Data Link Layer: Media Access Control (MAC) Overview

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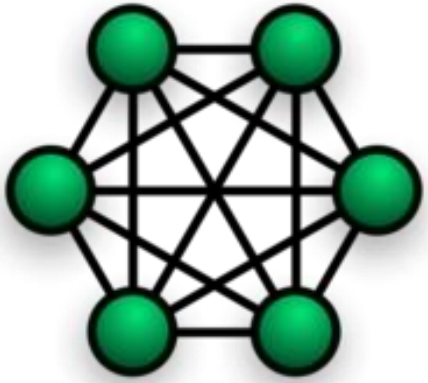
Problem

- Status: Can transfer data reliably between two point-to-point nodes

- Next: How to make a few tens of nodes talk?



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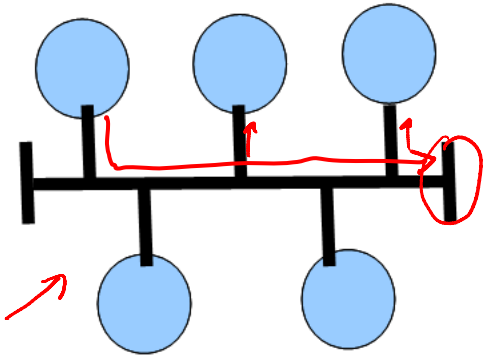
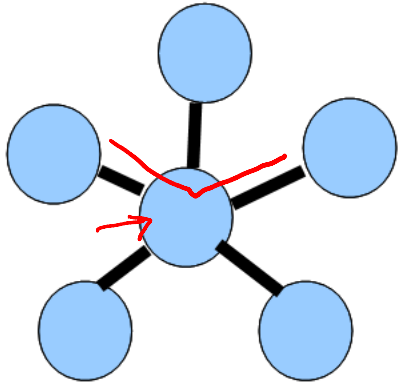
Outline

- How to interconnect nodes? Network Topology
- How to mediate access among the nodes? Media Access Control (MAC)
  - Categorize and discuss some popular MAC protocols
    - Overview, merits and demerits

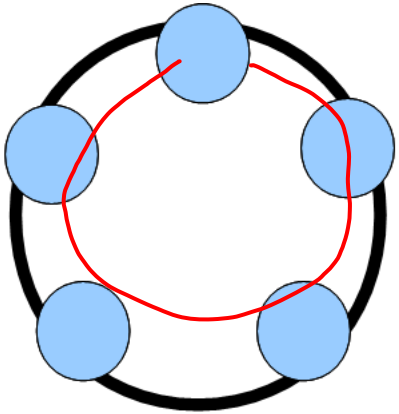
Network Topologies



BUS
E.g Ethernet
(Old-fashioned)



STAR
E.g. Ethernet Hubs



RING
E.g Token Ring

Note: Shared Wire or Medium is broadcast

Types of Transmission

- Unicast:
  - Packet is intended for one node only
- Broadcast
  - Packet intended for everyone
- Multicast
  - Packet intended for a subset.

Note: Shared Wire or Medium is broadcast

Media Access Control (MAC)

- Two or more simultaneous transmissions by nodes → interference (collision)
- **MAC: Protocol that determines how nodes share channel**
  - Determine when a node can transmit
  - Communication about channel sharing must use channel itself!

Ideal MAC

1 — N

- Broadcast channel of rate R bps
  - 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
  - Simple and easy to implement
  - Fault tolerant

