Adaptive Scheduling in Wireless Sensor Networks.

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Summary

- Requirements
- Motivation
- Applications
- Related issues
- Protocol used
- Adopted scheduling
- Virtual sectors
- Deployment if migrating agents
- Conclusion

WSNs primary Requirements

- **Energy-Efficiency**
- Scalability to the change in network size, node density and topology
- **"Adaptivity" to Network changes**
- Resiliency to node failures
- **Network self-configuring**

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Driven Motivation (1)

- Autonomic injection of local scheduling into the network during ongoing communication to :
  - save node energy through the network self-organization .
  - opportunistic change of network activity during ongoing communication according to the application;
  - Avoid compulsive network behaviour due to sudden anomalies;
  - Avoid overload on the low memory of the sensor node processors as a result of an event detection

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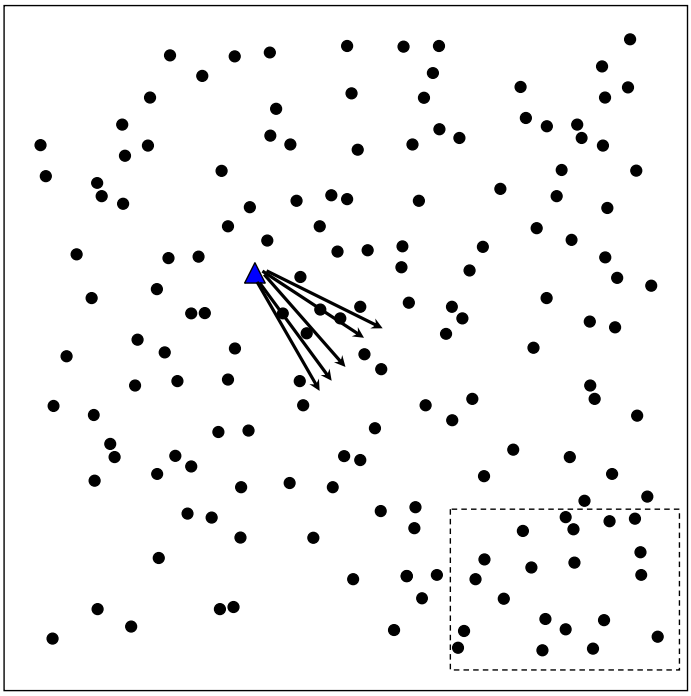
Application (1): Dynamic scheduling change



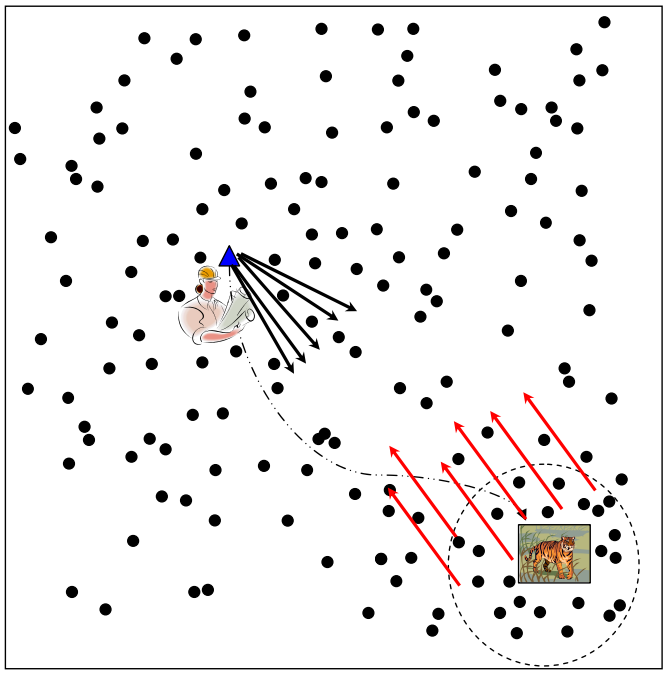
- Based on data received, the base station can opportunistically decide to change the data sampling of sensors in a area during network activity

Possible solution:

The base station broadcast a notifying message towards each node involved

Cons: High energy consuming

Application(2): Network anomaly intervention



Possible solution **Multiple Notification messages** *(High energy consuming)*

Proposed solution: **Migrating agent** *(Moderate energy consuming)*

Scheduling change: Related issues

- Facilitate the agent migration towards the affected region;
- Synchronization issues: The change of scheduling should not affect the normal communication of nodes;
- Latency issues: The agent should get the destination within a certain time;
- Design of dedicated agent: (1)Application-driven design; (2)Computational light;
- Design of a cross layer interaction between the application and routing layers

Protocol used:MERLIN*

- CSMA/TDMA Hybrid architecture;
- Lightweight protocol;
- Integrated MAC+Routing characteristics to address low memory capabilities of sensors;
- No handshake mechanisms (e.g.RTS/CTS/ACK) to address energy consumption and latency of packets
- Controlled multi-paths technique to improve the reliability;
- It can support node localization procedures;

(**Ruzzelli, Evers, Van Hoesel, Havinga*, EU Eyes project, Netherlands.)

