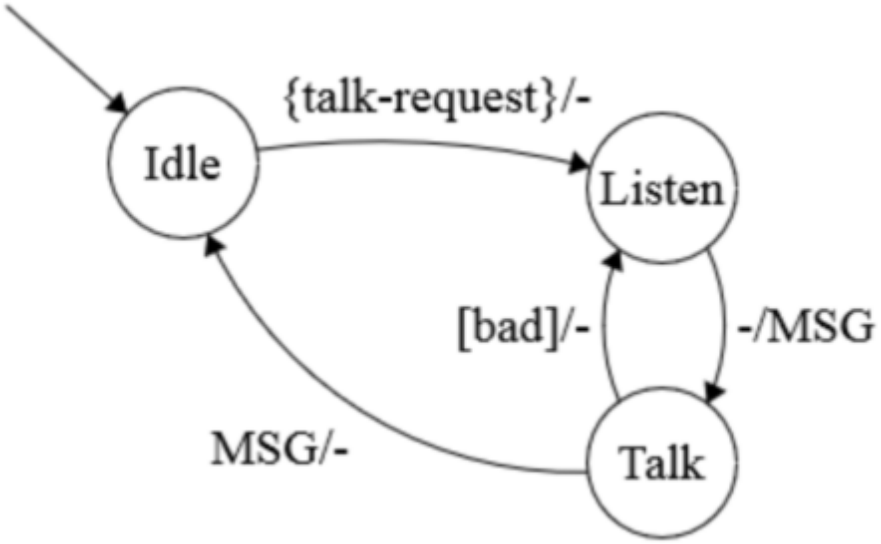
# Sharing Channels
# CS 118
# Computer Network Fundamentals
# Peter Reiher

# Outline

- Carrier sense channel sharing
- Naming
- ?
- ?

# Sending without a master

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



# CSMA (IEEE 802.3)

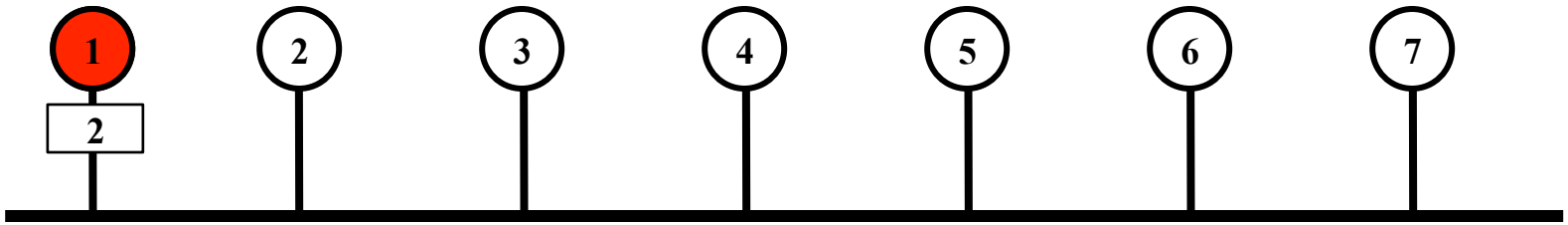
carrier sense multiple access

- An implementation of this idea
- Carrier-sense multiple access (1974)
  - Carrier = channel idle — sense whether channel is idle
  - Listen before talking — listen before you talk

ethernet is a shared channel, because it uses CSMA to monitor the traffic

# CSMA behavior

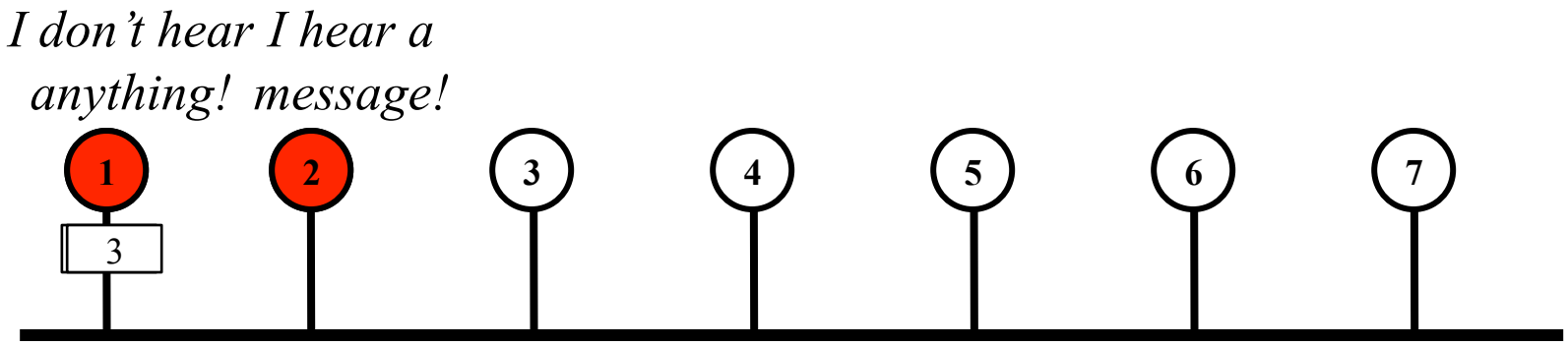
*I don't hear anything!*



# CSMA and persistence

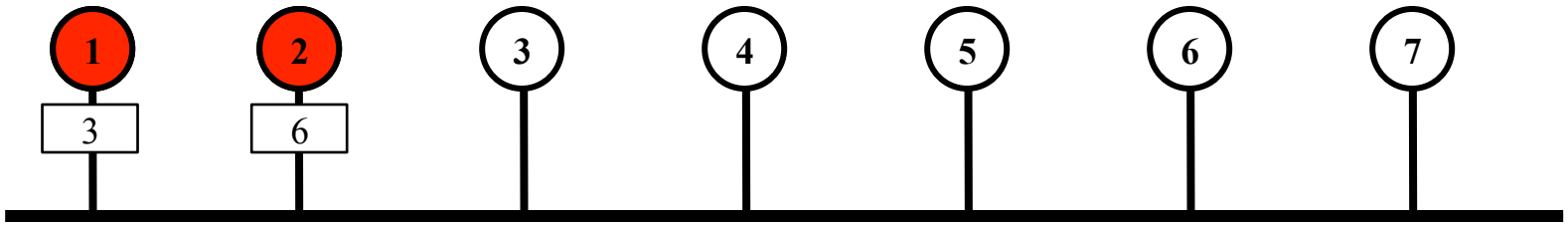
- OK, so I listen to the channel
- What if it's busy?
- Well, I certainly don't send now
  - My message would interfere with what I hear
- But do I keep listening?
- Persistent CSMA listens till channel is free
- Non-persistent CSMA stops listening and checks again later
  - After some random interval

# CSMA behavior




- Node 1 wants to send a message to node 3
- Node 1 listens to the medium
- It happens again
- But in the middle, node 2 wants to send a message to node 6
- Node 2 listens to the medium
- Node 2 doesn't send

