Neighbor Discovery in Multichannel Wireless Clique Networks: an Epidemic Approach

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Outline

1. Background

2. Multichannel epidemic neighbor discovery via coupon collector

3. MEDAL: Multichannel Epidemic Neighbor Discovery Algorithm

4. Experimental evaluation

5. Conclusions
Which are my neighbors (each node) ?
- discovery implies reception of a message from a neighbor !

**Fast** and a good **network knowledge** → **robustness, reliability**
- implies saving energy and faster network updates
Motivating example: slotted-Aloha

$N_i$ wants to discover the IDs of all its neighbors

- clique network, half-duplex transceivers, and unique IDs
- slotted-aloha operation

$$P_s = p(1 - p)^{n-1} \approx \frac{1}{ne}$$
**Coupon Collector**: $N_i$ wants to discover the IDs of all its neighbors [1] [2]

- $t_i$ - Geometric R.V. with parameter $(n - i)P_s$, and $E[t_i] = \frac{1}{(n-i)P_s}$
- $E[T] = \sum_{i=0}^{n-1} E[t_i] = \frac{1}{P_s} \sum_{j=0}^{n} \frac{1}{j} = ne (\ln n + \Theta(1))$

1 Vasudevan et. all 2009
For Wireless Sensor Networks, **energy conservation is key**

- reducing $T$ implies **saving energy** and **faster network updates**
- increasing $n$ increases $T$, because, $P_s$ decreases! **we need a better alternative**

$$E[T] = ne (\ln n + \Theta(1))$$
Contributions

1. multichannel epidemic neighbor discovery via coupon collector
2. multichannel epidemic neighbor discovery algorithm
3. impact of epidemics and the number of channels on $T$
4. experimental evaluation
How to reduce \( T \): approach

**multichannel communications + epidemic dissemination**

- multichannel communications alone cannot reduce \( T \! \)
  - fixed network size + arbitrary large number of channels: nodes meet less frequently

- epidemic dissemination: **use of indirect discovery**
Multichannel epidemic neighbor discovery via coupon collector

- $N$-nodes
- $k$-channels

Phase 1: multichannel coupon collector
Phase 2: epidemic dissemination coupon collector
Phase 3: broadcast

$E[T] = E[T_1] + E[T_2] + E[T_3] = e^{N/k} (\ln \frac{N}{k} + \Theta(1)) + ke (\ln k + \Theta(1)) + 1$

- theoretical benchmark
How to choose $k$ given $N$

\[ E[T] = e^{\frac{N}{k}} \left( \ln \frac{N}{k} + \Theta(1) \right) + k e^{\ln k + \Theta(1)} + 1 \]
Multichannel epidemic neighbor discovery via coupon collector

\[ E[T] = e^{\frac{N}{k}} \left( \ln \frac{N}{k} + \Theta(1) \right) + ke \left( \ln k + \Theta(1) \right) + 1 \]

- in practical scenarios is difficult to implement phases!
- **next section**: consider application in realistic scenarios!
MEDAL: Multichannel Epidemic Neighbor Discovery Algorithm

- example for $N = 6$, and $K = 2$

<table>
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<th>T=2</th>
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<td>4-()</td>
<td>6-(5)</td>
<td>*5-(4)</td>
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<tr>
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<td>3-()</td>
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<td>*2-(1,4,5)</td>
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<td></td>
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<td>5-()</td>
<td>4-(1)</td>
<td>5-(4)</td>
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</tr>
</tbody>
</table>

- synchronous and **single phase** algorithm
- **nodes choose channel** $k_i$ **uniformly at random**
- allows discovery of more than a node in a time-slot
- **epidemic behavior**
  - **Tx packet includes list of known neighbors**
Multichannel Neighbor Discovery **without epidemics**

- multichannel comm. alone is worse than single channel discovery
multichannel comm + epidemics is better than single channel discovery

**Note:** for $N \leq 5$ a single channel ($K = 1$) solution is better
MEDAL: impact of *epidemics* and *K*

Fraction of neighbors discovered for $N = 30, K = 8$

- 5X faster than single channel discovery
TestBed evaluation

- Contiki OS
- 30 TelosB motes
- C source code and Python scripts available upon request
Conclusions and future work

Conclusions

- we proposed a protocol for **neighbor discovery in multichannel networks with epidemic information dissemination** that reduces the **neighbor discovery time significantly** compared to single channel solution.

- experimental evaluations of the proposed protocol

- MEDAL can be used to extend the beaconing mechanism in the 802.15.4e standard

Future work

- include **loss probability** on comm. links

- consider networks other than clique
Thank You For Listening