Computer Networks

Medium Access Sublayer (Part I)

Topics

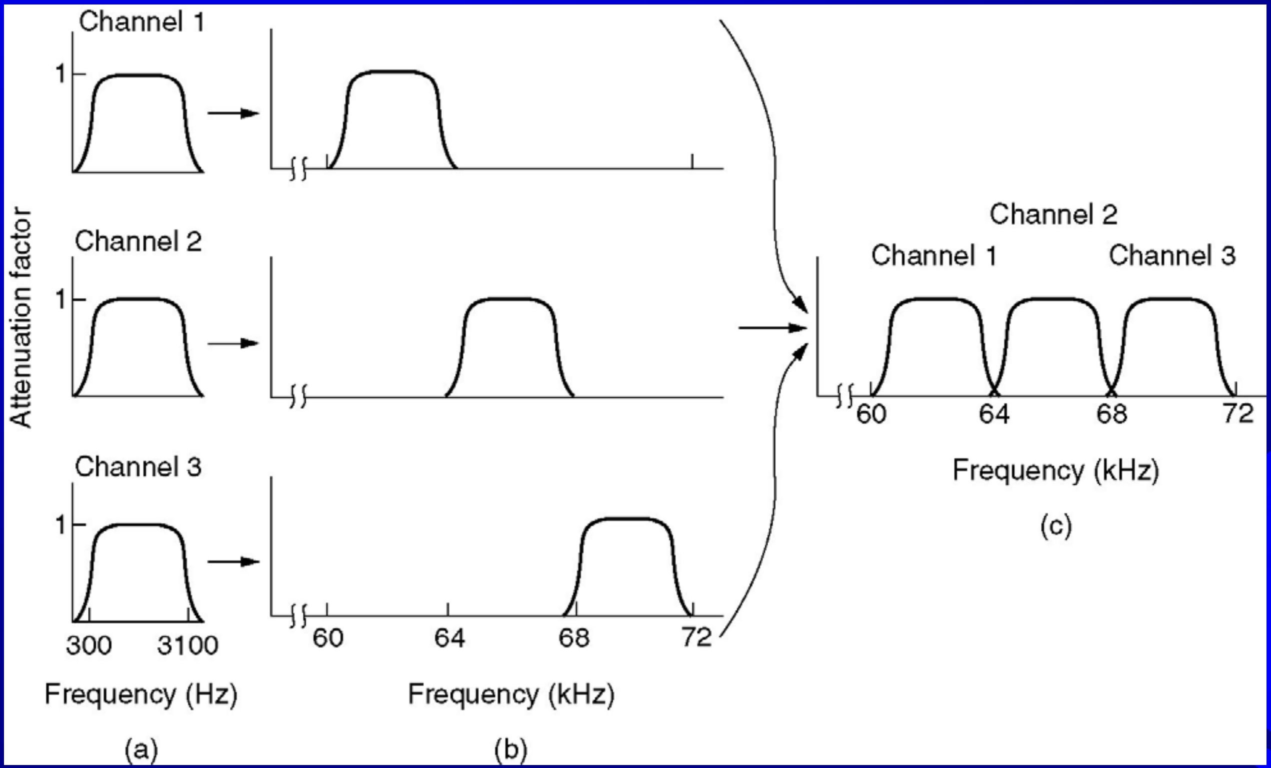
- Introduction
- Multiple Access Protocols
- Ethernet
- Wireless LAN Protocols
- Bridges
- Misc (brief)
  - High-Speed LANs
  - Satellite Networks

Introduction

- Remember, two categories of networks
  - point-to-point
  - broadcast
- Key issue is who gets channel
  - example: 6-person conference call
- Many protocols to decide
- Medium Access Control sublayer
  - lower part of data-link layer, but easier here
- Many LANs multiaccess
  - satellites, too

Fixed Channel Allocation

- Static channel allocation
  - FDM, TDM



FDM

- Time delay T
- Capacity C bps
- Arrival rate λ frames/sec
- Frames mean 1/μ bits

$$T = \frac{1}{\mu C - \lambda}$$

- Divide into N channels
- Each channel C/N bps

$$T = \frac{1}{\mu(C/N) - (\lambda/N)}$$

$$= \frac{N}{\mu C - \lambda}$$

$$= NT$$

TDM is the same

Dynamic Channel Allocation in LANs and MANs: Assumptions

- Station Model
  - N independent stations
- Single Channel Assumption.
  - One shared channel for transmission
- Collision Assumption.
  - garbled if transmissions overlap
- (a) Continuous Time.
  (b) Slotted Time.
- (a) Carrier Sense.
  (b) No Carrier Sense.

Multiple Access Protocols

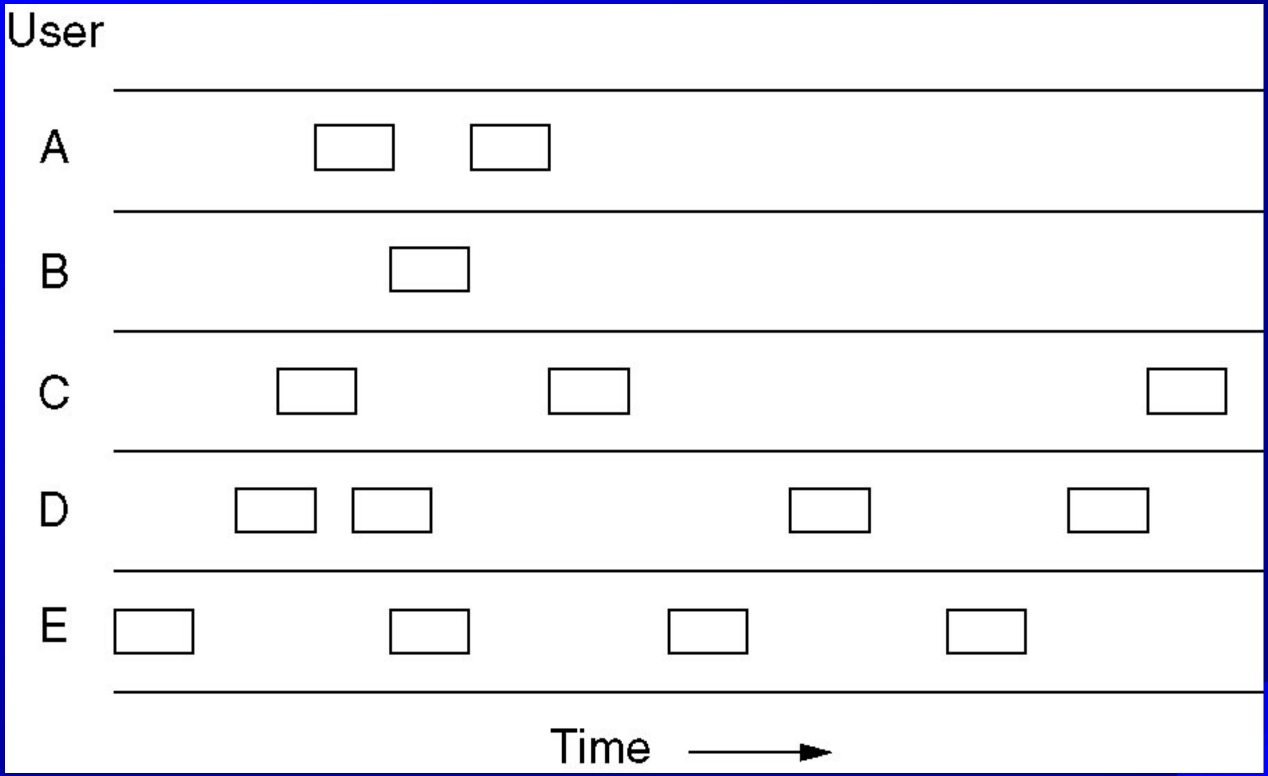
- ALOHA
- Carrier Sense Multiple Access Protocols
- Collision-Free Protocols
- Limited-Contention Protocols
- Wireless LAN Protocols

ALOHA - A Family of Contention Protocols

- 1970's, Abramson
- University of Hawaii
- Ground based broadcasting, packet radio
  - generalizes to uncoordinated users competing for single, shared channel
- Pure ALOHA
  - no time slots
- Slotted ALHOA
  - time slots for frames

Pure ALOHA

- Transmit whenever you want



- Detect collisions after sending
  - checksum error
- If collision, wait random time and retry

Pure ALOHA == Pure Chaos?