# What about node 2's message?

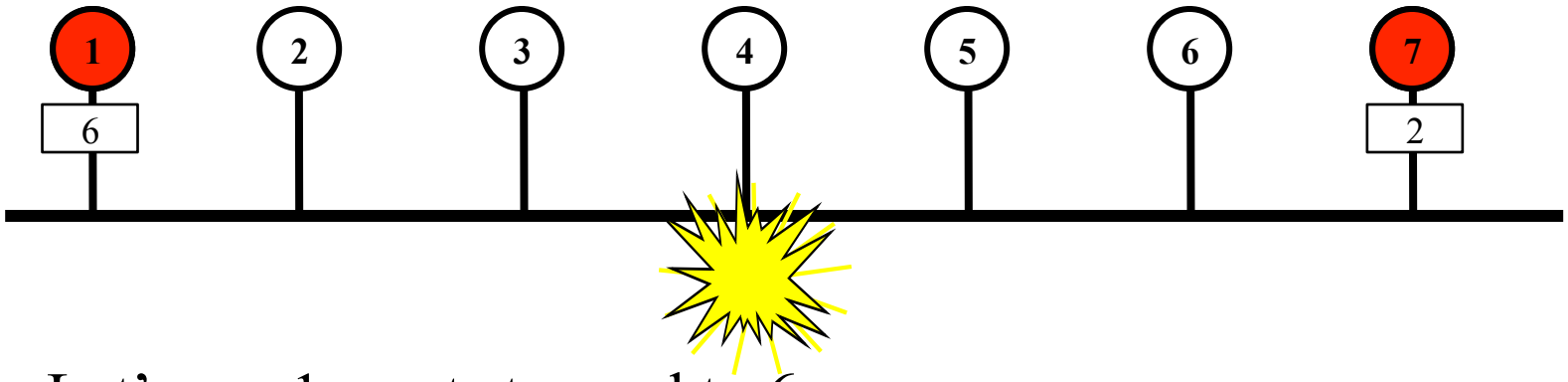



- Node 2 wants to send a message to node 6
- Node 2 listens to the medium
- Node 2 doesn't send
- Now node 2 can send his message

# CSMA and collisions

- CSMA involves sharing a channel
  - Multiple senders can all put messages on the same channel
- No master, no advanced reservations
- So more than one sender can try to use the channel at once
- When that happens, their messages *collide*
- Which corrupts both messages, making them useless (for most purposes)

# Collisions can happen




- Let's say 1 wants to send to 6
- He listens and hears nothing
- And 7 wants to send to 2, at about the same time
- He listens and hears nothing
- So they both send
- Both messages are destroyed

# CSMA variants

- CSMA/CD
  - Carrier Sense Multiple Access/Collision Detection
  - Essentially, listen to determine if the channel is in use and send if it isn't
  - Continue listening to detect if collisions occur
- CSMA/CA
  - Carrier Sense Multiple Access/Collision Avoidance
  - Essentially, listen longer to determine if the channel is in use and send if it isn't

# CSMA/CA- I'm Not Listening!

- CSMA/CA listens before sending
- But some versions don't listen during sending
- So they don't detect collisions by listening
- So what do they do?

# Why not listen?

- Not practical for some wireless channels
  - Need to send and listen at the same time
  - Sometimes expensive to build equipment that does both well simultaneously
- The hidden terminal problem
  - We'll get to that a little later

# Acknowledgements

use acknowledgements to send without listening - this means send message saying that you've got it

- One way to detect collisions without listening during send
- Receiver instantly acknowledges received message on channel
- Using the channel, of course
- Acknowledgements are short
- But do take up channel space
  - Possibly leading to collisions themselves

# A note about CSMA

- Benefits:
  - CA avoids always colliding after idle if multiple parties want to send
  - Non-persistent, like CA, helps avoid collisions but also avoids work during busy period (spin-lock)
  - CD reduces the impact of a collision
- These are NOT mutually exclusive
  - Though we usually talk about CSMA/CD *or* /CA
- There are other optimizations

# Ensuring channel capture

- Start sending data
  - Data can collide in unpredictable ways
    - Someone else might have just started to send, but it hasn't gotten to us yet
  - Message might be very short – how long do we wait to check to see if it worked?
- Solution: preamble
  - Floods the channel before sending message
  - Also enables frame sync

no one else can use it; send to receiver
speed is higher; message can bounce back faster

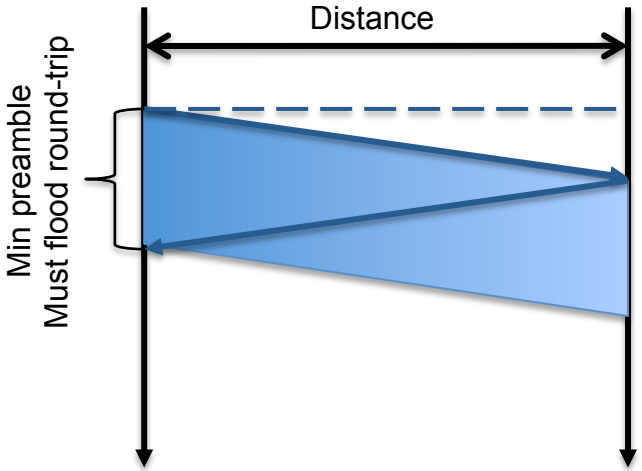
send something I don't care about - if received, unlikely have a collision

# Flooding the Channel

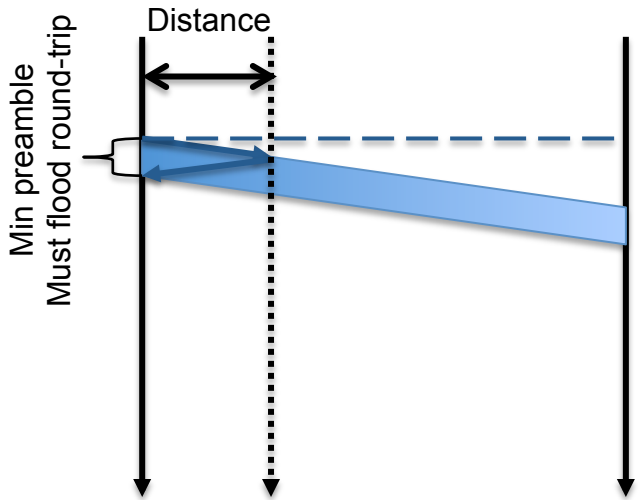
- Put an unimportant signal onto the (apparently idle) channel
  - The *preamble*
- Keep it there until you're sure that no one else is sending
  - Implying long enough for you to hear everyone else who might be flooding
  - And for them to hear you
- If preamble is trashed, someone else is sending too

# More on flooding

- Don't start sending until you know you have the whole channel
  - If you can send a round-trip bit with no collision, then the channel is yours




- At higher speeds, a given preamble is "shorter"
  - So the round-trip distance protected is less



# Limitations of no-master sharing

- Channel length
- Protocol overhead
- Capture effect
- Need for a single, shared channel

