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Wireless Networks

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Motivation

- Save energy, save Earth
- Maximize lifetime of mobile nodes operated by batteries
- Maximize spatial reuse of the constrained radio resource

Energy Conservation Approaches

Power Save

- Turn off transceivers when possible

Power Control

- Lower transmission power as much as possible

Sample Power Management Protocols

Power Save

- PAMAS
- Power Save in IEEE 802.11 Ad Hoc Mode

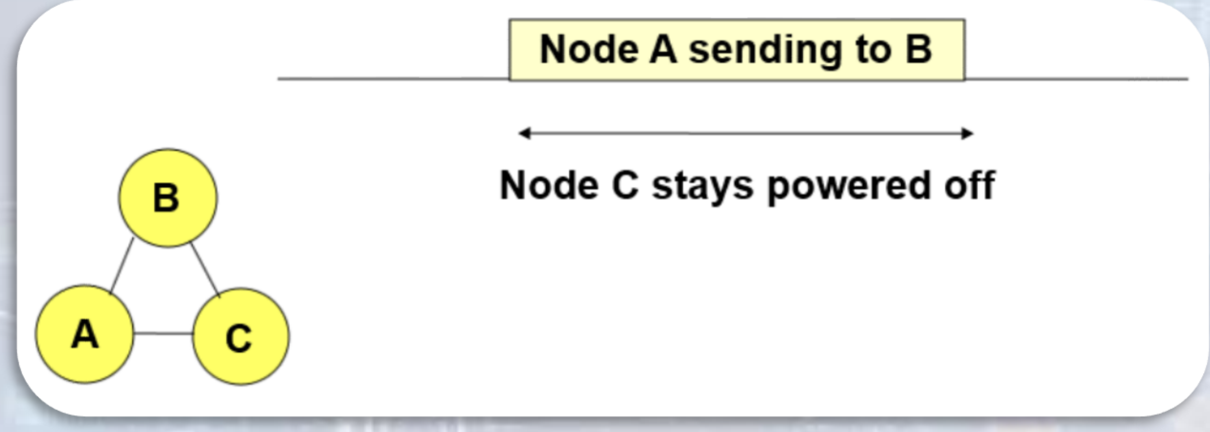
Power Control

- Power Control in 802.11

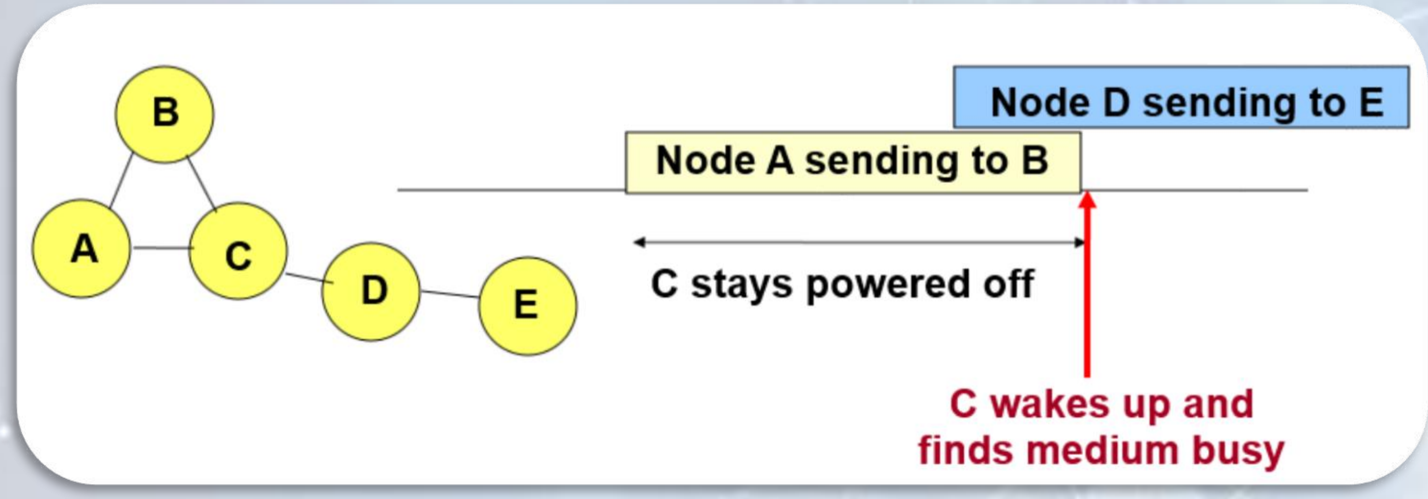
PAMAS

Power-Aware Multi-Access Protocol with Signaling

- Power off while any neighbor is transmitting to someone else.
- Node knows to keep off for how long from the message header.



PAMA Problem



- How does node C know its remaining sleep duration if it wakes up to finds that D is transmitting to someone else?
- As C misses the message header.

PAMAS Signaling Solution

- Use separate control channel

- If a node wakes up to find the medium busy:
