Sharing Channels
CS 118
Computer Network Fundamentals
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Outline

- Ways to share the channel

  channel is wireless network (UCLA Web or WiFi)
  divide up signal to determine which signal belongs to who

- Label (name) implications
- Emulated sharing
- Explicit coordination

  method of working together on the same channel with a laid out plan of what to do

Ways to share a channel

- Different channels
- Different times

  whoever is usin the channel at different times (clocked schedule)

- Different symbol sets (“languages”)

  it can carry different frequencies and overlay the signals

- Label the transmissions

  tells you who is doing what

Different channels

- Spatial Division Multiplexing (SDM)
  - Channels are spatially distinct

run different wires; very costly
expensive: anything that involves laying down wires cost hella

  - The most costly
    (basically where we started – doesn't scale)

laying wires and expensive because it is a physical device

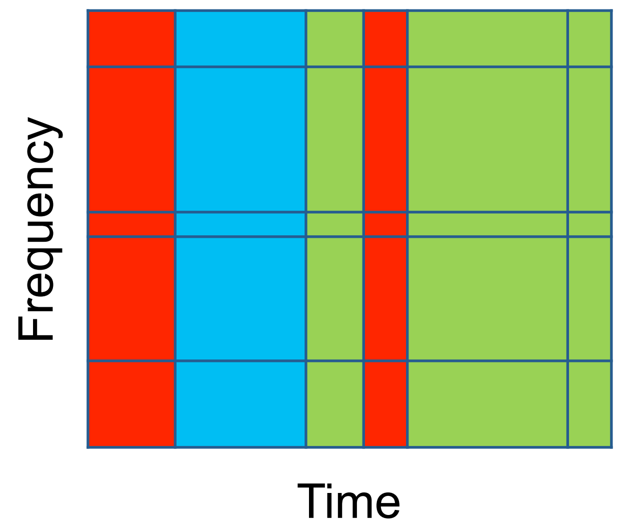
Different times (TDMA)

- Take turns using the channel
  - Whole channel
  - Split in time

color bands represents who is using the channel
at different time intervals

you have either the entire channel devoted to you
or you cannot do anything

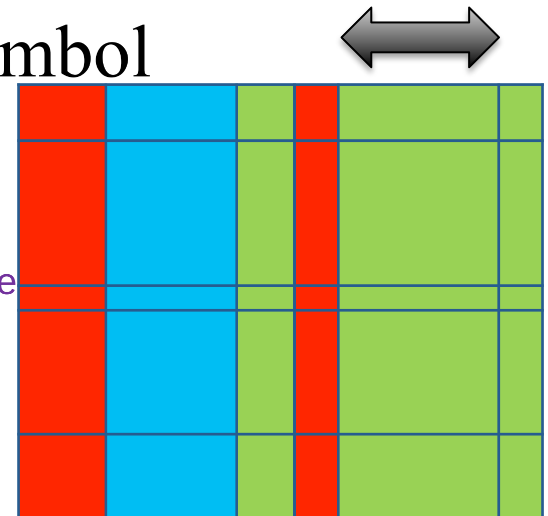
atomicity in the TDMA system



TDMA

TDMA concerns

- Time interval size at least long enough for at least one symbol
  - Long enough for at least one symbol



- Time interval allocation
  - Fairness everyone gets the same amount of time
  - Starvation a bunch of people use resource
  - Efficiency (unused slots)

if you have nothing to send, you have wasted channel, so keep track of unused time slots

- Gap between intervals
  - "Guard time"

use channel and stop at certain times

add a padding called guard time as safety precaution

Impact of guard time

- Guard time avoids sender overlap
  – All receivers should see non-overlapping slots
  – But: clock keeps getting further and further apart
    - Sender clocks drift (gain or lose offset)
    - Symbol delay varies overlap signals
- Consequence
  – TDMA needs clock coordination
  – TDMA has distance limit
    - Long distance = large guard gaps = inefficient channel

ex. GPS: works because clock synchronization on order of several miles

Different symbol sets

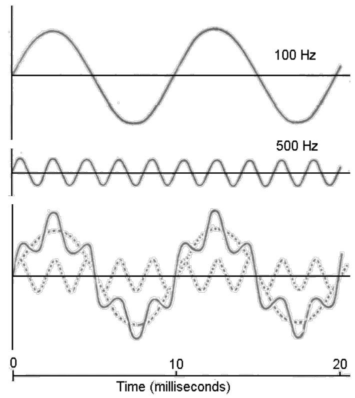
- Each symbol set is an independent “language”
  – Independence means that the bit encoding is separate from the way the sets are distinct
- Many different variants:
  – Different representations using independent physical properties
  – Different alphabets (logical representations)

