Karlsruhe Institute of Technology

Technology for Pervasive Computing

Emergent Radio

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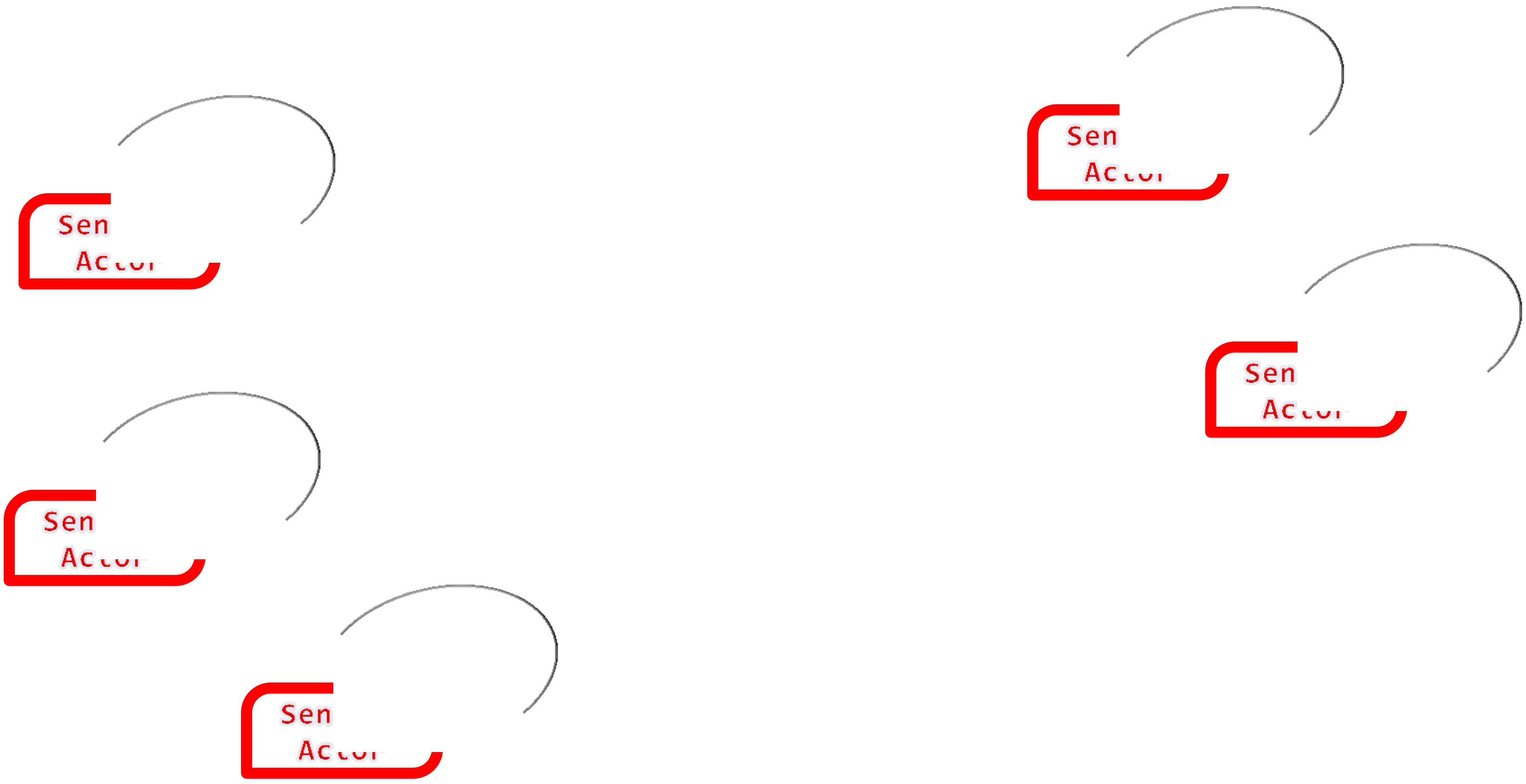
Pervasive Computing Systems – Prof. Dr.-Ing. Michael Beigl

Outline

- Status and some outlook
- Self-organized Collaborative data transmission
- MAC protocol optimization