- Assume infinite collection of stations
- Users in two states: *typing* or *waiting*
- User *typing* a line. When done, transmit it.
  - user *waiting* for response. When done, *typing*.
- *frame time* is time to put frame on wire
  - frame length / bit rate (fixed frame length)
- Mean number of new frames per frame time
  - N
  - What does $N > 1$ mean?

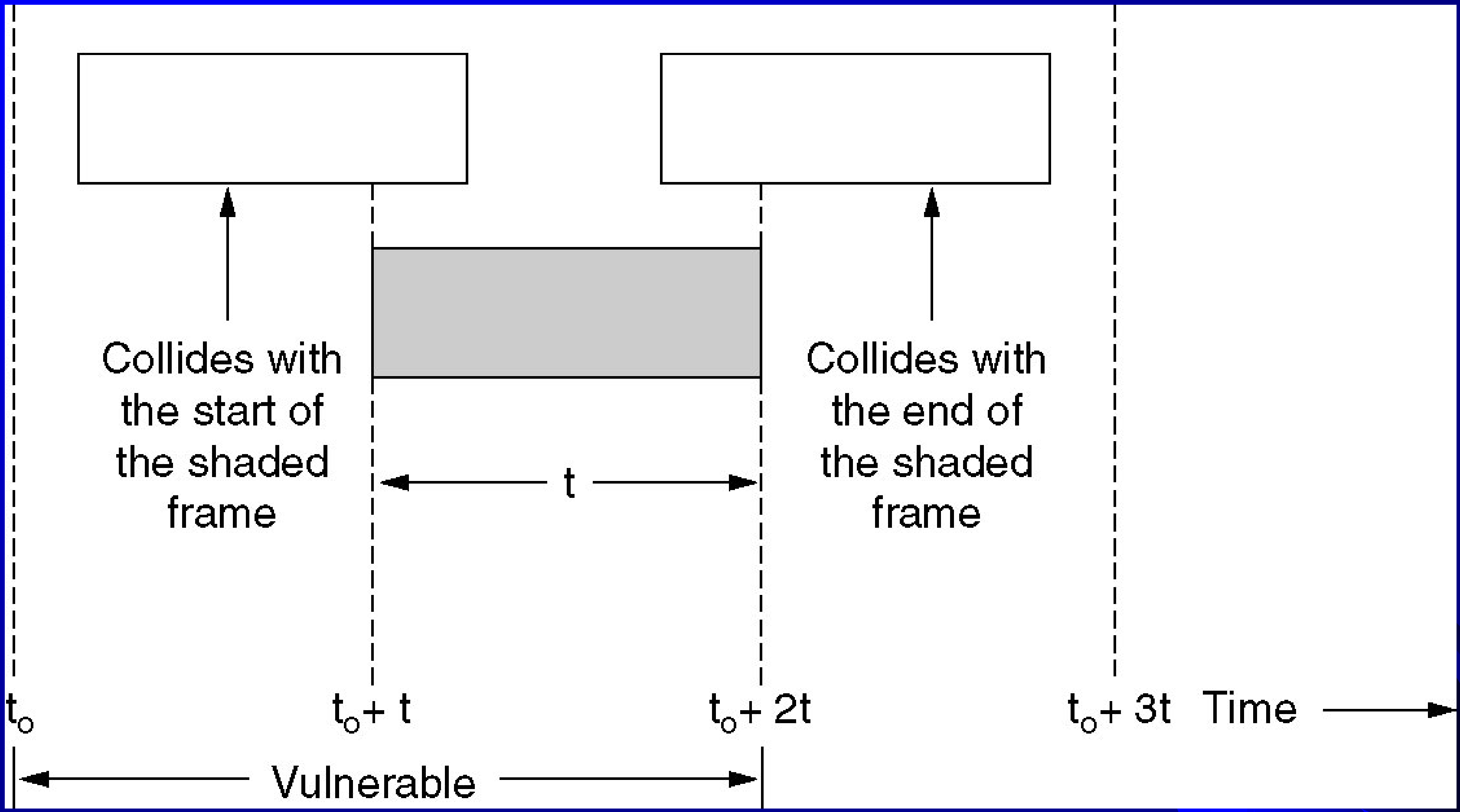
Analysis of Pure ALOHA

- Stations also re-generate collided frames
  - G is old plus new frames
  - $G > N$? $G = N$? $G < N$?
- Low load ($N \approx 0$), few collisions: $G \approx N$
- High load, many collisions: $G > N$
- Throughput per frame time is G times probability of frame having zero collisions:

$$S = G\,P_0$$

  - ex: G=.5, P_0=.5 so S = .25
  - Note: P_0 is probability of successful transmission

Frame Collisions



Analysis of Pure ALOHA (cont.)

- Probability *k* frames generated per frame time

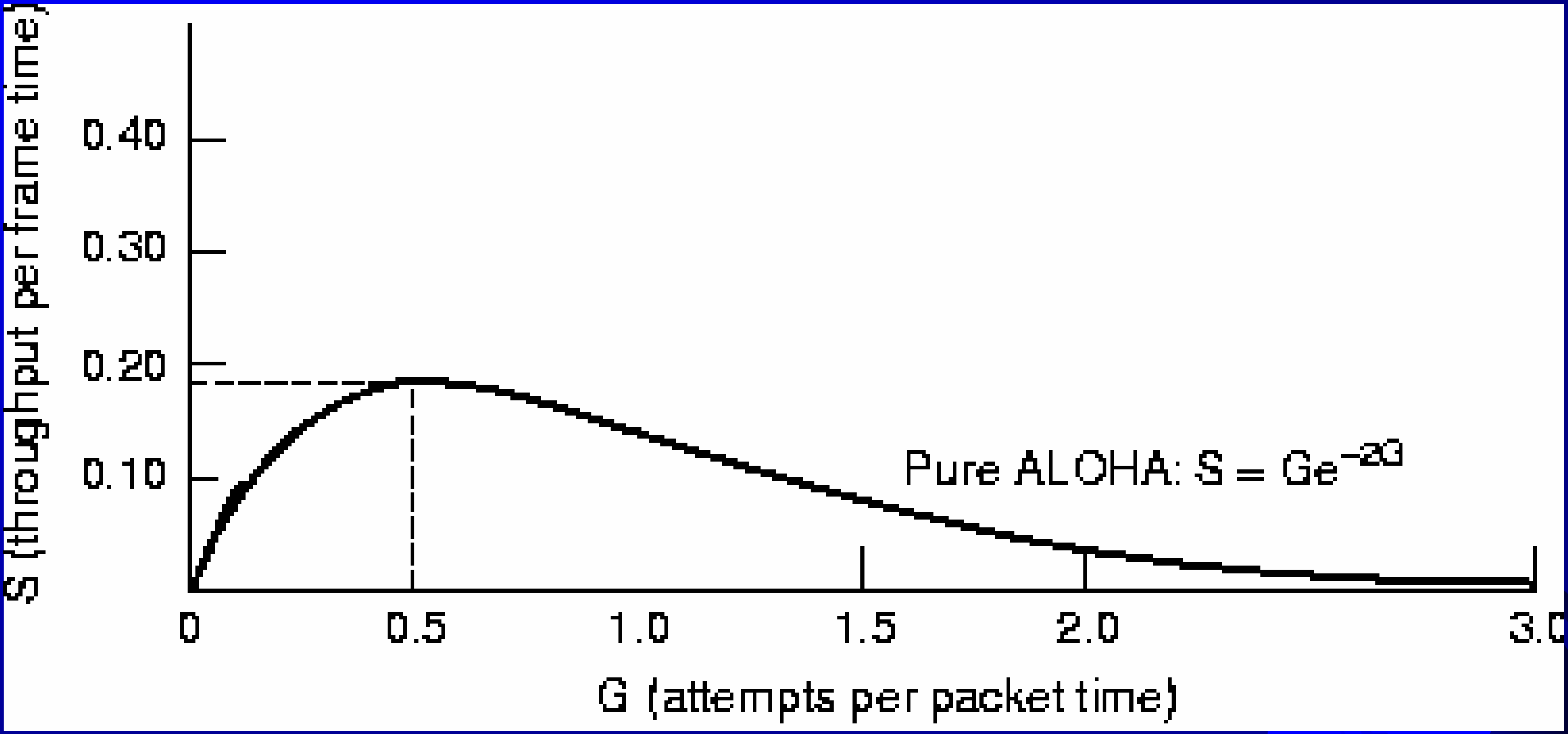
$$\mathbf{Pr}[k] = \frac{G^k e^{-G}}{k!}$$

