CS5222 Computer Networks and Internets Tutorial 11 (Week 11)

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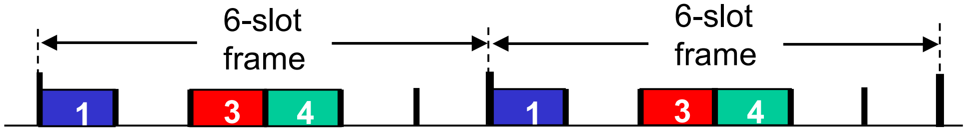
Slides based on book *Computer Networking: A Top-Down Approach.*

Revision

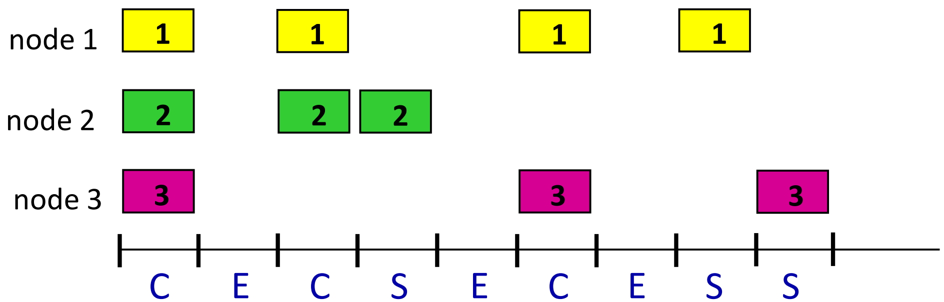
Channel partitioning MAC protocols: TDMA

TDMA: time division multiple access

- access to a shared channel in "rounds"
- each station is assigned a fixed length slot (slot length = a packet transmission time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have packets to send, slots 2,5,6 idle



Slotted ALOHA



C: collision
S: success
E: empty

Pros:
- single active node can continuously transmit at the full rate of channel
- highly decentralized: only slots in nodes need to be in sync
- simple

Cons:
- collisions, wasting slots
- idle slots
- nodes may be able to detect collisions in less than time to transmit packet
- clock synchronization

Slotted ALOHA: efficiency

Efficiency: long-run fraction of successful slots (many nodes, all with many frames to send)

- *Assumptions:* N nodes with many frames to send, each node transmits in a slot with probability p
  - prob that a given node has a success in a slot $= p(1-p)^{N-1}$
  - prob that *any* node has a success $= Np(1-p)^{N-1}$
  - **maximum efficiency**: find a p that maximizes $Np(1-p)^{N-1}$
  - $\rightarrow p = 1/N$
  - for many nodes, take limit of $Np(1-p)^{N-1}$ as N goes to infinity, gives:

max efficiency = 1/e = .37

- *at best:* channel used for useful transmissions 37% of time!

Pure ALOHA efficiency

P(success by given node) = P(node transmits) $\cdot$

P(no other node transmits in $[t_0\text{-}1,t_0]$ $\cdot$

P(no other node transmits in $[t_0,t_{0+1}]$

$$= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1}$$

$$= p \cdot (1-p)^{2(N-1)}$$

… choosing optimum p and then letting $n \rightarrow \infty$

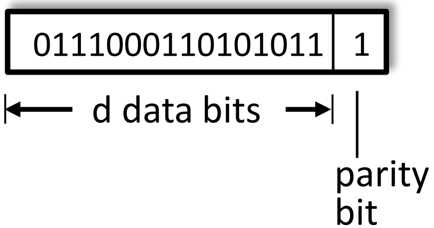
$$= 1/(2e) = \mathbf{0.18}$$

→ worse than slotted Aloha!

