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Energy-Efficient Networking for Wireless Sensor Networks – Contributions of the AVM Project

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Overview

- ***Motivation***
- Selected highlights
  - A new MAC protocol
  - Hardware/network interaction
  - Middleware for wireless sensor networks
- Conclusion

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Motivation

- Protocol design for wireless sensor networks has new requirements
  - Very limited battery capacity, processing power
  - Simple radio interface, limited communication range
- New challenges on all protocol layers
  - MAC, routing, session layer, …
  - Some protocols exist
- AVM nodes offer new functionality!
  - Directed antennas for communication
  - Wake up of neighbors
  - How to exploit these functionalities best?

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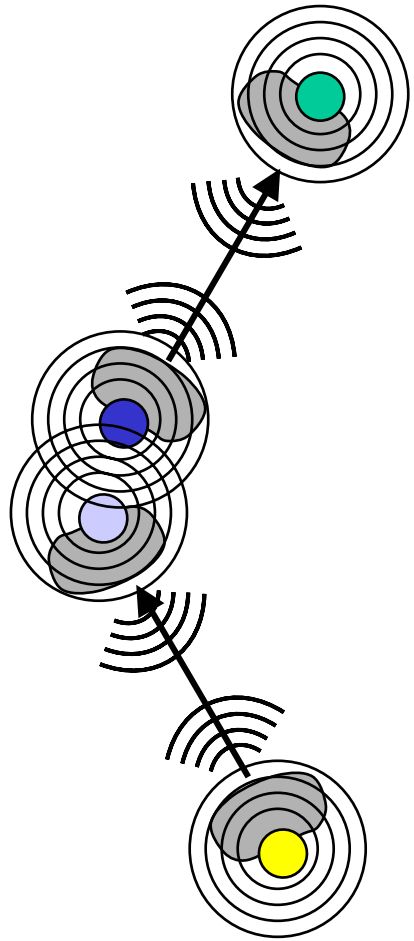
New AVM node capabilities: antennas

- Directed antennas
  - Reduce interference with neighbors
  - Allow higher spatial reuse of the medium
  - Can overcome longer distance
  - Can reduce transmission power required
    - ➢ Reduction of total power consumption
  - Can increase parallelism in network
- Suitable for event-triggered communication!
  - Handle many simultaneous communication requests from multiple sensors, triggered by a single event



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MAC design for directed antennas

- Control directed antennas from the MAC layer

- Proposed “directional” MAC
  - Transmission reserves antenna beams
  - Omnidirectionally listen to channel
  - RTS and CTS sent on all ***free*** antennas
  - Chose antenna with strongest signal
  - RTS/CTS exchange constructs DNAV (directional network allocation vector)

➔DATA and ACK sent directionally on the chosen antenna

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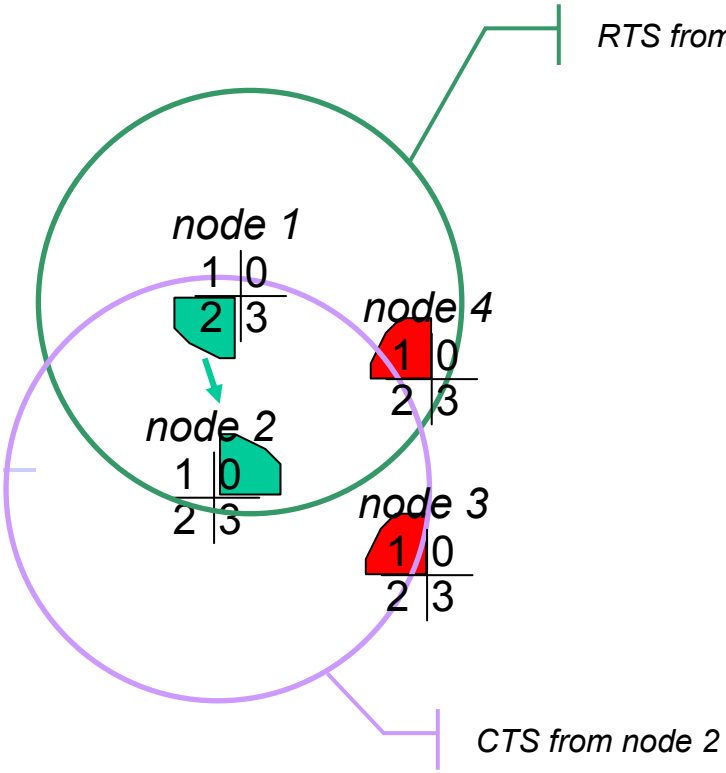
Directional MAC – Example



