DATA COMMUNICATOIN NETWORKING

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Course Book & Slides:
Computer Networking, A Top-Down Approach
By: Kurose, Ross

Course Overview

- **Basics of Computer Networks**
  - Internet & Protocol Stack
  - Application Layer
  - Transport Layer
  - Network Layer
  - Data Link Layer

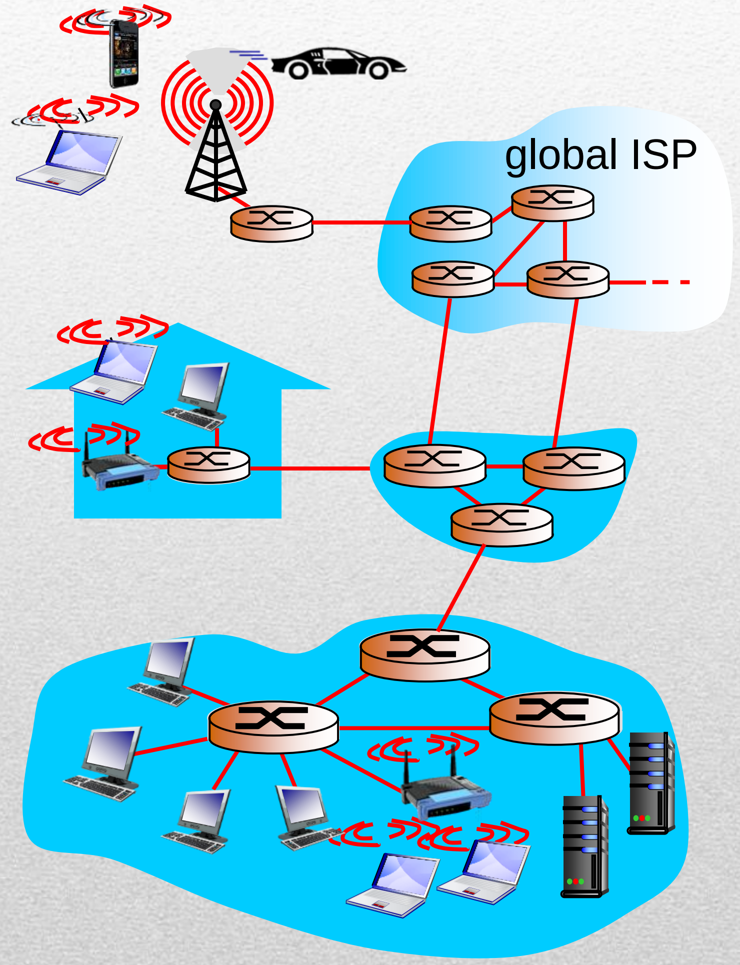
- **Advanced Topics**
  - Case Studies of Computer Networks
  - Internet Applications
  - Network Management
  - Network Security

Link Layer

- **We will learn**
  - Principles behind link layer services
    - Error detection
    - Error correction
    - Link layer addressing
    - Local area networks
      - Ethernet
      - WLANs
  - Installation & implementation of various link layer technologies

Link Layer

- Datagram transferred by different link protocols over different links
- Hosts and routers: Nodes
- Communication channels that connect adjacent nodes along the communication path: links
    - Wireless links
    - Wired links
    - LANs
- Layer 2 packet: Frame, encapsulated datagram



Data-link layer has responsibility of transferring datagram from one node to *physically adjacent* node over a link