Parity checking

single bit parity:

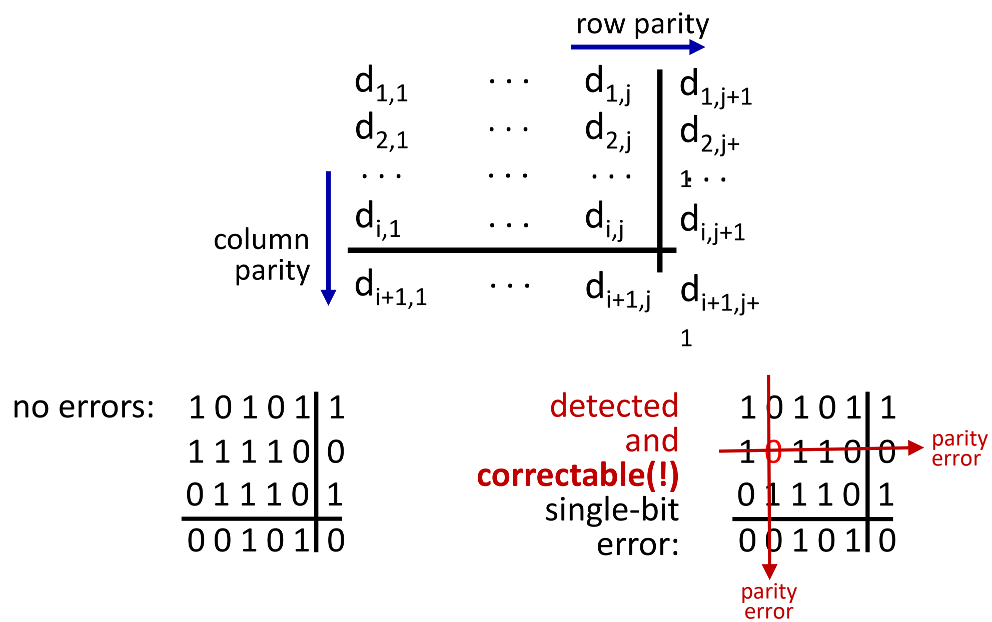
- detect single bit



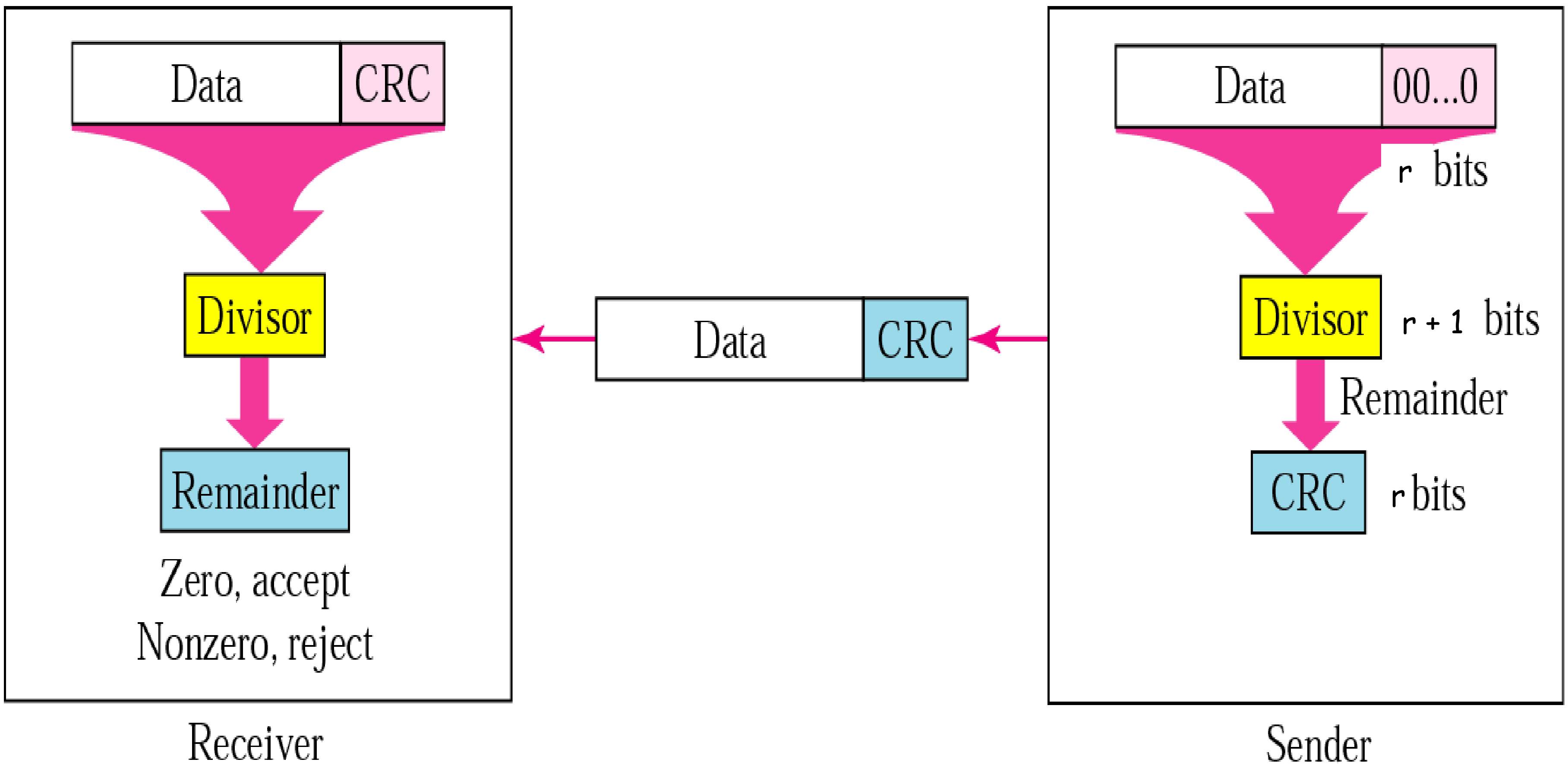
Even parity: set parity bit so there is an even number of 1's