Emergent Radio



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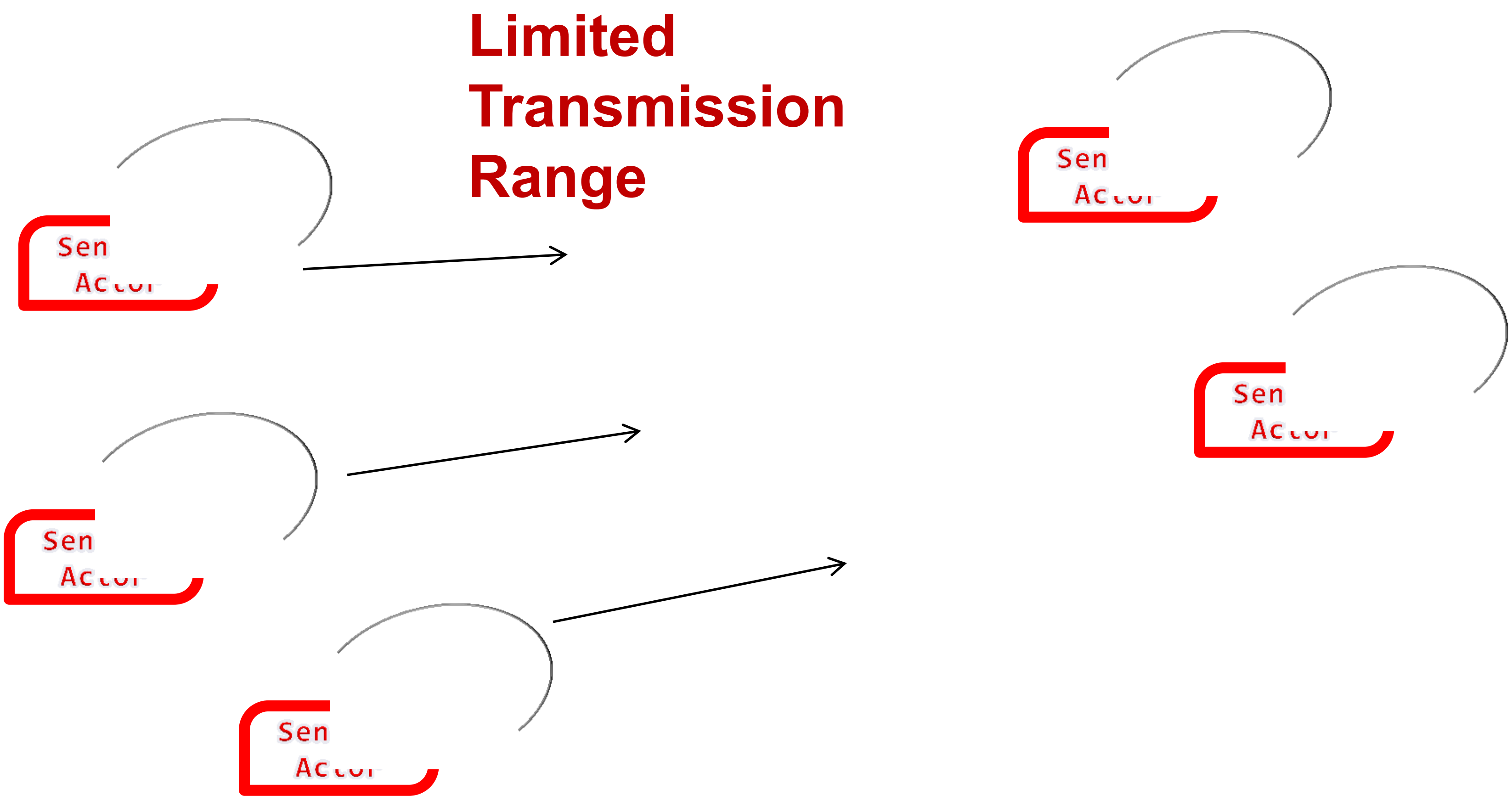