- Node 1 initiates communication with node 2 : sends RTS
- Node 4 hears RTS and sets antenna 1 quiet
- Node 2 replies with CTS
- Node 3 hears CTS and sets antenna 1 quiet
- Node 1 sends DATA directionally to node 2, using antennas 2 and 0

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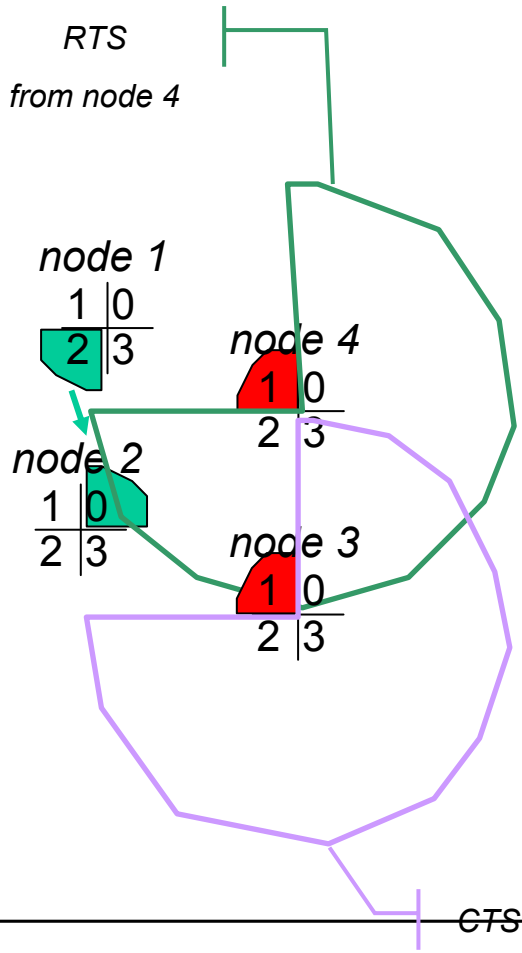
Directional MAC – Example



- Node 4 initiates communication with node 3: sends RTS
  - **Reduced interference with communication between 1 and 2**
- Node 3 replies with CTS
  - **Reduced interference with communication between 1 and 2**
- Possible modification: Node also considers CTS from node 2, turns off Antenna 2

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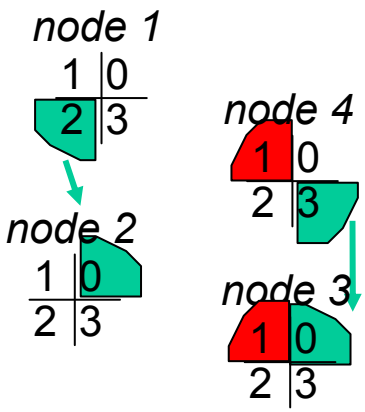
Directional MAC – Example



- Node 4 sends DATA directional to node 3
- Node 2 concludes communication with node 1 : sends ACK

➔ The two DATA exchanges have proceeded in parallel

- Expected results: lower interference, less errors, improved energy efficiency, better handling of sensor-network typical traffic patterns

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New AVM node capabilities: wake up

- Wake up radios: simple, low power receiver that triggers the main radio to be switched on
- Allows event driven communication
  - Sporadically, information has to be communicated
  - Natural pattern for sensor networks
- Nodes wake up when necessary
  - All nodes which hear this wakeup signal ? – Overhead!
  - Only a particular node (addressed in wake up signal) ? – Difficult!
- How to combine directional MAC with wake-up radio?
  - Use antennas to filter set of woken up nodes?

