Lecture 8:
Media Access Control

CSE 123: Computer Networks

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Overview

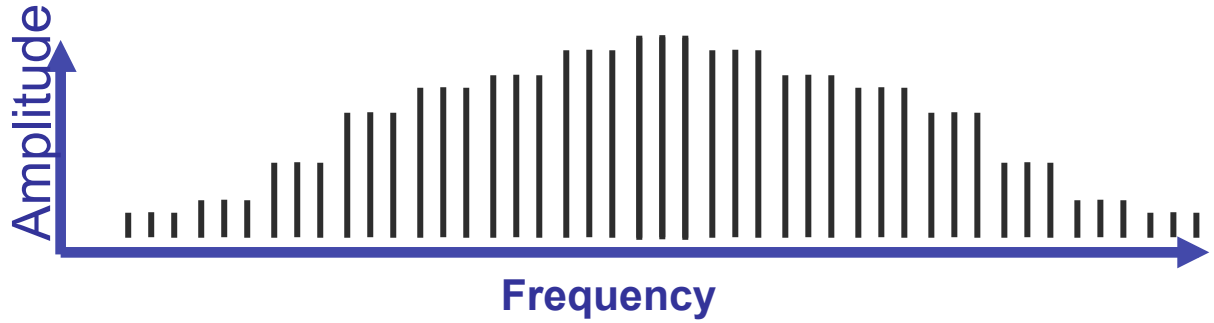
- Methods to share physical media: multiple access
  - Fixed partitioning
  - Random access
- Channelizing mechanisms
- Contention-based mechanisms
  - Aloha
  - Ethernet

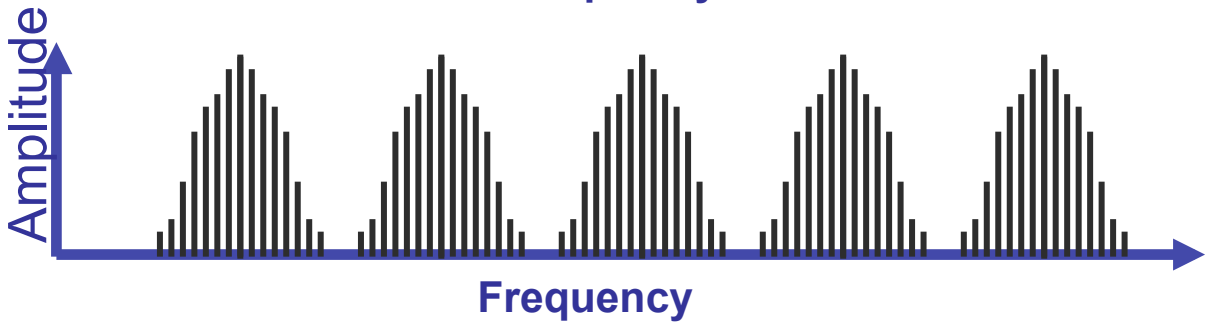
Fixed Partitioning

- Need to share media with multiple nodes (*n*)
  - Multiple *simultaneous* conversations
- A simple solution
  - Divide the channel into multiple, separate channels
- Channels are physically separate
  - Bitrate of the channel is split across channels
  - Nodes can only send/receive on their assigned channel
- Several different ways to do it
  - _____ Multiple Access madlibs…

Frequency Division (FDMA)

