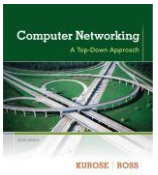
Chapter 5
Link Layer



Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

A note on the use of these ppt slides:
We're making these slides freely available to all (faculty, students, readers). They're in PowerPoint form so you see the animations; and can add, modify, and delete slides (including this one) and slide content to suit your needs. They obviously represent a lot of work on our part. In return for use, we only ask the following:

- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
- If you post any slides on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

Thanks and enjoy! JFK/KWR

The course notes are adapted for Bucknell's CSCI 363
Xiannong Meng
Spring 2016

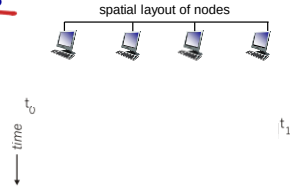
CSMA (carrier sense multiple access)

CSMA: listen before transmit:
if channel sensed idle: transmit entire frame
- if channel sensed busy, defer transmission

- human analogy: don't interrupt others!

CSMA collisions

- collisions *can* still occur: propagation delay means two nodes may not hear each other's transmission
- collision: entire packet transmission time wasted
  - distance & propagation delay play role in in determining collision probability

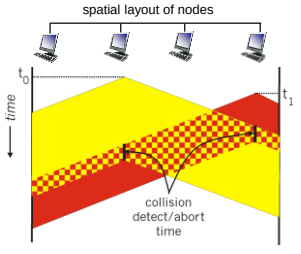


CSMA/CD (collision detection)

CSMA/CD: carrier sensing, deferral as in CSMA
- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: received signal strength overwhelmed by local transmission strength
- human analogy: the polite conversationalist

CSMA/CD (collision detection)



Ethernet CSMA/CD algorithm

1. NIC receives datagram from network layer, creates frame
2. If NIC senses channel idle, starts frame transmission. If NIC senses channel busy, waits until channel idle, then transmits.
3. If NIC transmits entire frame without detecting another transmission, NIC is done with frame !
4. If NIC detects another transmission while transmitting, aborts and sends jam signal
5. After aborting, NIC enters *binary (exponential) backoff*:
   - after *m*th collision, NIC chooses *K* at random from $\{0, 1, 2, \ldots, 2^m-1\}$. NIC waits $K \cdot 512$ bit times, returns to Step 2
   - longer backoff interval if more collisions

CSMA/CD efficiency (1)

- t_{prop} = max prop delay between 2 nodes in LAN
- t_{trans} = time to transmit max-size frame

$$efficiency = \frac{1}{1+5t_{prop}/t_{trans}}$$

- efficiency goes to 1
  - as t_{prop} goes to 0, or
  - as t_{trans} goes to infinity
- better performance than ALOHA: and simple, cheap, decentralized!

Schwartz (1987), page 445 says e = 1/(1+6.44 a), derivation from probability.

CSMA/CD efficiency (2)

- Performance of the CSMA/CD can be determined by one single number!
- Let a = t_{pro} / t_{trans}

$$efficiency = \frac{1}{1+5a}$$

By Simon Lam of UT Austin (1979):
http://www.cs.utexas.edu/ftp/techreports/tr79-113.pdf

- Some examples:
  - a = 0.1, efficiency = 0.667
  - a = 0.01, efficiency = 0.952
- How to make *a* small, thus higher efficiency?
  - Shorter cables → smaller t_{pro}
  - Slower(!!!) network → large t_{rans}
  - Larger packets → large t_{rans}

"Taking turns" MAC protocols

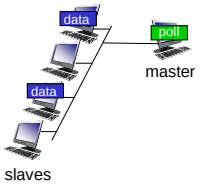
channel partitioning MAC protocols:
- share channel *efficiently* and *fairly* at high load
- inefficient at low load: delay in channel access, 1/N bandwidth allocated even if only 1 active node!

random access MAC protocols
- efficient at low load: single node can fully utilize channel
- high load: collision overhead

"taking turns" protocols
look for best of both worlds!

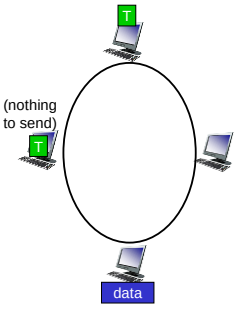
"Taking turns" MAC protocols

polling:
- master node "invites" slave nodes to transmit in turn
- typically used with "dumb" slave devices
- concerns:
  - polling overhead
  - latency
  - single point of failure (master)

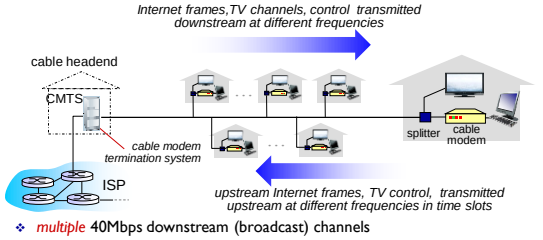


"Taking turns" MAC protocols

token passing:
- control *token* passed from one node to next sequentially.
- token message
- concerns:
  - token overhead
  - latency
  - single point of failure (token)

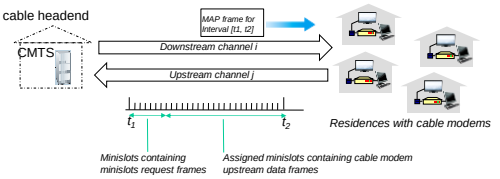


Cable access network



- *multiple* 40Mbps downstream (broadcast) channels
  - single CMTS transmits into channels
- *multiple* 30 Mbps upstream channels
  - *multiple access: all* users contend for certain upstream channel time slots (request slots), once granted, requesting data can be sent.
- Combination of random access (request slots), time division (request data slots), and frequency division (separate channels for signal and data)!

Cable access network



DOCSIS: data over cable service interface spec

- FDM over upstream, downstream frequency channels
- TDM upstream: some slots assigned, some have contention
  - downstream MAP frame: assigns upstream slots
  - request for upstream slots (and data) transmitted random access (binary backoff) in selected slots

Summary of MAC protocols

- *channel partitioning,* by time, frequency or code
  - Time Division, Frequency Division
- *random access* (dynamic),
  - ALOHA, S-ALOHA, CSMA, CSMA/CD
  - carrier sensing: easy in some technologies (wire), hard in others (wireless)
  - CSMA/CD used in Ethernet
  - CSMA/CA used in 802.11
- *taking turns*
  - polling from central site, token passing
  - bluetooth, FDDI, token ring
- *hybrid DOCSIS combines random access, TDMA, and FDMA*