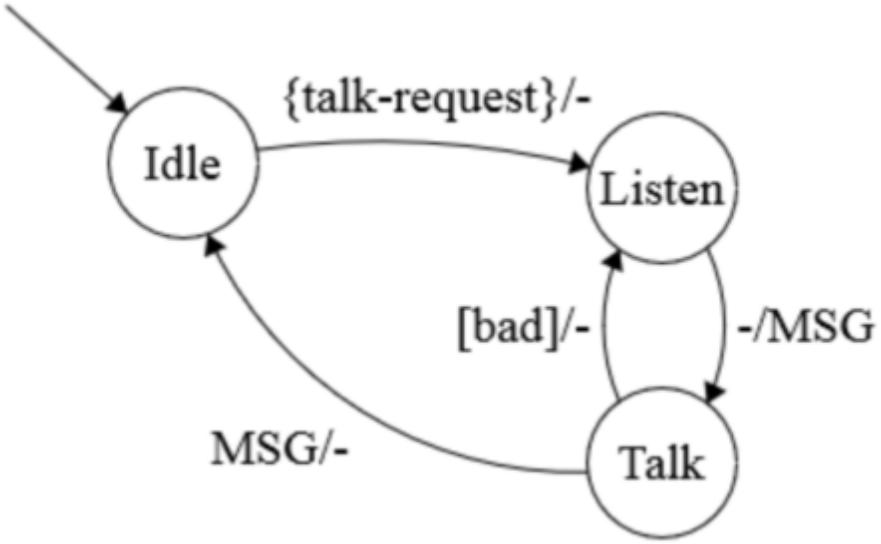
Sharing Channels
CS 118
Computer Network Fundamentals
Peter Reiher

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)

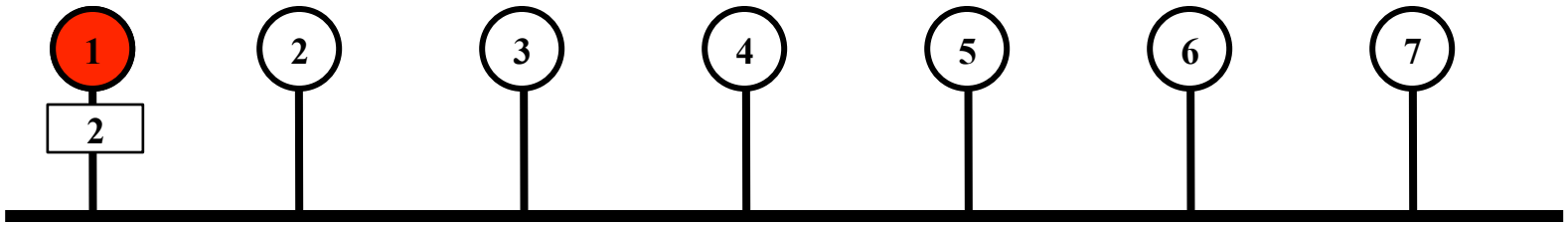


CSMA (IEEE 802.3)

- 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

CSMA behavior

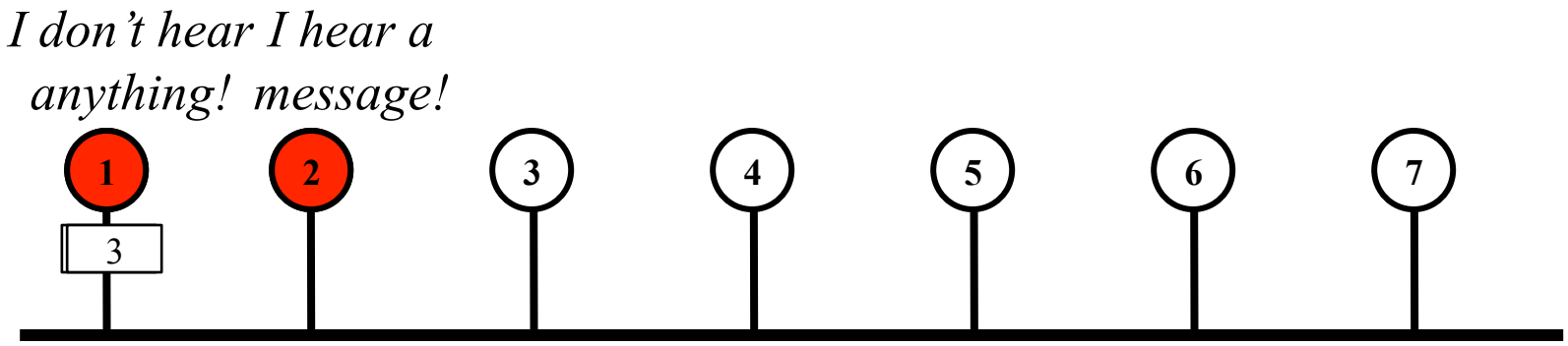
I don't hear anything!



CSMA and persistence

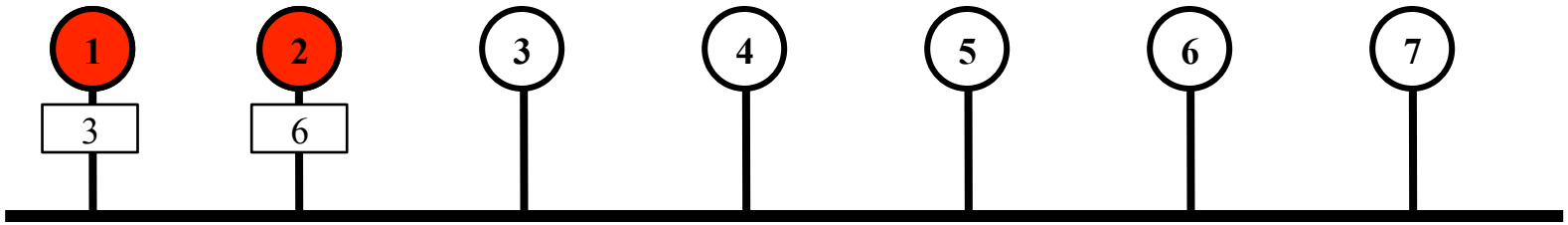
- OK, so I listen to the channel
- What if it's busy?
- Well, I certainly don't send now
  - My message would interfere with what I hear
- But do I keep listening?
- Persistent CSMA listens till channel is free
- Non-persistent CSMA stops listening and checks again later
  - After some random interval

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?