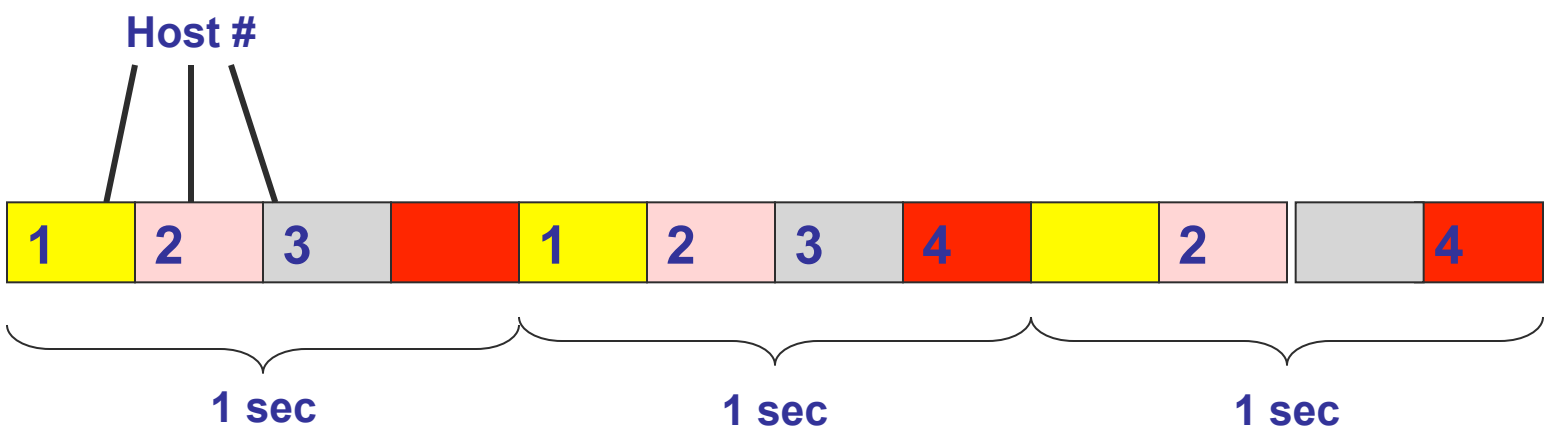
- Divide bandwidth of *f* Hz into *n* channels each with bandwidth *f/n* Hz
  - Easy to implement, but unused subchannels go idle
  - Used by traditional analog cell phone service, radio, TV





Time Division (TDMA)

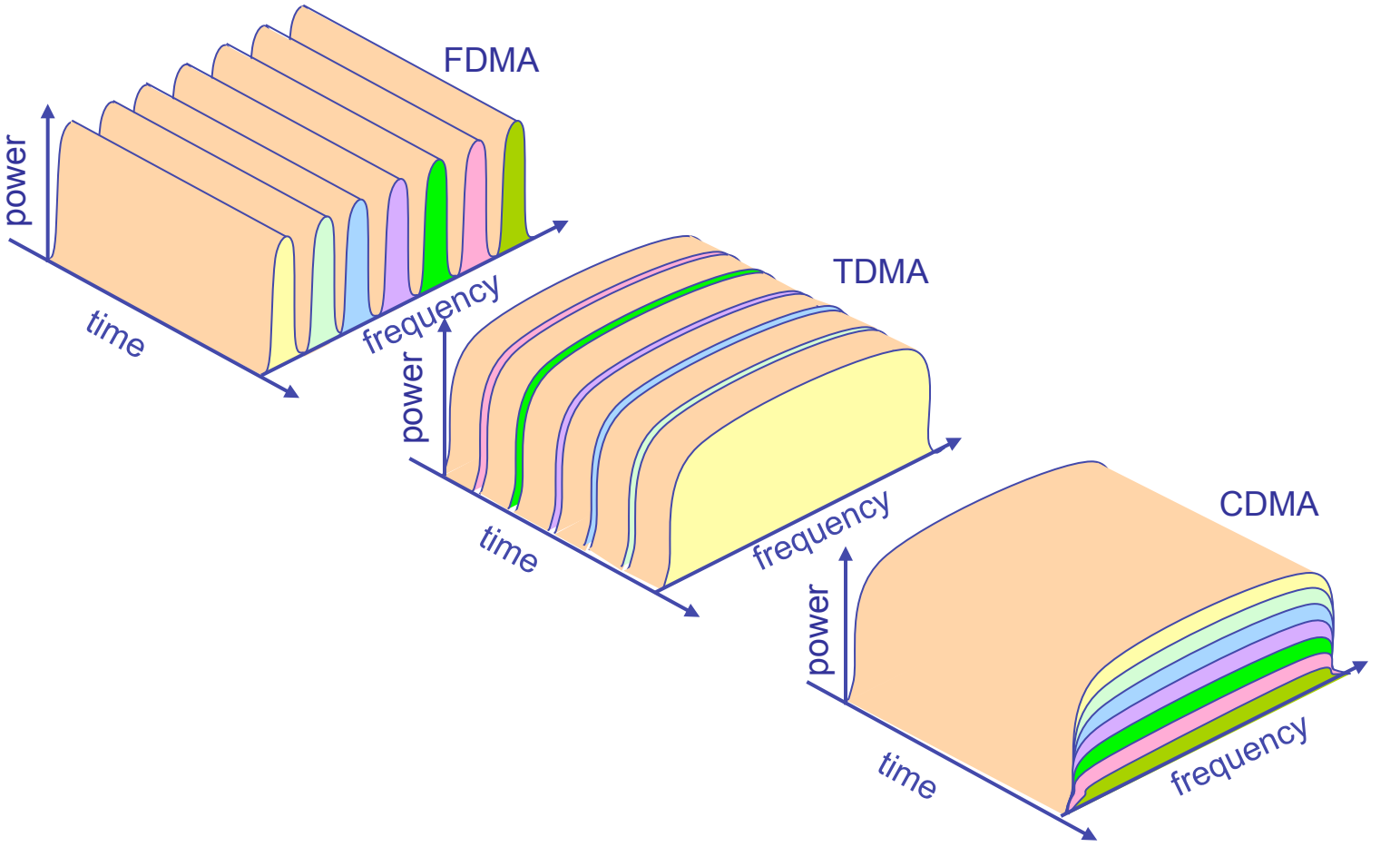
- Divide channel into rounds of *n* time slots each
  - Assign different hosts to different time slots within a round
  - Unused time slots are idle
  - Used in GSM cell phones & digital cordless phones
- Example with 1-second rounds
  - *n*=4 timeslots (250ms each) per round