Link Layer Services

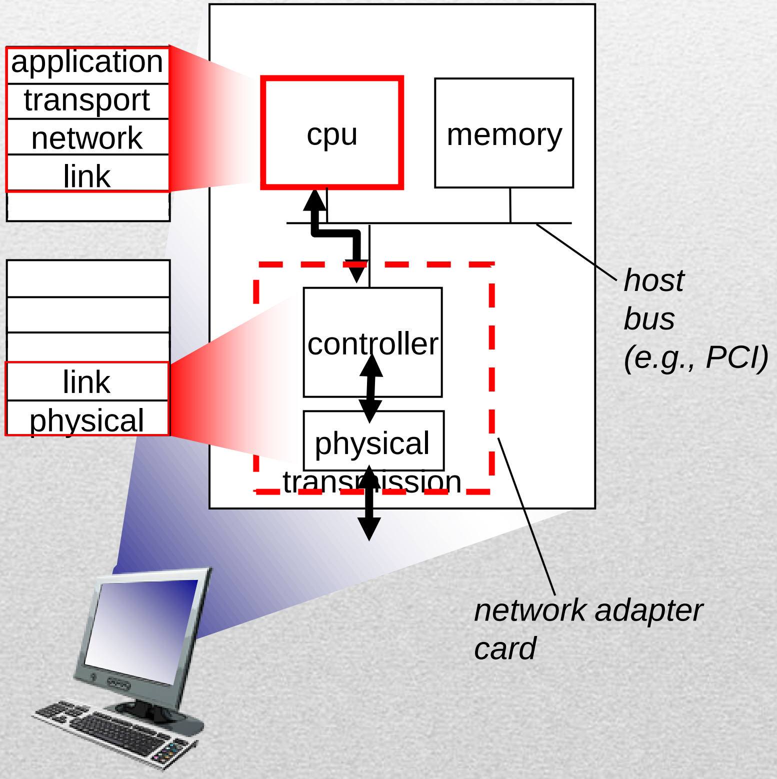
- Framing, link access:
  - Encapsulate datagram into **frame**, adding header, trailer
  - Channel access if shared medium
  - "MAC" addresses used in frame headers to identify source, destination
    - Different from IP address!
- Reliable delivery between adjacent nodes
  - Seldom used on low bit-error link (fiber, some twisted pair)
  - Wireless links: high error rates
    - **Q: why both link-level and end-end reliability?**

Link Layer Services

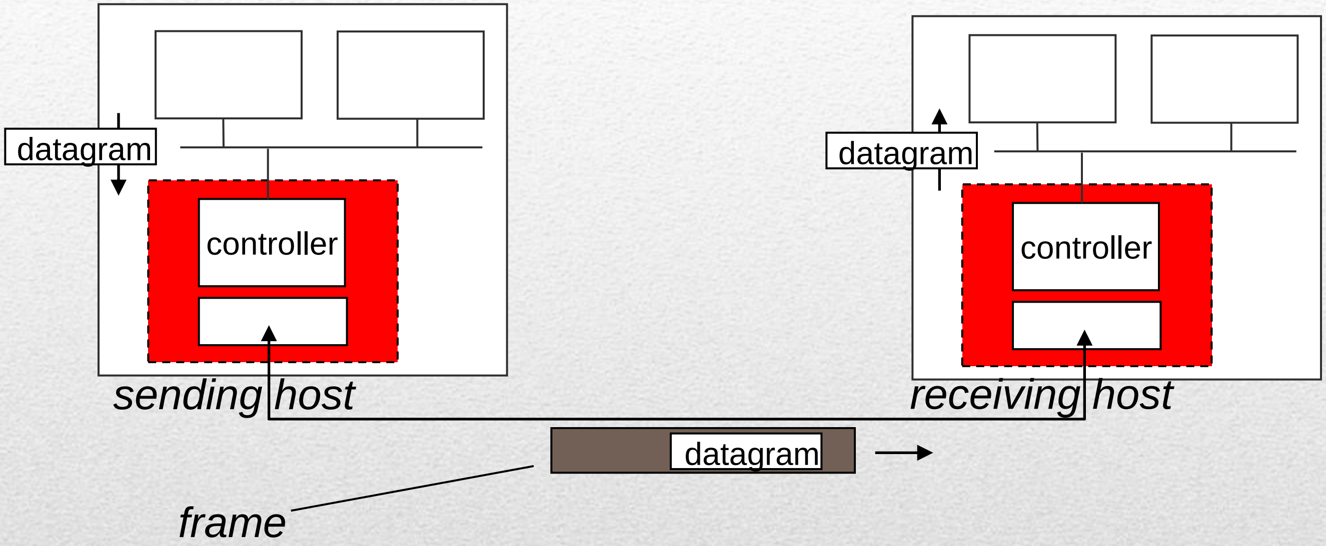
- Flow control
  - Pacing between adjacent sending and receiving nodes
- Error detection
  - Errors caused by signal attenuation, noise.
  - Receiver detects presence of errors
    - Signals sender for retransmission or drops frame
- Error correction
  - Receiver identifies and corrects bit error(s) without resorting to retransmission
- Half-duplex and full-duplex
  - With half duplex, nodes at both ends of link can transmit, but not at same time

