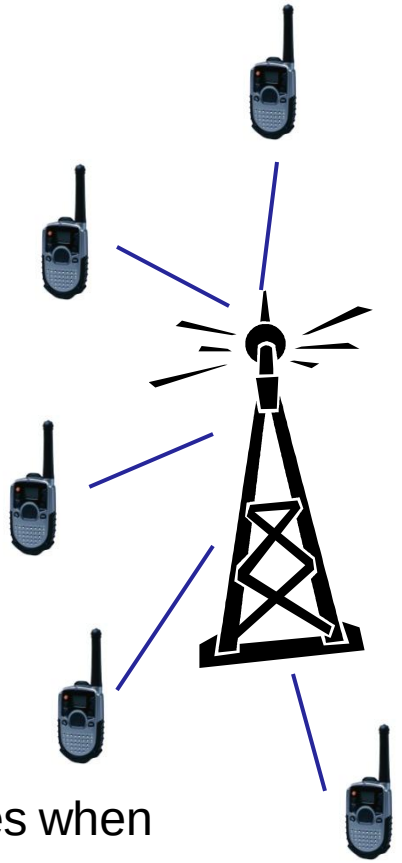
Distributed Medium Access Control

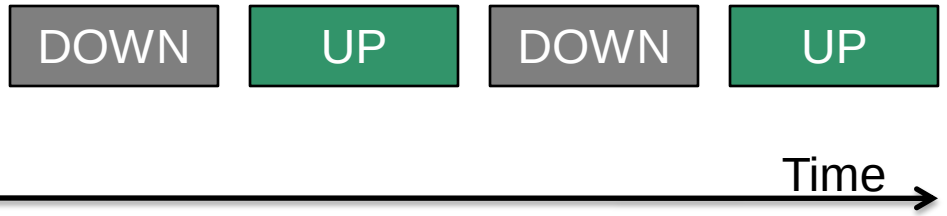
Medium Access Control

- Problem:
  - Single shared communications resource
    - RF spectrum, electrical cable, etc
  - Multiple users
  - How do you decide who communicates when?
- Two approaches:
  - Infrastructure
    - Central controller handles all packet scheduling
  - Distributed
    - Distributed algorithm for determining who communicates when

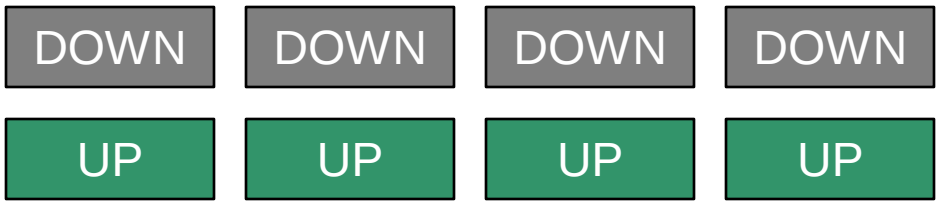


Infrastructure Duplexing

- Each device needs to both send and receive data -> two channels
- Uplink: channel from user to network
- Downlink: channel from network to user
- Time-Division Duplex (TDD)
  - Alternate sending and receiving in same channel
  - Half duplex
  - Example: voice communications



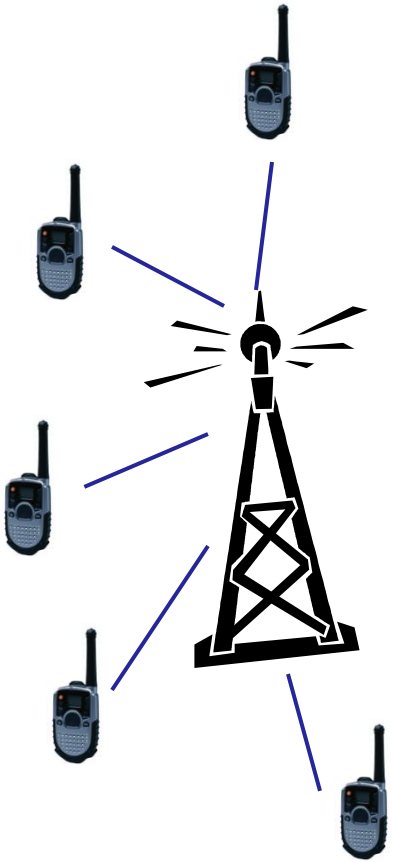
- Frequency-Division Duplex (FDD)
  - Transmit on one frequency, receive on another
  - Full duplex
  - Example: cell phones



- Space-Division Duplex
  - Isolated mediums for transmission
  - Full duplex
  - Example: fiber optic cable, modern Ethernet cable

