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Improving Multicast Tree Construction in Static Ad Hoc Networks

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The multicast tree problem

Ad hoc networks are likely to support applications where considerable amount of data is delivered to several destinations at the same time. In some settings the energy resources are scarce and difficult to replace. There is a need for well designed multicast trees to efficiently use the resources.

- Problem statement:

  > Select a set of sequential transmissions which connect a source to a set of receivers so that the sum of the transmission energy costs is minimised.

- Transmissions are omni-directional and have variable power.
- Previous work by Wieselthier et al. [1]
  - Multicast Incremental Power (MIP) algorithm.

ISPT-algorithm

- Constructs a multicast tree in two phases
  - Tree initialisation
  - Grafting (repeated for all receivers)
- Initial tree is an arbitrary subtree originating at the source node.
- Each grafting step consists of adding a multicast receiver (selected by the grafting order) to the tree using the path that yields the lowest incremental path cost, see Figure 1.
- Incremental path cost is the additional energy needed to reach the destination from the tree.
- Worst case complexity $O(N^3)$, where N is the number of nodes.

Performance analysis

Comparison with MIP

- Two versions of ISPT, both of which use the grafting order “lowest cost first”, but with initial trees as follows:
  - The source node itself (ISPT1).
  - The shortest path to the furthermost receiver (ISPT2, Fig. 1).
- Transmission cost is r^α, $2 \leq \alpha \leq 4$, where r is the distance.
- Comparison by relative difference x of the tree costs (alg1 and alg2), averaging over 1000 samples of 100 node networks,

$$x = \frac{\text{alg1} - \text{alg2}}{\text{alg1}}.$$

$\alpha = 2$	MIP vs. ISPT1	MIP vs. ISPT2	ISPT1 vs. ISPT2
# of Receivers	$\bar{x}$	$\bar{x}$	$\bar{x}$
5	19.4%	19.6%	-0.1%
10	14.6%	15.6%	0.8%
20	9.2%	11.7%	2.5%
50	1.5%	4.8%	3.2%
$\alpha = 4$			
5	11.2%	11.0%	-0.4%
10	7.3%	8.3%	0.9%
20	3.5%	5.6%	1.9%
50	-2.1%	1.4%	3.2%

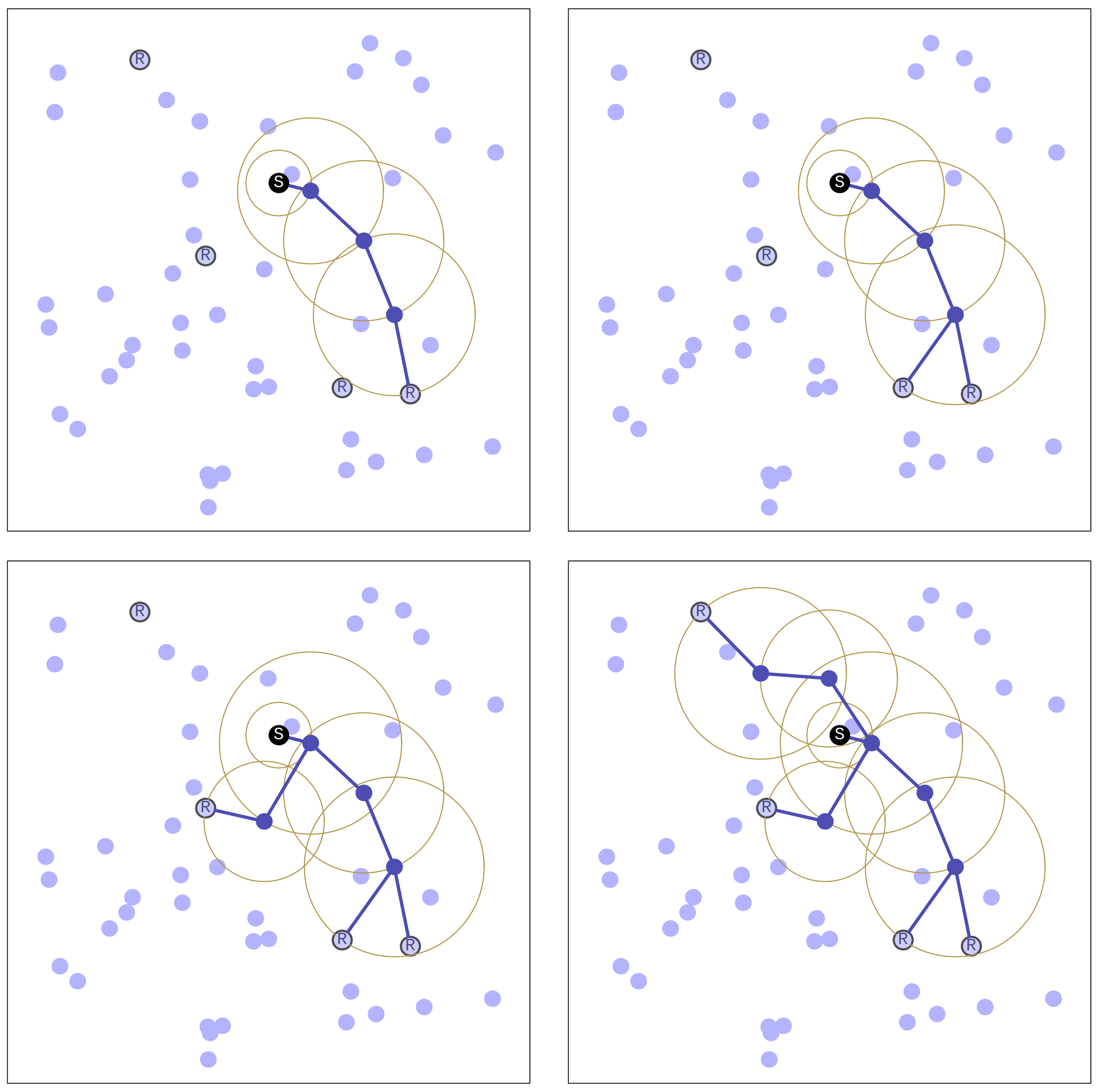

Figure 1: ISPT Example: Network of 50 nodes. Multicast receivers are marked with R and the source with S. Initial tree is the shortest path from the source to the furthermost receiver (ISPT2). The grafting is repeated iteratively by attaching a path connecting the tree to a receiver, for which the incremental path cost is lowest. Algorithm stops after all the receivers are connected.

Simulated annealing

- How far from the optimum are the trees produced by ISPT?
- Simulated annealing optimisation method to construct approximately optimal trees.
- On average, the ISPT2 performance is within 3% of the simulated annealing results.
- However, there are cases where the difference is nearly 30% due to the heuristic nature of ISPT.

Summary

- ISPT is simple and efficient for small receiver groups.
- An easy way of constructing a large set of energy efficient trees by changing the initial tree or grafting order.
- Distributed implementation requires
  - Unicast routing tables available at each node.
  - Some information needs to be relayed in the tree during its construction.

Acknowledgements

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References

[1] J.E. Wieselthier, G.D. Nguyen and A. Ephremides, *On the construction of energy-efficient broadcast and multicast trees in wireless networks*, In Proc. INFOCOM 2000, March 2000, pp. 585-594.