

Neighbor Discovery in Multichannel Wireless Clique Networks: an Epidemic Approach

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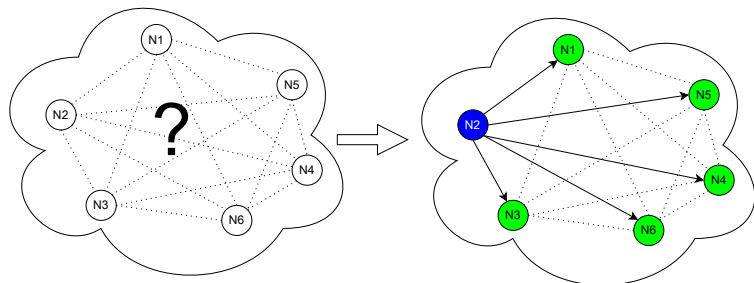
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- 1 Background
- 2 Multichannel epidemic neighbor discovery via coupon collector
- 3 MEDAL:Multichannel Epidemic Neighbor Discovery Algorithm
- 4 Experimental evaluation
- 5 Conclusions

Distributed ad-hoc communications

Short range or local communications in ad-hoc manner



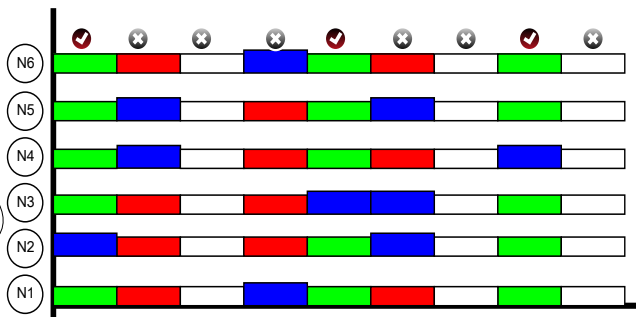
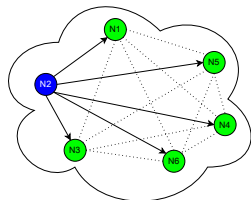
Which are my neighbors (each node) ?

- 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

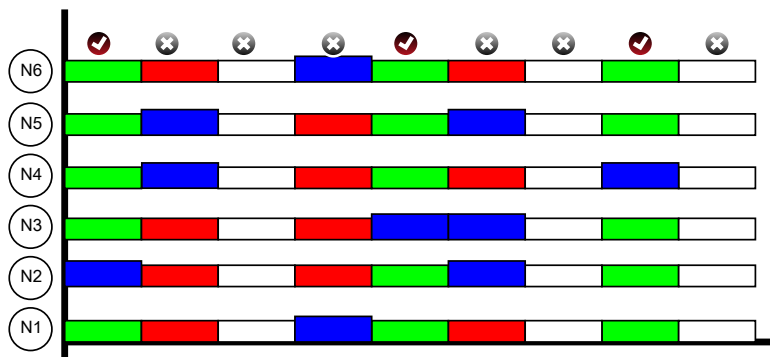


N_i wants to discover the *IDs* of all its neighbors

- 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

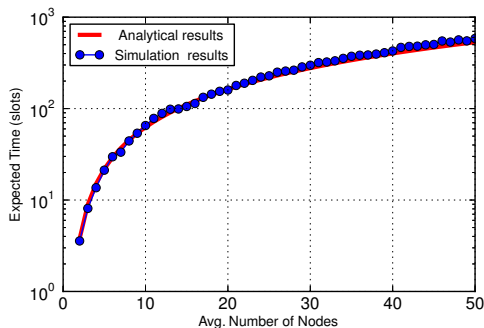


Coupon Collector: N_i wants to discover the *IDs* of all its neighbors
[1]¹ [2]

