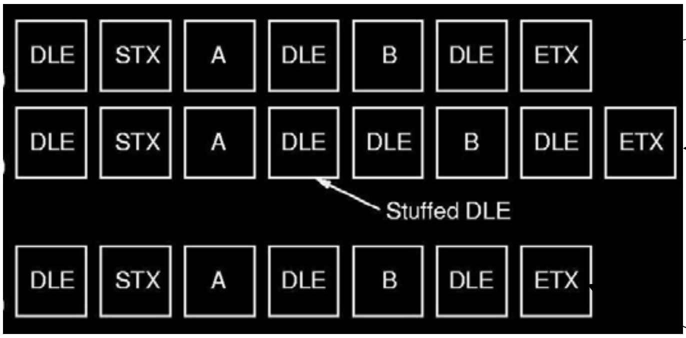

Data from Network Layer

Data after Character Stuffing

Dtata passed to network layer on the receiving side

Bit-Oriented Protocol

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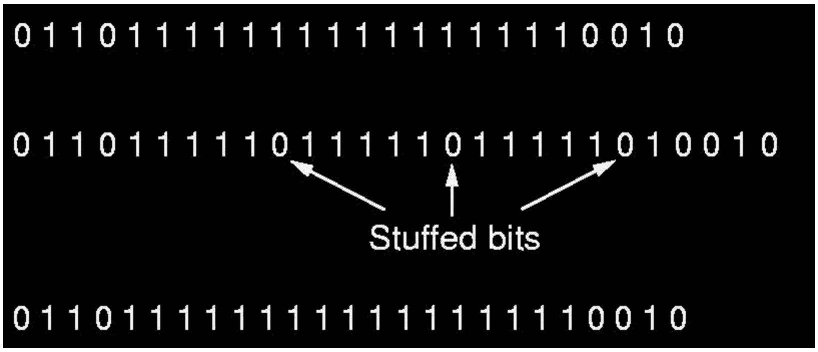
- A major disadvantage of the above protocol is that these are closely tied to 8-bit characters and ASCII codes.
- As networks developed, the disadvantages become obvious and new techniques developed which allows data frames to contain an arbitrary number of bits and character codes to be arbitrary number of bits per character.
- Example protocols are Synchronous Data Link Control (SDLC), High-level Data-Link Control (HDLC) and PPP.

Example HDLC

- Begin and End of Transmission is denoted by bit stream 01111110.
- It is also transmitted when the link is idle.
- Bit-Stuffing:



0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0

0 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 0 0 1 0

Stuffed bits

0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0

Error Detection and Correction

- Error correction is required in a network service.
- In some links such as on telephone line and on wireless networks links are noisy so some kind of mechanism is needed in the data-link layer to detect errors.
- In other links, like optical fibers the error rates are so low that error corrections can be done only at high levels.
- Errors handling requires transmission of some extra bits.

Errors generally happen in burst. As a result generally one or few consecutive packets are lost, while many packets remain good. But a sequence or errors are generally harder to detect.

Error-Correcting Codes

- Hamming Distance
  - The number of bit positions where two codes differs.
  - Example: 10001001+10110001= 00111000 = 3
- Check Bits
  - A Frame normally will have m data bits+ r check bits requiring n=m+r transmission bits.

Hamming Distance, Error Detection and Error Correction

- To Detect d-bit errors
  - we need a distance d+1 between code words, because with such a distance there is no way that an error can turn a valid code into another valid code.

Example: 0000000000, 0000011111, 1111100000, 1111111111

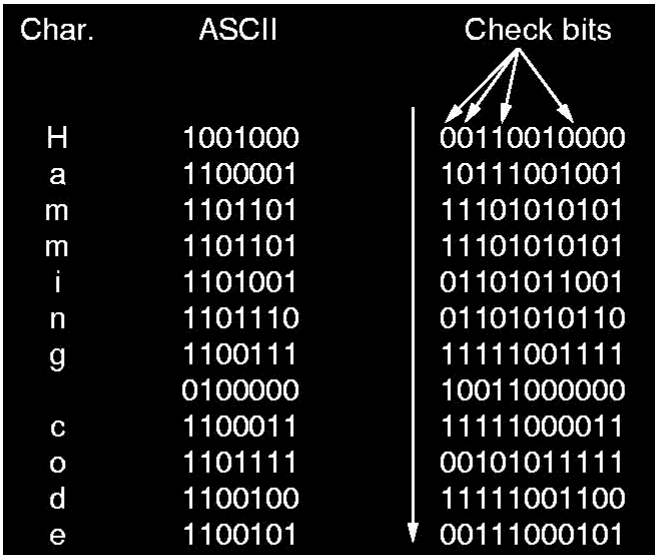
What is the distance? (5)
How many bit error it can correct? (2)
What is the correct code for received bit 0000000111?

- To Correct d-bit errors
  - we need a distance 2d+1 between code words, because with such a distance, with d bit error, the original code word is still closer than any other code word so that it can be uniquely determined.

