Energy-efficient Mac layer protocols in ad hoc networks

Outline

- Introduction
- Source of power waste and low-power MAC design principles
- Scheduling-based mechanism
- Power Control Techniques

Introduction

- Power conservation in ad ad hoc networks is the procedure of determining the transmit power of each communication terminal such that a design objective can be satisfied.
- Two major reasons for transmit power control:
  - To Decrease multi-user interference and increase spatial channel reuse and the number of simultaneous single-hop transmissions
  - To impact battery life, consequently prolonging the lifetime of the network

Introduction

- Power control mechanisms:
  - Low-power wireless access protocol
  - Power-aware routing for ad hoc and sensor networks
  - node-level energy-efficient information processing[1]
- Energy-aware MAC protocol in ad hoc network should satisfy the following three objectives:
  - MAC protocols should facilitate the creation of the network infrastructure
  - Sharing the wireless channels fairly and efficiently.
  - Should be energy-aware for extending the battery lifetime.

Sources of power waste

- Major sources of power waste in Mobile computing device :
  - radio communication and data processing

Table 1: LUCENT IEEE 802.11 WAVELAN PC CARD (2Mbps) CHARACTERISTICS

Modes	Energy Consumption
Sleep Mode	14 mA
Idle Mode	178 mA
Receive Mode	204 mA
Transmit Mode	280 mA

  - Power consumptions in radio communication:
    - Transmit, receive, idle listening, packet retransmission, overhearing, protocol overhead

Low-power MAC design principles

1. Minimize random access collision and the consequent retransmission
2. Minimize idle listening
3. Minimize overhearing
4. Minimize control overhead
5. Exploring the tradeoff between bandwidth utilization and energy consumption

- To increase the overall network throughput while maintain low energy consumption for packet processing and radio communication

Scheduling-based mechanism

- Reducing or avoiding the data link layer collision
  - Mechanisms: TDMA, CDMA, FDMA
- Benefit:
  - Improvement Network throughput
  - Decrease overhearing and idle listening
- Defect:
  - Complicated control
  - Can’t work well for burst traffic
  - Can’t work well if the topology is dynamic

Scheduling-based mechanisms

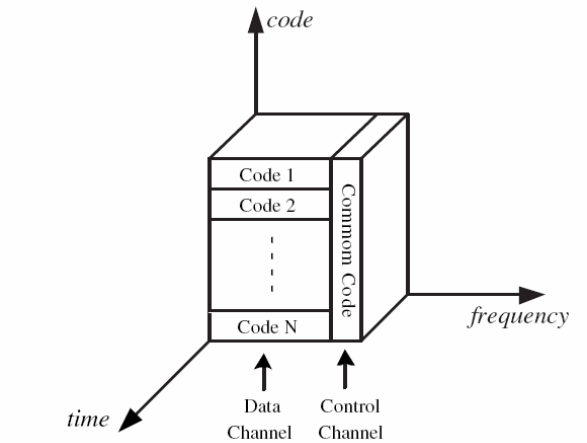
- CDMA
  - Benefits:
    - Enhance the capacity and relax power control requirement
    - Can provide up to six times larger than the capacity of TDMA or FDMA
    - Against Interference , jamming, signal degradation, multi-path fading resistance, and frequency diversity
  - Deficiencies:
    - Degrade network throughput for burst traffic
    - Can’t avoid Idle listening
    - Data transmission irate is limited

Scheduling-based mechanisms

- CDMA ad hoc networks
  - Higher throughput and shorter packet delay than centrally-controlled CDMA wireless LAN and cellular network.
  - Benefits:
    - Capacity improvement
    - Energy saving
    - Routing overhead reduction
  - Deficiencies:
    - Near-Far effect
    - Code design
    - Recording

Scheduling-based mechanisms

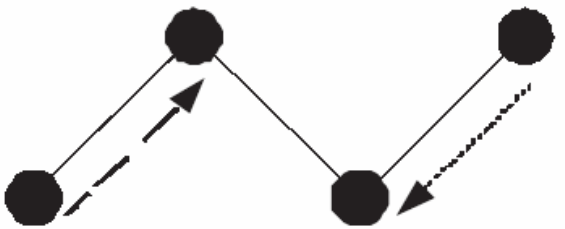
- TDMA
- FDMA
  - OFDM: Be used in the 802.11and 3G system
- Related protocols
  - CA-CDMA[2]



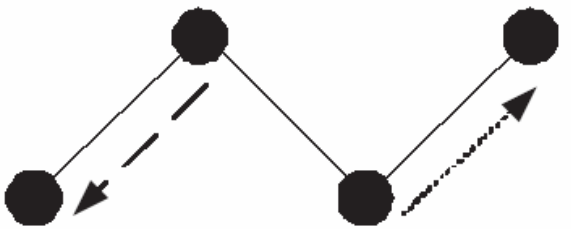
Energy-efficient MAC based on CDMA/TDMA[3]

Power Control Techniques

- Contention-based
  - IEEE 802.11DCF(CSMA/CA+RTS/CTS)