Human Analogy

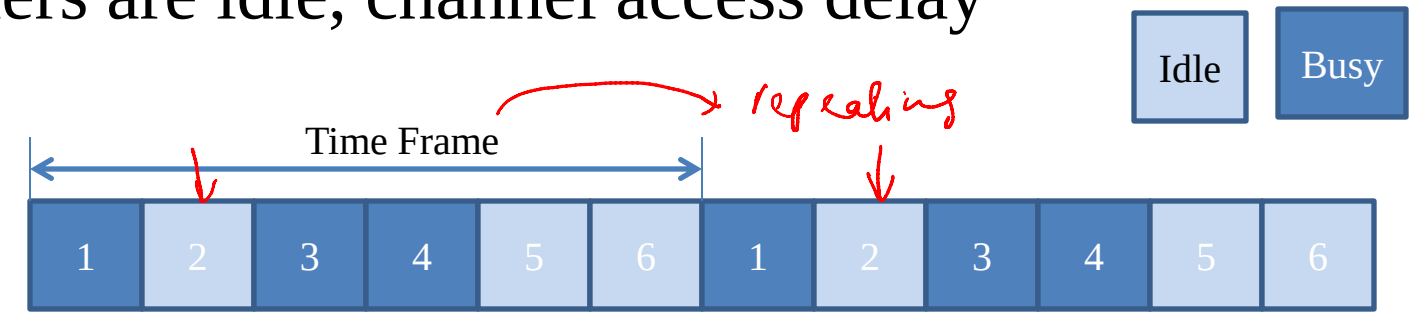
- Speed Dating Party: Couples want to talk with each other
  - Assumption: Everyone talks loudly, so everyone can hear everyone else in the room → If two speaker talk at same time, none can understand what was talked
- How would you facilitate meaningful conversations (no interference)?

Channel Partitioning Protocols

Divide resource into smaller “pieces”.
Allocate piece to node for exclusive use.

Time Division Multiplexing

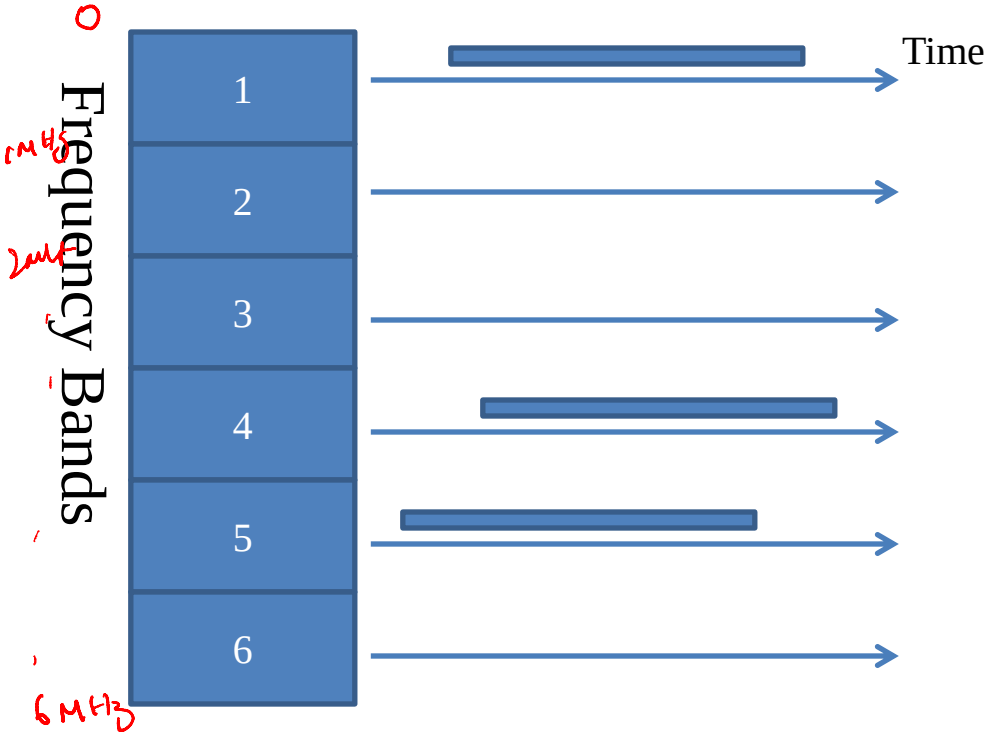
- Allocate couples different time slots → Time Division Multiplexing (TDM)
- Time divided into time frames. Time frames divided into N time slots. Each sender allocated one time slot.
- Disadvantage: Sender limited to R/N even when other senders are idle, channel access delay