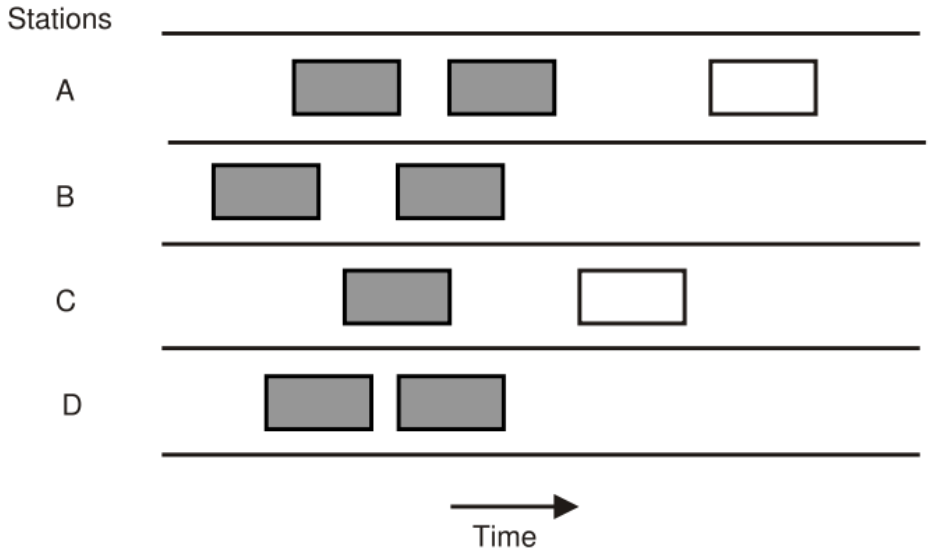
Multiple Access

- Infrastructure:
  - Control access to uplink
- Distributed:
  - Control access to shared medium
  - Distributed networks are half-duplex
  - No central controller -> users = network



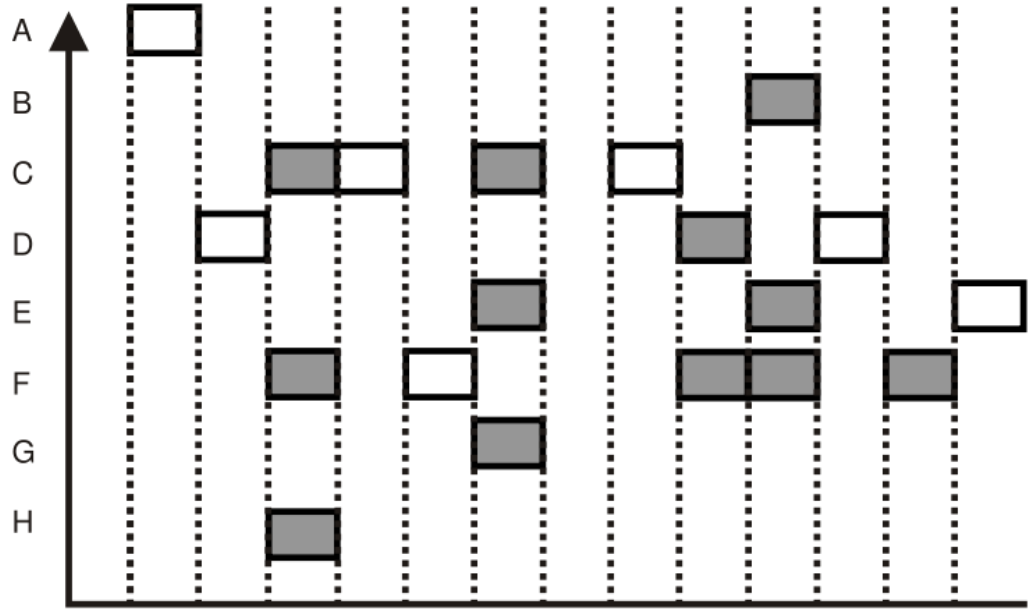
Early MAC Example

- In the 1970s, University of Hawaii constructed a packet radio network to interconnect Hawaiian islands
- In 1972 it was connected to ARPANET
- Basic MAC approach:
  - If you have data to send, send it
  - If the message you send interferes with someone else, try again



