Organic Principles in Complex Networks

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SPP 1183 Fifth Colloquium
Organic Computing,
13.-14.09.2007, Lübeck

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Outline

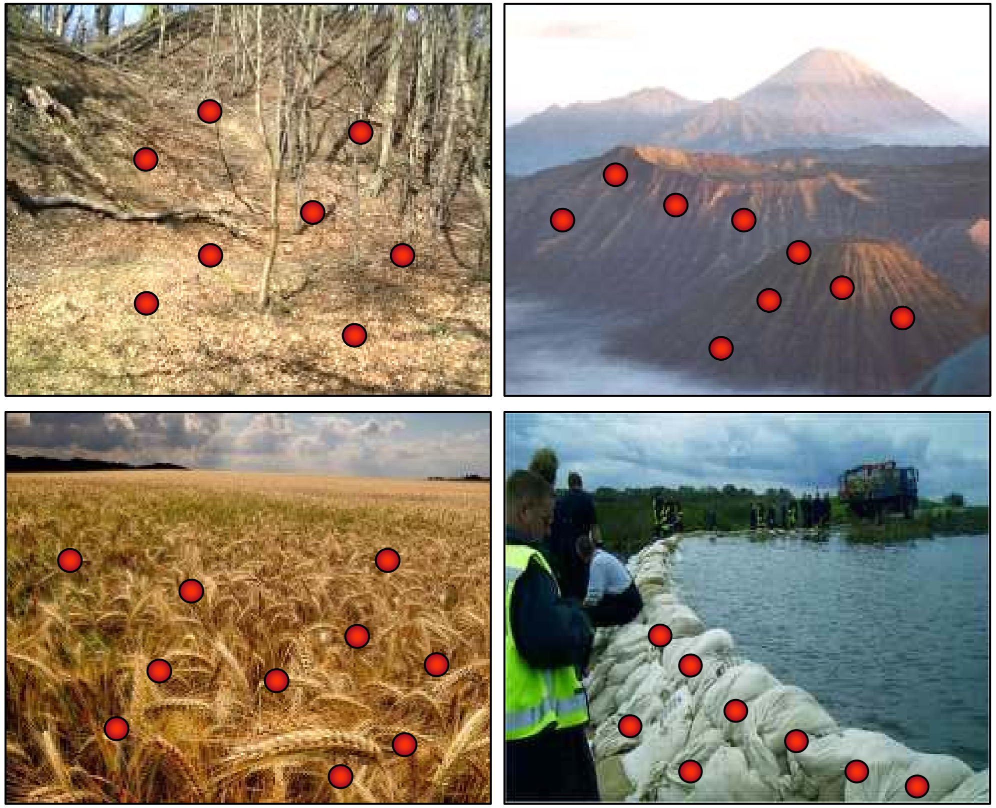
- Project Introduction
- Adopted OC Principles (First Project Phase)
  - Role Assignment/Role Changing, Flocking
  - Scale Free Networks, Graceful Degradation
- Dynamic Events (Second Project Phase)
- Conclusion

Project Introduction (1)

Sensor Network = paradigm of a complex network

Task:

- Collect sensor data at many locations
- Transmit collected data to sink



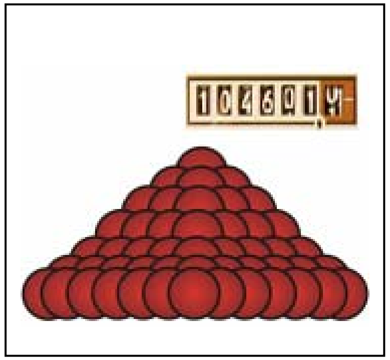
Scenario – Environment observation:

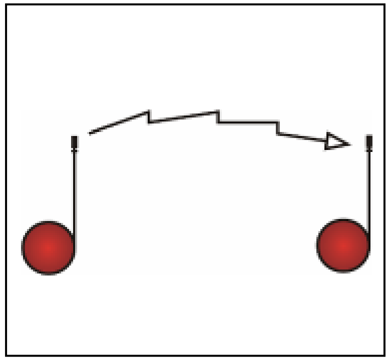
- Forest fire surveillance
- Detection of volcanic activity
- Precision farming
- Flood protection

Project Introduction (2)

Network Properties:

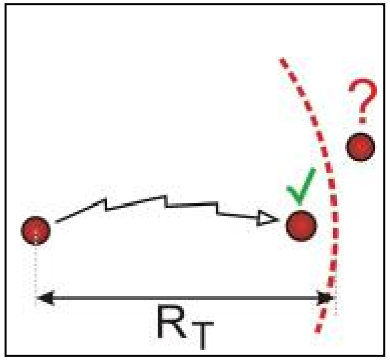
- High node count
- Random node distribution
- Wireless communication

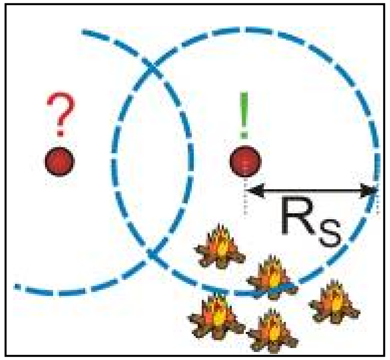




Node Properties:

- Limited transmission range
- Limited sensing range
- Limited resources





Project Introduction (3)

Typical Problems:

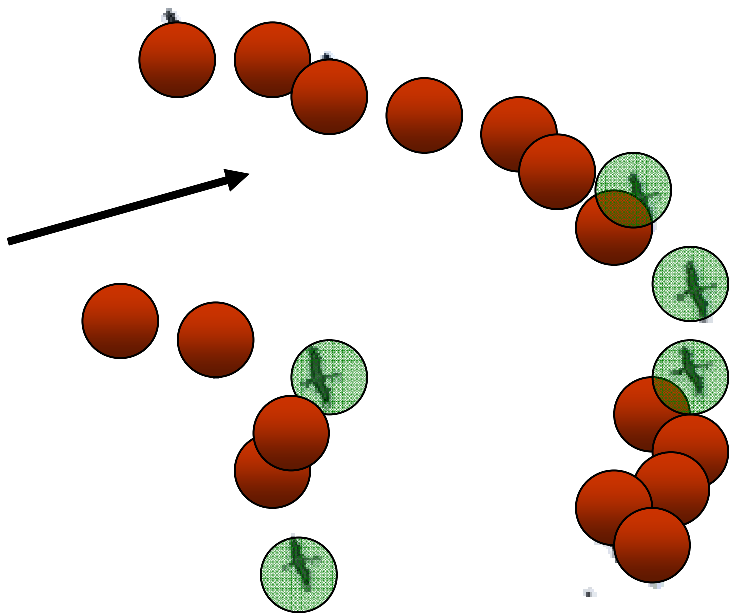
- Centralized control infeasible
- Network has to organize itself in an energy-aware way
- Dynamic events impact optimal network structure

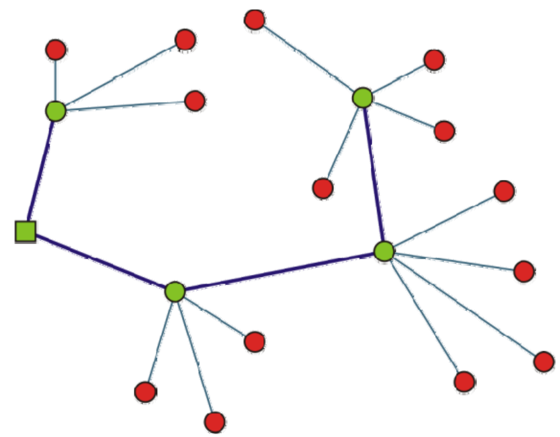
Our goal:

- Increase lifetime and robustness of sensor networks using self-organized communication and organic principles
- A network „lives“ completely:
  - iff phenomena still can be detected in each observed location
  - iff messages from acquiring nodes can reach the sink

Adopted OC Principles (1)

