Multicasting in ad hoc networks: Energy efficient

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Overview

- Introduction
- Sources of power consumption
- Directional antennas
- TCP
- Broadcast and multicast tree construction
- Energy-efficient multicasting
- Conclusions

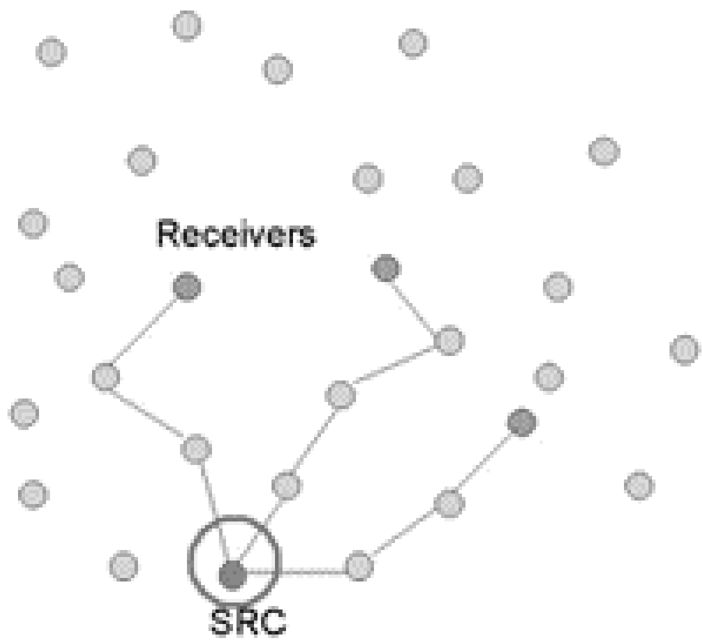
Introduction

- Multicasting, more complex in ad hoc networks
  - **mobility**
  - **interference** of wireless signals
  - **broadcast** communication
- Two types of multicasting protocols
  - **source-based**
  - **core-based**
- Energy is an issue
  - **limited** power supply
  - packets **transceiving consumes power**

Aim of power optimization

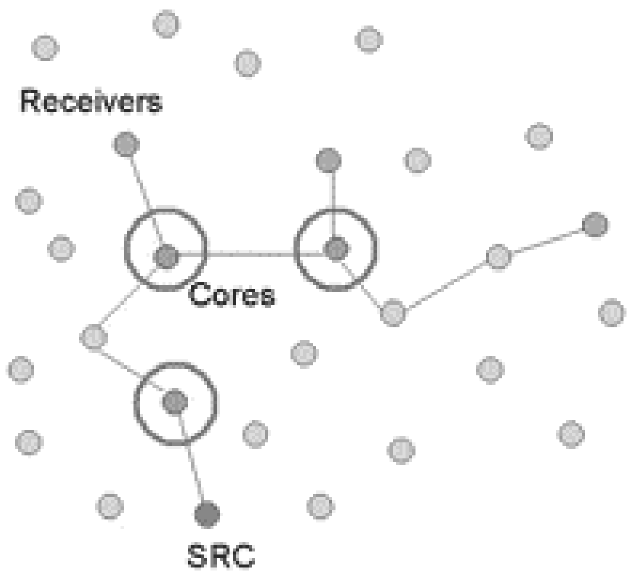
Increase the lifetime of the network

Introduction
Source-based protocols



- A tree for every source-group pair
- Bad scalability

Introduction
Core-based protocols



- Special nodes, **cores**, responsible for multicast data distribution
- Only **one multicast tree**

Sources of power consumption

- A mobile radio may be in three modes
  - **transmit**
  - **receive**
  - **standby**
- Power consumpt. for packet processing not analyzed
- As a <u>transmitter</u>,
  - **send packets** for control, request, response, data
  - send **routed packets** through this node
- As a <u>receiver</u>, receive
  - **own packets** (control and data)
  - **packets to be forwarded**

Directional antennas

- Energy focus in one direction
  - Increases **spatial reuse**
  - Provides **farther** transmission
  - Contributes in the **wireless multicast advantage**

The overall amt. of energy spent is reduced

- Other advantages:
  - Higher netw. capacity (**more simult. conn**., and **fewer hops**)
  - **Improved connectivity** (longer range)
  - **Reduced eavesdropping**

TCP

- TCP uses **timeouts** and **duplicate ACKs** to indicate congestion
- The wireless connections
  - high error rates, **retransmissions at the data link layer**
  - **packets** and **ACKs** are **delayed**
  - **transmission slows down**
  - packets are **retransmitted** (extra **energy spent** at the sender and at the intermediary nodes)

