

Link Layer Multiple Access Protocols

Kai Shen

1/28/2013 CSC 257/457 - Spring 2013 1

Assignment #1

- Web proxy server
 - users want to anonymize themselves from the Web server
 - a corporation wants to monitor or restrict employees' Web surfing
 - cache data to reduce the amount of global traffic
- HTTP protocol
- Multithreading
- Persistent connection

1/28/2013 CSC 257/457 - Spring 2013 2

Recap of Last Class

Link layer

- handle data transfer between neighboring network elements

Link layer services:

- **Encoding**
 - encode binary data into electromagnetic signals
- **Framing**
 - encapsulate data into frame, adding header, trailer
- **Error detection and correction**
 - receiver identifies and corrects bit error(s)

application

transport

network

link

physical

1/28/2013 CSC 257/457 - Spring 2013 3

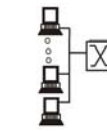
Multiple Access Links

Two types of "links":


- point-to-point duplex and shared wire or medium

Multiple access link:


- single shared broadcast channel
- two or more simultaneous transmissions by nodes => interference
 - only one node can send successfully at a time




shared wire
(e.g. Ethernet)



shared wireless
(e.g. Wavelan)



satellite



Blah, blah, blah
ZZZZZZZZZZ

cocktail party

1/28/2013 CSC 257/457 - Spring 2013 4

Multiple Access Protocol

Multiple access protocol:

- distributed algorithm that determines how nodes share channel, i.e., determine when nodes can transmit
- communication about channel sharing must use channel itself!

Objectives:

- Performance – for a multiple access channel of rate R bps:
 - when one node wants to transmit, it can send at rate R
 - when M nodes want to transmit, each can send at average rate R/M
- Robustness
 - no special node to coordinate transmissions
 - no synchronized clocks

1/28/2013

CSC 257/457 - Spring 2013

5

Types of Multiple Access Protocols

Three broad classes:

- Channel partitioning**
 - divide channel into smaller "pieces" (time slots, frequency, code)
 - allocate piece to node for exclusive use
- Random access**
 - channel not divided, allow collisions
 - "recover" from collisions
- Centrally controlled/coordinated**
 - centrally coordinate shared access to avoid collisions

1/28/2013

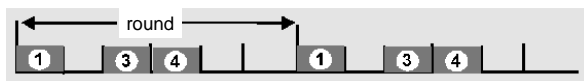
CSC 257/457 - Spring 2013

6

Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle



1/28/2013

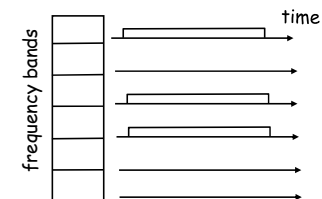
CSC 257/457 - Spring 2013

7

Channel Partitioning MAC protocols: FDMA

FDMA: frequency division multiple access

- channel spectrum divided into frequency bands
- each station assigned fixed frequency band
- unused transmission time in frequency bands go idle
- example: 6-station LAN, 1,3,4 have pkt, freq. bands 2,5,6 idle



1/28/2013

CSC 257/457 - Spring 2013

8

Channel Partitioning MAC protocols: C (code) DMA

- use coding to partition channel
- each user has its unique code
 - encoded signal: (original data) X (code)
 - decoding: (encoded signal) X (code)
- inner product
 - all codes consist of 1, -1 bits
 - any bit sequence multiplying itself becomes 1

1/28/2013 CSC 257/457 - Spring 2013 9

CDMA: Two-sender Interference

- allow multiple users to transmit simultaneously (if code1 X code2 = 0).
- combined signal is "data1 X code1 + data2 X code2"

Noise resistance.

1/28/2013 10

How good are Channel Partitioning Protocols?

- Performance – for a multiple access channel of rate R bps:
 - when all M nodes want to transmit, each can send at rate R/M
 - when one node wants to transmit, it can send at rate R/M **Inefficient!**
- Robustness
 - no special node to coordinate transmissions
 - synchronized clocks for all but FDMA

1/28/2013 CSC 257/457 - Spring 2013 11

Random Access Protocols

- When node has data to send
 - transmit at full channel data rate R.
 - no *a priori* coordination among nodes
- Two or more transmitting nodes -> "collision"
- Random access protocol specifies:
 - how to detect collisions
 - how to recover from collisions (e.g., via delayed retransmissions)

1/28/2013 CSC 257/457 - Spring 2013 12

Slotted ALOHA (Abramson)

Assumptions

- all frames same size
- time is divided into equal size slots, time to transmit 1 frame
- nodes start to transmit frames only at beginning of slots (nodes are synchronized!)
- if 2 or more nodes transmit in slot, all nodes detect collision

Operation

- when node obtains fresh frame, it transmits in next slot
- no collision, node can send new frame in next slot
- if collision, node retransmits frame in each subsequent slot with probability p until success
- why not retransmit right away?