Frequency Division Multiplexing

- Move couples to different rooms →Frequency Division Multiplexing (FDM)
- Spectrum divided into frequency bands
  - Sender/Receivers tune in to assigned frequency band
  - If there are N senders, each sender gets R/N bandwidth
- Disadvantages:
  - A sender limited to R/N even when other senders are idle
  - Sender-Receiver channel coordination

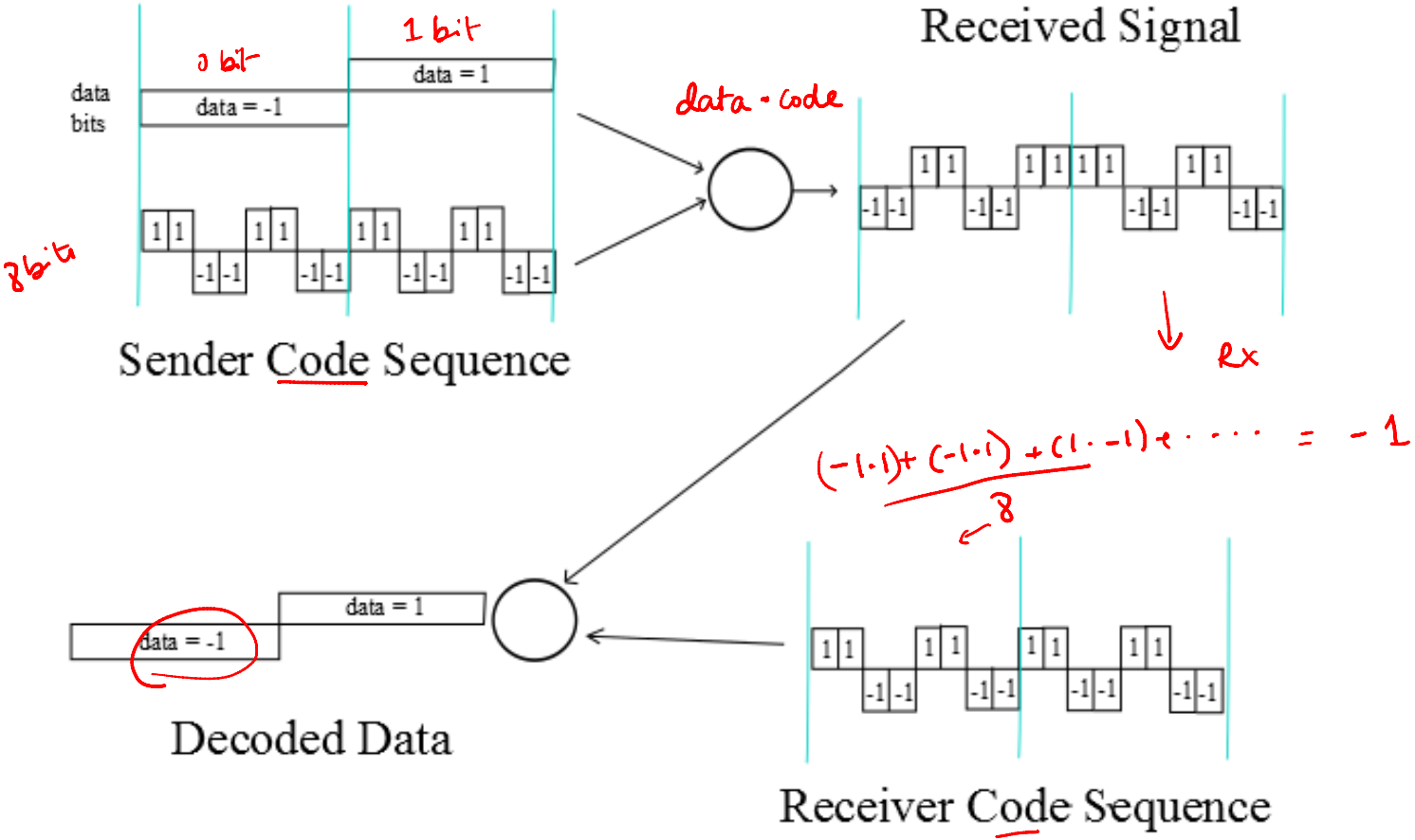
