Paper presentation – Ultra-Portable Devices

Paper:

Design Challenges for Energy-Constrained Ad Hoc Wireless Networks

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IEEE Wireless Communication
August 2002, pages 8-27

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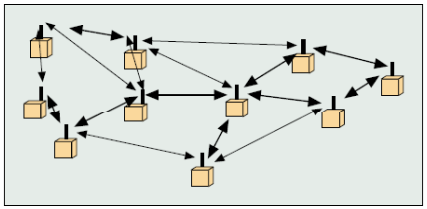
Outline

- Overview of ad hoc wireless networks
- Application with emphasis on energy constraints
- Cross-layer design
- Link layer design issues
- MAC layer design issues
- Networking design issues
- Application design issues
- Summary and conclusions

Overview of ad hoc wireless networks (I)

- Definition
  - *Ad hoc*: for the particular purpose in hand or in view
  - *Ah hoc wireless networks*: Self-configured *wireless mobile* nodes without established infrastructure
- Characteristics
  - Nodes handle control and networking tasks
  - Peer-to-peer communication
  - Multihop routing
  - Not flat depending on design requirement



Overview of ad hoc wireless networks (II)

- Two design issues of ad hoc networks
  - Mobility
  - Energy efficiency

Applications (I)

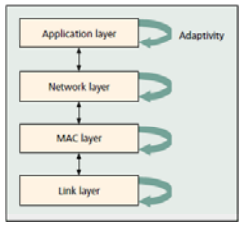
- Data networks
  - Data exchange between devices like laptops, palmtops, PDAs
  - Challenges are high data rate and cost
  - 802.11a and 802.11b standards
- Home networks
  - Communication between electronics in and around home
  - Challenges: varied QoS, cost, standardization and energy
  - 802.11a and 802.11b standards

Applications (II)

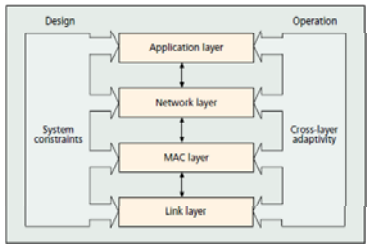
- Device networks
  - Short-range wireless connection between devices
  - Challenge is energy
  - Bluetooth standard
- Sensor networks
  - Large number of sensors used to sense, detect and track
  - Challenges are energy, size and cost
  - PicoRadio

Cross layer design (I)

- Why cross-layer design?
  Inflexibility, suboptimality and poor performance of layered approach



- How it can be done?
  - Information exchange across all layers in protocol stack
  - Adaptivity and optimization with respect to global system constraints and characteristics



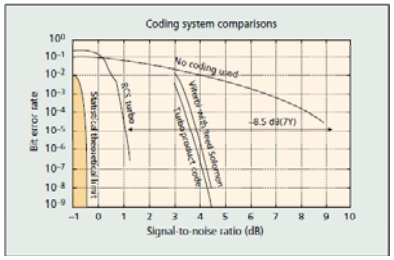
Cross layer design (II)

- To design an adaptive cross-layer protocol stack
  - What information should be exchanged and how that information should be adapted to?
  - How should global system constraints and characteristics be factored into protocol design at each layer?

Link layer design issues (I)

- Max. data rate
  - The goal is to reach fundamental capacity limit
  - Due to energy constraints, it is not possible to reach this max.data rate
  - We need a new definition for capacity limit which proposed as capacity per unit energy or capacity in bits
  - Energy constraints nodes can transmit finite no. of bits
- Coding

  Error control coding techniques can reduce transmit power



Link layer design issues (II)

- Multiple antennas
  - Techniques:
    - ✓ Diversity
    - ✓ Beamsteering
    - ✓ MIMO
  - Trade-off between multiple antennas and energy consumption
- Power control
  - Key role on enery-efficient cross-layer design
- Adaptive resource allocation

  adapts link transmission scheme to experienced channel, interference and data characteristics

MAC layer design issues (I)

