# Sharing Channels
# CS 118
# Computer Network Fundamentals
Peter Reiher

# Outline

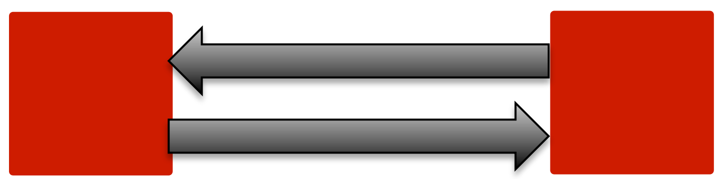
- Ways to share the channel
- Label (name) implications
- Emulated sharing
- Explicit coordination

# Ways to share a channel

- Different channels
- Different times
- Different symbol sets (“languages”)
- Label the transmissions

# Different channels

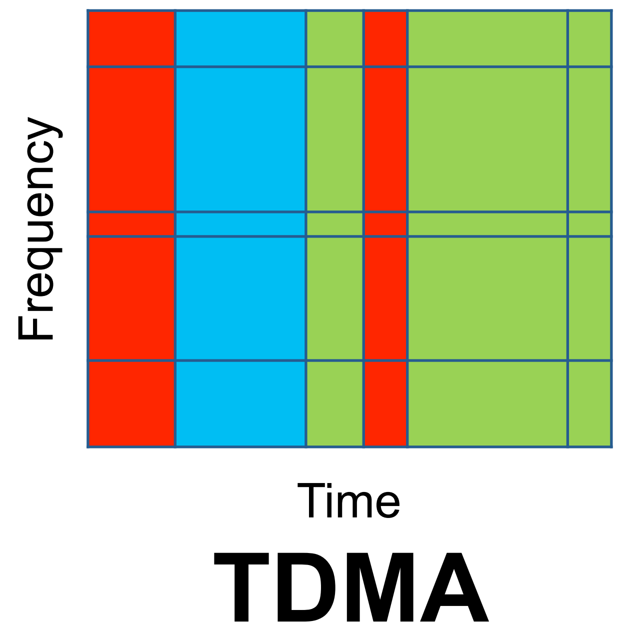
- Spatial Division Multiplexing (SDM)
  - Channels are spatially distinct



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

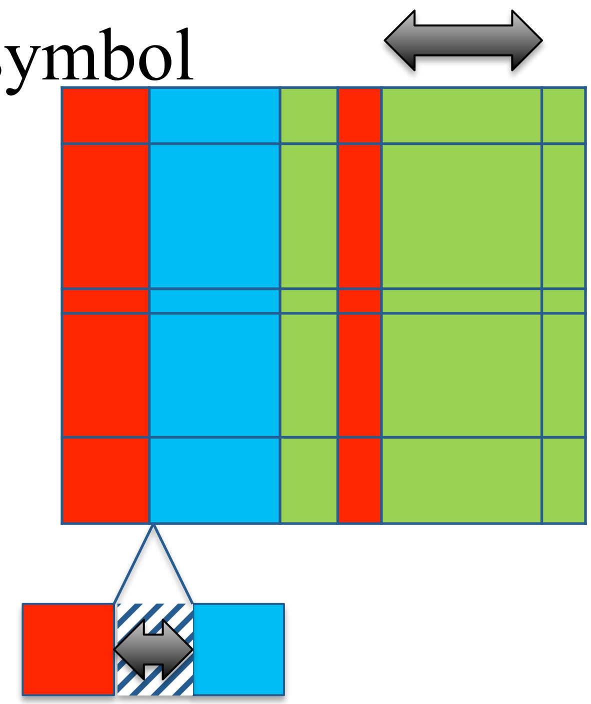
# Different times (TDMA)

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



# TDMA concerns

- Time interval size
  - Long enough for at least one symbol
- Time interval allocation
  - Fairness
  - Starvation
  - Efficiency (unused slots)
- Gap between intervals
  - "Guard time"