$$\mathbf{Pr}[0] = e^{-G}$$

- Need two frame times empty, 2*G* generated
  - for two slots, $\mathbf{Pr}[0] = e^{-2G}$
- Using S=GP$_0$, throughput per frame time

$$S = Ge^{-2G}$$

Pure ALOHA
Offered Load vs. Throughput



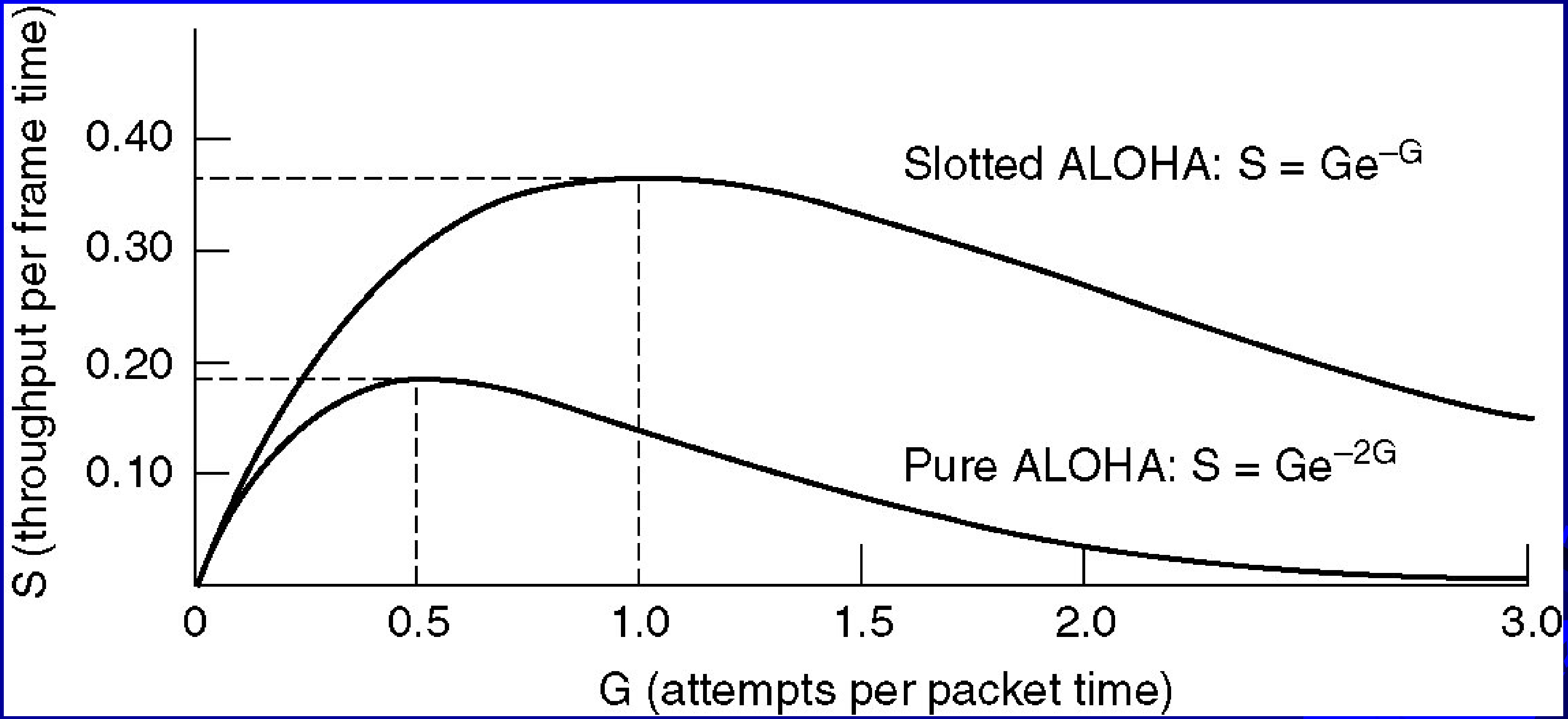
- Max at $G = 0.5$, $S = 1/2e$, only about 0.184 (18%)!
  – Can we do better?

Slotted ALOHA

- Divide time into intervals, one for each frame
- Stations agree upon time intervals
  - one can “pip” as time keeper, like a clock
- Users transmit only at beginning of slot
- Need one frame time to be empty, *G* generated
  - for one slot, **`Pr[0] = e`**$^{-G}$
- Throughput

$$S = Ge^{-G}$$

Slotted ALOHA
Offered Load vs. Throughput



- Max at $G = 1$, $S = 1/e$, only about 0.368 (37%)
  - This is ***not*** Ethernet!

Last Thoughts on Slotted ALOHA

- Best (G = 1):
  - 37% empty
  - 37% success
  - 26% collisions
- Raising G, reduces empties but increases collisions exponentially
- Expected transmissions (includes original)

$$E = e^{G}$$

  - G=0, then 1 transmission; G=1 then 2.X trans.
- Small increase in load, big decrease in perf

