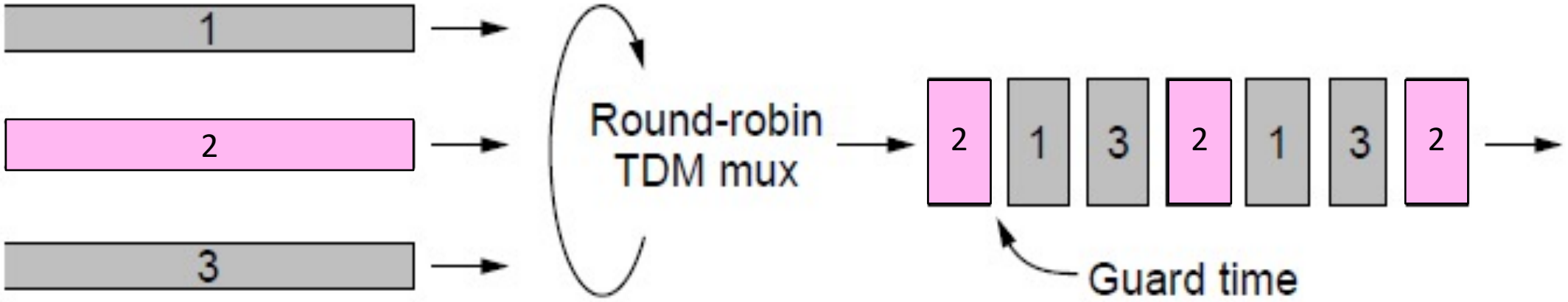
Multiple Access

Topic

- Multiplexing is the network word for the sharing of a resource
- Classic scenario is sharing a link among different users
  - Time Division Multiplexing (TDM)
  - Frequency Division Multiplexing (FDM)

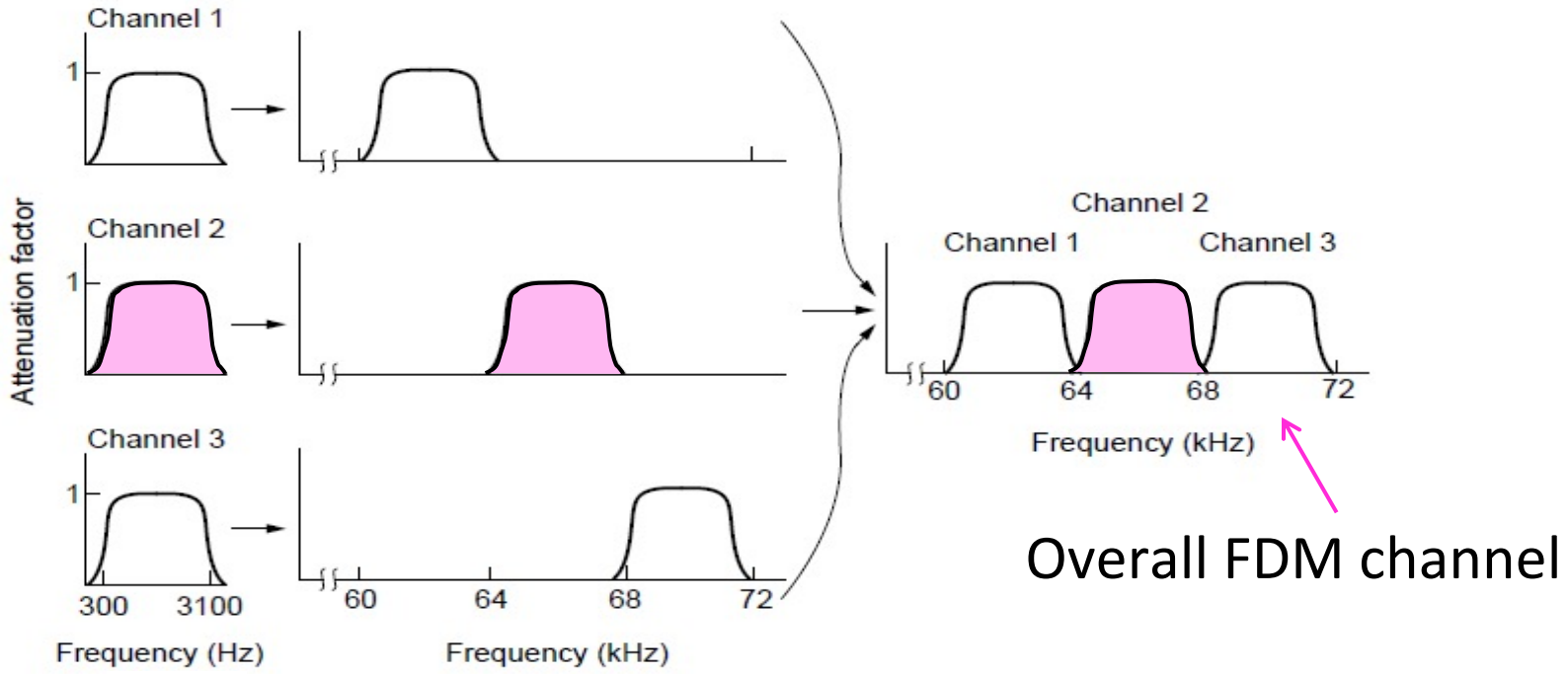
Time Division Multiplexing (TDM)

- Users take turns on a fixed schedule



Frequency Division Multiplexing (FDM)