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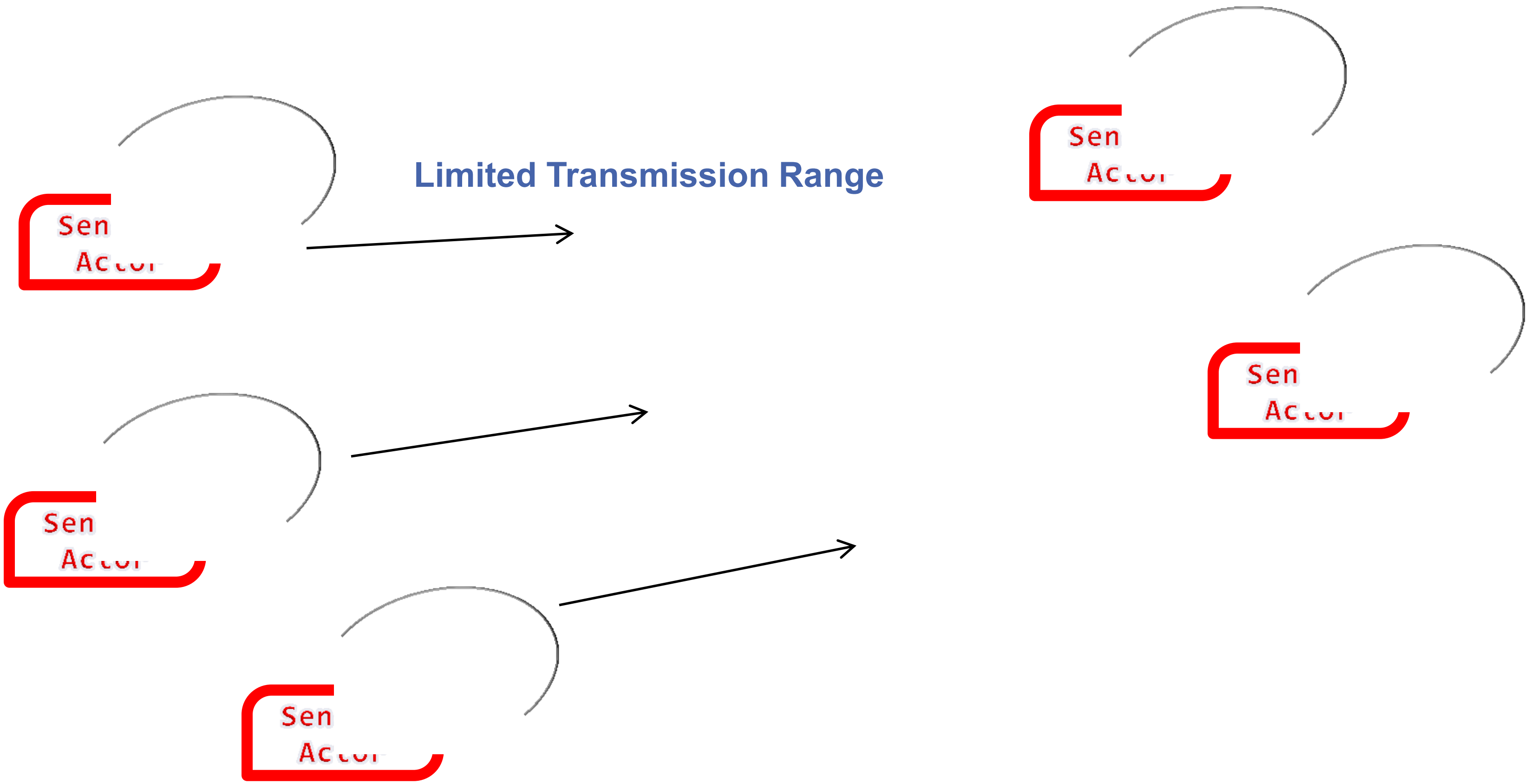

How can we bridge the gap?

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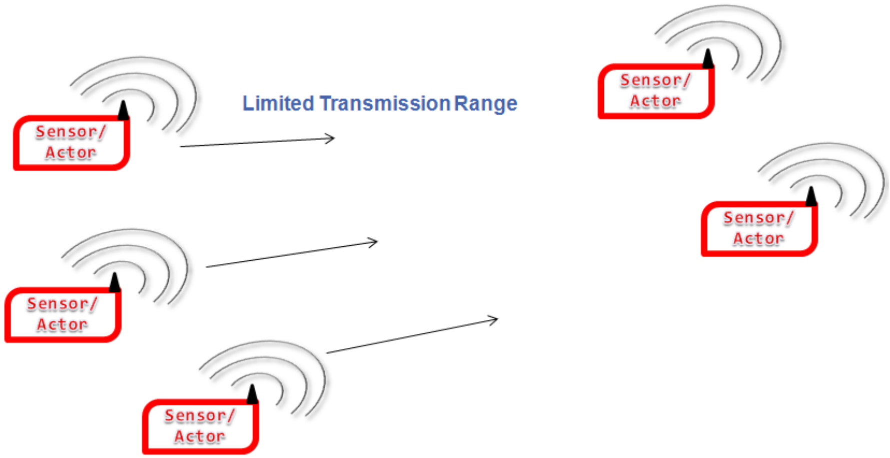


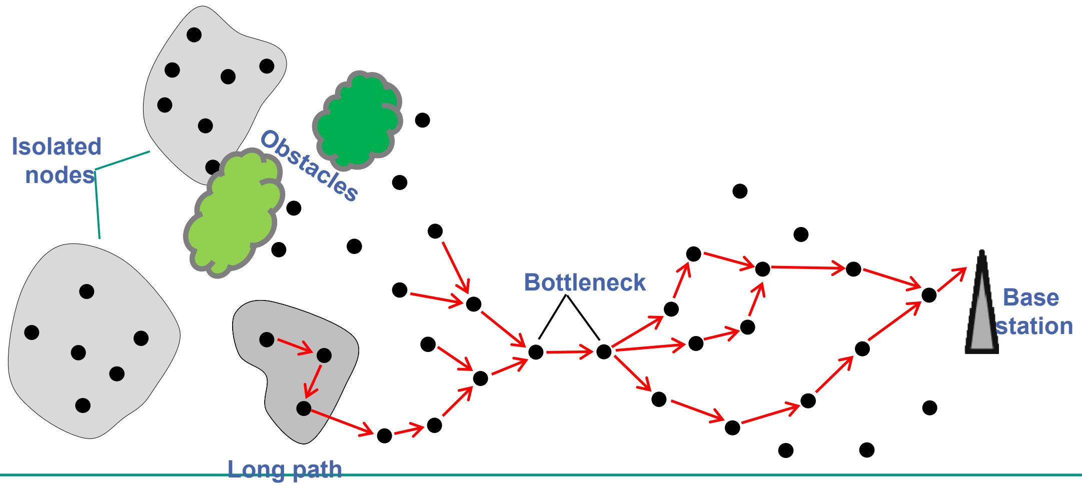
- How can we bridge the gap?
- Answer:
  - Selforganize Sensor/Actor nodes so that they are able to collaboratively solve the problem
  - → Collaborative Data Transmission
  - Several variants presented in the last 2 years
  - 12 publications, among them 2 IEEE Transactions on Mobile Computing