MERLIN protocol at a glance (2)

▲ Gateway

● Node

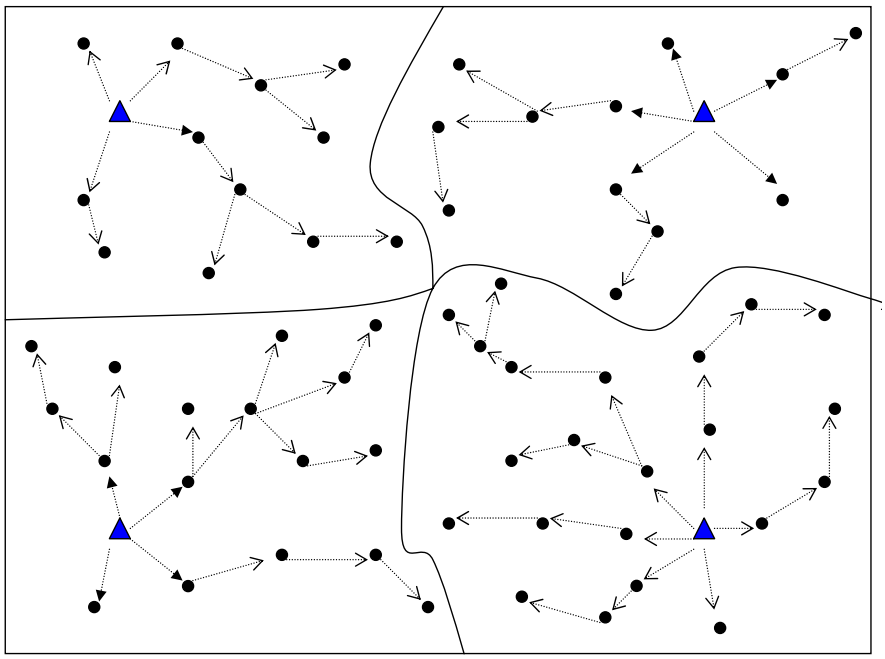
Why Time Zones?

Nodes with the same color are in the same time zone

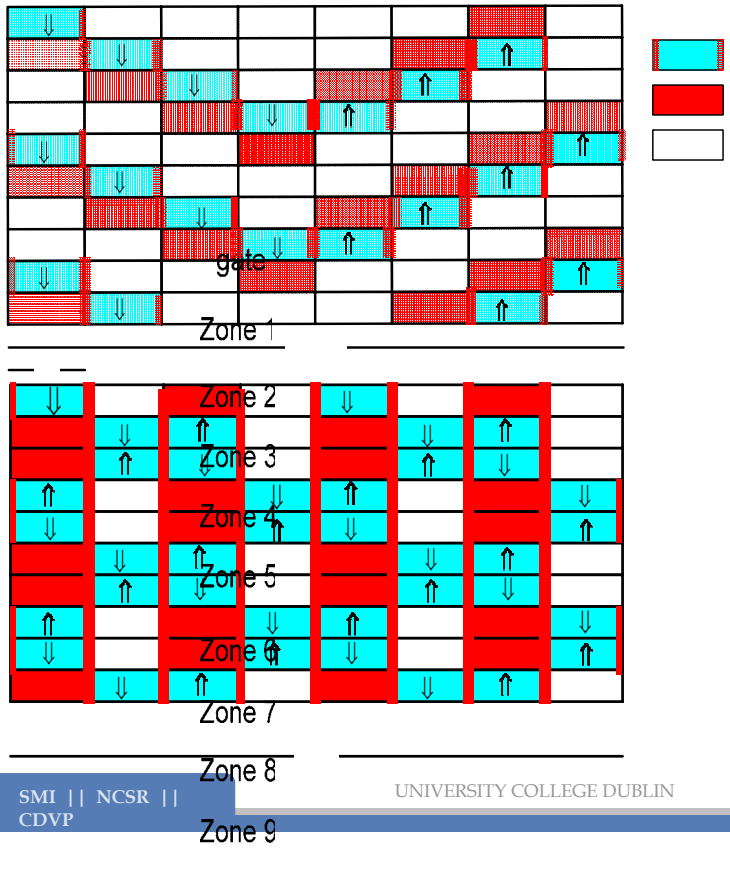
Nodes within the same subset belong to the same gateway