# Preamble vs. channel length

distance physical

- Preamble
  - 7 bytes = 56 bits
- Maximum shared link size
  - @3 Mbps = 1866 m
  - @10 Mbps = 560 m (set to 500 m)
  - @100 Mbps = 56 m
  - @1 Gbps = 5.6 m

presistent
keeps listening
non-persistent
you don't wait

# Protocol overhead

- Converse of channel length limit
- Faster symbol rate = longer preamble
  more opportunities for collision
- Longer preamble = higher overhead

# Backoff

- What do you do if your packet is trashed when someone else also sends?
- Try again
- But not right away
- Wait some period of time before re-sending
- That's *backoff* a term
- Commonly used in many non-master channel sharing schemes

# Capture effect

effect - one thing is getting pushed off in the corner

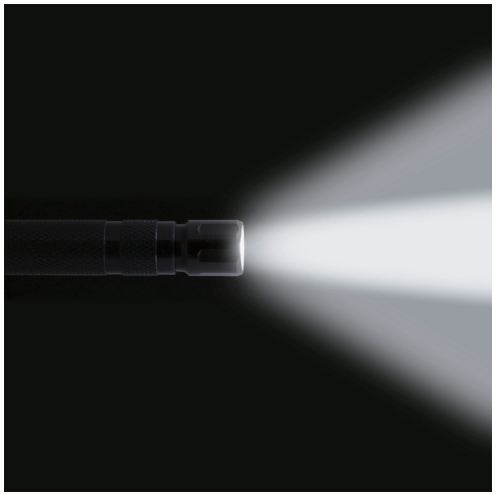
- Collision backoff is not fair (known in 1994)
  - Ethernet backoff picks a random value in a range that increases with each failure
  - A & B collide
    - Both pick from the small initial interval
  - A wins and transmits
  - A & B collide
    - A now picks from the small initial interval
    - B picks from a larger, second-try interval
  - A usually wins (repeatedly)
    - A is rewarded by having its interval reset whenever it wins

# Single, shared channel limit

- Signal power
- Protocol
- Topology
- Hidden terminal

# Signal power

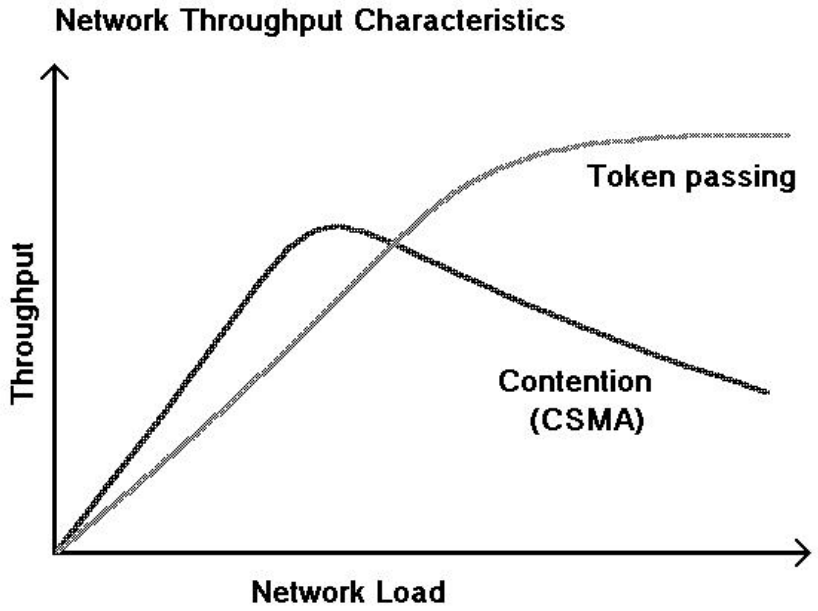
- Distance
  - Power absorption (except for a vacuum)
  - Most beams spread out
- Number of receivers
  - Power needs to increase for everyone to get "some" of the signal



Result: effective distance limit

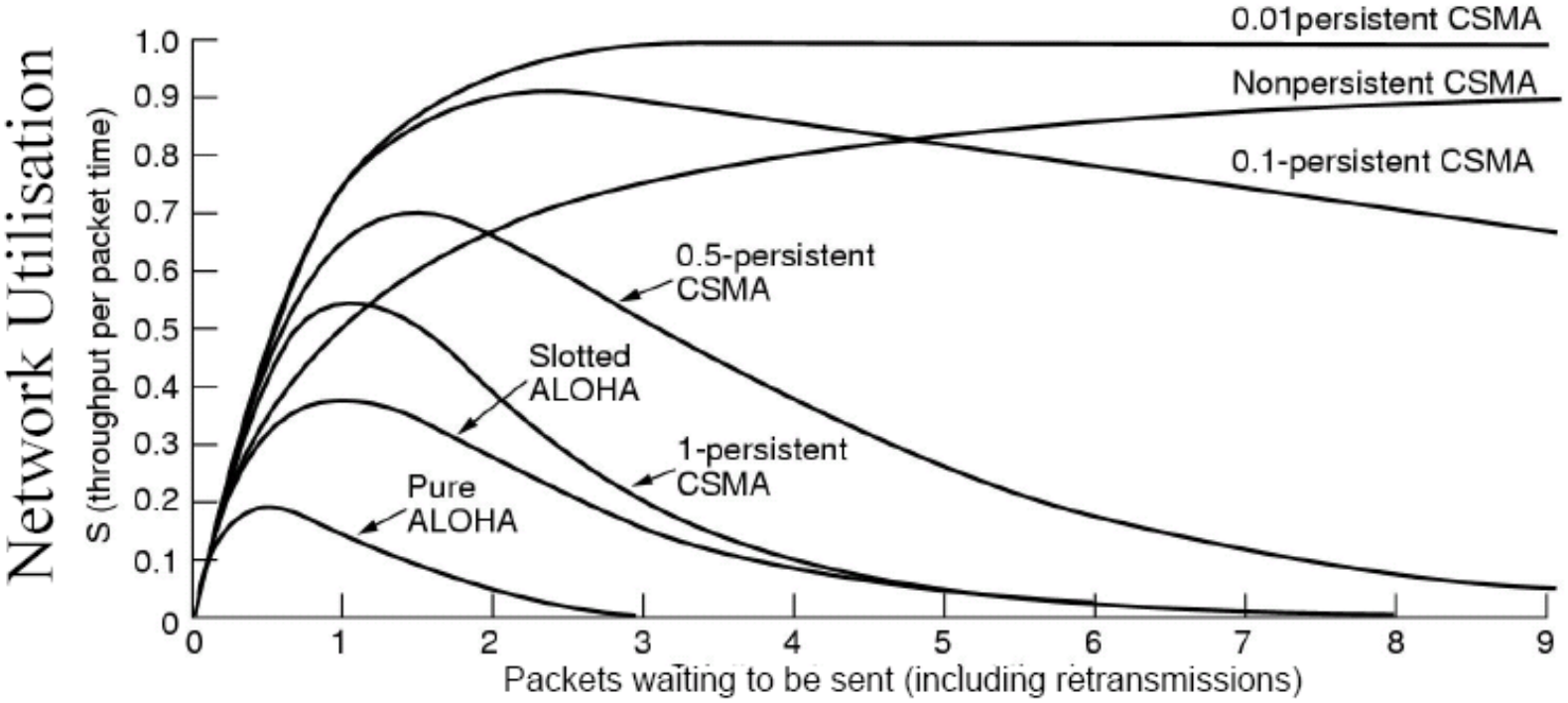
# Protocol effects

- Sharing can be inefficient
  - Collisions = no transfer



# Protocol variations

- Slight variations can have large effect



# Protocol effect implications

- Channel negotiation takes time
  - During which you might lose what you send
  - And you can't know until you try

