Routing for Network Capacity Maximization in Energy-constrained Ad-hoc Networks

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Outline

- Introduction
- Related work
- The CMAX algorithm
- Implementation issues
- Simulation results
Introduction

Objective

- Maximize total number of messages successfully carried by the network (network capacity)
- No assumptions on future message arrivals
Related work

- Motivated by $\max\min zP_{\min}$
  - Assumes messages generate at constant rate
  - Involves several shortest path computation
CMAX Algorithm

Step 1. Consider routing message $k$ on the network $G$. Eliminate all links $(i, j) \in A$ for which $e_{ij} > \frac{E_i(k)}{l_k}$ to form a reduced network.

$e_{ij}$ := energy consumed for transmitting a unit message along link $(i, j)$

$E_i(k)$ := the residual energy of node $i$ when $k$ generated
CMAX Algorithm (cont’d)

Step 2. Associate weights \( w_{ij} \) with each link \((i, j)\) in the reduced graph, where \( w_{ij} = e_{ij}(\lambda^{c_i(k)} - 1) \).

\( \lambda \) := appropriate constant
CMAX Algorithm (cont’d)

Step 3. Find the shortest path from $s_k$ to $d_k$ in the reduced graph with link weights $w_{ij}$, as defined in Step 2.

$s_k :=$ source node of message $k$

$d_k :=$ destination node of message $k$

$w_{ij} :=$ weight of link $(i, j)$
CMAX Algorithm (cont’d)

Step 4. Let $\gamma_k$ be the length of the shortest path found in Step 3 ($\gamma_k = \infty$ if no path was found). If $\gamma_k \leq \sigma$, route the message along the shortest path, otherwise reject it.

$\sigma :=$ appropriate constant
Competitive bound

Theorem 1: Let $\lambda = 2(n\rho + 1)$ and $\sigma = n\epsilon_{\text{max}}$. For all messages $k$, let

$$l_k \leq \frac{\min_{i \in N} E_i}{e_{\text{max}} \log \lambda}$$

Then

$$\frac{L(k)}{L_{\text{opt}}(k)} \geq \frac{1}{1 + 2 \log \lambda} \quad \forall k.$$ 

Therefore, Competitive ratio of CMAX: $O(\log \eta \rho)$
Implementation

- Whole network topology
  - Relatively static → any changes disseminated throughout the network

- Current energy utilization at each node
  - Changes frequently
  - Dissemination of global energy information is not feasible in large networks
  - → use Limited Flooding Approach
Limited Flooding Approach

- In order to get neighborhood’s energy information.
- Hop-by-hop routing like OSPF
  - Each node computes shortest path
  - Periodically broadcast its residual energy
  - Within limited distance
- We call it D-CMAX
Effect of $\lambda$ and $\sigma$

- $\sigma \leq 70$, $\lambda \leq 140,000$ from Theorem 1.
- $\sigma < \lambda$ implies admission control
Simulation result
CMAX vs. D-CMAX
Discussions

- How much does the energy consumption decrease?