# Impact of guard time

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

# Different symbol sets

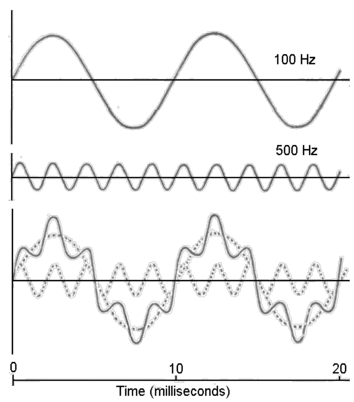
- Each symbol set is an independent “language”
  – Independence means that the bit encoding is separate from the way the sets are distinct
- Many different variants:
  – Different representations using independent physical properties
  – Different alphabets (logical representations)

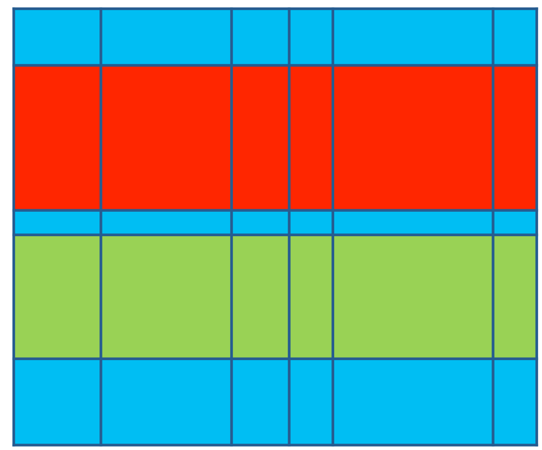
# Different physical representations

- 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)

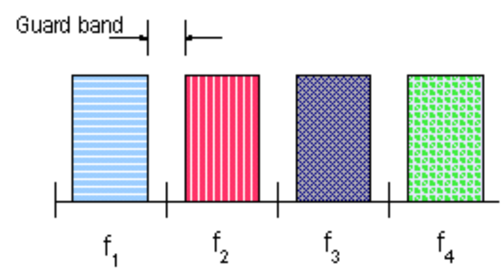


**FDMA**

# FDMA concerns

- Width of the band (bandwidth)
  - Large enough for desired bitrate
- Band allocation
  - Fairness
    - Starvation
    - Efficiency (unused frequencies)
  - Gap between bands
  - "Guard bands"

# Impact of guard bands

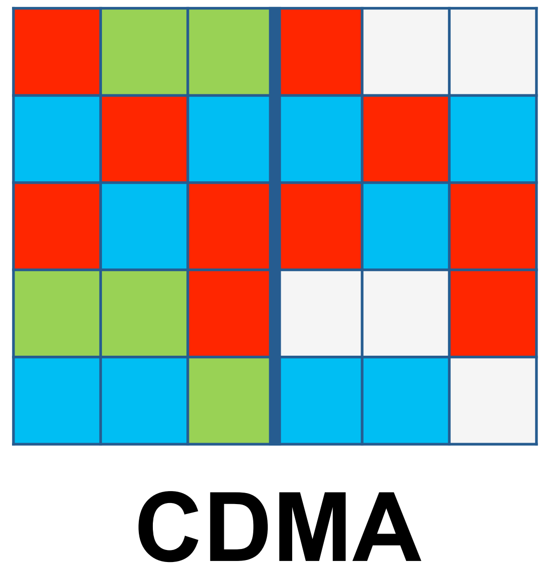
- Guard bands avoids sender overlap
  - All receivers should see non-overlapping bands
  - But:
    - Sender frequencies drift
    - Motion affects frequency (Doppler shift)
- Consequence
  - FDMA needs frequency coordination
  - FDMA has band size limit