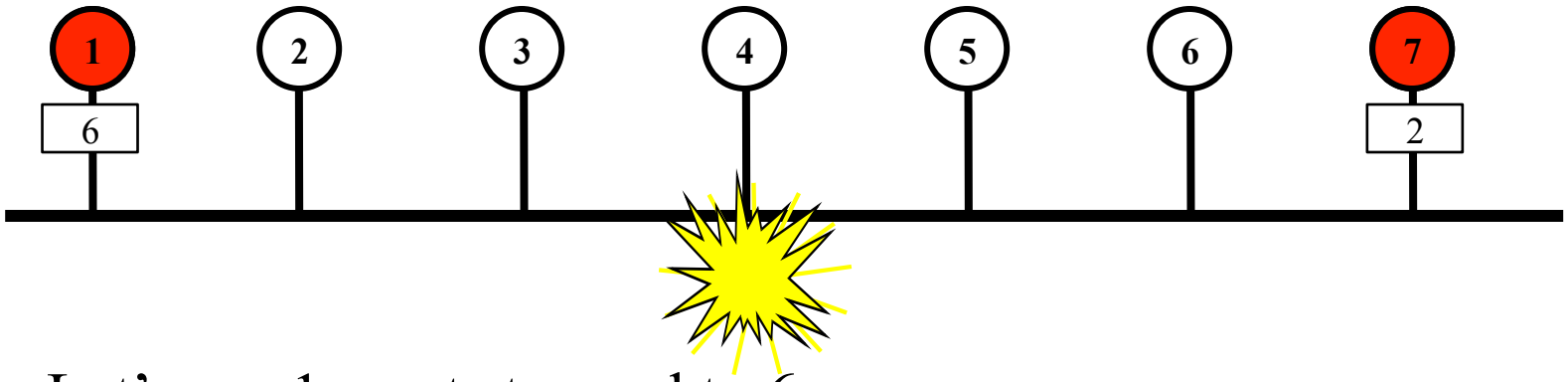


- Node 2 wants to send a message to node 6
- Node 2 listens to the medium
- Node 2 doesn't send
- Now node 2 can send his message

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

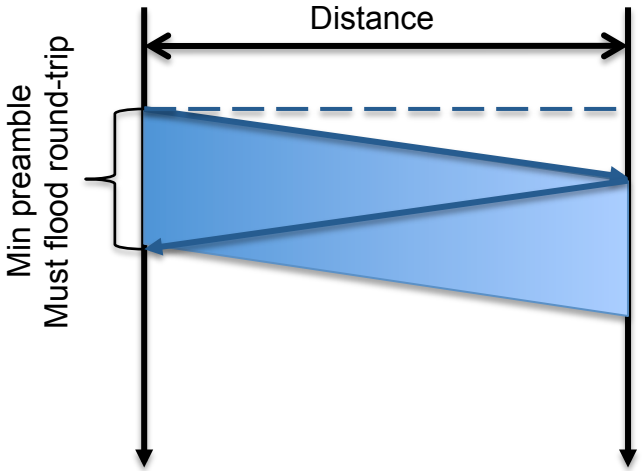
send something I don't care about - if received, unlikely have a collision

Flooding the Channel

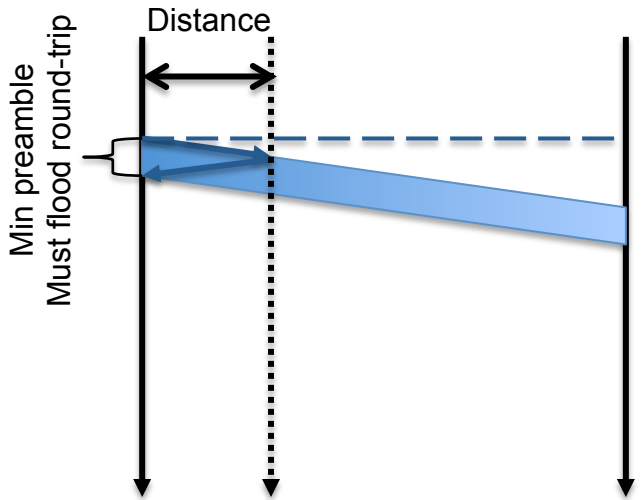
- Put an unimportant signal onto the (apparently idle) channel
  - The *preamble*
- Keep it there until you're sure that no one else is sending
  - Implying long enough for you to hear everyone else who might be flooding
  - And for them to hear you
- If preamble is trashed, someone else is sending too

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

- 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

Protocol overhead

- Converse of channel length limit
- Faster symbol rate = longer preamble
- 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*
- Commonly used in many non-master channel sharing schemes