Nodes within the same zone wake up and go into sleep simultaneously

CSMA applied



Scheduling tables: V-schedule vs. X- Schedule



- **Frame is divided in 8 slots;**
- **Nodes in the same zone transmit simultaneously**
- **The X scheduling is obtained by super positioning 2 V-sched one of which upside-down**
- **Nodes go into sleep immediately after the transmission**

Properties of the two tables [1]

- The X scheduling should be used for applications in which some energy can be traded off for a decrease of latency of messages and for applications in which latency is a tighter constraint;
- V-scheduling is more suitable for low data traffic applications where the need of saving energy is of paramount importance.

[1] Ruzzelli, A., Tynan, R., G.M.P.O'Hare: A low-latency routing protocol for wireless sensor networks. In proceeding of SENET'05 Advanced Industrial Conference on Wireless Technologies. Montreal (2005)

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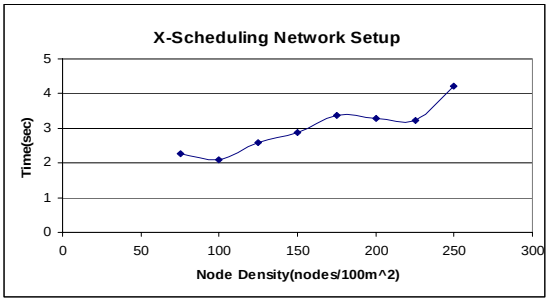
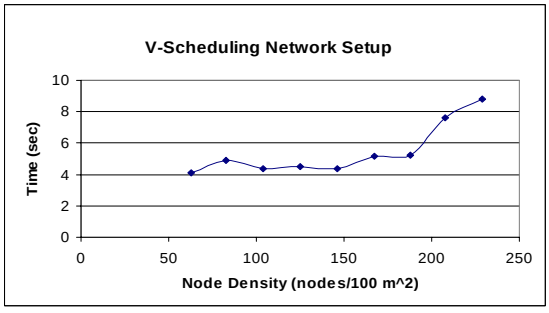
X and V scheduling setup time





- V-sched shows double network setup time with respect to X-sched;
- X and V scheduling can be setup in less than 10 seconds for 250 nodes network density.

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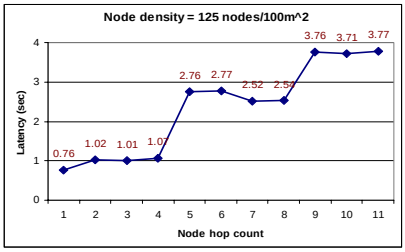
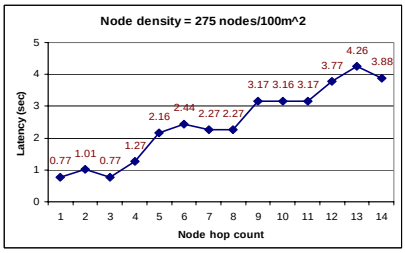
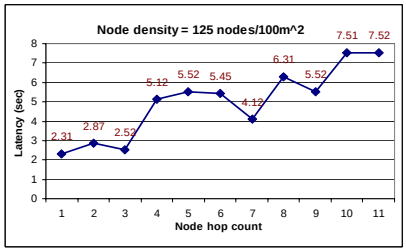
End-to-end packet delay

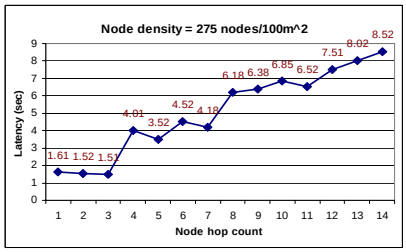
X-scheduling





V-scheduling





- The controlled multiple path mechanism may cause a lower delay for nodes farther from the gateway than other;
- A periodic and discontinuous increase of latency at the intersection of data traffic flows due to:
  - **X-sched:** Packet Collisions hence retransmission;
  - **V-sched:** Periodical stop of nodes activity that go into sleep.