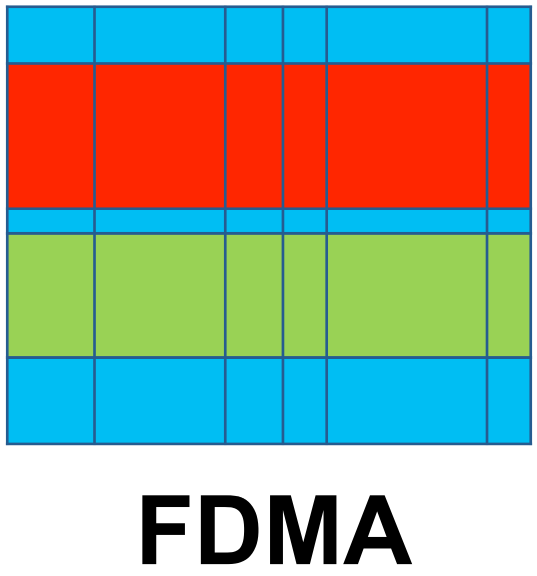
Different physical representations

- Frequency
- Polarization
- Orbital angular momentum
- Combinations of the above

Frequency (FDMA)

- Split channel capacity into non-overlapping ranges
  - Works for wavelengths
  - E.g., for EM (light, RF)

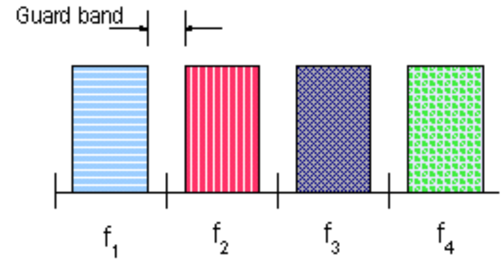




colored bands indicate a particular party performing communication
no one else can use that range of frequencies ever

FDMA concerns

- Width of the band (bandwidth)
  - Large enough for desired bitrate
- Band allocation
  - Fairness wasted resources if not allocated well
    - Starvation
    - Efficiency (unused frequencies)
  - Gap between bands
  - "Guard bands"



Impact of guard bands

- Guard bands avoids sender overlap
  - All receivers should see non-overlapping bands
  - But:
    - Sender frequencies drift
    - Motion affects frequency (Doppler shift)

limit to how little you can send something if you want to translate to particular rate

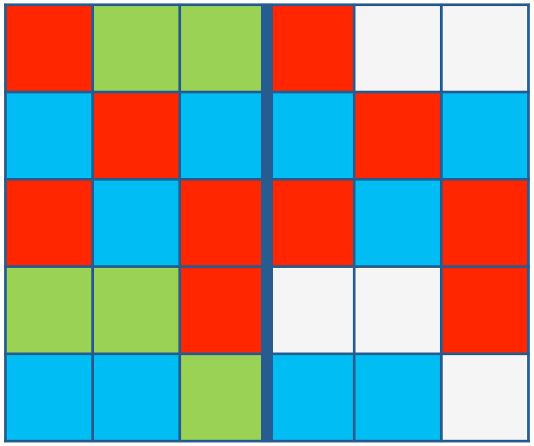
- Consequence
  - FDMA needs frequency coordination
  - FDMA has band size limit

Different alphabets

- A different way to group by physical property
  - Instead of using independent properties, separate groups by the values of one or more properties
  - Need the groups to be independently usable

Code (CDMA)

- Combines frequency and time
  - A combination of time and frequency that allows partial overlap that can enable communication in the presence of increased noise



CDMA

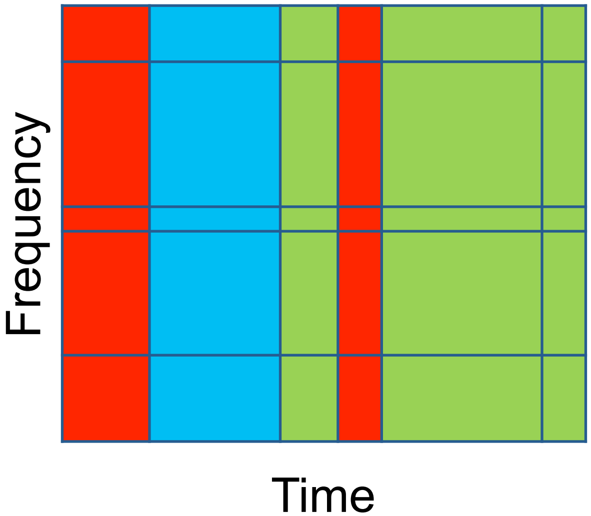
white slots indicate we don't have anything to send at the time

xDM vs xDMA

- {Space, Time, Code} Division Multiplexing
  - Sharing (dividing a resource) by multiplexing (merging) or demultiplexing (splitting) based on spatial, temporal, or coding context
- {S/T/C) Division Multiple-Access
  - Using xDM to coordinate shared access of a channel by multiple sources or receivers