- Put different users on different frequency bands

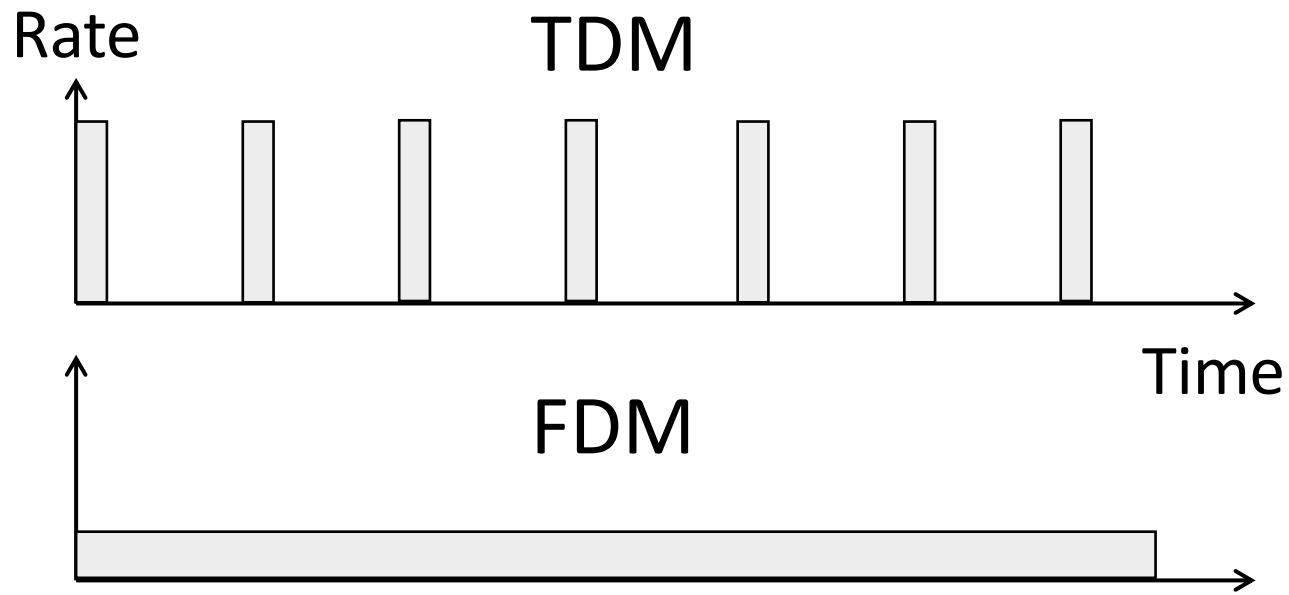


TDM versus FDM

- In TDM a user sends at a high rate a fraction of the time; in FDM, a user sends at a low rate all the time

TDM versus FDM (2)

- In TDM a user sends at a high rate a fraction of the time; in FDM, a user sends at a low rate all the time

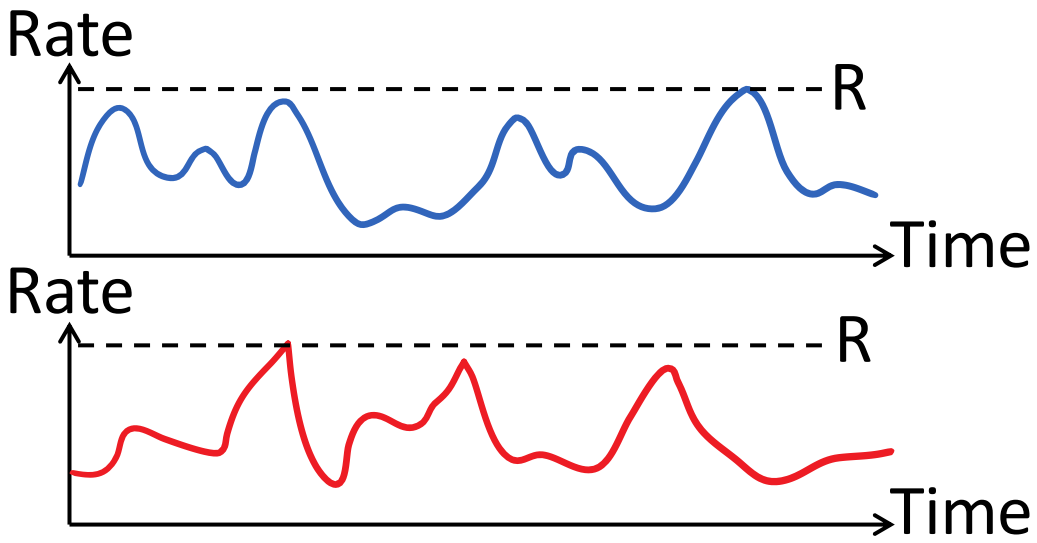


TDM/FDM Usage

- Statically divide a resource
  - Suited for continuous traffic, fixed number of users
- Widely used in telecommunications
  - TV and radio stations (FDM)
  - GSM (2G cellular) allocates calls using TDM within FDM