Role assignment / Role changing – Introduction





Role assignment

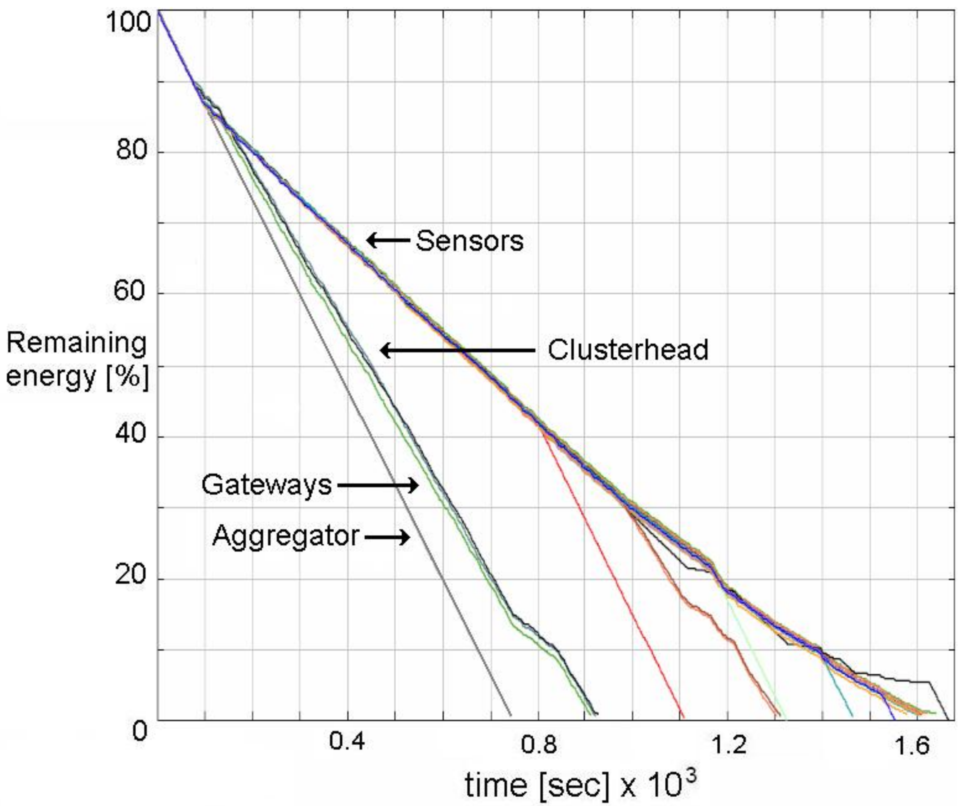
- Hierarchy
- Specialization
- Learning effects

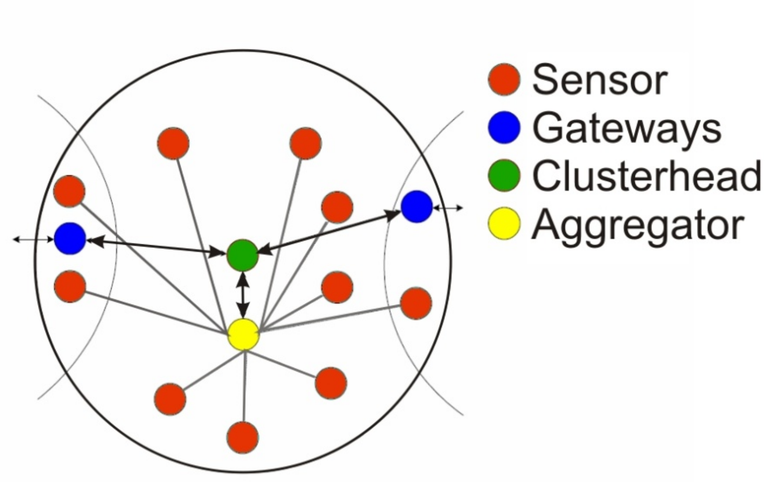
Role changing

- Energy balance
- Resilience

Adopted OC Principles (2)

Role assignment / Role changing – Application [REI06]





Benefit: Lifetime extension by 40%

Requirement: Nodes have to be able to adopt all roles → "Flocking" strategy

Adopted OC Principles (2)

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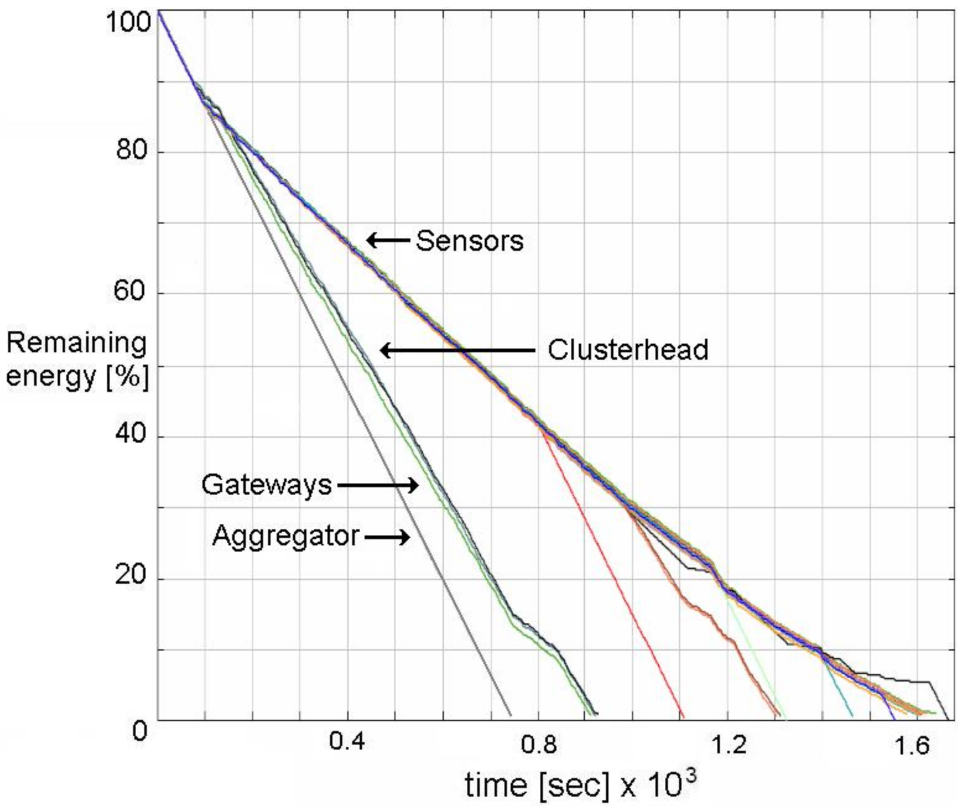

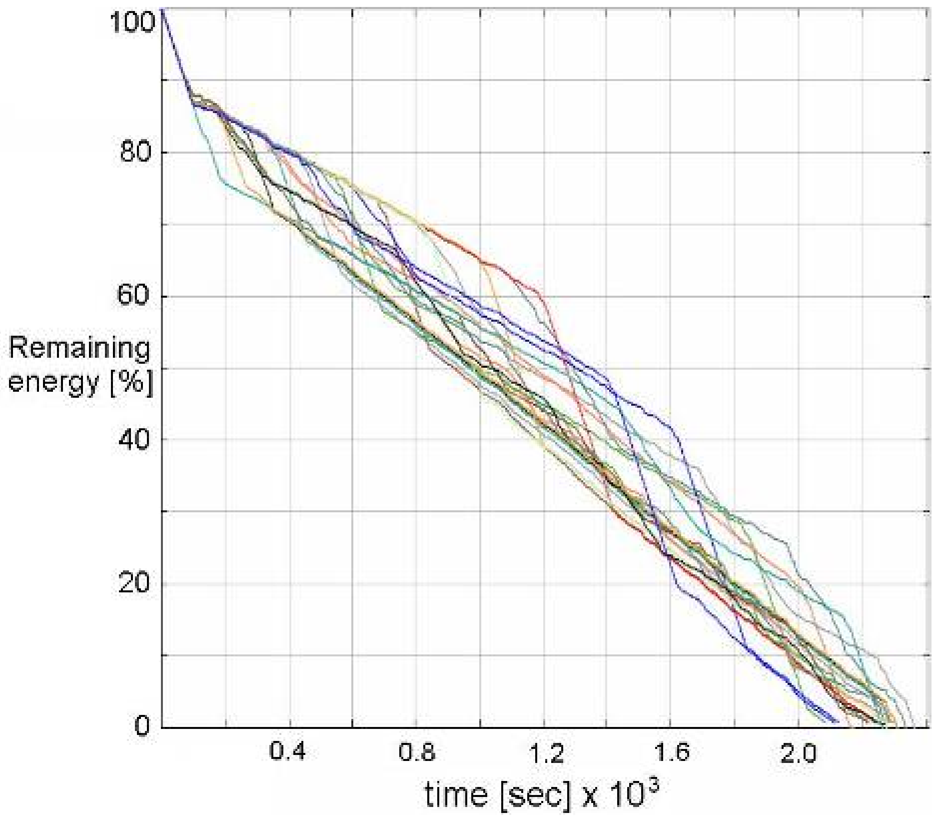

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Adopted OC Principles (3)