What‘s up? What‘s next? Part I

- Implementation of features into protocol
- PHY layer
- Implementation into Routing
  - ZigBee AODV Standard
  - WirelessHART mesh routing (BMBF DignOptiMesh)

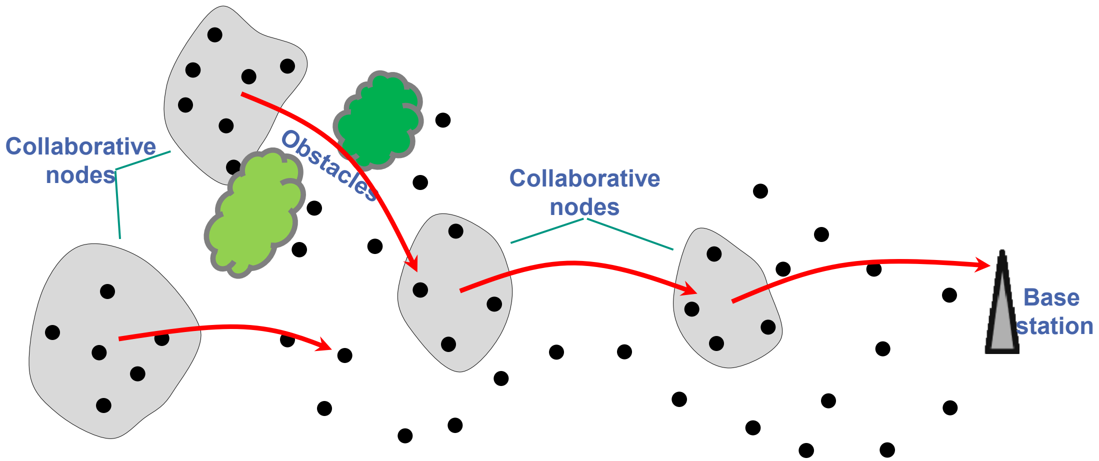
Collaborative Transmission for WSN Routing

- Implementation into Routing
  - ZigBee AODV Standard
  - WirelessHART mesh routing (BMBF DignOptiMesh)
- Challenges:
  - Node Isolation
  - Bandwidth bottleneck
  - Long time delay



Collaborative Transmission for WSN Routing

- Implementation into Routing
  - ZigBee AODV Standard
  - WirelessHART mesh routing (BMBF DiagnOptiMesh)
- Solution:
  - Multi-step forwarding
  - Extension of transmission Range
- Challenges
  - Novel Routing Protocols that are organically changing!



What‘s up? What‘s next? Part II

- Use of contextual information
  - We are able to learn correlations between environmental conditions and proper reactions
  - Especially interesting in noisy (industrial) environments (BMBF RobAn)
  - Smartness (e.g. labeling, learning) of a system depends on external feedback
  - BUT: requires additional sensors….

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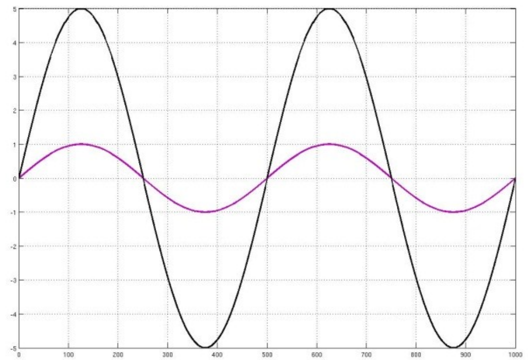
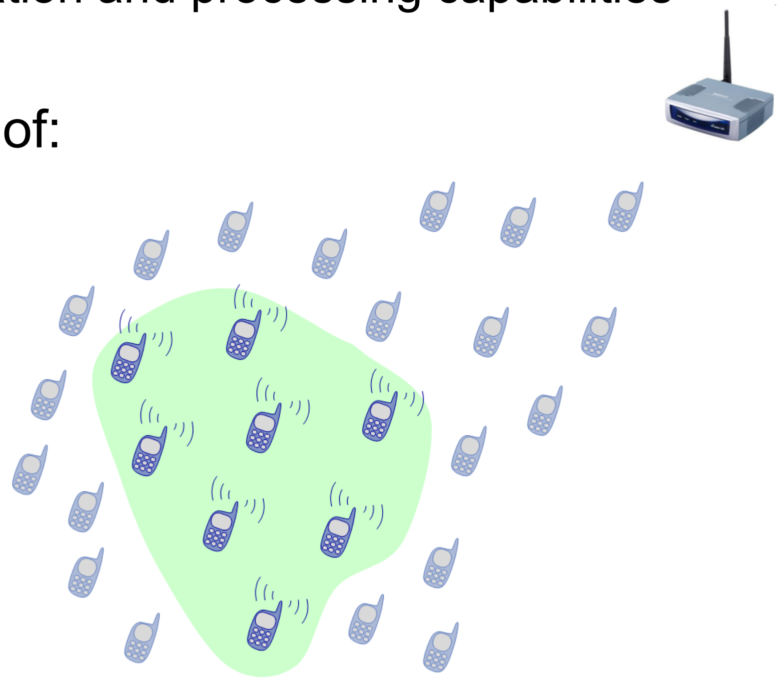
- **Solution: Use RF Signal as a contextual information source!**

