Year 2 Review
Paris, November 8th and 9th, 2006

Scientific Highlights :

Dynamic & Pervasive Networks

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Outline

- Motivation
- ART Cluster Skills & Background
- Emerging Topics
- The New Activity

Motivation (1)

- Information technology is going through another major revolution:
  - it is being embedded into a growing range of physical devices linked together through networks
    - a trend driven by
      - the increasing capabilities and continuously declining costs of computing and communicating devices
- These networks of embedded systems are becoming ever more pervasive as the component technologies become smaller, faster, and cheaper

Pervasiveness √

Motivation (2)

- The pervasive and ubiquitous nature of these networks imply that systems are able to:
  - configure themselves (internal and external motivations)
  - adapt to their environments automatically (“ ” “ ” “ ”)
- The challenge is on adaptation techniques
  - distributed paradigms and techniques
  - heuristic-based approaches
  - collaborative computing
  - quality of service to resource consumption mapping
  - efficient networking protocols, etc.

Dynamic and Pervasive Networking √

Motivation (3)

- Alignment with major research frameworks (1)
  - (taken from ARTEMIS)
    - Vision: The vision driving ARTEMIS is a major evolution of our society in which all systems, machines, and objects will become digital, communicating, self-managed resources. These transformations will be possible through advances in Embedded Systems technologies and their large-scale deployment in all areas of human activity.
    - Target: ARTEMIS will therefore facilitate and stimulate European success in Embedded Systems by …
      - focusing research and development to make more effective use of resources
        - » Embedded Systems will be context-aware and able to make optimum use of available resources

Motivation (4)

- Alignment with major research frameworks (2)
  - (taken from FP7)
    - one of the 9 themes:
      - Information and communication technology (ICT): one of the 6 "ICT Technology Pillars":
        - » *Embedded systems, computing and control*: powerful, secure and distributed, **reliable and efficient** computing, **storage** and communication systems **and products** that are embedded in objects and physical infrastructures and that can **sense,** control and adapt to their environment; **interoperability of discrete and continuous systems**.

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- **ART Cluster Skills & Background**
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ART Cluster Skills & Background (1)

- Adaptive Real-Time techniques and technologies
  - as a means to provide for timeliness in such dynamic and pervasive networked systems
  - using RT techniques as a means to make more effective use of the (scarce and varying) resources

ART Cluster Skills & Background (2)

- Recent achievements by the cluster members on
  - improve error confinement in CAN networks - star topologies for CAN (Aveiro, Baleares)
  - engineering CAN-based systems by decoupling priorities and identifiers (Catania)
  - new response-time analysis for CAN networks (York)
  - extensions to the Flexible Time Triggered (FTT): FTT-SE - FTT over Switched Ethernet; FTT switches for full integration in Ethernet (Aveiro)
  - dynamic QoS management for distributed multimedia and control (Aveiro, Catalonia, Pisa, Porto)
  - dynamic service composition and replication management (Aveiro, Madrid, Porto)
  - synchronous RT scheduling services for CORBA and RMI (Aveiro, Madrid)
  - TDMA communication paradigms with slot-skipping - TDMA-SS (Porto)
  - feedback-based resource managment applied to the network level (Catalonia)
  - real-time support for wireless networks for factory-floor, including IEEE802.11, bluetooth, hybrid PROFIBUS (Catania, Porto)
  - Wireless Sensor Networks (WSNs) and Mobile Ad-hoc Networks (MANETs) (Aveiro, Catalonia, Catania, Kaiserlautern, Madrid, Pisa, Porto, York)

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- **Emerging Topics**
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Emerging Topics (WSN) (1)

- One of the key advantages of Wireless Sensor Networks (WSN) is their ability to bridge the gap between the physical and logical worlds
- Cost and size considerations imply that the resources available to individual nodes are severely limited. However, the limited processor bandwidth and memory may only be temporary constraints in sensor networks, thus potentially widening more demanding sensing capabilities such as video and imagery
- The energy constraints on the other hand are more fundamental. Energy constraints are unlikely to be solved in the near future given the slow progress in battery capacity

Emerging Topics (WSN) (2)