Geographical flocking – XGAF* [SAL07a]

* Extended Geographic Adaptive Fidelity

Goal:

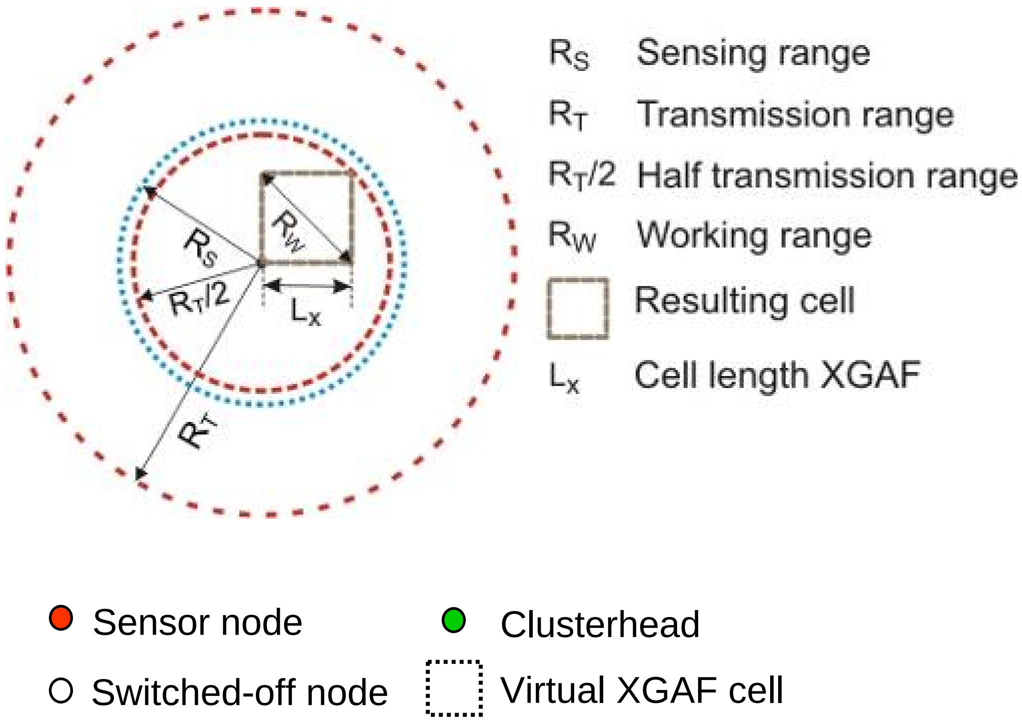
- Achieve flocks in the way that each node can adopt each role in its cluster independent from its position

Idea:

- Partition the network into virtual regular cells with equal dimensions

Cell dimension depends on:

- Sensing and Transmission Range
- $R_W = \min(R_S; R_T/2)$
- R_W determines maximum cell size



Establishing a virtual grid

Possibility to save energy by switching-off all nodes but one per cell

* Geographic Adaptive Fidelity

Adopted OC Principles (3)

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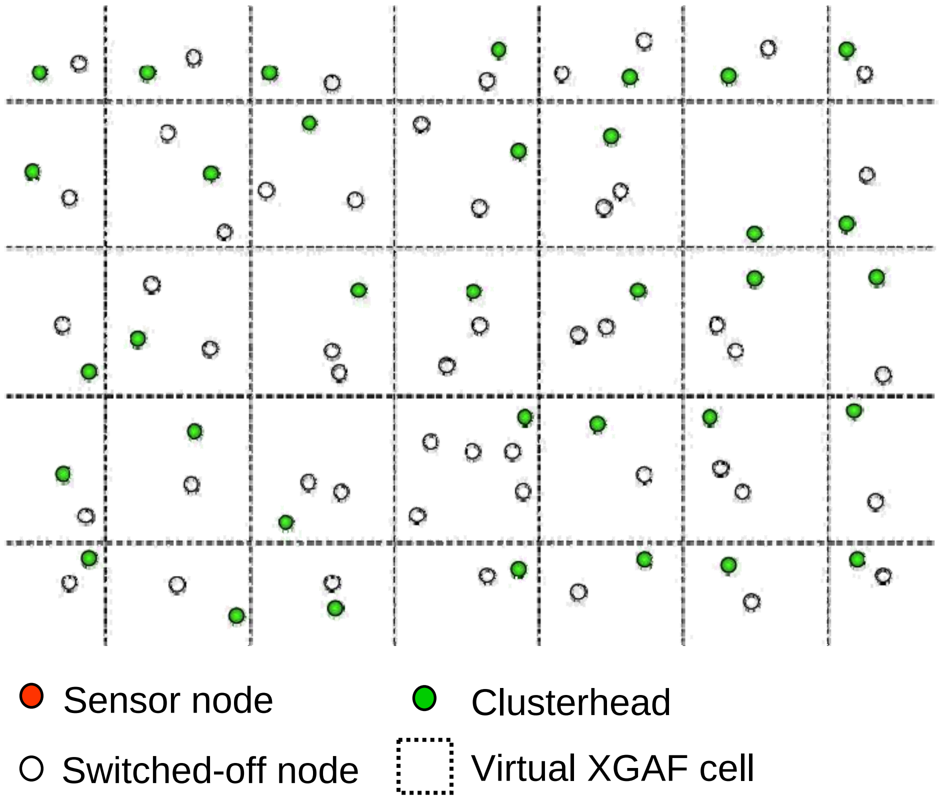
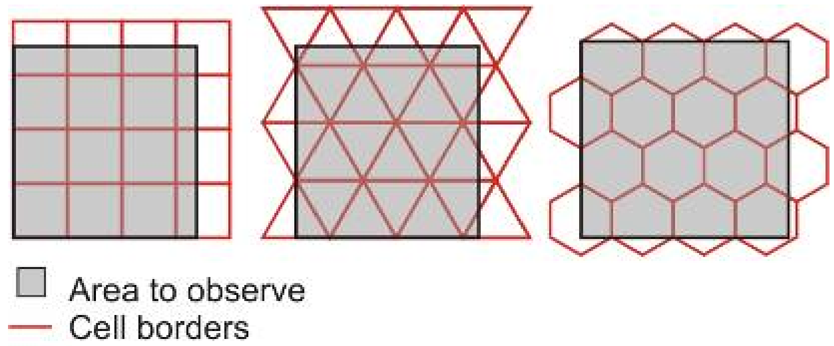


* Geographic Adaptive Fidelity

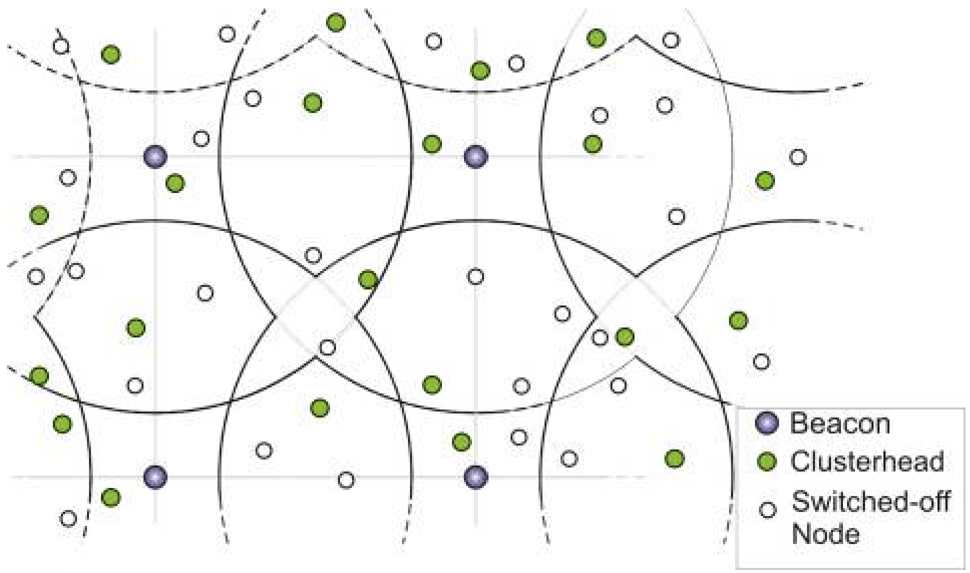
Adopted OC Principles (6)