Collaborative data communication

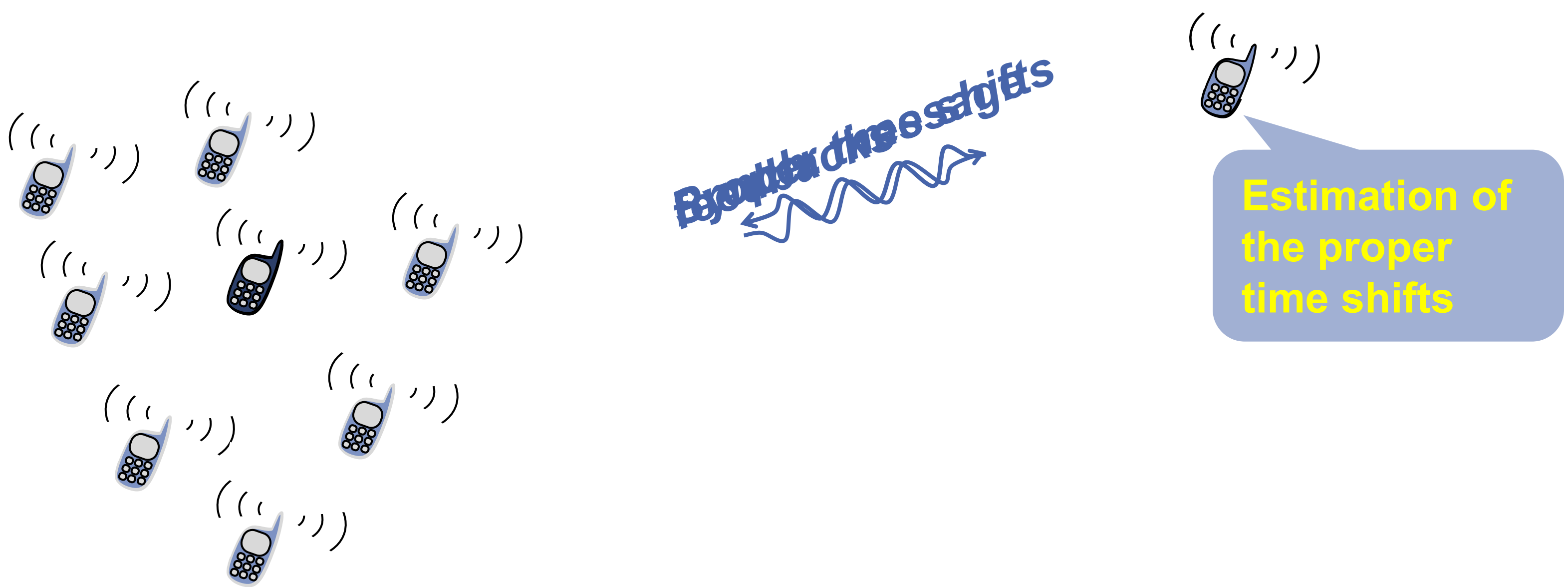
- Sensor nodes …
  - Limited battery storage and communication and processing capabilities
  - Low performance in the individual case
- Collaboration is advantageous in terms of:
  - Transmission range or signal quality
  - Reliability
  - Battery storage





Synchronization

- Closed-Loop Full-feedback synch. method [1]:
  - Broadcasting of the synch. message
  - Receiving of the synch. message and sending it back
  - Calculation of the proper time shifts for synchronization
  - Sending the time shifts to the collaborative nodes



[1] Y. Tu and G. Pottie, **Coherent Cooperative Transmission from Multiple Adjacent Antennas to a Distant Stationary ...**