Implementation

- In each and every host
- Link layer implemented in adaptor (*network interface card,* NIC) or on a chip
  - Ethernet card, 802.11 card; Ethernet chipset
  - implements link, physical layer
- Attaches into host's system buses
- Combination of hardware, software, firmware



Link Layer Services

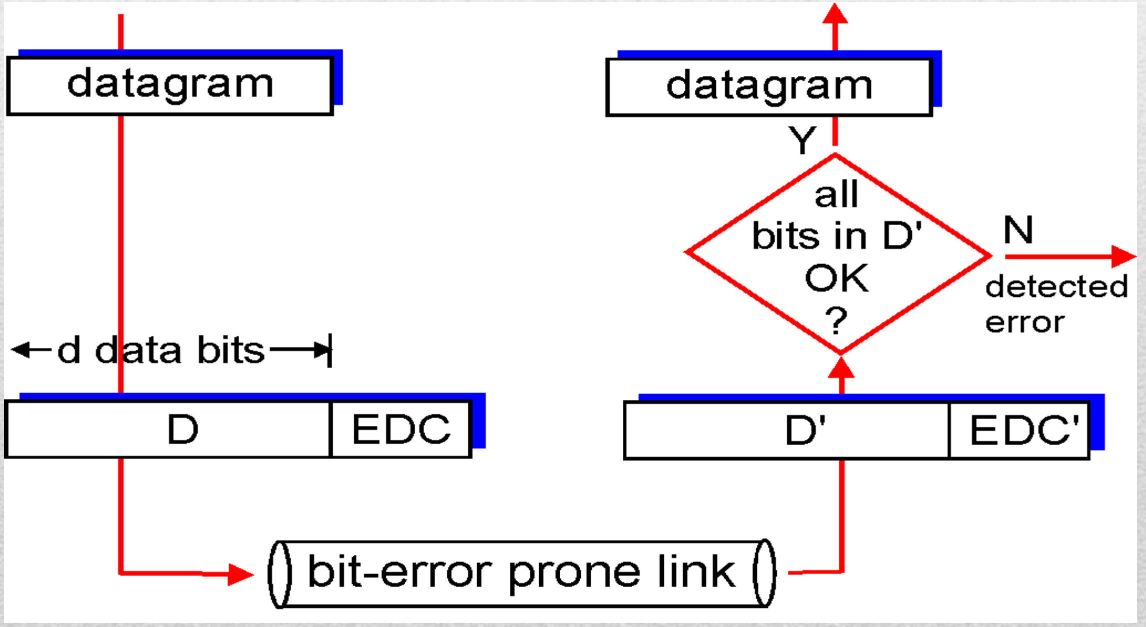


- Sending side:
  - Encapsulates datagram in frame
  - Adds error checking bits, rdt, flow control, etc.
- Receiving side
  - Looks for errors, rdt, flow control, etc
  - Extracts datagram, passes to upper layer at receiving side

Error Detection

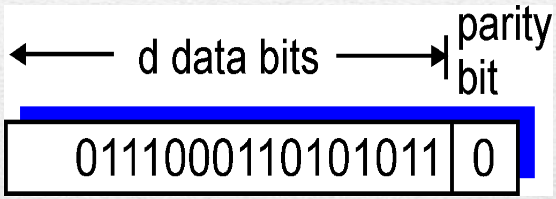
EDC= Error Detection and Correction bits (redundancy)
D = Data protected by error checking, may include header fields

- Error detection not 100% reliable!
  - Protocol may miss some errors, but rarely
  - Larger EDC field yields better detection and correction

