CSC 465
Data Communication and Computer Networks

Lecture 8
Data Link Layer

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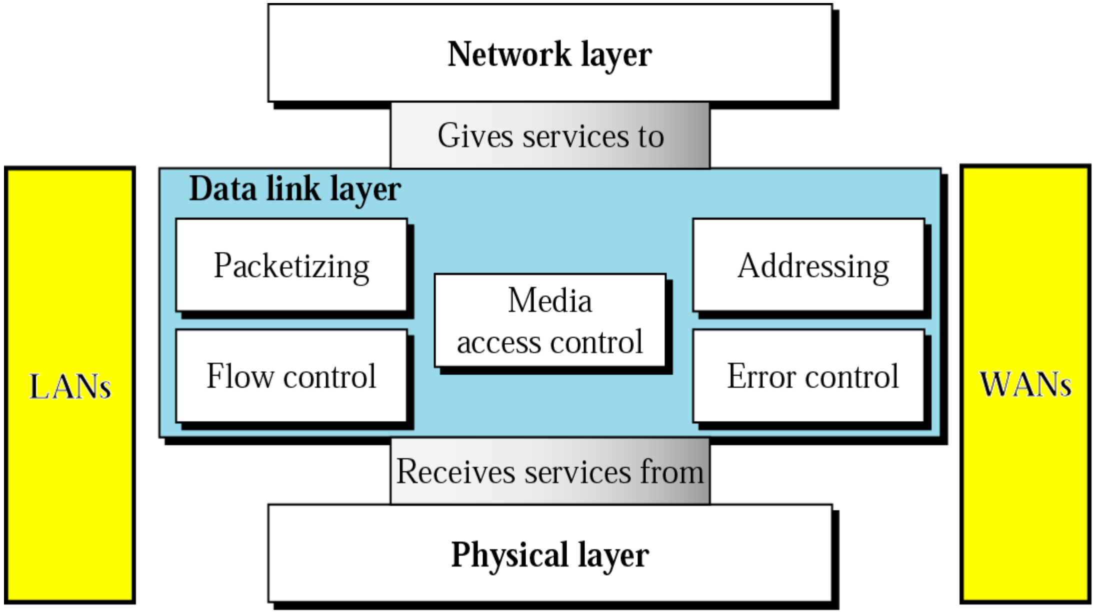
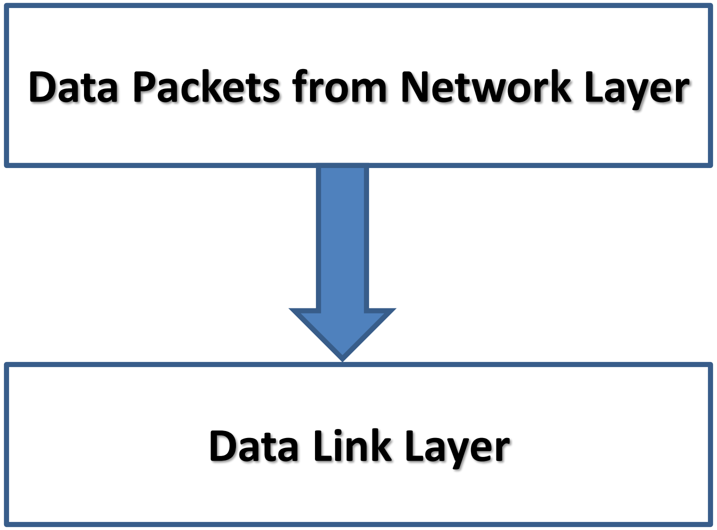
- Violation of English as the First Language in the Campus will lead to administrative and disciplinary action.
- All are urged to help each other to develop the Facility of Communicating in English as the First Language in the Campus