How many check bits are needed to correct errors?

- Example (for single errors):
  - n= m message bits+r check bits
  - n+1 codes have be be reserved for each of 2^m valid codes.
  - $(n+1)2^m =< 2^n$
  - $(m+r+1) =< 2^r$
  - If m=7 then r=4
  - Hamming Code [Hamming 1950] can achieve this optimality.

Hamming Code



Char.	ASCII	Check bits
H	1001000	00110010000
a	1100001	10111001001
m	1101101	11101010101
m	1101101	11101010101
i	1101001	01101011001
n	1101110	01101010110
g	1100111	11111001111
	0100000	10011000000
c	1100011	11111000011
o	1101111	00101011111
d	1100100	11111001100
e	1100101	00111000101

- Number the bits 1,2,3,.. From left.
- Bits (1,2,4,8,16.. Are check parity bits.
- A bit may be included in several parity bit. Example bit 11=1+2+8, bit 29=1+4+8+16.
- Hamming code can only correct single error.
- A matrix arrangement can be used to correct burst error.

Error Detection

- Error detection can be performed with much less extra bits.
- These extra-bits plus occasional retransmission can be much efficient if errors are infrequent.

CRC Cyclic Redundancy Code

- Invented by Peterson [1961].
- It is a powerful method backed by field theory.
- Each code is considered as a polynomial with coefficients 0 or 1.
  - Example: 10011010 is $M(x)=x^7+x^4+x^3+x^1$
- Select a k-bit code and a divisor polynomial
  - Example k=3, code 111, $C(x)= x^3+x^2+x^1$

CRC Cyclic Redundancy Code

- The idea is to always transmit a polynomial P(x) which is exactly divisible by C(x).
- On the receiving end P(x)+E(x) (E(x) is error) will be received and divided by C(x).
- The result will be zero if there is no error or the error E(x) is also divisible by C(x).

- How to compute P(x) from M(x) and C(x)?
- How to make sure that E(x) is not divisible by C(X)?

How to Compute P(x)?

- Use the simple mathematics.
  - Multiply M(X) by ‘100’ (k-bit shift) get N(x).
  - Divide the multiplied value N(x) by C(x).
  - Compute reminder. Subtract the reminder from N(x).
- For a polynomial with , 1/0 coefficients the addition and subtraction is just EX-OR operation. Multiplication is simply left-shift.

Example

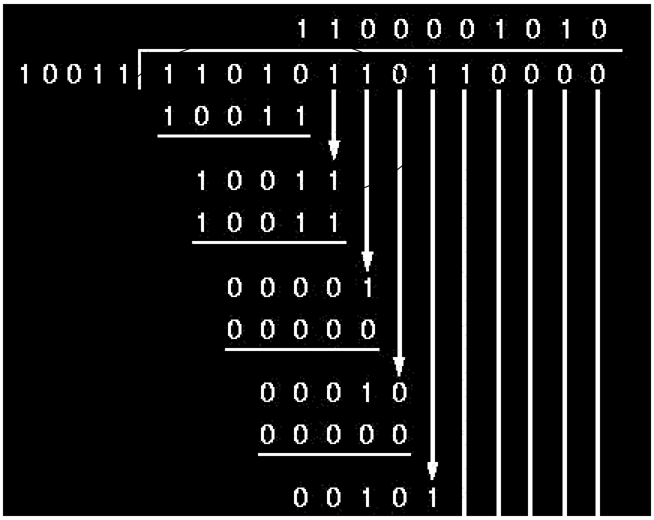
Frame : 1 1 0 1 0 1 1 0 1 1

Generator: 1 0 0 1 1

Message after appending 4 zero bits: 1 1 0 1 0 1 1 0 0 0 0

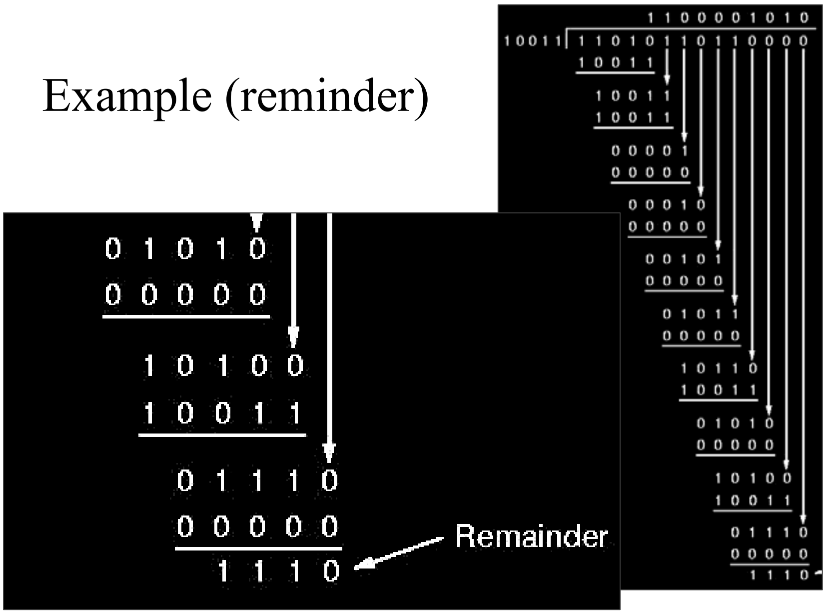
- P(x)
- C(x)
- N(X)