Geographical flocking – Further research [SAL07c,SAL07d]

- Different regular cell shapes
  - Lifetime
  - Routeability

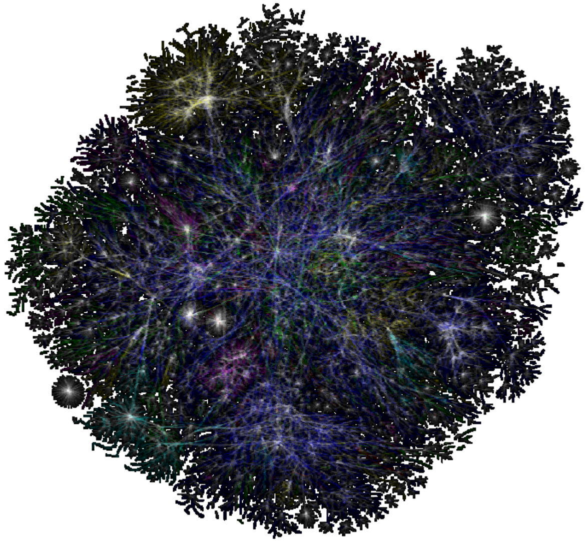


- Adapting cells to shapes given by localization schemes
  - Node deployment
  - Cell shapes
  - Optimal beacon range

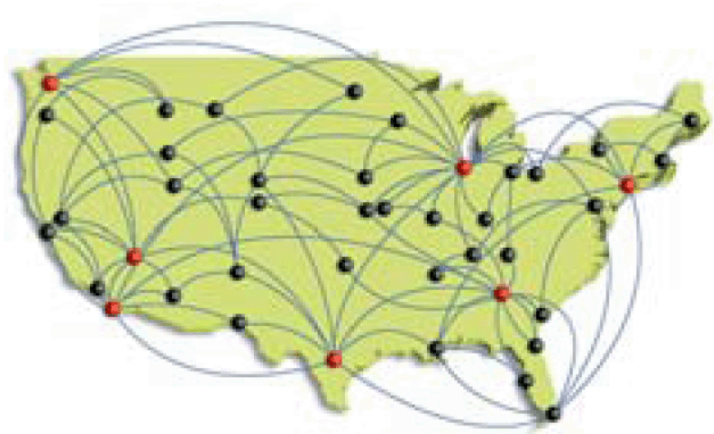


Adopted OC Principles (7)

Scale free networks – Introduction



Internet



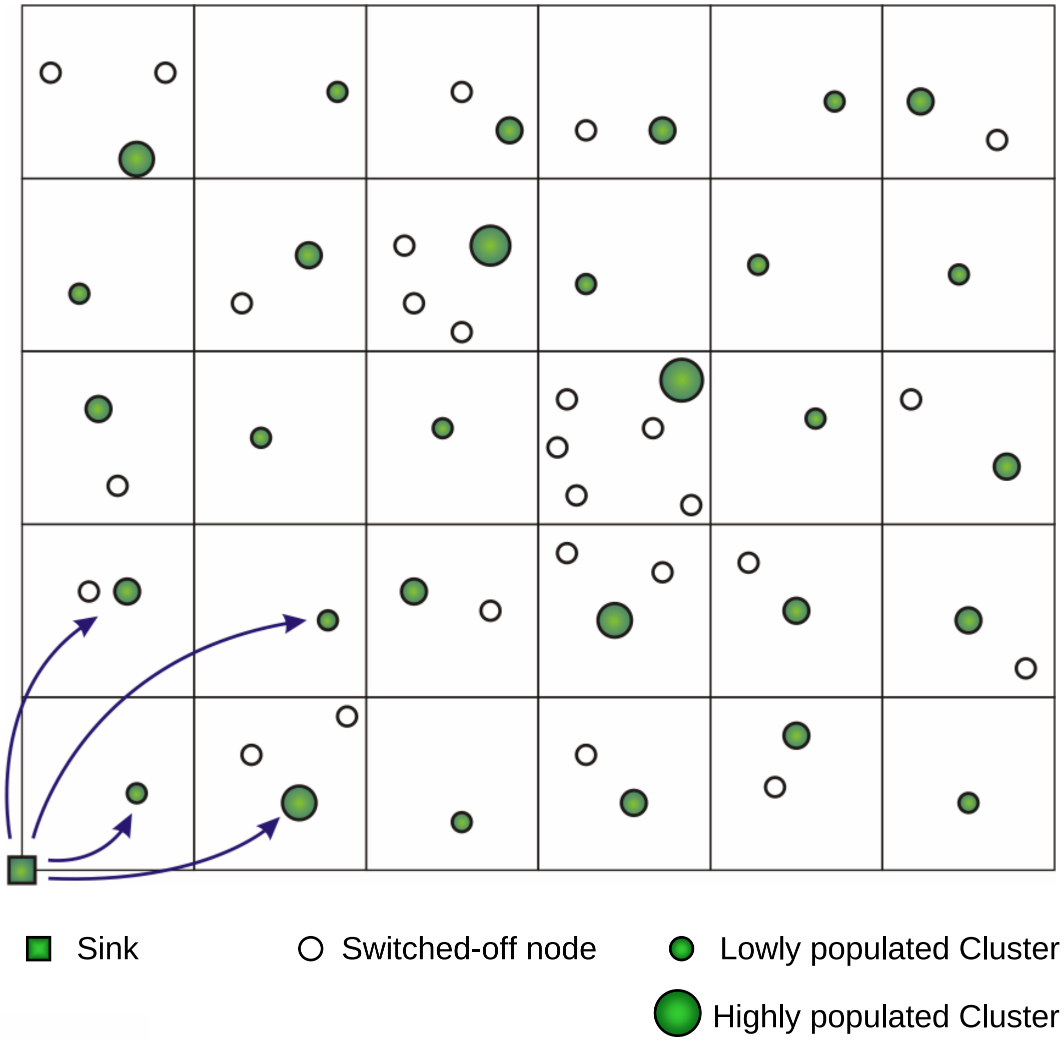
US airline system

- Network results from connections to preferred nodes
- Many nodes with few connections, few nodes with many connections
- Robust against random attacks

Adopted OC Principles (8)

Scale free networks – Application [SAL07a]

- Our approach:
  - Starting with the sink
  - After joining the network, nodes connect with all unconnected nodes in range



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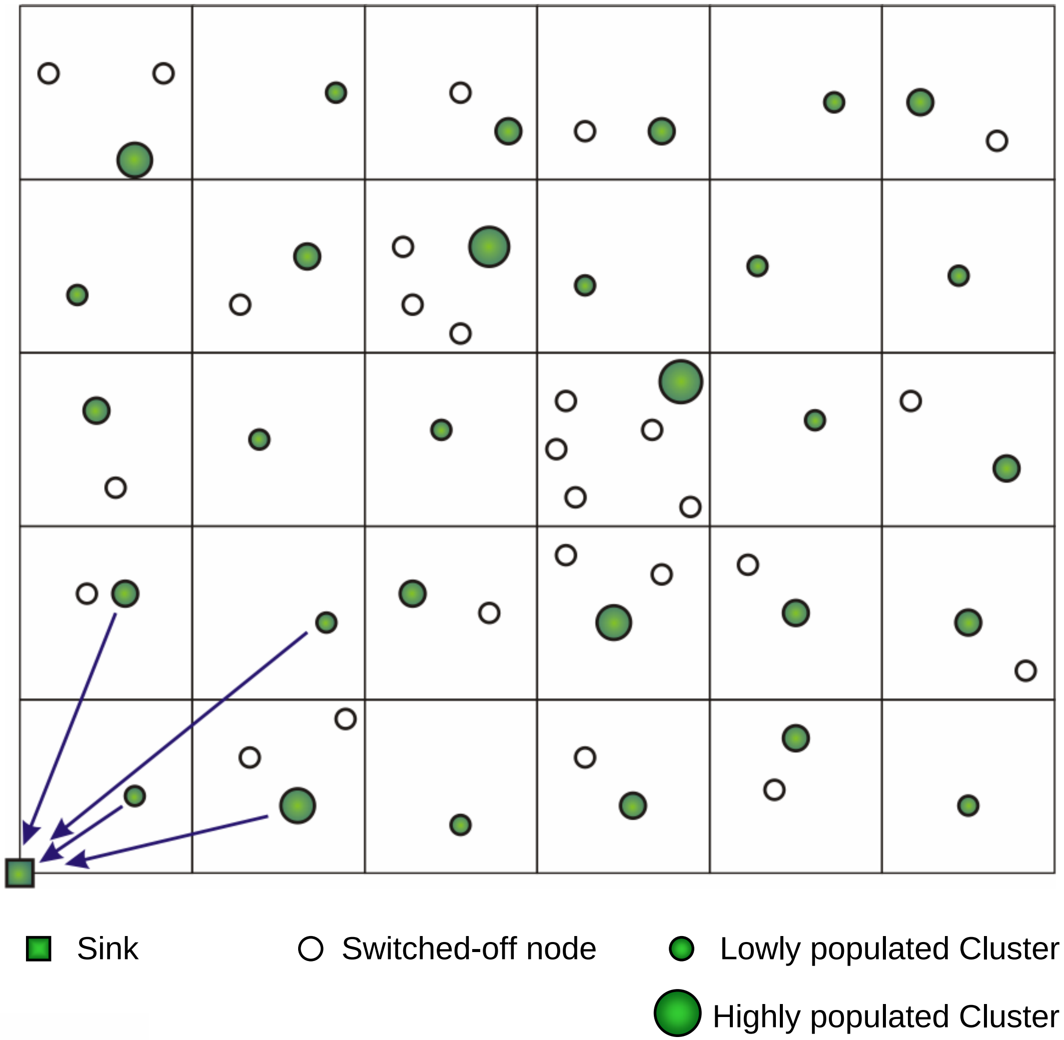