Data link layer

- **Position and responsibilities of the data link layer**



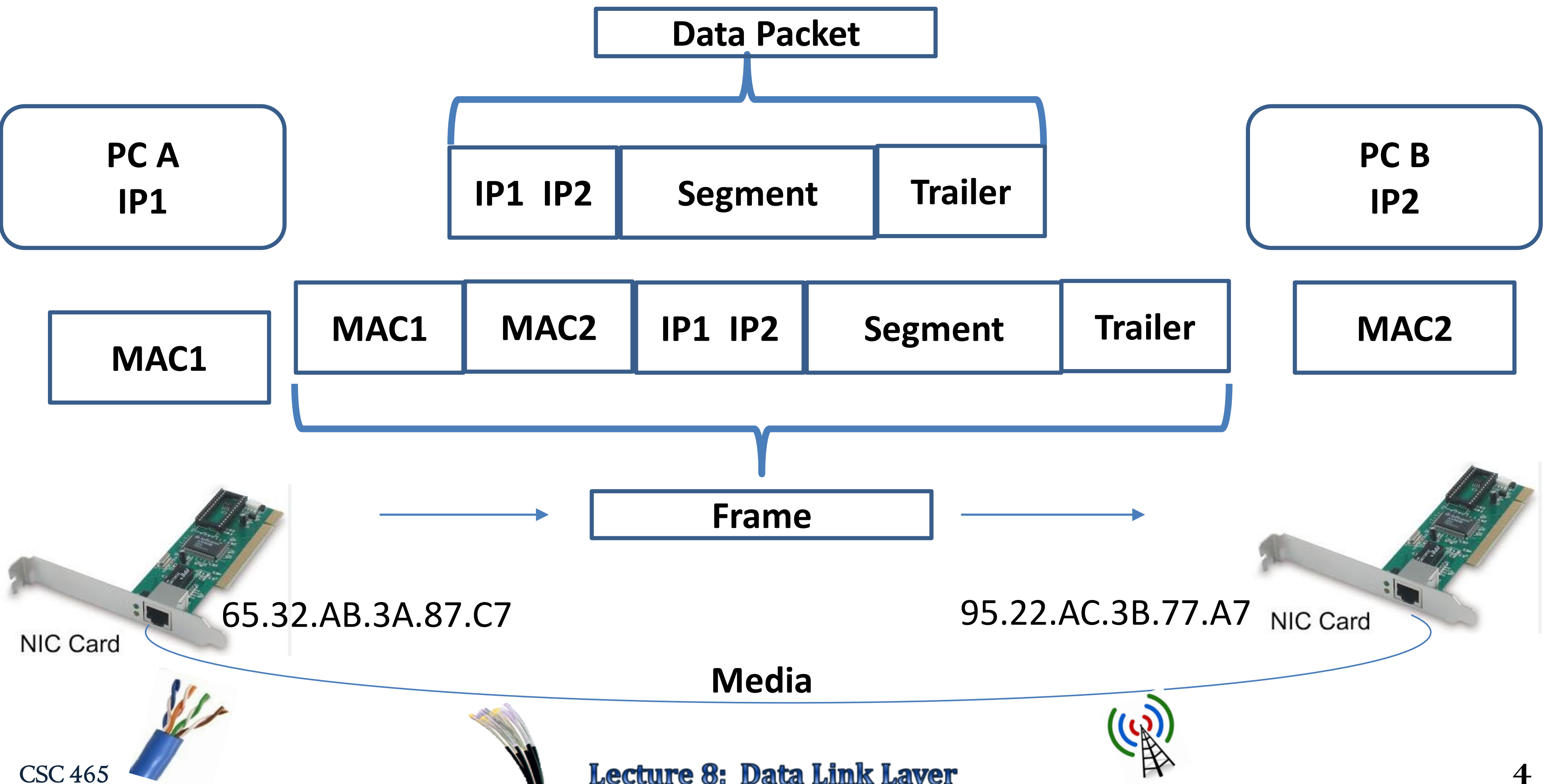


Data link layer

ADDRESSSING

Logical Addressing : Networking Layer

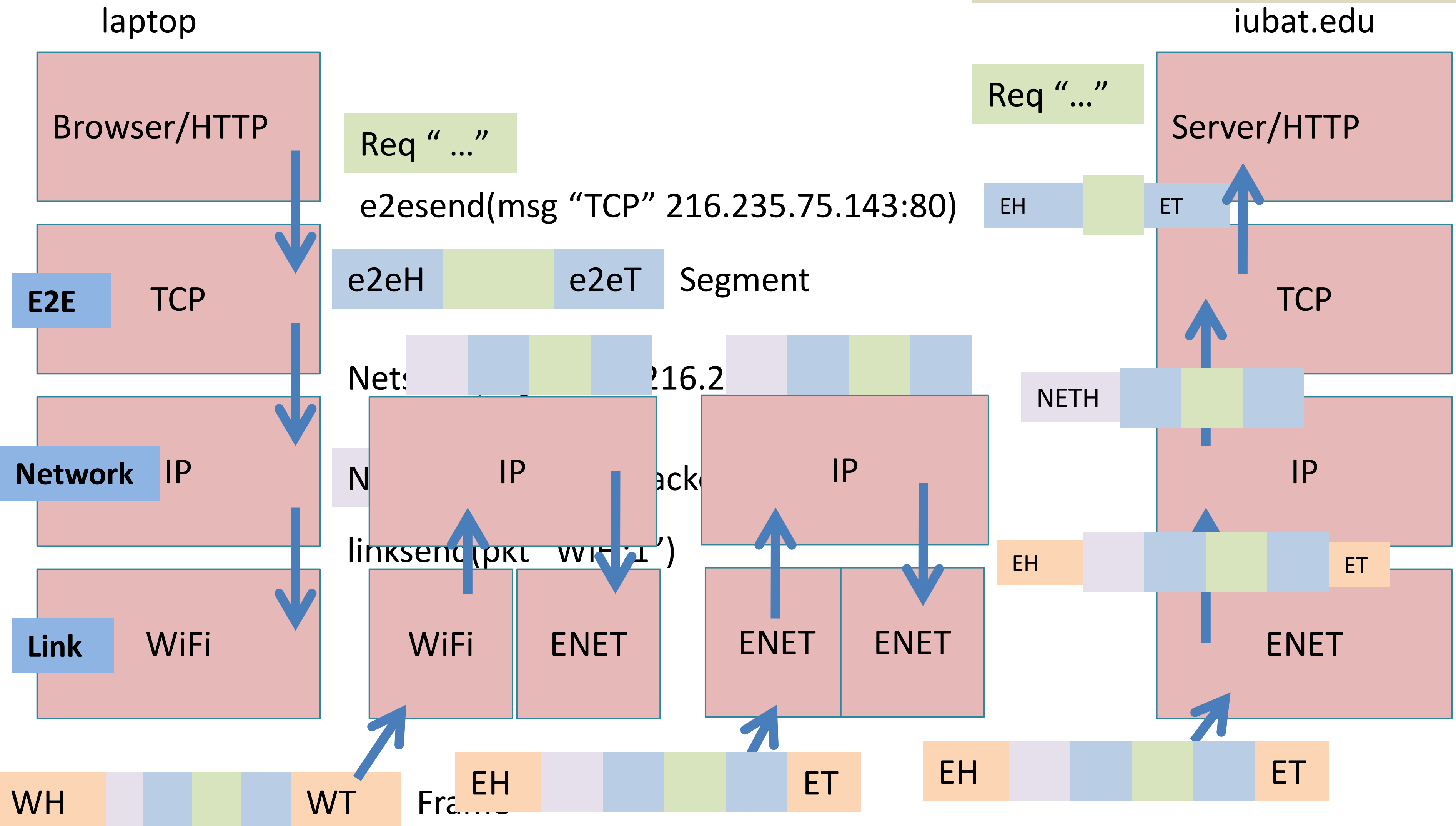
Physical Addressing: Data Link Layer



Two basic functions of data link layer

1. It allows upper layers of OSI model to access media
Use Technique: Framing

Search the request and send



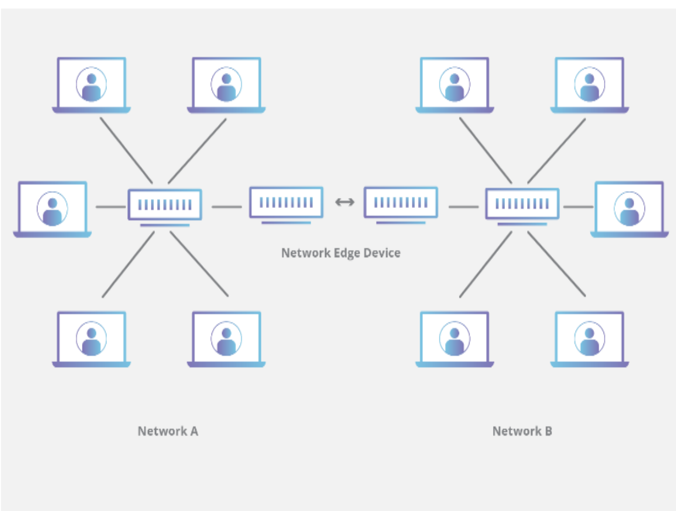
Two basic functions of data link layer

It controls how data is placed and received from media
Use Techniques:
Media Access Control (MAC)
Error Control

- The technique used to get the frame on and over the media is call media access control (MAC)

Data Link Layer

LAN Cable, Optical Fiber, Air



- If two or more devices connected to same media, same data in same time, there is a possibility to collision of the two massages resulting useless message
- Data link layer keeps listening and wait for getting the heard media free for successful data transfer between two devices called CSMA – Carrier sense multiple access that avoids the situation
- DLL with MAC controls data transmissions

Two basic functions of data link layer

It controls how data is placed and received from media
Use Techniques:
Media Access Control (MAC)
Error Control

- Trailer of each frame contain bits which are used to detect errors in the received frame
- Errors occur due to certain limitations over the media use for transmitting data

MEDIA ACCESS CONTROL

- What is medium access?
  - Who gets to transmit? How? When?
  - Multiplexing: How many stations can share a single link?
    - FDMA, TDMA, CDMA in circuit switched voice networks
    - CSMA/CD in Ethernet (simplicity)
  - Duplexing
    - How communication from station A to station B is separated from the communication from station B to station A
    - FDD or TDD
- Impact of architectures
    - Infrastructure – Centralized, fixed base station
    - Ad Hoc – Distributed, Peer-to-Peer
- Simplicity and overhead