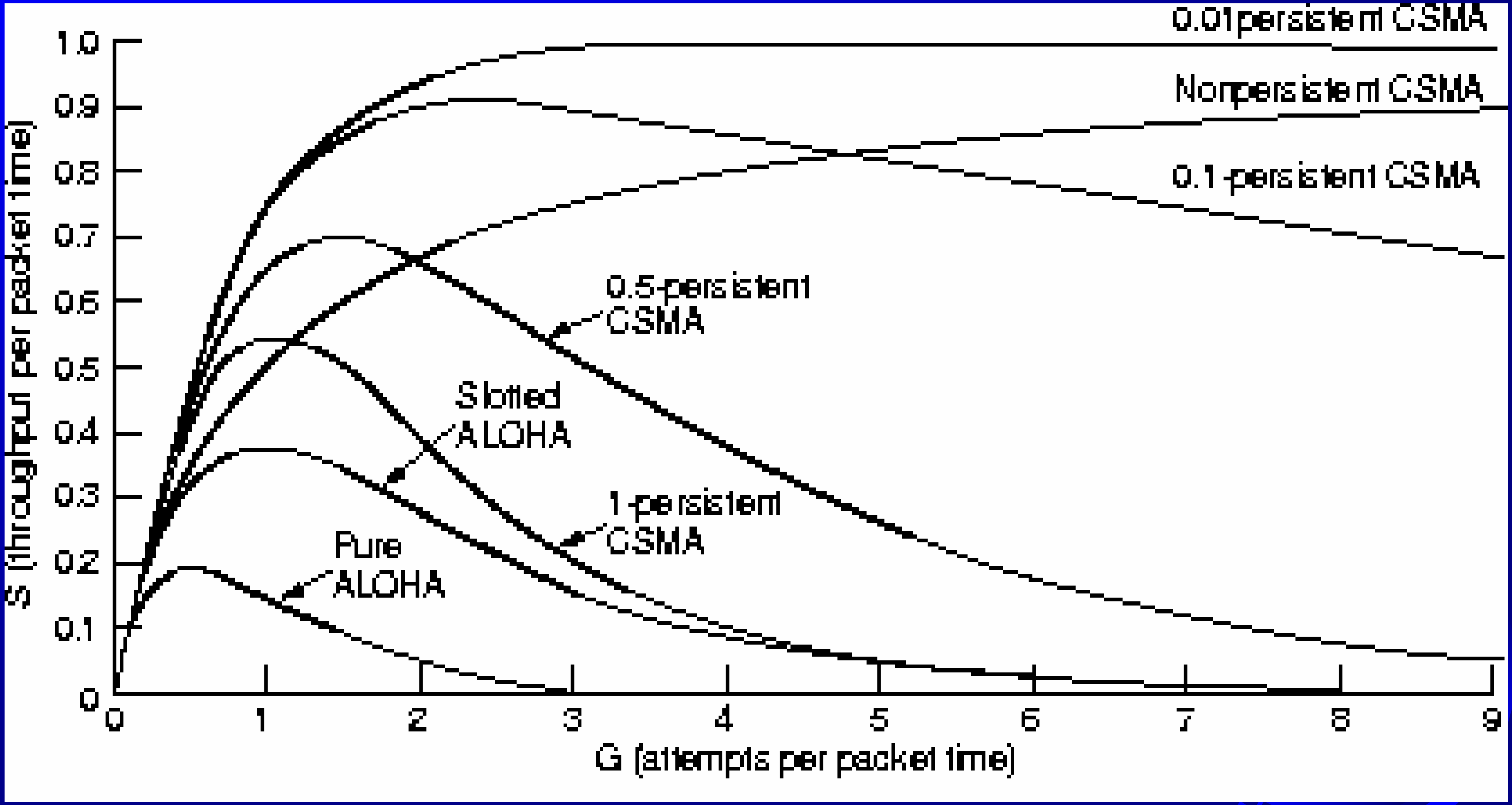
Carrier Sense Multiple Access - CSMA Protocols

- Sending without paying attention is obviously limiting
- In LANs, can detect what others are doing
- Stations listen for a transmission
  - *carrier sense protocols*

Persistent and Nonpersistent

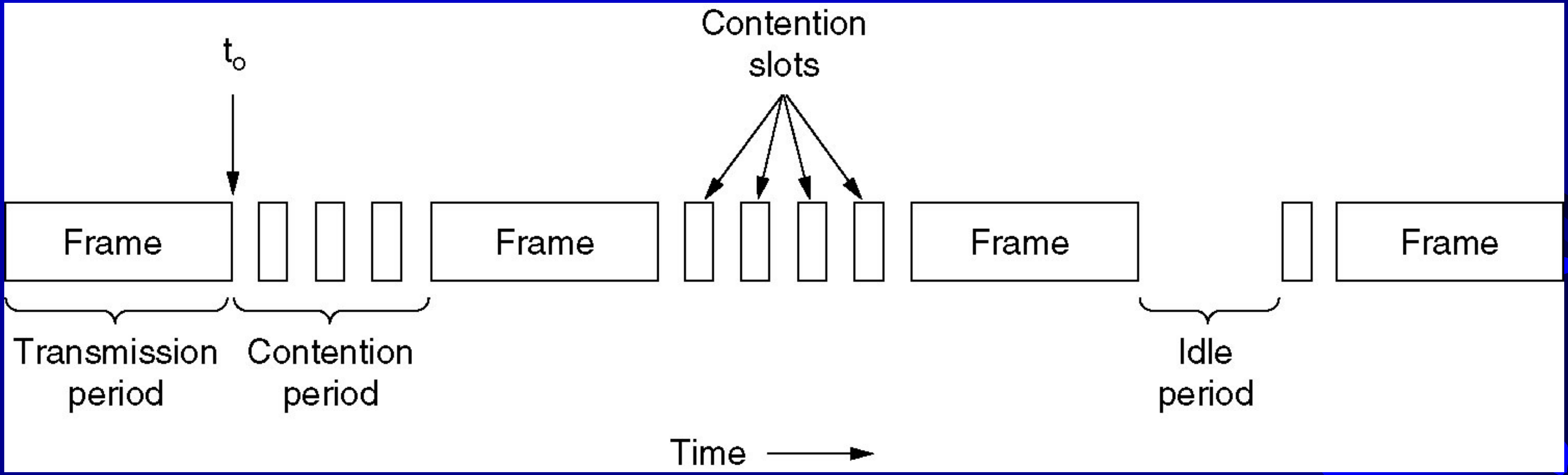
- *1-persistent* CSMA
  – detect, send at first chance
  – wait if another sending
  – longer delay, more collisions
- *non-persistent* CSMA
  – if empty, send
  – if not, less greedy, waits random time then repeats
  – fewer collisions, longer delay
- *p-persistent* CSMA
  – if empty, sends with probability p
  – defers with probability $q = 1 - p$

Carrier Sense Multiple Access



CSMA with Collision Detection

- If detect collision, stop transmitting
  - frame will be garbled anyway
- CSMA with Collision Detection (CD)



CSMA/CD Closing Comments

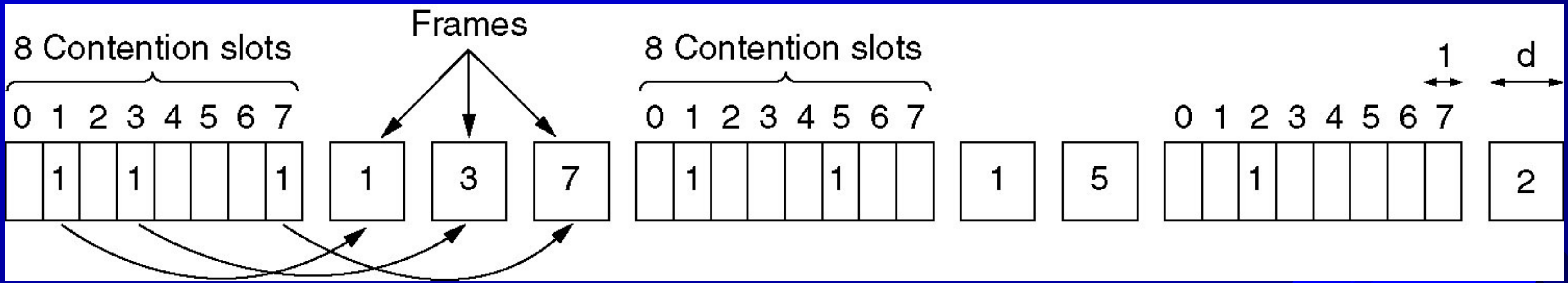
- How long until realize a collision? Time to travel length of cable? Why not?
- Propogation τ, need 2τ to “seize” the line
- Model 2τ slot as slotted ALOHA
- 1-km cable has $\tau \approx 5\ \mu\text{sec}$
- Collision detection *analog*
  - special hardware encoding so can detect
- Does not guarantee reliable delivery
- Basis IEEE 802.3 (*Ethernet*)

