Neighbor Discovery in Multichannel Wireless Clique Networks: an Epidemic Approach

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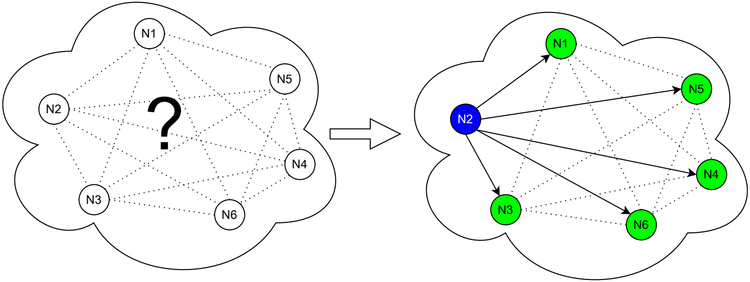
Outline

1. Background
2. Multichannel epidemic neighbor discovery via coupon collector
3. MEDAL:Multichannel Epidemic Neighbor Discovery Algorithm
4. Experimental evaluation
5. Conclusions

Distributed ad-hoc communications

Short range or local communications in ad-hoc manner



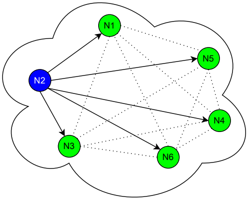
Which are my neighbors (each node) ?

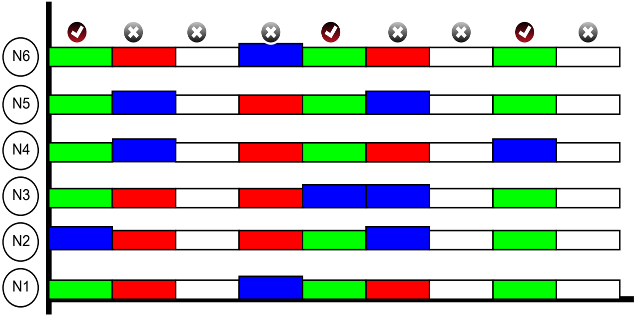
- discovery implies reception of a message from a neighbor !

Fast and a good **network knowledge** → **robustness, reliability**

- implies saving energy and faster network updates

Motivating example: slotted-Aloha



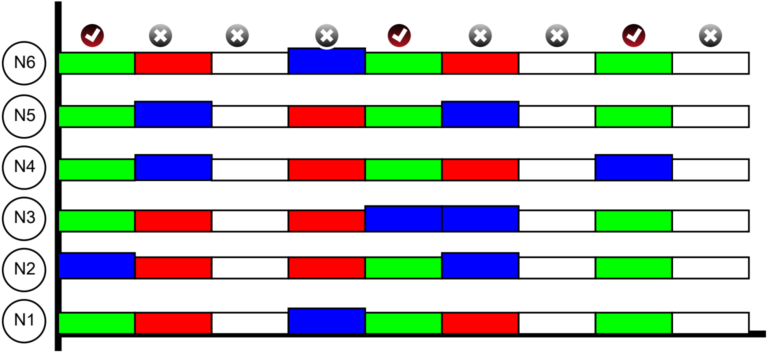


N_i wants to discover the *IDs* of all its neighbors

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

$$P_s = p\,(1-p)^{n-1} \approx \frac{1}{ne}$$

Coupon collector: single channel neighbor discovery

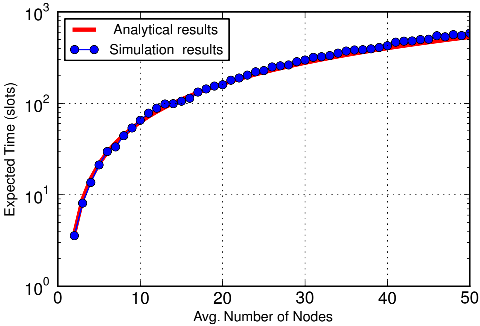


Coupon Collector: N_i wants to discover the *IDs* of all its neighbors [1][1] [2]