  - Determine the longest remaining transmission time using **binary probe**
    - Send a probe with parameter L (longest packet duration)
      → "I'll power off for duration L"
    - Neighbors transmitting respond if remaining time between [L/2, L] →**(>=L/2)**
    - So the node goes back to sleep.
    - If no response, probe [L/4,L/2]
    - And so on.

Disadvantages of PAMAS

- Use of a separate control channel
  - Nodes have to be able to receive on the control channel while they are transmitting on the data channel
  - And also transmit on data and control channels simultaneously

- A node (such as C) should be able to determine when probe responses from multiple senders collide

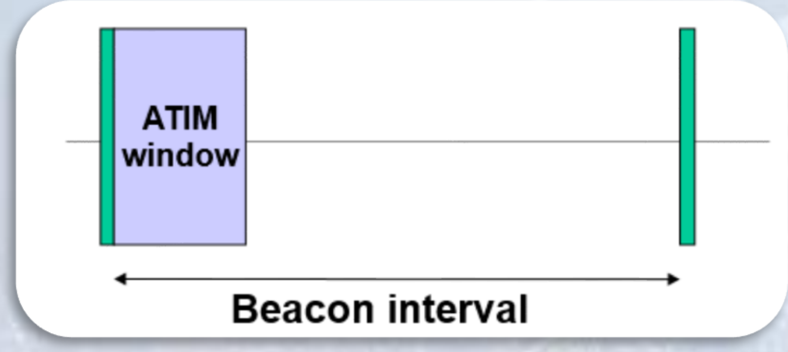
Another Proposal in PAMAS

- To avoid the probing, a node should switch off the interface for data channel, but not for the control channel (which carries RTS/CTS packets)
  - Advantage:
    - Each sleeping node always knows how long to sleep by watching the control channel
  - Disadvantage:
    - This may not be useful when hardware is shared for the control and data channels
    - Interference may happen on the control channel