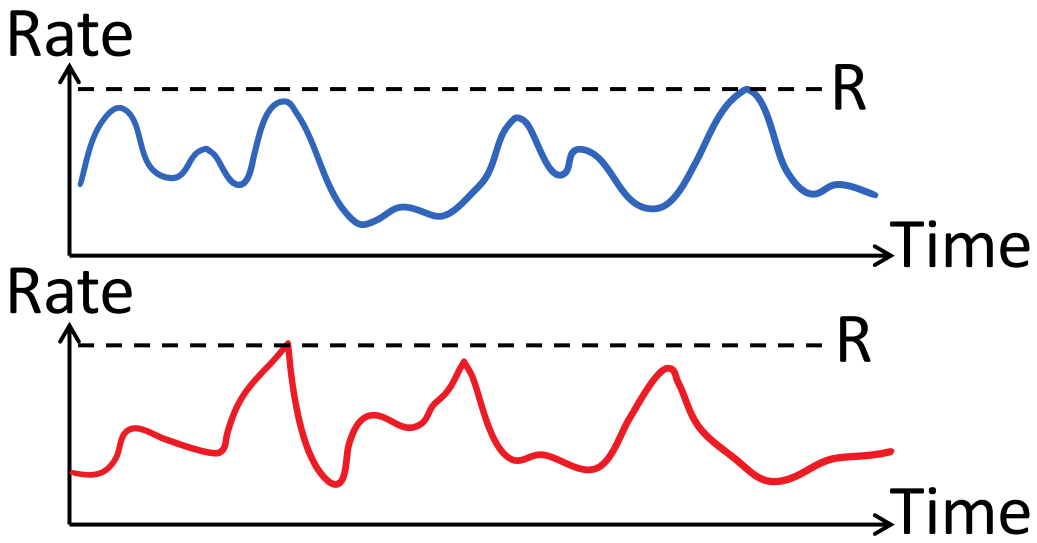
Multiplexing Network Traffic

- Network traffic is bursty
  - ON/OFF sources
  - Load varies greatly over time



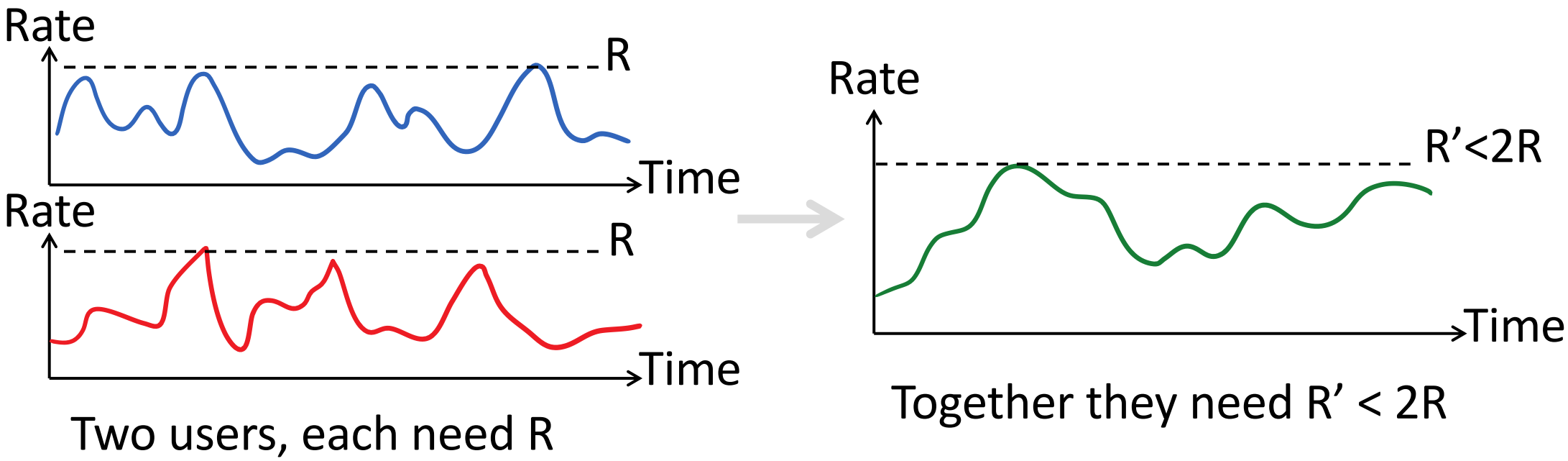
Multiplexing Network Traffic (2)

- Network traffic is bursty
  - Inefficient to always allocate user their ON needs with TDM/FDM



Multiplexing Network Traffic (3)

- Multiple access schemes multiplex users according to demands – for gains of statistical multiplexing



How to control?

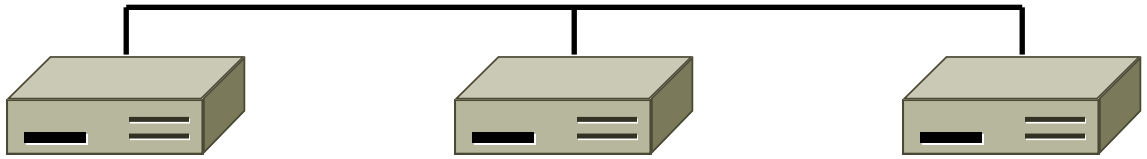
Two classes of multiple access algorithms

- **Centralized**: Use a "Scheduler" to pick who transmits and when
  - Scales well and is usually efficient, but requires setup and management
  - Example: Cellular networks (tower coordinates)

- **Distributed**: Have participants "figure it out" via some mechanism
  - Operates well under low load and easy set up but scaling efficiently is hard
  - Example: WiFi networks

Distributed (random) Access

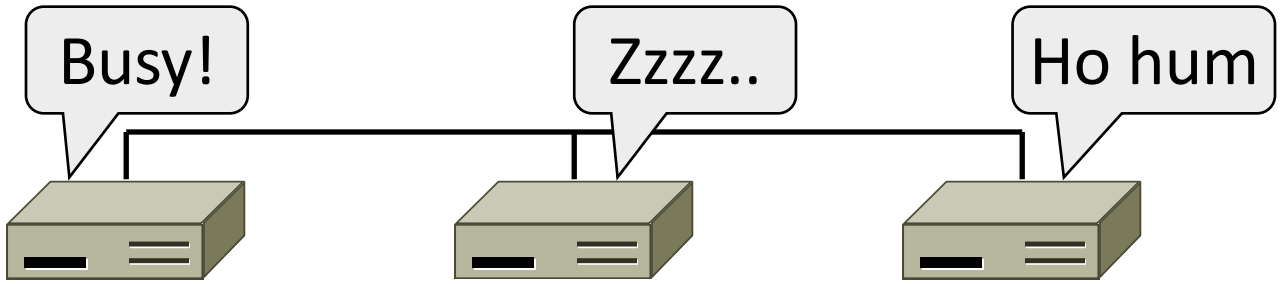
- How do nodes share a single link? Who sends when?
  - Explore with a simple model



