A Context-Aware Method for Spontaneous Clustering of Dynamic Wireless Sensor Nodes

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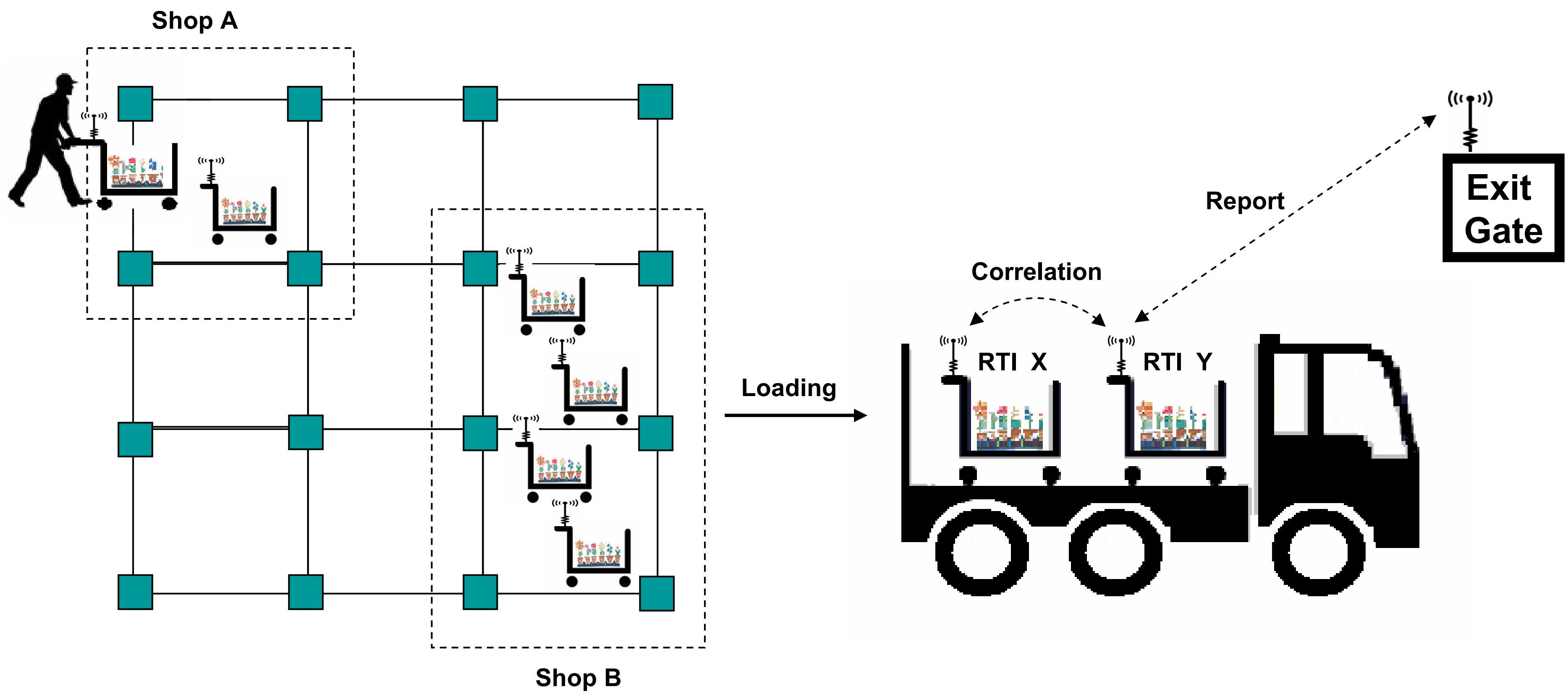
Self-organization

- Self-organization in wireless ad-hoc and sensor networks
  - From an initially unstructured network, build a structure in a distributed manner
  - Decisions are based on networking characteristics (e.g. link quality), node capabilities (e.g. amount of storage), probabilistic…
  - Purpose: efficient networking, data storage, querying
  - Operation: MAC, routing, transport, service discovery
  - Examples of structures: P2P overlay networks (e.g. DHT), hierarchical (e.g. spanning tree), hybrid (e.g. hierarchical rings, local hierarchies – clusters)