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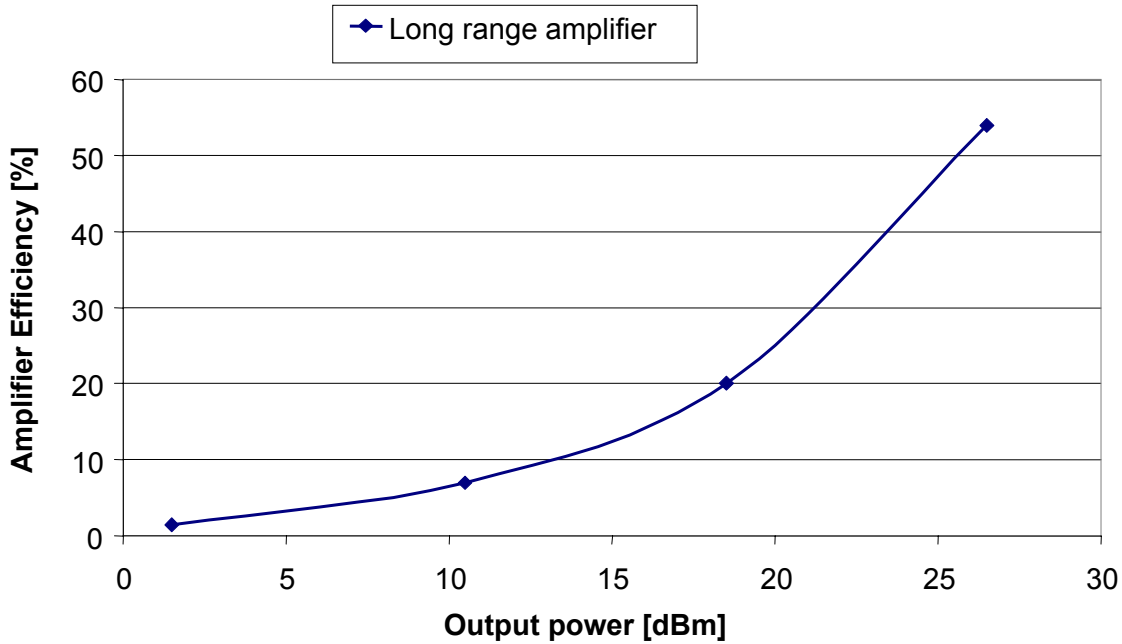
Amplifier behavior

- Amplifier is major power sink in wireless NICs
- Designed to have highest efficiency at maximum output power (e.g., RF2155)



- Choice of maximal distance to overcome determines amplifier

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Amplifier behavior

- But: in realistic scenarios the distance between communication nodes in a network is variable
- Shorter distances are actually often preferable
  - Interference reduction in ad hoc networks
  - Multi-hopping reduces energy consumption

➔Maximum output power rarely used

- Amplifier consumes too much power due to low efficiency in lower output power modes

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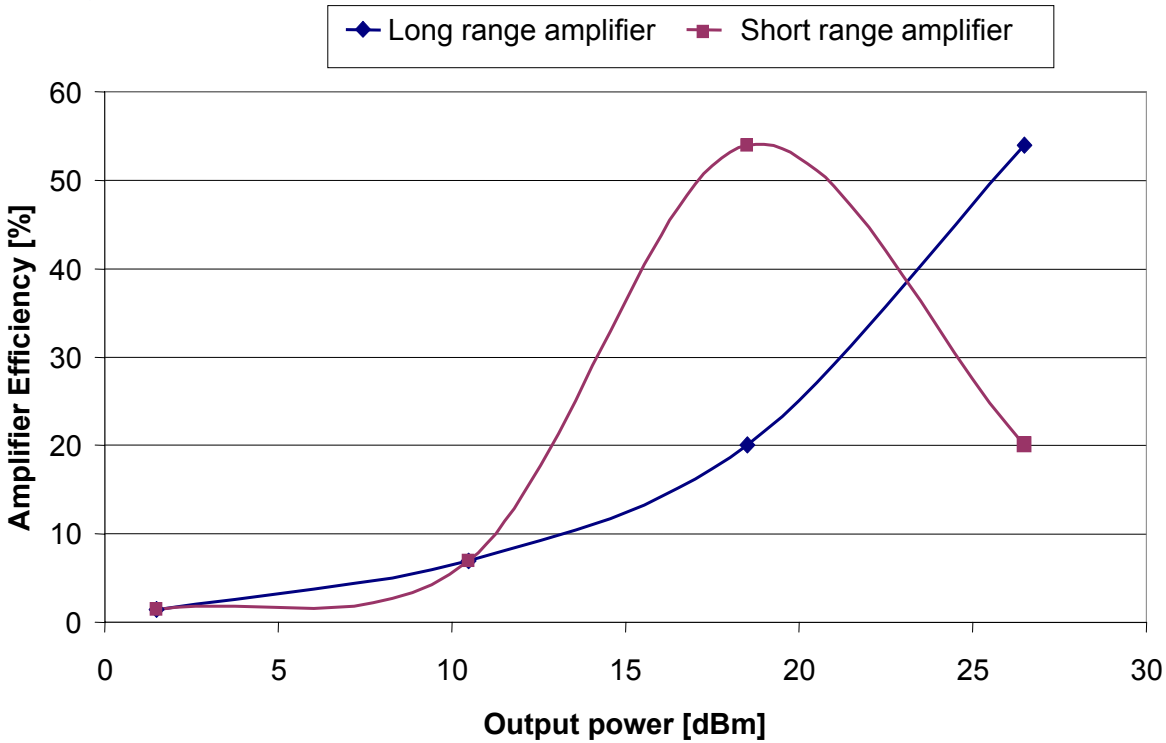
Amplifier behavior