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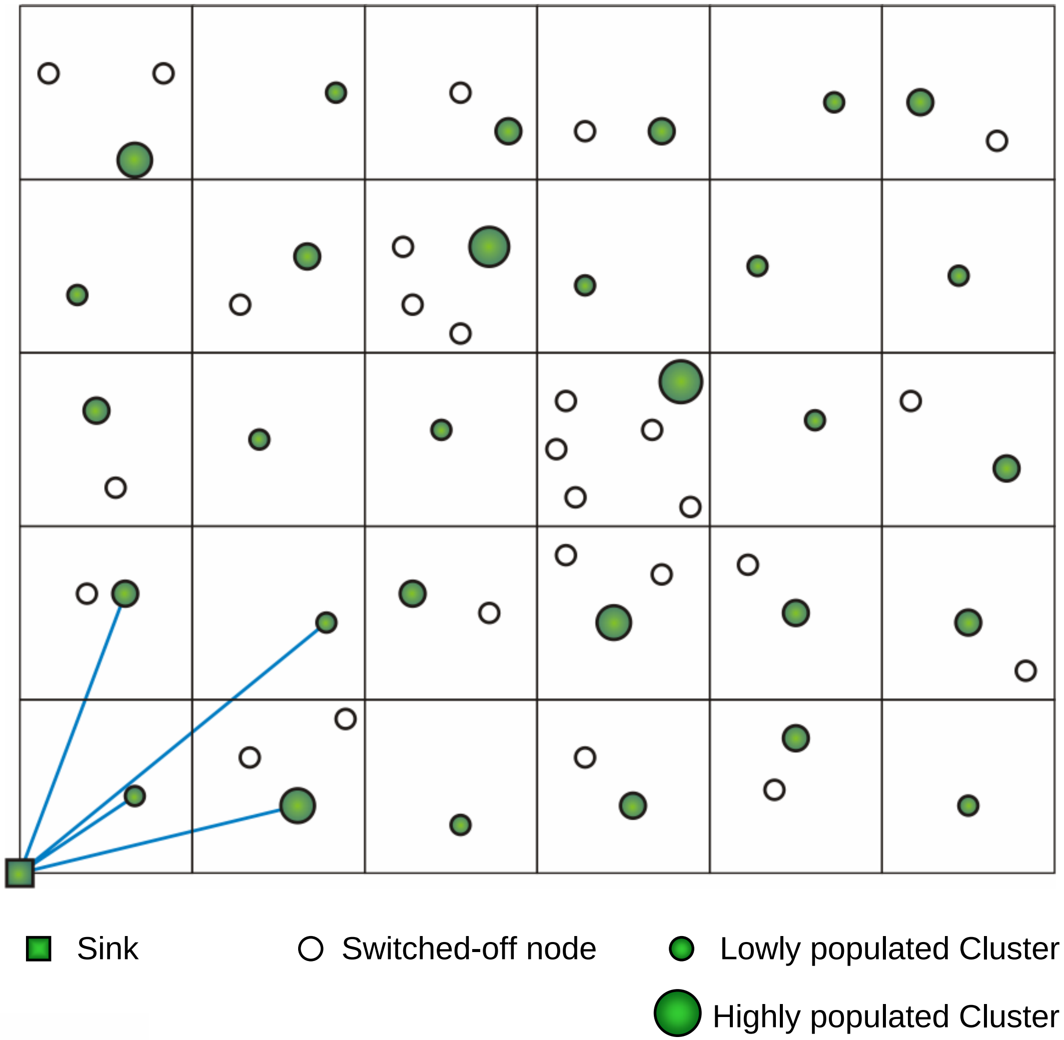

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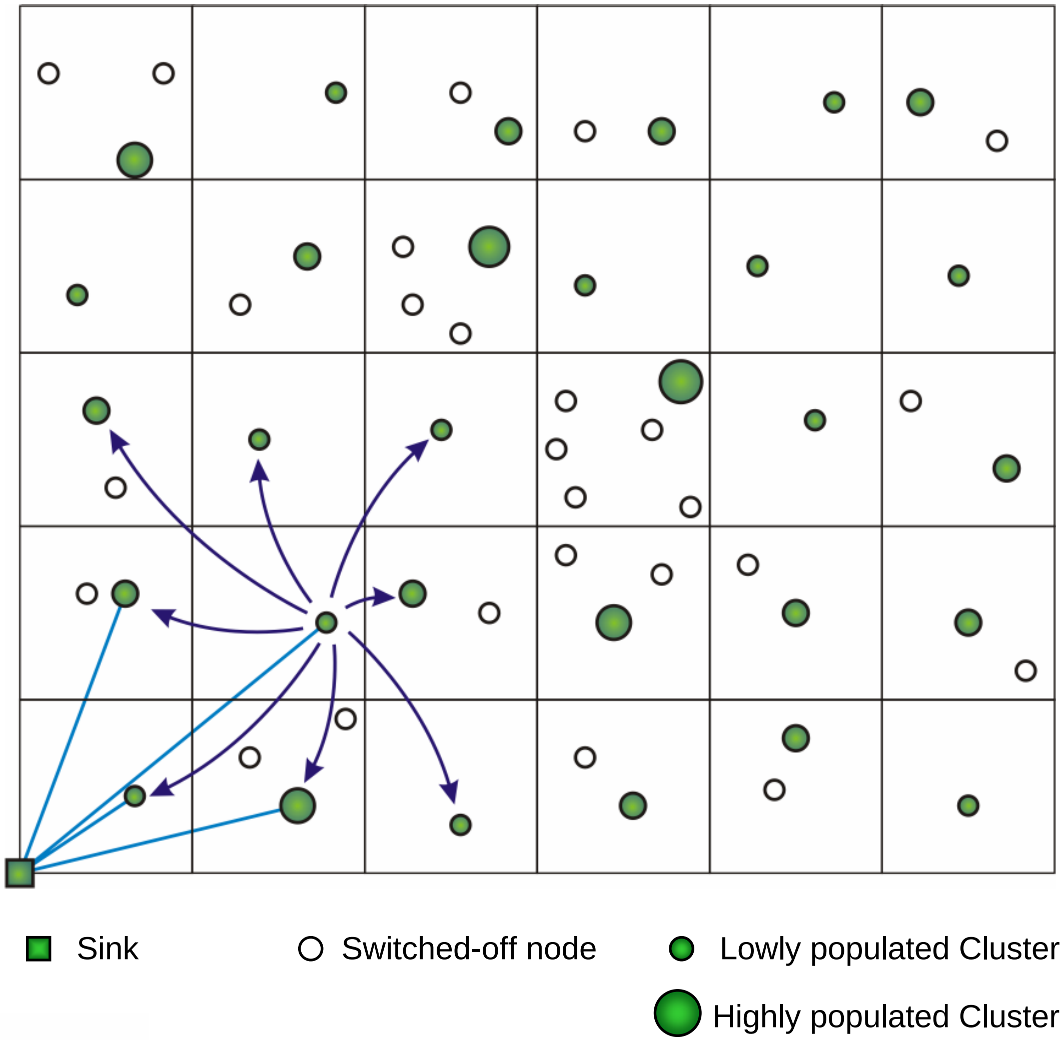

