Contention Protocols (Cont'd)

- CSMA (Carrier Sense Multiple Access)
  - Improvement: Start transmission only if no transmission is ongoing
- CSMA/CD (CSMA with Collision Detection)
  - Improvement: Stop ongoing transmission if a collision is detected
- CSMA/CA (CSMA with Collision Avoidance)
  - Improvement: Wait a random time and try again when carrier is quiet. If still quiet, then transmit
- CSMA/CA with ACK
- CSMA/CA with RTS/CTS

The Family of CSMA Schemes

- In 1-persistent CSMA and in non-persistent CSMA, if a channel is idle upon access, the station transmits its packets.
- If a channel is busy, the 1-persistent scheme waits until the channel is released and then transmits its packets.
- If a channel is busy, the non-persistent scheme sets up a backoff counter that determines when the station will revisit the channel again.
- The p-persistent CSMA scheme is slotted. If a current slot is idle, the station transmits with probability p, otherwise, it defers with probability p until the next slot, where the same algorithm is performed again.

Family of CSMA Protocols

- Nonpersistent CSMA Protocol:

  Step 1: If the medium is idle, transmit immediately

  Step 2: If the medium is busy, wait a random amount of time and repeat **Step 1**

  - Random backoff reduces probability of collisions
  - Waste idle time if the backoff time is too long

- 1-persistent CSMA Protocol:

  Step 1: If the medium is idle, transmit immediately

  Step 2: If the medium is busy, continue to listen until medium becomes idle, and then transmit immediately

  - There will always be a collision if two nodes want to retransmit (usually you stop transmission attempts after few tries)

Family of CSMA Protocols

- p-persistent CSMA Protocol:

  Step 1: If the medium is idle, transmit with probability p, and delay for worst case propagation delay for one packet with probability (1-p)

  Step 2: If the medium is busy, continue to listen until medium becomes idle, then go to **Step 1**

  Step 3: If transmission is delayed by one time slot, continue with **Step 1**

- A good tradeoff between non-persistent and 1-persistent CSMA

CSMA/CD (CSMA with Collision Detection)

- In CSMA, if 2 terminals begin sending packet at the same time, each will transmit its complete packet (although collision is taking place).
- Wasting medium for an entire packet time.
- CSMA/CD

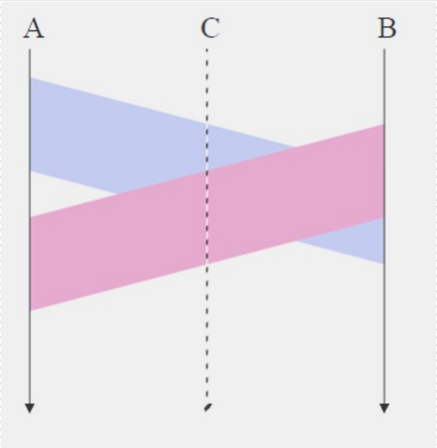
  Step 1: If the medium is idle, transmit

  Step 2: If the medium is busy, continue to listen until the channel is idle then transmit

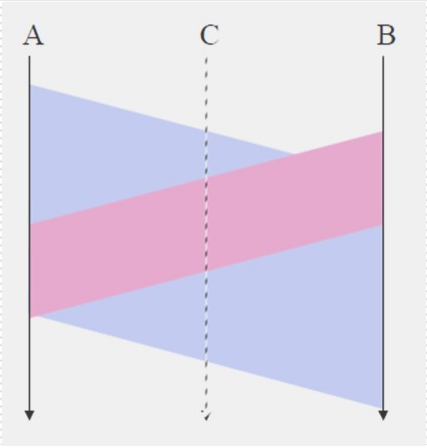
  Step 3: If a collision is detected during transmission, cease transmitting