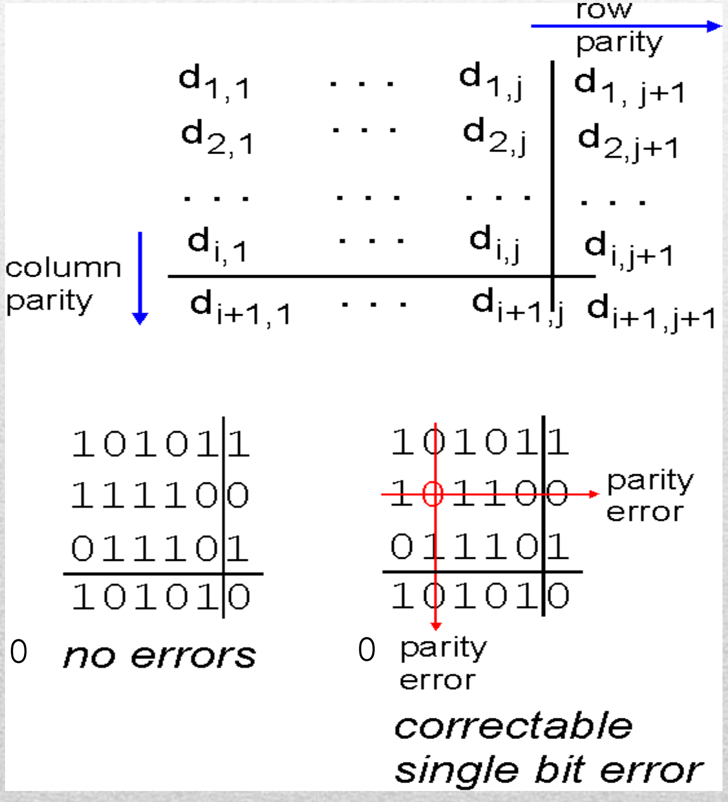


Error Detection

Single bit parity:
detect single bit errors



Two-dimensional bit parity:
detect and correct single bit errors



Internet Checksum

Goal: detect "errors" (e.g., flipped bits) in transmitted packet (note: used at transport layer only)

Sender

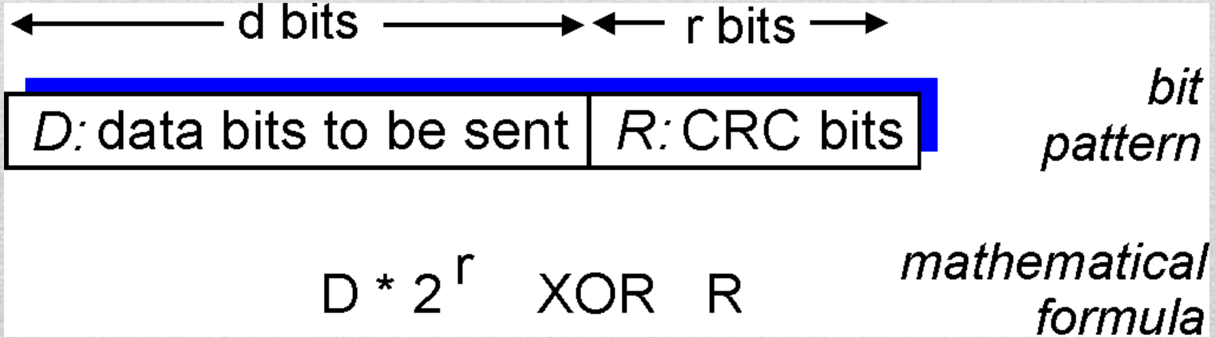
- Treat segment contents as sequence of 16-bit integers
- Checksum: addition (1's complement sum) of segment contents
- Sender puts checksum value into UDP checksum field

Receiver

- Compute checksum of received segment
- Check if computed checksum equals checksum field value:
  - NO - error detected
  - YES - no error detected. But maybe errors nonetheless?