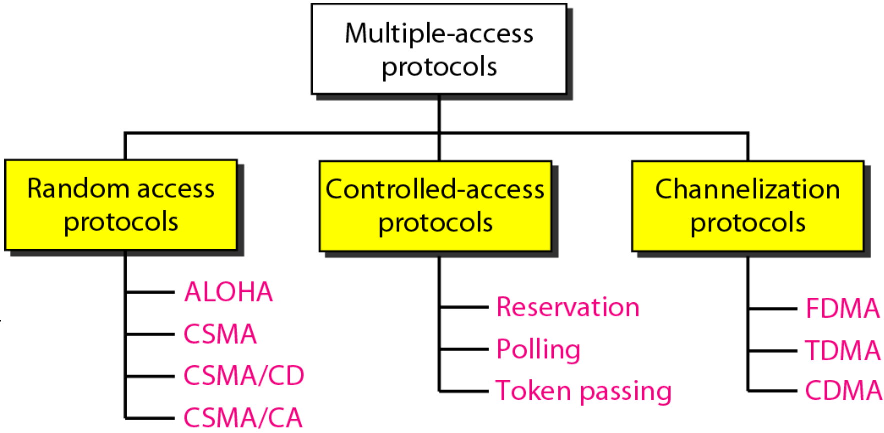
Duplexing Modes

- Simplex – one way communication (e.g., broadcast AM)
- Duplex – two way communication
  - Frequency Division Duplex (FDD)
    - Users get two channels – one for each direction of communication
    - For example, one channel for uplink (mobile to base station) another channel for downlink (base station to mobile)
    - Half-duplex
      - As in 802.11, a device cannot simultaneously be transmitting and receiving
  - Time Division Duplex (TDD)
    - Users take turns on the channel

MEDIA ACCESS CONTROL

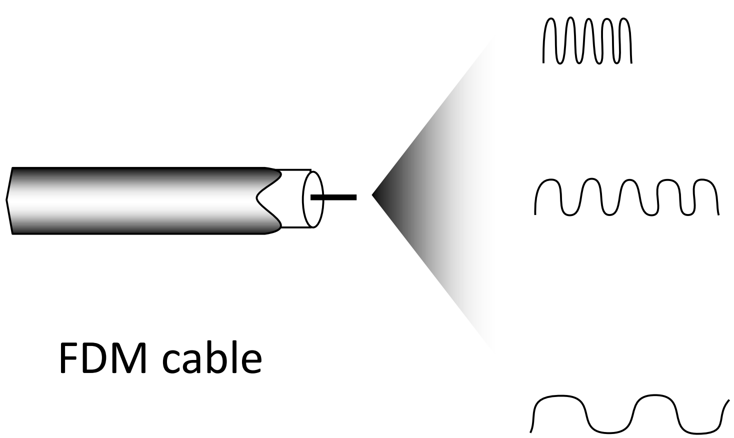
MAC protocol Taxonomy

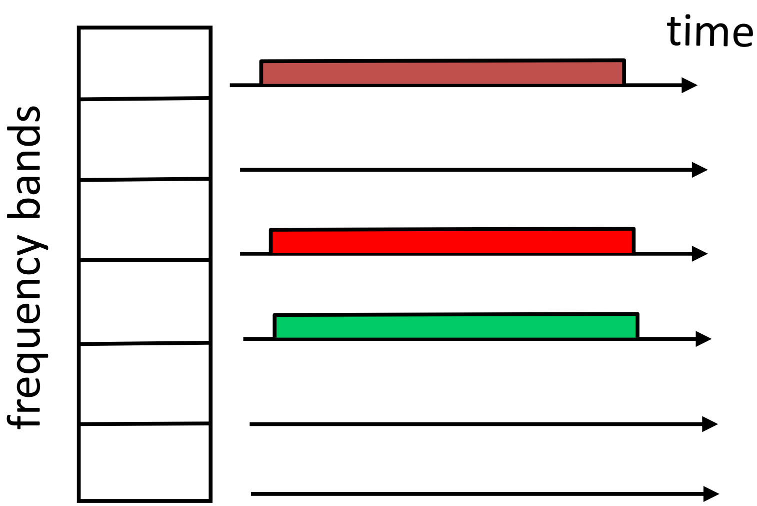
- **Three broad classes:**
  - Channel Partitioning
    - divide channel into smaller "pieces" (time slots, frequency and code)
    - allocate piece to node for exclusive use
  - Random Access
    - channel not divided, allow collisions.
    - "recover" from collisions.
  - Controlled-Access Protocols
    - nodes take turns, but nodes with more to send can take longer turns.



Frequency Division Multiple Access (FDMA)

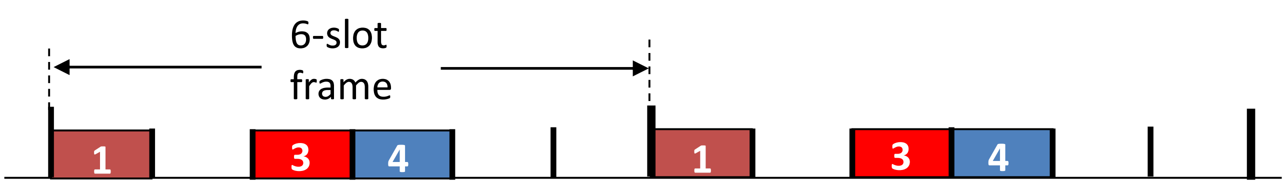
- Channel spectrum divided into frequency bands.
- Each station assigned fixed frequency band.
- Unused transmission time in frequency bands go idle.
- Example: 6-station LAN, 1,3,4 have packet, frequency bands 2,5,6 idle.
- Used in First Generation Cellular (AMPS - Advanced Mobile Phone Service) Analog





Time Division Multiple Access (TDMA)

- Access to channel in "rounds“.
- Each station gets fixed length slot (length = packet transmission time) in each round. (N * T Seconds)
- Unused slots go idle.
- Example: 6-station LAN, 1,3,4 have packet, slots 2,5,6 wasted (idle).
- Used in 2nd generation – GSM (Global System for Mobile communication), GPRS (General Packet Radio Services), EDGE (Enhanced Data Rates for Global Evolution)



Code Division Multiple Access (CDMA)

- Assign a user a unique code for transmission between sender and receiver, users transmit on the same frequency at the same time
- Narrowband message signal is multiplied by very large bandwidth spreading signal using direct sequence spread spectrum
- All users can use same carrier frequency and may transmit simultaneously
- Each user has own unique access spreading codeword which is approximately orthogonal to other users codewords
- Receiver performs time correlation operation to detect only specific codeword, other users codewords appear as noise due to decorrelation
- Used in 3rd generation - 3GPP2-CDMA (3rd Generation Partnership Project 2), CDMA-EVDO