Possible solutions instead of TCP counters

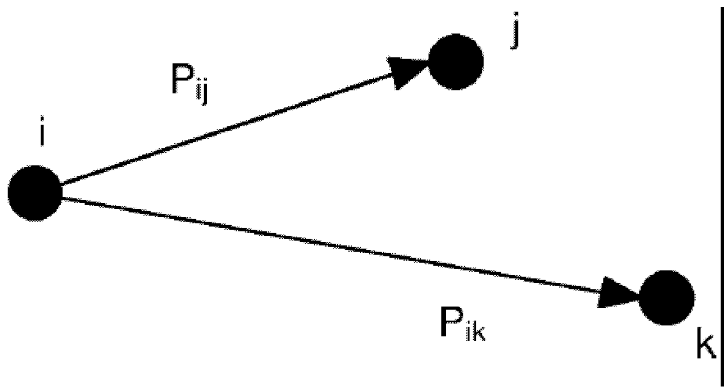
- Explicit Link Failure Notification (**ELFN**)
- Explicit Congestion Notification (**ECN**)

TCP (2)

- The mobility of the nodes
  - packets arrive along **different routes**
  - **duplicate ACKs** => **retransmission** => **throughput reduced**
  - **increased energy consumption**

Possible solution
  - **retransmit** the packet
  - **not decrease traffic**

Broadcast and multicast tree construction
The wireless multicast advantage

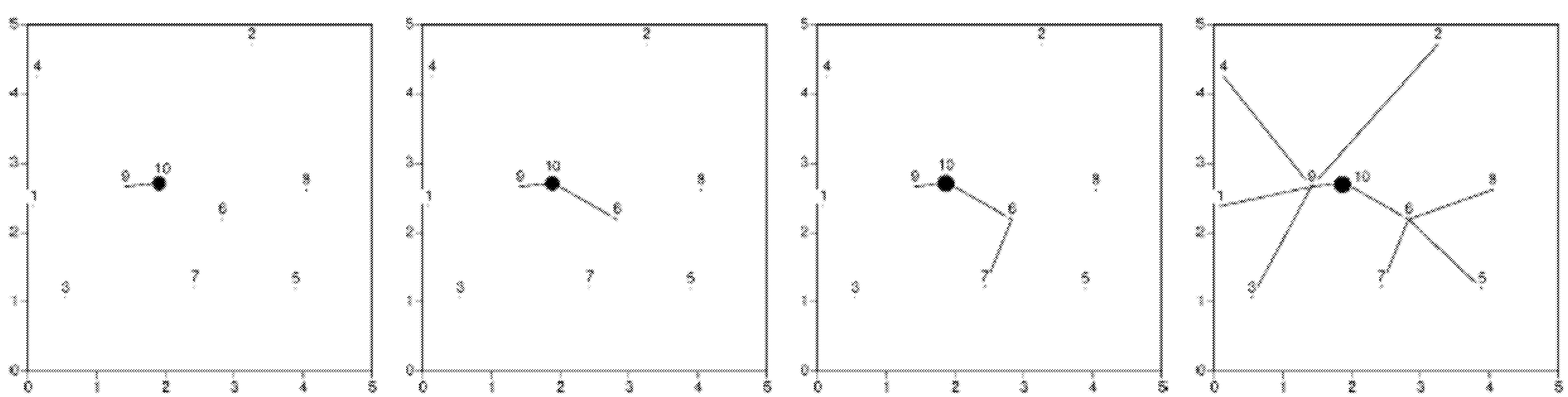


The power to communicate with nodes j and k:

$P_{i,(j,k)} = \max(P_{ij}, P_{ik})$

- The power required to transmit to the farthest node

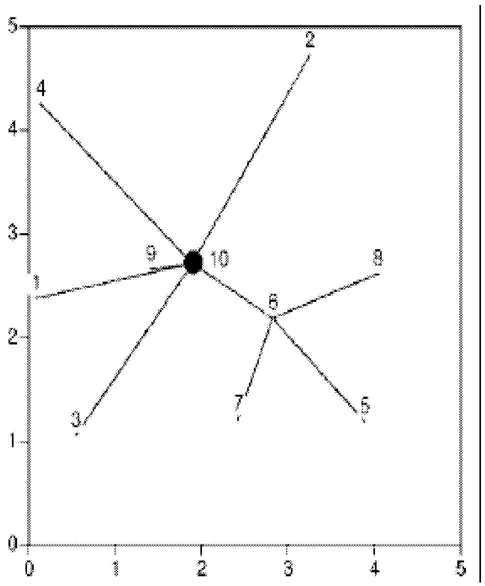
Broadcast and multicast tree construction
Broadcast Incremental Power (BIP)