1/28/2013

CSC 257/457 - Spring 2013

13

Slotted ALOHA

Pros

- single active node can continuously transmit at full rate of channel

Cons

- wasting slots (collisions, idle slots)
- require nodes to be synchronized

1/28/2013

CSC 257/457 - Spring 2013

14

Slotted Aloha Efficiency

Efficiency is the long-run fraction of successful slots (assuming each node always has frames to send)

- Suppose N nodes with many frames to send, each transmits in slot with probability p
- prob that one particular node has success in a slot
 - $p(1-p)^{N-1}$
- prob that some node has a success
 - $Np(1-p)^{N-1}$

- For max efficiency with N nodes, find p^* that maximizes $Np(1-p)^{N-1}$
 - find p^* for $N=1$ and $N=2$?
 - find p^* for any N ?
- For many nodes, take limit of $Np(1-p)^{N-1}$ as N goes to infinity, gives $1/e = .37$
 - successful channel transmissions at 37% of the time!

1/28/2013

CSC 257/457 - Spring 2013

15

Pure (unslotted) ALOHA

- Unslotted Aloha: no synchronization
- When frame first arrives, transmit immediately
- Collision probability increases:
 - frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$

1/28/2013

CSC 257/457 - Spring 2013

16

Pure Aloha Efficiency

$P(\text{success by given node}) = P(\text{node transmits}) \times$
 $P(\text{no other node transmits in } [t_0-1, t_0]) \times$
 $P(\text{no other node transmits in } [t_0, t_0+1])$
 $= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1}$
 $= p \cdot (1-p)^{2(N-1)}$

choosing optimum p and then letting $n \rightarrow \infty$...
 $= 1/(2e) = .18$

Half as efficient as slotted Aloha!

1/28/2013 CSC 257/457 - Spring 2013 17

CSMA (Carrier Sense Multiple Access)

CSMA: listen before transmit:

- If channel sensed idle: transmit entire frame
- If channel sensed busy: defer transmission

Human analogy: listen before speaking!

1/28/2013 CSC 257/457 - Spring 2013 18

CSMA Collisions

collisions can still occur:
 propagation delay means two nodes may not hear each other's transmission

chance of collision:
 depends on distance & propagation speed

collision:
 entire packet transmission time wasted

1/28/2013 CSC 257/457 - Spring 2013 19

CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, same as in CSMA

- collisions detected within short time
- colliding transmissions aborted, reducing channel wastage

- Human analogy: if too many people are talking so no one can hear clearly, stop talking.

1/28/2013 CSC 257/457 - Spring 2013 20

How good are Random Access Protocols?

- Performance – for a multiple access channel of rate R bps:
 - when one node wants to transmit, it can send at full rate R .
 - when all M nodes want to transmit, each can send at average rate less than R/M . **Not ideal!**
- Robustness (decentralization):
 - no special node to coordinate transmissions
 - no synchronized clocks except for slotted ALOHA

1/28/2013

CSC 257/457 - Spring 2013

21

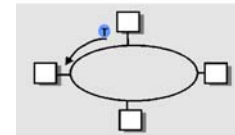
“Centrally Controlled” MAC protocols

Polling:

- control node “invites” regular nodes to transmit in turn
- concerns:
 - single point of failure (control node)
 - polling overhead (bandwidth & latency)

Token passing:

- control **token** passed from one node to next sequentially.
- transmit only when holding the token
- concerns:
 - single point of failure (token)
 - token overhead (bandwidth & latency)



1/28/2013

CSC 257/457 - Spring 2013

22

Summary of MAC protocols

- Channel partitioning
 - Time Division, Frequency Division, Code Division
- Random access
 - ALOHA, S-ALOHA, CSMA, CSMA/CD
- Centrally controlled
 - polling from a central site
 - controlled by a token
- Comparison on performance and robustness

1/28/2013

CSC 257/457 - Spring 2013

23

Disclaimer

- Parts of the lecture slides contain original work of James Kurose, Larry Peterson, and Keith Ross. The slides are intended for the sole purpose of instruction of computer networks at the University of Rochester. All copyrighted materials belong to their original owner(s).

1/28/2013

CSC 257/457 - Spring 2013

24