Self-organization

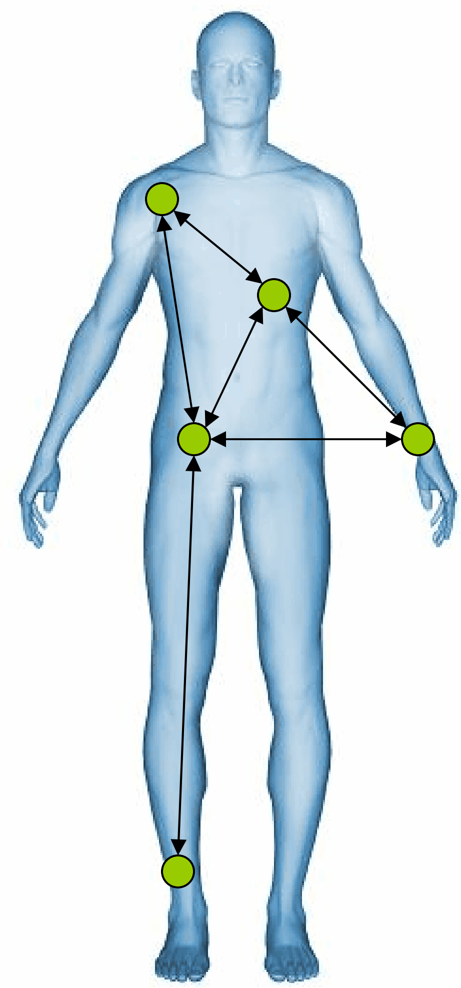
- Wireless ad-hoc and sensor networks – self-organization at the **application** layer
  - Rely on operational networking protocols
  - Build a structure in a distributed manner, based on **context information** (e.g. moving together) – virtual representation of the structures present in the real world
  - Purpose: provide a service for the application
  - Challenge: how to build stable clusters when the context information changes in time?

Application: transport and logistics



Application: Body Area Networks

- Wearable computing – nodes placed on the same person
- Clustering of nodes based on movement of people
  - Automatic identification of the sensors worn
  - Contribute to the activity monitoring and recognition
  - Can form a secure network



Phases of self-organization

1. Context-recognition algorithm
2. Communication of context information
   - Context is permanently evaluated and communicated
3. Algorithm of self-organization based on context information
   - Takes into account the variability of context information

Context-recognition algorithm – moving together

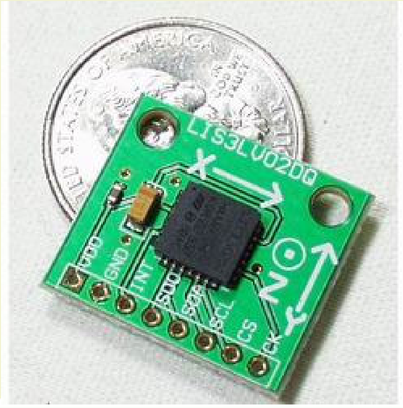
Tilt switches

- Binary information over the status of the device (moving/not moving)
- We use the number of contacts per time unit

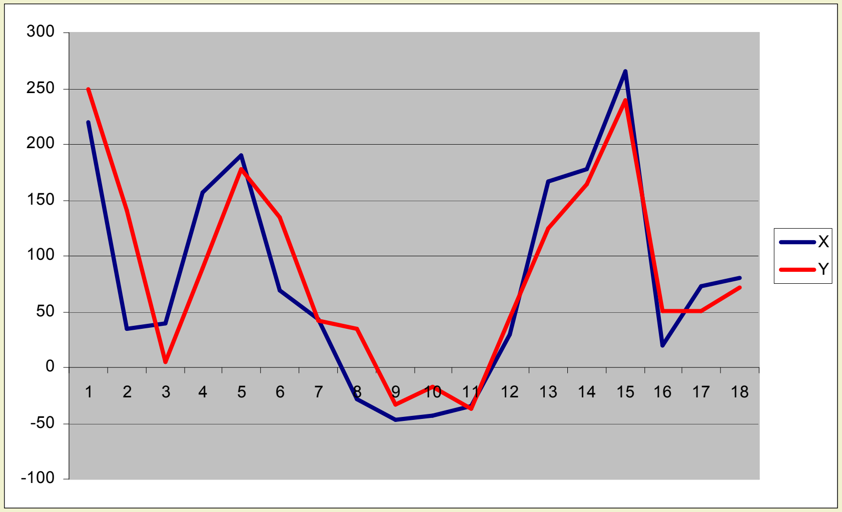
Accelerometers

- Measures the acceleration on three axis
- We use the magnitude of the acceleration vector:

$$\| \mathbf{a} \| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$



Context-recognition algorithm – moving together



Corr = 0.896

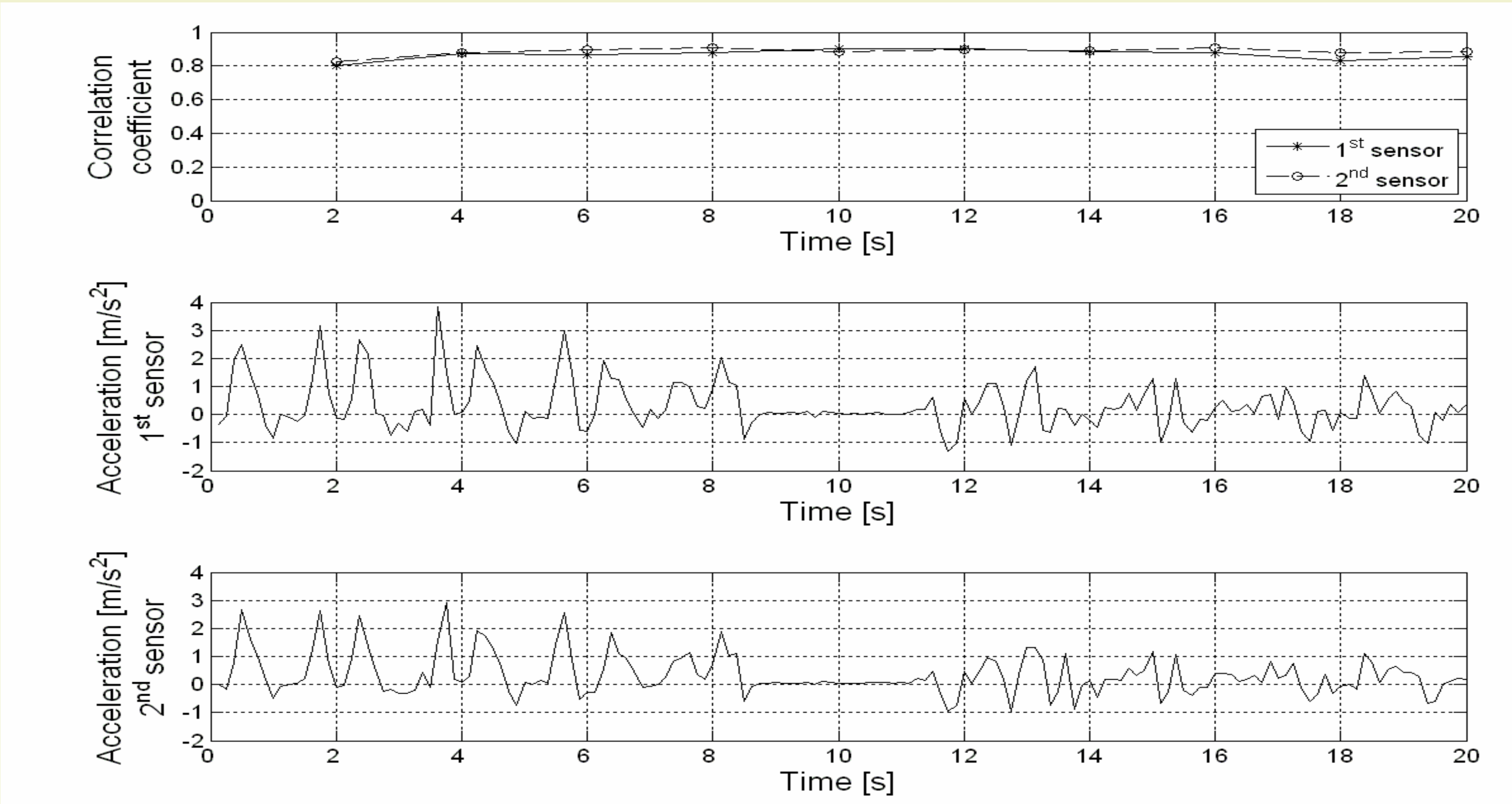
- Sampling of movement sensors
- Communication of movement data
- Computation of the correlation coefficient