- Assume no-one is in charge
  - Distributed system

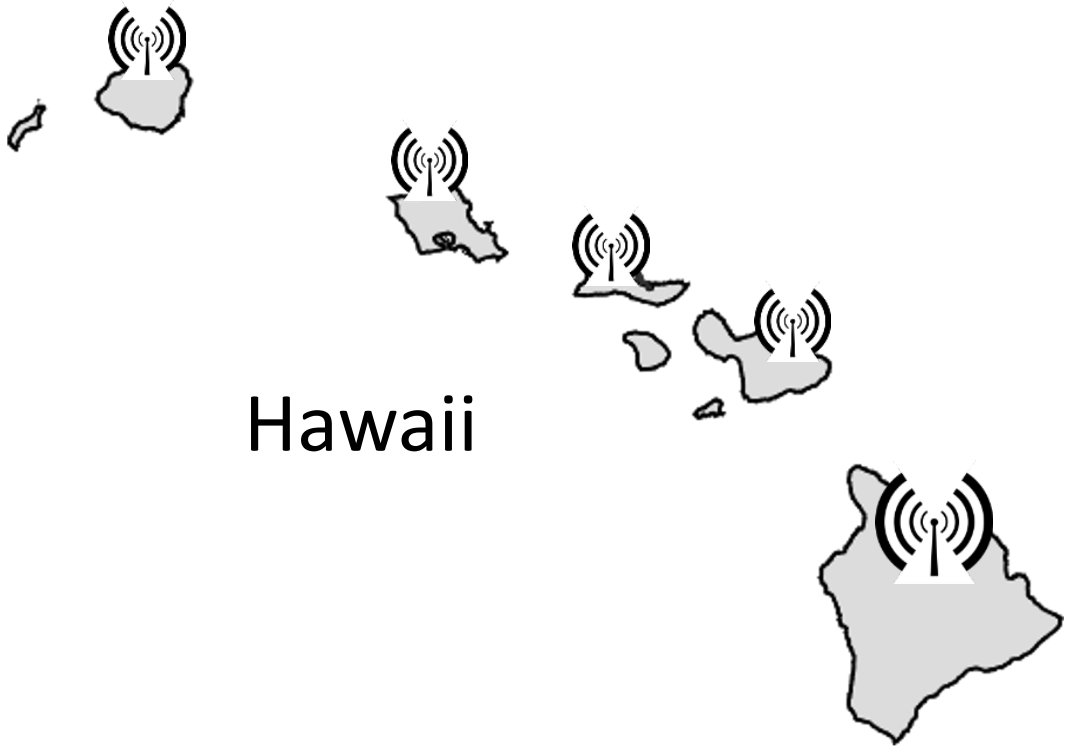
Distributed (random) Access (2)

- We will explore random multiple access control (MAC) protocols
  - This is the basis for classic Ethernet
  - Remember: data traffic is bursty



ALOHA Network

- Seminal computer network connecting the Hawaiian islands in the late 1960s
  - When should nodes send?
  - A new protocol was devised by Norm Abramson …

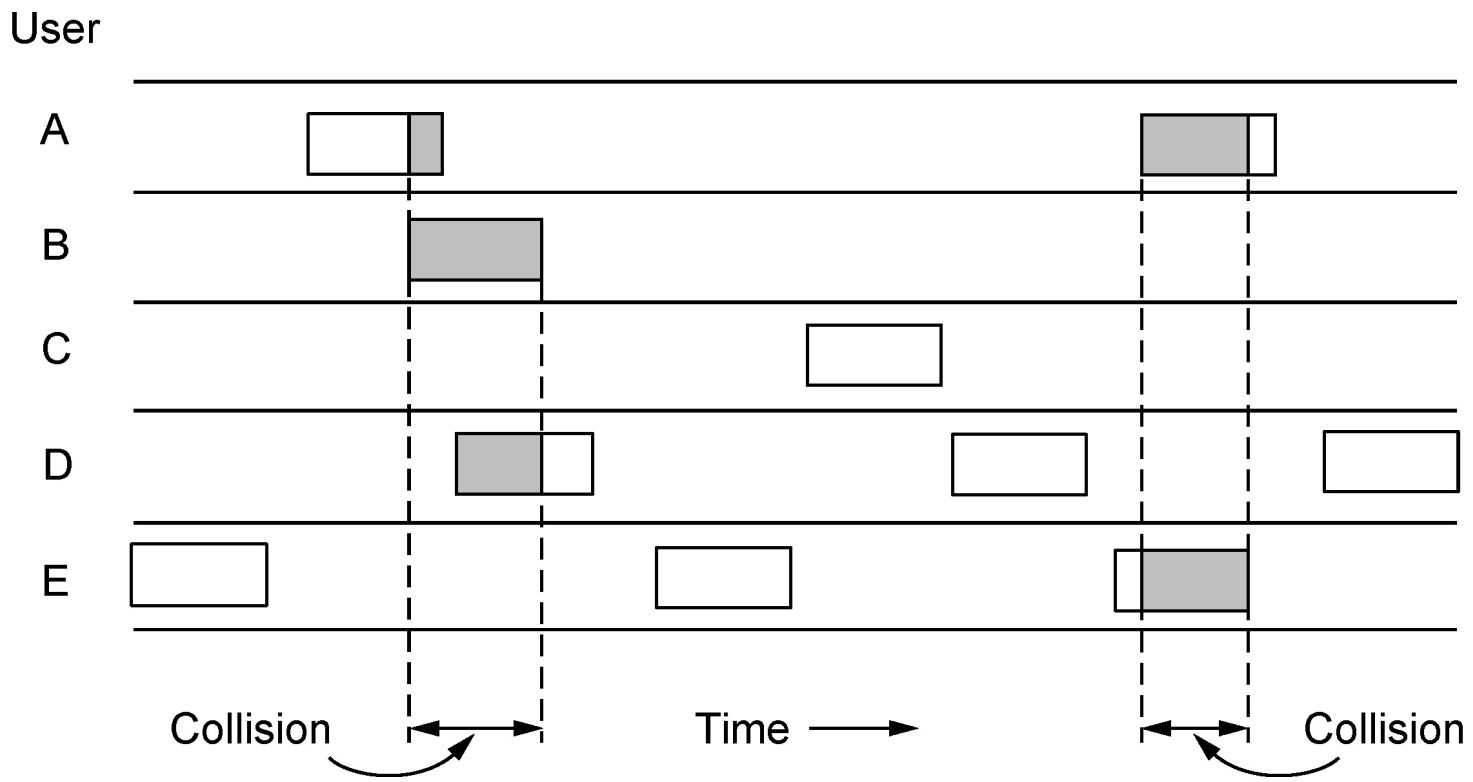


ALOHA Protocol

- Simple idea:
  - Node just sends when it has traffic.
  - If there was a collision (no ACK received) then wait a random time and resend
- That's it!