# 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

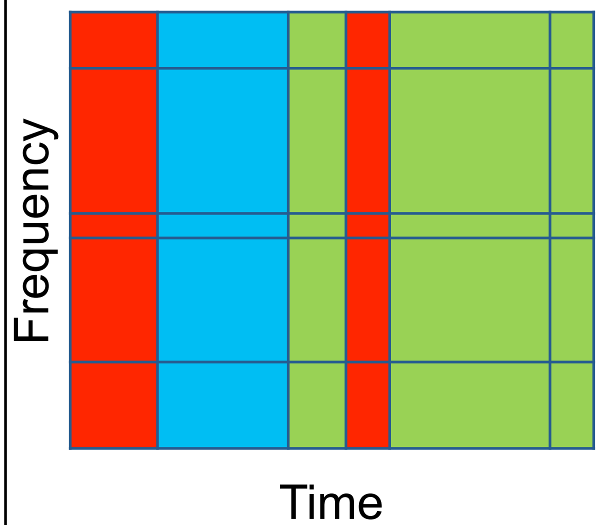


# xDM vs xDMA

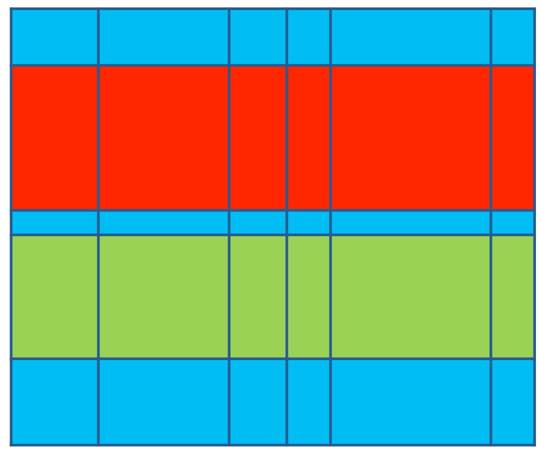
- {Space, Time, Code} Division Multiplexing
  – Sharing (dividing a resource) by multiplexing (merging) or demultiplexing (splitting) based on spatial, temporal, or coding context
- {S/T/C) Division Multiple-Access
  – Using xDM to coordinate shared access of a channel by multiple sources or receivers

*Often used somewhat interchangeably*

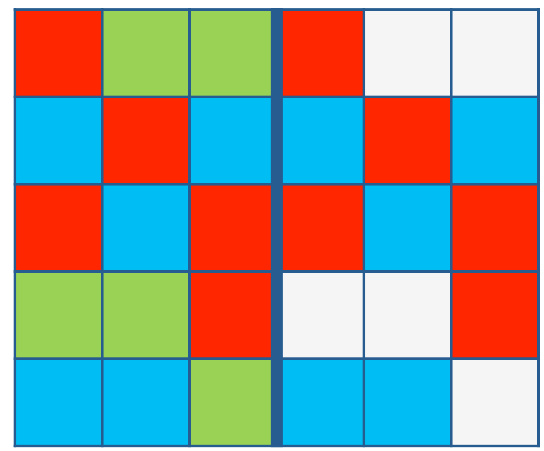
# Sharing compared




**TDMA**



**FDMA**



**CDMA**

# 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

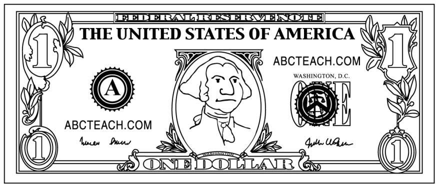
- Context (N:1)
  - Know the channel
  - MAY mean the source knows the receiver
- Uniqueness
  - MUST be unique per-sender on this channel
- Shared
  - MUST be known by sender and receiver
  - Sender attaches its name to message
  - Receiver knows where the message came from