two-dimensional bit parity:

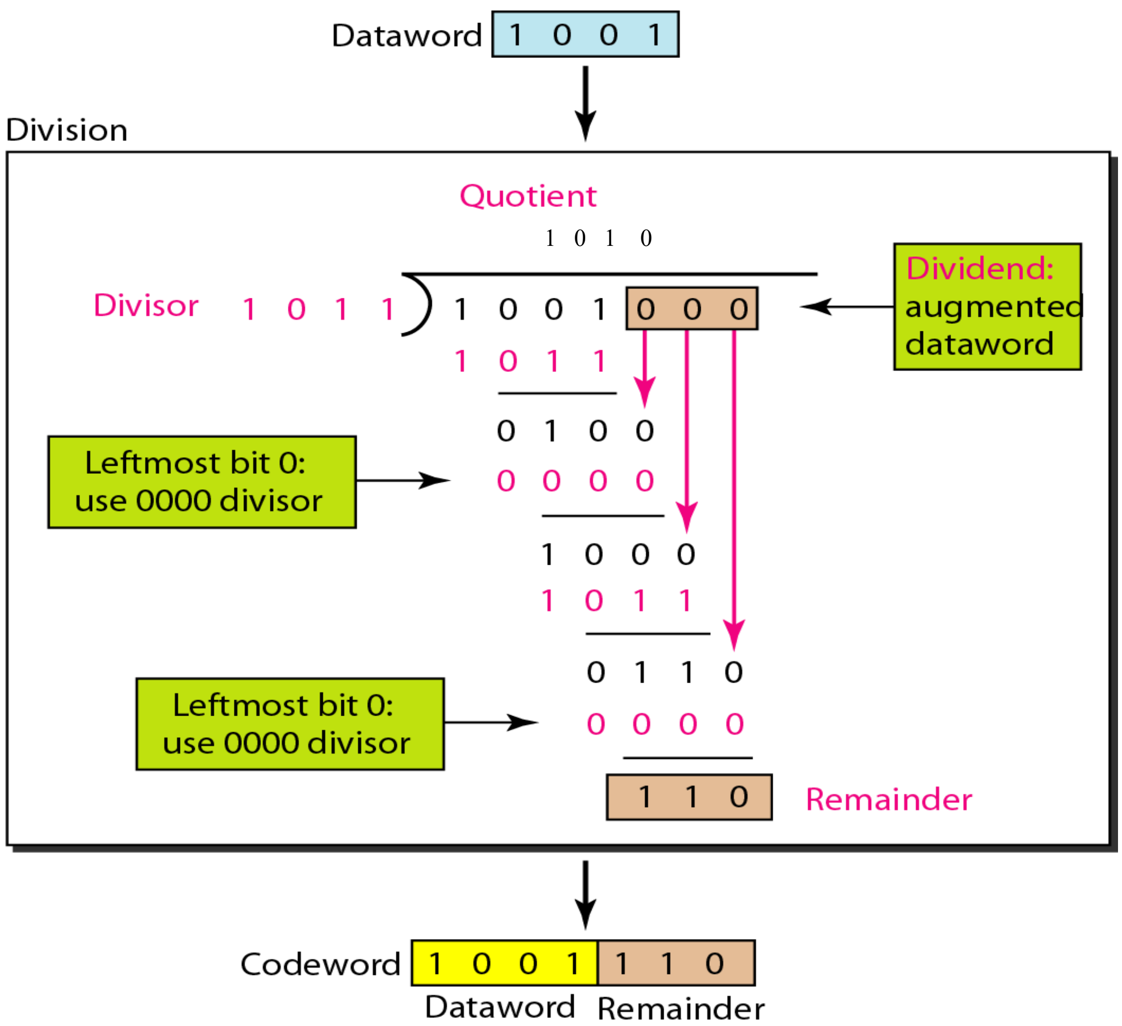
- detect *and correct* single bit errors