Power Save in IEEE 802.11 Ad Hoc Mode

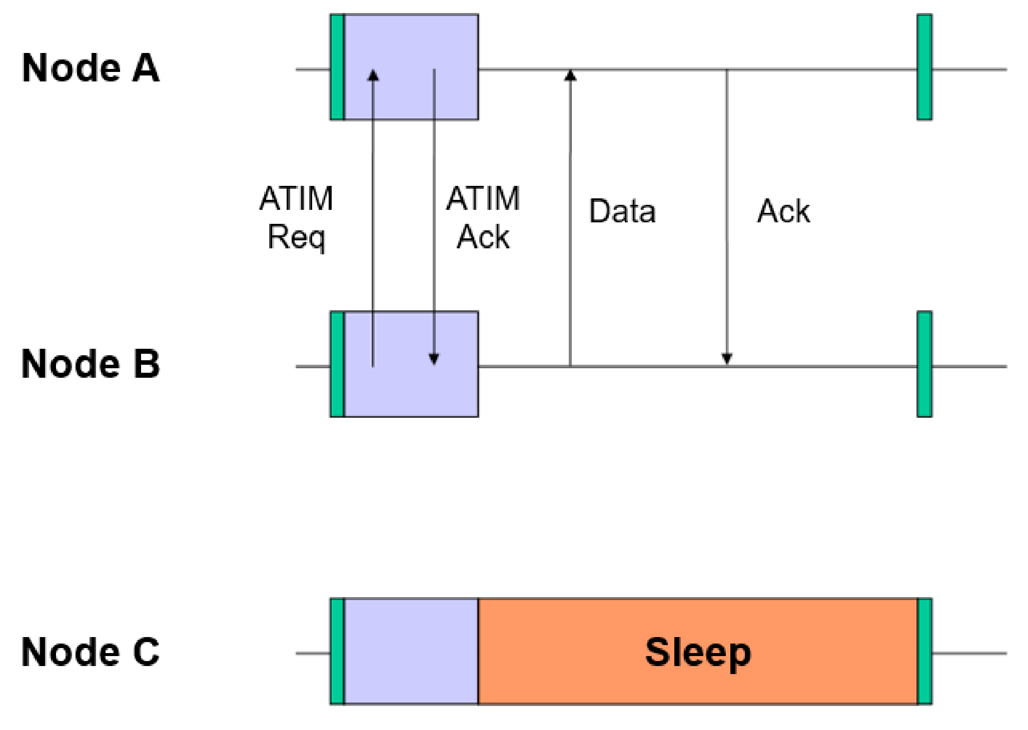
- Time is divided into beacon intervals

- Each beacon interval begins with an ATIM window



Power Save in IEEE 802.11 Ad Hoc Mode

- If host A has a packet to transmit to B, A must send an **ATIM Request** to B during an ATIM Window
- On receipt of ATIM Request from A, B will reply by sending an **ATIM Ack**, and stay up during the rest of the beacon interval
- If a host does not receive an ATIM Request during an ATIM window, and has no pending packets to transmit, it may sleep during rest of the beacon interval



Power Save in IEEE 802.11 Ad Hoc Mode

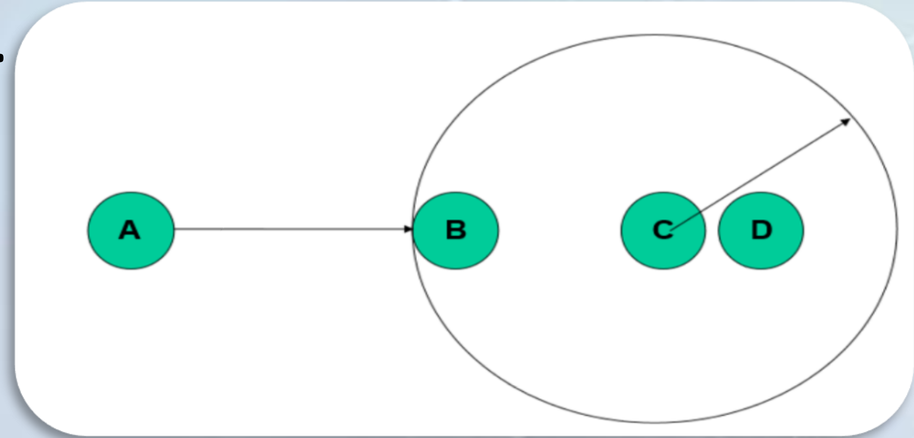
- Size of ATIM window and beacon interval affects performance
  - If ATIM window is too large, power saving is reduced
    - Energy consumed during ATIM window.
  - If ATIM window is too small, not enough time to send ATIM request
    - Delay increases, specially in high load conditions since ATIM requests will collide so nodes won’t receive ACKs and will wait for the next beacon interval.

- How to choose ATIM window dynamically?
  - Based on observed load: load increase → increase ATIM window
  - (power saving decreases but delay decreases as well)