Capture effect

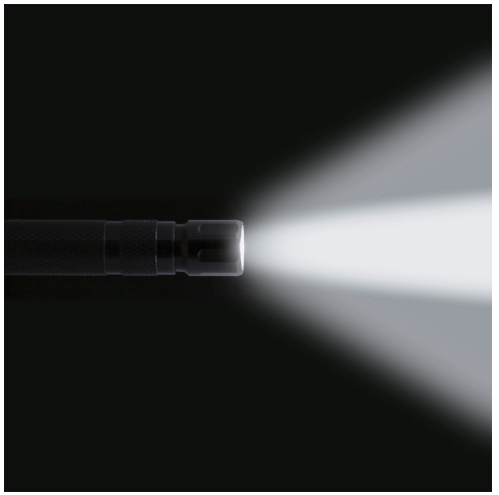
- Collision backoff is not fair (known in 1994)
  - Ethernet backoff picks a random value in a range that increases with each failure
  - A & B collide
    - Both pick from the small initial interval
  - A wins and transmits
  - A & B collide
    - A now picks from the small initial interval
    - B 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

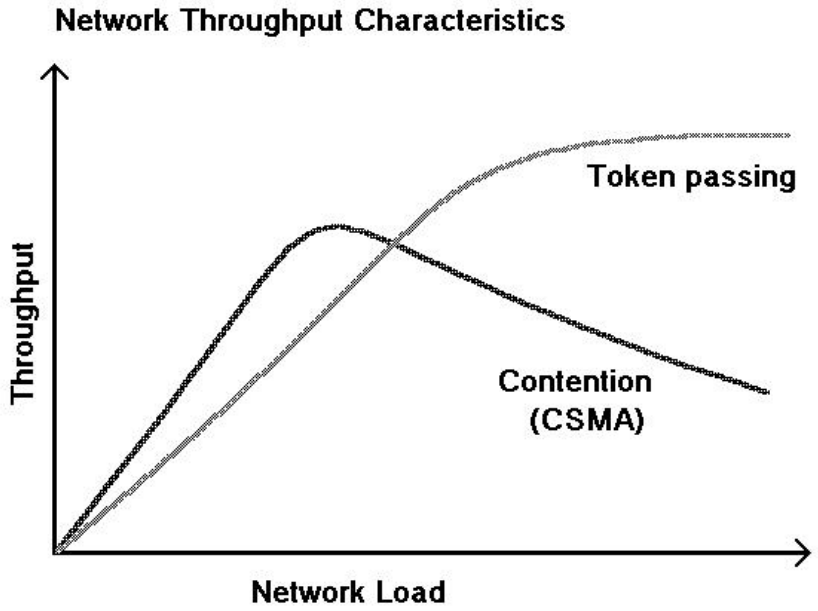
- Distance
  - Power absorption (except for a vacuum)
  - Most beams spread out
- Number of receivers
  - Power needs to increase for everyone to get "some" of the signal