# 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)

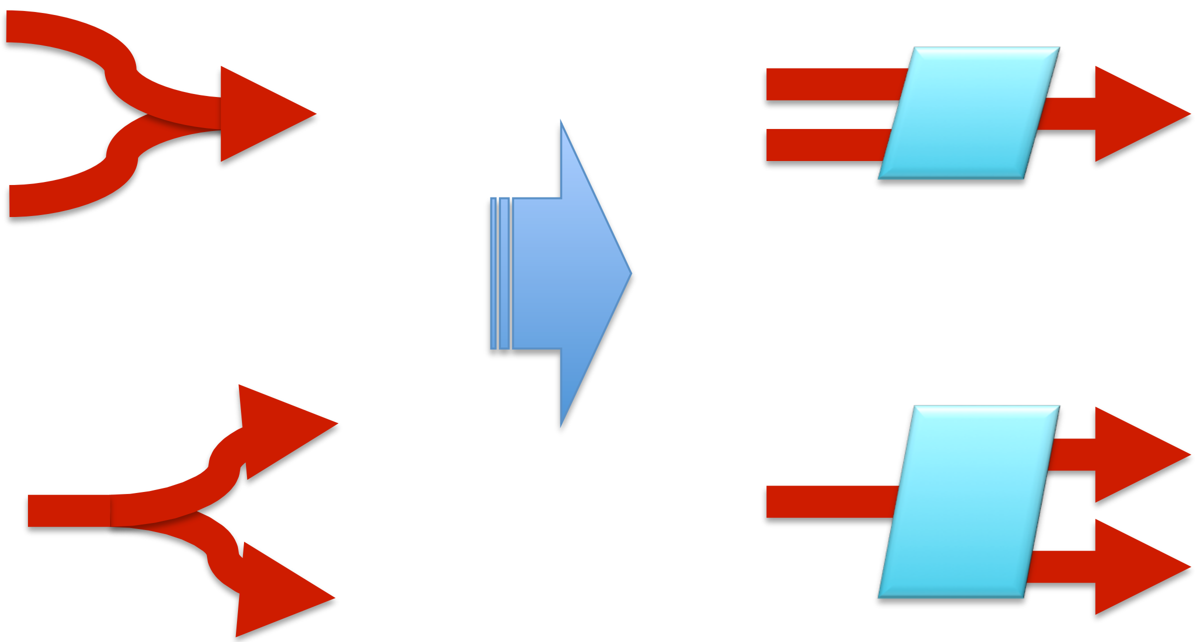
# Name assignment

- 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

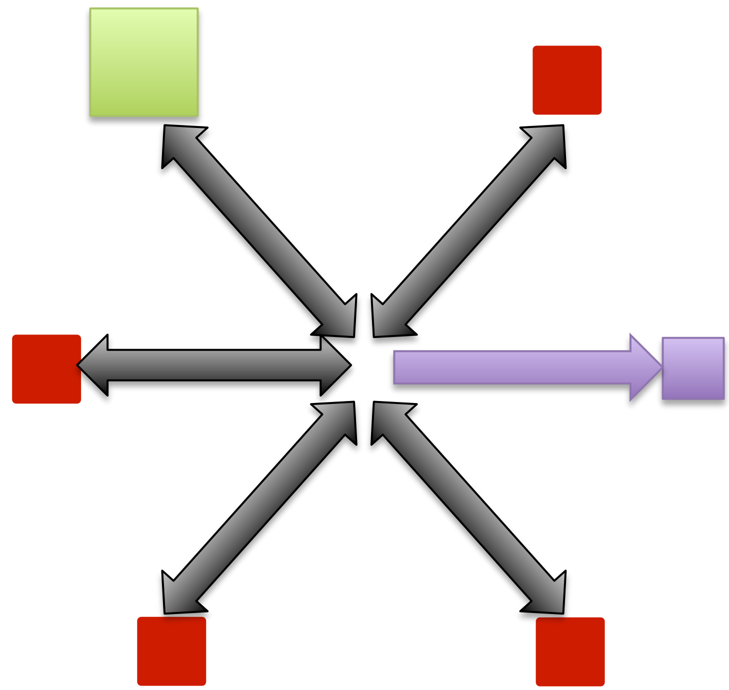
- Requires coordination
  - Need to build it into the protocol
  - Still needs a starting point (time, frequency)
- Inefficient
  - Slow/costly to change (repeated coordination)
  - Fixed allocations can't adapt to dynamic uses
  - Can't easily add/remove nodes or resources