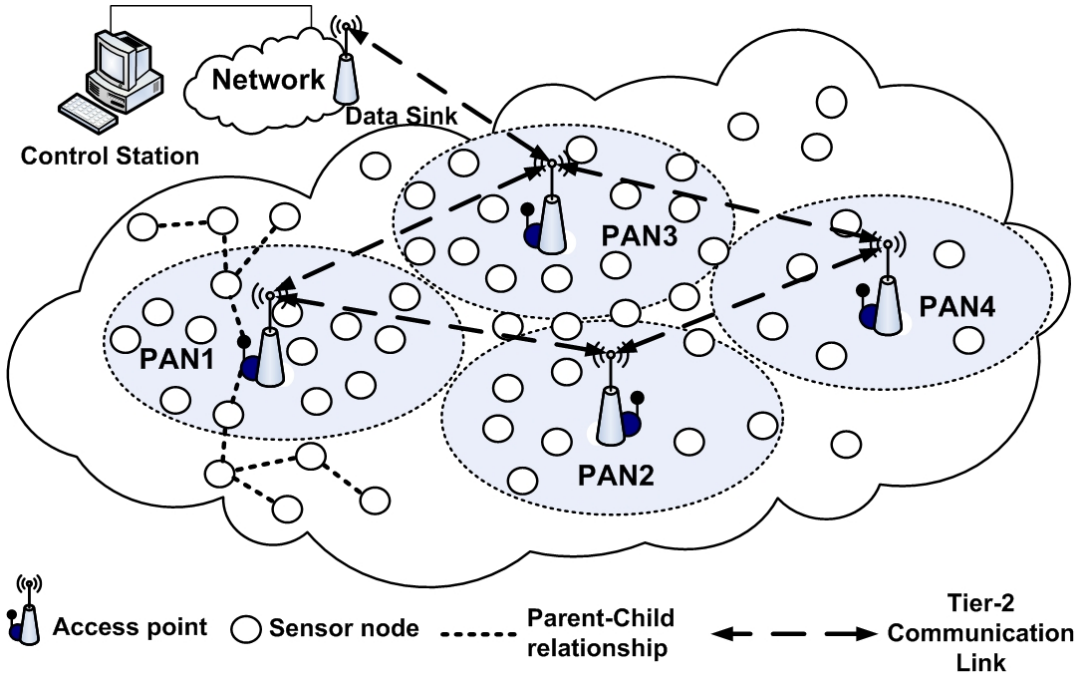
- Energy-awareness is turning out to become a major research challenge for WSN, drawing into
  - innovative and efficient networking protocols
    - medium access control (MAC), routing, security
    - operating systems and platforms
    - Middleware
    - computing paradigms, data aggregation and fusion
    - etc.
  - Adaptive Real-Time techniques play a major role here as well

Emerging Topics (WSN) (3)

- Just a few examples of ongoing work
  - ART-WiSe (large scale systems based on COTS technology)
  - WiDom (prioritized wireless MAC protocol)

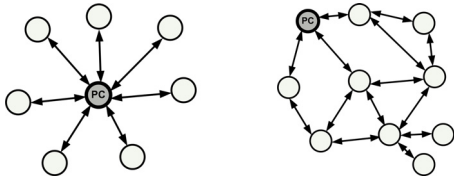
ART-WiSe (1)

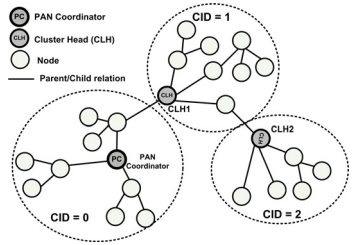
- Architecture for Real-Time Communications in Wireless Sensor Networks (http://www.hurray.isep.ipp.pt/art-wise)
- Design Goals
  - Real-Time
  - Reliability
  - Scalability
  - Self-Organizing
  - Cost & Energy Effective
- 2-Tiered Architecture
  - Tier-2: IEEE 802.11
  - Tier-1: IEEE 802.15.4/ZigBee

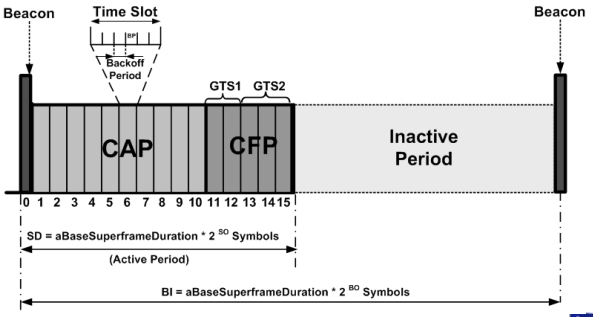


ART-WiSe (2)