Cyclic redundancy check



Cyclic redundancy check



In each step: check the **leading most significant bit**

- If it's 0: place a 0 in the quotient and XOR the current bits with 000.
- If it's 1: place a 1 in the quotient and XOR the current bits with the divisor

1. A bit stream 10011101 is transmitted using the standard CRC method. The generator polynomial is x^3+1. (i) Show the actual bit string transmitted. (ii) Suppose the third bit from the left is inverted during transmissions. Explain how this error is detected at the receiver's end.

1. A bit stream 10011101 is transmitted using the standard CRC method. The generator polynomial is x^3+1. Show the actual bit string transmitted. Suppose the third bit from the left is inverted during transmissions. Explain how this error is detected at the receiver's end.

Answer:

- Since the polynomial is x^3+1, it is $1*x^3+0*x^2+0*x^1+1*x^0$, the divisor (i.e. generator) is 1001.
- Thus, the remainder will have 4-1 = 3 bits.

- 10011101000 is divided by 1001, the remainder is 100.
- Thus, the actual bit string transmitted is: 10011101100.

- If the received bit string is 10111101100, then when 10111101100 is divided by 1001, the remainder is 100.
- The receiver will know that an error has happened.

2. Three users X, Y and Z use a shared link to connect to the Internet. Only one of X, Y and Z can use the link at any given time, and the link has a capacity of 1 Mbps. Suppose that TDMA is used. Each time frame is divided into 3 equal time slots, one for each user. Does the TDMA work for the following two cases? Justify your answers.

a) X, Y and Z send a 40Kbytes file every 1sec.

Answer:

- X, Y, or Z needs to send 40*8 K bits/second=0.32M bits/second.
- With TDMA, for a link with 1Mbps bandwidth, each user will be able to transmit 0.333Mbps.
- Thus, TDMA will allow all users to transmit their data immediately. It works fine.

2. Three users X, Y and Z use a shared link to connect to the Internet. Only one of X, Y and Z can use the link at any given time, and the link has a capacity of 1 Mbps. Suppose that TDMA is used. Each time frame is divided into 3 equal time slots, one for each user. Does the TDMA work for the following two cases? Justify your answers.

b) X sends 80Kbytes files per sec, while Y and Z send 10 Kbytes files per sec.