Cyclic Redundancy Check

- More powerful error-detection coding
- View data bits, D, as a binary number
- Choose r+1 bit pattern (generator), G
- Goal: choose r CRC bits, R, such that
  - <D,R> exactly divisible by G (modulo 2)
  - Receiver knows G, divides <D,R> by G. If non-zero remainder: error detected!
  - Can detect all burst errors less than r+1 bits
- Widely used in practice (Ethernet, 802.11 WiFi, ATM)



CRC Example

We want:

$D \cdot 2^r$ XOR R = nG

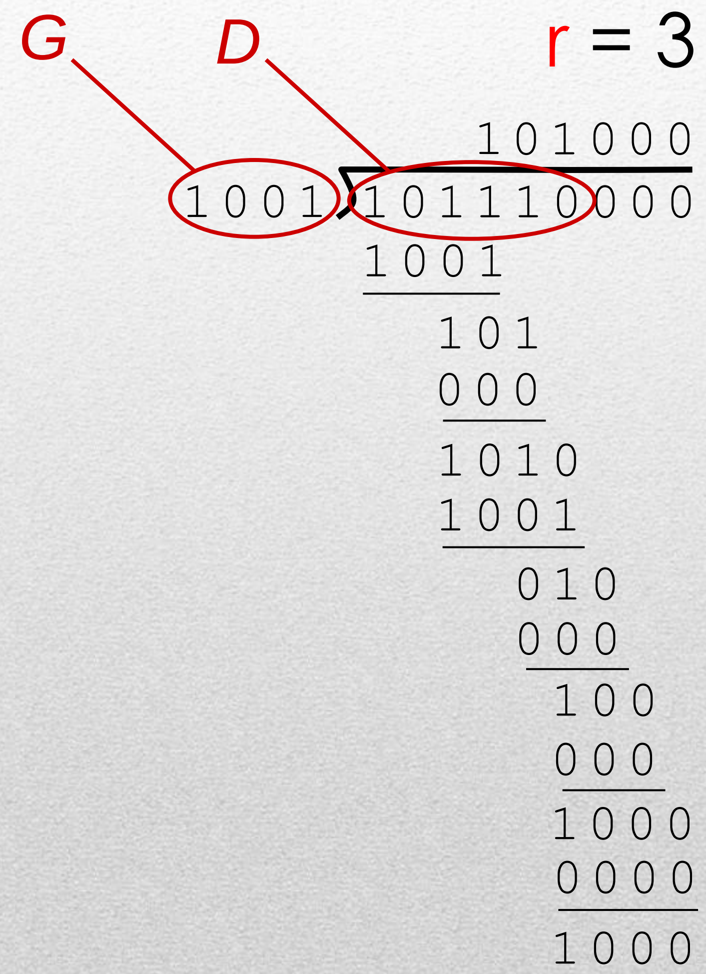
Equivalently:

$D \cdot 2^r$ = nG XOR R

Equivalently:

if we divide $D \cdot 2^r$ by G, want remainder R to satisfy:

$$R = \text{remainder}\left[\frac{D \cdot 2^r}{G}\right]$$

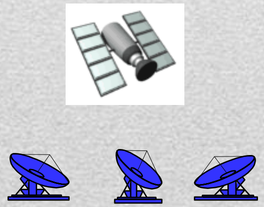


Multiple Access

- Two types of “links”
  - Point-to-point
    - PPP for dial-up access
    - Point-to-point link between Ethernet switch, host
  - Broadcast (shared wire or medium)
    - Old-fashioned Ethernet
    - Upstream HFC
    - 802.11 wireless LAN

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)



shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

Course Overview

Single shared broadcast channel

- Two or more simultaneous transmissions by nodes
  - Interference
  - Collision if node receives two or more signals at the same time

Multiple access protocol

- Distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- Communication about channel sharing must use channel itself!
  - No out-of-band channel for coordination

An Ideal MA Protocol

Given: broadcast channel of rate R bps

Desired:

- When one node wants to transmit, it can send at rate R.
- When M nodes want to transmit, each can send at average rate R/M
- Fully decentralized:
  - No special node to coordinate transmissions
  - No synchronization of clocks, slots
- Simple