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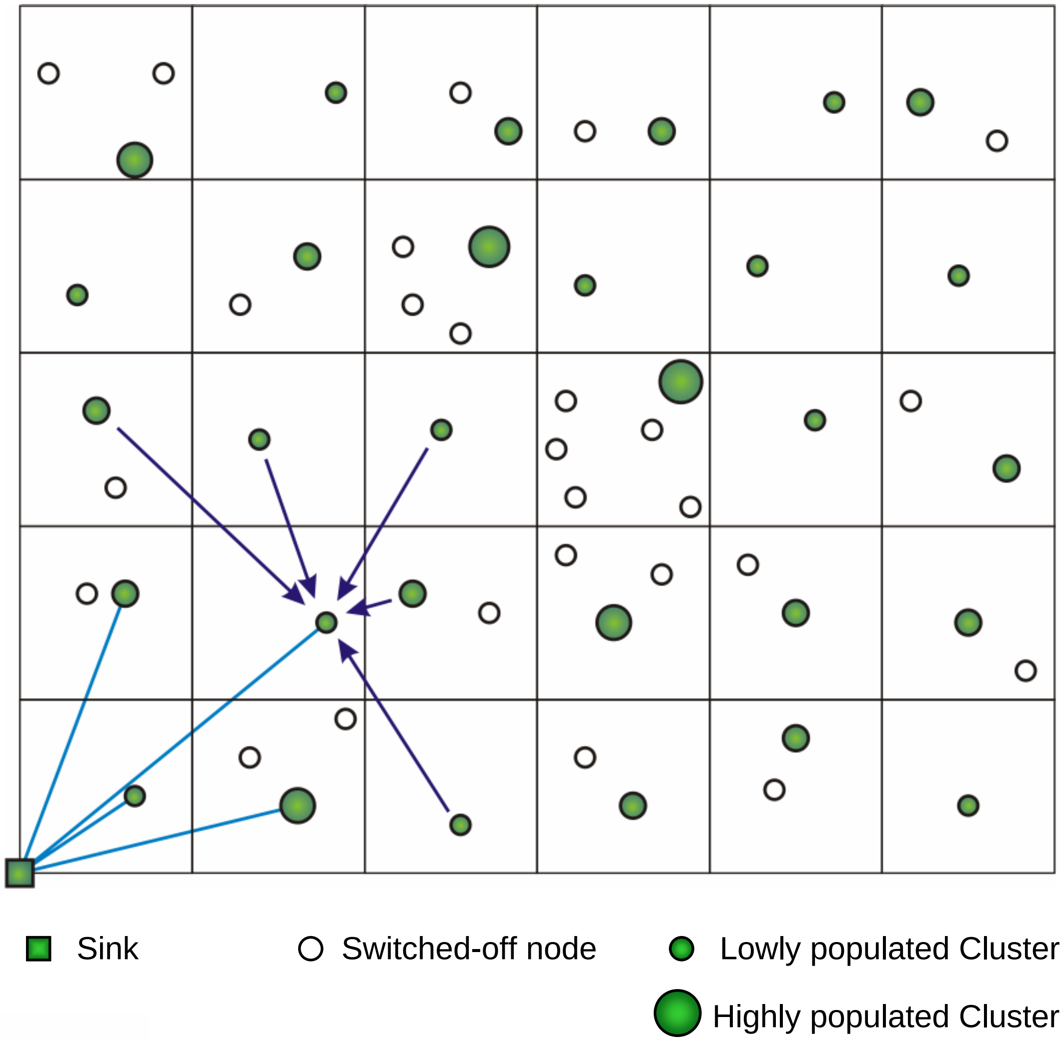

Adopted OC Principles (8)

Scale free networks – Application [SAL07a]

- Our approach:
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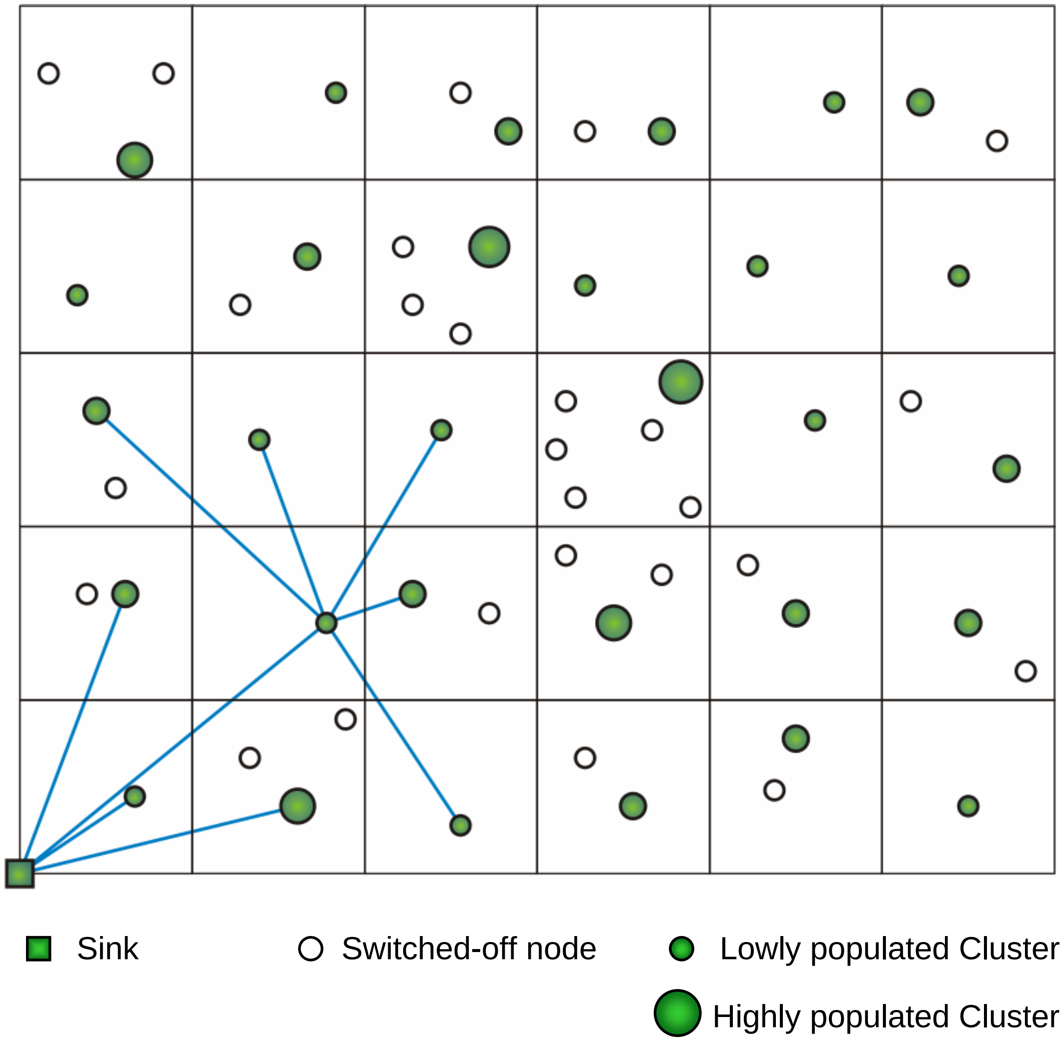
  - After joining the network, nodes connect with all unconnected nodes in range
- Build up a network with scale free behavior