ALOHA Protocol (2)

- Some frames will be lost, but many may get through…
- Limitations?

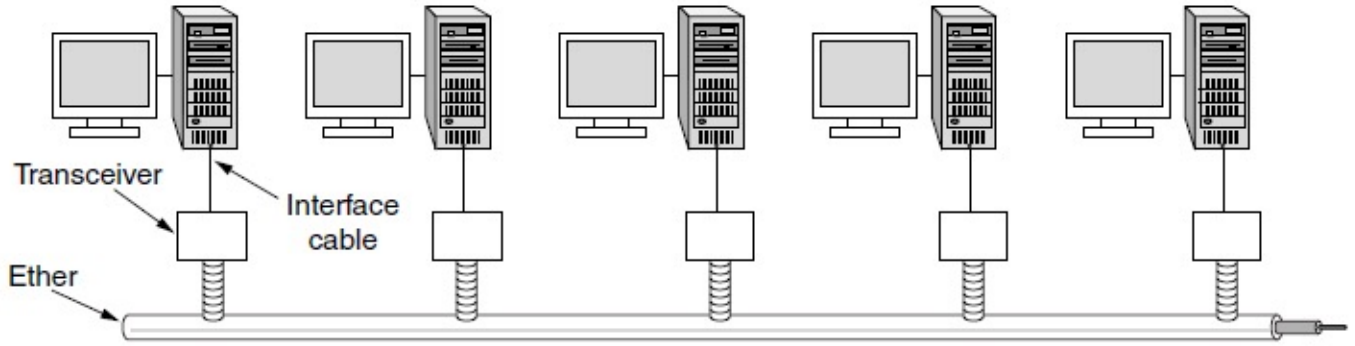


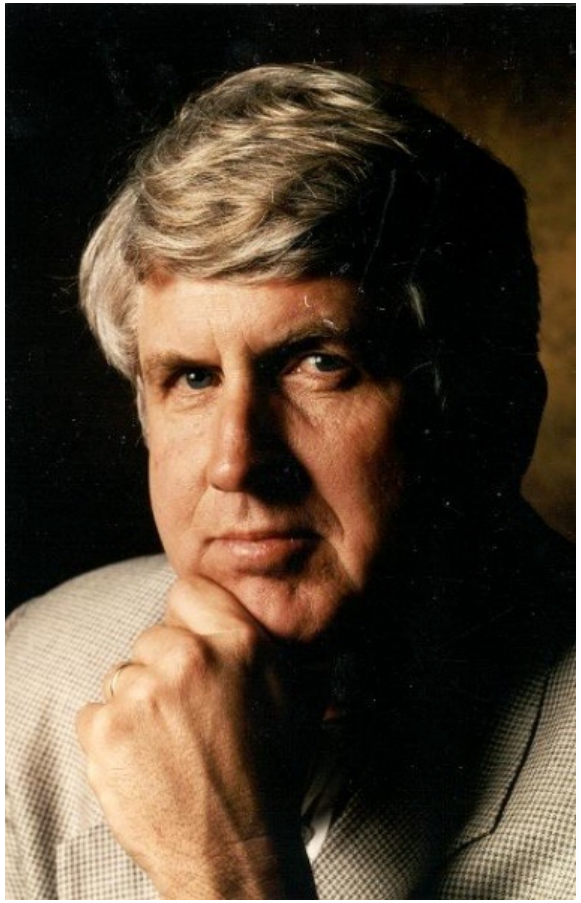
ALOHA Protocol (3)

- Simple, decentralized protocol that works well under low load!
- Not efficient under high load
  - Analysis shows at most 18% efficiency
  - Improvement: divide time into slots and efficiency goes up to 36%
- We'll look at other improvements

Classic Ethernet

- ALOHA inspired Bob Metcalfe to invent Ethernet for LANs in 1973
  - Nodes share 10 Mbps coaxial cable
  - Hugely popular in 1980s, 1990s





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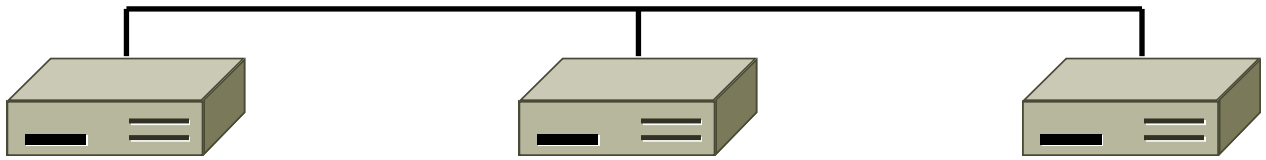
CSMA (Carrier Sense Multiple Access)

- Improve ALOHA by listening for activity before we send (Doh!)
  - Easy with wires, recently made possible for wireless
- So does this eliminate collisions?
  - Why or why not?

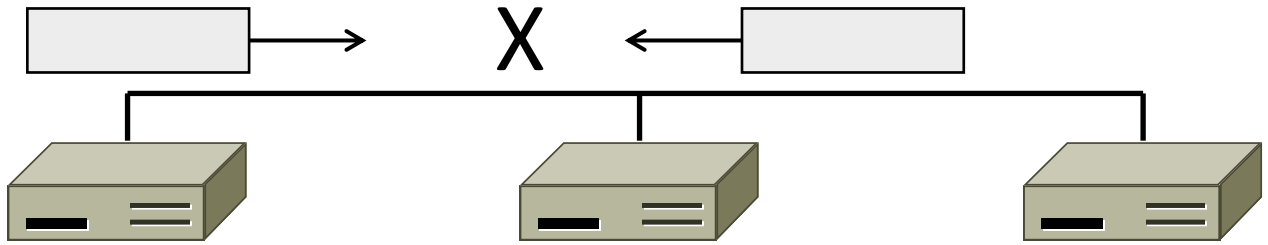
CSMA (2)