- Achievements: performance assessment and improvement of the IEEE 802.15.4 protocol
  - analytical and simulation modeling → MATLAB, OPNET,…
  - on the CSMA/CA mechanism
    - assessment → WFCS'06
    - improvement → RTN'06
  - on the Guaranteed Time Slot (GTS) mechanism
    - assessment (star) → WPDRTS'06
    - improvement (star)→ ECRTS'06
    - assessment (cluster-tree) → RTSS'06
    - improvement (cluster-tree) → future

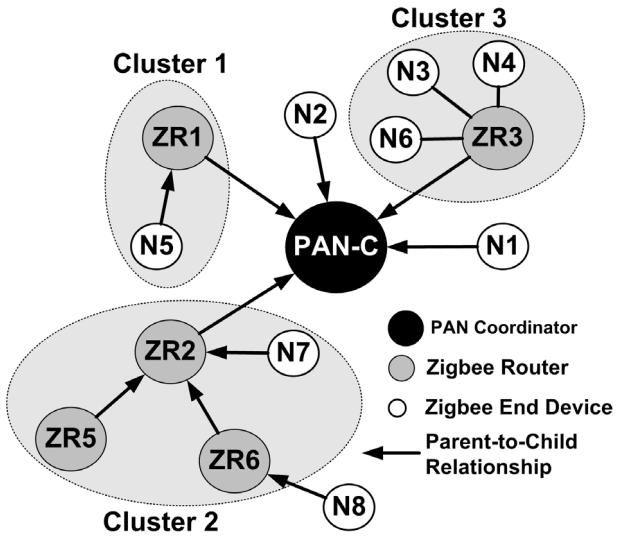






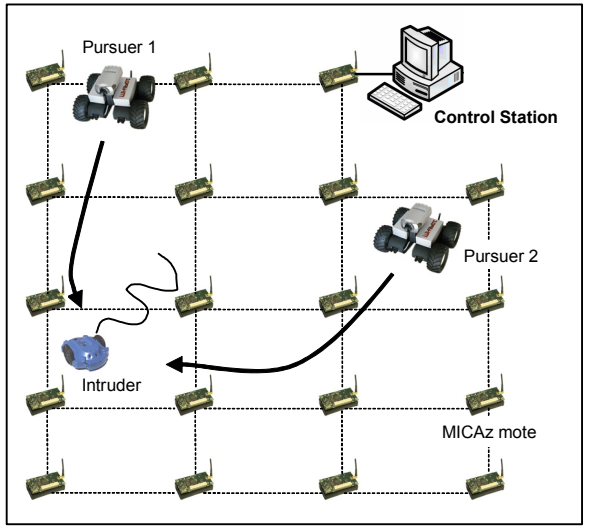
ART-WiSe (3)

- Achievements: engineering ZigBee cluster-tree networks
  - ZigBee NL core functionalities are being implemented
    - network formation mechanisms, tree-routing protocol,…
    - MICAz motes, running TinyOS (nesC)
  - Some add-ons are envisaged:
    - beacon synchronization (mandatory)
      - two alternative solutions proposed
      - ongoing experimental work
    - tackling the hidden-nodes problem
      - ongoing work
    - supporting mobility
      - mobility of ZED, ZC,…
      - future work



ART-WiSe (4)

- Achievements: implementation
  - For assessing, validating and demonstrating the ART-WiSe architecture → WiP ECRTS'06
  - Implementation of (open source) protocol stack
    - IEEE 802.15.4 (full)
    - ZigBee NL (tree-routing)
    - http://www.open-ZB.net (in a few weeks)
  - Development of a pursuit-evasion/search-rescue application
    - pursuer robots track and pursuit intruder robots
    - real-time communication requirements
    - feasible with available resources (human, equipment)

