Organic Sensor Networks

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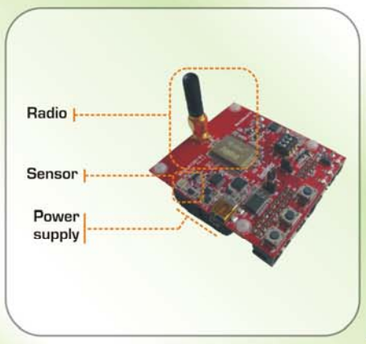
Wireless Sensor Networks - Background Knowledge

Network properties:
- Sensoring of values at many locations
- Random node deployment
- Data transmission to a sink

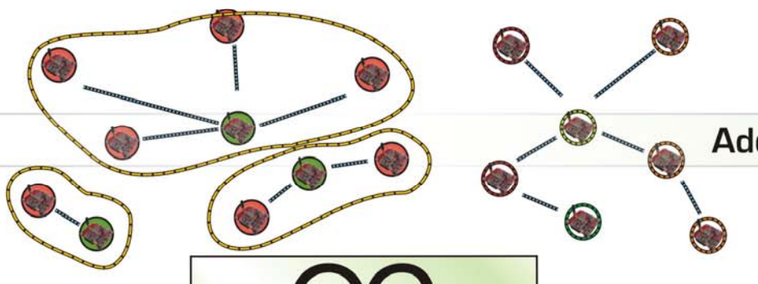
Node properties:
- Wireless communication
- Limited resources
- Error-proneness
- Limited sensing range
- Limited transmission range



Challenges:
- High and unknown node count makes centralized control infeasible
- Limited resources force the network to energy-aware organization
- Dynamic events impact optimal network structure
- Self-X properties necessary

Legend:
Sensor node
Routing path
Lot of energy left
Few energy left
Clusterhead
Cluster member
Switched-off node
Cluster border

Scenarios:
- Environment surveillance
- Natural disaster prevention
- Medical healthcare
- Precision agriculture
- Military applications
...



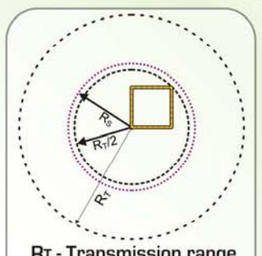
First Project Phase — Adoption of Organic Principles to Sensor Networks

Clustering
- Data aggregation
- Redundancy exploitation
- Power saving

Adopted organic principles:
- Hierarchy
- Role assignment / Role changing
- Flocking

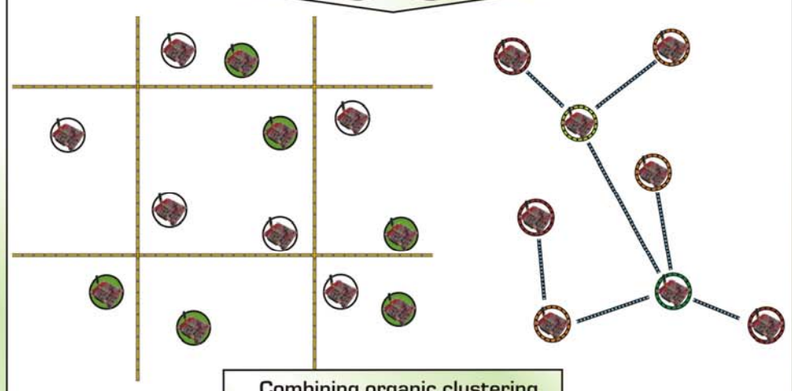
Clustering Approach XGAF*
*eXtended Geographic Adaptive Fidelity

- Cluster size depends on transmission and sensing range
- One node per cluster is sufficient to fullfill all sensing and transmission tasks
- All nodes but one are switched-off temporary
- Intracluster organization by "Energy aware role changing"
- Developed enhancement: MASCLE-algorithms**
**Mutual Assistance in a Cluster Environment

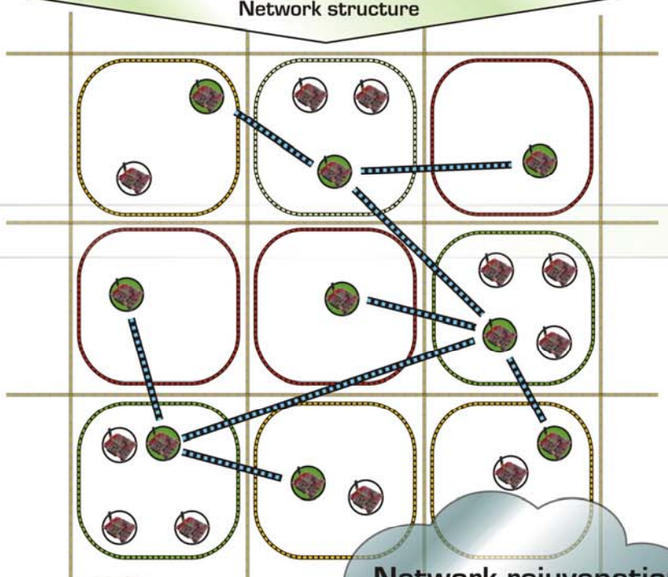


RT - Transmission range
RS - Sensing range

OC rganic omputing



Combining organic clustering and routing to an organic Network structure



Routing
- Wireless connection between nodes (clusters)
- Dedicated message propagation
- Fast event notification by the sink