Receivers cannot be neighbors

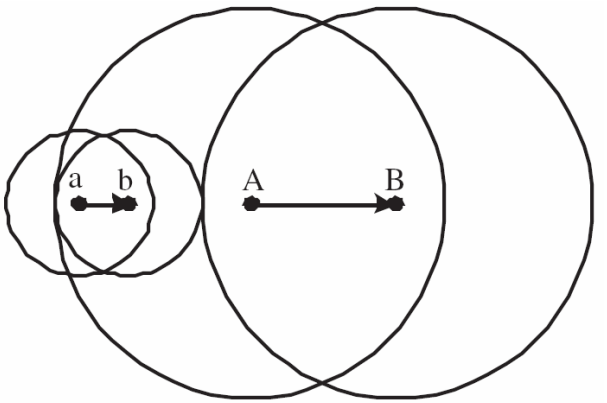


Senders cannot be neighbors

- To modify the transmission power levels for network capacity improvement

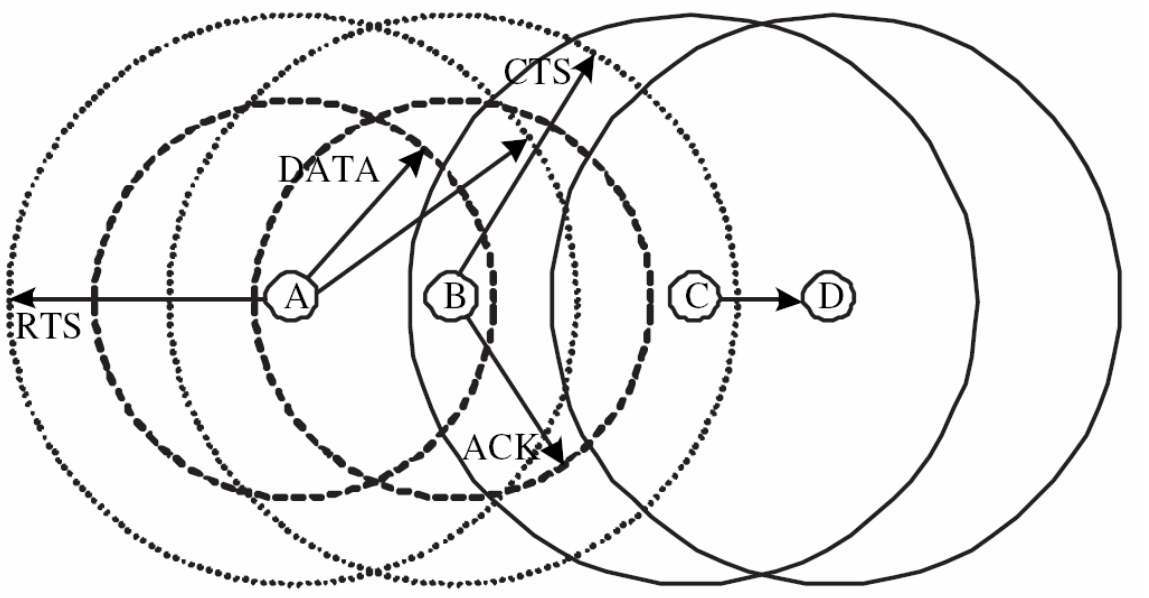
Power Control Techniques

- Benefit:
  - Energy conservation
  - Spatial reuse
  - Avoiding overhearing and interference
- Defect:
  - Asymmetry
    - Broadcast CTS multiple times
  - New collisions
    - Adaptive power control loop scheme
    - Optimal common transmit power level



Power Control Techniques

- Related protocols
  - PCM[4]



Power Control Techniques

- PCMA[5]
  - Two channels: data channel and busy tone channel
- DCA-PC[6]
  - Two channels
- PCDC[7]
  - Utilize the inter0layer dependence between the MAC and networks layer

Reference

1. M. Chu, H. Haussecker, and F. Zhao, Scalable information-driven sen-sor querying and routing for ad hoc heterogeneous sensor networks,*IEEE Journal of High Performance Computing Applications*, Vol.16 No.3(2002) pp. 90-110.
2. A. Muqattash and M. Krunz, CDMA-based MAC protocol for wireless ad hoc networks, *Proceedings of the International Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC'03)*, (Annapolis, June 2003).
3. K.T. Jin and D.H. Cho, A new MAC algorithm based on reservation and scheduling for energy-limited ad hoc networks, *IEEE Transactions on Consumer Electronics*, Vol.49 (Feb. 2003) pp. 135-141
4. E.-S Jung and N.H. Vaidya, A power control MAC protocol for ad hoc networks, *Proceedings of ACM MOBICOM'02*, (Sep 2002).
5. J. Monks, V. Bharghavan, and W. Hwu, A power controlled multiple access protocol for wireless packet networks, *Proceedings of IEEE Info-com*, (April 2001), pp. 219-228
6. S.L. Wu, Y.C. Tseng, C.Y. Lin, and J.P. Sheu, A multi-channel MAC protocol with power control for multi-hop mobile ad hoc networks, *The Computer Journal (SCI)*, Vol.45 No.1 (2002) pp. 101-110
7. A. Muqattash and M. Krunz, Power controlled dual channel (PCDC) medium access protocol for wireless ad hoc networks, *IEEE INFOCOM 2003*.