Often used somewhat interchangeably

Sharing compared

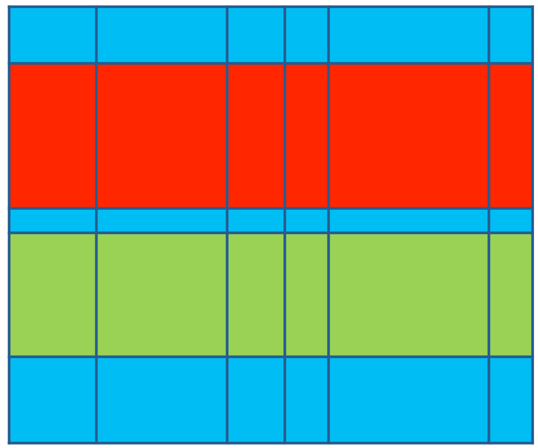


TDMA

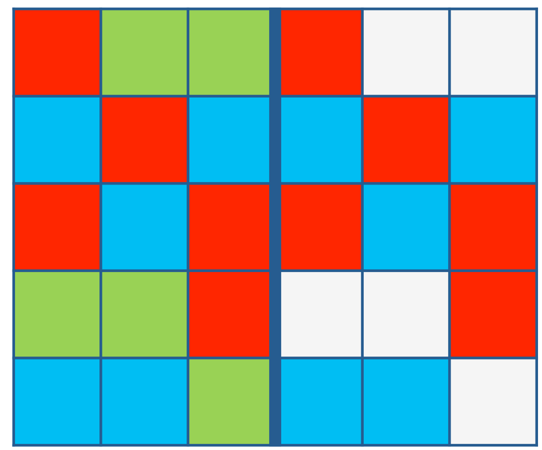
shared medium networks

share same freq. shannel by dividing
the signal into different time slots

FDMA: used more in satellite systems, coordinating
access between multiple users



FDMA



CDMA

radio comm
technologiess

CDMA: get through coordinated stuff today
divide CDMA into so many pieces, assuming we don't have parties that
go forever, we will still have that same issue
who gets that period of time in TDMA vs FDMA

Label (name) implications

- If you only worry about multiparty:
  - Unique per-node peer names
  - Unique per-node internal state/TM subset names
- If you also worry about channel sharing
  - Name sets used in overlapping contexts
  - Need to ensure no namespace collisions
  - Need to ensure both ends agree on names

Destination names

- Context (1:N)
  - Know the channel
  - MAY mean the receiver knows the source
- Uniqueness
  - MUST be unique per-receiver on this channel
- Shared
  - MUST be known by sender and receiver
  - Sender knows what to attach to a message
  - Receiver knows where message goes to

Source names

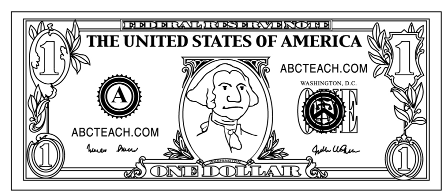
- Context (N:1)
  - Know the channel
  - MAY mean the source knows the receiver
- Uniqueness
  - MUST be unique per-sender on this channel
- Shared
  - MUST be known by sender and receiver
  - Sender attaches its name to message
  - Receiver knows where the message came from

Combined names

- Context (N:N)
  - Maybe know the subset of senders/receivers
  - Not very useful
- Uniqueness
  - Send names MUST be unique
  - Receive names MUST be unique
  - MAY (usually) correlate send:receive names
- Shared
  - MUST be known by all senders and receivers
  - Senders attach BOTH names (its send, dest's recv)
  - Receiver uses BOTH names (determine source, decide to accept)

