- One solution: Multiple Access with Collision Avoidance (MACA)
- Clears radio neighborhoods in advance of transmission; avoids both the hidden terminal and exposed terminal problems
- Protocol design:
    - Two nodes: X and Y. X has a packet of data to send to Y.
    - X sends a control message to Y called Request-to-Send (RTS). This lets Y know that a packet is coming.
    - When Y is ready to receive the packet, Y sends a control message to X called Clear-to-Send (CTS).
    - X sends the data packet to Y.
    - Y confirms that it received the packet by sending a control message to X called Acknowledgment (ACK).
- Main rule of operation:
    - If a node observes a CTS message destined for a node other than itself, it remains silent until it observes the corresponding ACK message.
- Solves the hidden terminal problem:
    - Say Z is in radio range of Y, but not in radio range of X. Then Z is a "hidden terminal".
    - In MACA, Z does not see X's RTS, but Z does see Y's CTS. Thus, Z remains silent until Y transmits ACK to X.
- Solves the exposed terminal problem:
    - Say nodes are arranged W, X, Y, Z in a line, where neighbors on the line are in radio range of each other (i.e. X in range of W, W and Y in range of X, X and Z in range of Y, Y in range of Z.)
    - Then Z is an "exposed terminal" for transmissions from X to W.
    - Say X sends RTS to W. Y observes the RTS.
    - W sends CTS to X. Since Y is not in radio range of W, Y does not observe W's CTS.

    - Since Y observed X's RTS but not CTS, Y concludes that its transmissions will not interfere with X's.
- This protocol is used in IEEE 802.11 (WiFi)

(At this point please do a couple of simple examples.)

- A couple of problems with MACA

- First problem: Suppose round-trip times between nodes are much larger than the data packet length.
- Example: Wireless signals to and from a satellite in geostationary orbit:
    - Altitude of geostationary satellite: roughly 36,000 km; speed of light = 3×10^8 m/s; ground to satellite time = d/c = 0.12 seconds
    - So the shortest possible duration between CTS and ACK is: 0.12s + (t_{DATA}+0.12s) + (t_{ACK} + 0.12s), where t_{DATA} and t_{ACK} are the durations of the data and ACK packets, respectively.
    - At high data rates t_{DATA} and t_{ACK} are << 0.36s, so this this is inefficient.
- A good alternative in this case: ALOHA, where there is no access control and nodes transmit whenever they please. Packets are simply discarded and retransmitted in the event of collisions.

- Second problem: What if not everyone agrees to use MACA? Need a protocol that is robust to interference (i.e., if a collision occurs, the system must handle that situation)
- This situation occurs for point-to-point wireless links in the ISM band, e.g., Bluetooth, which connects consumer electronic devices to a central hub
- Frequency hopping spread spectrum (FHSS): divide time and the available bandwidth into equal-sized chunks.

- In each time segment, choose one of the frequency segments at random from all the possibilities, and only transmit in that segment
- The chance that two devices will choose to transmit in the same segment is very low, so interference is limited
- Also, the chances that anybody else is using a particular band is very low, so they will also cause little interference even if they are not using the same FHSS protocol
- Need a way to recover from the (relatively few) corrupted packets, e.g., retransmission or error-control coding
- FHSS is in fact used in Blueto