Adopted organic principles:
- Scale-free networks
- Stigmergy
- Graceful degradation

Scale-free routing
- Interlacing of organic principles during the creation of a routing tree
- Nodes with high remaining energy are allowed to:
  - Connect with more nodes
  - Increase their transmission range
  - Connect faster with new nodes
- Emerging routing tree has scale-free behavior
  - "Strong" nodes gain more importance
  - "Weak" nodes have few routing tasks
- Energy balanced network

Second Project Phase — Self-Organized Reaction to Dynamic Occurences

Design time adaptation

Prediction of dynamic events, proactvie adaptation of network algorithms

Avoiding required preconditions
- Localization
- Uniform node distribution
- Fixed routing tree

Leave room for runtime adaptation

Preparation of sensor node:
- Memory reservation
- Periodic situation control
- Flexible roles
- Situation depending program flow

Network rejuvenation

Battery recovery effects

Node movements
Loss of links
Unexpected loss of nodes

Flexible network structure without global informations and fixed communication structure

Runtime adaptation

(Re-) Cognition of changed situation

Detection of dynamic events by recognizing unexpected changes:
- Sensor readings
- Neighborhood

Refine own situation observation
Recording of dynamic characteristics for recognition

Adaptation to new situation

Application of trained situation handling
- Role changing
- Situation propagation

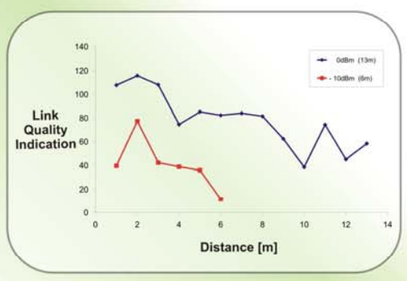
Learning of optimized situation handling
- Reinforcement by sink or surrounding nodes

Third Project Phase — Self-Organized Adaptation to Real World Challenges

Real world challenges

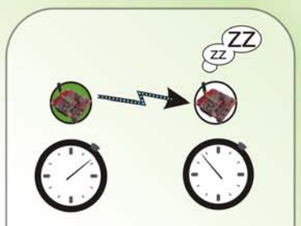
Physical layer

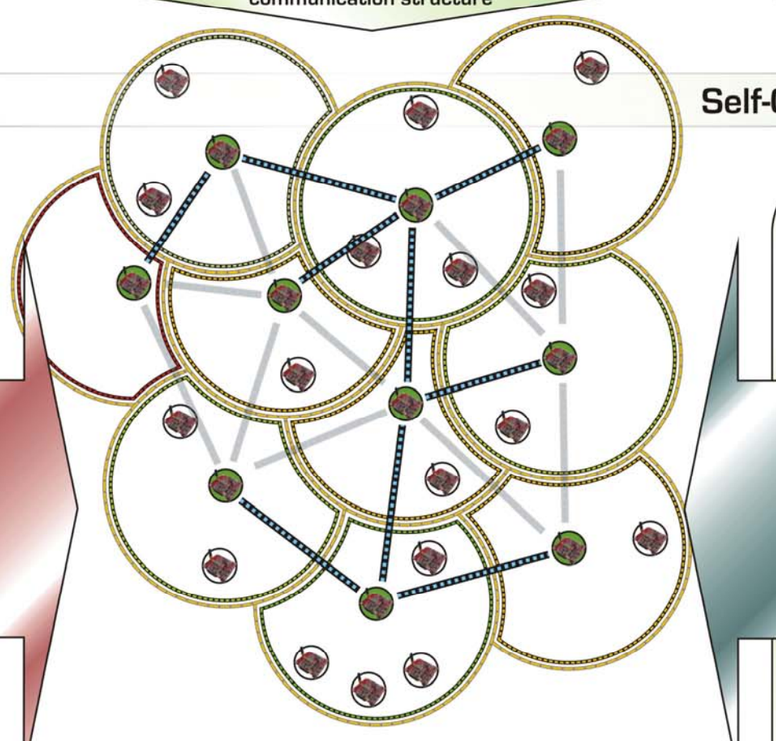
Realistic channel model:
- Shadowing
- Reflection
- Fading



Data link layer

Real multiple medium access:
- Overhearing
- Idle listening
- Unsynchronized clocks
- Hidden terminals





Organic adaptation strategies
- Connectivity-based clustering/routing
  - Breakup of fixed cluster borders, recalculation of exchangeable nodes per cluster
  - Recalculation of optimal routing pathes, consideration of link quality
- Channel correlation between adjacent nodes
  - Utilization of channel parameters for proximity detection
- Utilization of mass of nodes
  - Avoidance of overhearing, idle listening and collisions via node density consideration
  - Utilization of "birthday paradoxon"
  - Altruism of strong redundant or erroneous nodes
- Synchronization via swarm behavior

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