Result: effective distance limit

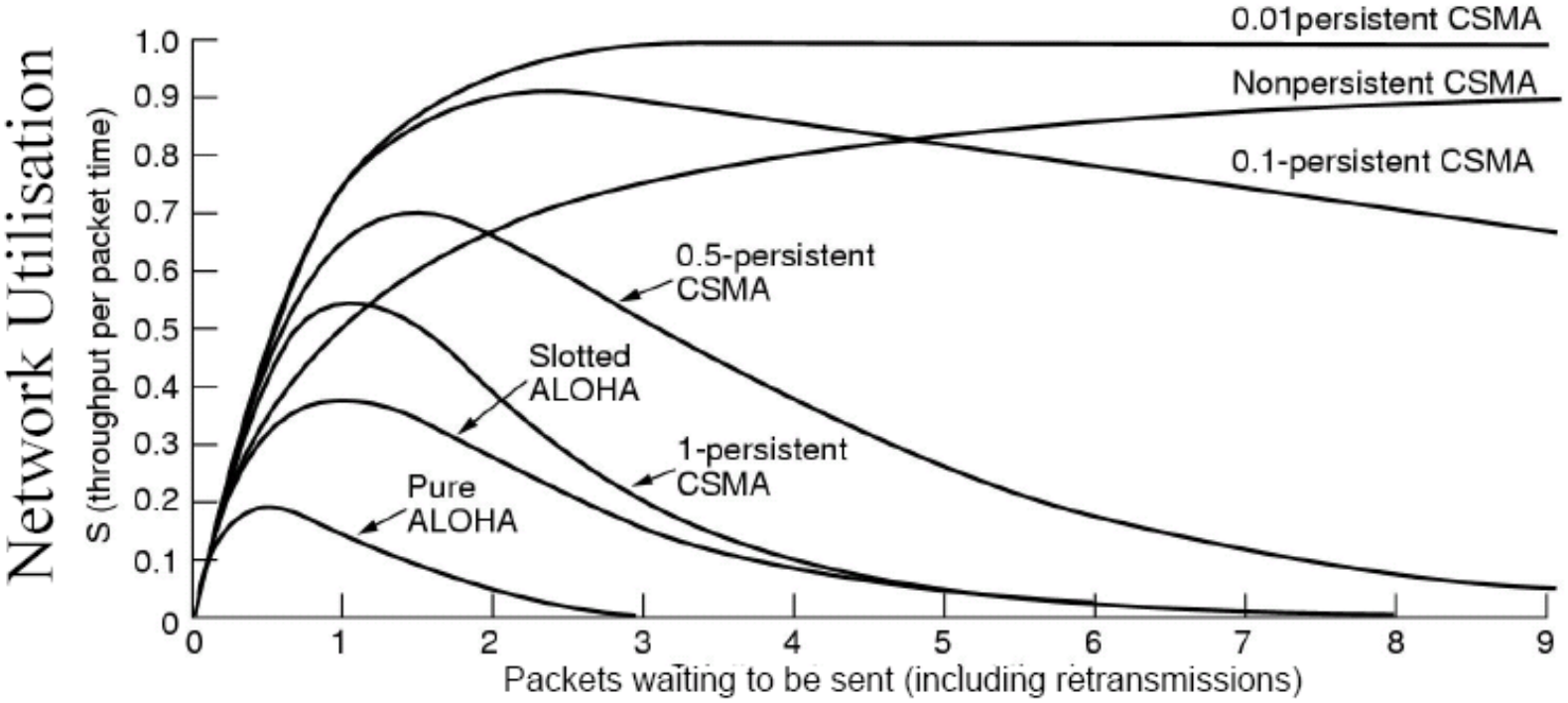
Protocol effects

- 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

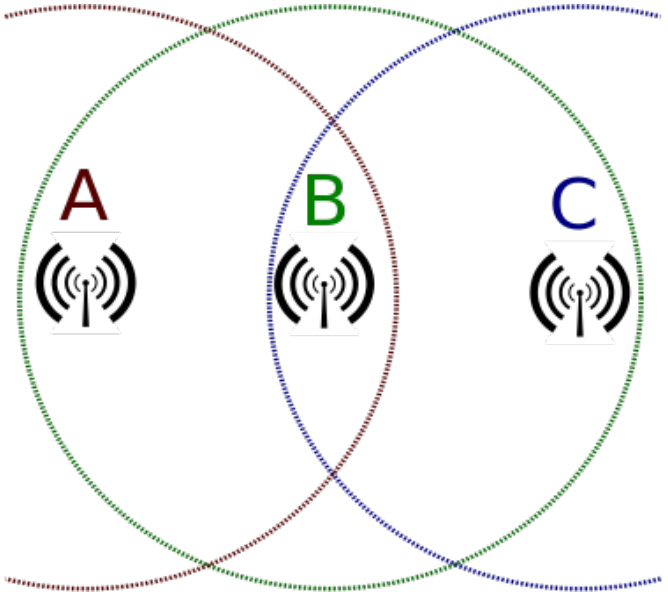
Result: strict distance limit, efficiency limit

Topology

- A single channel can be hard to deploy
  - RF doesn't go around corners
  - 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

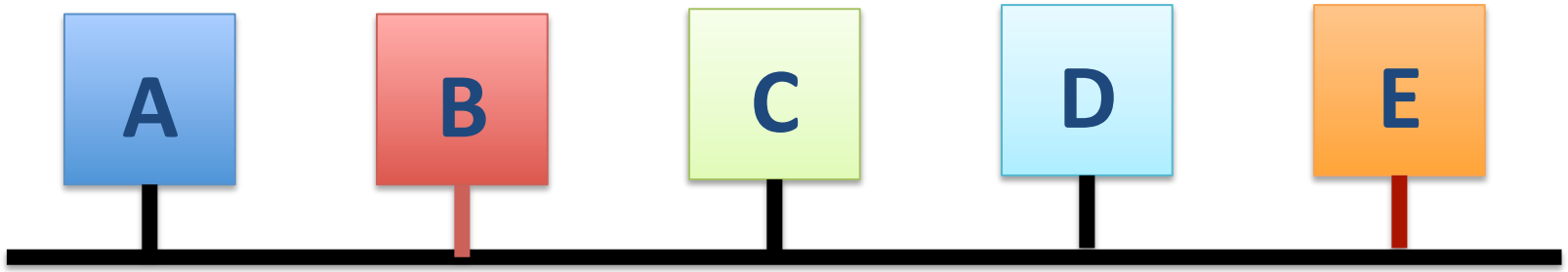
- Name for "everyone"
  - Enables native (one-step) broadcast
  - Often "all 1's"
- Name for "a group"
  - Enables native (one-step) multicast
- Name for "I don't have an address yet"
  - Often "all 0's" (for another day)

