

CSc 450/550 Computer Networks Link Layer

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Summer 2006

7/13/06

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1

Review

- Application layer
 - HTTP, DNS
- Transport layer: segment
 - TCP, UDP
- Network layer: packet
 - IP, routing protocols
- Link layer

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2

Link layer

- Service provided to network layer
 - frame delivery
 - flow control
 - error control
 - medium access (with shared medium)
- Service provided by physical layer
 - bit delivery
 - hertz, baud, symbol-per-second, bit-per-second

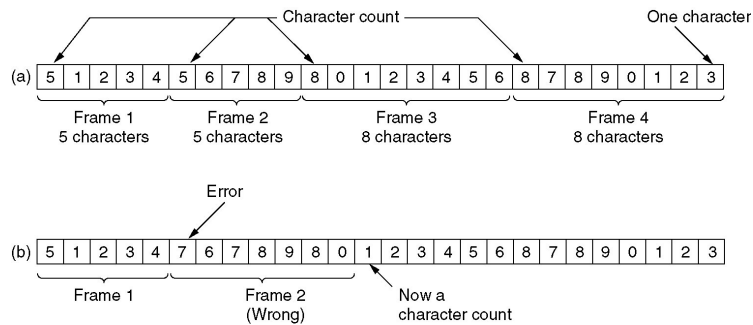
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3

Byte-oriented framing

- Character count
 - count error, and error propagation



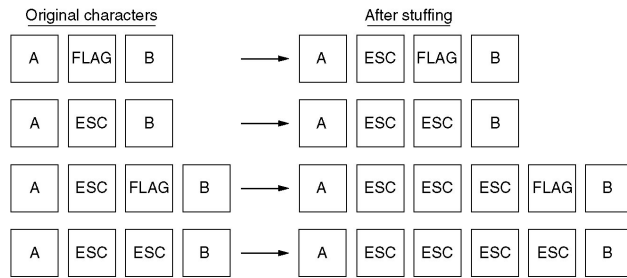
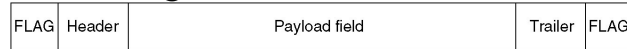
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4

Byte-oriented framing: more

- Byte stuffing



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5

Bit-oriented framing

- Flag: 01111110

– data transparency: bit stuffing

- sender: insert a 0 after 5 1's
- receiver: remove a 0 after 5 1's

(a) 0110111111111111111111110010

(b) 011011111011111011111010010

↑
Stuffed bits

(c) 0110111111111111111111110010

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6

Error control

- Hamming distance of codeword a and b
 - number of *pairwisely* different bits
 - number of bit flips needed to turn a to b
- Hamming distance of codeword set $\{a_i\}$
 - minimal distance btw a_i and a_j , when $i \neq j$
- A cordword set of Hamming distance d
 - detect up to $d-1$ bit error
 - correct up to $\text{floor}(d/2)$ bit error

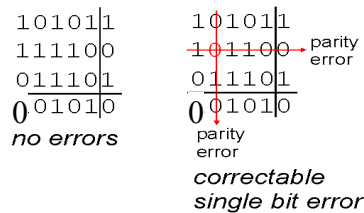
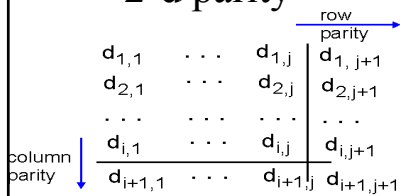
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7

Error correcting

- 2-d parity



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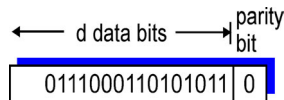
- Hamming code

Char.	ASCII	Check bits
H	1001000	00110010000
a	1100001	10111001001
m	1101101	11101010101
m	1101101	11101010101
i	1101001	01101011001
n	1101110	01101010110
g	1100111	01111001111
c	0100000	10011000000
c	1100011	11111000011
o	1101111	10101011111
d	1100100	11111001100
e	1100101	00111000101