Frequency Division Multiplexing



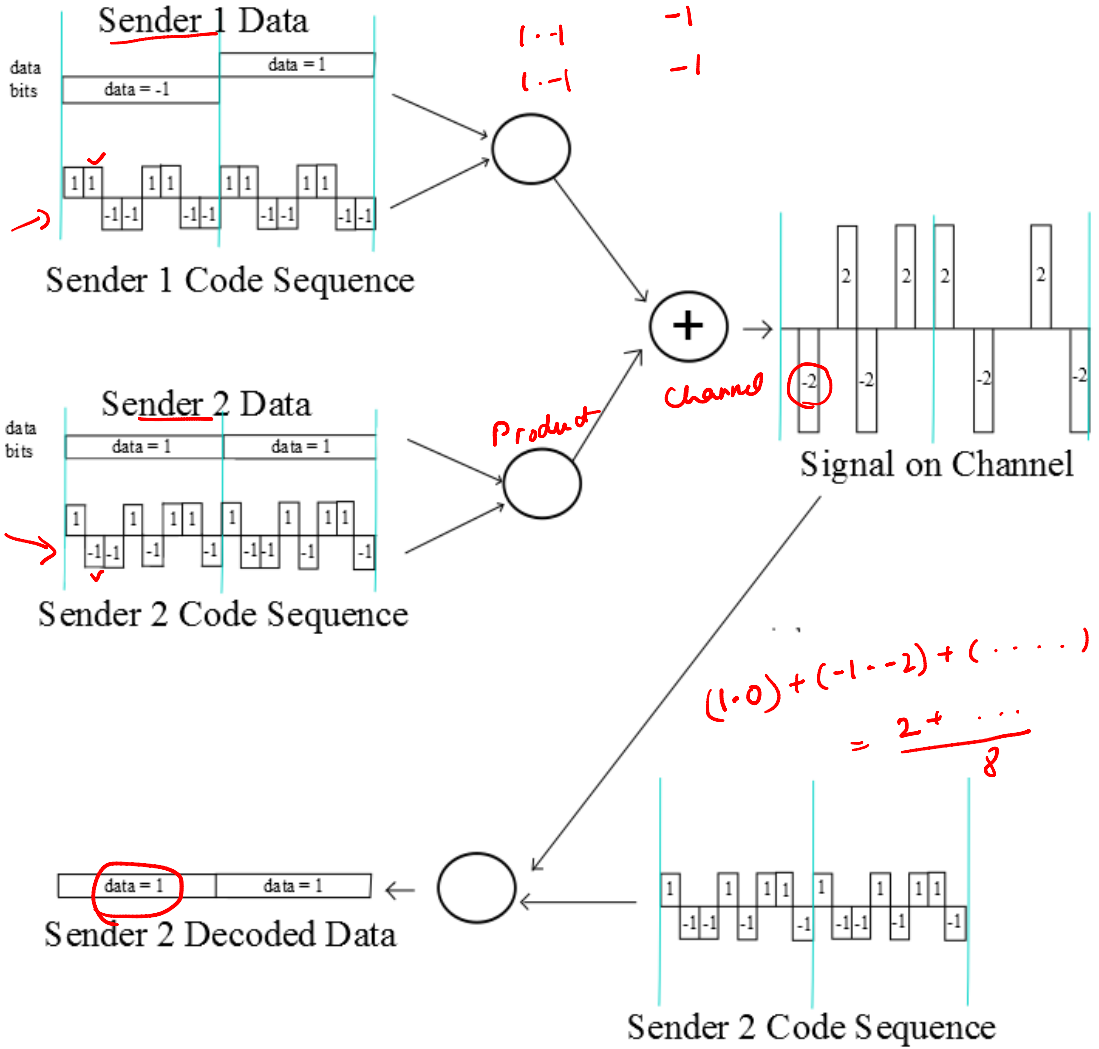
Code Division Multiplexing

- Ask couples to speak in different languages → Code Division Multiple Access (CDMA)
- Each sender is assigned a different code
  - Sender can transmit in the entire frequency band (Rbps) all the time,
  - With N senders, achievable rate is still R/N
- Same problem as with previous protocols