  Step 4: Wait a random amount of time and repeats the same algorithm

CSMA/CD Minimum Frame Size



Collision visible at C, but not at A

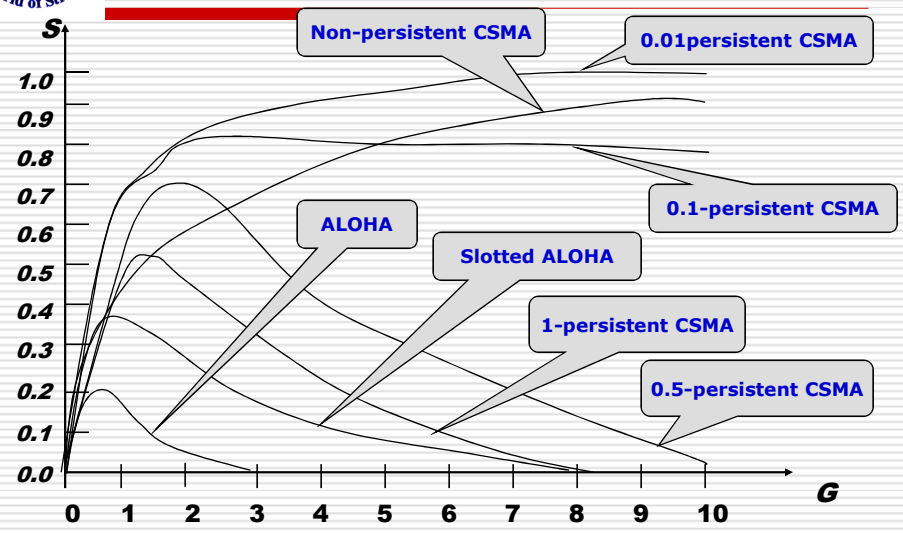


Collision visible at C and at A

Exponential Backoff Algorithm

- $k = min\,(10, AttemptNb)$
- $r = rand(0, 2^k - 1) \cdot slotTime$
- Note: $k = 1$ is the first retransmission
- $AttemptNb$ is the number of attempted retransmissions
- E.g.,
  - 1st retransmission attempt: $k = 1, r = 0, 1\ [slotTime]$
  - 2nd retransmission attempt: $k = 1, r = 0, 1, 2, 3\ [slotTime]$

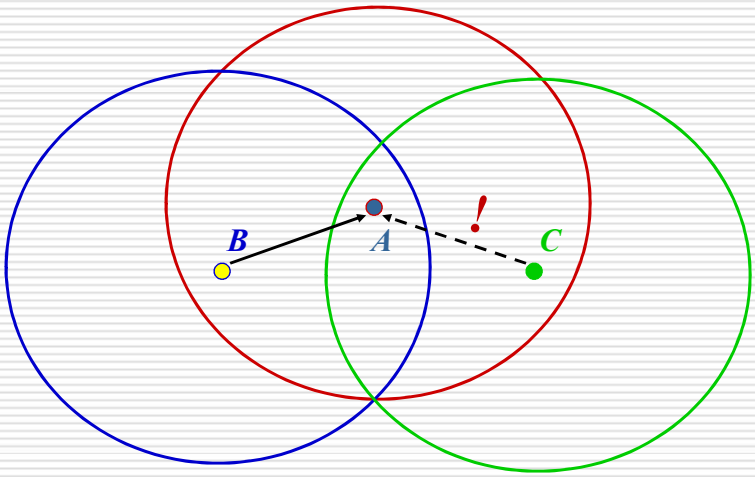
Comparison of the Traditional MAC Schemes



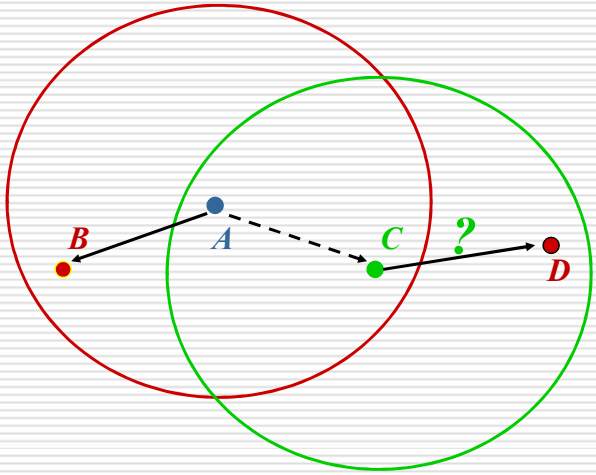
CSMA vs. RTS/CTS-based access ...

