MAC Sublayer

Abusayeed Saifullah

CS 5600 Computer Networks

These slides are adapted from Kurose and Ross
Multiple access links

two types of “links”:

- **point-to-point**
  - PPP for dial-up access
  - point-to-point link between Ethernet switch, host

- **broadcast (shared wire or medium)**
  - old-fashioned Ethernet
  - 802.11 wireless LAN
  - 802.15.4

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)

shared RF (satellite)

humans at a cocktail party (shared air, acoustical)
Interference

- shared broadcast channel
- **Interference**: Reception at a node A from a desired sender B can be interfered by an unexpected transmission
- **Collision**: if node receives two or more signals at the same time

- $a$ and $c$: conflicting for half-duplex radio
- $b$ and $e$: conflicting for half-duplex radio
- $d$ and $e$: conflicting
- $c$ and $d$: can interfere each other

Need to avoid/minimize interference and collision.

But nodes do not have global knowledge. They only have local information.
Handling interference and collision

- Schedule conflicting links in different times
  - Let not the fighting guys see each other

- How?
  - Needs a judicious assignment of times to all contenders
Handling interference and collision

- Schedule conflicting links on different channels
  - Make the fighting guys happy with their own resource

**Issues**
- Limited # of channels
- Channel assignment
Handling interference and collision

- Transmission power control
  - If the audience can hear your lower voice, no need to shout.
Handling interference and collision

- Check before you transmit: collision avoidance
- Collision detection
- Be random on what you cannot predict
- Recovery
  - Capture effect
  - Retransmission
  - Retry
  - Detour
media access control (MAC) protocol

- determines how nodes share the medium
  - allocates resources: time, channel
- handles interference/collision
  - avoidance
  - detection
  - recovery
- communication about channel sharing must use channel itself!
  - no out-of-band channel for coordination
An ideal MAC protocol

given: broadcast channel of rate R bps

desiderata:
1. when one node wants to transmit, it can send at rate R.
2. when M nodes want to transmit, each can send at average rate R/M
3. fully decentralized:
   • no special node to coordinate transmissions
   • no synchronization of clocks, slots
4. no collision, no interference
5. simple
MAC protocols: taxonomy

three broad classes:

- **resource partitioning**
  - divide resource into smaller “pieces” (time slots, frequency, code)
  - allocate piece to node for exclusive use

- **random access**
  - resource not divided, allow collisions
  - “recover” from collisions

- **“taking turns”**
  - nodes take turns, but nodes with more to send can take longer turns
Resource partitioning MAC protocols

- **time division multiple access (TDMA):** partition the time

- **frequency division multiple access (FDMA):** partition the channel spectrum
TDMA protocol

- 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
TDMA

❖ **Advantage:** collision free

❖ **Disadvantage:**
  - Unused slot at a node goes useless while another node could use it

Station 3 has another packet but cannot send it until the next turn comes while stations 2, 5, 6 are wasting slots.

❖ TDMA requires time synchronization

❖ Why is time synchronization a headache
  - Extra communication
  - Synchronization error. Why?
  - Does not scale
TDMA

When is TDMA good?

When is TDMA bad?
TDMA

When is TDMA good?
- Huge traffic
- Predictable traffic
- Smaller network (in hop-count and # of nodes)

When is TDMA bad?
- Light traffic
- Random/unpredictable traffic
- Too large a network (in hop-count and # of nodes)
FDMA (freq. 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, frequency bands 2,5,6 idle
Random access protocols

- when node has packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes

- two or more transmitting nodes $\rightarrow$ “collision”,

- random access MAC protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)

- examples of random access MAC protocols:
  - slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA
**Slotted ALOHA**

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

**operation:**
- when node obtains fresh frame, transmits in next slot
  - *if no collision:* node can send new frame in next slot
  - *if collision:* node retransmits frame in each subsequent slot with prob. p until success
Pros:
- Single active node can continuously transmit at full rate of channel
- Highly decentralized:
  - Only slots in nodes need to be in sync
  - Local decision to transmit
- Simple

Cons:
- Collisions, wasting slots
- Idle slots
- Nodes may be able to detect collision in less than time to transmit packet
- Clock synchronization

Slotted ALOHA

Node 1
1 1 1

Node 2
2 2 2

Node 3
3 3 3

Key:
- C = Collision slot
- E = Empty slot
- S = Successful slot
**Slotted ALOHA: efficiency**

**efficiency**: long-run fraction of successful slots (many nodes, all with many frames to send)

- *suppose*: $N$ nodes with many frames to send, each transmits in slot with probability $p$
- prob that given node has success in a slot = $p(1-p)^{N-1}$
- prob that *any* node has a success = $Np(1-p)^{N-1}$

- max efficiency: find $p^*$ that maximizes $Np(1-p)^{N-1}$
- for many nodes, take limit of $Np^*(1-p^*)^{N-1}$ as $N$ goes to infinity, gives: 
  \[ \text{max efficiency} = \frac{1}{e} = .37 \]

*at best*: channel used for useful transmissions 37% of time!