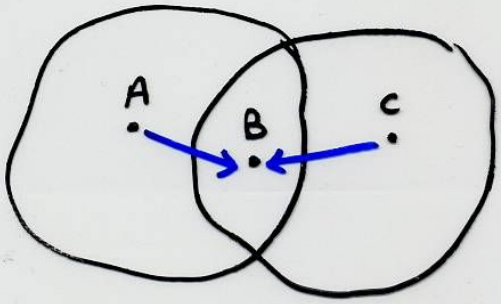
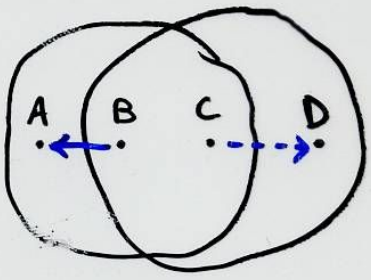
- CSMA with collision avoidance (CSMA/CA)

  - In wireless networks,
    - in general not all nodes are within receiving range of each other
    - received signal energies are very low so it is difficult to achieve reliable collision detection while transmitting
  - Hidden node problem → collisions



  - A & C both send to B, causing a collision that both A & C are unaware of
  - A & C are hidden nodes w.r.t. each other
  - Exposed node problem → ↓ spatial reuse



  - C can hear B's transmission
  - since A is out of C's range & D is out of B's range, it is a waste for C to defer to B

- RTS/CTS mechanism

- data transfer is preceded by a handshake between source & destination
- before transmitting a data packet, the source transmits a short RTS (request to send) packet
- if the destination receives the RTS successfully (i.e. it is not in the range of another transmission), it replies with a CTS (clear to send) packet, indicating that the source can begin data transmission
- if the source does not receive the CTS within a specified timeout period, it waits for a random backoff period before trying again
- by including the data packet length in the RTS & CTS frames, nodes that decode these packets can estimate when the transmission will end & defer their transmissions accordingly
- if transmission ranges are symmetrical, in principle all collisions except those between RTSs can be avoided (less time wasted since RTS packets are small)

- a node that is hidden from the source node but within range of the destination node hears the CTS & is thus informed of the imminent packet transmission (however, if it is unable to decode the CTS, which can be the case if it is within interference but not transmission range, it does not know how long to defer)
- the RTS/CTS mechanism does not solve the exposed node problem — any node within range of the source node is exposed & unable to receive CTS packets

- 802.11 wireless LAN MAC protocol

- RTS/CTS exchange is used only to reserve the channel for a long data frame (since RTS/CTS frames introduce delay & consume channel capacity)
- each node can set an RTS threshold; RTS/CTS exchange is used only for data frames longer than the threshold
- when a node has a new frame to send, it senses the channel
  - if the channel is idle, the node waits a short period of time, the Distributed Inter-Frame Space (DIFS), & then transmits

- if the channel is busy, the node chooses a random backoff value $k\delta$, where δ is a constant slot duration, & k is an integer drawn uniformly at random from a contention window $[0, CW_{min}-1]$
- for each slot in which the channel is idle, the backoff counter k is decremented; if the channel is busy, the counter is frozen
- when the counter reaches zero, which happens during an idle slot, the node transmits

- for every failed transmission (an RTS not followed by a CTS, or a data frame not followed by an ACK), the node reenters the backoff phase, with the backoff counter k chosen randomly from a larger interval
- after a successful data frame transmission, the node reenters the backoff phase, with the backoff counter k chosen randomly from the original contention window $[0, CW_{min}-1]$
- eg 802.11a: $\delta = 9\,\mu s$, DIFS $= 25\,\mu s$, $CW_{min} = 32$