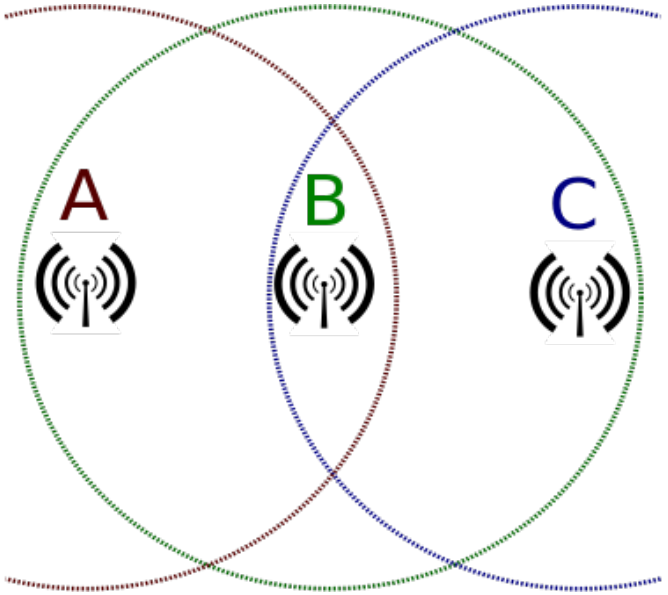
Result: strict distance limit, efficiency limit

# Topology

- A single channel can be hard to deploy
  - RF doesn't go around corners radio frequency
  - Wire doesn't go where you want

# The hidden terminal problem

- Incomplete sharing
  - Not all nodes reach all others
  - CSMA no longer works
  - A and C won't know their transmissions collide
- Acknowledgements can help



# Naming implications for shared medium

- Sharing is sharing
  - Same rules about uniqueness of names
  - In 1:N, only destination name must be unique
  - In N:1, only source name must be unique
  - In N:N (with no other info), source/destination pair must be unique
    - And there could be $N^2$ pairs
- How do we achieve uniqueness?
  - A priori coordination

# The cost of naming

- Worst case: $N^2$ names
  - Costly to add one more party
  - Does not scale!
- Simpler cases: $N$ names
  - Adding one party adds at most one name
    - One more receiver in 1:N
    - One more sender in N:1
  - Need to be sure chosen names are unique
  - Scales well

# Shared media naming techniques

- Central authority
  - Two-level delegation
    - First three assigned per-organization (OUI)
    - Rest assigned locally
  - IEEE 802.* addresses are 48 bits (6 bytes)
  - IEEE also assigns 64 bit addresses
  - ATM NSAP
    - Multi-level hierarchy, starting at ITU, including IANA
  - IPv4 addresses
    - Multi-level delegation, starting at IANA
- Self-assignment
  - IPv6 local part is self-assigned, then check for duplicates ("roll again!" = "Duplicate Address Detection"/DAD)

# Other names

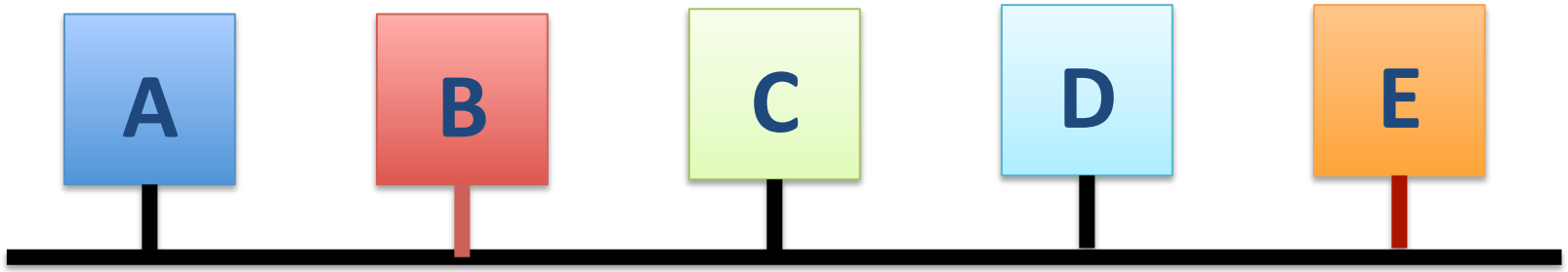
- Name for "everyone"
  - Enables native (one-step) broadcast
  - Often "all 1's"
- Name for "a group"
  - Enables native (one-step) multicast
- Name for "I don't have an address yet"
  - Often "all 0's" (for another day)

# More switching

- Recall:
  - Switching emulates sharing
- What makes it useful?
  - Simper wiring (direct to closet)
  - Independence
  - Enhanced coordination