(a) Step 1: $10 \rightarrow 9$ (b) Step 2: $10 \rightarrow 6$ (c) Step 3: $6 \rightarrow 7$ (d) final tree ($P = 10.90$)

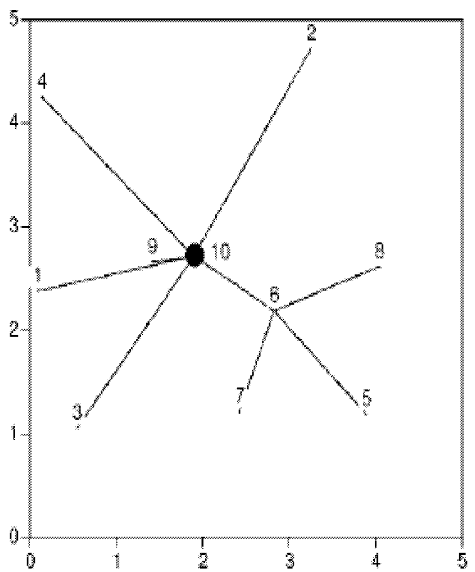
- Objective: minimum-power tree
- Nodes added one at a time
- Next node determined by least incremental power
- Considers the wireless multicast advantage
- MIP is obtained from pruning the undesired branches

Broadcast and multicast tree construction
Broadcast Least Unicast (BLU)



- To construct the tree:
  - assumption of an **underlying unicast alg**. – provides min distance unicast paths
  - **superposition of the best unicast paths** to the destinations
- The algorithm
  - **fails** to consider **the wireless multicast advantage**
  - MLU obtained by the superposition of **only the routes to the desired destination nodes**

Broadcast and multicast tree construction
Broadcast Link-based Minimum-cost Spanning tree (BLiMST)



- To construct the tree:
  - Associate a **link power-cost** to **each pair of nodes**
- The algorithm
  - **fails** to consider **the wireless multicast advantage**
  - MLU obtained by the **pruning** the **undesired nodes** from the tree

Energy-efficient multicasting for reliable data transfer

1. Energy-Efficient Reliable Broadcast and Multicast Protocols
2. A Distributed Power-Aware Multicast Routing Protocol
3. Energy-Efficient Multicast Routing Protocol
4. Energy-Efficient Cluster Adaptation of Multicast Protocol

1. Energy-Efficient Reliable Broadcast and Multicast Protocols

- **Reliability** means that **retransmission** might be **needed**
- **Packet-error probability** is considered
- BIP, BLU, BLiMST, MIP, MLU, and MLiMST can be modified to consider $E_{ij(reliable)}$

$$E_{ij(reliable)} = E_{ij} / (1 - p_{ij})$$

$\mathbf{p_{ij}}$ – packet-error probability

$\mathbf{1 / (1 - p_{ij})}$ – the expected rate of retransmission from node I to node j

2. A Distributed Power-Aware Multicast Routing Protocol

- An **underlying unicast protocol** implied
- **Two** possible **metrics** for **minimal node-to-node path**

$$C = (P_{1,2} + P_{2,3} + \ldots + P_{j-1,j}) / \min(K_1, K_2, \ldots, K_j)$$

K_i – no of transceivers at node i

P_{ij} – power needed for transmitting a packet from node i to j

$$D_{i,j} = P_{i,j} / \min(K_i, K_j)$$

Then, **D** would be

$$D = D_{0,1} + D_{1,2} + \ldots + D_{n-1,n}$$

3. Energy-Efficient Multicast Routing Protocol

- Two phases:
  - Minimum Energy Consumed per Packet (**MECP**)
  - Minimum Maximum Node Cost (**MMNC**)
- **MECP** considers the **energy consumption** for packet transmission along the **path**
- MMNC considers the **power level** at the **nodes** along the **path**
- The two **phases** are **alternated periodically**

4. Energy-Efficient Cluster Adaptation of Multicast Protocol

- Proposed for **cluster-based schemes**
- Each cluster has a **head**
- The **fewer cluster heads**, the **more energy** spent by head to **reach distant nodes**
- The **more cluster heads**, the **more energy** spent for the overhead at the **supernode level**

Some balance is needed

- Nodes **start out as cluster heads**
- Information exchanged, they **join clusters**
- Nodes become **head of cluster in turns** (so some nodes do not power out fast)

Conclusions

- The **wireless multicast advantage** should be exploited
- **Other efforts** also combined (TCP, directional antennas)
- The ultimate purpose – **prolonging the lifetime of the network**