- Still possible to listen and hear nothing when another node is sending because of delay



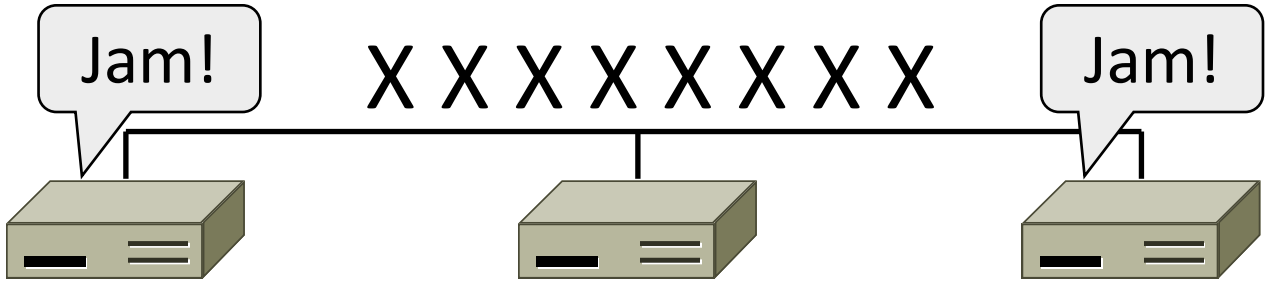
CSMA (3)

- CSMA is a good defense against collisions only when BD is small



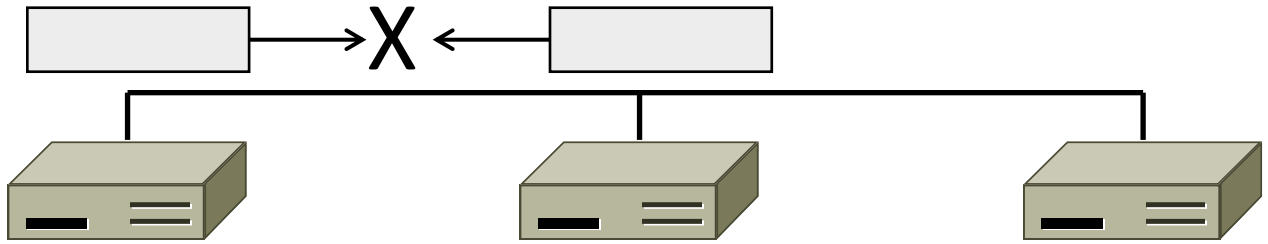
CSMA/CD (with Collision Detection)

- Can reduce the cost of collisions by detecting them and aborting (Jam) the rest of the frame time
  - Again, easy with wires, recently made possible for wireless



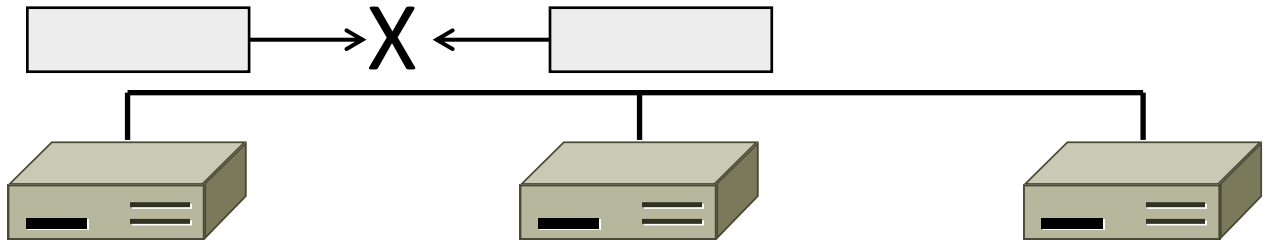
CSMA/CD Complications

- Everyone who collides needs to know it happened
  - How long do we need to wait to know there wasn't a JAM?



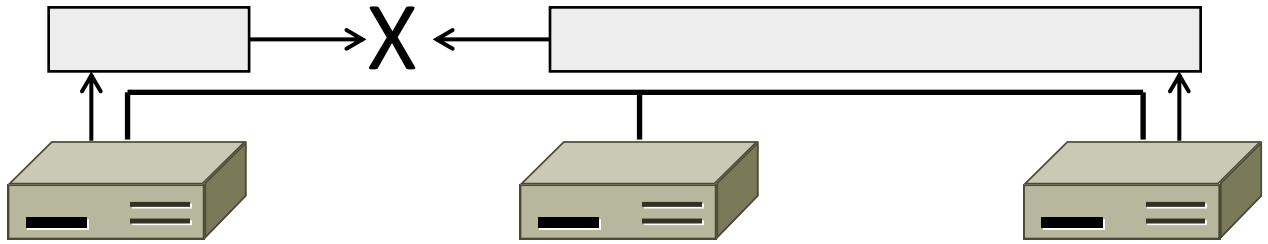
CSMA/CD Complications

- Everyone who collides needs to know it happened
  - How long do we need to wait to know there wasn't a JAM?
  - Time window in which a node may hear of a collision (transmission + jam) is 2D seconds



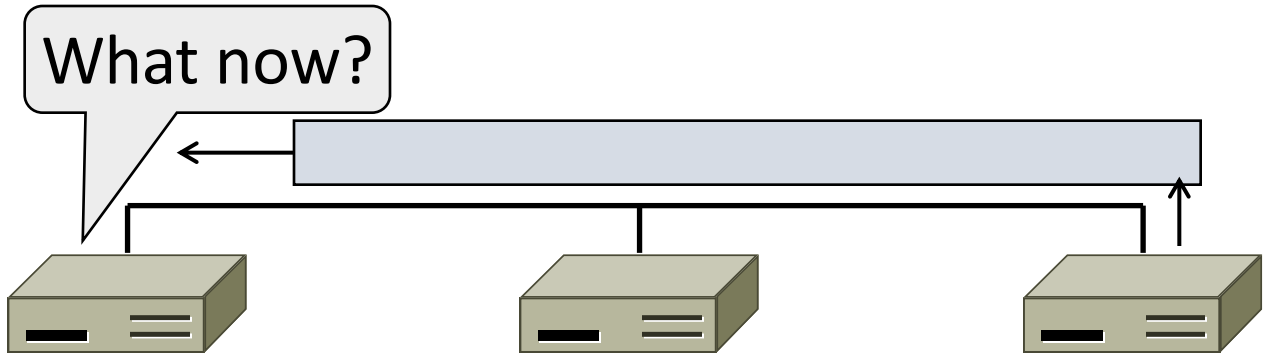
CSMA/CD Complications (2)

