Monitoring Churn in Wireless Networks

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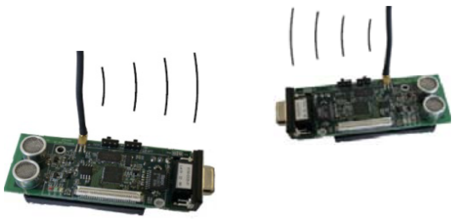
Motivation / Intro

Network of sensor nodes:

- measuring certain properties of their environment
- wireless, communicating on several channels
- battery powered

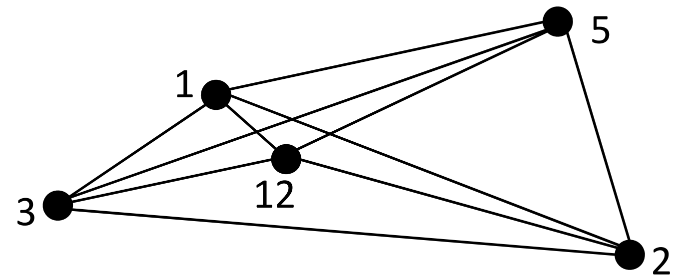


Nodes might fail / nodes may be added

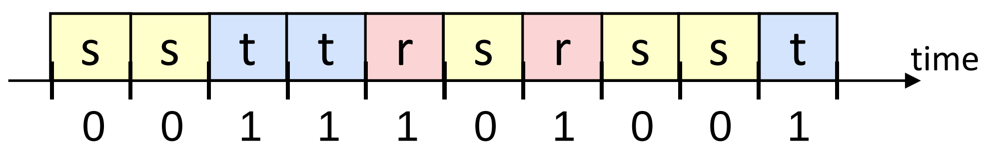
All nodes should be aware of all present nodes

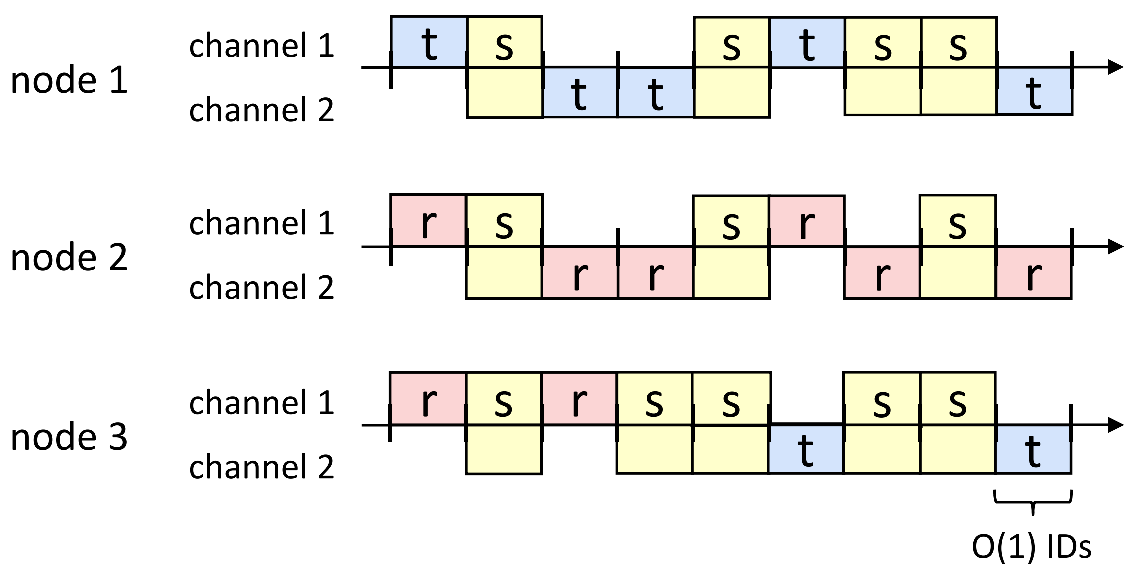
- with small delay
- with little energy consumption
- using few channels for communication

