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 energy-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 users 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:
    - aloha, slotted aloha,
    - CSMA, aloha with CSMA, four-way handshake (802.11)
    - 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 \(\rightarrow\) 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
  - Adaptive 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