Context-recognition algorithm – moving together

Experimental Settings

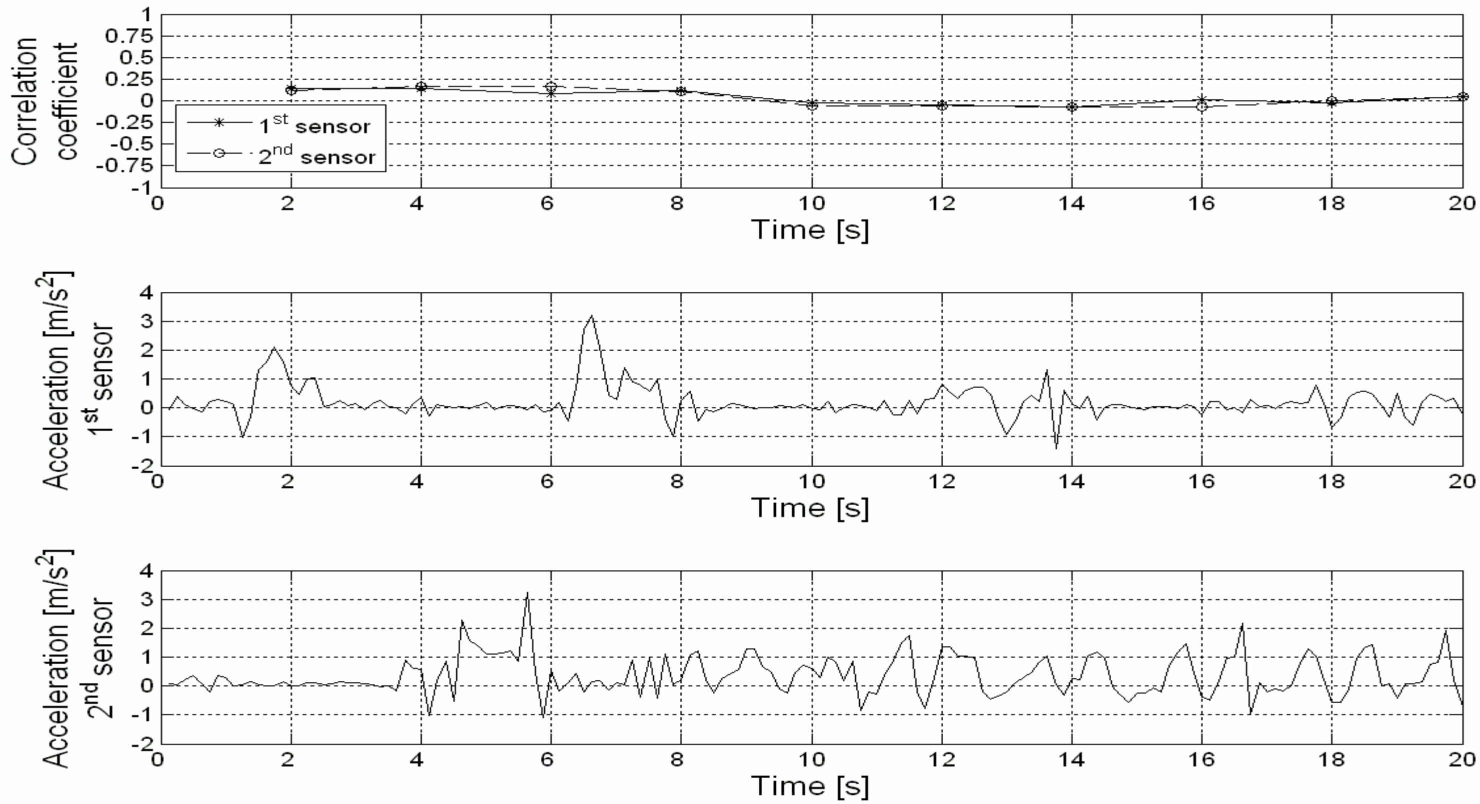
Context-recognition algorithm – moving together