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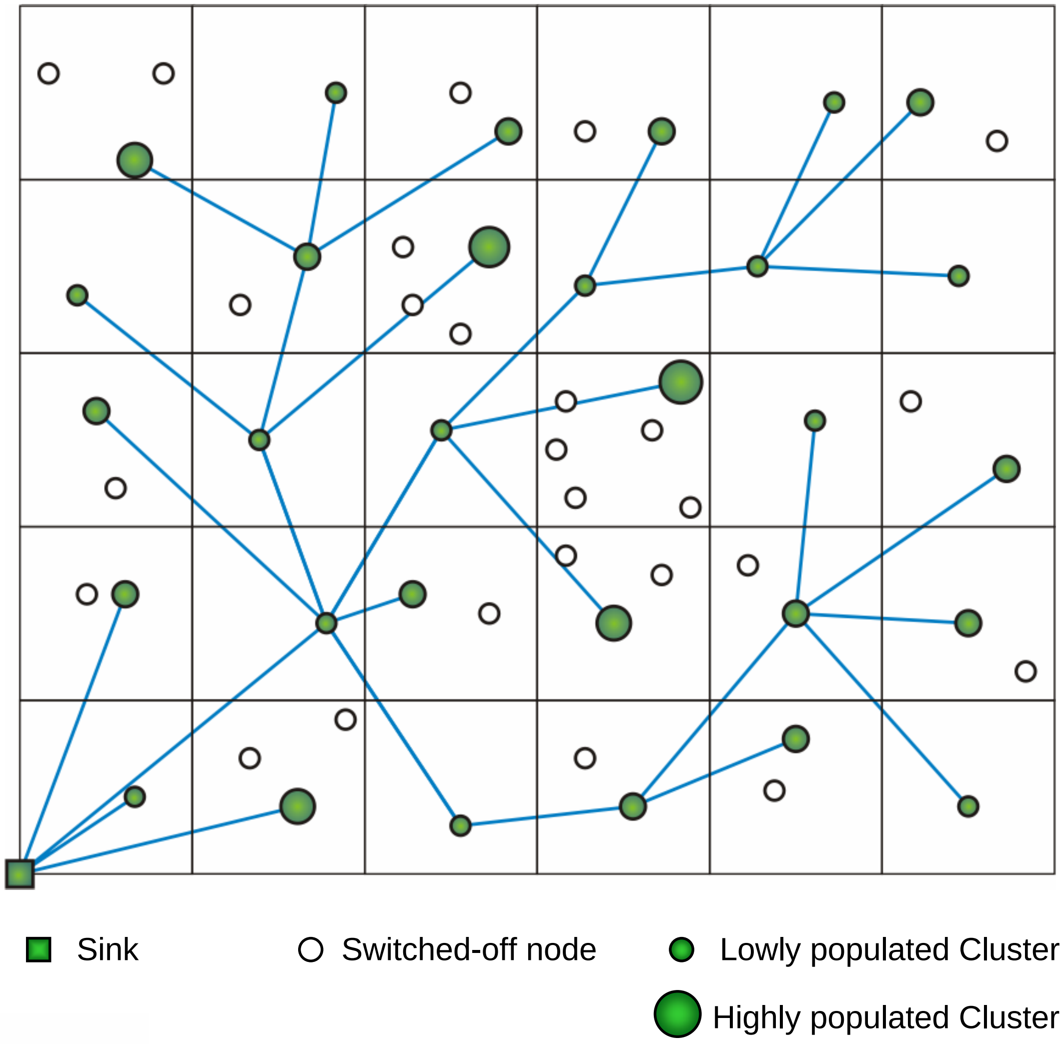

Adopted OC Principles (8)

Scale free networks – Application [SAL07a]

- Our approach:
  - Starting with the sink
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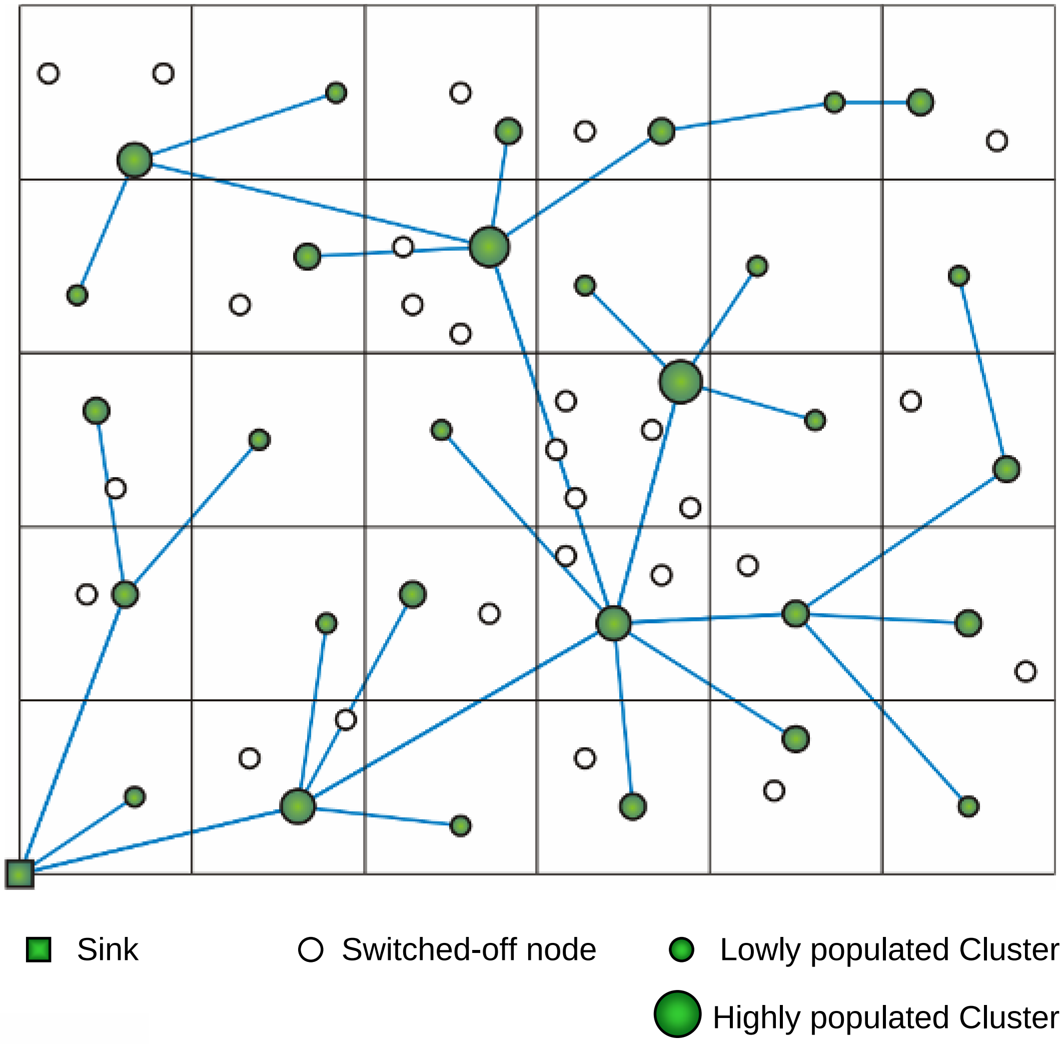
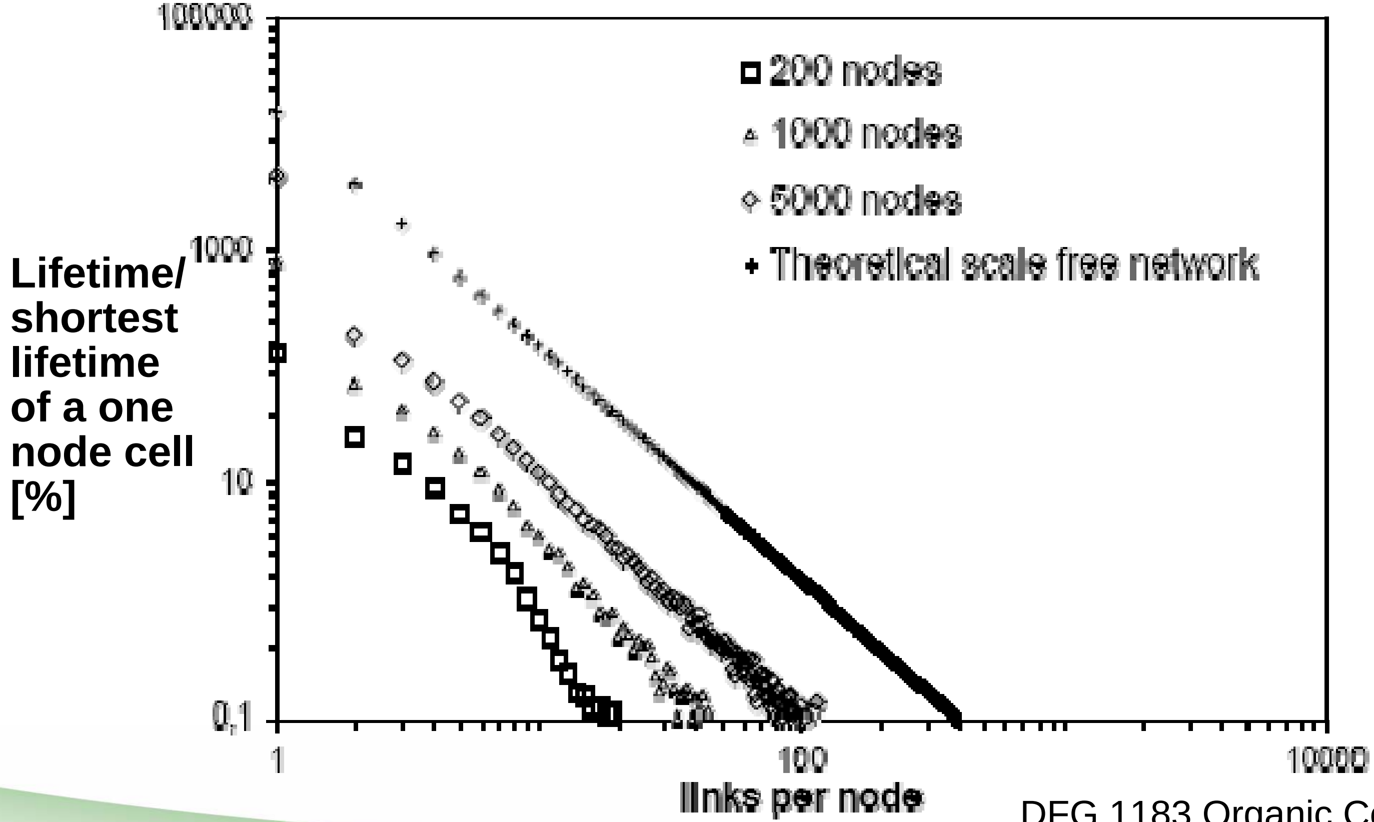
- Build up a network with scale free behavior
- Optimizations:
  - Range Reduction
  - Limited Connectivity
  - Wait and See
- Well populated clusters become hubs