MEDIA ACCESS CONTROL

CDMA Example

Data bit => *0 represent (-1)*
=> *1 represent (+1)*

*Code1 * Code2 = 0*
{1 1 1 1} * {1 -1 1 -1} = 0

*Code1 * Code1 = 4*
{1 1 1 1} * {1 1 1 1} = 4

User Station1

Code1 = {1 1 1 1}
Data1 = -1
Code1Data1 = {-1 -1 -1 -1}

User Station2

Code2 = {1 -1 1 -1}
Data2 = 1
Code2Data2 = {1 -1 1 -1}

Encoding

{ 0 -4 0 0}

User Station3

Code3 = {1 1 -1 -1}
Data3 = -1
Code3Data3 = {-1 -1 1 1}

User Station4

Code4 = {1 -1 -1 1}
Data4 = 1
Code4Data4 = {1 -1 -1 1}

Decoding

Receiver1 = {1 1 1 1} * (0 -4 0 0} = {0 -4 0 0} = -4/4 = -1

Receiver2 = {1 -1 1 -1} * (0 -4 0 0} = {0 4 0 0} = 4/4 = +1

Receiver3 = {1 1 -1 -1} * (0 -4 0 0} = {0 -4 0 0} = -4/4 = -1

Receiver4 = {1 -1 -1 1} * (0 -4 0 0} = {0 4 0 0} = 4/4 = +1

Carrier Sensing

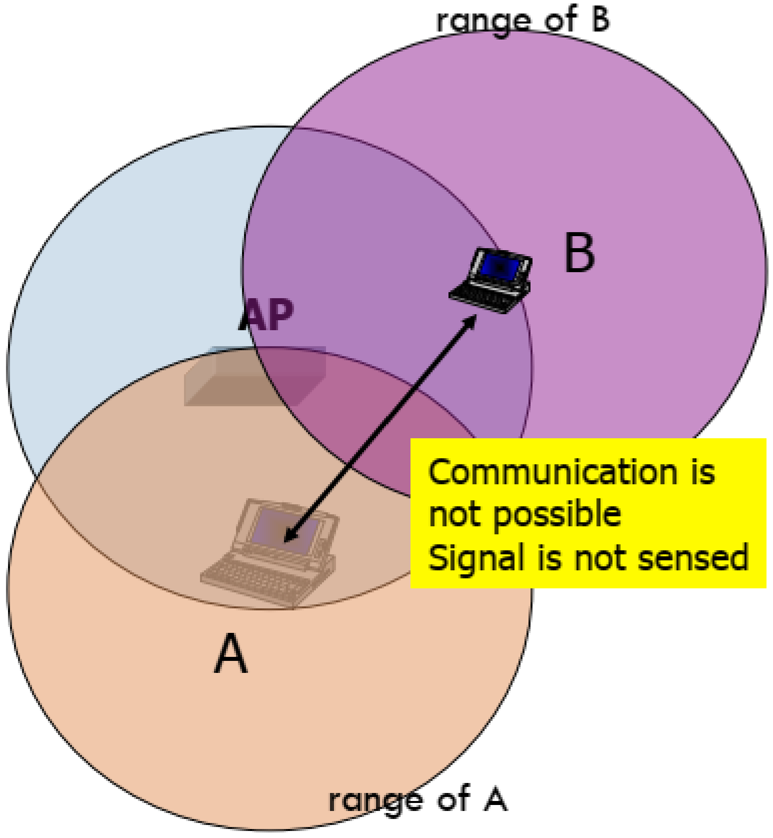
- Carrier sensing
  - It is an improvement of ALOHA (no carrier sensing in ALOHA)
  - Depending on the protocol a variety of CSMA protocols exist
    - Non-persistent
    - *p*-persistent
    - Binary exponential back-off
  - Collision detection Vs Collision avoidance
- Most random access protocols are based on some form of carrier sensing

Problems with Carrier Sensing

- The signal strength is a function of distance and location
  - Not all terminals at the same distance from a transmitter can "hear" the transmitter and vice versa
- The hidden node problem
- The exposed node problem
- capture

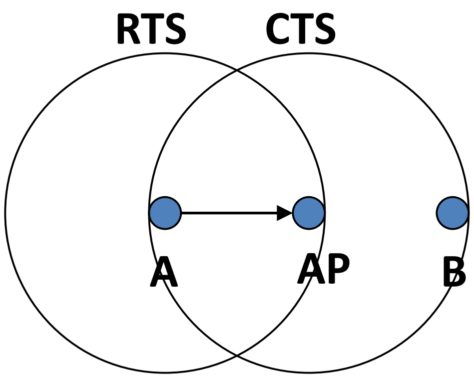
Hidden node/terminal problem

- A MS that is within the range of the destination but out of range of a transmitter
- MS A transmits to the AP
- MS B cannot sense the signal
    - MS B may also transmit resulting in collisions
    - MS B is called a “hidden terminal” with respect to MS A



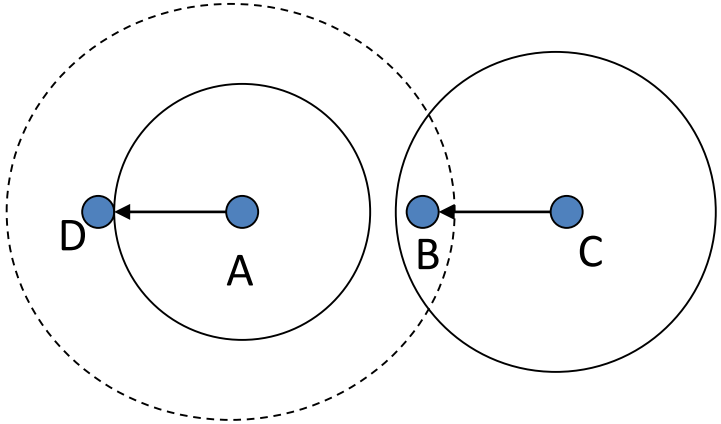
Solution to hidden terminal problem

- **Busy-tone multiple access (BTMA)**
  - Out of band signaling scheme
  - Any node that hears a transmission will transmit a busy tone in an out of band channel
- **Control handshaking**
  - Use a three-way handshake
  - Terminal A sends a short request-to-send (RTS) packet to the AP
  - The AP sends a short clear-to-send (CTS) packet that is received by Terminal A AND Terminal B
  - Terminal B defers to terminal A



Exposed terminal problem

- Hidden terminal is not the only challenge for a distributed wireless MAC protocol
- A blocks B, and C doesn't know what is happening (B is exposed)



- **Solution:**
    - Proper frequency planning
    - Intelligent thresholds for carrier sensing

Carrier Sense Multiple Access (CSMA)
Transmission Strategies

non-persistent CSMA

'the less-greedy algorithm'

1. Sense the channel.
2. IF the channel is ***idle***, THEN transmit.
3. IF the channel is ***busy***, THEN wait a **random amount of time** and repeat the algorithm.

1-persistent CSMA

'the greedy algorithm'

1. Sense the channel.
2. IF the channel is ***idle***, THEN transmit.
3. IF the channel is ***busy***, THEN continue to listen until channel is *idle* and transmit immediately.