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

¹Vasudevan et. al 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

- 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

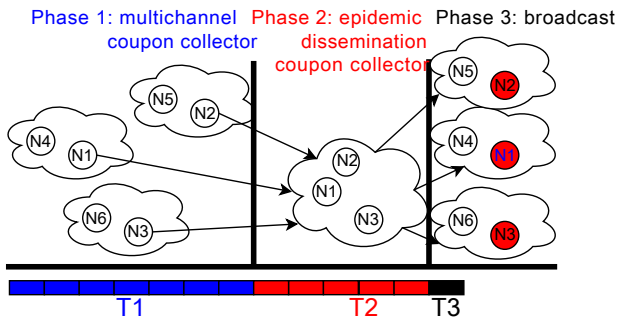
How to reduce T : approach

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

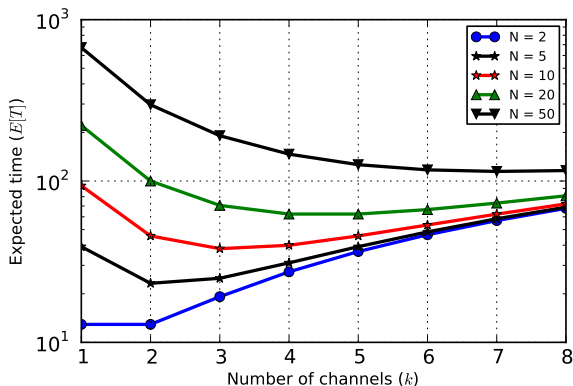
- N -nodes
- k -channels



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

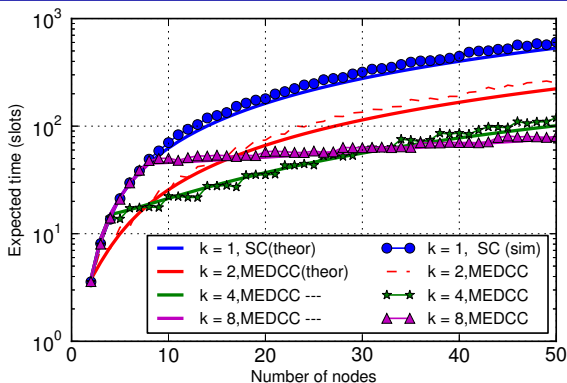
- **theoretical benchmark**

How to choose k given N



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

Multichannel epidemic neighbor discovery via coupon collector



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

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

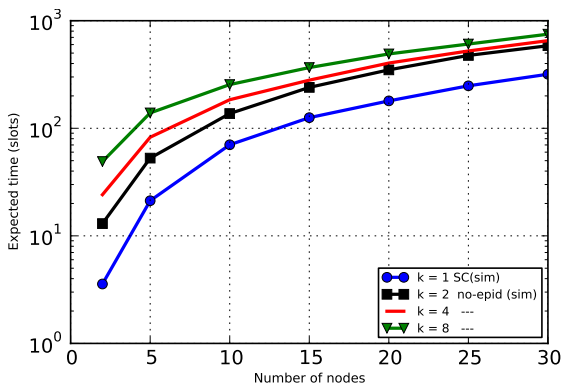
MEDAL: Multichannel Epidemic Neighbor Discovery Algorithm

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

	T=0	T=1	T=2	T=3	T=5
K2	4-() 2-() *1-()	6-(5) *2-(1) 3-(5)	*5-(4) 2-(1) 3-(5,2)	1-(4,5,2,6) 6-(5,2) *3-(5,2,4)	*1-(4,5,2,6,3) 5-(4,1) 4-(1,5,2,6)
K1	3-() 6-() *5-()	*4-(1) 1-() 5-()	1-(4) *6-(5,2) 4-(1)	4-(1,5,2,6) *2-(1,4,5) 5-(4)	6-(5,2,4) *2-(1,4,5) 3-(5,2,4)

- 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**

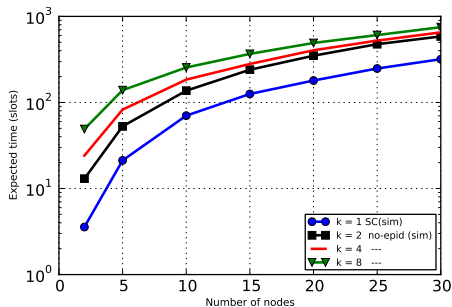
Multichannel Neighbor Discovery **without epidemics**



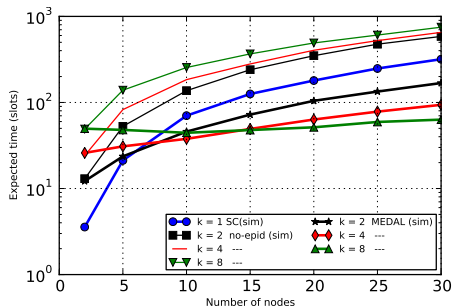
- **multichannel comm. alone is worse than single channel discovery**

MEDAL: multichannel comm. + epidemics

w/o Epidemics



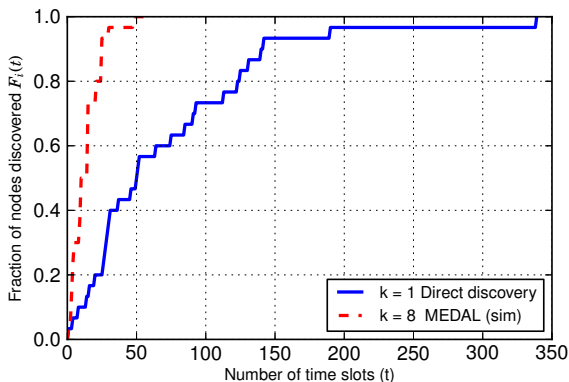
w/ Epidemics



- 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

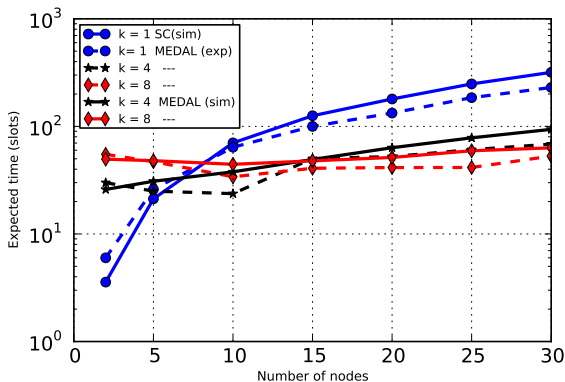
Fraction of neighbors discovered for $N = 30, K = 8$



- 5X faster than single channel discovery

TestBed evaluation

- Contiki OS
- 30 TelosB motes
- **C** source code and **Python** scripts available upon request



Conclusions



- 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

-  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.