# Centralized coordination

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

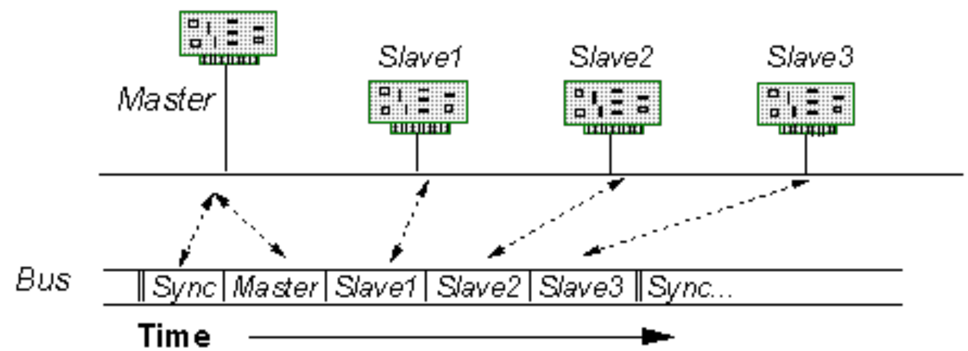
# Requirements for central coordination

- 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

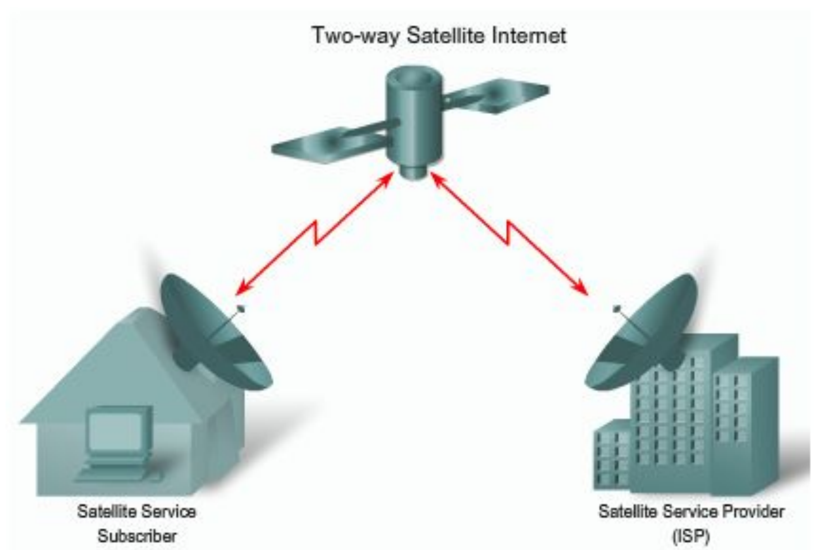
- Potentially very efficient
  - Esp. if requirements are stable (don't vary)
- Potential for global balance
  - Manager knows all, so can make the most informed decisions
  - Trivial to avoid starvation, ensure fairness
- Simple to implement
  - Simple coordination protocol