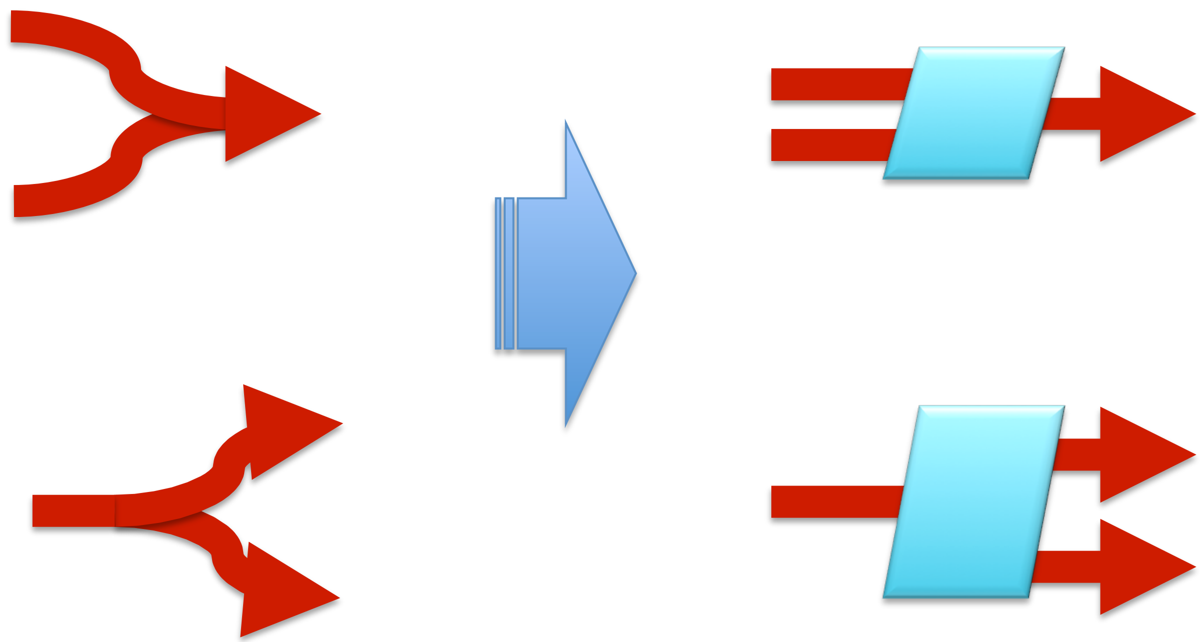
Name assignment

- A-priori here (for now)
  - Part of the protocol configuration
- How?
  - An organization (IANA, IEEE, etc.)
  - To ensure uniqueness
  - How expensive?



Emulated sharing

- Devices can emulate sharing



Demultiplexer

- 1:N
  - One source, multiple receivers
- Isolates receiver from sharing
  - Source still thinks the channel is shared
    - Needs to indicate the destination
  - Receiver thinks it has direct channels
    - Doesn't need to know whether to listen
- What's in the box?
  - Copies / splits symbols
  - Use destination names to demultiplex (pick output port)
  - Can remove the differences (translation) i.e., using a FSM

Multiplexer

- N:1
  - Multiple sources, one receivers
- Isolates sender from sharing
  - Source still thinks it has direct channels
    - Doesn't need to indicate the source name
  - Receiver thinks the channel is shared
    - Needs to know the source
- What's in the box?
  - Merges / interleaves symbols
  - Add source names to output
  - Adds the differences (translation)
    i.e., using a FSM

Switch

- N:N
  - Multiple sources, multiple recvs
  - Combines demux with mux
- Isolates sender and a receiver in different ways
  - Sender still needs to indicate receiver (like demux)
  - Receiver still needs to know sender (like mux)
- Centralizes coordination
  - Internal to the switch

Switch pros and cons

- Pros
  - Coordination is internal
  - Easier to install/manage channel wiring/fibers
  - All the pros of explicit coordination
    - Efficient, global balance, simple to implement
- Cons
  - All the cons of explicit coordination
    - Load, fault tolerance, trust
  - Still needs source/dest to participate in naming
  - Still needs unique names

What about circuits vs. packets?

- Really just a continuum of TDMA
- Smaller allocation avoids impact to others
- In this case, doesn’t matter much!
  - It will matter more in later lectures

Explicit resource coordination

- Why coordinate?
  – N:1 sharing needs to avoid collisions
- Where is 1:N sharing coordinated?
  – Can be just inside the OS in the endpoint
- Why explicit?
  – Simple case, focus of this class

A-priori coordination

- Part of the pre-shared rules
  - I.e., part of the protocol

- Fixed allocation
  - Fixed schedule, frequency bands, etc.

Limits of a-priori coordination

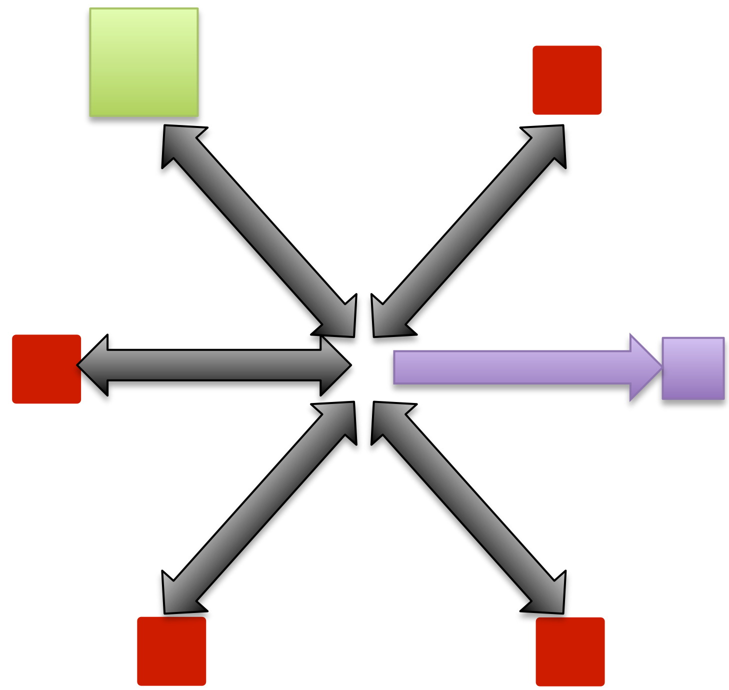
- Requires coordination
  - Need to build it into the protocol
  - Still needs a starting point (time, frequency)
- Inefficient
  - Slow/costly to change (repeated coordination)
  - Fixed allocations can't adapt to dynamic uses
  - Can't easily add/remove nodes or resources