- Impose a minimum frame length of 2D seconds
  - So node can't finish before collision
  - Ethernet minimum frame is 64 bytes – Also sets maximum network length (500m w/ coax, 100m w/ Twisted Pair)



CSMA "Persistence"

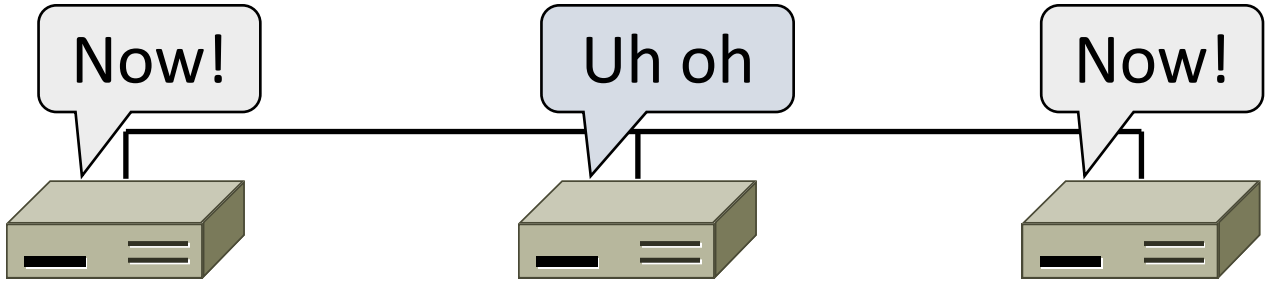
- What should a node do if another node is sending?



- Idea: Wait until it is done, and send

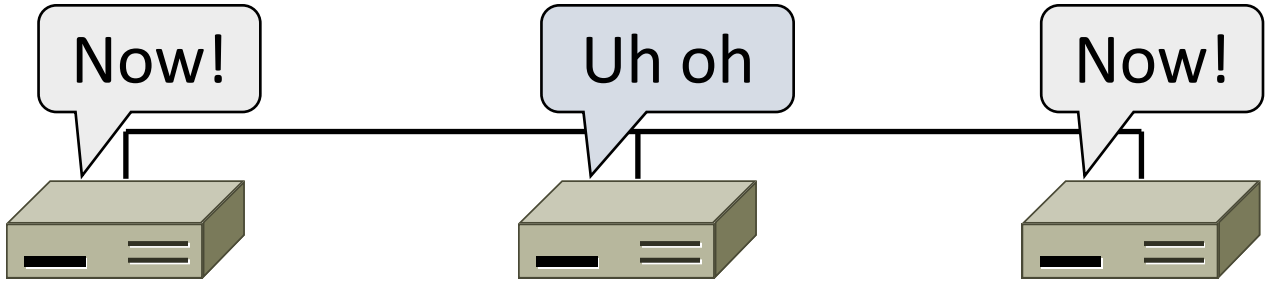
CSMA "Persistence" (2)

- Problem is that multiple waiting nodes will queue up then collide
  - More load, more of a problem



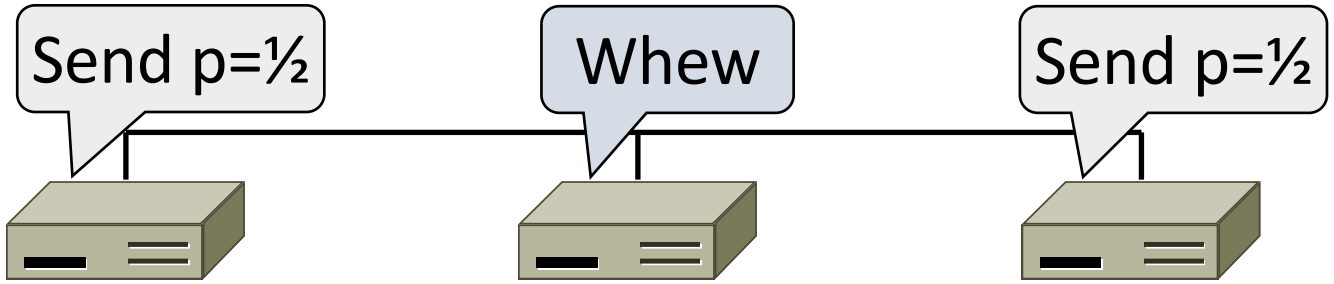
CSMA "Persistence" (2)

- Problem is that multiple waiting nodes will queue up then collide
  - Ideas?



CSMA "Persistence" (3)

- Intuition for a better solution
  - If there are N queued senders, we want each to send next with probability 1/N