Code Division (CDMA)

- Do nothing to physically separate the channels
  - All stations transmit at same time in same frequency bands
  - One of so-called spread-spectrum techniques
- Sender modulates their signal on top of unique code
  - Sort of like the way Manchester modulates on top of clock
  - The bit rate of resulting signal much lower than entire channel
- Receiver applies code filter to extract desired sender
  - All other senders seem like *noise* with respect to signal
- Used in newer digital cellular technologies

Partitioning Visualization



Courtesy Takashi Inoue

Problem w/Channel partitioning

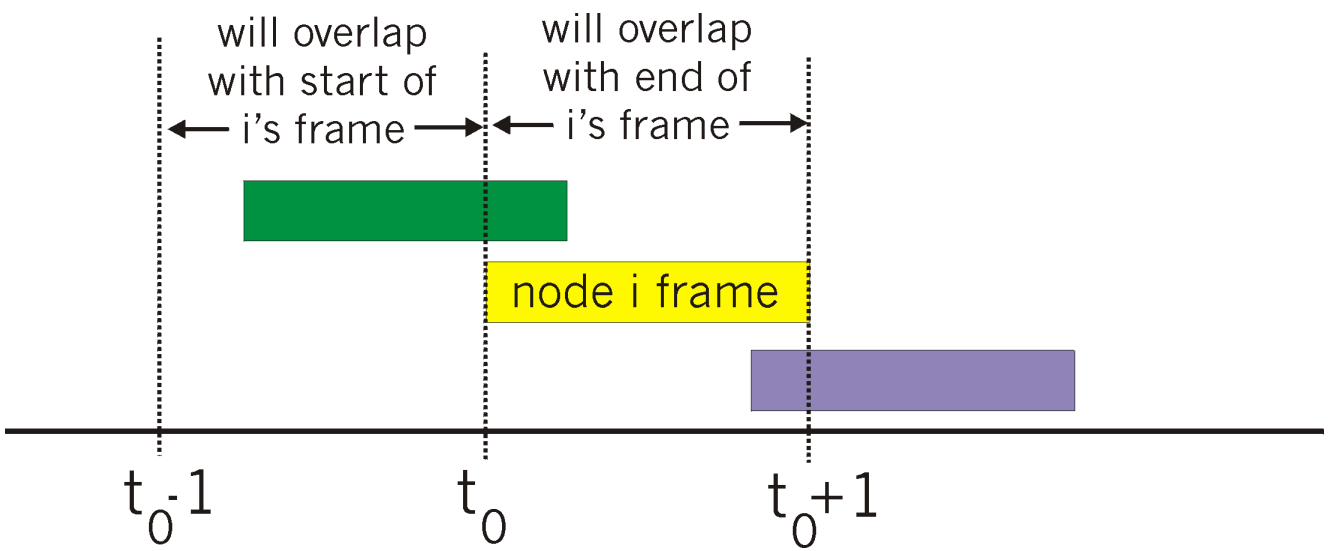
- Not terribly well suited for random access usage
  - Why?
- Instead, design schemes for more common situations
  - Not all nodes want to send all the time
  - Don’t have a fixed number of nodes
- Potentially higher throughput for transmissions
  - Active nodes get full channel bandwidth

Aloha

- Designed in 1970 to support wireless data connectivity
  - Between Hawaiian Islands—rough!
- Goal: distributed access control (no central arbitrator)
  - Over a shared *broadcast* channel
- Aloha protocol in a nutshell:
  - When you have data **send it**
  - If data doesn't get through (receiver sends acknowledgement) then **retransmit after a random delay**
  - Why not a fixed delay?