More switching

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

Simpler wiring

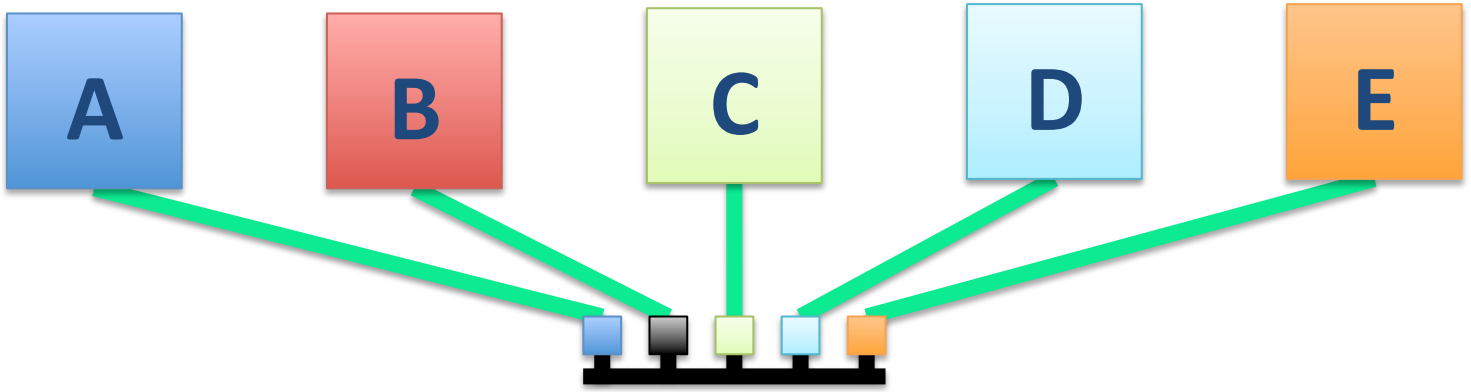
- First step: everyone on a bus



Limited by the bus path

Simpler wiring 2

- Second step: delegate to a shorter bus

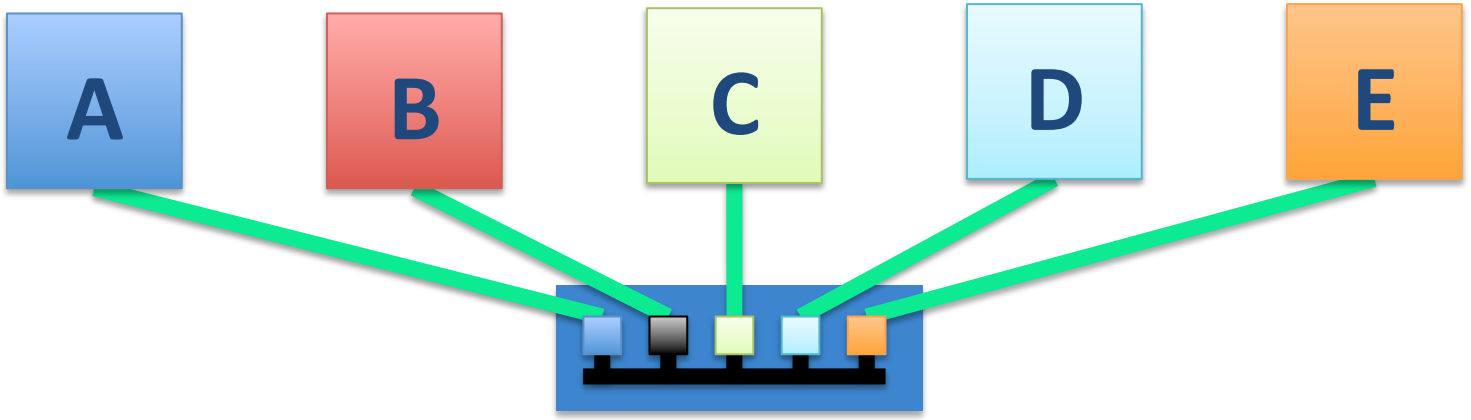


Move per-node smarts together

E.g.: Ethernet MAU

Simpler wiring 3

- Third step: box it up!



Simpler to manage and operate

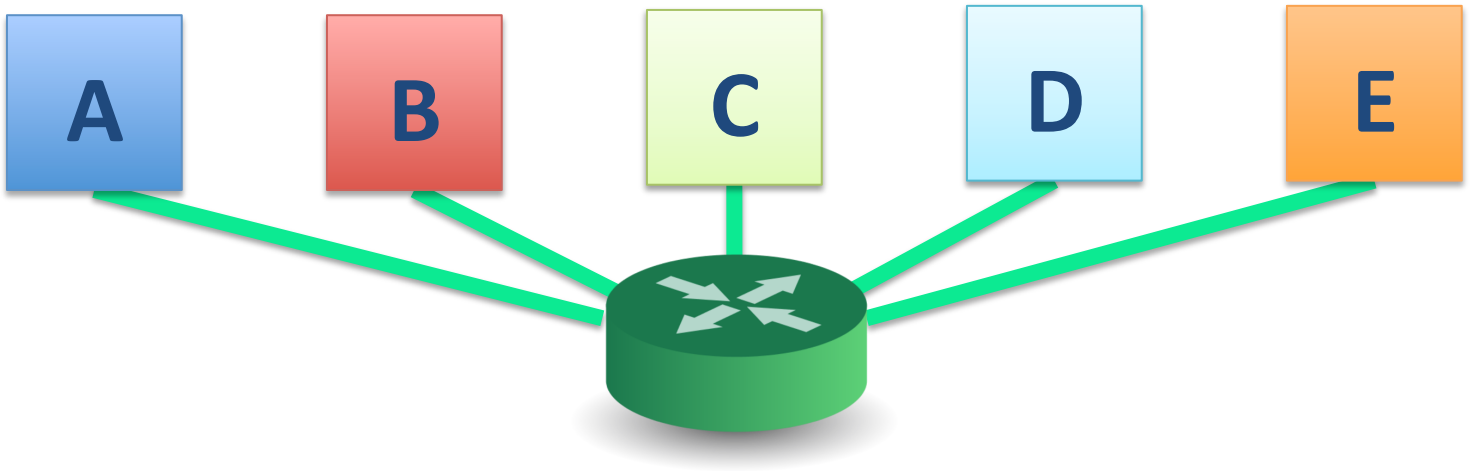
A note about MAC protocols

media access control

- Media access control
  - Just a name
  - Protocol to control shared access
  - NOT NEEDED without shared access!

Simpler wiring 4

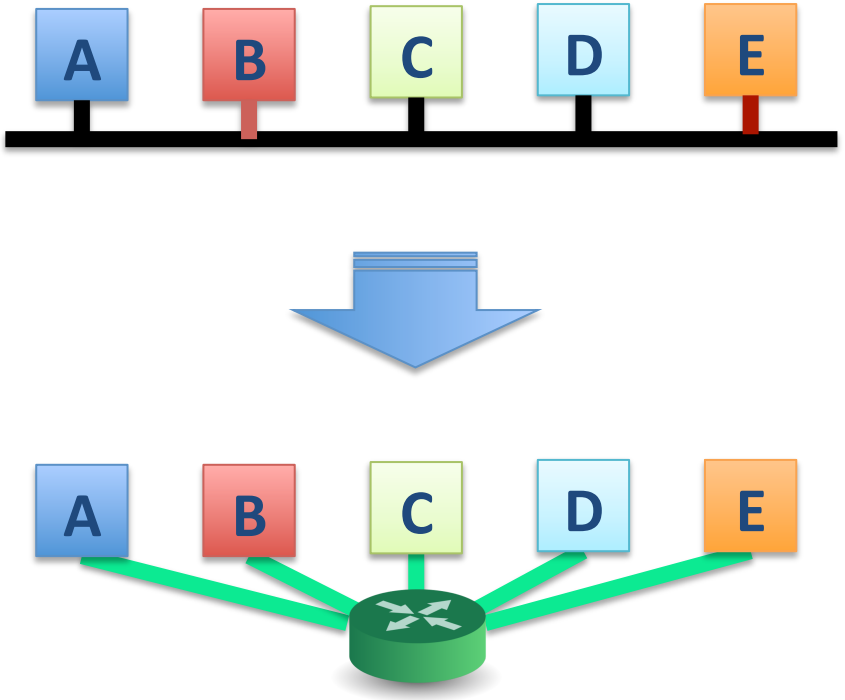
- Final step: who cares what's in the box?
  - There are many ways to build N:N exchanges



- 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



  - 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

So what's a switch really?