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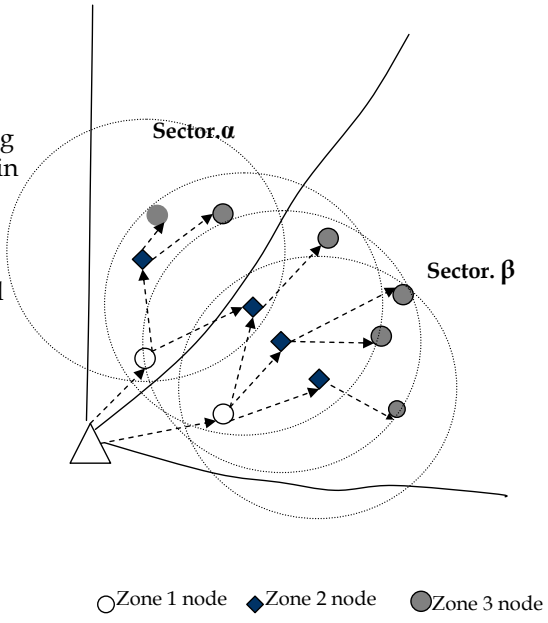
Novel mechanism: **Virtual sectors**

- Virtual sectors are generated by simply using the CSMA approach already in use by nodes in the same zone.
- During initialization, nodes in zone 2 , after receiving the init-msg from zone 1 nodes, will generate a *sectorID* based on the parent node ID in zone 1 and then proceed to flood the network with their *sectorIDmsg*.
- The sectorID is a unique number related to the zone 2 node ID-number.
- Because of the Contention Period (CP), only some nodes that are far apart can win the channel then transmit simultaneously
- The rest of nodes will refer the transmission to the next frame



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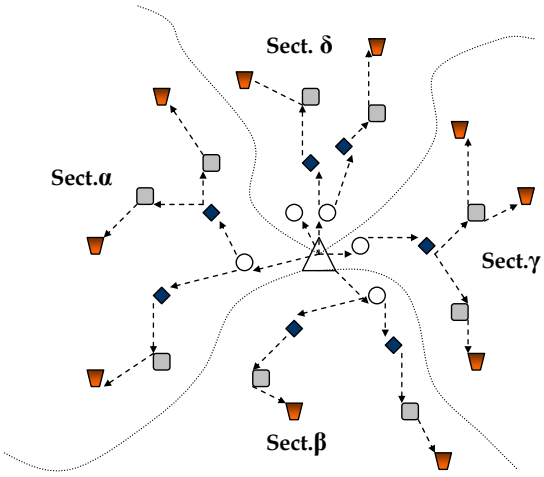
Virtual sector: Bigger view

- Nodes in farther zones will inherit the sector.
- Nodes in zone one will get the sensor from zone 2 nodes
- The simple mechanism together with a table of neighbours provided for each node allows agents to migrate towards the affected node/area that presents an irregularity



△ Gateway ○Zone 1 node ◆Zone 2 node ▢Zone 3 node ▼Zone 4 node

How a change in scheduling is Effected

- The X and V scheduling tables have the same slot length, same frame time and same number of zones → **They are interchangeable** under certain timing conditions
- The agent can order a change of scheduling for the entire sector or a portion of it, for example from zone N to the zone N+M in a sector.
- Nodes in the border zones (N and M) an adoption of both the old and the new scheduling to keep the continuity of message flow.
- The agent should give the time of scheduling change

Simultaneous scheduling adoption

In order to have a simultaneous scheduling adoption for the entire group of nodes involved, the migrating agent should

- Firstly identify the number of zones that will join the change;
- Secondly calculate the overall time necessary so that the packet can be forwarded to all the nodes interested;

Example of agent commitment rules

- Migration to a particular zone

BELIEF(*nodeReceptRate*(?*val*; ?*nodeID*)) &
BELIEF(*NodeThreshold*(?*trigger* &
BELIEF(*NodT hreshExceed*(*TRUE*)
→ *COMMIT*(*Self*;*Now*;*Belief* (*True*);
SEQ(*Migrate*(?*nodeSector*);*Migrate*(?*nodeTimeZone*))

- Adoption of a new scheduling for a zone

BELIEF(*BufferSize*(?*val*))
&*BELIEF*(*similPercent*(?*threshold*))
→ *COMMIT*(*Self*;*Now*;*Belief* (*True*);
SEQ(*AdoptZone*(?*ZoneID*; *V SCHEDULING*; ?*T*);
Migrate(?*timeZone* + 1; ?*sectorID*; ?*nodeID*)))

Conclusion

- We investigated the use of intelligent agents in the delivery of adaptivity at the networking layers has been investigated;
- This research has described a method of optimizing energy resources in times when unexpected or heavy network activity occurs.
- Three instruments facilitate this: (1) the provision of two efficient and interchangeable scheduling tables; (2) the ability to generate virtual network sectors; (3) the adoption of autonomous mobile agents.
- Agents monitor network activity and determine which of the two scheduling regimes would be most appropriate
- Autonomous agents can deliberate and dynamically apply the respective schedules at either network or sector level.

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Thanks for your attention

Questions are welcome!

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