Model



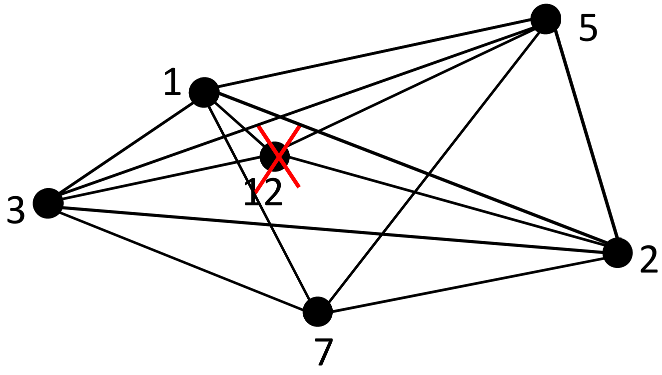
- n nodes with IDs
- single-hop
- synchronized time slots
- transmit / receive / sleep
- energy 1 / 1 / 0
- local computations free
- k channels
- no collision detection
- bounded message size





Model cont’d

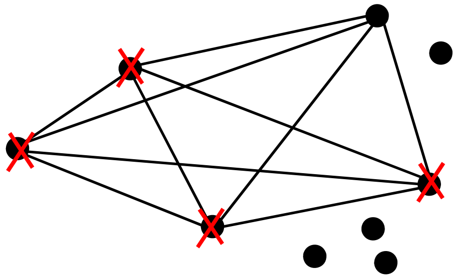
Nodes may join or crash at any time



churn = joins and crashes

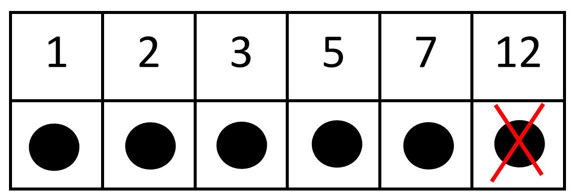
burst = large number of joins and crashes in short time

Adversary:
May let nodes crash or join in order to make an algorithm fail



Goal

Every node must know the IDs of all nodes currently in the network



Simple Lower Bounds

What time / energy is at least necessary in this model?

• every node can only receive one message per time slot containing at most a constant number of IDs

→ on average only constant rate of churn tolerable per time slot

→ $\Omega(b)$ time slots necessary to learn about b joins / crashes

→ every node needs $\Omega(b)$ energy units to learn about b joins / crashes

Results

Our Monitoring Algorithm:

- tolerates churn bursts in any order of magnitude
- is deterministic except for detection of joining nodes
- handles asymptotically maximum average rate of churn tolerable in this model
- after each burst of size b it takes
  - $O(b + \log n)$ time slots and
  - $O(b + \log n)$ energy per node

until all nodes have updated their ID table (optimal up to additive logarithmic term)

- needs $\Theta(n/\log n)$ channels

Results cont'd

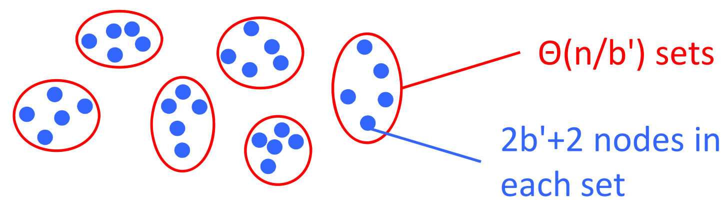
Our Monitoring Algorithm:

- can get by with less than Θ(n/log n) channels:
- k channels available → time $O\left(b + \frac{n}{k}\log\left(\frac{b}{\log n}\right)\right)$.

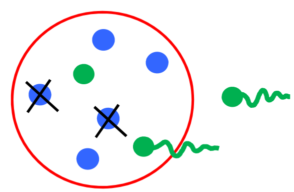
Monitoring Algorithm

- burst size is assumed to be b'=log n

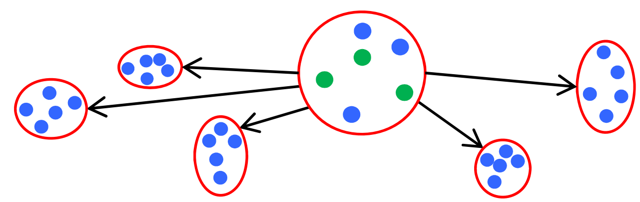
- nodes partitioned into n/(2b'+2)-1 sets



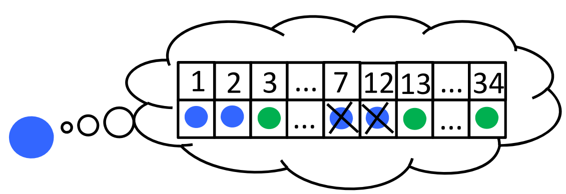
- each set detects crashed and joined nodes on its own channel



- disseminate information to all nodes



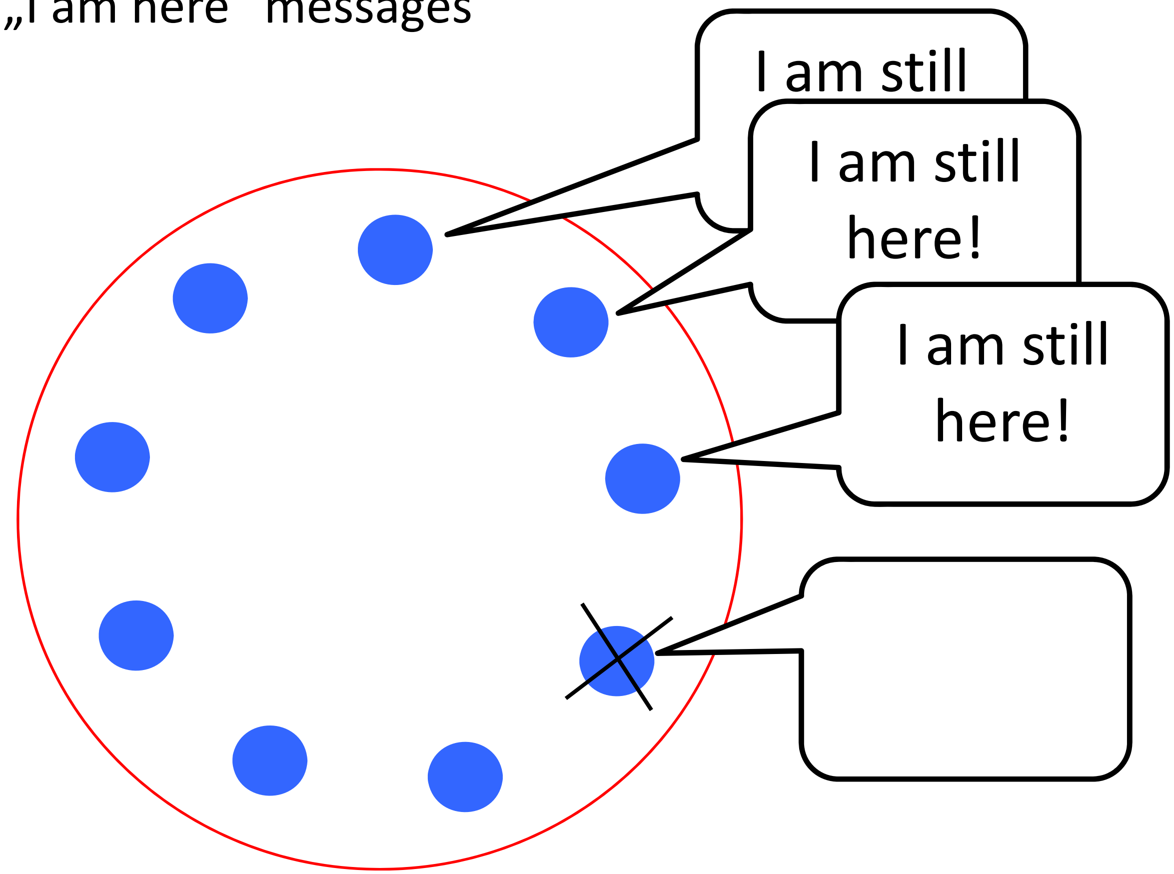
- all nodes update ID table



- double b' if algo did not work

Crash Detection

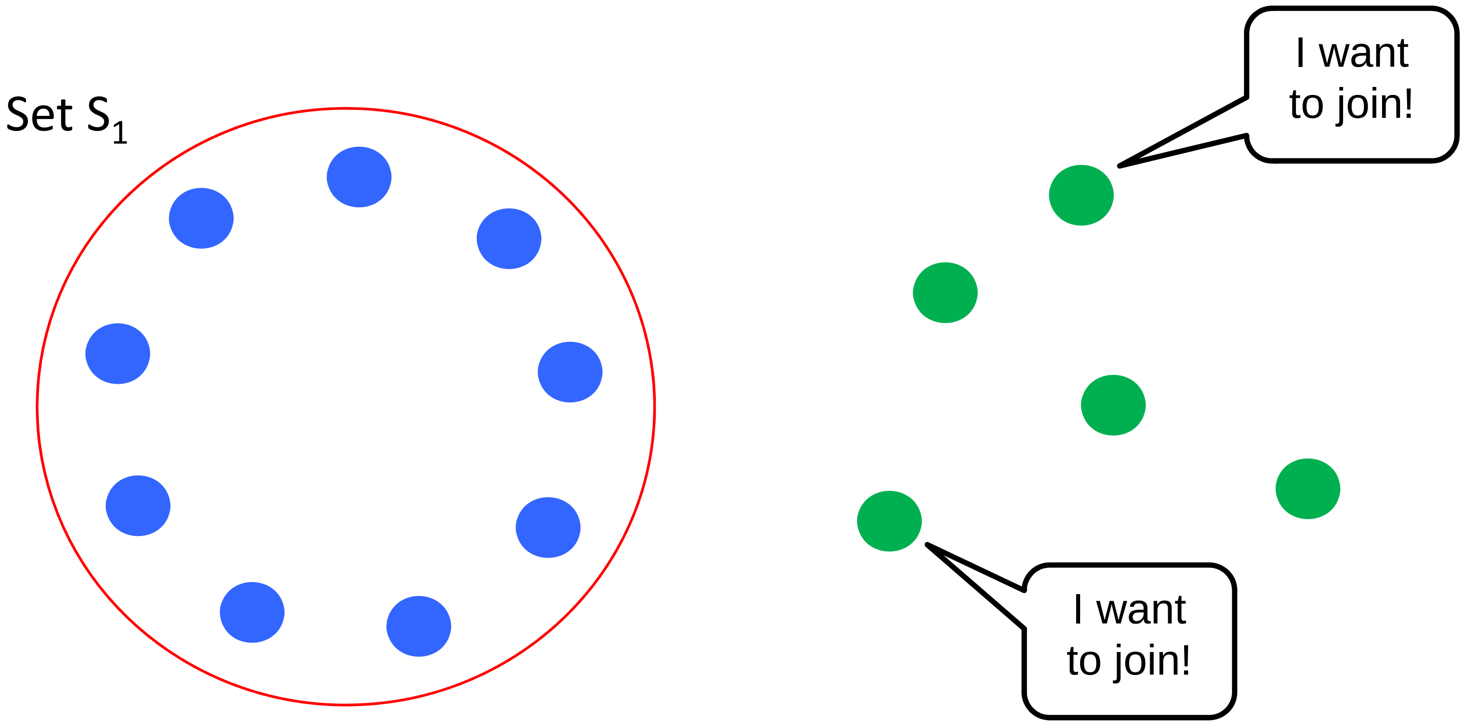
- nodes send „I am here“ messages



- min(2b'+2,n) time slots necessary

Join Detection

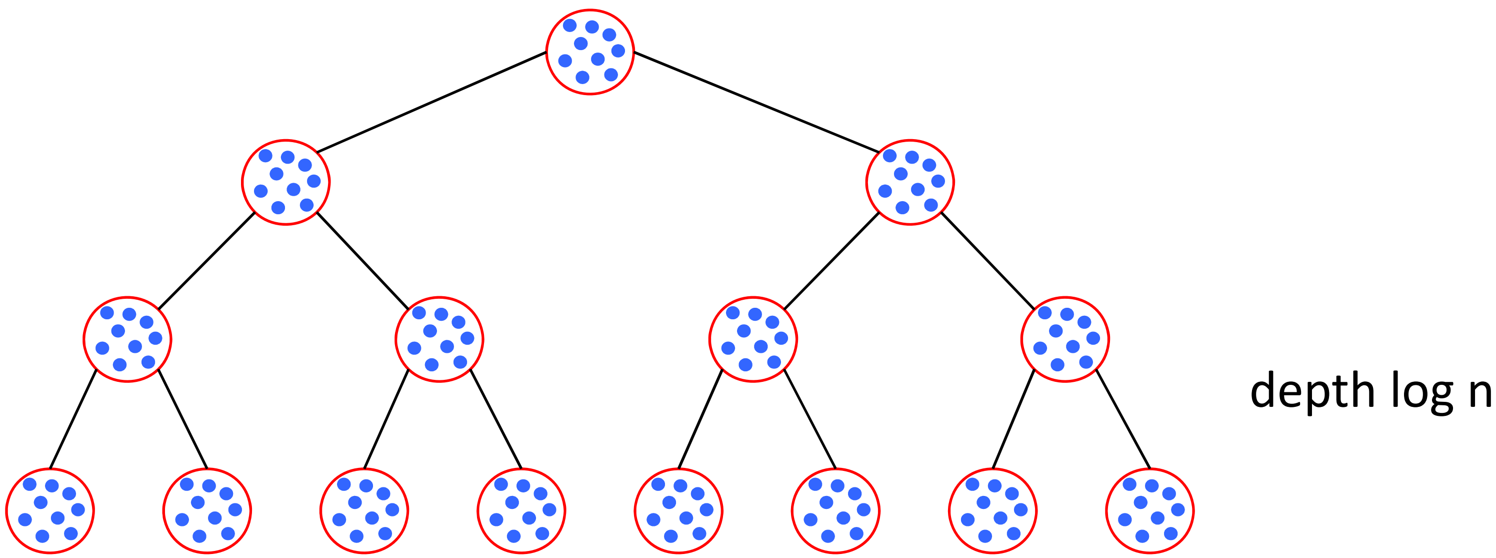
- joiners send join requests to with S_1 with probability 1/b'



- b' in Ω(b) → in constant number of rounds at least 1 joiner

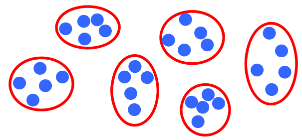
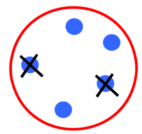
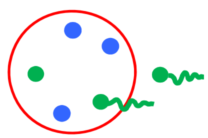
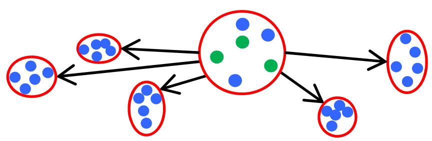
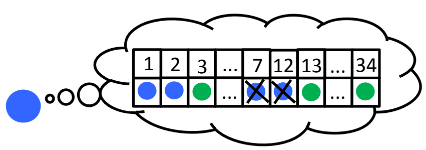
Information Dissemination

- every set becomes vertex of balanced binary tree



- every set forwards information on node v with smallest ID first
- information on v disseminated after O(log n) time slots
- all information disseminated after O(log n + b') time slots

Monitoring Algorithm

Step		Time
• b' = log n		O(1)
• partitioning		O(1)
• crash detection		O(min(b', n))
• join detection		O(b' + log n)
• dissemination		O(b' + log n)
• update ID table		O(1)
• double b'		O(1)

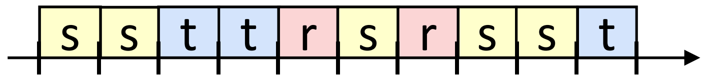
log(b/log n) times
⇩
runtime O(b + log n)

What if critical nodes crash?

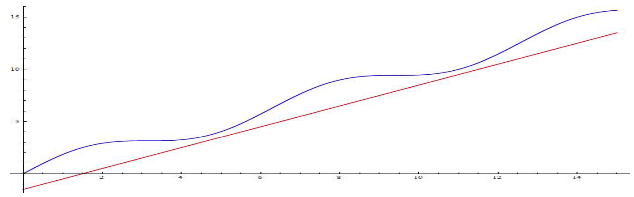
- in each set node which is responsible for communication with other sets = representative
- all other nodes replacements
- replacements take over if representative does not send
- delay of at most b'
- still runtime of O(b' + log n) per round

Conclusions & Future Work

- Model

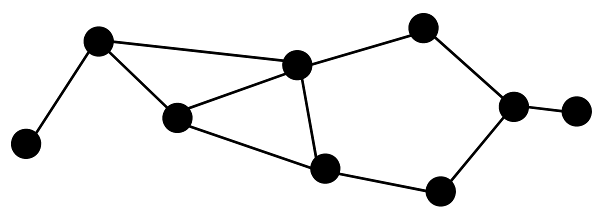


- Lower Bounds



- Monitoring Algorithm

- Future Work: Multi-hop



Thank You!

Questions & Comments?

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