P-persistent CSMA

'a slotted approximation'

1. Sense the channel.
2. IF the channel is *idle*, THEN with probability **p** transmit and with probability **(1-p)** delay ***one time slot*** and repeat the algorithm.
3. IF the channel is ***busy***, THEN delay ***one time slot*** and repeat the algorithm.

CSMA/CD (Collision Detection) [Cont']

- If a collision is detected during transmission, then immediately cease transmitting the frame.
- The first station to detect a collision sends a ***jam signal*** to all stations to indicate that there has been a collision.
- After receiving a ***jam signal***, a station that was attempting to transmit waits a **random amount of time** before attempting to retransmit.
- The maximum time needed to detect a collision is 2 x propagation delay

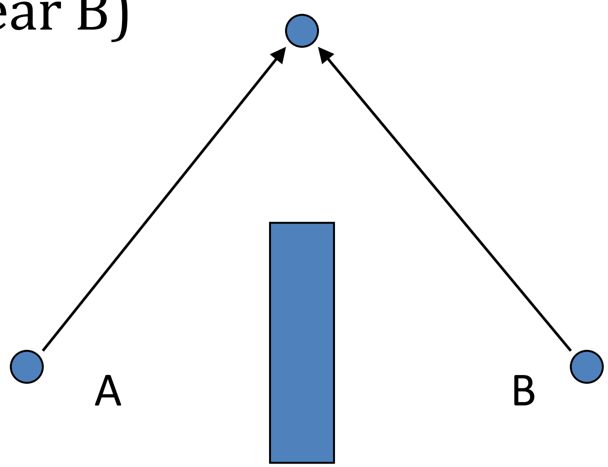
CSMA VS CSMA/CD

- CSMA is essentially a historic technology until we include **Wireless LANs**.
- If propagation time is short compared to transmission time, station can be *listening before sending* with CSMA.
- Collision detection (CD) is accomplished by detecting voltage levels outside acceptable range. Thus attenuation limits distance without a repeater.
- If the collision time is short compared to packet time (i.e., small ***a***), performance will increase due to CD

CSMA/CA (Collision Avoidance)

- **Procedure**
  - Similar to CSMA but instead of sending packets control frames are exchanged
  - RTS = request to send
  - CTS = clear to send
  - DATA = actual packet
  - ACK = acknowledgement

- **Advantages**
  - Small control frames lessen the cost of collisions (when data is large)
  - RTS + CTS provide “virtual” carrier sense which protects against hidden terminal collisions (where A can’t hear B)

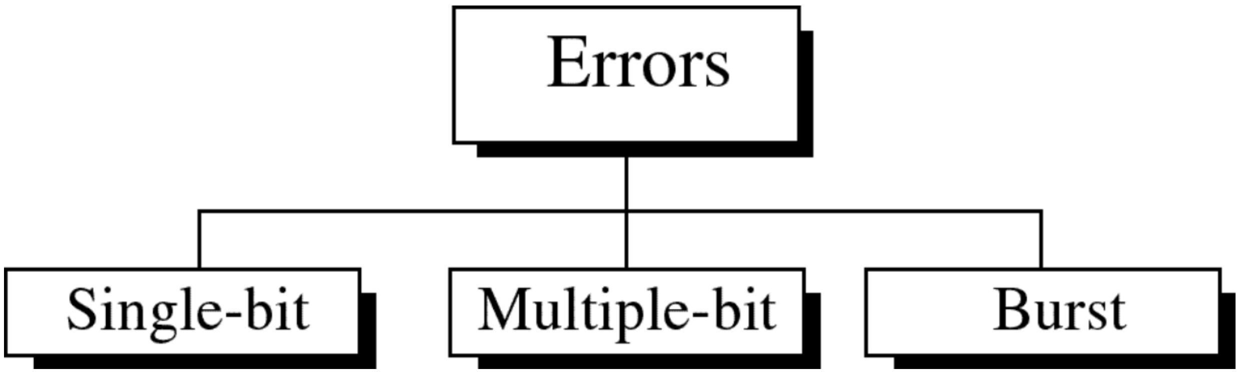


- **Disadvantages**
  - Not as efficient as CSMA-CD
  - Doesn’t solve all the problems of MAC in wireless networks (more to come)

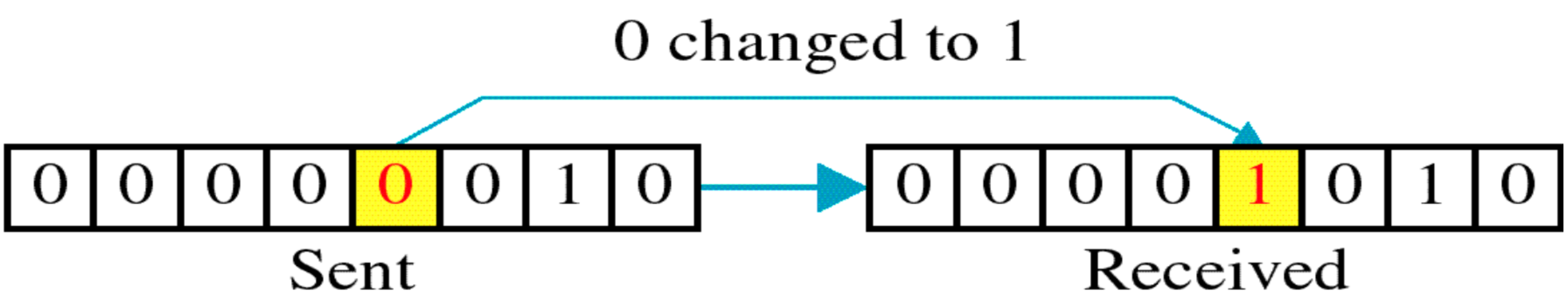
Error Detection and Correction

- **Basic Concepts**
  - Networks must be able to transfer data from one device to another with complete accuracy
  - Data can be corrupted during transmission.
  - For reliable communication, errors must be detected and corrected
  - **Error detection and correction** are implemented either at the **data link layer** or the **transport layer** of the OSI model