ALOHA

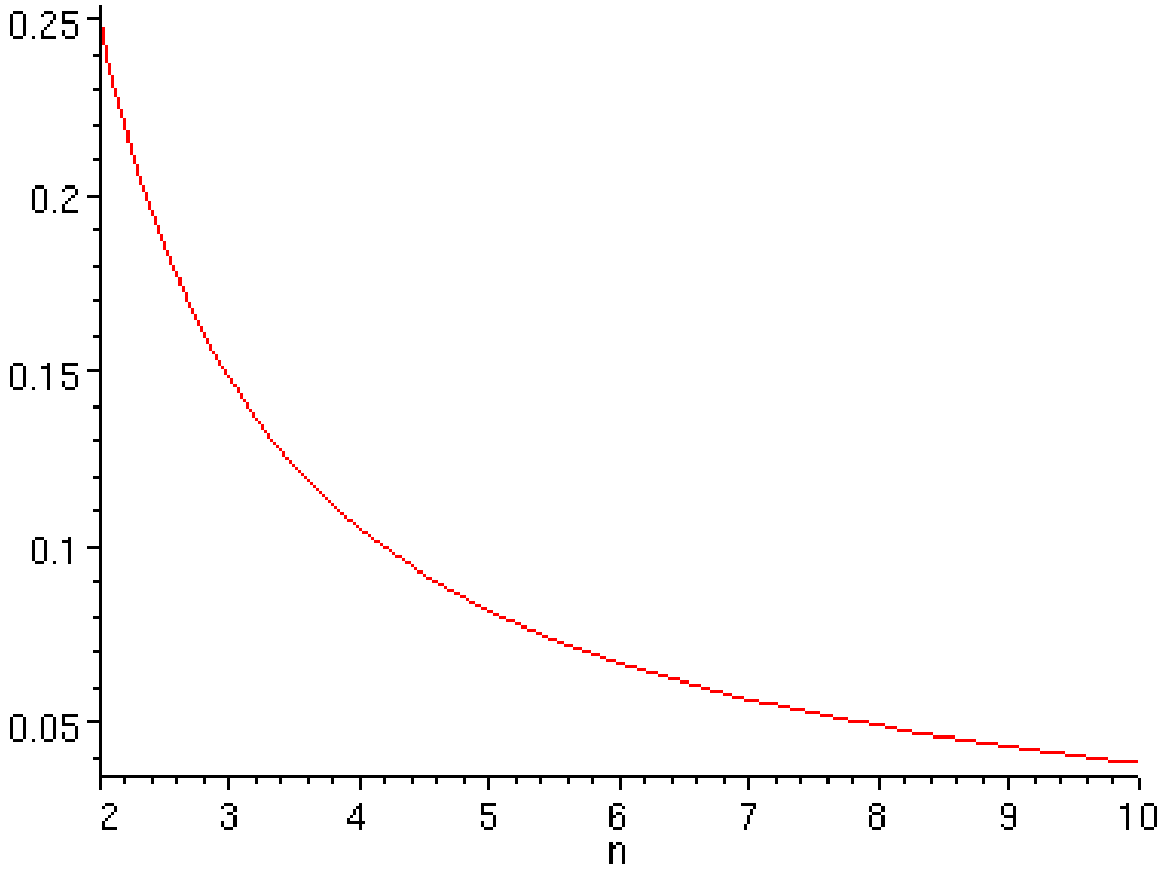
- Performance very poor
- Introduced slotted Aloha
- Time broken up into slots, transmissions aligned to slots
- Successful if only one transmission during slot



Slotted ALOHA protocol (shaded slots indicate collision)

ALOHA Performance

- Per-user rate as a function of users
- Total rate converges to 0.368



ALOHA Performance

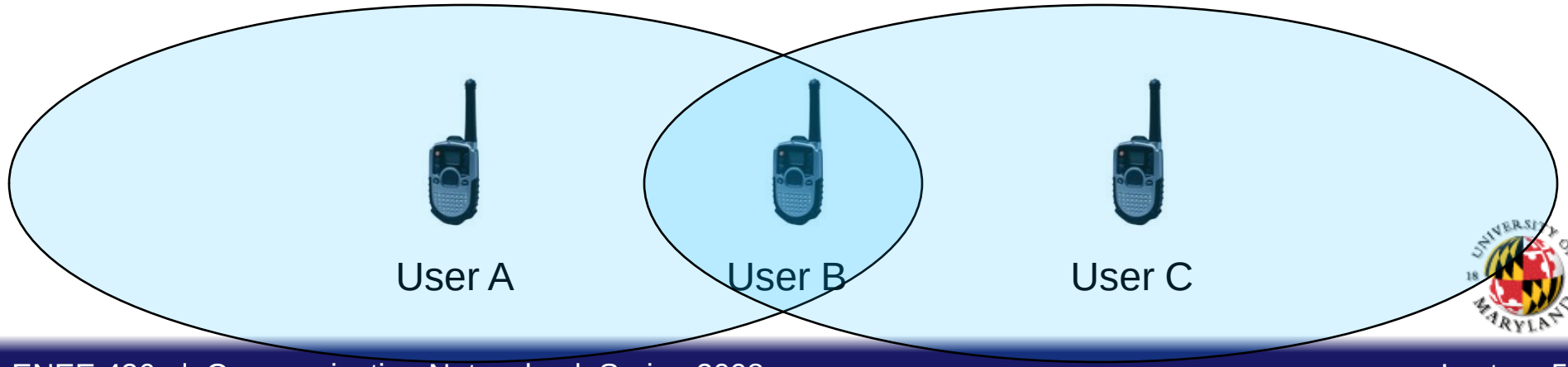
- Poor performance due to statistical independence of time slots
- If collision occurs
  - Wait before retransmitting
    - How long?
  - Probability of retransmitting in next slot decreases exponentially
  - **Exponential backoff**

