Introduction to LAN/WAN

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 $\lambda$ frames/sec
- Frames mean $1/\mu$ bits

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

TDM is the same

$$T = \frac{1}{\mu C - \lambda}$$
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 ALOHA
  - 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: $G = 0.5$, $P_0 = 0.5$ so $S = 0.25$
  - Note: $P_0$ is probability of successful transmission
Frame Collisions

Collides with the start of the shaded frame

Collides with the end of the shaded frame

$t_0$, $t_0 + t$, $t_0 + 2t$, $t_0 + 3t$

Vulnerable

Time
Analysis of Pure ALOHA (cont.)

- Probability $k$ frames generated per frame time
  \[ G^k e^{-G} \]
  \[ \Pr[k] = \frac{G^k e^{-G}}{k!} \]
  \[ \Pr[0] = e^{-G} \]

- Need two frame times empty, $2G$ generated
  - for two slots, \[ \Pr[0] = e^{-2G} \]

- Using $S = G\Pr_0$, 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)

  - 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

\textit{1-persistent CSMA}
- detect, send at first chance
- wait if another sending
- longer delay, more collisions

\textit{non-persistent CSMA}
- if empty, send
- if not, less greedy, waits random time then repeats
- fewer collisions, longer delay

\textit{p-persistent CSMA}
- if empty, sends with probability \( p \)
- defers with probability \( q = 1 - p \)
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 $\tau$, need $2\tau$ to “seize” the line
- Model $2\tau$ slot as slotted ALOHA
- 1-km cable has $\tau \approx 5 \mu$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 $\tau$)
- 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?

- Introduction
- Multiple Access Protocols
  - contention
  - collision-free
- Ethernet
- Wireless LAN Protocols
- Bridges
- 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: \( \frac{d}{d + \log_2 N} \)
- 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: \( C, H, A, G, B, E, F, D \)
Contestation 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)
Three kinds of Ethernet cabling.
(a) 10Base5, (b) 10Base2, (c) 10Base-T.

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

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

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<th>Bit stream</th>
<th>1</th>
<th>0</th>
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<td>Differential Manchester encoding</td>
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Transition here indicates a 0
Lack of transition here indicates a 1
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

- Packet starts at time 0

- Frame must be $> 2\tau$

- Otherwise, how to tell collision from short frame?

- Packet almost at B at $\tau - \epsilon$

- Noise burst gets back to A at $2\tau$
Collision Action?

- Each slot of length $2\tau$
- 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