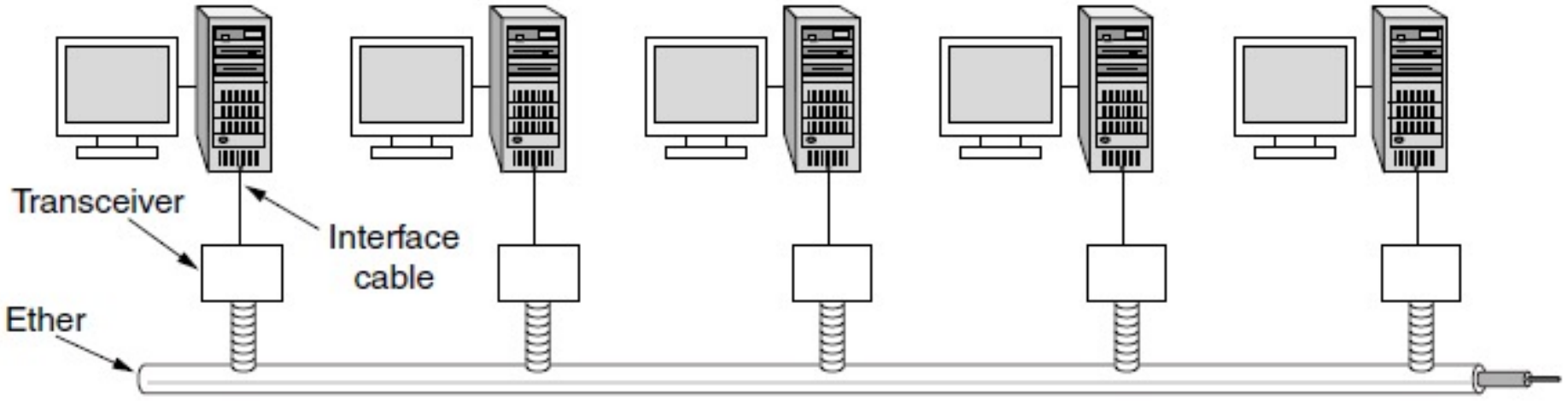


Binary Exponential Backoff (BEB)

- Cleverly estimates the probability
  - 1st collision, wait 0 or 1 frame times
  - 2nd collision, wait from 0 to 3 times
  - 3rd collision, wait from 0 to 7 times …
- BEB doubles interval for each successive collision
  - Quickly gets large enough to work
  - Very efficient in practice

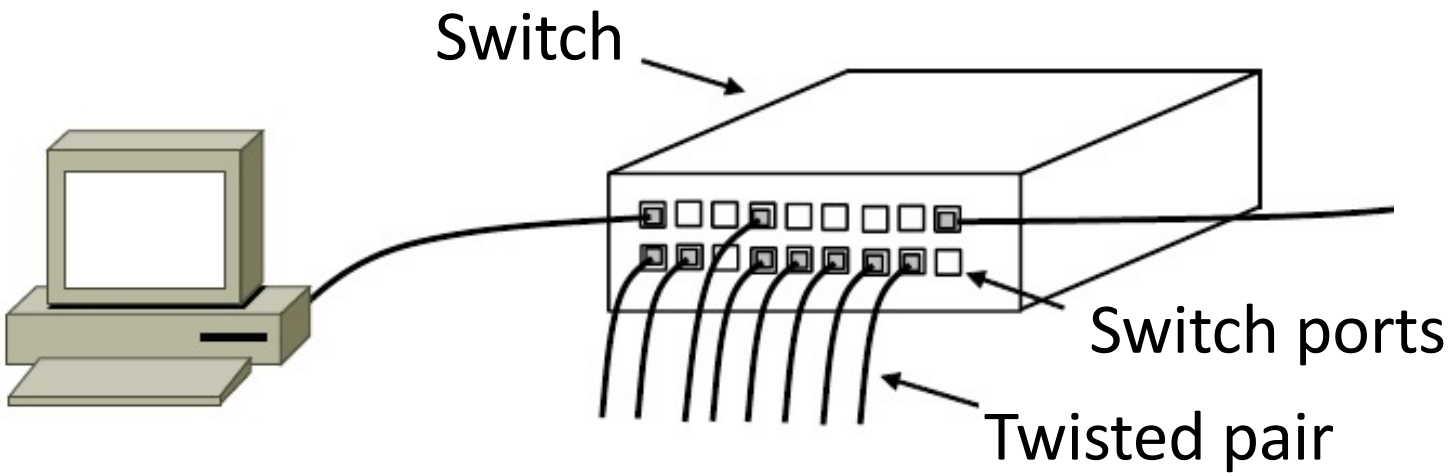
Classic Ethernet, or IEEE 802.3

- Most popular LAN of the 1980s, 1990s
  - 10 Mbps over shared coaxial cable
  - Multiple access with persistent CSMA/CD with BEB



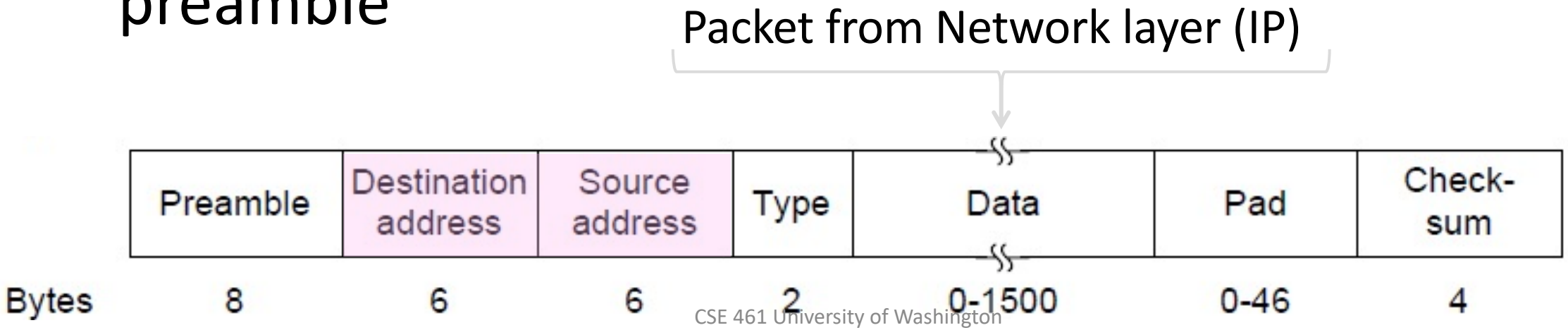
Modern Ethernet

- Based on switches, not multiple access, but still called Ethernet



Ethernet Frame Format

- Has addresses to identify the sender and receiver
- CRC-32 for error detection; no ACKs or retransmission
- Start of frame identified with physical layer preamble



Recap: MAC layer ideas

- Random wait times upon collisions
- Carrier sense
  - Persistence
- Collision detection
- Binary exponential backoff