Power Optimal Routing for Wireless Ad Hoc Network with End-to-end QoS Guarantees

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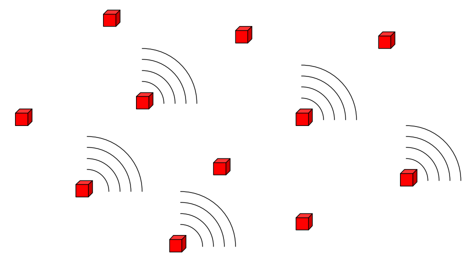
Introduction

- Minimization of power plays an important role in the design of wireless ad hoc networks.
- Multi-hop routing enables power saving.
- Cross-layer coupling: Error propagation at the physical layer affects performance of routing at the network layer.
- We provide an end-to-end approach: minimize to total power expended over the multi-hop route subject to an end-to-end QoS guarantee.

System Model



Forward data from the source through multiple relays to the destination

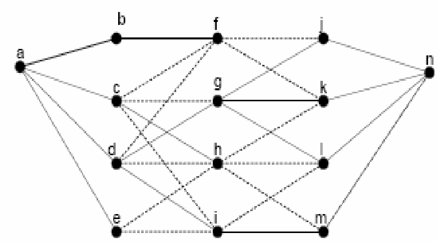
Relay Types

- Forward without demodulation
  - No decoding at the relays, just forward noisy observations
  - Noise propagates to the destination.
  - Extra transmission power is required to maintain QoS.
  - Same as amplify and forward (AF)
- Forward with demodulation
  - Data is processed with demodulation at each hop.
  - Decoding error propagates to the destination.
  - Less transmission power, more processing power
- Hybrid forwarding scheme
  - Either at the above is applied at each hop in a route.

Searching for The Optimal Route

- Route search:
  - A message with ID and location information are broadcasted from the source to its neighbors.
  - Neighbors of one node is defined as all possible nodes within the transmission range of that node.
  - Use Viterbi algorithm with power cost metrics, we can reduce the computational complexity.
- Data transmission:
  - The optimal route information gets flooded back from the destination.
  - Data is transmitted through the route.

Viterbi Algorithm



Trellis diagram for Viterbi algorithm

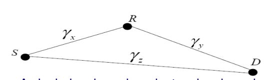
Channel Models

- Path loss model:
  - Deterministic fading model
  - Forwarding with demodulation outperforms forwarding without demodulation.
- Frequency-flat and slow fading model (Rayleigh fading)
  - Power performance is similar between forwarding with demodulation and forwarding without demodulation.
  - Due to the extra processing power of forwarding with demodulation, forwarding without demodulation is advantageous in a fading environment

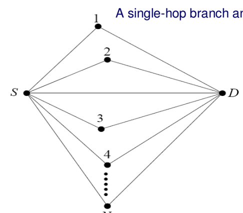
Improvement Through Diversity Combining

- Motivation:
  - Signal transmission through independent paths to the destination provides diversity gain
  - For fixed end-to-end QoS requirement, diversity enables power saving
- Methods:
  - Multiple independent routes
  - Forward without demodulation
  - Maximum ratio combining (MRC) at the destination
  - Slotted forwarding in time and frequency

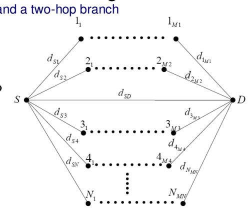
Network Models



A single-hop branch and a two-hop branch



Multiple branches and two hops

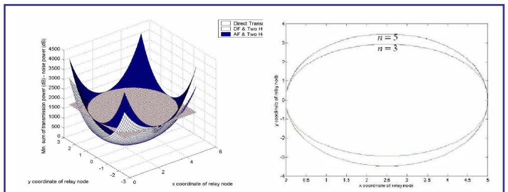


Multiple branches and multiple hops

Solution

- Properties:
  - Feasible solution region depends on network topology
  - Not every branch (route) provides power saving
  - Convex optimization problem
- Solution:
  - Formulate the lagragian and find the KKT conditions
  - Discard power “ inefficient” routes
  - Iterative algorithm for the power optimal solution

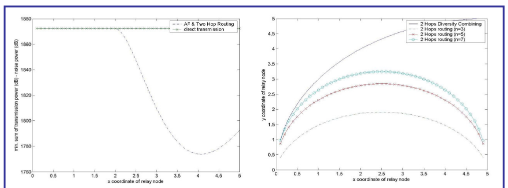
Simulation Results-without diversity



(c) (d)

- Figure (c): Minimum power consumption of AF, DF and direct transmission
- Figure (d): relay region for DF relay type

Simulation Results-diversity



(e) (f)

- Figure (e): Minimum power consumption of direction and 2 hop diversity
- Figure (f): relay region comparison among 2 hops diversity combining and 2 hops routing with different path loss exponents

Conclusions

- Power savings can be achieved by multi-hop routing.
- Forwarding without demodulation requires less processing power, forwarding with demodulation requires less transmission power
- Viterbi algorithm is used to reduce the complexity of the searching for the optimal route.
- Diversity combining improves power efficiency.
- Globally optimum power route is found with an end-to-end QoS guarantee.

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