# 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 . . .

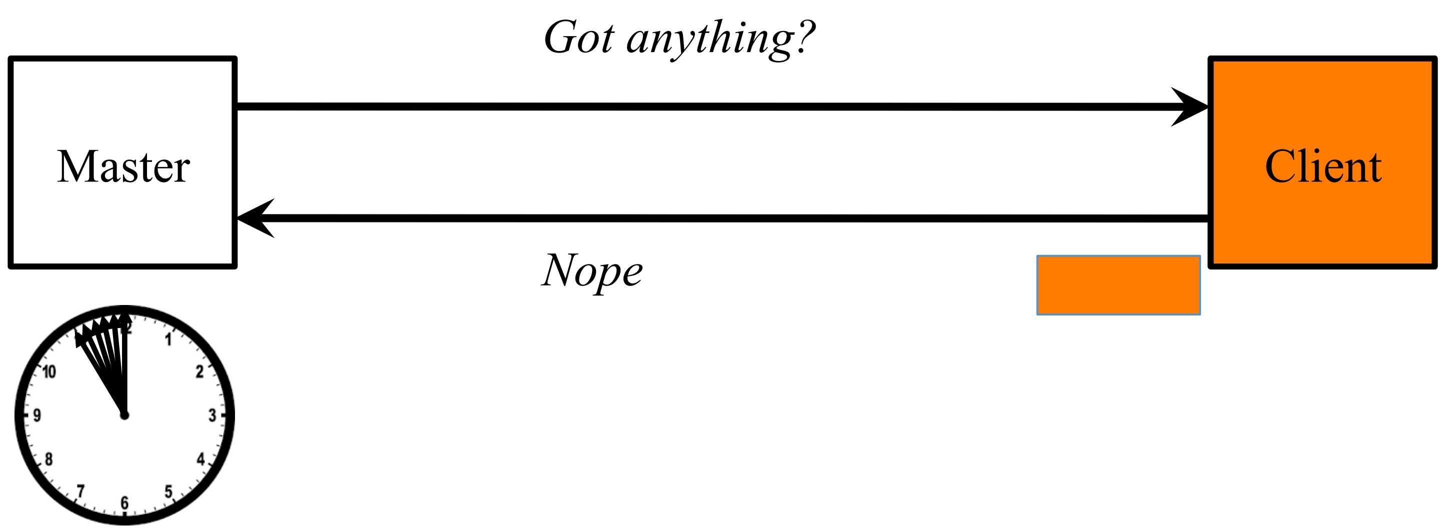
# 2-party bias

- 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
- Same issues
  - Controller (master) selection
  - Fault tolerance
  - Bias

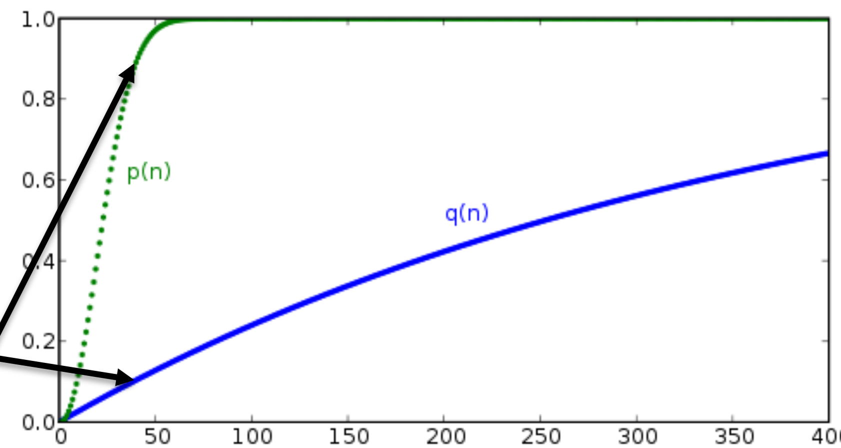
# N-party controller selection

- 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*

# 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

# 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)

# 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 (1971)
  - One shared channel


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

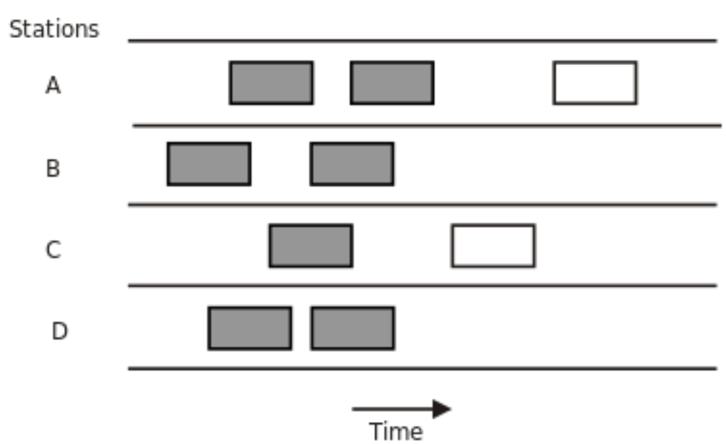
- If your message is stepped on, don't send right away
- Wait for a random time and try again
- You hope the other guy waits longer
  - Or sufficiently shorter
- In which case you don't step on each other again
- Obvious issue of utilization vs. chances of repeated collisions

