Maximizing the Probability of Delivery of MPR in Wireless Ad Hoc Networks with a Realistic Physical Layer

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Introduction

Overview of Ad Hoc Networks and Broadcasting

Physical Layer Models
- The Unit Disc Graph Model
- The Log-Normal Shadowing Model
- Comparison

MPR and the LNS Model
- The Multipoint Relay Protocol
- Performance of MPR with the LNS Model

New Heuristics for MPR
- Heuristics 1: Straightforward Approach
- Heuristics 2: Clever Approach
- Heuristics 3: Robustness Approach
- Energy Consumption

Conclusion
Ad Hoc Networks

- Composed by mobile devices
- Wireless communications, limited radius
- No infrastructure, no centralized information

They are represented by a graph $G = (V, E)$

- $V$ is the set of vertices (mobile devices)
- $E$ is the set of edges (available communications)
A good broadcasting algorithm must be:

- **Energy wise** - Energy is a very important resource
- **Reliable** - The target is a coverage of at least 95%
- **Fast** - The topology is not static
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The *Unit Disc Graph* (UDG) is the most spread physical model

**Definition**

Two nodes \( u \) and \( v \) can communicate together if the distance \( d(u, v) \) is not greater than the communication radius \( R \).
The *Log-Normal Shadowing* (LNS) Model

The probability of correct reception depends on many parameters, but an approximated function $P(x)$ can be used:

$$P(x) = \begin{cases} 1 - \frac{(\frac{x}{R})^{2\beta}}{2} & \text{if } x < R \\ \frac{(\frac{2R-x}{R})^{2\beta}}{2} & \text{otherwise} \end{cases}$$
### The UDG model
- It is very easy to simulate
- It cannot be considered as realistic!

### The LNS model
- It takes into account signal strength fluctuations
- We only add a weight (probability) on edges
- It is much more suited to simulations

*For clarity, we use \( p(u, v) \) instead of \( p(d(u, v)) \)*
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The Multipoint Relay Protocol (MPR) [Qayyum et al., 2002]

Algorithm for selecting relays

1. Mandatory 1-hop neighbors are chosen
2. 1-hop neighbors that cover the highest number of uncovered 2-hop neighbors are repeatedly chosen

Choices are forwarded within the broadcast packet
Only at most 70% of nodes are reached with LNS model!
**Average distance between a node and its relays (R = 75)**

The chosen relays are the **furthest** neighbors!
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Straightforward approach

- Replace the value used to choose relays at each iteration
- For a neighbor $v$ of a node $u$, compute a score $S(v)$ based on:
  - The probability $p(u, v)$
  - The coverage offered by the node $v$

$$S(v_1) = p(u, v_1) \times 3$$
$$S(v_2) = p(u, v_2) \times 1$$
Network coverage with LNS model

![Network coverage with LNS model](image-url)
Clever approach

- The distance between relays and the nodes they cover is not considered!
- For a neighbor \( v \) of a node \( u \), compute a score \( S(v) \) based on:
  - The probability \( p(u, v) \)
  - The average ‘coverage probability’ provided by the node \( v \)

\[
S(v_1) = p(u, v_1) \times \frac{p(v_1, w_1) + p(v_1, w_2) + p(v_1, w_3)}{3}
\]

\[
S(v_2) = p(u, v_2) \times p(v_2, w_3)
\]
Network coverage with LNS model
Robustness approach

- The broadcast can be stopped by one bad reception!
- We introduce the concept of ‘coverage level’: 2-hop neighbors are removed only when the probability to cover them is high enough.

\[ CL(w_3) = 1 - (p(v_1, w_3) \times p(v_2, w_3)) \]

Under the UDG model, all these heuristics give the same results.
Network coverage with LNS model
**Percentage of transmitters with LNS model (1)**

![Graph showing percentage of transmitters with LNS model]

*Only receivers are taken into account!*
With only a few redundant transmitters, a far better coverage is achieved!
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- The MPR original heuristics does not suit to LNS model
- It can be replaced by a better one which:
  - Chooses almost the same quantity of relays
  - Greatly improves the coverage of the network

Future work

- Analyze the impact on OLSR?
- Analyze other protocols under the LNS model
- Improve them?
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