Outline

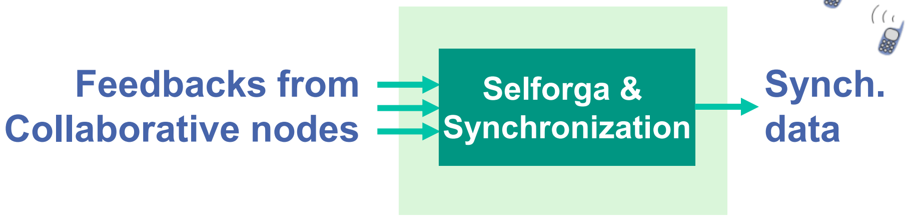
- General overview
- Self-organized collaborative data transmission
- MAC protocol optimization

Self-organized Collaborative data transmission

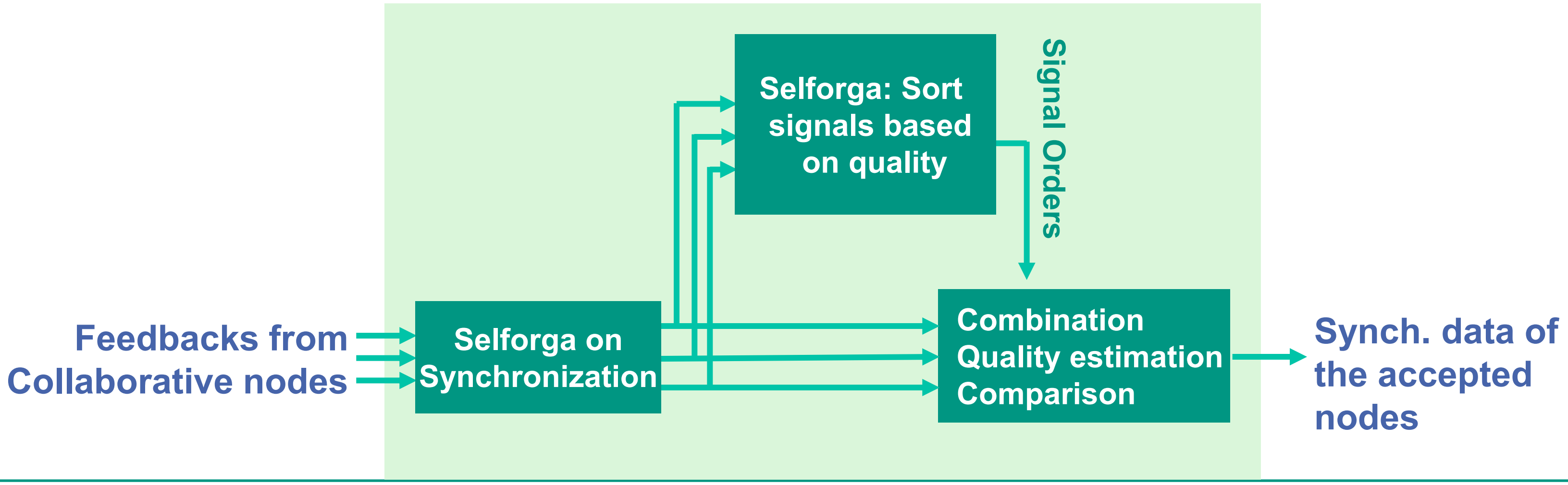
- Challenges
  - Metrics to select suitable nodes for collaboration in terms of:
    - Relative position
    - Battery charge level
    - Transmission channel quality
  - Optimum number of collaborative nodes
    - More than optimum → Energy waste
    - Less than optimum → Low signal quality / Reliability