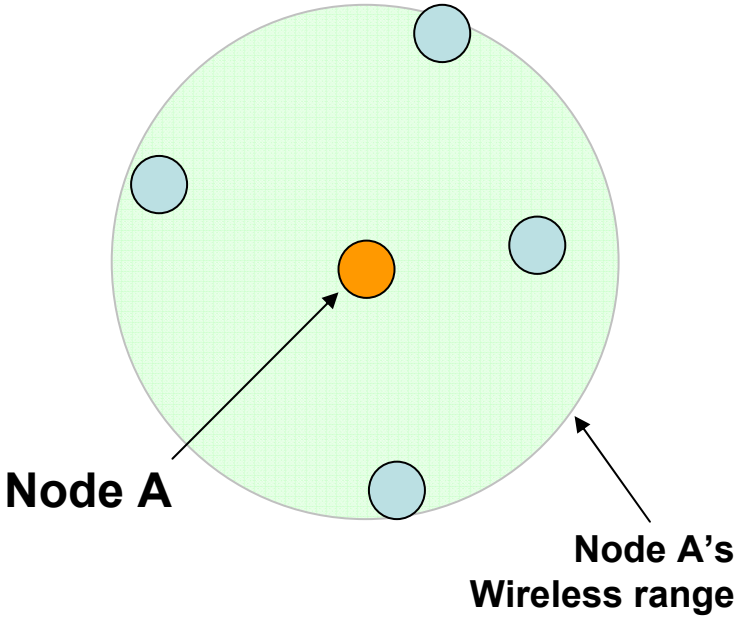


WiDom (1)

- Surely you know about CAN…
  - Dominance/Binary-Countdown protocol
- What could "CAN-like" wireless medium access do for us:
  - strictly prioritized and collision free medium access
  - efficient handling of sporadic message streams
  - Many novel applications…
    - Aggregate quantities (maximum, minimum)
    - Estimation of "living" nodes (majority voting, average, etc.)
    - Interpolation by combining with location awareness
    - etc.

WiDom (2)

- How can node A compute the minimum temperature reading among its neighbors?



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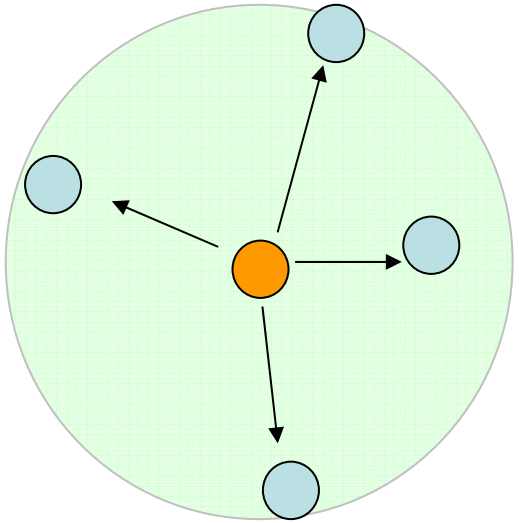

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WiDom (2)

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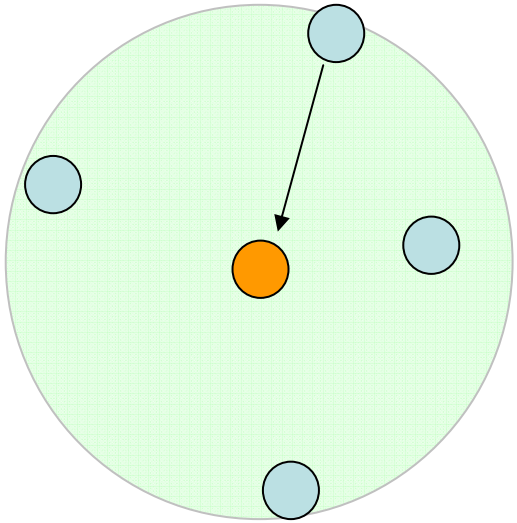