# Simpler wiring

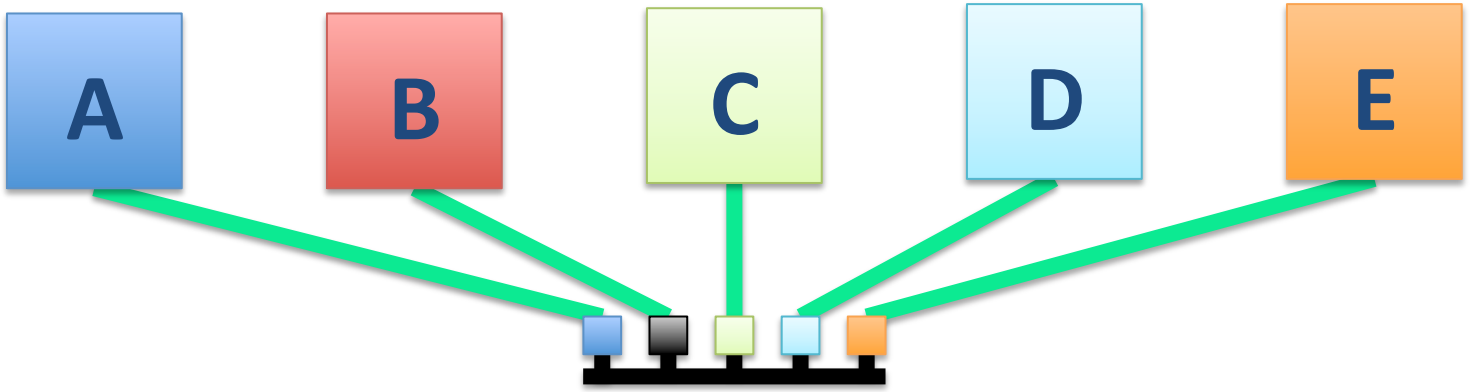
- First step: everyone on a bus




Limited by the bus path

# Simpler wiring 2

- Second step: delegate to a shorter bus

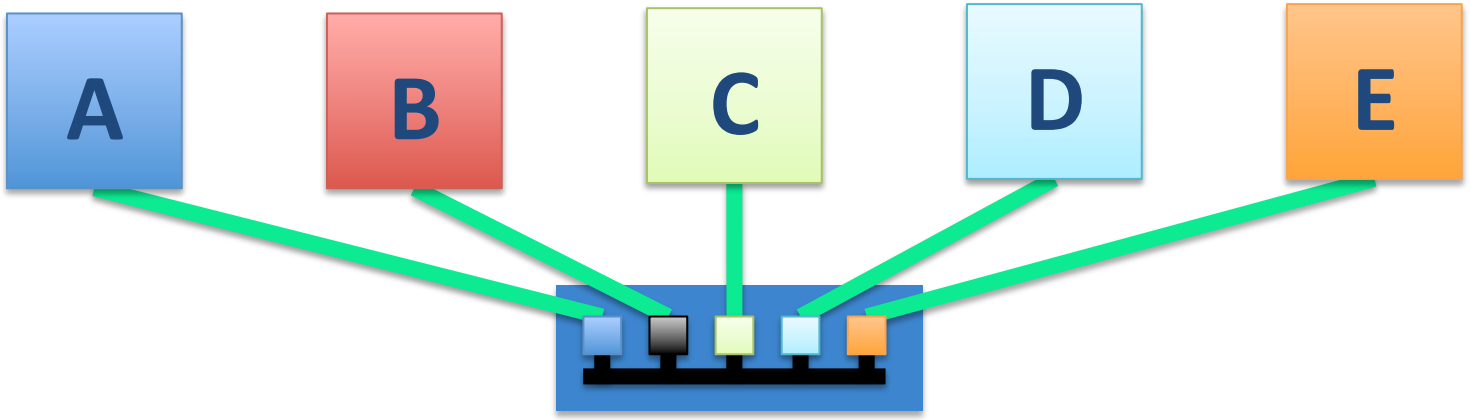



Move per-node smarts together

E.g.: Ethernet MAU

# Simpler wiring 3

- Third step: box it up!




Simpler to manage and operate

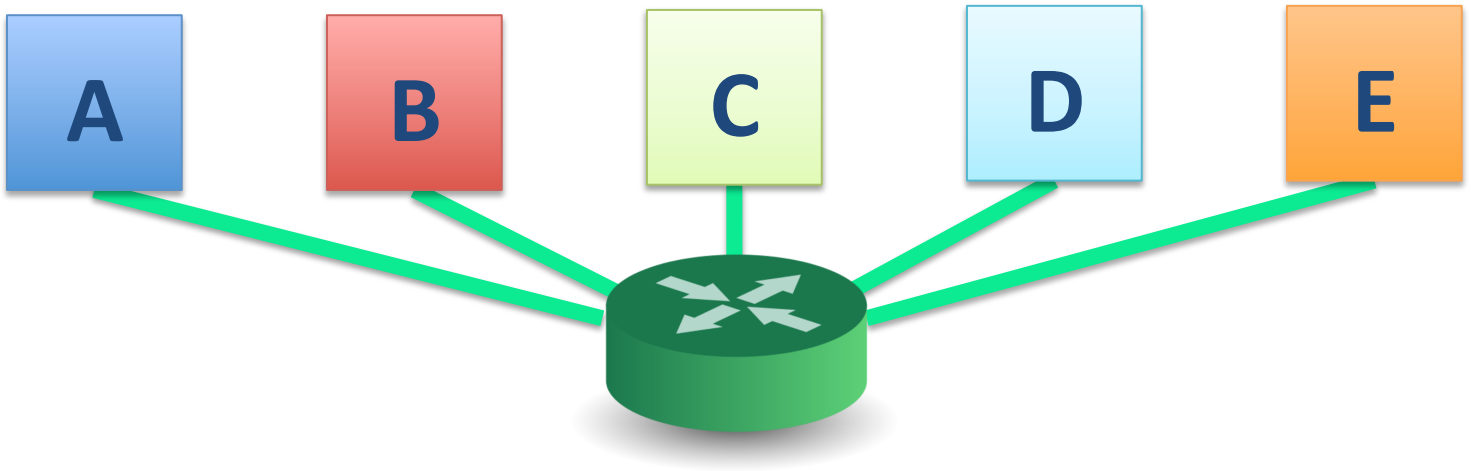
# A note about MAC protocols

media access control

- Media access control — determines the rules for sharing to a channel
  - Just a name
  - Protocol to control shared access
  - NOT NEEDED without shared access!

# Simpler wiring 4

- Final step: who cares what's in the box?
  - There are many ways to build N:N exchanges

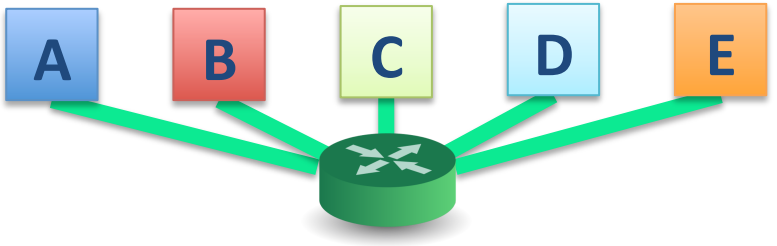



- What else changed?

# Non-sharing protocol!

- We can turn channel sharing
  - A sharing protocol
- Into central switching
  - A 2-party protocol *to the switch*
  - A non-sharing protocol


MAC




  - NOTE THIS!

# Benefits of independence

- Add/remove nodes without affecting others
  - No need to shift wires
  - Dead (or mostly-dead) node can't contaminate the network

# Enhanced coordination

- What can a switch see?
  - Everything at once, quickly (shorter channel)
- What can a switch do?
  - Coordinate! (takeover role of master)
  - Enforce long-term fairness, avoid starvation

enforce

# So what's a switch really?

- A way to emulate a shared link
  - Without the physical constraints

emulate a shared link

# Switch examples

- Ethernet
  - Emulates an RF channel
- SONET
  - Emulates a wire
- ATM
  - Emulates a phone wire (in particular)

radio freq

Not all of these emulate sharing!

# How do switches work?

- Shared media
  - An internal star coupler, bus, or memory
  - A control algorithm to share the in/out links
  - Usually TDMA on the in/out links
- A bunch of relays

# Goal: scalable communication

| | Number of channels for N nodes | Maximum distance between two nodes |
|---|---|---|
| **2-party channels (direct point-to-point)** | $N^2$ | Limited by direct signal |
| | | |
| | | |

Can we do better?