Solution

- Initialization in …
  - 1-step method: collaboration method

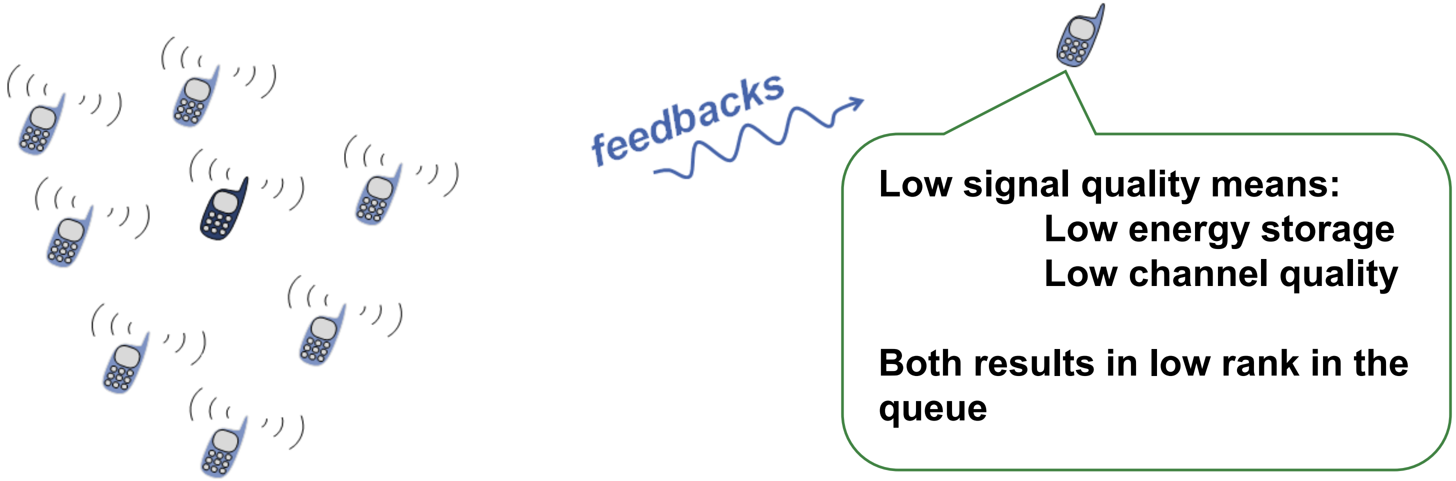


  - 2-step method: Additional Quality based collaboration method



How to apply energy storage level

- To attach the energy storage data to the feedbacks
- To relate the transmission power of the feedbacks with the energy storage level



Min. number of nodes

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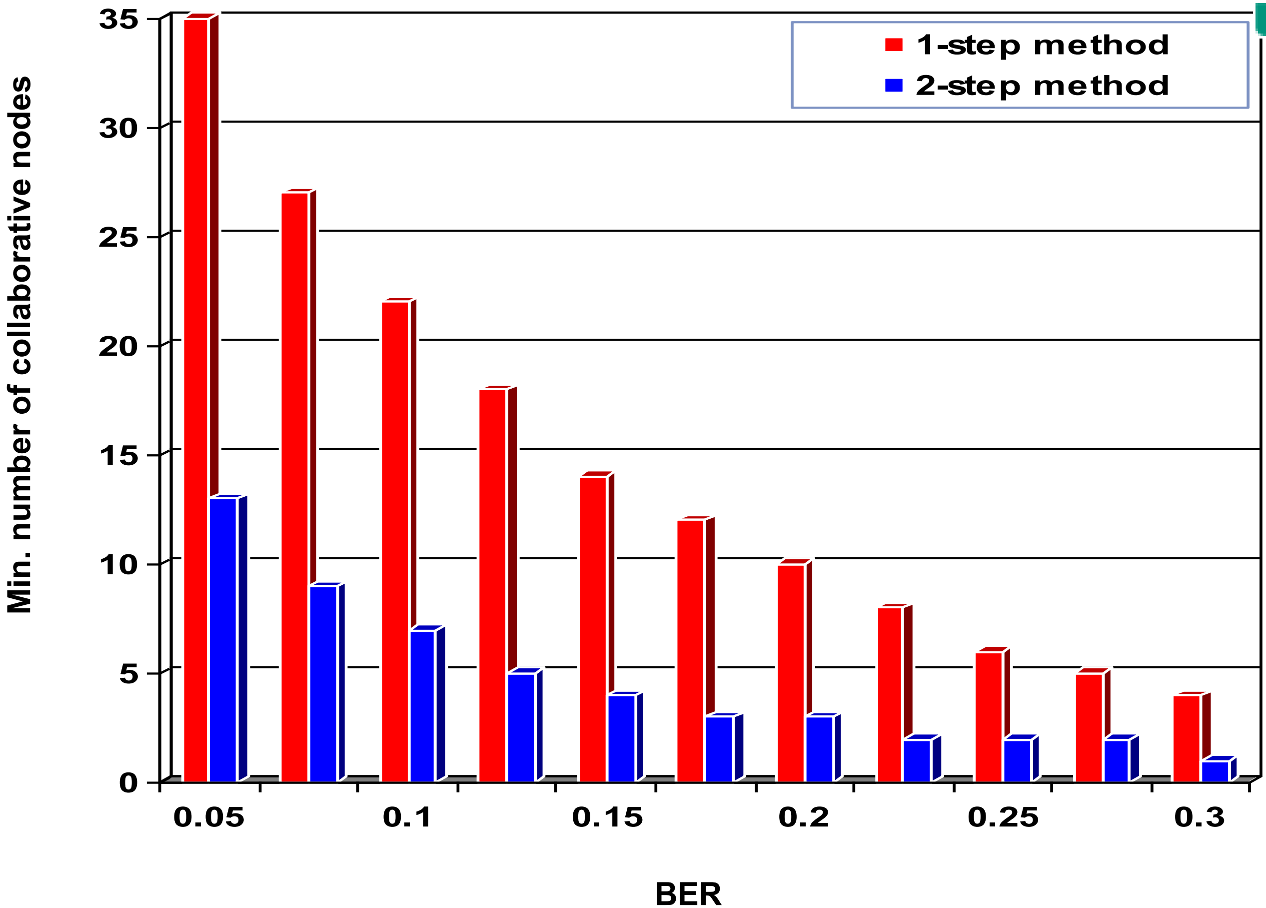