Adopted OC Principles (9)

Scale free networks – Results

- Emerging tree with scale free behavior
- Lifetime balancing
- Lifetime increase by 130%



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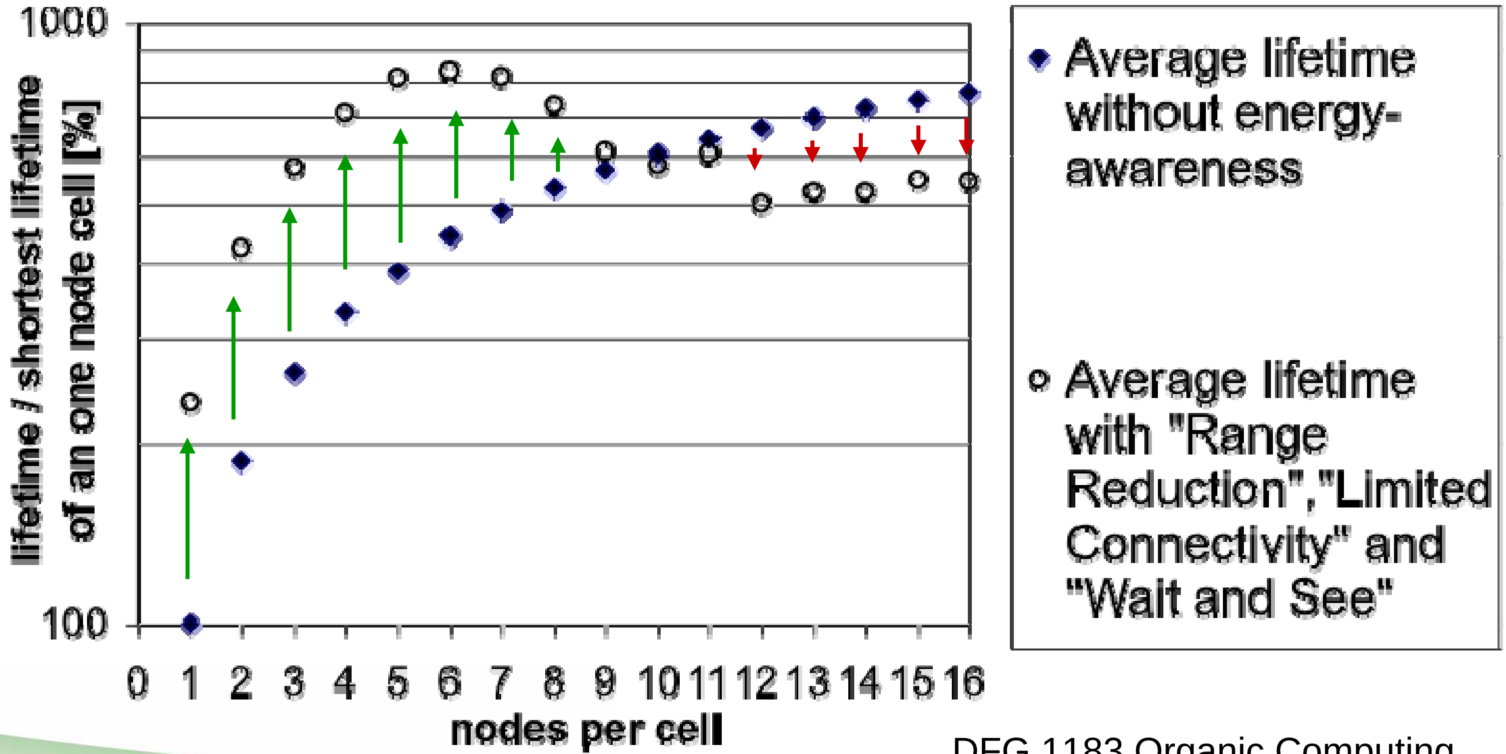

Dynamic Events (1)
Network Changes

Analysis and Classification of dynamic network changes

- Spontaneous changes (unexpected failures)
- Slow continuous changes (moving nodes, energy consumption/ regeneration)
- Periodic Changes (rejuvenation)

Self-organized detection and adaptation to changed network

- Adaptation of existing network structures to new node relations
- Transfer of acquired knowledge to new nodes

Dynamic Events (2)

Environmental changes

Analysis and Classification of dynamic environmental changes

- Spontaneous changes (Moving obstacles)
- Slow continuous changes (Plant growth)
- Periodic Changes (Day-Night cycles)

Self-organized detection and adaptation to changed environment

- Adaptation to different sensing and transmission ranges
- Adoption of emerging advantages
- Prediction of future environmental events

Conclusion

First Project Phase

- Adoption of organic principles to a sensor network
  - Role assignment/role changing
  - Flocking
  - Scale free networks
- Goal: Static network with optimal lifetime and robustness

Second Project Phase (starting April 2008)

- Adaptation of the network to dynamic events
  - Changes of environment
  - Changes of environment
- Goal: Energy-aware handling of expected and unexpected phenomena

Questions ?

Publications:

[REI06] Reichenbach, Frank; Bobek, Andreas; Hagen, Phillip; Timmermann, Dirk; Increasing Lifetime of Wireless Sensor Networks with Energy-Aware Role-Changing; In Proceedings of the 2nd IEEE International Workshop on Self-Managed Networks, Systems & Services (SelfMan 2006), Dublin, Ireland, Jun 2006

[SAL07A] Salzmann, Jakob; Kubisch, Stephan; Reichenbach, Frank; Timmermann, Dirk; Energy and Coverage Aware Routing Algorithm in Self Organized Sensor Networks; Proceedings of Fourth International Conference on Networked Sensing Systems, pp. 77-80, ISBN: 1-4244-1231-5, Braunschweig, Deutschland, Jun 2007

[SAL07B] Salzmann, Jakob; Behnke, Ralf; Lieckfeldt, Dominik; Timmermann, Dirk; 2-Mascle – A Coverage Aware Clustering Algorithm with Self Healing Abilities; 3. International Conference on Intelligent Sensors, Sensor Networks and Information Processing, Melbourne, Australia, Dec 2007, **submitted**

[SAL07C] Salzmann, Jakob; Behnke, Ralf; Timmermann, Dirk; Analyse regelmäßiger Clusterformen in Sensornetzwerken; 12. Symposium Maritime Elektrotechnik, Elektronik und Informationstechnik, Rostock, Deutschland, Oct 2007, **accepted**

[SAL07D] Salzmann, Jakob; Behnke, Ralf; Timmermann, Dirk; Geographical Clustering with Coarse-Grained Localization, 5. Internation Forum „Life Science Automation“, Washington DC, Oct 2007, **accepted**