Collision-Free Protocols

- Collisions still occur in CSMA/CD
- More so when "wire" long (large τ)
- Short frames, too, since contention period becomes more significant
- Want *collision free protocols*
- Need to assume *N* stations have numbers 0 to (N-1) wired in

Bit-Map Protocol

- Have N contention slots
- Station N puts 1 in slot N-1, else 0
  - ex: station 0 wants to send, 1 in 0th slot



Bit-Map Protocol Performance

- *N* contention slots, so *N* bits overhead /frame
- *d* data bits
- Station wants to transmit, waits
  - Low numbered: avg *N*/2 slots (current) + N for next
  - High numbered: avg. N/2
  - Combined avg. delay: *N*
- Efficiency under low load (1 sending):
  - d /(N+d)
  - average delay: N/2
- High load (N sending): can prorate overhead
  - d/(d+1)
  - average delay: N(d+1)/2

Where the Heck Were We?

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  - contention
  - collision-free
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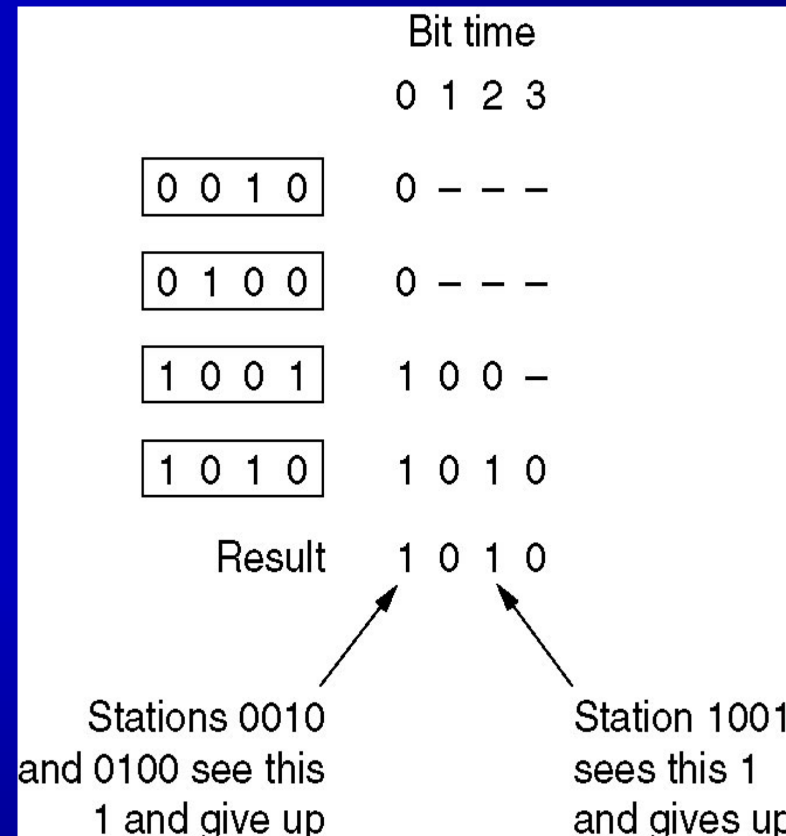
- Misc (brief)
  - High-Speed LAN

Binary Countdown

- Instead of 1 bit per station, encode in binary
  - transmit address in binary
- Assume all stations see inserted bits instantaneously
- When multiple transmit, OR together
- When a station sees high-order 1 bit where it has a zero, it gives up



Binary Countdown Performance

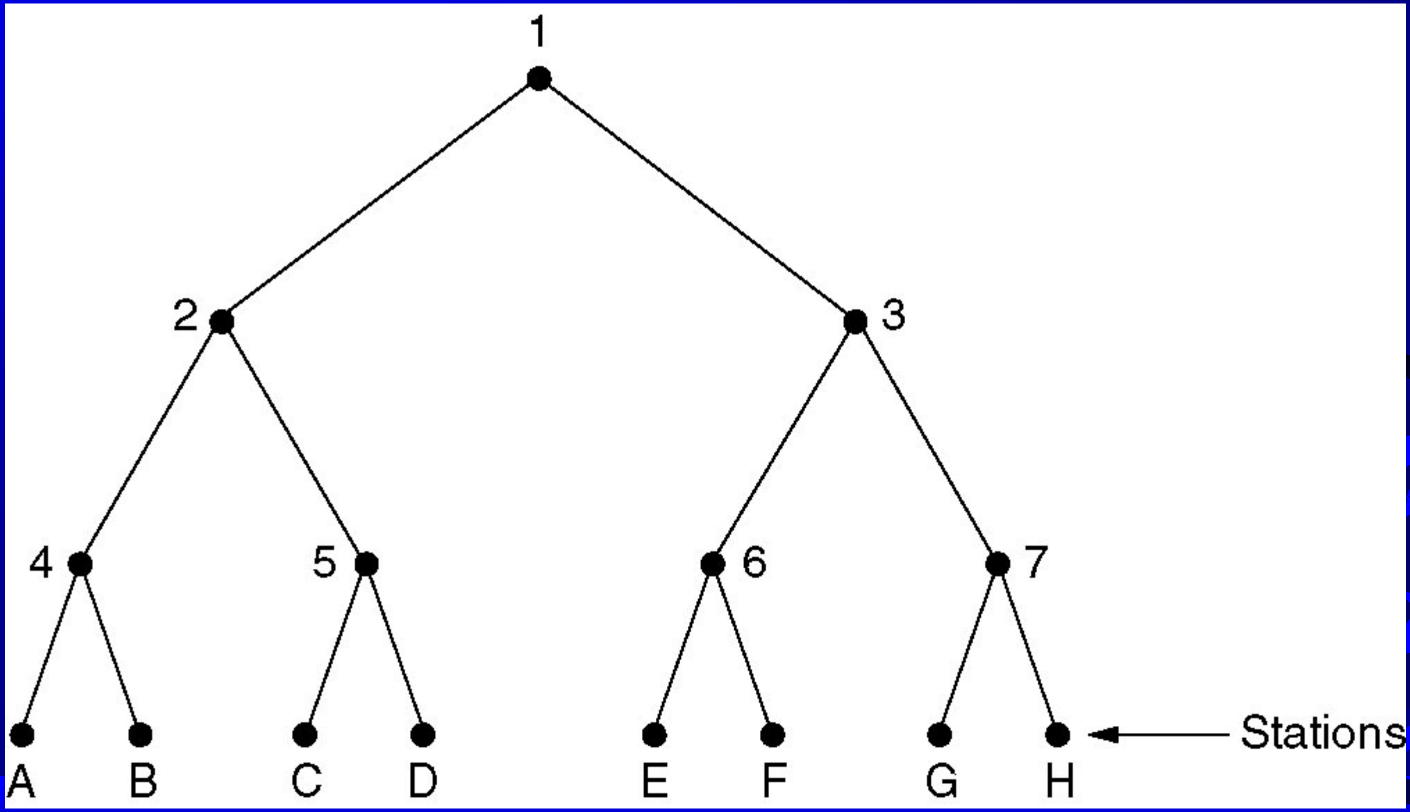
- Efficiency: $d/(d+\log_2 N)$
- Sender address as first field and *no* overhead
- Fairness/Unfairness?
  – Mok and Ward (1979): Use virtual station numbers
  – **`C,H,D,A,G,B,E,F`** are **`7,6,5,4,3,2,1,0`**
  – **`D`** sends: **`C,H,A,G,B,E,F,D`**