- Minimum number of nodes (Y-axis)
- to gain demanded Bit Error Rate(X-axis)

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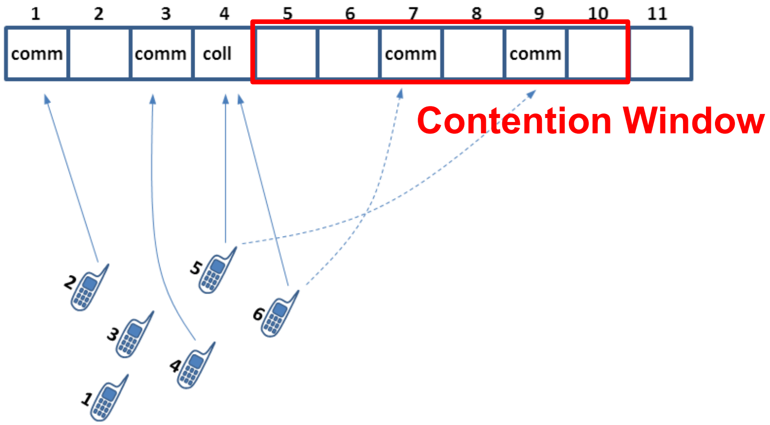
Self-organized MAC Layer algorithm

- Scenario:
  - Emergency situations (e.g. Fire)
  - **Slotted-ALOHA** as the multiple access method
  - **Exponential Back-off** to control the collision rate
- Challenge:
  - Dramatically high increase of channel access demands and so collision rate
  - High time delay
  - Sensor nodes may scorched before successful report

Scenario

- Slotted-ALOHA
  - Shorter *CW*
    - more collision, higher throughput
  - Longer *CW*
    - Less collision, high time delay

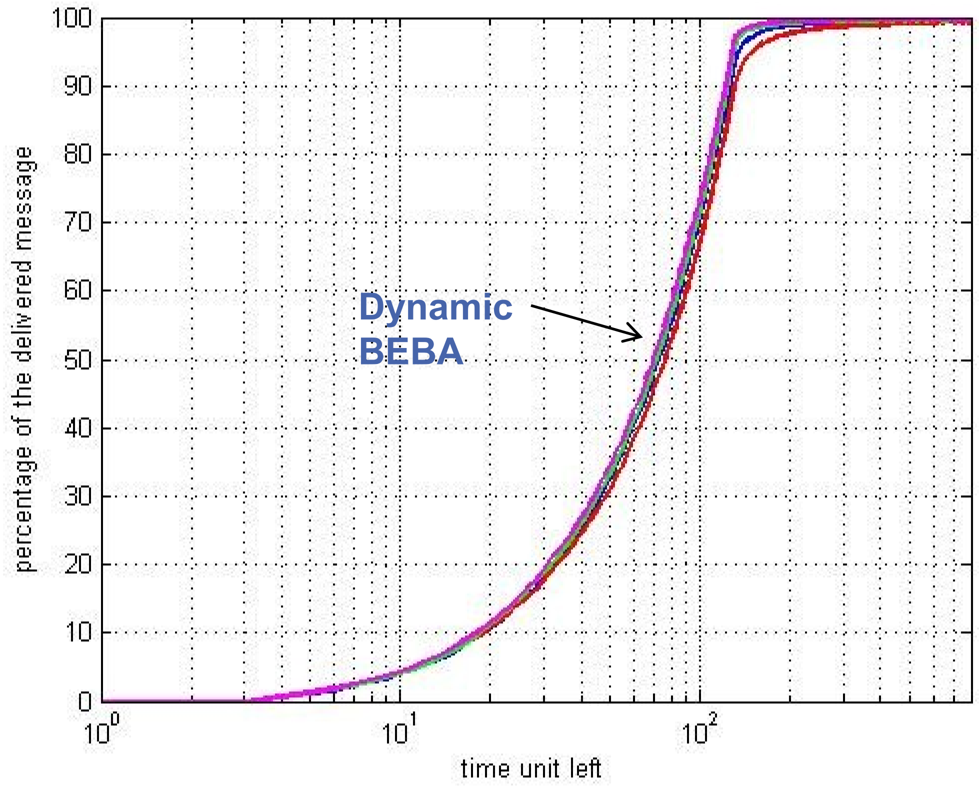


- Binary Exponential Back-off (BEBA)
  - Extends the *CW* as $2^i - 1$ where *i* is the order of collision
  - Acceptable performance for normal situations

Optimization for Emergency situations

- Objective:
  - Maximum throughput in a limited time as sensor nodes have limited respites
  - In real-world applications number of nodes is unknown
- Methodology:
  - Modification of the CW
    - For static situation, a fixed (preset) pattern
    - For dynamic situations: it should be adopt with the collision rate

Optimization for Emergency situations



Optimization for Emergency situations