- 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

Single channel neighbor discovery



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

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**

Contributions

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

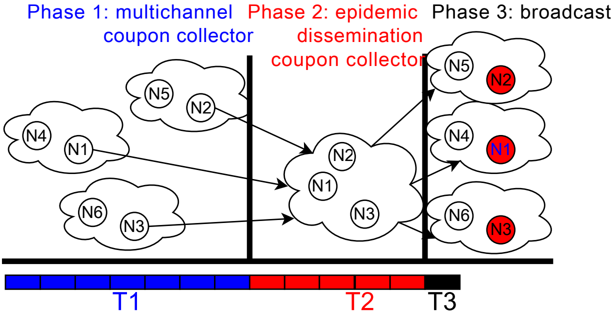
How to reduce T: approach

multichannel communications **+ e**pidemic 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

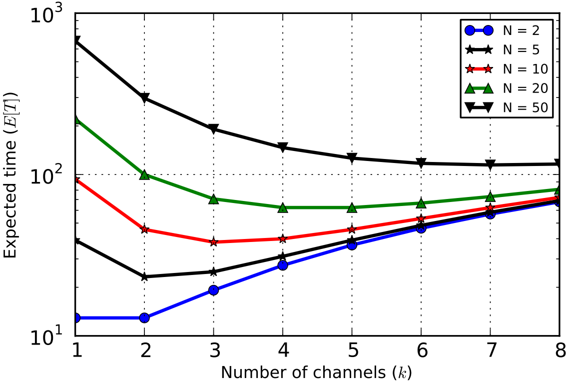
- N-nodes
- k-channels



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

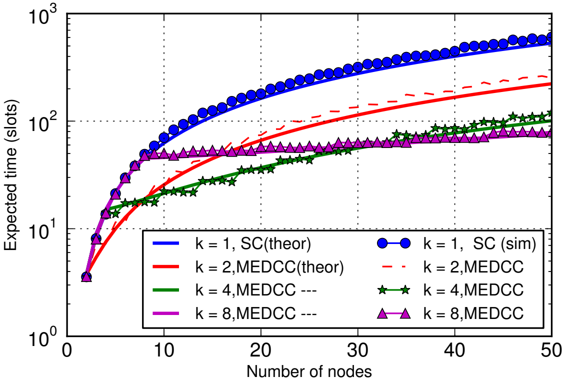
- **theoretical benchmark**

How to choose k given N



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

Multichannel epidemic neighbor discovery via coupon collector

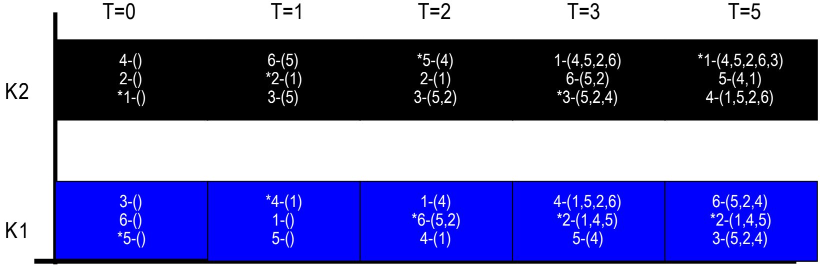


$$E[T] = e\frac{N}{k}\left(\ln\frac{N}{k} + \Theta(1)\right) + ke\left(\ln k + \Theta(1)\right) + 1$$

- in practical scenarios is difficult to implement phases !
- **next section**: consider application in realistic scenarios!