# Goal: scalable communication

| | Number of channels for N nodes | Maximum distance between two nodes |
|---|---|---|
| good for small groups<br>**2-party channels (direct point-to-point)** | $N^2$ | Limited by direct signal |
| **Shared media (shared multiparty)** | 1 (<M) | Limited by signal sharing and MAC protocol |
| | | |

Good for small groups – what about large?

# Sharing and relaying

CSMA is mutliparty
mutliparty share with many peopl

- Emulate full connectivity
  - *Networking* to enable *communication*
- Reduce connection cost
  - Sharing can be expensive or limiting

# Sharing vs. relaying

splitting the resources

- Sharing
  - Increases endpoint work
  - Simple topology
  - Efficient small scale
  - Poor number scaling
  - Poor size scaling

dividing up the labor

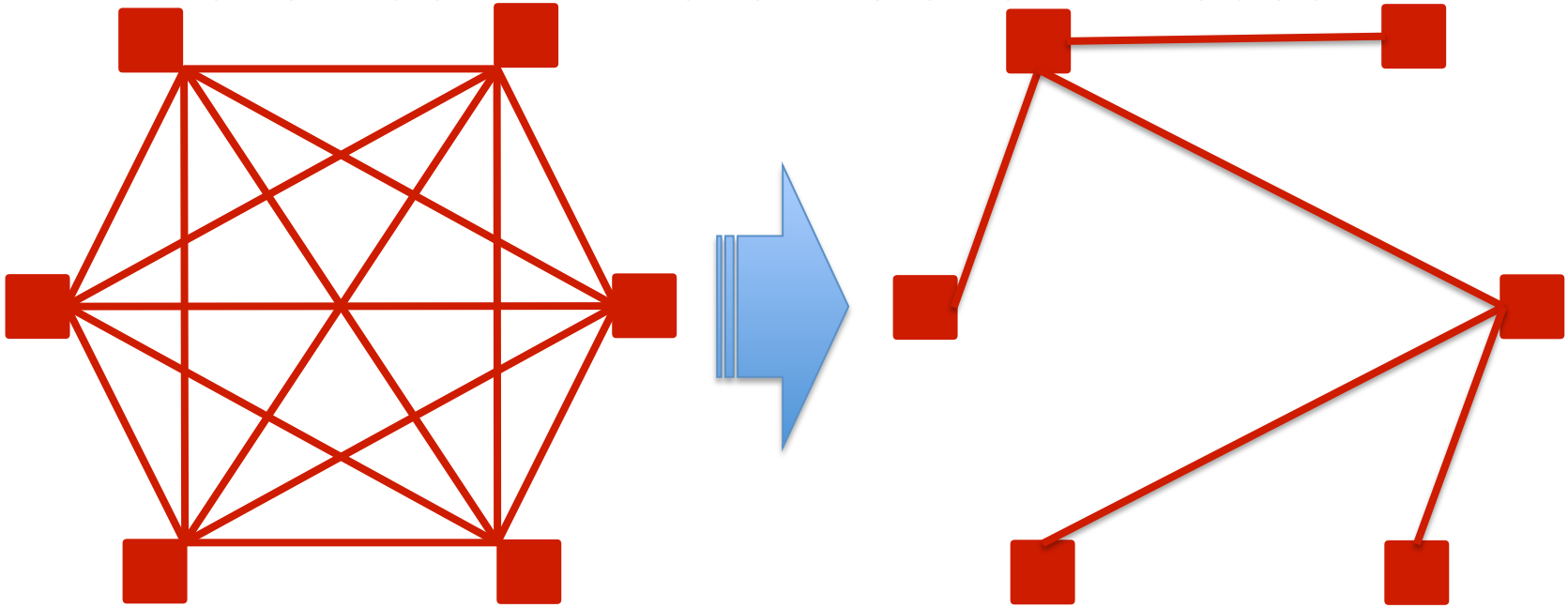
- Relaying
  - Spreads the work
  - Allows complex topologies
  - Efficient at large scales
  - Good number scaling
  - Good size scaling
    - If designed well

# Relaying to the rescue!

- Communicate through a third party
  - A to B, B to C = A to C
  - "Transitive closure"

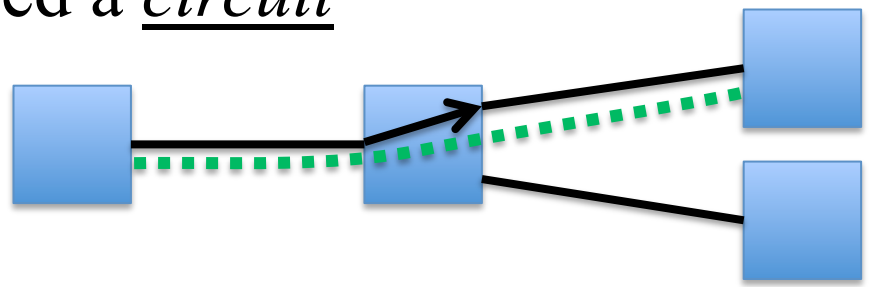
# How does relaying help?

- Allows us to remove some of the channels
  - As few as $N - 1$ channels for $N$ nodes



# How can we relay? #1

- 2-party channels
  - Media for action at a distance
  - Telephone lines originally direct copper pairs
- Relay using actual switches
  - Switch selects alternate direct copper paths
  - Continuous path is called a *circuit*



# The good, the bad, and…

- Good news
  - Relaying can reduce the number of links
- Bad news
  - This kind of relaying limits how many pairs can communicate at once

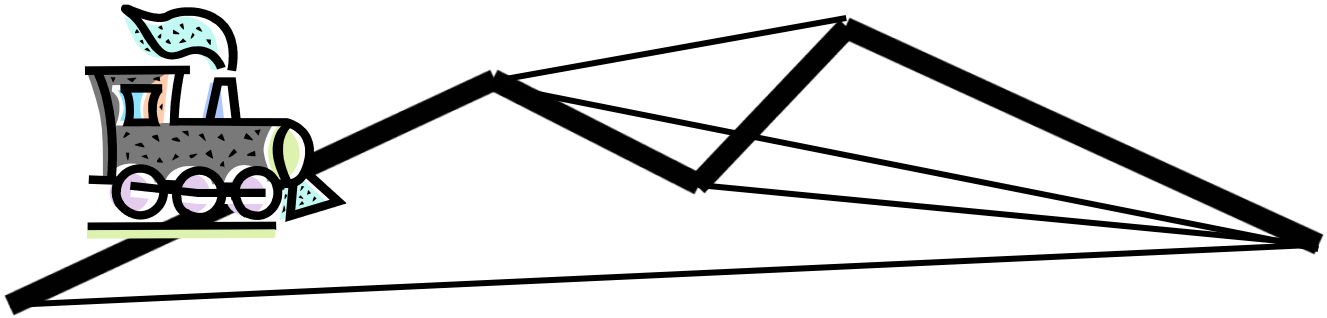
circuits have advantages - ex. trains on a track can be a circuit
schedules in advance - once you schedule it, it is set up that way
the resources are locked

# Circuits – a sure thing

- Trains on a track
  - Scheduled in advance
  - Allocated whether in use or not
  - Resources locked along entire path
  - Path is fixed

circuits are set up in advance; they are not flexible

prevent collisions, jitter: will two things take the same amount of time to reach a dest.