Centralized coordination

- Manager node controls each shared channel
  - They decide when each source can transmit
  - Can ask the sources about needs

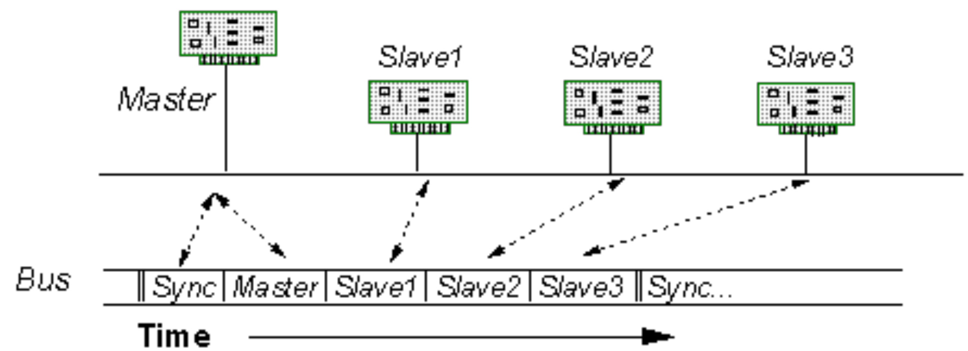
Requirements for central coordination

- Symmetric channel
  - All possible sources need to be able to hear the manager
  - All possible sources need to respond to the manager
  - Also receive-only nodes



Central coordination protocol

- Polling
  - Non-PC terms:
    - "Master"
    - "Slave"
  - Channel
    - Bus



- Master does the following
  - Ask each source in turn – anything to send?
  - Then schedules and gives each source a slot to send

Limits of central coordination

- Load
  - Pushes all the work to one manager
- Fault tolerance
  - Manager could fail
  - Channel to manager can fail
- Trust
  - Manager has all the power!

Hierarchical/delegated coordination

- Extend central coordination
  - Single manager can split a shared resource and assign each to another to manage
- Pros
  - Relieves load on a single manager
- Cons
  - Less flexible; hard to coordinate sharing across delegated fractions

Benefits of explicit coordination

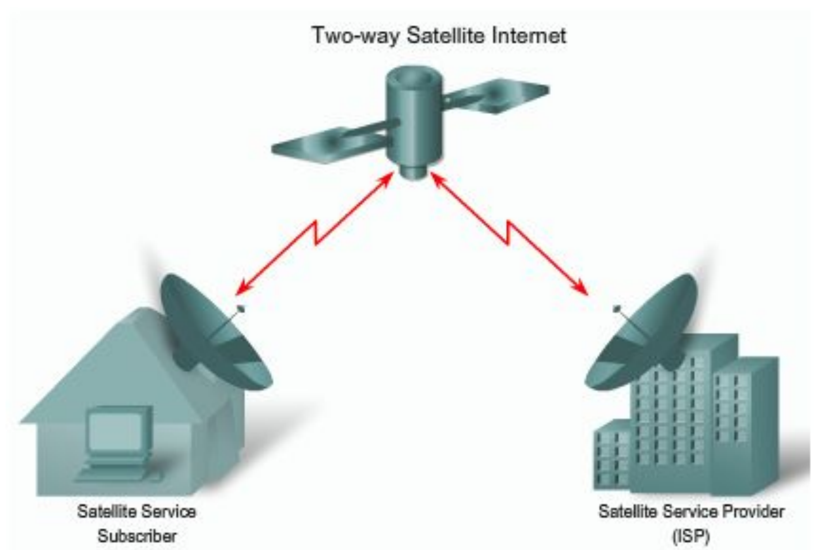
- Potentially very efficient
  - Esp. if requirements are stable (don't vary)
- Potential for global balance
  - Manager knows all, so can make the most informed decisions
  - Trivial to avoid starvation, ensure fairness
- Simple to implement
  - Simple coordination protocol

Limits of explicit coordination

- Potentially very inefficient
  - Inflexible, slow to react
  - Can require lots of messages to parties not involved in the communication
- Vulnerable
  - Faults, non-malicious, and malicious errors
  - All can completely halt shared channel use
- Can be costly to implement
  - Focused management can require centralized resources (CPU, memory, etc.)

Use cases for explicit coordination

- When all communication already flows through one party
- When does that happen?
  - Satellite
  - Airplane/blimp
  - Ceiling (infrared)
  - Ethernet switch
  - WIFI switch



Decentralized Sharing

- Extending 2-party and N-party masters
- Sharing without a master
- Limitations of no-master sharing
- Naming implications
- More switching

Overall sharing goals

- Fairness
  - Allocation is proportional to needs
- Starvation-Free
  - All members receive non-zero allocations
- Efficient
  - Minimize resources not usefully allocated

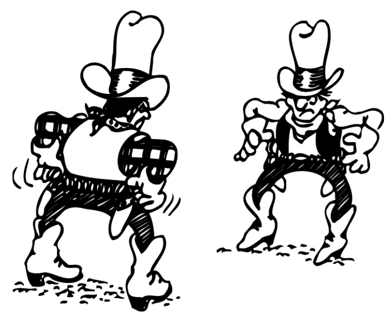
As with any resource allocation

2-party master

- Recall:
  - One side controls the system
  - Master: sends as desired, polls other side
- Issues
  - Controller (master) selection
  - Fault tolerance
  - Bias

2-party controller selection

- Seek inspiration
  - O.K. Corral: whoever shoots first wins
  - Backgammon: roll dice; highest roll goes first



- Tie-breaking
  - O.K. Corral: not needed (both dead!)
  - Backgammon: try again!