Error Detection
Types of Errors

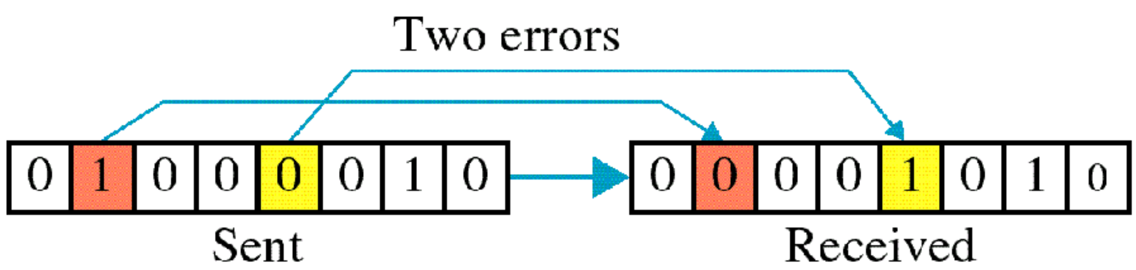


- **Single-Bit Error** is when only one bit in the data unit has changed

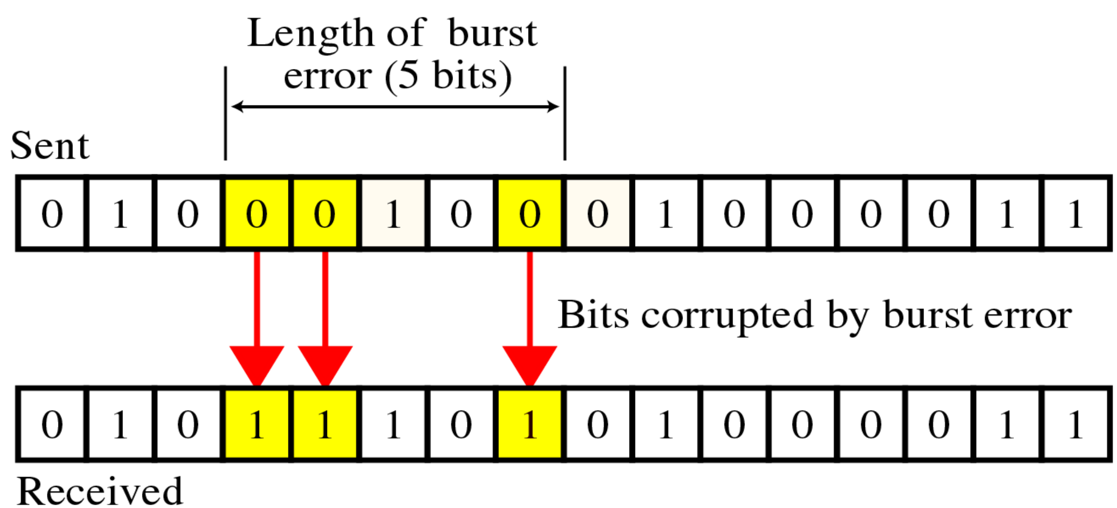


Error Detection
Types of Errors (Cont')

- **Multiple-Bit Error** is when two or more nonconsecutive bits in the data unit have changed



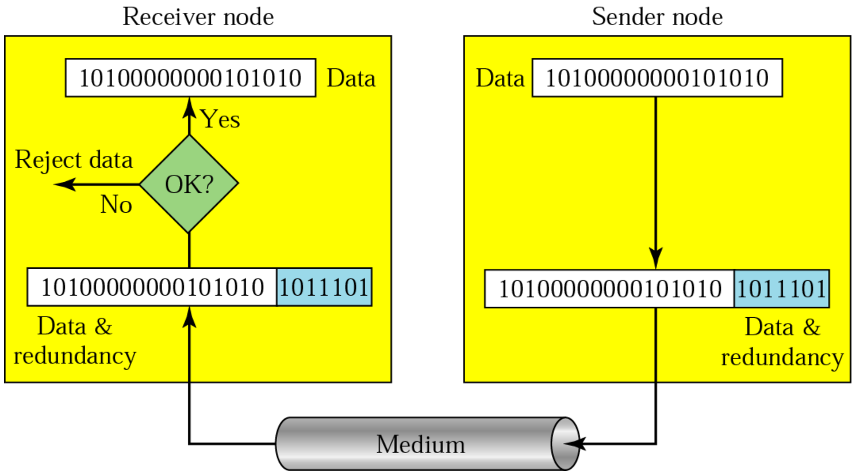
- **Burst Error** means that 2 or more consecutive bits in the data unit have changed



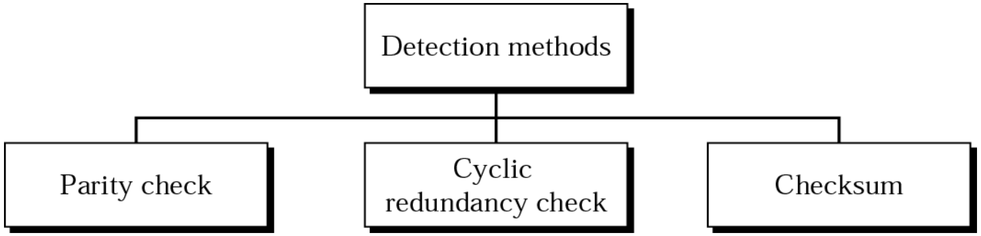
Error Detection

- Error detection means to decide whether the received data is correct or not without having a copy of the original message
- Error detection **uses the concept of redundancy, which means** adding extra bits for detecting errors at the destination

- **Redundancy**



- **Error Detection Methods**

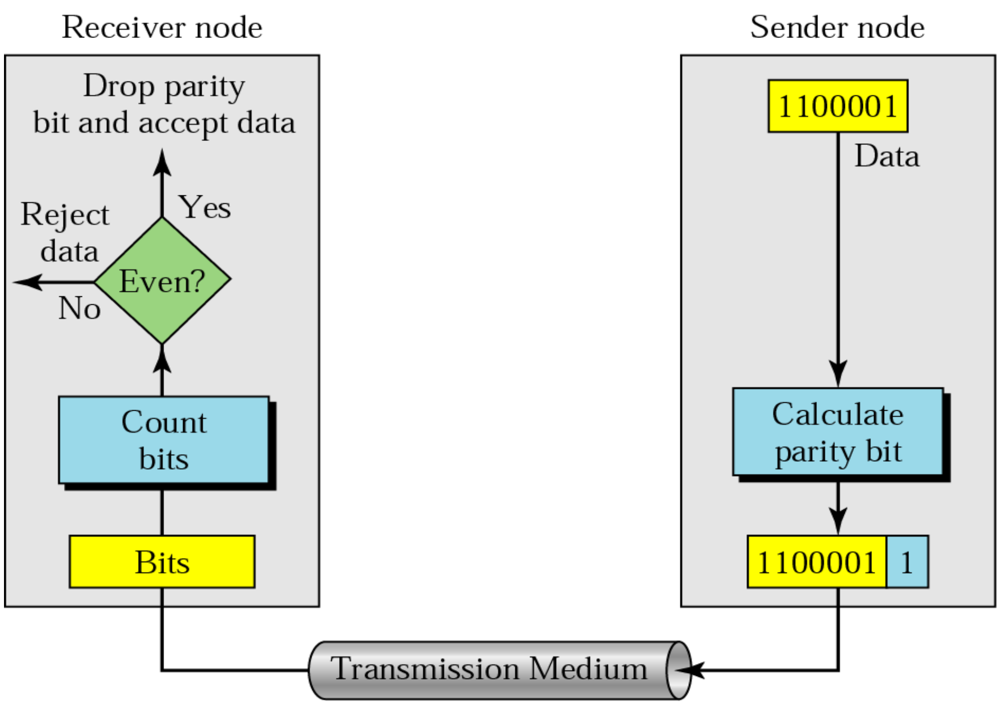


Error Detection (Cont')

➢ **Parity Check**

A parity bit is added to every data unit so that the total number of 1s(including the parity bit) becomes even for even-parity check or odd for odd-parity check

- **Simple Parity Check**



Error Detection (Cont')

❑ Examples :

- Suppose the sender wants to send the word *world*. In ASCII the five characters are coded as

1110111 1101111 1110010 1101100 1100100

The following shows the actual bits sent

1110111**0** 1101111**0** 1110010**0** 1101100**0** 1100100**1**

- Now, suppose the word *world* is received by the receiver without being corrupted in transmission.