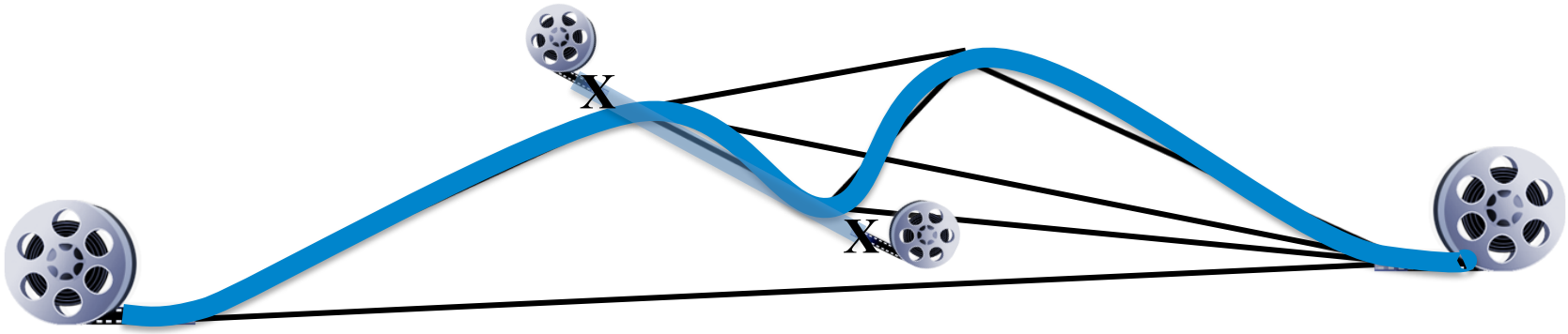


- Guarantees no competing traffic
  - Fixed delay, fixed jitter, fixed capacity
  - Can't share resources concurrently

# Circuit movie transfer

- One long, continuous path
  - No need to reformat the movie
  - Lossless, in-order delivery

from a point source to a destination
lossless;
single static path - which means nothing gets lost in the way



- Along a *single*, *static* path
  - That blocks everything else until you're done

# Circuits – pros

- Guaranteed service
  - Fixed capacity
  - Fixed delay
- Advance knowledge
  - Properties known in advance
  - Advance reservation (if use-bounded)
- Efficiency within a single stream
  - No overhead for processing, labels, etc.
  - The circuit ***is*** the label (no names after setup)

fixed delay;
fixed time;

packets allow circuits to be shared

# Circuits – cons

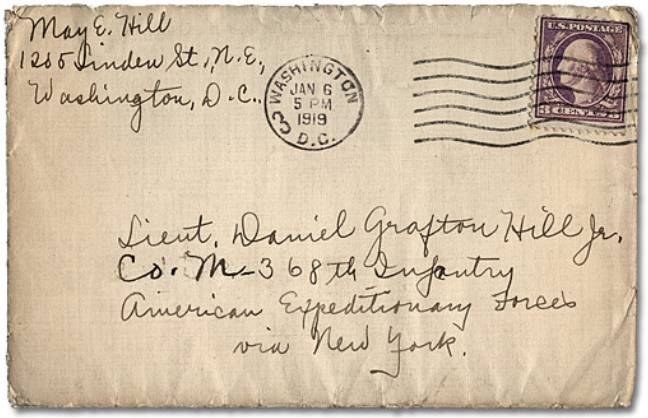
- Fairness on a per-circuit basis
  - Per reservation
  - At the time of reservation
  - At the time of use
- Path blocking blocked even if not used
  - Resources blocked (even if not actively used)
- Capacity limited
  - Min. of per-hop capacity of a single path

# How can we relay? #2

- Packets to the rescue

  packet switching - time division and time segment given to someone else

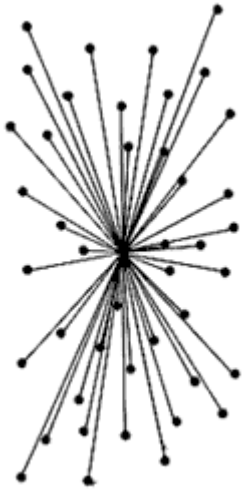
  – TDMA relaying
  – Allows circuits to be shared
  – Avoids blocking of cross-traffic
  – "Packet" coined in 1968 (Donald Davies)

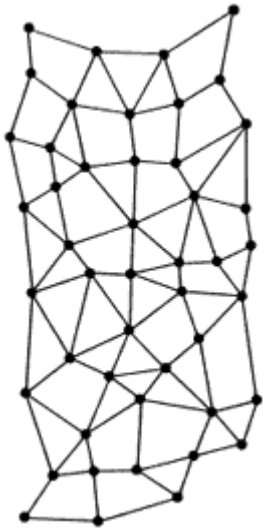


# Baran's study

don't need fully connected network

- Compared central and distributed nets

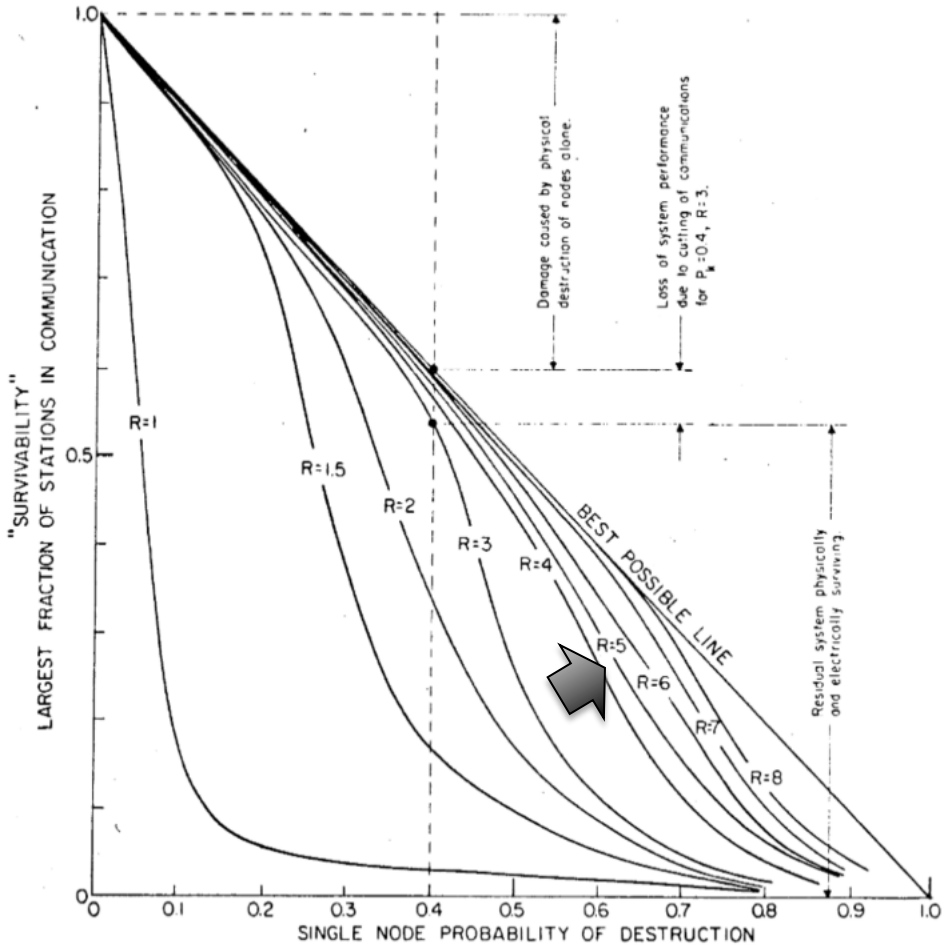




- Divide messages into "blocks" (packets)