- For operating "properly," the CSMA protocol requires that all the stations can hear each other (a fully connected network).
- This is not the case for wireless networks.
- The problem is that collisions occur at the receiver, while the CSMA-based schemes observe the channel at the transmitter!
- The above observation results in two access problems:
  - the hidden terminal problem, and
  - the exposed terminal problem

The hidden-terminal problem



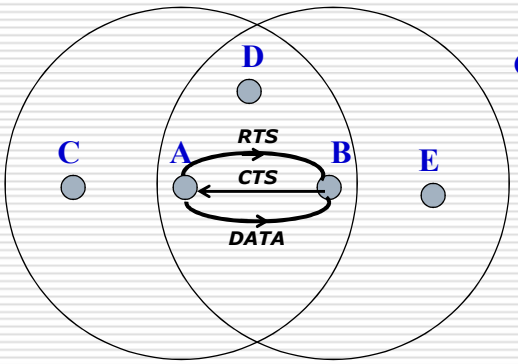
The exposed-terminal problem

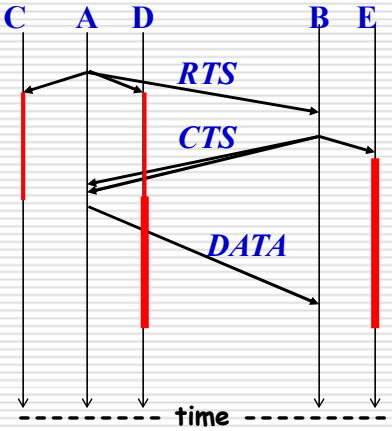


The RTS/CTS - dialogue

- An alternative to Carrier Sensing was proposed in which the coordination among the stations is performed by two basic control messages: Request-To-Send and Clear-To-Send.
- These messages "reserve" spatially and temporarily the channel for the about-to-communicate nodes.

The RTS/CTS - dialogue





= Access to channel is disabled

MACA - Multiple Access with Collision Avoidance

(P. Karn, "MACA - A New Channel Access Method for Packet Radio," 9th Computer Networking Conference, 1990)

- MACA is based on the RTS/CTS dialogue. It does not rely on the carrier-sensing feature.
- There are two (short) control packets: the Request-to-Send (RTS) and the Clear-to-Send (CTS)
- To send, the source transmits RTS to the destination. The destination responds with CTS.
- If the source did not receive the CTS by timeout, it retries.

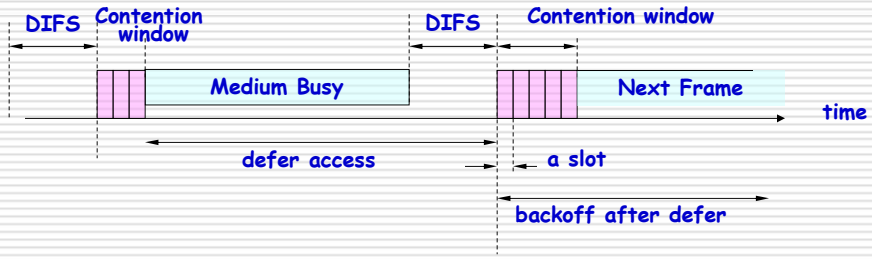
MACA (con't)

- Upon receipt of the CTS, the source sends its data packet(s).
- Any node, other than the destination, that hears a RTS, defers any transmission for long enough for the destination to respond with the CTS.
- Any node, other than the source, that hears the CTS response, defers any transmission for long enough for the source to transmit the data packet.
- MACA relieves (but not eliminates) the hidden- and the exposed-terminal problems.

CSMA/CA (CSMA with Collision Avoidance)

- All terminals listen to the same medium.
- Terminal ready to transmit senses the medium.
- If medium is busy it waits until the end of current transmission.
- It again waits for an additional predetermined time period DIFS (Distributed Inter Frame Space) (=34 usec for 802.11a)
- Then picks up a random number of slots (the initial value of backoff counter) within a contention window to wait before transmitting its frame.
- If there are transmissions by other terminals during this time period (backoff time), the terminal freezes its counter.
- It resumes count down after other terminals finish transmission + DIFS. The terminal can start its transmission when the counter reaches to zero.

CSMA/CA Explained



DIFS – Distributed Inter Frame Spacing

Note: contention window doubles with every deferred attempt to transmit, until it reaches maximum; after a successful transmission, the contention window is reset.

CSMA/CA with RTS/CTS (cont'd)