11101110 11011110 11100100 11011000 11001001

The receiver counts the 1s in each character and comes up with even numbers (6, 6, 4, 4, 4). The data are accepted.

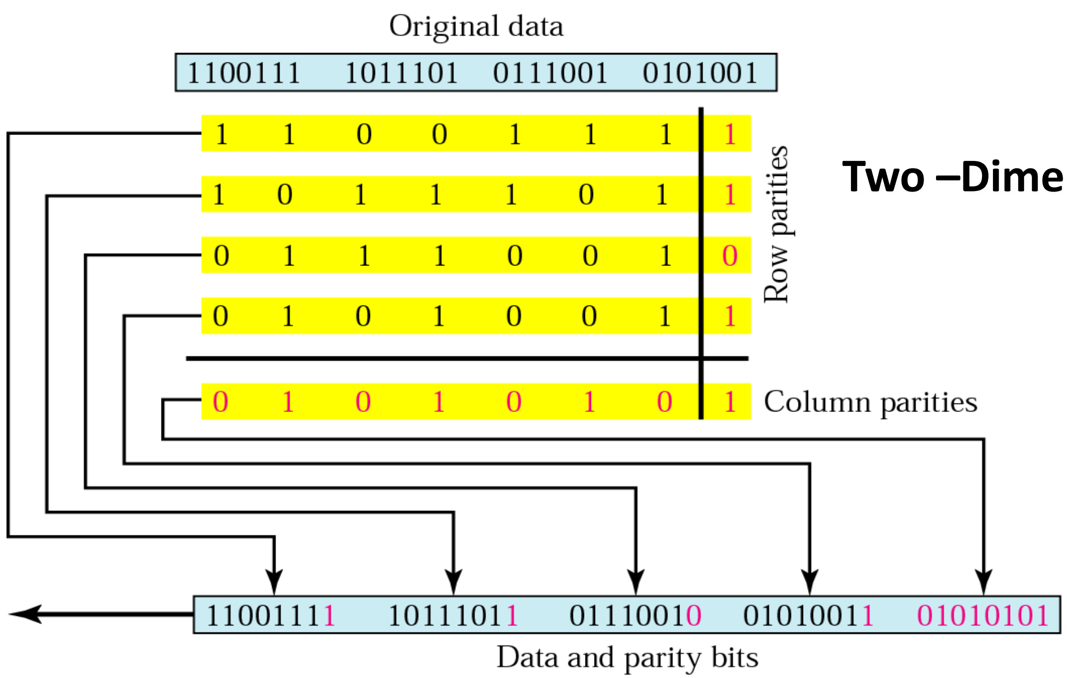
Error Detection (Cont')

❑ Examples (Cont') :

- Now suppose the word *world* is corrupted during transmission

11111110 11011110 11101100 11011000 11001001

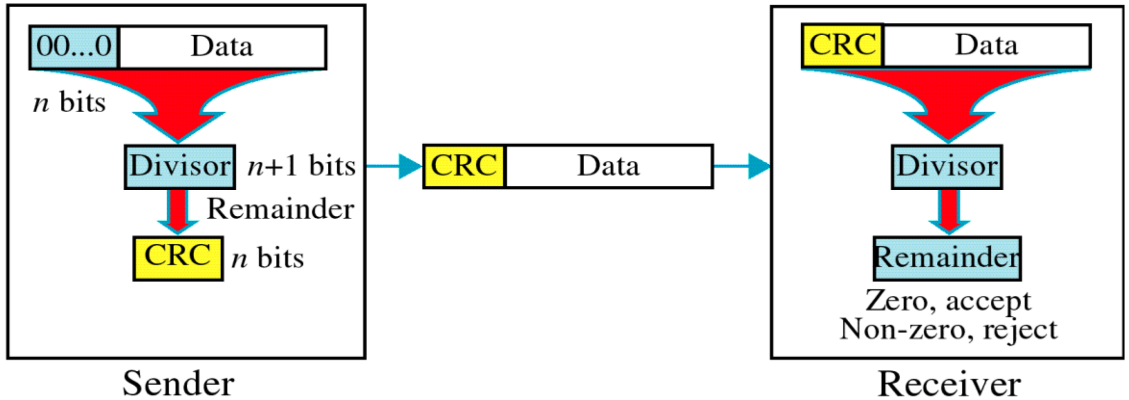
The receiver counts the 1s in each character and comes up with even and odd numbers (7, 6, 5, 4, 4). The receiver knows that the data are corrupted, discards them, and asks for retransmission



Two –Dimensional Parity Check

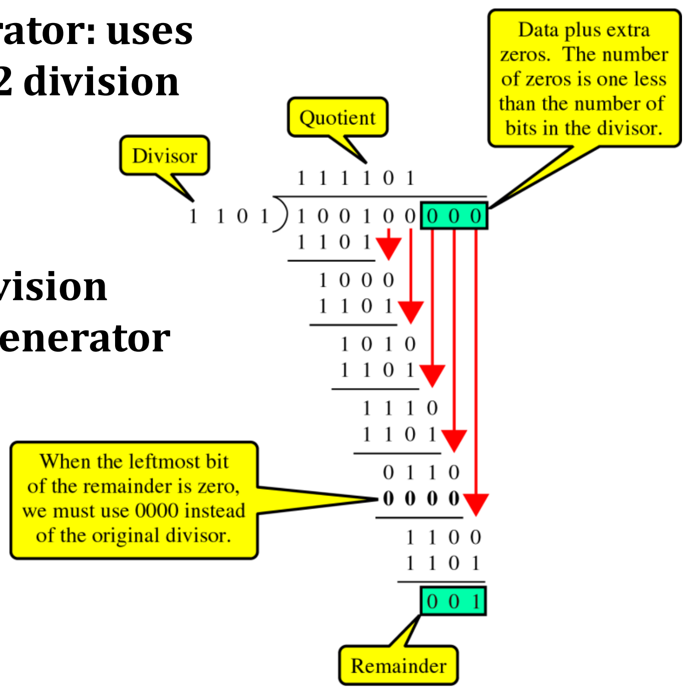
Error Detection (Cont')