CDMA: Single Sender



CDMA: Two Senders



Human Analogy

- Speed Dating Party: Couples need to talk with each other
  - Assumption: Everyone talks loudly, so everyone can hear everyone else in the room
- How would you facilitate meaningful conversations (no interference)?

Random Access Protocols

- Polite Speaker: Listen. If its quiet, start talking. If this clashes with others, backoff and try again.
- No *a priori coordination among nodes*
- Sender transmits at full rate. If two or more transmit at same time → Collision

Random Access Protocols

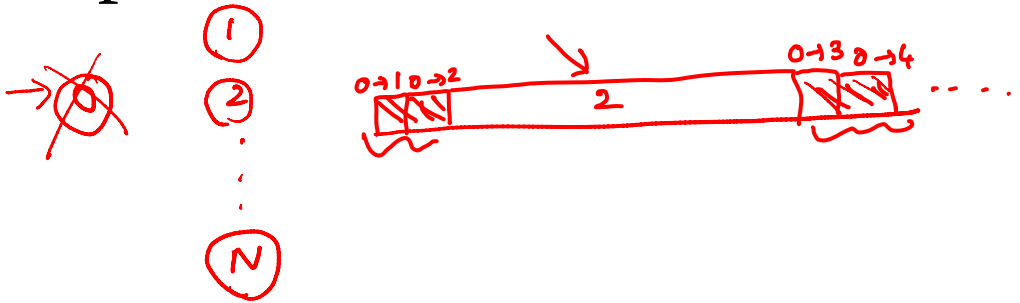
- Specify:
  - How to detect collisions?
  - How to recover from collisions?
- Disadvantages:
  - High load leads to too many collisions and wastage of resources

Taking Turns Protocols

- Quickly poll to see who wants to talk, give time slots to only speakers
- Channel partitioning MAC protocols: efficient and fair at high load, inefficient at low load
- Random access MAC protocols: efficient at low load, inefficient at high load
- Taking Turns protocols: Make the best of both worlds!

Polling (Centralized)

- A central coordinator polls nodes in a round robin fashion

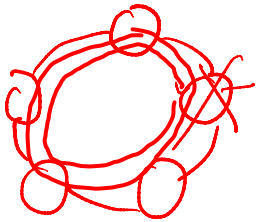


- Disadvantages:
  - Polling overhead (single user will get rate < R)
  - Single point of failure (coordinator)

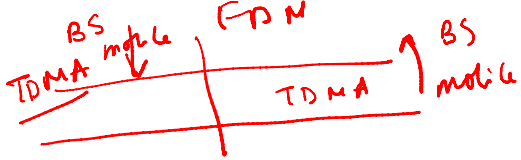
Token Passing (Decentralized)

- Control token passed from one node to next in certain order

Send a Packet



- Concerns
  - Token overhead
  - Single point of failure (token)



Usage

- TDMA with FDM: GSM, WiMAX, 3-4G
- CDMA: IS-95, CDMA2000, 3-4G
- Random Access: Ethernet, WiFi
- Polling: Bluetooth
- Token Passing: Token Ring

Summary

- Many nodes sharing a link → Need Media Access Control
- Three broad classes of Protocols:
  - Channel Partitioning: Divide resource into smaller "pieces" (time slots, frequency, code); Allocate piece to node for exclusive use
  - Random Access: Allow full access to resource but provide means to recover from collisions
  - Taking turns: Take turns using the resource, but nodes with more need get longer turns
- Next: Explore some popular technologies along with their corresponding MAC