Accelerometers moving together



Context-recognition algorithm – moving together

Accelerometers moving separately



Context-recognition algorithm – moving together

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Accuracy

Sensor	Setting	Movement type	Mean	Stdev	Accuracy [%]
Tilt switch	RTI	joint	0.641	0.087	95.89
Tilt switch	RTI	separate	-0.017	0.249	99.45
Tilt switch	car	joint	0.700	0.121	93.77
Tilt switch	car	separate	0.086	0.208	95.50
Accelerometer	RTI	joint	0.817	0.106	99.31
Accelerometer	RTI	separate	0.009	0.124	100
Accelerometer	car	joint	0.796	0.102	98.93
Accelerometer	car	separate	-0.003	0.127	100

[1] Raluca Marin-Perianu, Mihai Marin-Perianu, Paul Havinga, Hans Scholten. *Movement-based Group Awareness with Wireless Sensor Networks,* Pervasive 2007

Context-recognition algorithm – moving together

- Body Area Networks - coherence function [2]
  - A number in [0,1] that indicates whether two signals are correlated at a particular frequency
  - Accuracy 70% - 87.5%

[2] J. Lester, B. Hannaford, G. Borriello. *"Are You with Me?" – Using Accelerometers to determine if two devices are carried by the same person,* Pervasive 2004

Algorithm of self-organization - Tandem

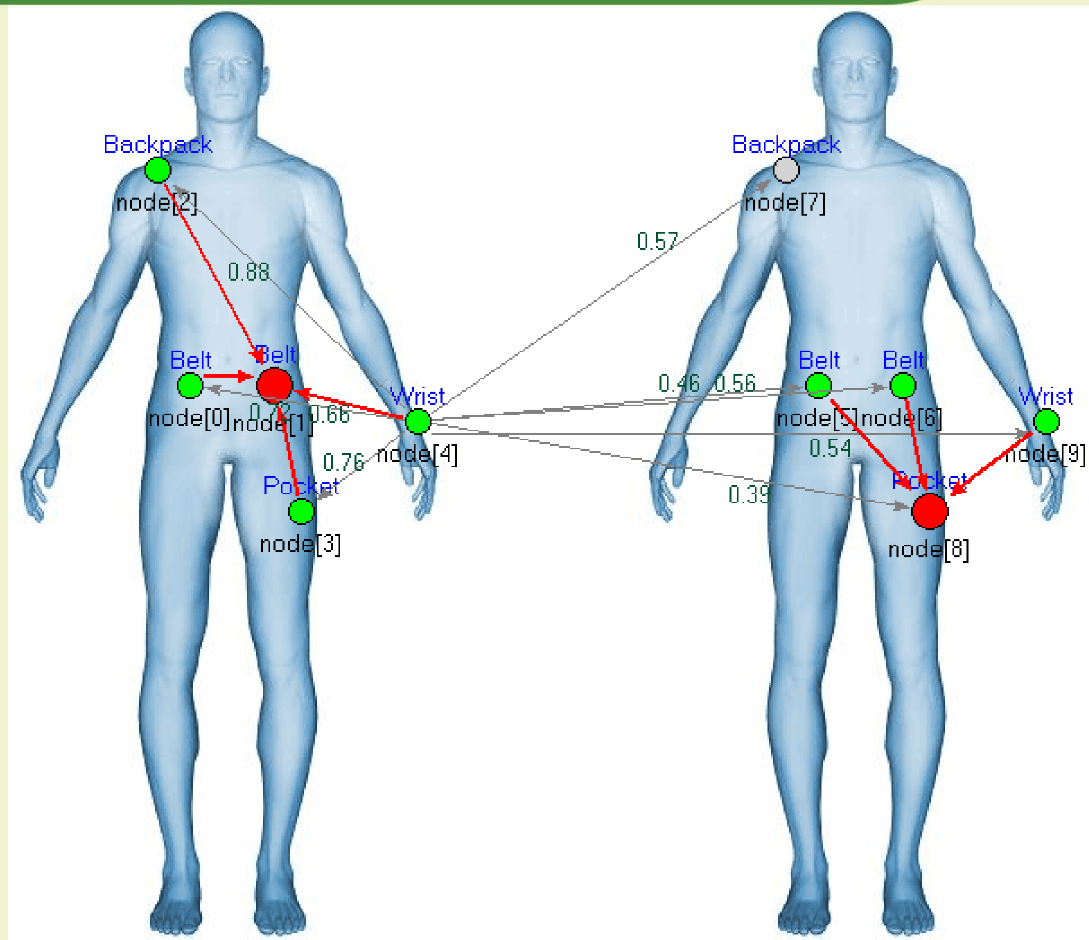
- Assumption: each node runs a **context recognition algorithm** for all the neighbours
  - Provides a number on a scale, the confidence value
    - Coherence function [0:1]
    - Correlation coefficient [-1:1]
  - Permanently evaluates the context
  - The confidence value changes in time
  - The algorithm has a certain accuracy
  - False negatives and false positives for the perceived shared-context