Tie-breaking 101

- Problem
  - Computers are deterministic
  - Rolls are pseudorandom sequences
  - Algorithm and seed generates one sequence
- Solution
  - Highest serial number
  - Requires a serial number that can never tie

2-party fault tolerance

- What happens if controller halts?
  - No problem!
  - No communication anyway!

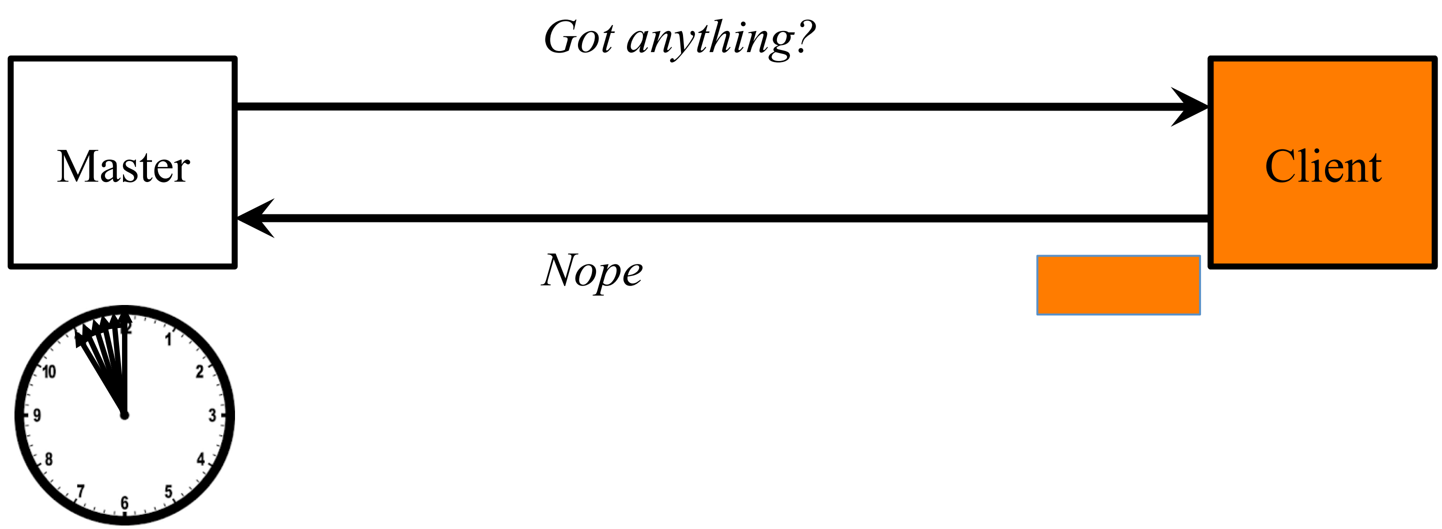
- "Fate sharing"
  - The controller and 2-party system share fate
  - No case where communication *could* happen but a dead controller prevents it
- More complex issue when we get beyond 2 parties . . .

2-party bias

- Controller
  - Can send whenever desired
- Other side
  - Needs to wait for controller to poll
- Impact:
  - Biased controller can undermine fairness
  - Even a “good” controller has problems

Why are there problems?

- Client request might occur just after every poll



- When a poll returns NO, client must wait for next poll
- Whereas the server can send immediately

Solving 2-party control

- Transfer control of a master
  - Helps balance bias over the long term
  - Additional cost to initiate/confirm the transfer
- Shift from master to ping-pong
  - One side starts
  - Send message or shift the token
  - Token "ping-pongs" until useful data is sent
  - Both sides get an equal chance to send
  - Fair if message lengths are equal (on average) (can establish length upper bound)

N-party master

- Like 2-party in general
  - Controller (master) polls each member

    master does polling to see who is a controller
    whole lot of parties sharing same channel: trying to send through same medium
- Same issues
  - Controller (master) selection
  - Fault tolerance
  - Bias