Order of bit transmission

Error detecting

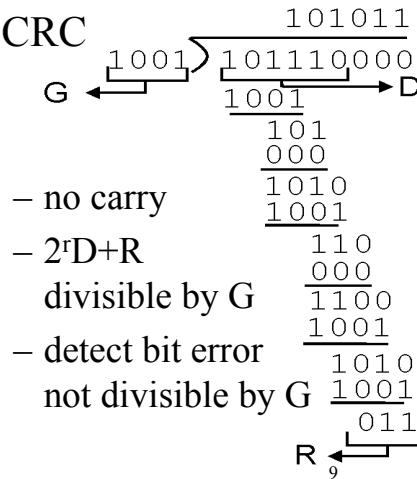
- Parity



- Checksum

- 1's complement of 1's complement sum
- with carry bit

- CRC



- no carry
- $2^D + R$ divisible by G
- detect bit error not divisible by G

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Error recovery

- Positive acknowledgment

- cumulative acknowledgment
 - acknowledge packet x: acknowledge packets 1..x
 - when timeout, go-back-N
- selective acknowledgment
 - acknowledge packet x: packet x is received OK
 - when timeout, selective repeat

- Negative acknowledgment

- report: x is corrupted or *missing*

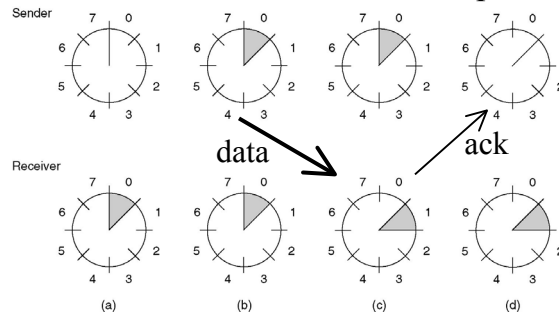
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10

Flow control

- Sliding window
 - e.g., window size = 1, sequence space = 8
 - maximal window size $\leq 1/2$ sequence space



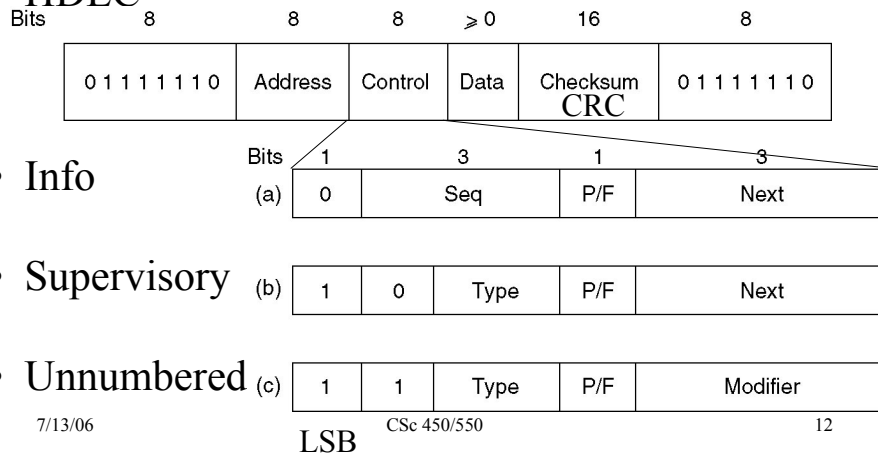
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11

High-level data link control

- HDLC



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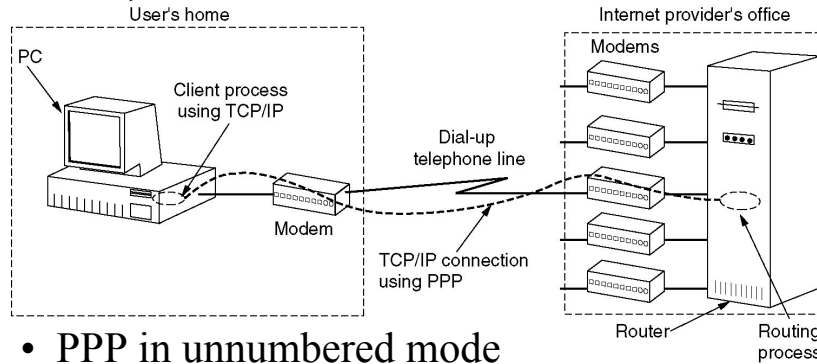
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12

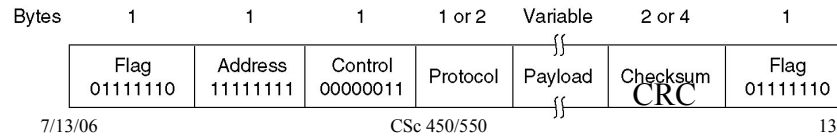
LSB

Point-to-point protocol

- PPP, PPPoE



- PPP in unnumbered mode



This lecture

- Link layer
 - framing
 - error control
 - error correcting, error detecting, error recovery
 - flow control
 - sliding window
 - HDLC, PPP

Next lecture

- Medium access control
 - read CN Chapter 4