MEDAL: Multichannel Epidemic Neighbor Discovery Algorithm

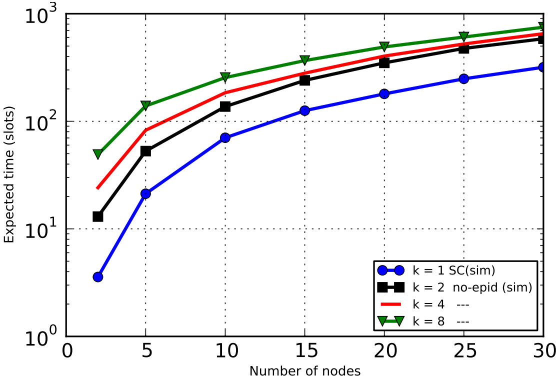
- example for $N = 6$, and $K = 2$



- 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**

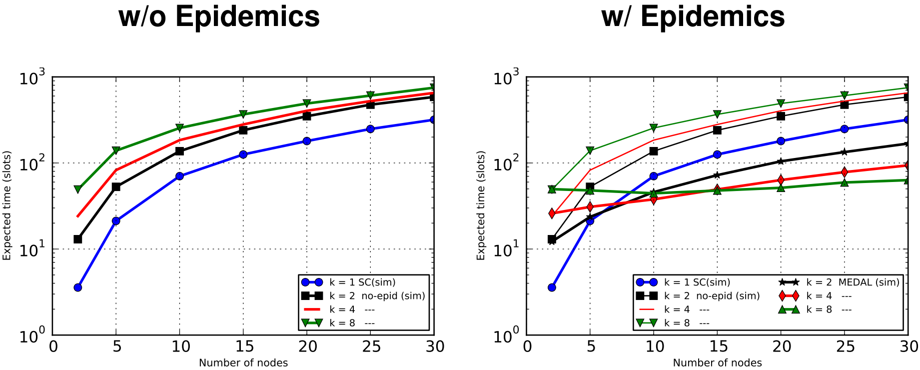
MEDAL: multichannel comm. alone cannot reduce T

Multichannel Neighbor Discovery **without epidemics**



- **multichannel comm. alone is worse than single channel discovery**

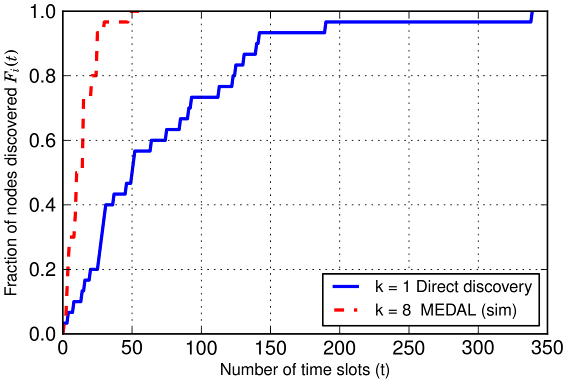
MEDAL: multichannel comm. + epidemics



- multichannel comm + epidemics is better than single channel discovery
- **Note:** for $N <= 5$ a single channel ($K = 1$) solution is better

MEDAL: impact of **epidemics** and **K**

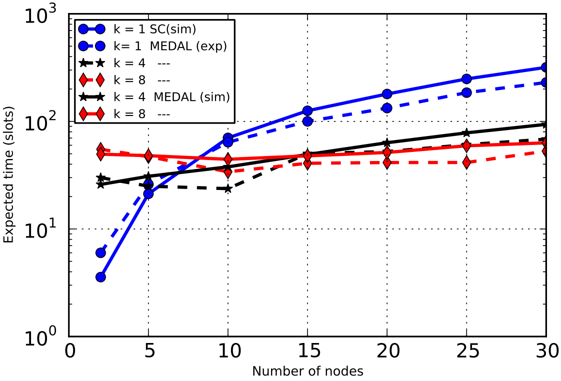
Fraction of neighbors discovered for $N = 30, K = 8$



- $5X$ 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

Questions?

Thank You For Listening

References

S. Vasudevan, D. Towsley, and D. Groeckel, “Neighbor discovery in wireless networks and the coupon collector’s problem,” *In Proc. of ACM MobiCom*, pp. 181–192, 2009.

M. Mitzenmacher and E. Upfal, *Probability and Computing: Randomized Algorithms and Probabilistic Analysis*. Cambridge University Press, April 2005.