1. Node A broadcasts a request
2. Neighbor nodes reply when they eventually access the medium

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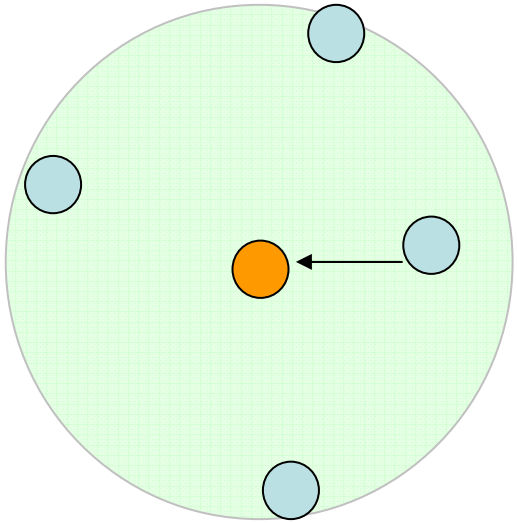

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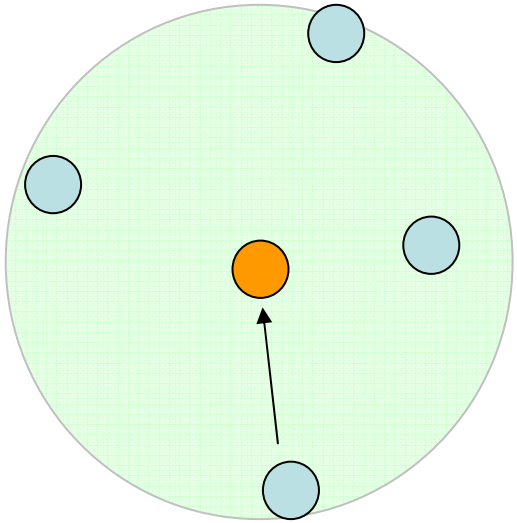

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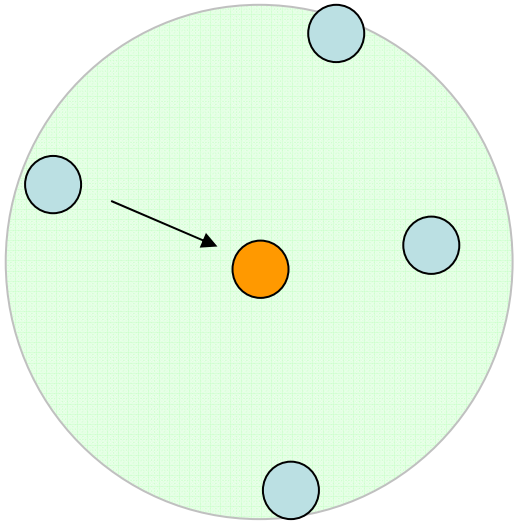

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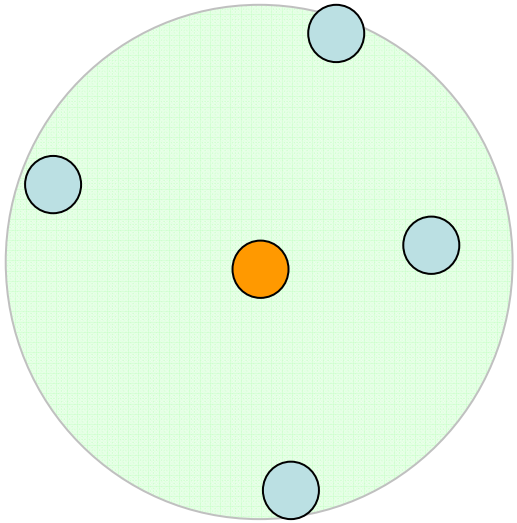
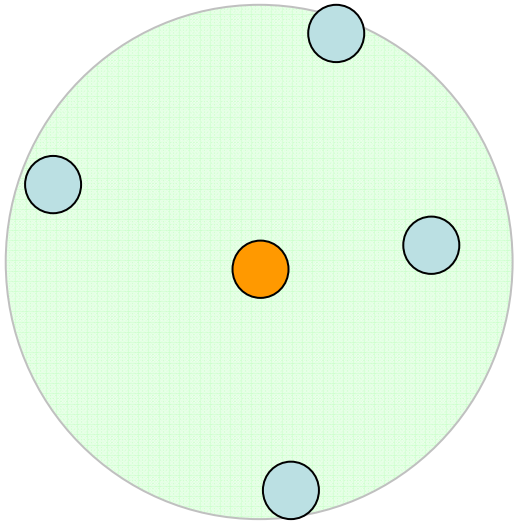


1. Node A broadcasts a request
2. Neighbor nodes reply when they eventually access the medium
3. Node A then computes the minimum value (assuming it knows the number of neighbors...)