Example (divide)



```
                 1 1 0 0 0 0 1 0 1 0
10011 | 1 1 0 1 0 1 1 0 1 1 0 0 0 0
        1 0 0 1 1
          1 0 0 1 1
          1 0 0 1 1
            0 0 0 0 1
            0 0 0 0 0
              0 0 0 1 0
              0 0 0 0 0
                0 0 1 0 1
```

Example (reminder)



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Final Code

Frame : 1 1 0 1 0 1 1 0 1 1
Generator: 1 0 0 1 1
Message after appending 4 zero bits: 1 1 0 1 0 1 1 0 0 0 0

Reminder: 1110

Transmitted frame: 1 1 0 1 0 1 1 0 1 1 1 1 1 0

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How to Select a Good C(x)?

- If C(x) has at least two terms all single-bit errors will be detected.
- If C(x) has at least one factor with three terms, all double-bit errors will be detected.
- Any odd number of errors will be detected as long as C(x) has a factor (x+1).
- Any burst error will be detected for which the length of any burst is less than k.

How to Select a Good C(x): Proofs

- If C(x) has at least two terms all single-bit errors will be detected.
  - $E(x)/G(x)$ cannot be zero if $E(x)= x^i$
- If C(x) has at least one factor with three terms, all double-bit errors will be detected.
  - For two bit-errors $E(x)=(X^i+X^j)=X^i(X^{i-j}+1)$,
  - Thus, all two bit errors will have factors with at most two terms.
  - Any G(x) with three terms will not divide by X^k or $(X^{kj}+1)$

How to Select a Good C(x): Proofs

- Any odd number of errors will be detected as long as C(x) has a factor (x+1).
  - No modulo 2 polynomial exists which has odd number of terms and divides by (x+1)
  - If there is one , then it will be $E(x)=(x+1)\,Q(x)$ and $E(1)=(1+1)\,Q(x) \bmod 2 = 0$,
  - If E(x) has odd number of terms then then E(I)= 1+ 1 ..+1 (odd number of ones) =1
- Any burst error of length will be detected for which the length of any burst is less than k bits.
  - For burst error < k bits at ith location from right $E(x)=x^i(x^{k-1}+..+1)$. It is not divisible by G(x) which has last term 1 and the first term x^k

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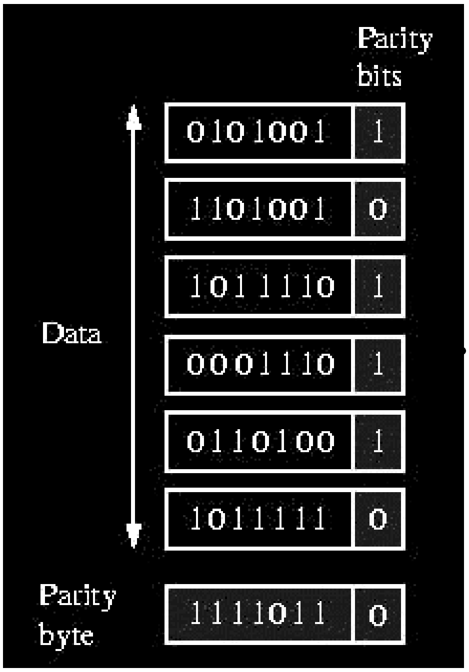
Some Common C(x)

CRC-8:	$X^8+X^2+X^1+1$
CRC-10:	$X^{10}+X^9+X^5+X^4+X^1+1$
CRC-12	$X^{12}+X^{11}+X^3+X^2+X^1+1$
CRC-16:	$X^{16}+X^{15}+X^2+1$
CRC-CCITT:	$X^{16}+x^{12}+X^5+1$

- Peterson and Brown [1961] also discovered than this seemingly complex scheme can be implemented by very simple hardware with X-OR and shift register.
- This is the most commonly used Error Handling mechanism in Networking.
- Six versions of CRC are widely used in link-level protocols. Ethernet and FDDI networks use CRC-32. HDLC use CRC-CCITT. ATM use CRC-8 and CRC-10.



Data	Parity bits
0101001	1
1101001	0
1011110	1
0001110	1
0110100	1
1011111	0
Parity byte: 1111011	0

Two-Dimensional Parity

- It can catch 1,2,3 and most 4 bit errors.

NEXT CLASS
RELIABLE TRANSMISSION
FLOW CONTROL