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

Switch examples

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

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
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

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

Sharing vs. relaying

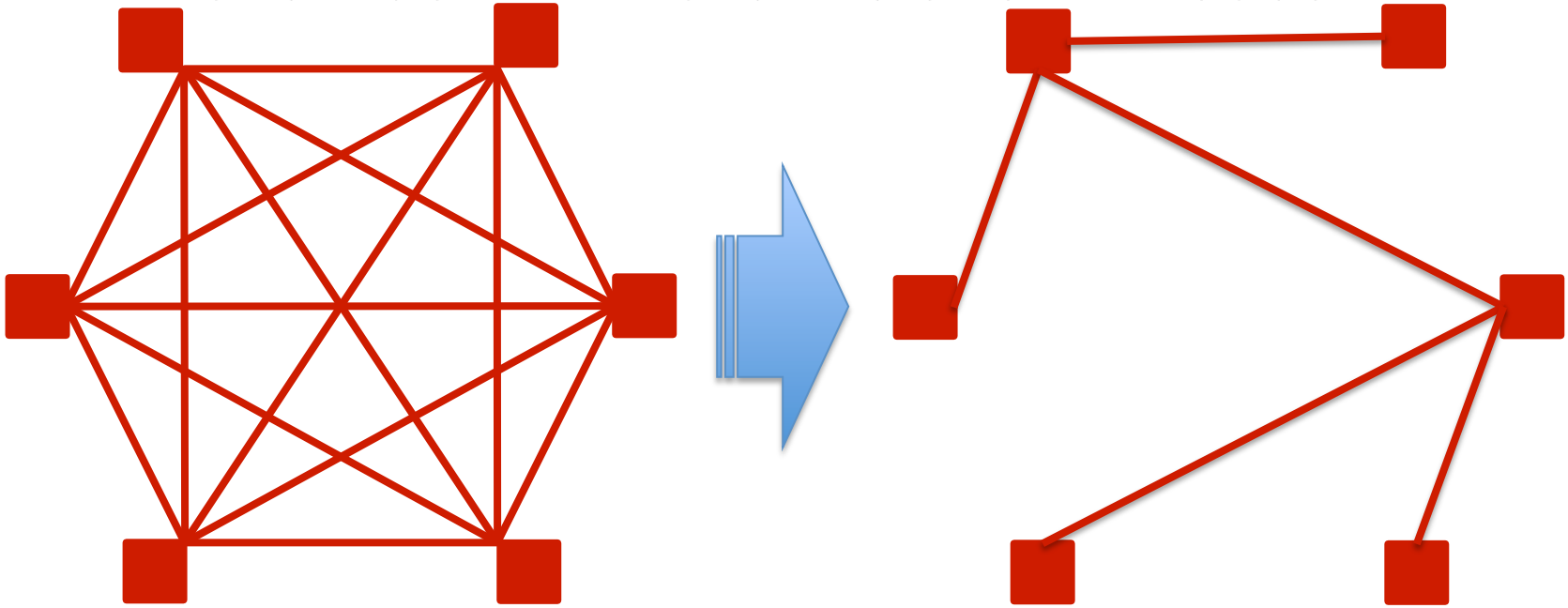
- Sharing
  - Increases endpoint work
  - Simple topology
  - Efficient small scale
  - Poor number scaling
  - Poor size scaling
- Relaying
  - Spreads the work
  - Allows complex topologies
  - Efficient at large scales
  - Good number scaling
  - Good size scaling
    - If designed well

Relaying to the rescue!

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

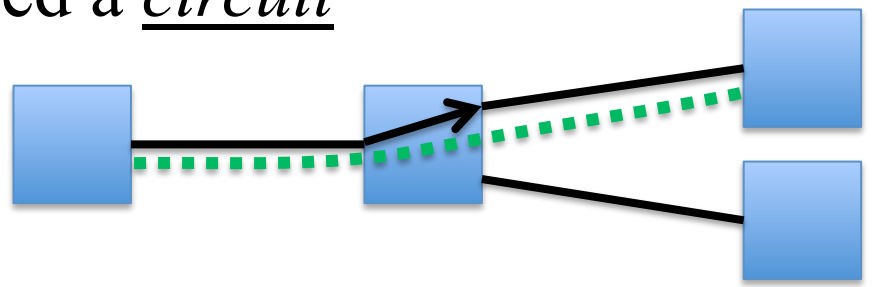
How does relaying help?