ALOHA's impact

- Foundation of modern CSMA/CD
  - Carrier Sense Multiple Access / Collision Detection
- Steps:
  - Carrier present?
    - If busy, restart
    - if idle transmit
  - Packet received without errors?
    - If yes, done
    - If no, transmit jamming signal so others know a packet collision occurred and wait random amount of time and restart
- Protocol used in Ethernet 10 Mbps MAC

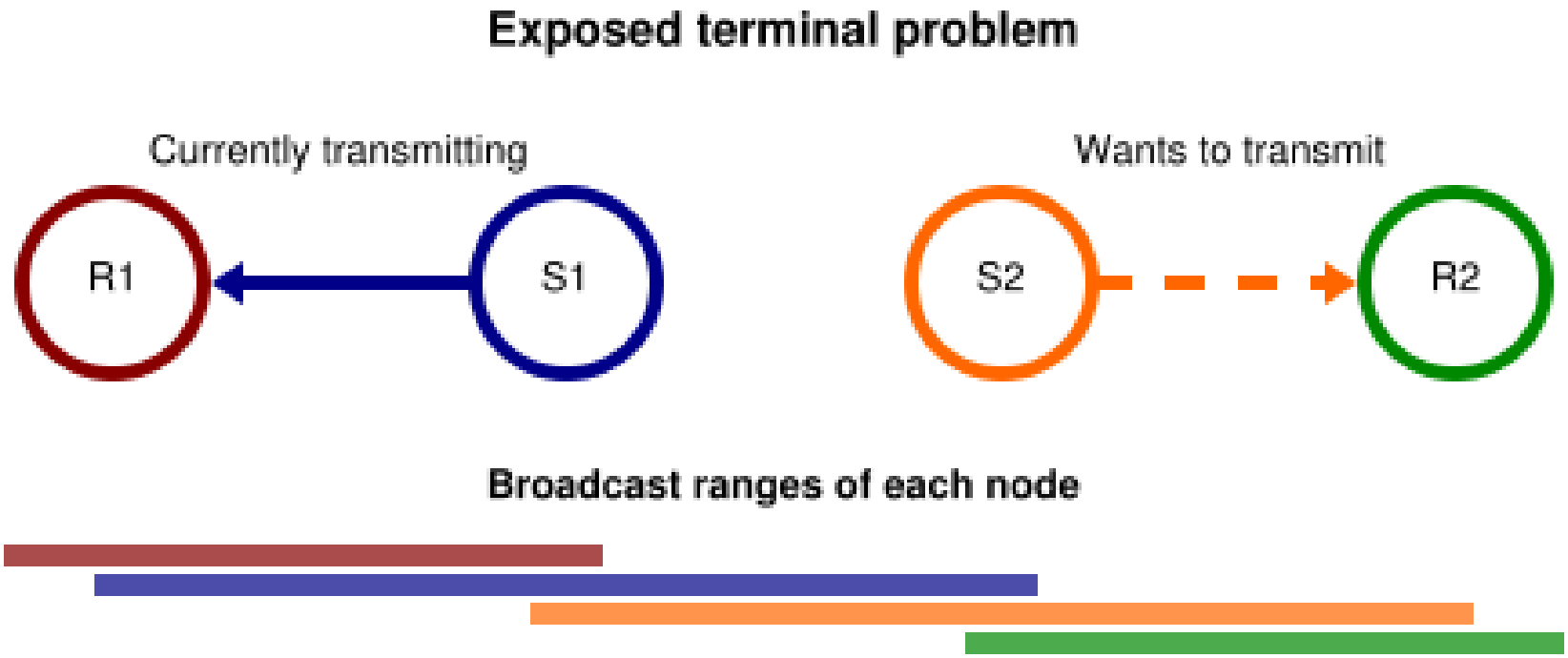
Hidden Terminal Problem

- In RF, range of shared medium is limited
- Result: Hidden Terminal Problem
- Scenario:
  - User A starts transmitting to user B
  - User C listens, hears idle
  - User C starts transmitting to user B
  - Packet collision



Exposed Terminal Problem

- Nodes may determine medium is busy when it is in fact idle



CSMA/CD Improvements

- CSMA/CD insufficient for wireless broadcast channels
- CSMA/CA
  - Carrier Sense Multiple Access / Collision Avoidance
- Add new management messages
  - Request to Send (RTS)
  - Clear to Send (CTS)
- RTS is transmitted and CTS is received before data is transmitted
- RTS and CTS are small packets, so their overhead and probability of interfering is small