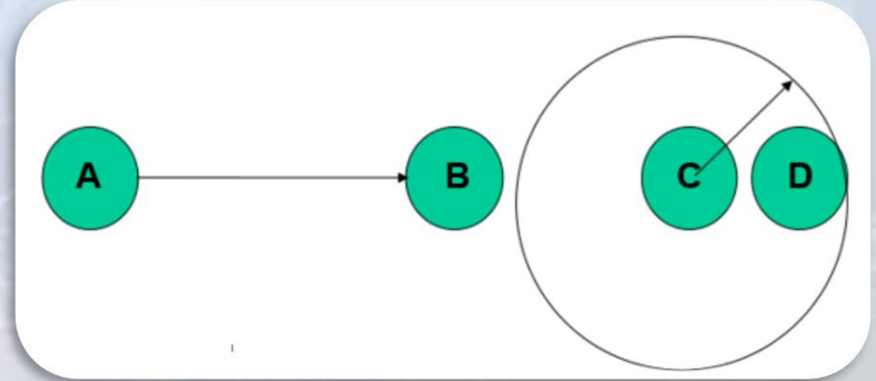
- How to synchronize hosts?
  - If two hosts’ ATIM windows do not overlap in time, they cannot exchange ATIM requests.
  - Coordination requires that each host stay awake long enough (at least periodically) to discover out-of-sync neighbors.

Power Control

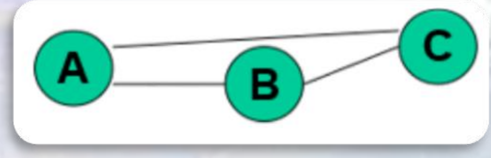
- When C transmits to D at a high power level, B cannot receive A's transmission due to interference from C.



- If C reduces transmit power, it can still communicate with D
  - Reduces energy consumption at node C
  - Allows B to receive A's transmission (spatial reuse)

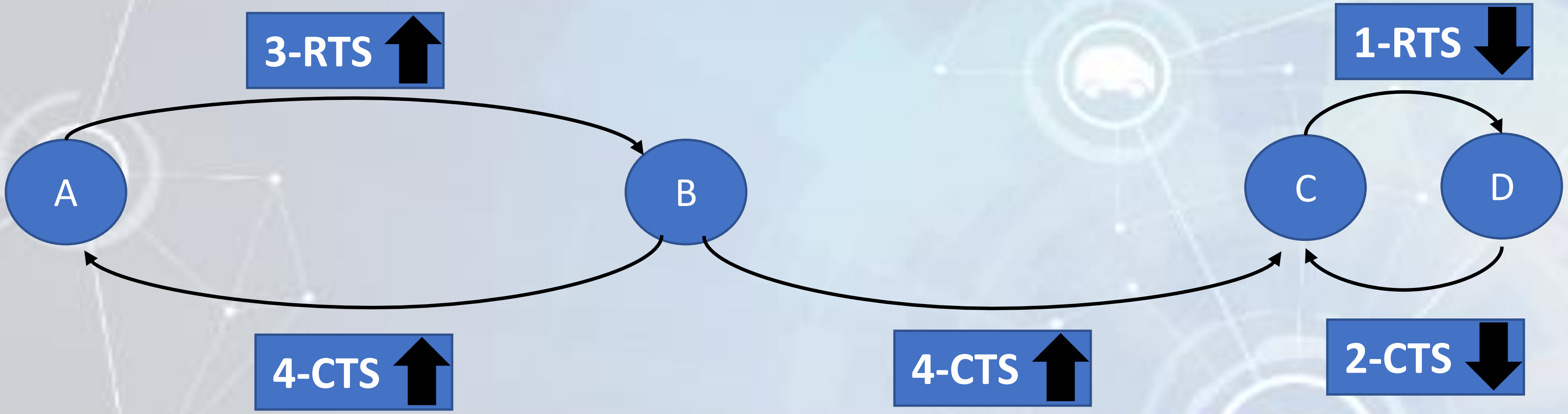


- Shorter hops typically preferred for energy consumption
  - Transmit to C from A via B, instead of directly from A to C



Power Control in 802.11

- Transmit RTS/CTS/DATA/ACK at the least power level needed to communicate with the receiver



- B won’t get RTS from C, C will get CTS from B so interference happens at C “hidden terminal problem” returns.
- Solution: send RTS/CTS at the highest power, and DATA/ACK at the smallest necessary power level.
  - Drawback:
    - Transmitting RTS at the highest power level also reduces spatial reuse
    - Nodes receiving RTS/CTS have to defer transmissions


Thank You