WiDom (2)

- How can node A compute the minimum temperature reading among its neighbors?
- Can a prioritized MAC do better ?



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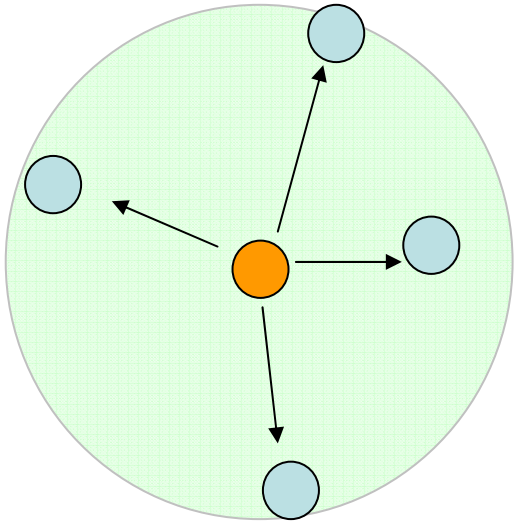

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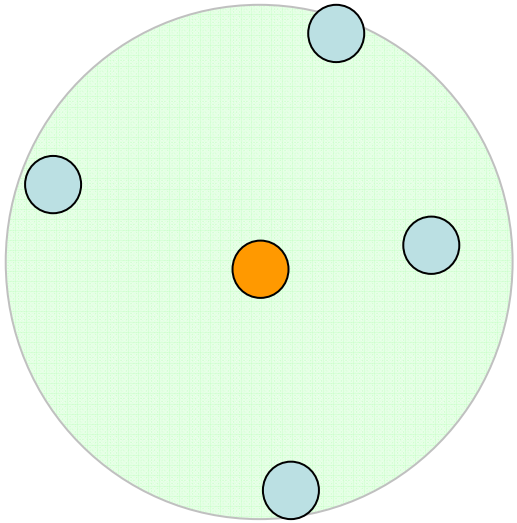

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WiDom (2)

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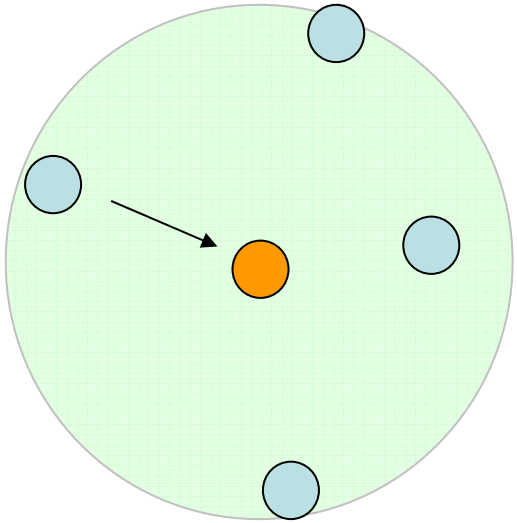

- Can a prioritized MAC do better ?

1. Node A broadcasts a request
2. Neighbor nodes perform contention for the medium using their temperature reading as the priority
3. The node that wins, is the one with the minimum temperature

WiDom (3)

- With this basic mechanism, one can efficiently perform many distributed "computations":
  - Estimate MIN, MAX and the number of live nodes
  - Leader election
  - Perform interpolation of sensor data

All with a time complexity that does not depend on the number of nodes

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- **The New Activity**

The New Activity (1)

Dynamic and Pervasive Networking

(already started 10/2006)

THANKS!

The New Activity (2)

- Milestones
  - Year 3
    - Kick-off meeting (4th quarter 2006)
    - White paper on taxonomy of Wireless Sensor Networks (WSNs) and Mobile Ad-Hoc Networks (MANETs) (1st quarter 2007)
    - Organise and participate in the 6th International Workshop on RTN (3rd quarter 2007)
    - Concrete contributions on MAC and Routing protocols (4th quarter 2007)
  - Year 4
    - Contributions on distributed computing paradigms, dynamic QoS management, flexible scheduling, resource management in distributed systems
    - summer school on Real-Time Networks
    - A SOTA report on WSN and MANETs
    - Contributions to the standardization bodies