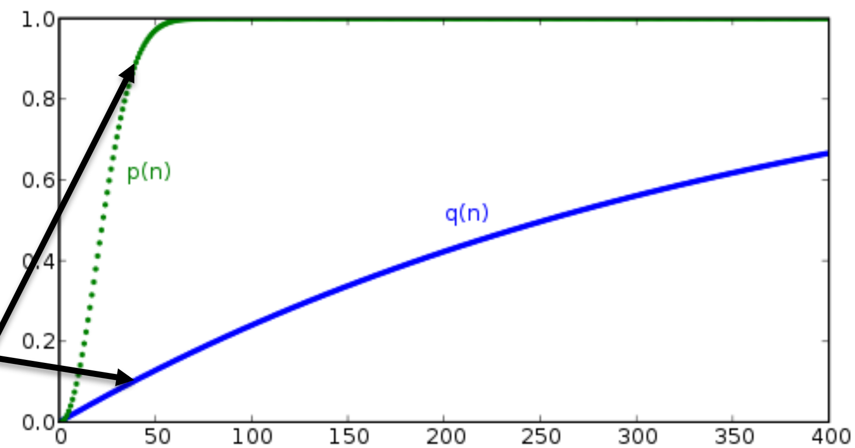
N-party controller selection

- Same solutions
  - Go-first (time)
  - Highest-roll (value)
- Same tie-breaking
  - Try again
- Doesn't scale very well
  - Many selection algorithms prone to ties at high scale
  - The Birthday Problem

Happy Birthday!

- What's the probability that one of you shares Ben Franklin's birthday (Jan. 17)?
  – For 40 people, 1-(364/365)^40 = 10%
- What's the probability that two of you share one birthday?
  – Roughly 90% for 40 people

• *How does this apply to controller selection?*



• *Unless random space is much larger than the number of candidates, ties are likely*

pure probability can help you see this

N-party fault tolerance

- What happens if controller halts?
  - "A failure to communicate"

- No more "fate sharing"
  - A controller can halt while other pairs could still want to communicate

N-party bias

- Controller has much more “control”
  – Can treat clients preferentially
  – Can keep all clients waiting
- New issues
  – Not just controller/client message sizes, but also the sizes of each client’s messages

master may give N-a people more preference than the others

Solving N-party control

- Shift from master to rotation
  - Rotation is N-party version of ping-pong cycle
  - Aboriginal “Talking stick”
- Rules:
  - Starts with the chief
    - Need a “chief election” protocol (dice?)
  - Pass in a circle to the right
  - Only the stick holder can talk
- This is “Token bus” (IEEE 802.4)
  - Used by GM for automation
  - Derived from a ring network
    (but we haven’t even gotten there yet)

token bus (IEEE 802.4) is derived from the ring network

Problems with token bus

- Token generation
  - Protocol to select the token holder
- Token regeneration
  - What if the token holder fails?
- Enforcing single-token rule
  - Members can cheat
- Membership changes
  - Add member – repair sequence
  - Remove member – repair sequence, regenerate token

Result – largely abandoned

Sharing without a master

- Inspiration:
  - Discussion group without a talking stick
  - “Party line” telephone

Aloha!

Radio network required

- Radio network (1971)
  - One shared channel

same time ARPNET was designed

1. Message to send
2. Send message
3. Did you hear it?
   - Yes – DONE
   - No – resend (goto #2)

Why didn’t you hear your message?

- Because someone else stepped on it
  - By transmitting at the same time
- What do you do about it?
  - Send again
  - Hoping it won’t get stepped on again
- A little problem
  - The other guy’s message also got stepped on
    - By you
  - He’s going to send again, too

Using random delays

- If your message is stepped on, don't send right away
- Wait for a random time and try again
- You hope the other guy waits longer
  - Or sufficiently shorter
- In which case you don't step on each other again
- Obvious issue of utilization vs. chances of repeated collisions