- 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*



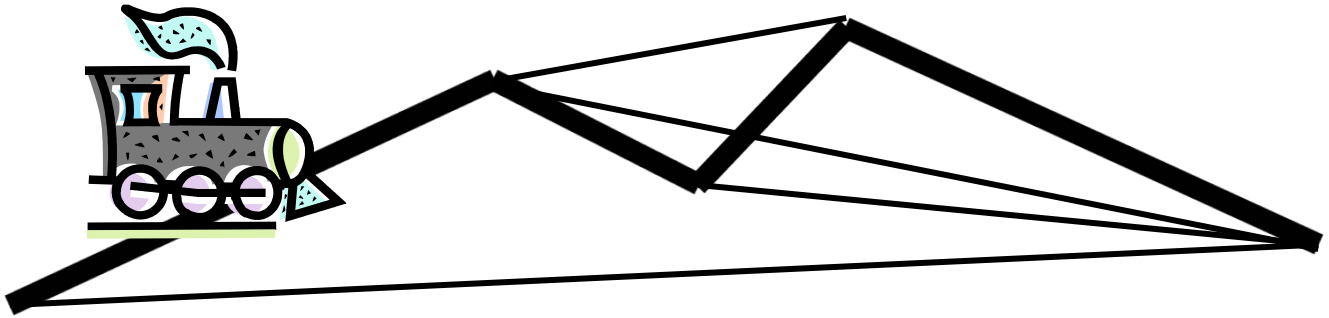
The good, the bad, and…

- 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

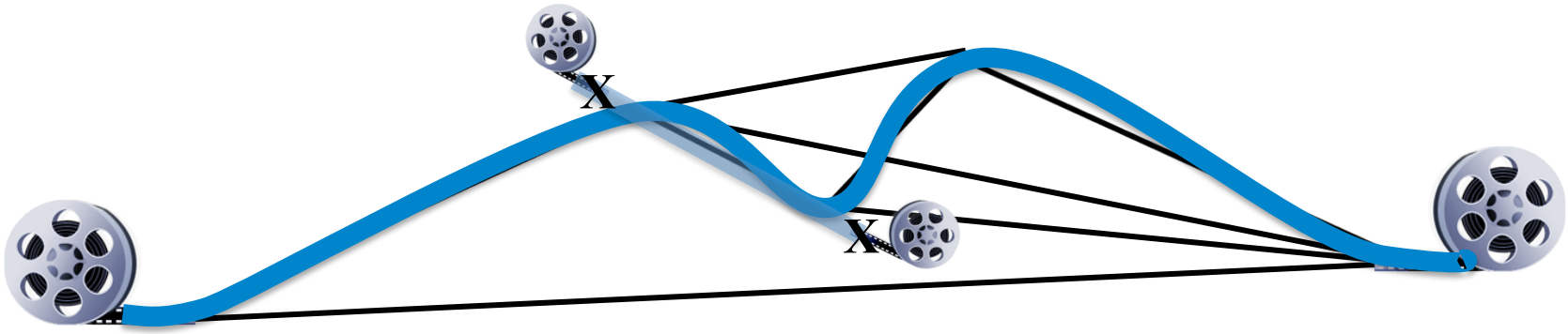


- Guarantees no competing traffic
  - Fixed delay, fixed jitter, fixed capacity
  - Can't share resources concurrently

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)

Circuits – cons

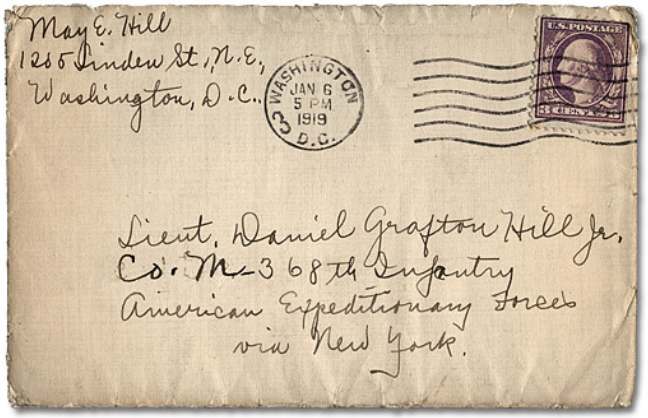
- Fairness on a per-circuit basis
  - Per reservation
  - At the time of reservation
  - At the time of use
- Path blocking
  - Resources blocked (even if not actively used)
- Capacity limited
  - Min. of per-hop capacity of a single path

How can we relay? #2

- Packets to the rescue

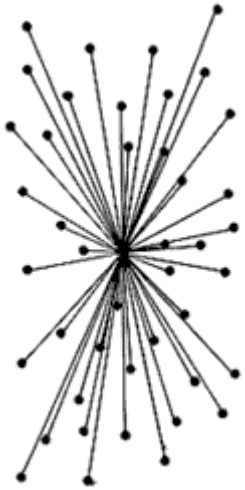
  packet switching - time division and time segment given to someone else

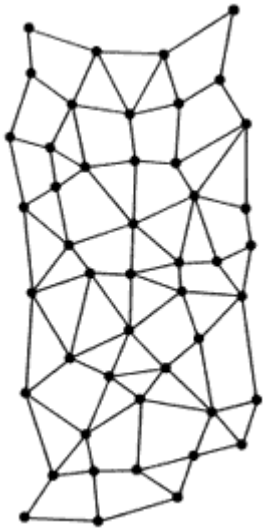
  – TDMA relaying
  – Allows circuits to be shared
  – Avoids blocking of cross-traffic
  – "Packet" coined in 1968 (Donald Davies)