Answer:

- X needs to send 640K bits per second, each of Y and Z needs to send 80K bits per second. The total of 800K (=640K+160K) bits per second is less than 1M (=1,000K) bits per second.

- However, if TDMA is adopted, X will not be able to send 640K bits per second as it is only allowed to transmit at 1/3 bandwidth per second (333Kbps). Y and Z will waste some allocated bandwidth as they do not have much data to transmit.

- TDMA does not work in this case.

3) Suppose that there are 4 nodes in a network using slotted ALOHA. Each node has a large number of packets to send. Suppose that each node will have probability ¼ to retransmit a packet after a collision happens. What will be the efficiency of the network?

Answer: $N=4$ and $p=1/4$

The maximum efficiency of each user is

$p(1-p)^{N-1}=1/4*(1-1/4)^3=27/256=10.5\%$

- The efficiency of the network is
- $N*p(1-1/p)^{N-1}=4*1/4*(1-1/4)^3=27/64=42\%$.

4) Suppose that there are three nodes seeking access to a shared medium using slotted ALOHA, where each packet takes one time slot to transmit. Assume that each node has many packets to send, and node i has probability p_i of sending a packet in each time slot with i = 1, 2, 3. Suppose that the sending probabilities of the three nodes are $p_1 = 2p$ and $p_2 = p_3 = p$, respectively.

a) What is the efficiency of the shared medium?

Answer: $p_1 = 2p$ and $p_2 = p_3 = p$,

- the utilization/efficiency of the shared medium is:

- $p_1(1-p_2)(1-p_3) + p_2(1-p_1)(1-p_3) + p_3(1-p_1)(1-p_2)$
- $= 2p(1-p)^2 + 2p(1-2p)(1-p)$
- $= 6p^3 - 10p^2 + 4p$

- Let $E(p) = 6p^3 - 10p^2 + 4p$

4) Suppose that there are three nodes seeking access to a shared medium using slotted Aloha, where each packet takes one slot to transmit. Assume that each node has a lot of packets to send, and that node i has probability p_i of sending a packet in each slot, for i = 1, 2, 3. Suppose that we assign the sending probabilities so that $p_1 = 2p$ and $p_2 = p_3 = p$.

b) What are the probabilities that maximize the utilization? and what is the corresponding utilization?

Answer:

- $E(p) = 6p^3 - 10p^2 + 4p$.

- To maximize the value of E(p), we have $E'(p) = 18p^2 - 20p + 4 = 0$,
- when p =(5-sqrt(7))/9 =0.2616, the value of E(p) is maximized. The other solution p=(5+sqrt(7))/9 that will result in p_1 larger than 1 is discarded.
- Thus, $p_1=0.5232$, $p_2=p_3=0.2616$, will maximize the efficiency, and the efficiency is: $E(p)=6*0.2616^3-10*0.2616^2+4*0.2616 = 0.4695$

5) Give an example where the two-dimensional parity scheme detects but cannot correct a double-bit error.

Answer:

- Suppose we begin with the initial two-dimensional parity matrix:

$$\begin{array}{ccc|c} 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 \\ \hline 1 & 0 & 1 & 0 \end{array}$$

- With a bit error in row 2, column 3, the parity of row 2 and column 3 is now wrong in the matrix below, and hence we can detect the error at position (2,3):

$$\begin{array}{ccc|c} 0 & 0 & 0 & 0 \\ 1 & 1 & \color{red}{0} & 1 \\ 0 & 1 & 0 & 1 \\ \hline 1 & 0 & 1 & 0 \end{array}$$

- Now suppose there are bit errors in row 2, column 2, and row 2, column 3, respectively.
- The parity of row 2 is now correct.
- The parity of columns 2 and 3 is wrong. But we can't detect in which rows the error occurred.

$$\begin{array}{ccc|c} 0 & 0 & 0 & 0 \\ 1 & \color{red}{0} & \color{red}{0} & 1 \\ 0 & 1 & 0 & 1 \\ \hline 1 & 0 & 1 & 0 \end{array}$$

- The above example shows that a double bit error can be detected but not corrected.