Contention vs. Collision-Free

- Contention better under low load. *Why*?
- Collision-free better under high load. *Why*?
- Hybrid: *limited contention protocols*
- Instead of symmetric contention, asymmetric
- Divide into groups. Each group contents for same slot.
- How to assign to slots?
  - 1 per slot, then collision free (Binary Countdown)
  - All in same slot, then contention (CSMA/CD)

Adaptive Tree Walk Protocol

- U.S. Army test for Syphilis
  - Test group, if negative all ok
  - If positive, then split in two and re-test

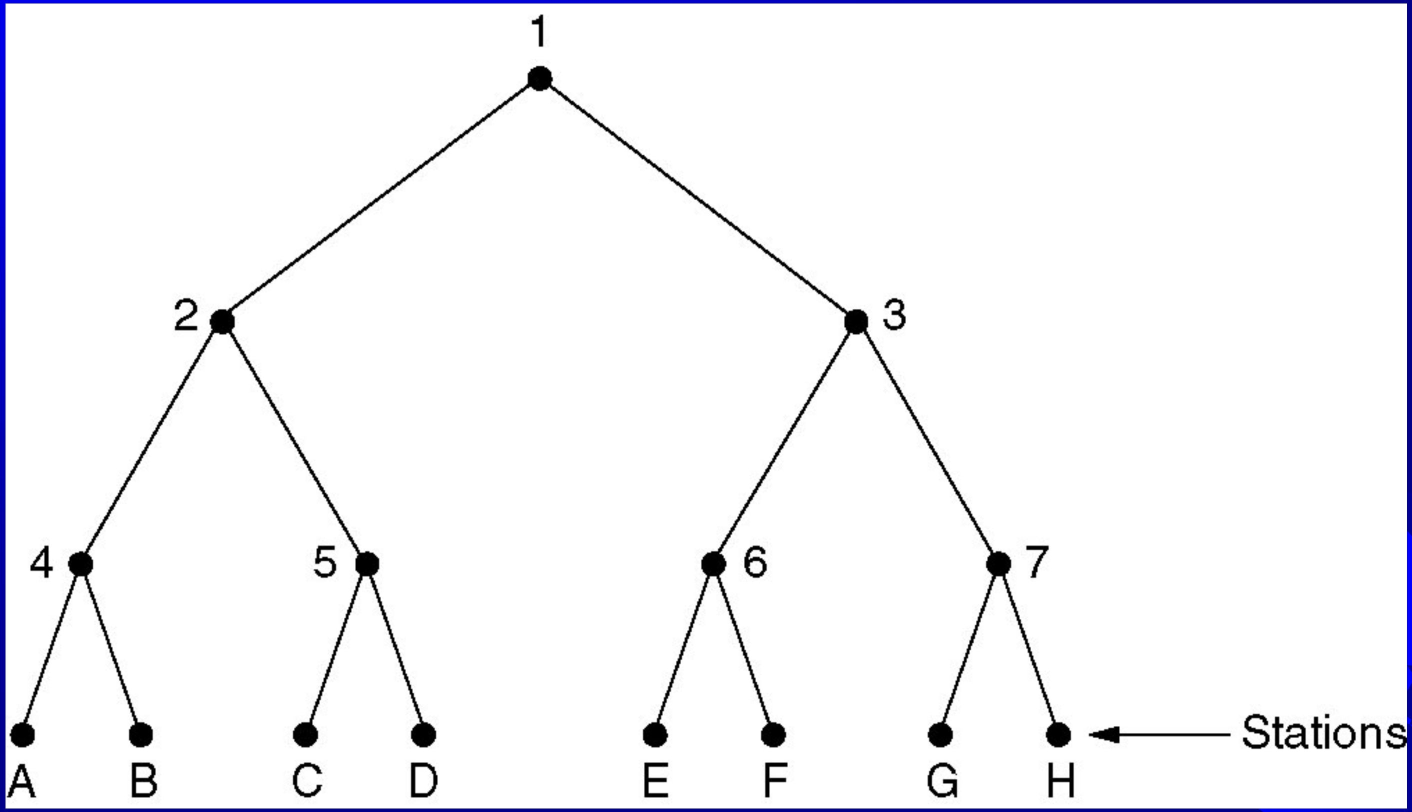


Adaptive Tree Walk Protocol

- Where to begin searching (entire army?)
  - if heavily loaded, not at the top since there will always be a collision
- Number levels 0, 1, 2 …
- At level i, $1/2^i$ stations below it
  - ex: level 0, all stations below it, 1 has 1/2 below…
- If q stations want to transmit, then $q/2^i$ below
- Want number below to be 1 (no collisions)
  - $q/2^i = 1$, $i = \log_2 q$

Other Improvements

- If collision at 1, 2 idle, do we need to search 3?



Heck, Here We Are

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Ethernet

- Ethernet Cabling
- Manchester Encoding
- The Ethernet MAC Sublayer Protocol
- The Binary Exponential Backoff Algorithm
- Ethernet Performance
- Switched Ethernet
- Fast Ethernet
- Gigabit Ethernet
- IEEE 802.2: Logical Link Control

Ethernet (IEEE 802.3)