MAC Protocols: Taxonomy

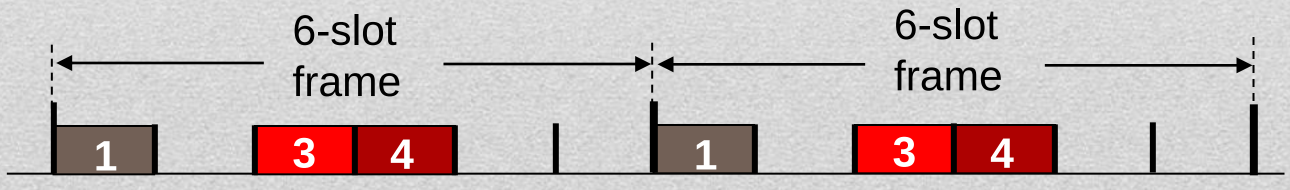
Three broad classes

- **Channel partitioning**
  - Divide channel into smaller “pieces” (time slots, frequency, code)
  - Allocate piece to node for exclusive use
- **Random access**
  - Channel not divided, allow collisions
  - Recover from collisions
- **Taking turns**
  - Nodes take turns, but nodes with more to send can take longer turns

Channel Partitioning: TDMA

TDMA: time division multiple access

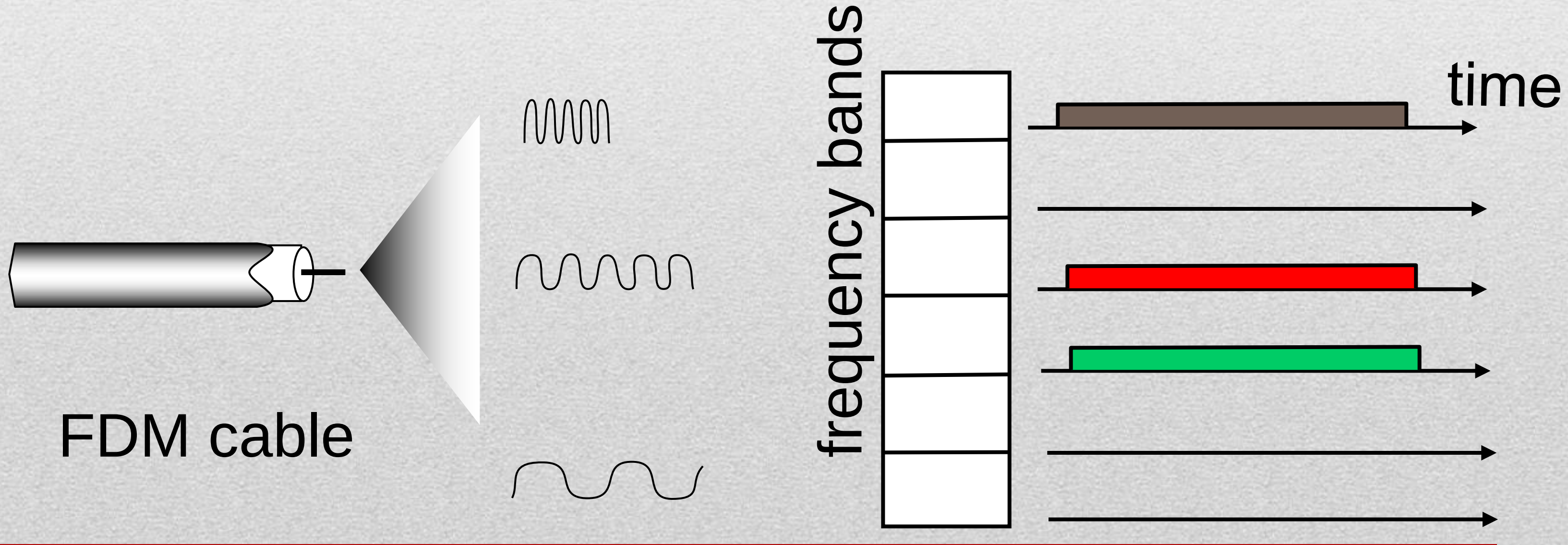
- Access to channel in rounds
- each station gets fixed length slot
  (length = packet trans time) in each round
- Unused slots go idle
- Example: 6-station LAN, 1,3,4 have packet, slots 2,5,6 idle



Channel Partitioning: FDMA

FDMA: frequency division multiple access

- 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 pkt, frequency bands 2,5,6 idle



Random Access

- When node has packet to send
  - Transmit at full channel data rate R.
  - No a priori coordination among nodes

- Two or more transmitting nodes ➜ "collision"

- Random access MAC protocol specifies:
  - How to detect collisions
  - How to recover from collisions (e.g., via delayed retransmissions)

- Examples of random access MAC protocols:
  - Slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA