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Algorithms for Radio Networks

Wireless Sensor Networks: Lifetime

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Energy Saving Methdos

- **Schedule for sleep cycles**
  - MAC, routing protocol, sensoring
- **Optimize transmission routes**
  - many hops of few hops
- **Selection of nodes depending on the charge battery status**
  - data acquisition
  - change of cluster heads
  - route choice may consider battery status
- **Reduction of the amount of data**
  - data aggregation
  - compression
  - filtering

Lifetime of a Sensor Network

- **Wireless Sensor Networks (WSN)**
  - cheap and energy optimized sensors
  - send data to sinks
- **Lifetime of the network**
  - is hard to analyze
- **Depends from**
  - network architecture, protocols
  - event or input behavior
  - definition of lifetime
  - hardware, channel characteristics

Lifetime

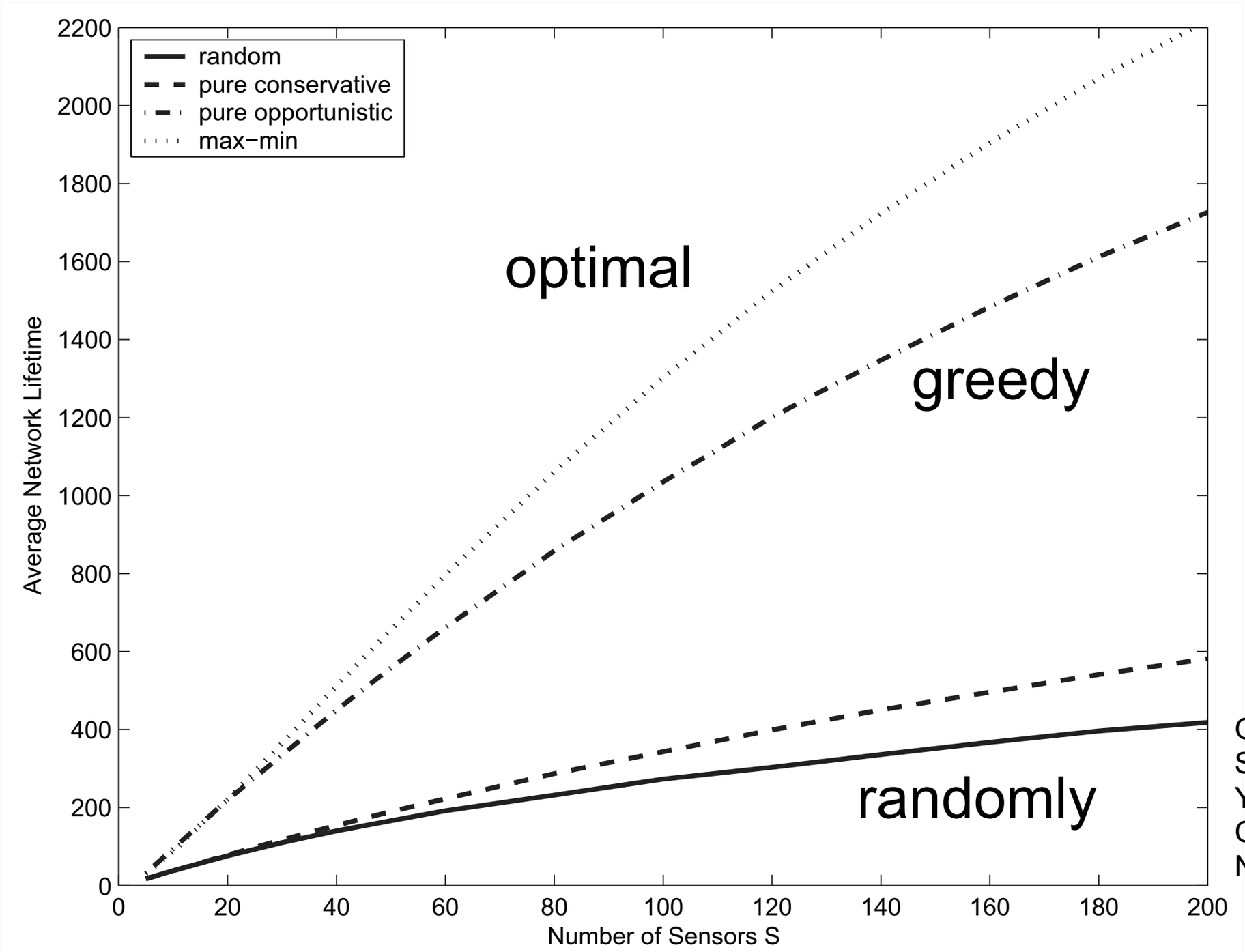
- **On the Lifetime of Wireless Sensor Networks**
  - Yunxia Chen, Qing Zhao, Communication Letters, Vol. 9, No. 11, Nov. 2005
- **Theorem**
  - For a WSN where
    - E_0: non-rechargable inital energy E_0
    - P_c: constant continuous power consumption in the complete network
    - **E**[E_w]: expected waste of energy
    - λ: average number of reported events
    - **E**[E_r]: expected energy necessary to report an event

$$E[\mathcal{L}] = \frac{\mathcal{E}_0 - E[E_w]}{P_c + \lambda E[E_r]}$$

Greedy Lifetime Maximization

- **Question**
  - Which sensors should collect the data
- **Greedy Algorithmus**
  - Choose the sensor with the maximum energy efficiency index γ_i:
  - $$\gamma_i = e_i - E_r(c_i)$$
  - $E_r(c_i)$: Energy for the transport of a message for node i
  - e_i: Available energy at the node i

Performance Greedy-Algorithm

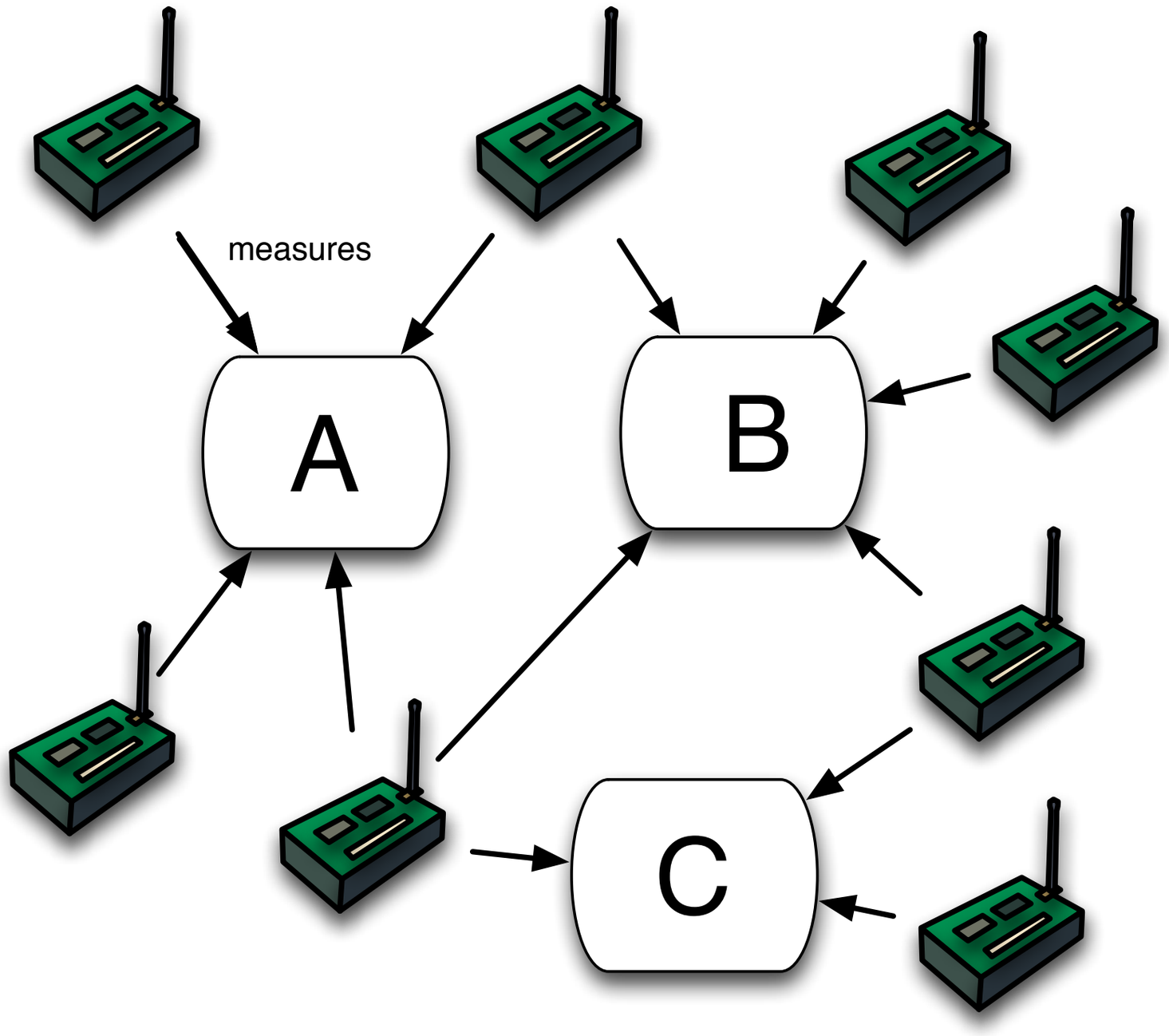


On the Lifetime of Wireless Sensor Networks
Yunxia Chen, Qing Zhao,
Communication Letters, Vol. 9, No. 11, Nov. 2005

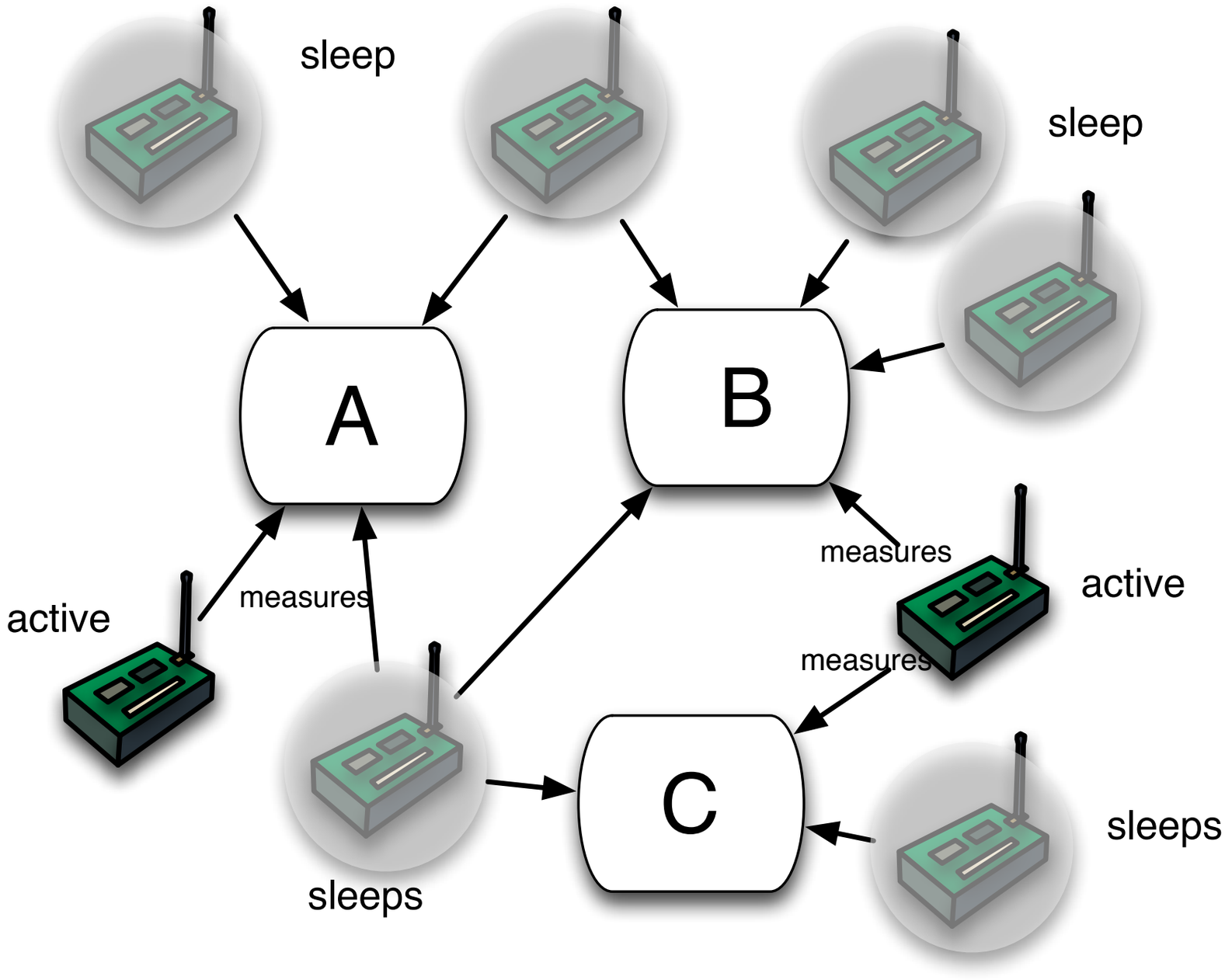
Lifetime Maximization by Scheduling

- **Cardei, Du**
  - *Improving Wireless Sensor Network Lifetime through Power Aware Organization*, Wireless Networks 11, 333–340, 2005
- **Problem**
  - Measurement points are covered by more than one sensors
  - Multiple measurements waste energy
- **Solution**
  - Activate only the nodes with minimum set-cover

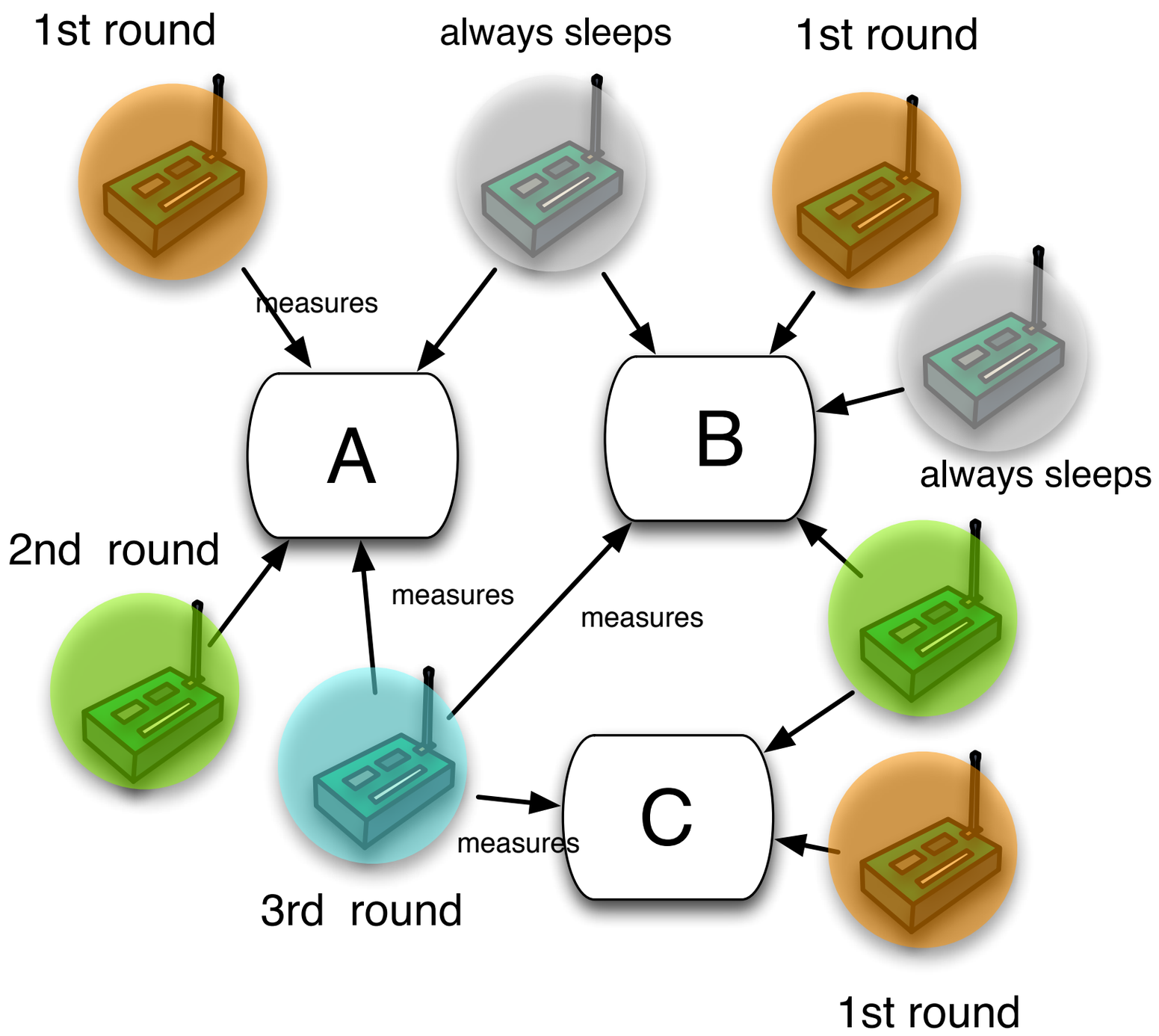
Multiple Coverage of Sensors



Covering Set



Disjoint Set-Cover



Definition Disjoint Set-Cover (DSC)

- **Given**
  - n sensors $S=\{S_1, S_2, ..., S_n\}$
  - m measurement points $T=\{T_1, T_2, ..., T_m\}$
  - Sensor coverage $S_i \subseteq T$
- **Compute**
  - Maximal number of disjoint coverings, i.e.
    - disjoint sets $M_1, .., M_k$ from S, such that each set covers the set T
- **Motivation**
  - The network lifetime increases by a factor of k

Complexity von Disjoint Set-Cover (DSC)

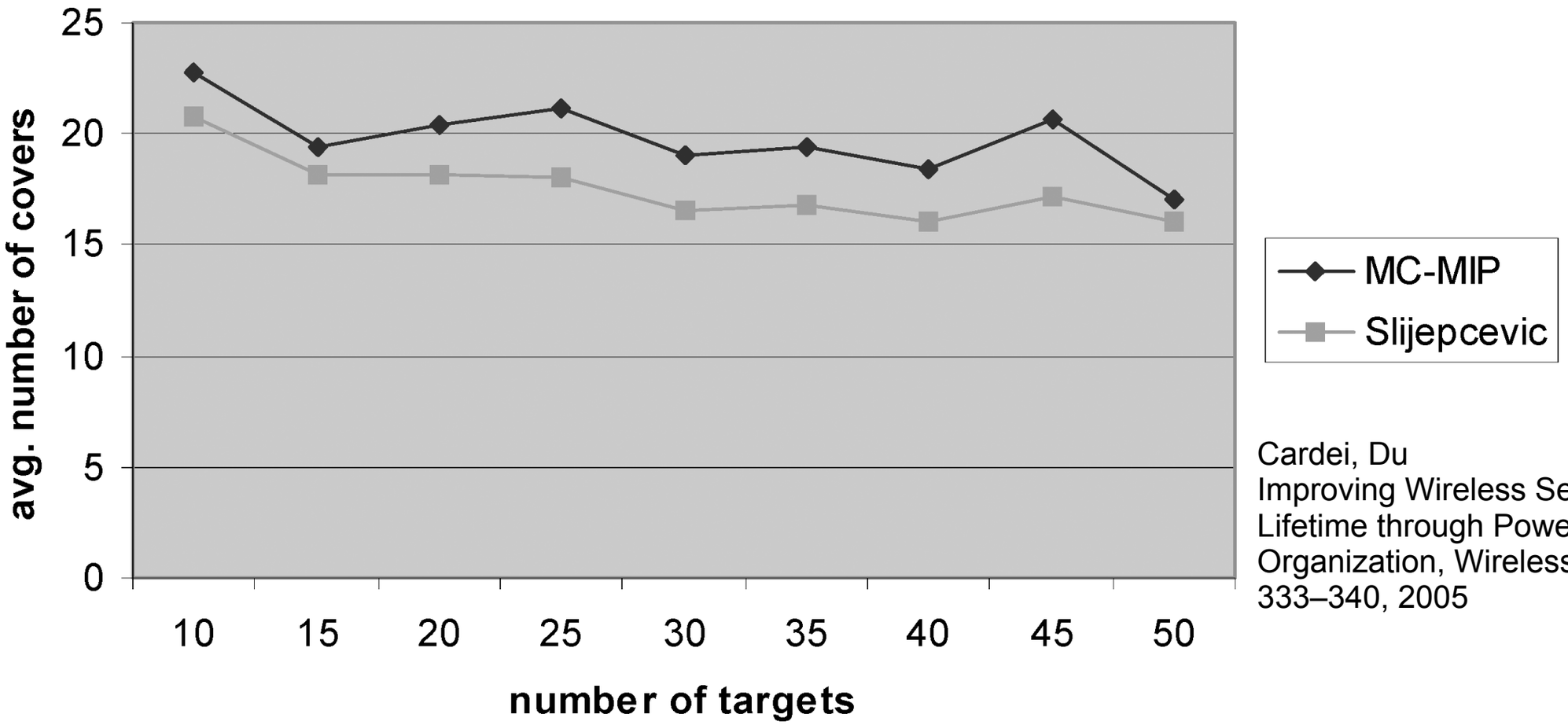
- **Theorem**
  - DSC is NP-hard for two sets
  - DSC is in general NP-hard
  - DSC can not be approximated by a factor of 2 without solving an NP-hard problem
- **Several heuristics are known**

Heuristiks for DSC

- **Slijepcevic Potkonjak 2001**
  - *Power Efficient Organization of Wireless Sensor Networks*, IEEE International Conference on Communications
  - Greedy algorithm
    - Greedily selects a mimal covering set
    - Removed this one and repeated until no more covering set is found
- **Cardei, Du 2006**
  - Problem is represented as flow problem
  - This is solved as linear problem
  - The solution gives an approximation of the disjoint set-cover problem

Comparison

- **Slijepcevic Potkonjak 2001**
  - simple distributed greedy solution
- **Cardei, Du 2006**
  - MC-MIP complex central algorithm

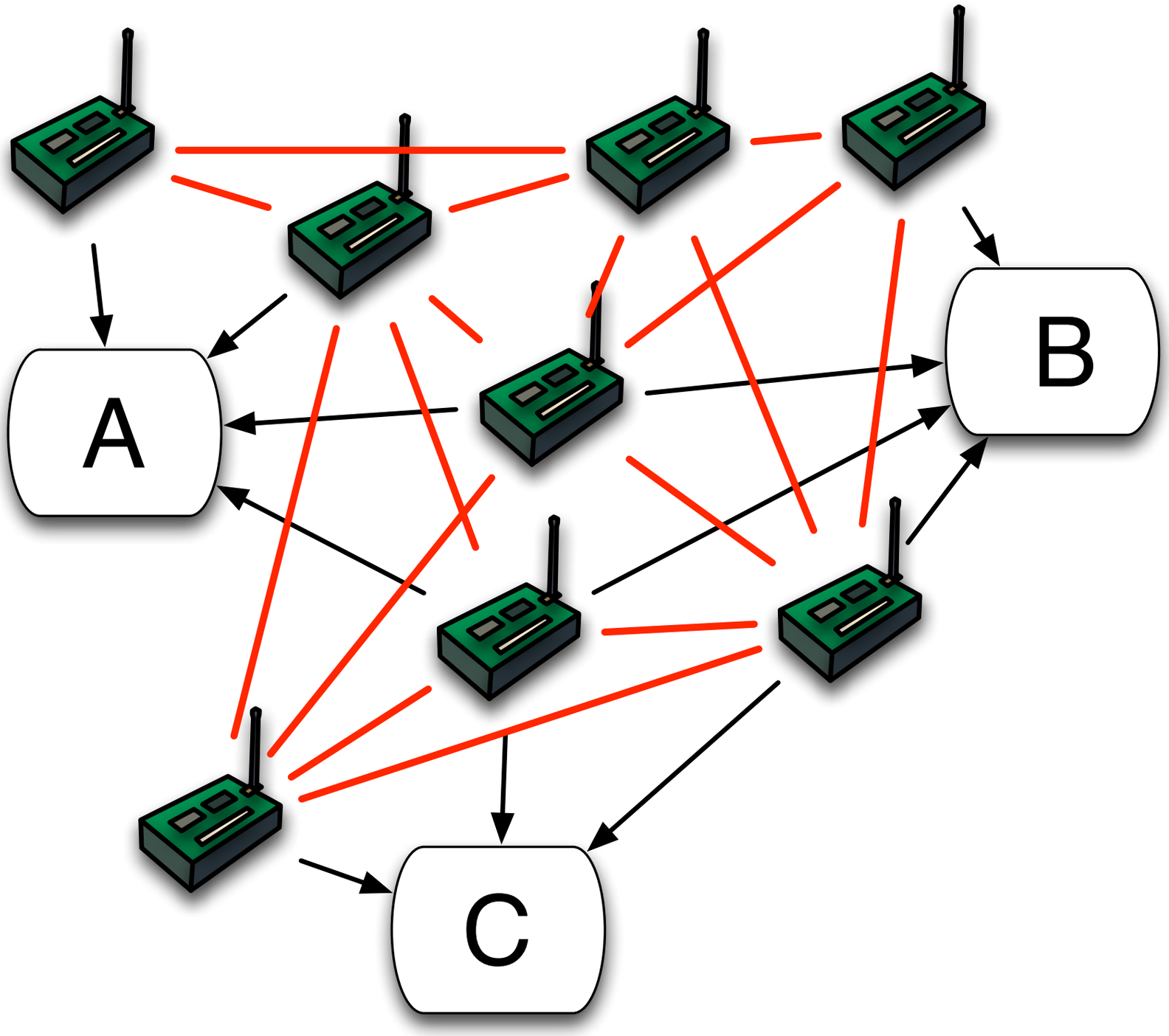


Cardei, Du
Improving Wireless Sensor Network Lifetime through Power Aware Organization, Wireless Networks 11, 333–340, 2005

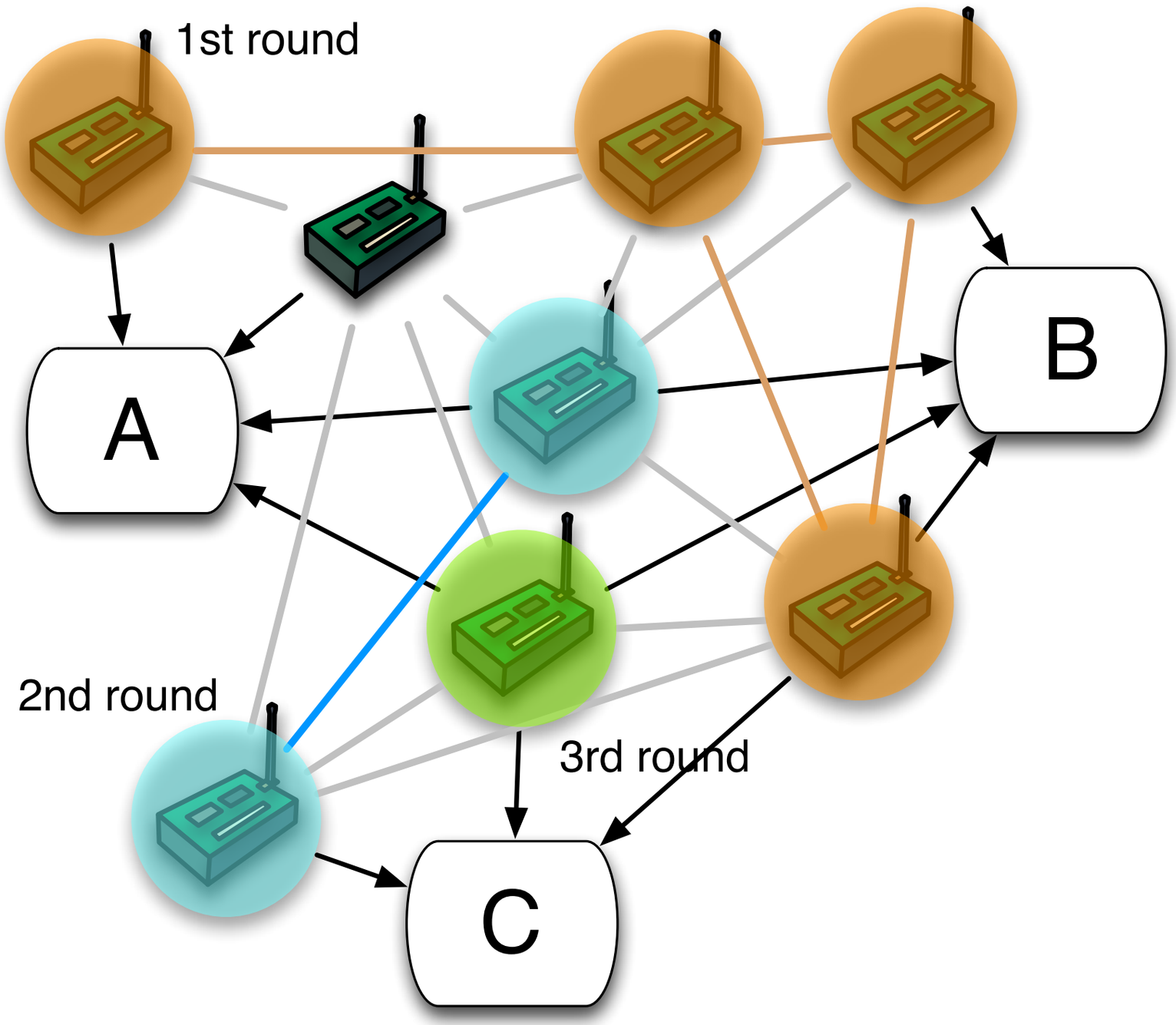
Outlook

- **Disjoint sets of network nodes may not be useful**
  - might be too far away from each other
  - important relay nodes are not activated
- **Extension**
  - Disjoint Connected Set Problem::
    - Find vertex-connected subgraph
      - Also NP-hard
- **Similar heuristics exist**

Disjoint Connected Set Problem



Disjoint Connected Set Problem



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