Collisions

- Frame sent at t_0 collides with frames sent in $[t_0\text{-}1, t_0\text{+}1]$
  - Assuming unit-length frames
  - Ignores propagation delay



Slotted Aloha

- Time is divided into equal size slots (frame size)
- Host wanting to transmit starts at start of next slot
  - Retransmit like w/Aloha, but quantize to nearest next slot
- Requires **time synchronization** between hosts

Success (S), Collision (C), Empty (E) slots

Channel Efficiency

Q: What is max fraction slots successful?

A: Suppose *n* stations have packets to send

- Each transmits in slot with probability *p*
- Prob[successful transmission], *S*, is:

$$S = p\,(1-p)^{(n-1)}$$

- any of *n* nodes:

S = Prob[one transmits] = $np(1-p)^{(n-1)}$

(optimal *p* as *n*->infinity = *1/n*)

= *1/e* = *.37*

At best: channel used for useful transmissions 37% of time!

Carrier Sense (CSMA)

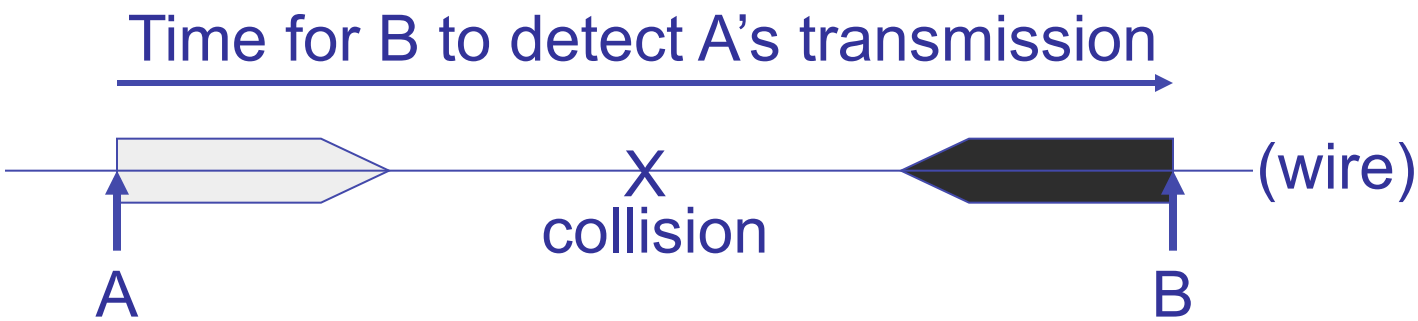
- Aloha transmits even if another host is transmitting
  - Thus guaranteeing a *collision*
- Instead, listen *first* to make sure channel is idle
  - Useful only if channel is frequently idle
  - Why?
- How long to be confident channel is idle?
  - Depends on maximum propagation delay
  - Small (<<1 frame length) for LANs
  - Large (>>1 frame length) for satellites

Retransmission Options

- non-persistent CSMA
  - Give up, or send after some random delay
  - Problem: may incur larger delay when channel is idle
- 1-persistent CSMA
  - Send as soon as channel is idle
  - Problem: blocked senders all try to send at once
- *P*-persistent CSMA
  - If idle, send packet with probability p; repeat
  - Make sure $(p * n) < 1$

Jamming

- Even with CSMA there can still be collisions. Why?



- If nodes can detect collisions, abort! (CSMA/CD)
  - Requires a minimum frame size ("acquiring the medium")
  - *B* must continue sending ("jam") until *A* detects collision
- Requires a full duplex channel
  - Wireless is typically half duplex; need an alternative