# Baran's insight

- $N$ links is minimum
  - But one link or node failure disrupts others
- $N^2$ is maximum
  - No link or node failure disrupts others
- $4N$ is *nearly as good*
  - For some specific but reasonable assumptions




how much redundancy are needed so we are still good to have another network

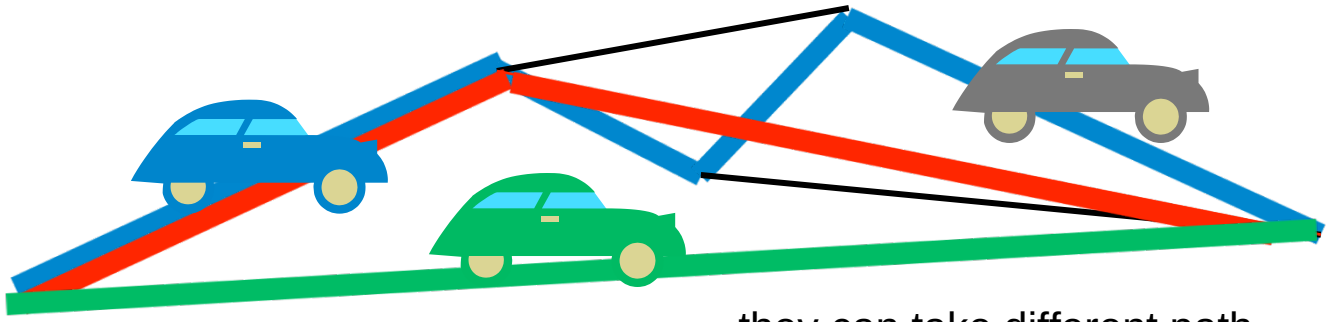
# Packet example

packet switching gives very little jitter, which is nice

variable jitter

- Cars on a highway
  - No need to schedule
  - Resource used only during transit
  - Path can vary, even given identical headers

no need to schedule everything in advance



they can take different path

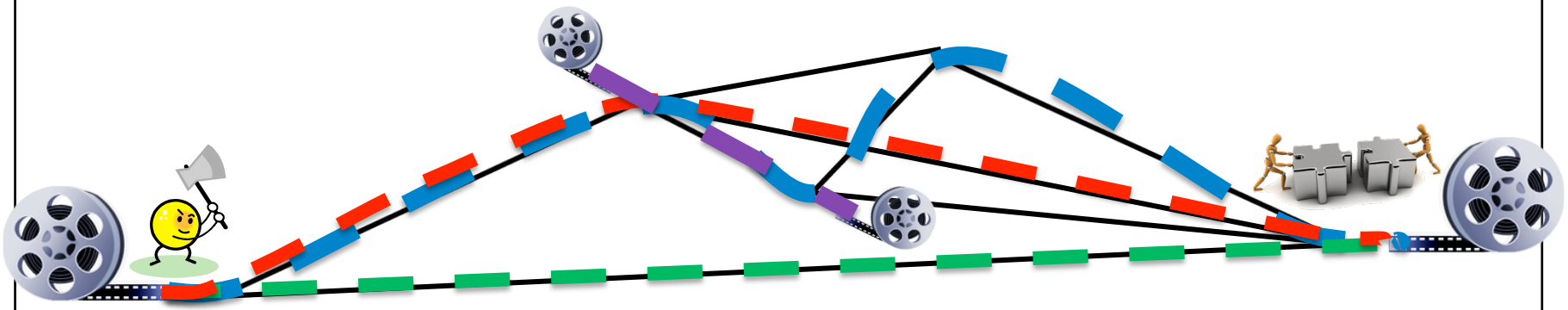
- Focuses on sharing
  - Aggregate, concurrent resource use
  - Results in variable delay, variable jitter, variable capacity, and potential for loss
  - Each car is independent, so these variations not too important



packets are circuits being Time Multiplexed

# Packet movie transfer

- Fragmentation split into chunks for sending
  - Split into chunks, label for reordering
- Reassembly
  - Gather and restore the stream



- Sharing
  - Concurrent transfers supported
  - But there are relationships between the packets . . .

# Packets – pros

- Sharing
  - "Stat-Mux" (statistical multiplexing) gain (2x-10x)
- Fair over shorter time-scales
  - More dynamic and agile
- Avoids path blocking avoid path blocking
  - Brief uses share better and complete faster
- Allows multipath allow multipath
  - Concurrent use of multiple paths
  - Can increase capacity for a given transfer
- Allows dynamic path variation
  - Can route around outages, delays

# Packets – cons

- More work
  - Pack/unpack
  - Compute checksums
  - Manage reordering, loss
- Capacity overhead
  - Addressing – to guide the chunks
  - Demultiplexing fields – allowing sharing
  - Signaling fields – to help undo chunking effects
- Storage required
  - Buffering to accommodate reordering, loss

packets may go outo f order
misordered packets with retransmission
there is overhead
in order to do packet switching,
all packets carry extra information
b/c packet switching doesn't know info
that is coming in

overhead - too much information
not needed

# Circuits *vs.* Packets

this is an important slide

- When circuits win:
  - Data patterns are mostly predictable
  - Sharing isn't important
  - Service guarantees are important
  - Data length is long (path setup is worth the benefit)
- When packets win:
  - Data patterns are unpredictable
  - Sharing is important
  - Guarantees are more flexible
  - Data length is short (relative to path setup cost)

# Goal: scalable communication

AT&T did not do packet switching - landlines are circuit switched

| | Number of channels for N nodes | Maximum distance between two nodes |
|---|---|---|
| **2-party channels (direct point-to-point)** | $N^2$ | Limited by direct signal |
| **Shared media (shared multiparty)** | 1 (<M) | Limited by signal sharing and MAC protocol |
| **Relaying** | $O(N)$ | Unlimited |

Sounds too good to be true…

# Summary

- We can share a channel without a master
  - If parties can all listen to what's going on
- We can overcome some drawbacks of channel sharing by relaying
  - Sending data over multiple separate channels connected together
- Relaying can be done via circuit switching or packet switching

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