Announcements

- Project 1 assigned.
- Due date: 04.22.
- Suggested list for project 2 posted.
- Project proposal due 04.17.
- Proposal should contain project selection, short description of approach, experimental methodology, expected results, timeline.
- Brief tutorial on GloMoSim: 04.10.

Today

- MAC (cont’d).
  - Contention-based MACs.
  - 802.11

MAC approaches

- Contention.
- Round-robin.
- Token-based.
- Reservation.
Contention
- No control.
- Stations try to acquire the medium.
- Distributed in nature.
- Perform well for bursty traffic.
- Can get very inefficient under heavy load.
- Example: Aloha family.

NOTE: round-robin and contention are the most common.

Contention-Based MACs
- Carrier sensing (listen before transmit): Stations sense the channel before transmitting a data packet (e.g., CSMA).
- Listen before and during transmission: Stations listen before transmitting and stop if noise is heard while transmitting (CSMA/CD).
- Collision avoidance (floor acquisition): Stations carry out a handshake to determine which one can send a data packet (e.g., MACA, FAMA, IEEE802.11, RIMA).
- Collision resolution: Stations determine which one should try again after a collision.

The ALOHA Protocol
- Developed @ U of Hawaii in early 70’s.
- Packet radio networks.
- “Free for all”: whenever station has a frame to send, it does so.
  - Station listens for maximum RTT for an ACK.
  - If no ACK, re-sends frame for a number of times and then gives up.
  - Receivers check FCS and destination address to ACK.

Collisions
- Invalid frames may be caused by channel noise or
- Because other station(s) transmitted at the same time: collision.
- Collision happens even when the last bit of a frame overlaps with the first bit of the next frame.
ALOHA’s Performance 1

\[ S = G e^{-G} \]

where \( S \) is the throughput (rate of successful transmissions) and \( G \) is the offered load.

\[ S = S_{\text{max}} = \frac{1}{2e} = 0.184 \text{ for } G = 0.5. \]

Slotted Aloha

- Doubles performance of ALOHA.
- Frames can only be transmitted at beginning of slot: "discrete" ALOHA.
- Vulnerable period is halved.
- \( S = G e^{-G} \).
- \( S = S_{\text{max}} = \frac{1}{e} = 0.368 \text{ for } G = 1. \)

Carrier Sense Multiple Access

- The capacity of ALOHA or slotted ALOHA is limited by the large vulnerability period of a packet.
- By listening before transmitting, stations try to reduce the vulnerability period to one propagation delay.
- This is the basis of CSMA (Kleinrock and Tobagi, UCLA, 1975).
CSMA

- Station that wants to transmit first listens to check if another transmission is in progress (carrier sense).
- If medium is in use, station waits; else, it transmits.
- Collisions can still occur.
- Transmitter waits for ACK; if no ACKs, retransmits.

CSMA (cont’d)

- Effective when average transmission time >> propagation time.
- Collisions can occur only when 2 or more stations begin transmitting within short time.
- If station transmits and no collisions during the time leading edge of frame propagates to farthest station, then NO collisions.

CSMA Protocol

- After detecting carrier, a station can persist trying to transmit after the channel is idle again.
- 1-persistent CSMA (IEEE 802.3)
  - If medium idle, transmit; if medium busy, wait until idle; then transmit with p=1.
  - If collision, wait random period and start again.
- P-persistent: when channel idle detected, transmits packet in the first slot with p.
- Non-persistent CSMA: if medium idle, transmit; otherwise wait a random time before re-trying.
CSMA/CD
- CSMA with collision detection.
- Problem: when frames collide, medium is unusable for duration of both (damaged) frames.
- For long frames (when compared to propagation time), considerable waste.
- What if station listens while transmitting?

CSMA/CD Protocol
1. If medium idle, transmit; otherwise 2.
2. If medium busy, wait until idle, then transmit with p=1.
3. If collision detected, transmit brief jamming signal and abort transmission.
4. After aborting, wait random time, try again.

Collision Avoidance
- Collision avoidance emulates collision detection in networks where stations are half duplex.
- This is the case of wireless: full-duplex radios are $$$!
- First protocol was proposed by Kleinrock and Tobagi (Split Reservation Multiple Access).
- Many protocols have been proposed since then: MACA, MACAW, FAMA, RIMA.
- The objective of collision avoidance protocols is to eliminate the hidden-terminal problem of CSMA.
802.11
- IEEE standard for wireless LANs.
- Specifies the physical- and MAC layers.

802.11 Access Methods
- Distributed access control mechanism based on CSMA/CA: Distributed Coordination Function (DCF).
- Centralized control: Point Coordination Function (PCF) uses polling.

802.1.1 CSMA/CA (DCF)
- Station that wants to Xmit, senses medium.
- If medium busy, defers.
- Else, if medium free for DIFS (distributed inter-frame space), Xmits.
- Receiver checks CRC and sends ACK if correct Xmission.
- If sender does not receive ACK, reXmits.

Virtual Carrier Sensing
- Complements CS and CA.
- Tries to reduce collision probability due to hidden terminals.
- Use of short control packets: RTS/CTS,
  - Reserve medium for duration of DATA+ACK.
  - Stations receiving either use this info combined with physical CS when they need to Xmit.
  - CTS protects receiver against terminals hidden from Xmitter.
  - RTS protects Xmitter from stations hidden from receiver.
Virtual Carrier Sensing (cont’d)

- Short packets mean low overhead.
- Collisions are recognized faster.

802.11 CSMA/CA (DCF)

- RTS: source, destination, data+ACK duration.
- CTS: data+ACK duration.
- DATA and ACK.

<table>
<thead>
<tr>
<th>Source</th>
<th>RTS</th>
<th>Data</th>
<th>ACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destination</td>
<td>RTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Defer (RTS)</td>
<td></td>
<td>Defer (CTS)</td>
</tr>
</tbody>
</table>

D(IFS): new transmission
S(IFS): switching modes

802.11 Exponential Backoff

- If station tries to transmit and medium is busy, increase maximum backoff time exponentially.
- Exponential backoff executed:
  - First attempt at transmitting frame and medium busy.
  - After retransmission attempt and medium busy.
- Backoff time decremented after successful RTS-CTS exchange.

802.11 Architecture

- Originally based on cellular concept.
Joining a BSS

- Entering cell, powering up, etc.
- Need synchronization information.
  - Gets it from AP (in cellular mode) or other station (in ad hoc mode).
  - Passive versus active scanning.
    - AP sends out beacons
    - Station tries to locate AP with probes.

Synchronization and Power Saving

- Performed by AP.
- Synchronization: AP periodically transmits beacon frames.
  - Contain AP’s clock.
  - Stations correct their clocks accordingly.
- Power saving: AP buffers frames for stations in sleep mode.
  - Until stations wake up or request frames.
  - Beacon frames contain information on which stations have buffered frames.

802.11 Frame Types

- Data.
- Control: RTS, CTS, ACK.
- Management: Beacon (transmitted like data frames but not forwarded to upper layers).

802.11 Frame Format

- 802.11 Frame
  - Preamble
  - Header
  - MAC Data
  - CRC
  - Frame Check Sequence (FCS)
  - Sequence Number
  - Duration
  - Addressing
  - Frame Body
  - CRC
802.11 Ad Hoc Mode

- No infrastructure, i.e., no APs.
- Beacon generation and synchronization performed by stations.
- Other AP functions (e.g., power savings) not provided.