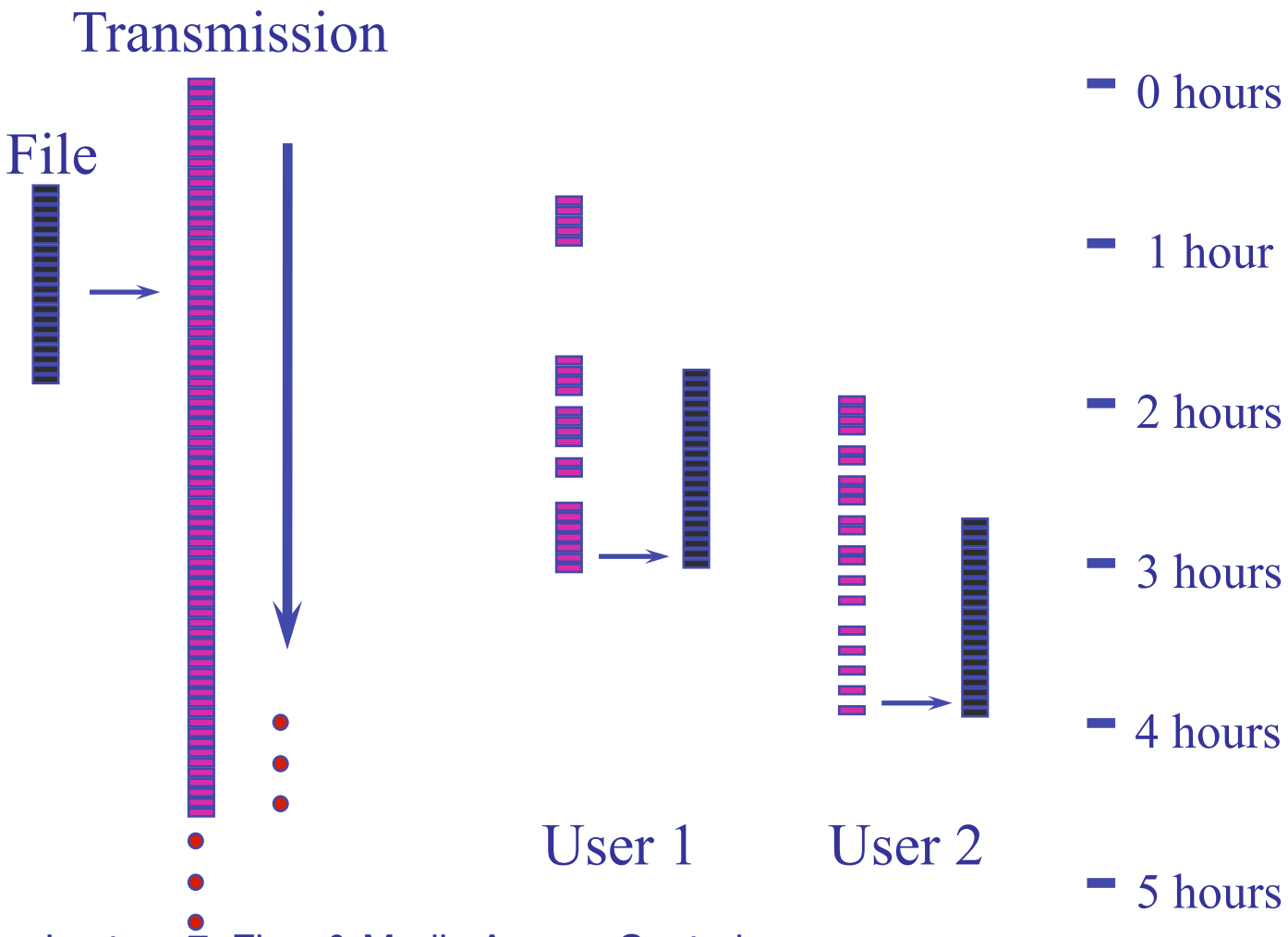
Collision Detection

- How can A know that a collision has taken place?
  - Worst case:
    - » Latency between nodes A& B is d
    - » A sends a message at time t and B sends a message at t + d – epsilon (just before receiving A's message)
  - B knows there is a collision, but not A… A must keep transmitting until it can tell if a collision occurred
  - How long? *2 * d*
- IEEE 802.3 Ethernet specifies max value of *2d* to be 51.2us
  - This relates to maximum distance of 2500m between hosts
  - At 10Mbps it takes 0.1us to transmit one bit so 512 bits take 51.2us to send
  - So, Ethernet frames must be at least 64B (512 bits) long
    - » Padding is used if data is too small
- Send jamming signal to insure all hosts see collision
  - 48 bit signal

For Next Time

- Read 3-3.2 in P&D
- Keep going on the project…

Forward Error Correction

- Use erasure codes to redundantly encode *k* data frames into *m*>*k* encoded frames
  - Why do it at the frame level?
  - E.g., Reed Solomon Codes, Tornado codes
- Multicast/broadcast encoded frames speculatively
- A receiver can reconstruct message from *any k* frames in the set of *m* encoded frames

A "Digital Fountain"