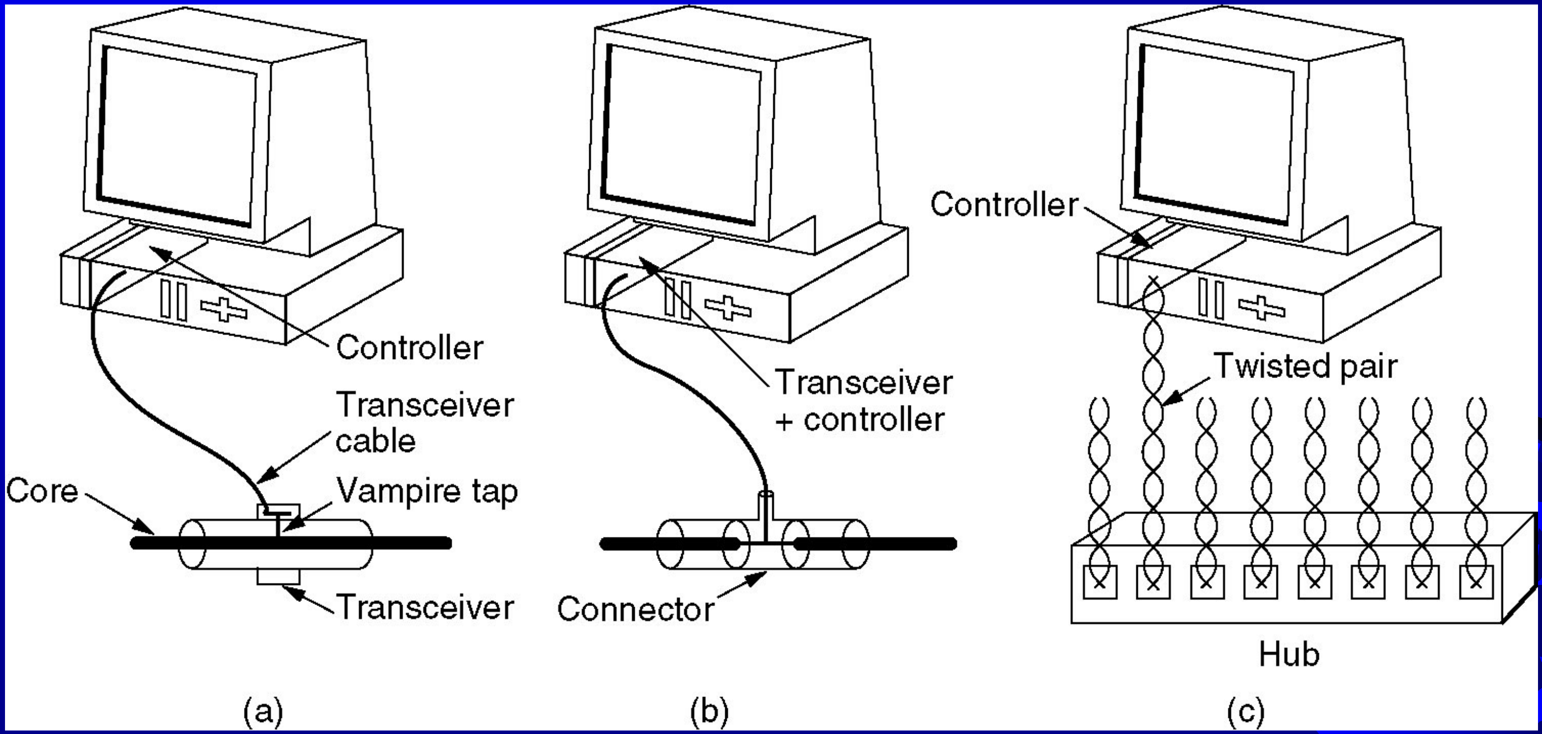
- Began as ALOHA, added carrier sense
- Xerox PARC built 3 Mbps version for workstations and called it *Ethernet*
  - old scientist dudes thought waves propagated through substance called “ether”, so a geeky joke
- Xerox, DEC and Intel made 10 Mbps standard
  - 1 to 10 Mbps
  - not “Ethernet”, but close enough

Ethernet Cabling

- 10Base5 - “Thick Ethernet”
  - 10 Mbps, 500 meters
- 10Base2 - “Thin Ethernet” or “Thinnet”
  - BNC connectors, or T-junctions
  - Easier and more reliable than 10Base5
  - But only 200 meters and 30 stations per segment
- All on one line, then difficult to find break
  - *domain reflectometry*
  - *hubs*
- 10BaseT (Twisted pair)
- 10BaseF (Fiber)

Kinds of Ethernet Cabling

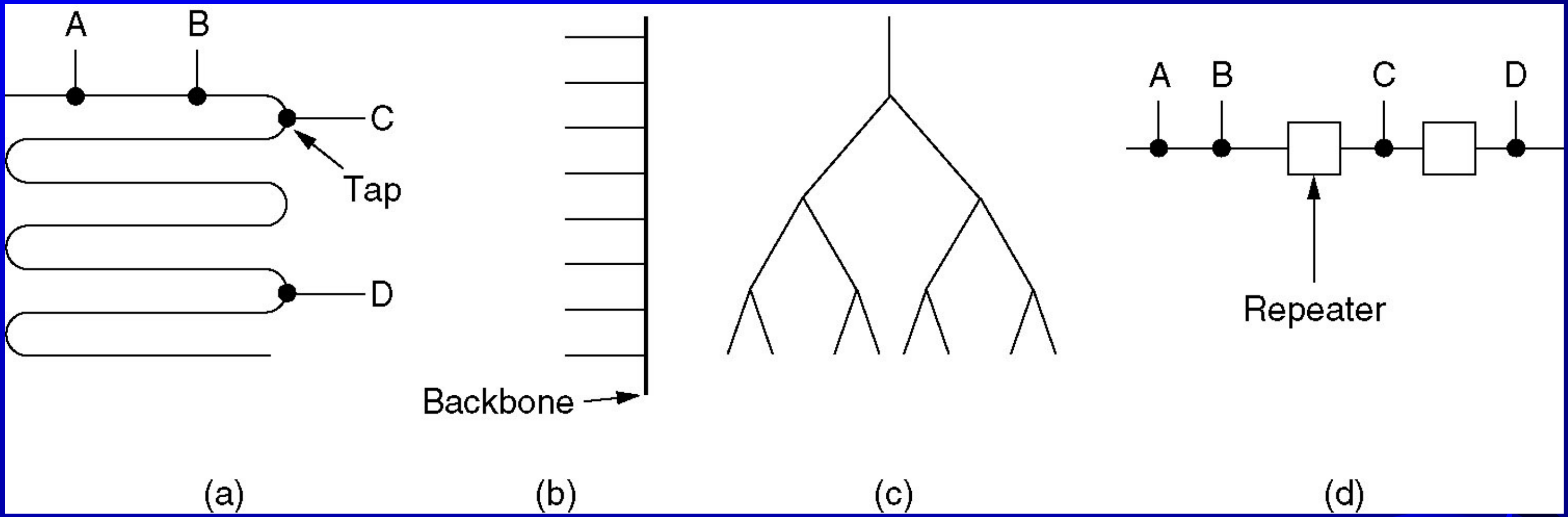
Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings



Three kinds of Ethernet cabling.

(a) 10Base5, (b) 10Base2, (c) 10Base-T.