- Cyclic Redundancy Check : It is based on binary division

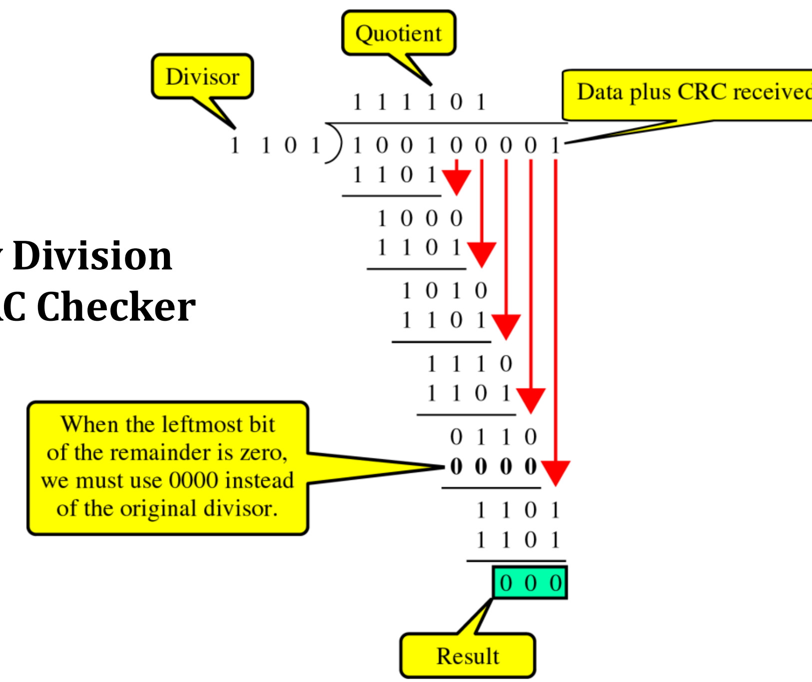


CRC generator: uses modular-2 division

Binary Division in a CRC Generator

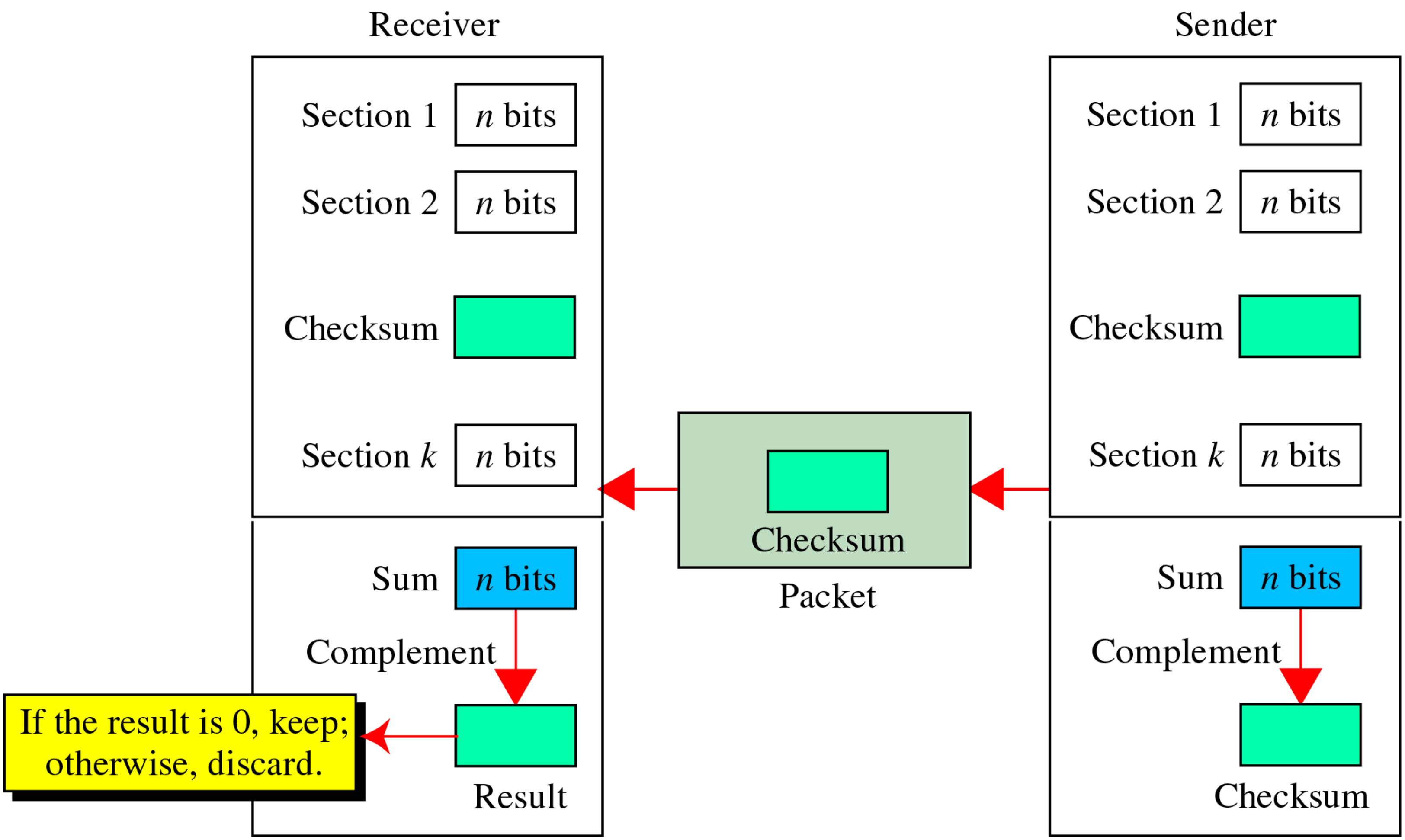


Binary Division in a CRC Checker



Error Detection (Cont')

- **Checksum**



Error Detection (Cont')

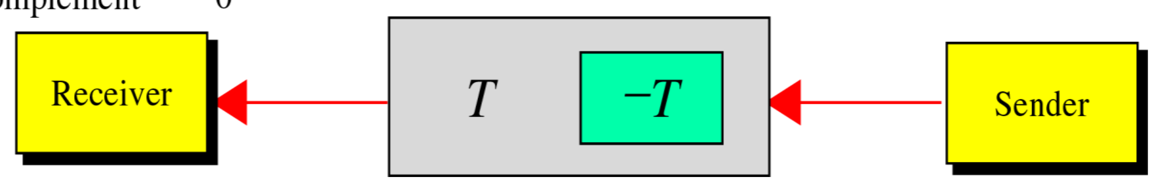
- To create the checksum the sender does the following:
  - The unit is divided into K sections, each of n bits
  - Section 1 and 2 are added together using one's complement
  - Section 3 is added to the result of the previous step
  - Section 4 is added to the result of the previous step
  - The process repeats until section k is added to the result of the previous step
  - The final result is complemented to make the checksum

> The receiver adds the data unit and the checksum field. If the result is all 1s, the data unit is accepted; otherwise it is discarded.

- **Data unit and Checksum**

	T
	$-T$

Sum	-0
Complement	0



Error Detection (Cont’)

- **Checksum Example:**

✓**Sender**

Original data : 10101001 00111001

10101001

00111001

11100010 Sum

00011101 Checksum

10101001 00111001 00011101 (Checksum added)

✓**Receiver**

Received data : 10101001 00111001 00011101

10101001

00111001

00011101

11111111 ← Sum

00000000 ← Complement