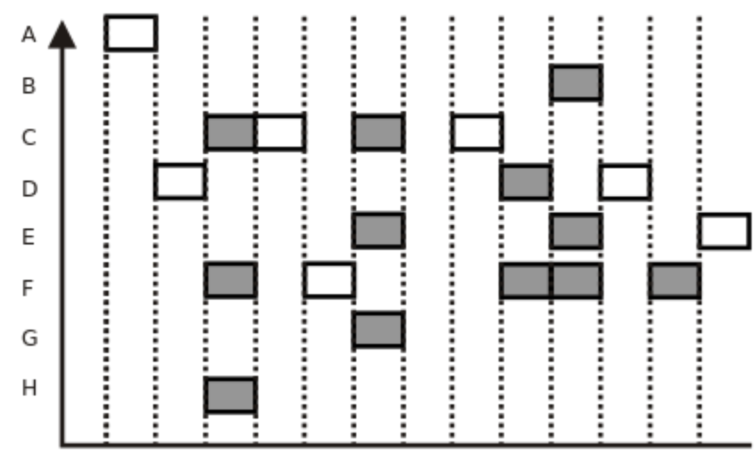
# One solution

- 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

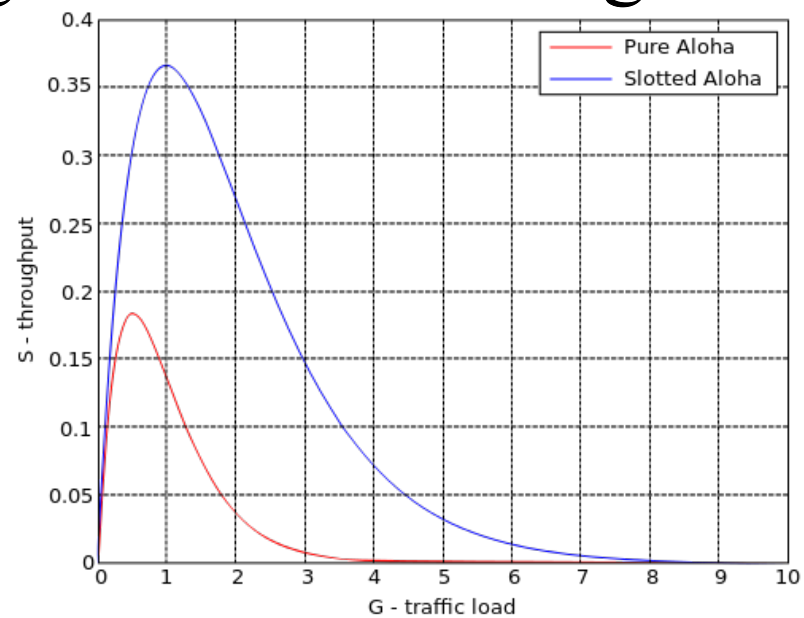



Slotted ALOHA protocol (shaded slots indicate collision)

# Pure vs. slotted

- Assuming fixed-size messages



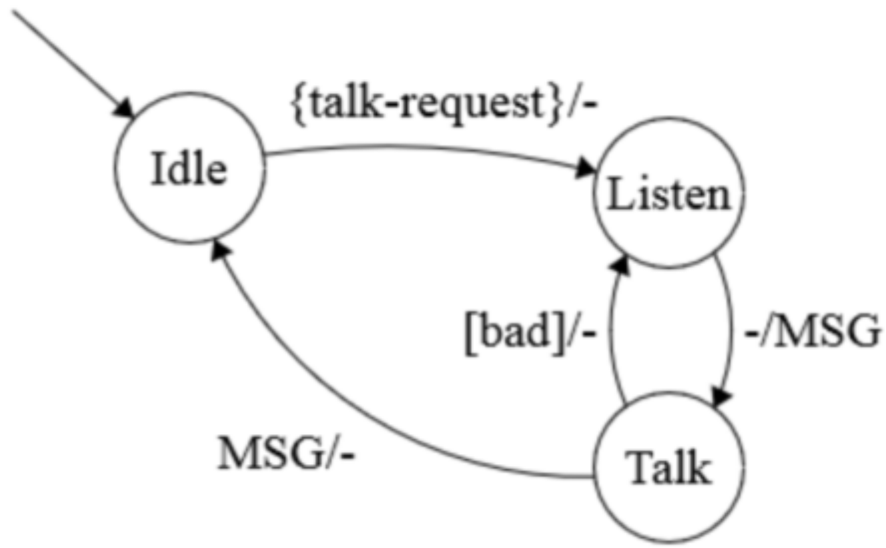

- Assuming Poisson arrivals

# 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