Cable Topologies

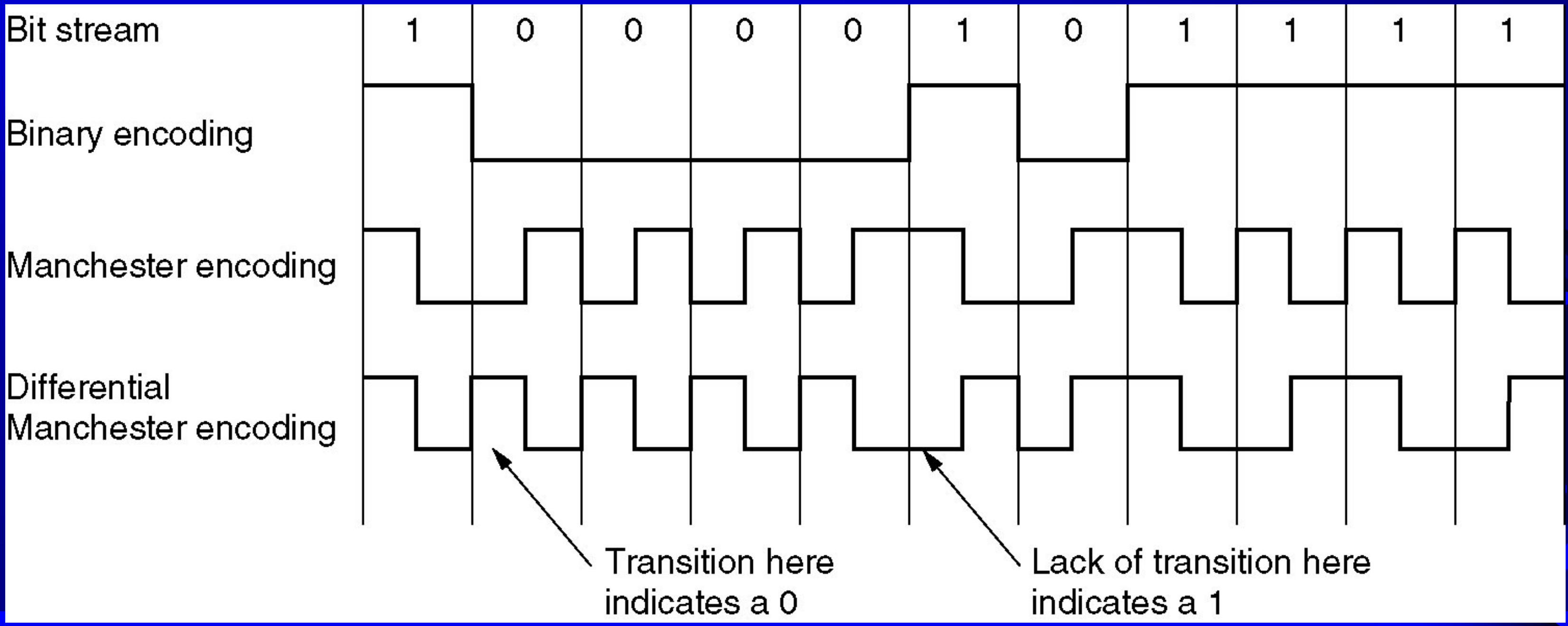


Cable topologies. (a) Linear, (b) Spine, (c) Tree, (d) Segmented.

Repeaters?

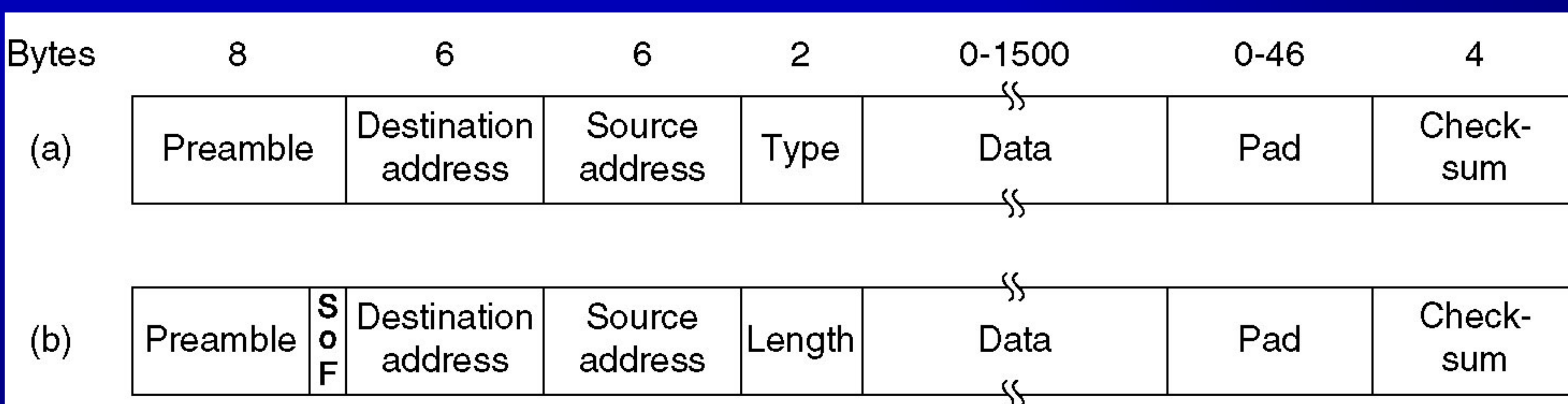
Encoding

- 0 volts for 0 and 5 volts for 1 can be misleading
- Want start, middle and end of each bit without reference to external clock
  - *Manchester Encoding*
  - *Differential Manchester Encoding* uses changes



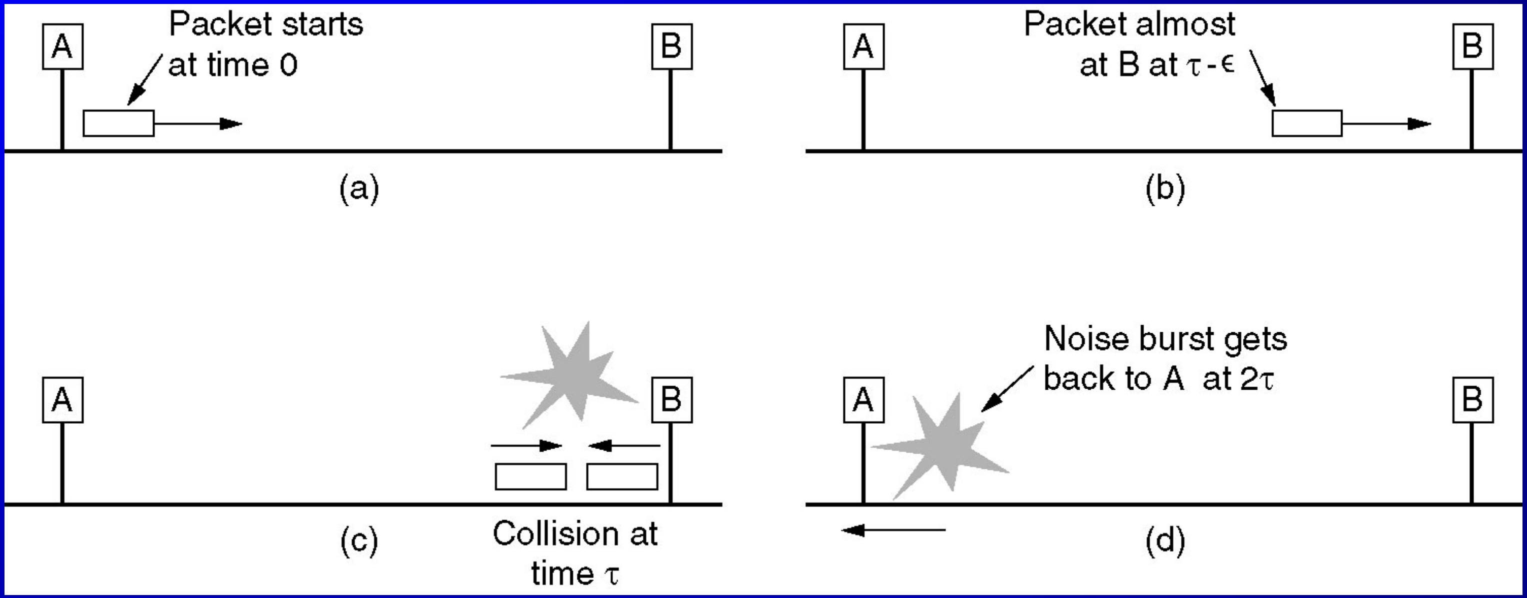
Ethernet Protocol

- Preamble: 10101010 to allow clock synch
- Start of Frame: 10101011
- Source and Destination addr: 2 or 6 bytes
  - 1 for high order bit means "multicast"
  - all 1's means "broadcast"
- Length: data length, 46 to 1500
  - very small frames, problems, so pad to 46



Frame formats. (a) DIX Ethernet, (b) IEEE 802.3.

Short, Short Frames



- Frame must be > 2τ
- Otherwise, how to tell collision from short frame?

Collision Action?

- Each slot of length 2τ
- If collision, then wait 0 or 1 slot
- If another collision, then wait 0, 1, 2, 3 slots
- If another collision, then wait 0 to 2^3-1 slots
- After *i* collisions, wait 0 to 2^i-1 slots
  - called *binary exponential backoff*
  - why is this a good idea? Consider other options
- After 10 collisions, wait 0 to 1023 slots
- After 16 collisions, throw in the towel

Now,Where Were We?

- Introduction
- Multiple Access Protocols
- IEEE 802 Standard
  - Ethernet (802.3) ←
- Wireless LAN Protocols
- Misc