Baran's study

- Compared central and distributed nets

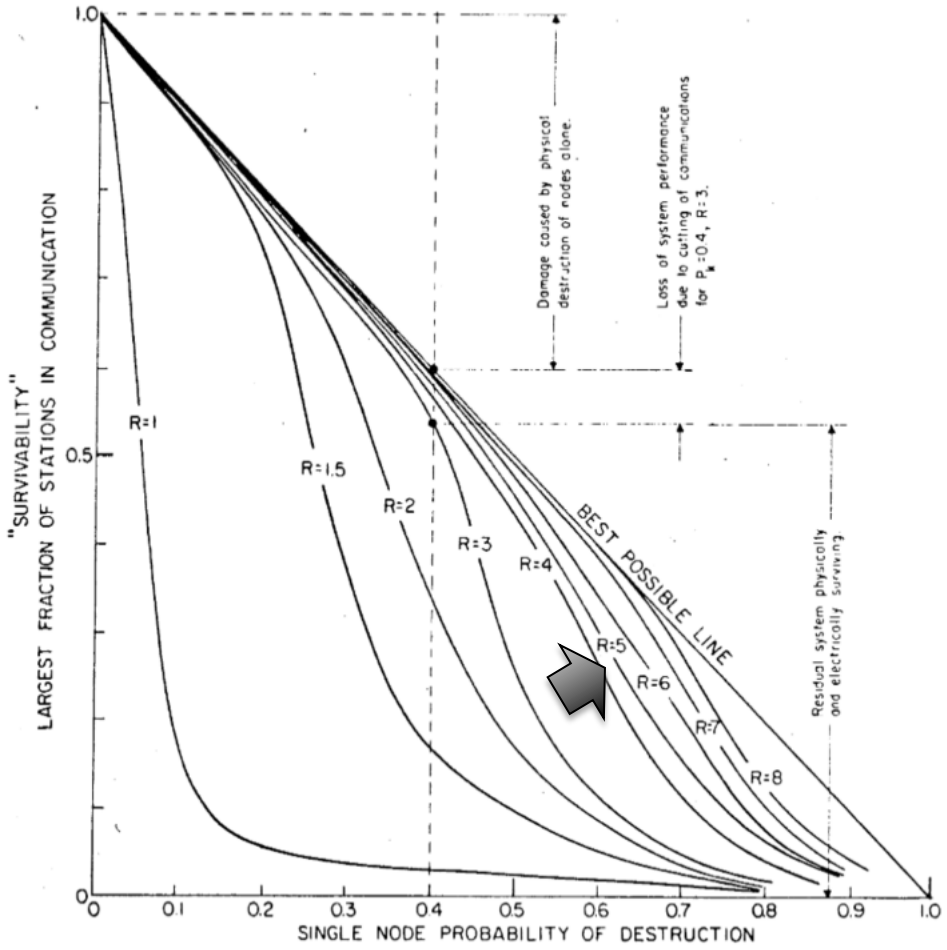




- Divide messages into "blocks" (packets)

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

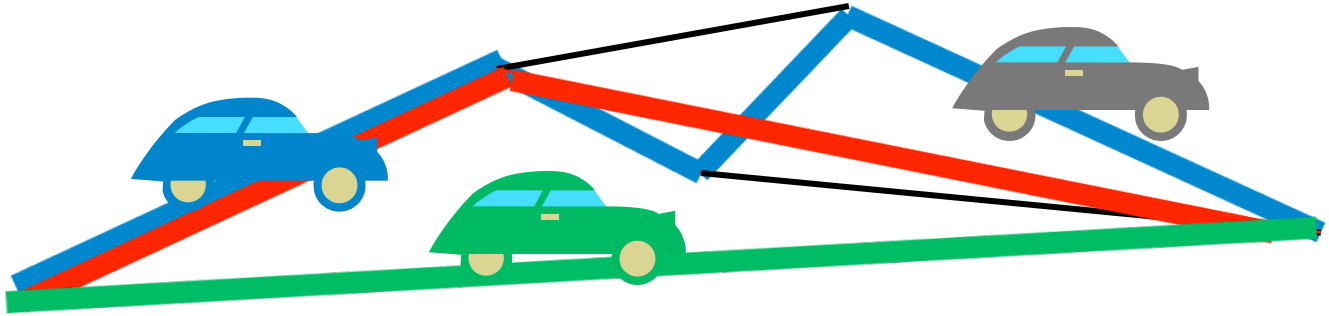


how much redundancy are needed so we are still good to have another network

Packet example

packet switching gives very little jitter, which is nice

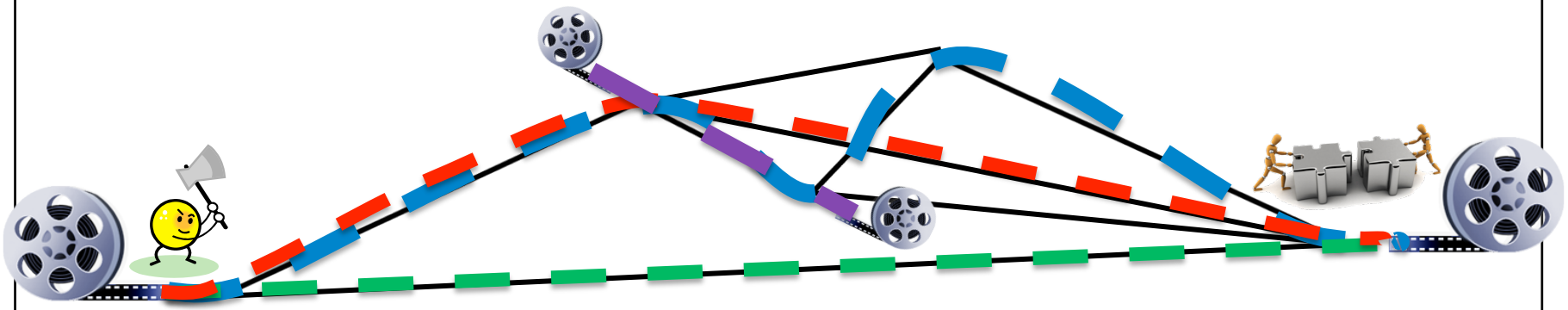
- Cars on a highway
  - No need to schedule
  - Resource used only during transit
  - Path can vary, even given identical headers



- 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

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
  - Brief uses share better and complete faster
- Allows 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

- 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 -

	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

send som