- IDEA: Why not shift the efficiency characteristic ?
- E.g.:



- Applied in networks, it reduces required energy by up to 40 %

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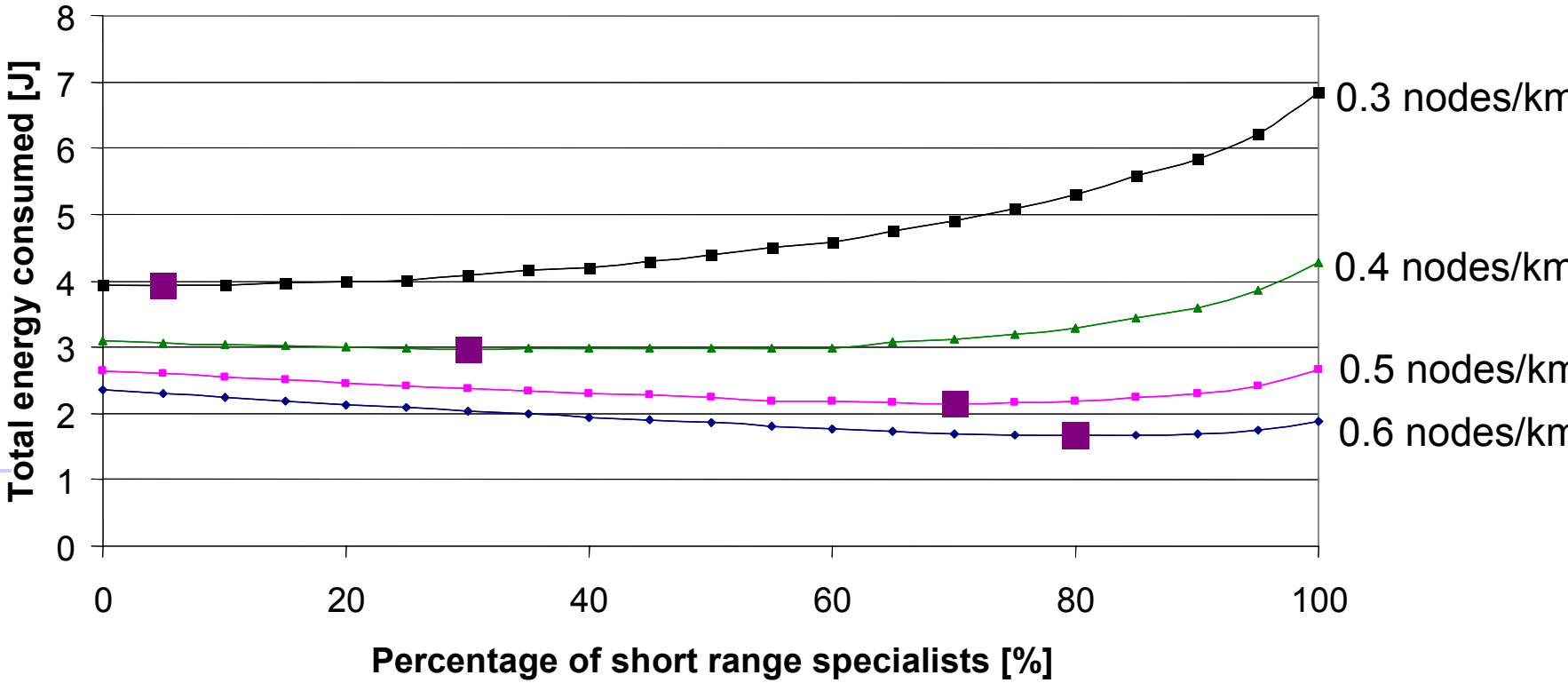
Mixing different amplifiers



- Optimal mixture exists, depending on density!