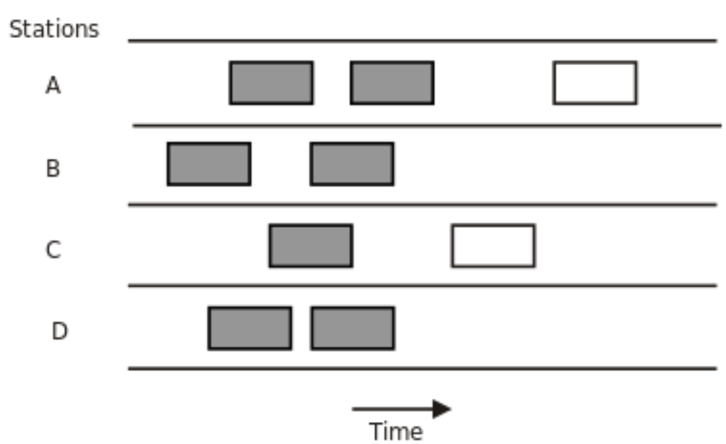
One solution

slots of time - only send message in slotted time

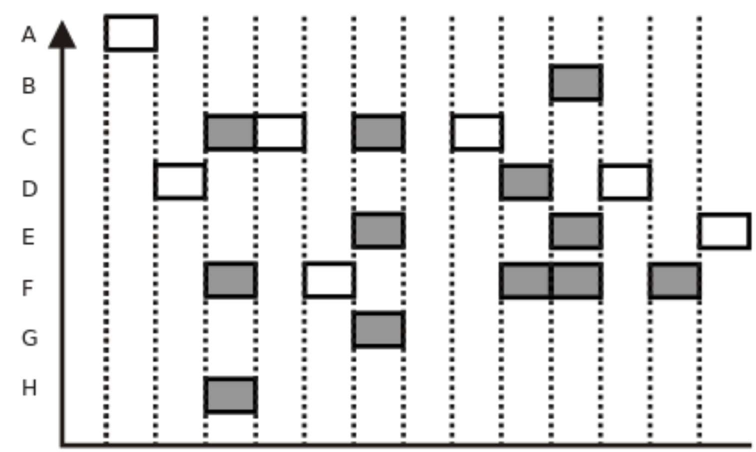
- Slotted Aloha
- Don't send just any time
- Divide time into slots
- Only send at the start of a slot
- On collision, retransmit in next slot
  - With probability p (<1)

Pure vs. Slotted

- Pure
  - Send whenever



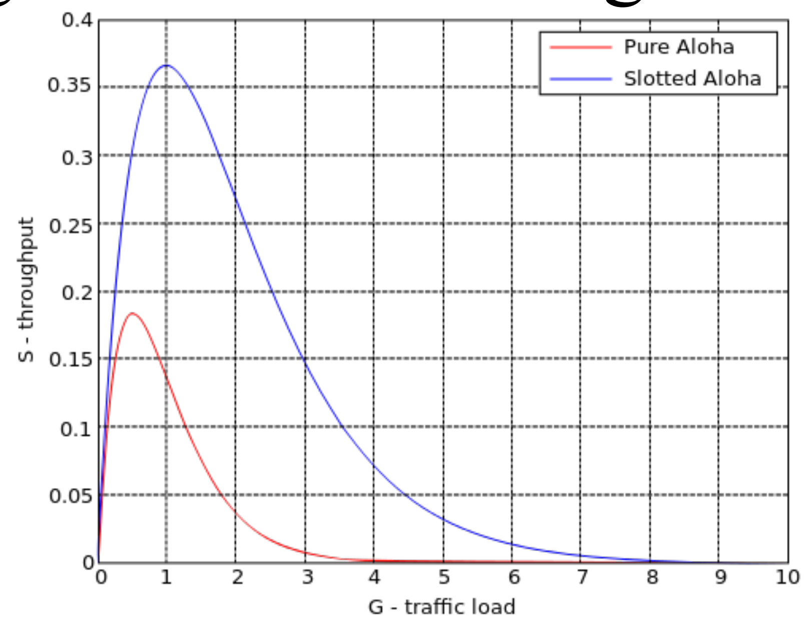
- Slotted
  - Common slot time
  - Send at slot start only
  - Mixes in TDMA



Slotted ALOHA protocol (shaded slots indicate collision)

Pure vs. slotted

- Assuming fixed-size messages



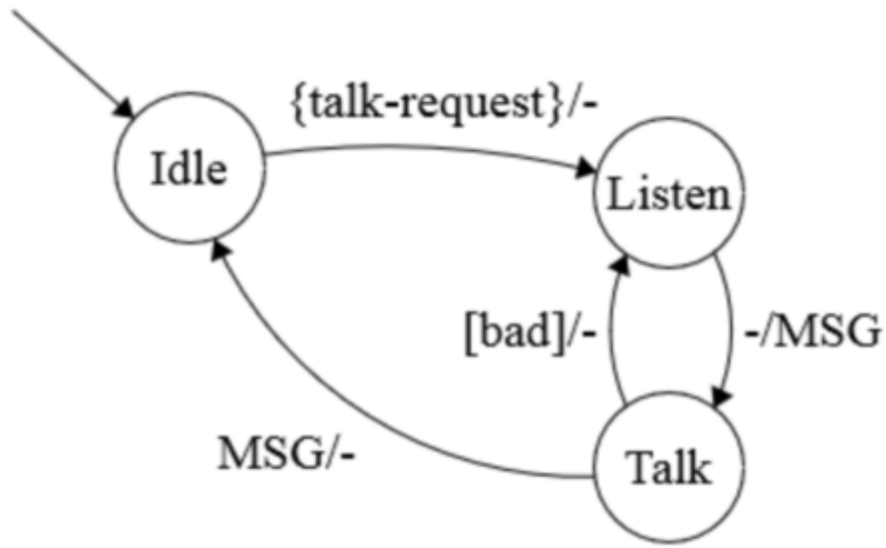
- Assuming Poisson arrivals

Do you hear what I hear?

- Maybe we can do better, if we just listen first

Discussion group rules

1. Message to send
2. *<u>Listen for quiet</u>*
3. Send message
4. Did you hear it?
   – Yes – DONE
   – No – resend (goto #3)



• But there are some issues . . .

Summary

- Multiple parties can share channels in various ways
  - TDMA, FDMA, CDMA
- Sharing suggests coordination
  - Built into protocol
  - Via a master (static or changing)
- Like most things, more complex at high scale
- If everyone can hear results, can sometimes share without any master