Algorithm of self-organization - Tandem

Follows the idea of a greedy algorithm, with the characteristics:

1. Incorporate dynamics
   - Merging and splitting of clusters depending on:
     - Topology changes
     - Context changes
2. Stability
   - The periodic re-evaluation of shared context may lead to unstable clusters
     - Analyze the confidence value for a longer period of time
     - Tradeoff between stability and delay

Algorithm of self-organization - Tandem



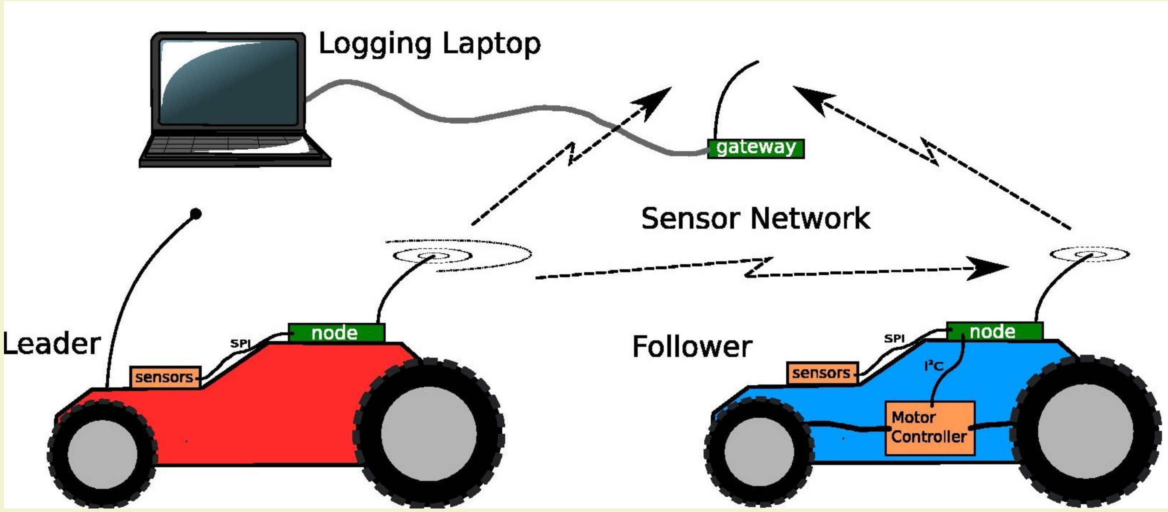
[3] Raluca Marin-Perianu, Hans Scholten, Paul Havinga, *Tandem – a context-aware method for spontaneous clustering of dynamic wireless sensor nodes,* Internet of Things 2008

Context-aware self-organization

- Context-aware self-organization – a variant of the classical clustering, with different applications and requirements
  - Virtual representation of structures present in the real world
  - **Passive** approach, does not act, but only tries to understand
- **Active** self-organization: wireless sensors and actuator networks
  - **Build and control** the structures of the real world

Collaborative unmanned vehicles

- Equip vehicles with wireless sensor and actuator nodes.
- Make the vehicles coordinate their motion, e.g. follow a leader and thus maintain a formation.



FollowMe!

[4] Stephan Bosch, Mihai Marin-Perianu, Raluca Marin-Perianu, Hans Scholten, Paul Havinga, *FollowMe! Mobile Team Coordination in Wireless Sensor and Actuator Networks,* PerCom 2009

FollowMe!

- For a presentation and demonstration video, please visit: http://www.youtube.com/watch?v=ZzWYO5dbo1M