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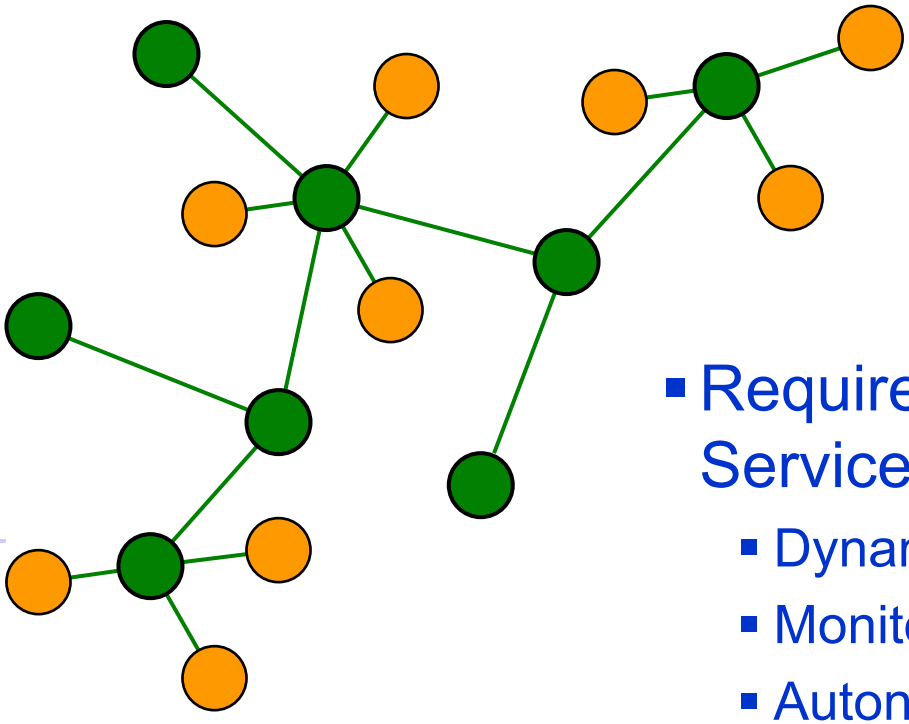
AVM Middleware



- Requirements to Services and Service Logic
  - Dynamic discovery of services
  - Monitoring of service parameters
  - Autonomous configuration

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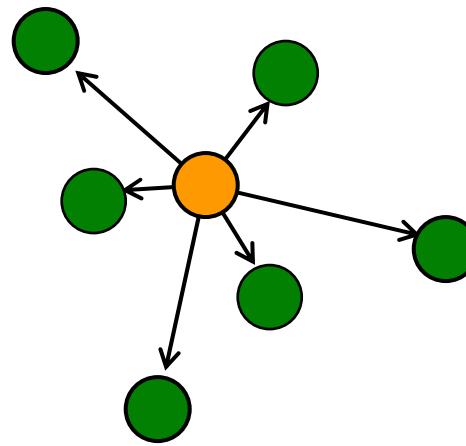
Dynamic Discovery of Services

- Announcement of services
- Method: Each node inform others about offered services
  - On activation, node sends ANNOUNCE-messages to neighbour
  - ANNOUNCE-message contains compact description of offered services
  - Neighbour nodes can store descriptions in addition to the data of corresponding node (IP address, port)

  ➔Each node ‚knows' the functionality of neighbour nodes and can utilize their service, if required



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Dynamic Discovery of Services

- Dynamic search for services
  - Complements the announcement method
  - Enables nodes to search for services actively
- Method summary: Nodes search for required services in their environment
  - The node sends SEARCH-request with description of service features it is looking for
  - The nodes that possess the services with sought-after service functionality respond to the request by sending their contact data (IP address, port) and description of service controls
  - The search initiator can use this data to access the services and utilize their functionality

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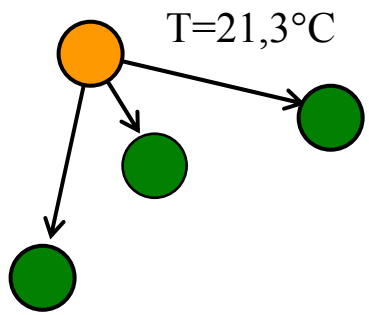
Monitoring of Service Parameters

- Monitoring of service parameters enables to obtain data on current status of a node
  - Observers register with the node whose parameters they are going to monitor
  - The node stores addresses of observers
  - When the values of service parameters are changed, all registered observers receive notifications with new values of parameters

Example: a temperature sensor placed in a room sends measured values to nodes registered as observers every time the temperature changes



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Autonomous Configuration

- Autonomous configuration of services
  - Clients can control service execution
  - The control of services is realized through configuration of service parameters
  - Each node possesses information about its services‘ parameters and values enabled for them; on request this data can be sent to other nodes (clients)
  - Clients can propose new values for service parameters
  - The configured node has to check if the proposed values are appropriate for its parameters
  - Security aspects are particularly important in configuration issues

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Conclusion

- Wireless sensor networks present a new challenge to the design of communication protocols
  - Specifically, energy efficiency becomes a prime concern
  - New questions asked for MAC, routing, service discovery, …
- The intended innovations of the AVM sensor nodes offer new possibilities
  - Wakeup, directed antennas
- Interesting solutions with promising preliminary performance results have been introduced already

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