- Medium access control (MAC) protocol

  determines how different user share available spectrum

- Two components of spectrum allocation
  - Channelization: How to divide spectrum into different channels
  - Channel access: How to assign different channels to different users

MAC layer design issues (II)

Channelization Methods

- Frequency division
  - ✓ System bandwidth divided into nonoverlapping channels
  - ✓ Simple to implement, inflexible, limited no. of users
- Time division
  - ✓ Time divided into orthogonal time slot
  - ✓ Difficult to implement, flexible, limited no. of users
- Code division
  - ✓ Data modulated by orthogonal or semi-orthogonal spreading code
  - ✓ Complex, flexible
- Hybrid combinations of these methods
- Trade-off between frequency, time and code channelization

MAC layer design issues (III)

Channel access

- Random access
  - ✓ Channels are allocated to users that need them
  - ✓ Techniques:
    - o aloha, slotted aloha,
    - o CSMA, aloha with CSMA, four-way handshake (802.11)
    - o RX and TX busy tone transmission
  - ✓ Issues: collision, hidden terminals, exposed terminals
  - ✓ Energy efficient technique: limit transmitting and receiving time period
- Scheduling
  - ✓ Channels are assigned to users to avoid conflicts
  - ✓ Scheduled access and aloha combination for ad hoc networks (PRMA)
  - ✓ Energy efficient technique: schedule optimization

Network layer design issues (I)

- Neighbor discovery
  - Process of determining number and identity of network nodes with which direct communication can be established given max. power level and min. link requirements
- Network connectivity
  - Ad hoc networks assume a fully-connected network
  - Connectivity gets influenced by
    - ✓ Node mobility
    - ✓ Link layer parameters
    - ✓ Power efficiency

Network layer design issues (II)

Routing

- Flooding
  - ✓ Highly robust to changing network topology
  - ✓ Little routing overhead
  - ✓ Wasting bandwidth and battery power
  - ✓ Proper for small networks
- Centralized routing
  - ✓ Efficient due to optimality
  - ✓ Cannot adapt to fast changes
  - ✓ Requires much overhead
  - ✓ Proper for small networks

Network layer design issues (III)

Routing

- Distributed routing
  - ✓ Little routing overheads
  - ✓ Adapts quickly to changes
  - ✓ Suboptimal
- Reactive routing
  - ✓ Globally efficient
  - ✓ Little overhead
  - ✓ Significant delay → combination of proactive and reactive
- Multi-hop routing gets influenced by
  - ✓ Mobility
  - ✓ Energy efficiency

Network layer design issues (IV)

- Scalability and distributed protocols
  - How scalable the distributed control network algorithm are
- Network capacity
  - How to improve per-user rates in a large network

Application design issues

- Application must adapt to time-varying QoS due to dynamic characteristics of network
- Application must adapt itself to offered QoS

Summary

- In energy constraints systems
  - Cross-layer design saves energy across entire protocol stack
  - Adaptivite solutions and optimized algorithms based on design requirements improve performance and minimize energy consumption
  - Trade-off between local algorithm and global system energy saving

List of interesting papers

- Applications (Picoradio): [27] J. Rabaey et al., “PicoRadio Supports Ad Hoc ultra low Power Wireless Networking,” IEEE Comp., July 2000, pp. 42–48.
- Link layer (fundamental capacity limit): [41] H. Mandyam and A. J. Goldsmith, “Capacity of Finite Energy Channels,” Proc. Allerton Conf. Commun. Cntl. Comp., Oct. 2001.
- MAC layer (scheduling): [91] E. Uysal-Biyikoglu, B. Prabhakar and A. El Gamal , “Energy-Efficient Transmission of Packets in a Wireless Network,” to appear IEEE Trans. Net., also Proc. IEEE INFOCOM, Mar. 2002.
- [15] J. M. Kahn, R. H. Katz, and K. S. Pister, “Emerging Challenges: Mobile Networking for “Smart Dust,” J. Commun. Net., Aug. 2000, pp. 188–96.