1-1-2007

Ambient intelligence through Wireless Ad-hoc Control Networks

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Origin of concept

- **Observation:** All nodes in a control network are fitted with microcontrollers which manage communications.
- **Question:** Can we use the free time of these many microcontrollers to control the whole process ?
- **What for:** cost reduction, decentralisation, modularity, distribution.

introduction

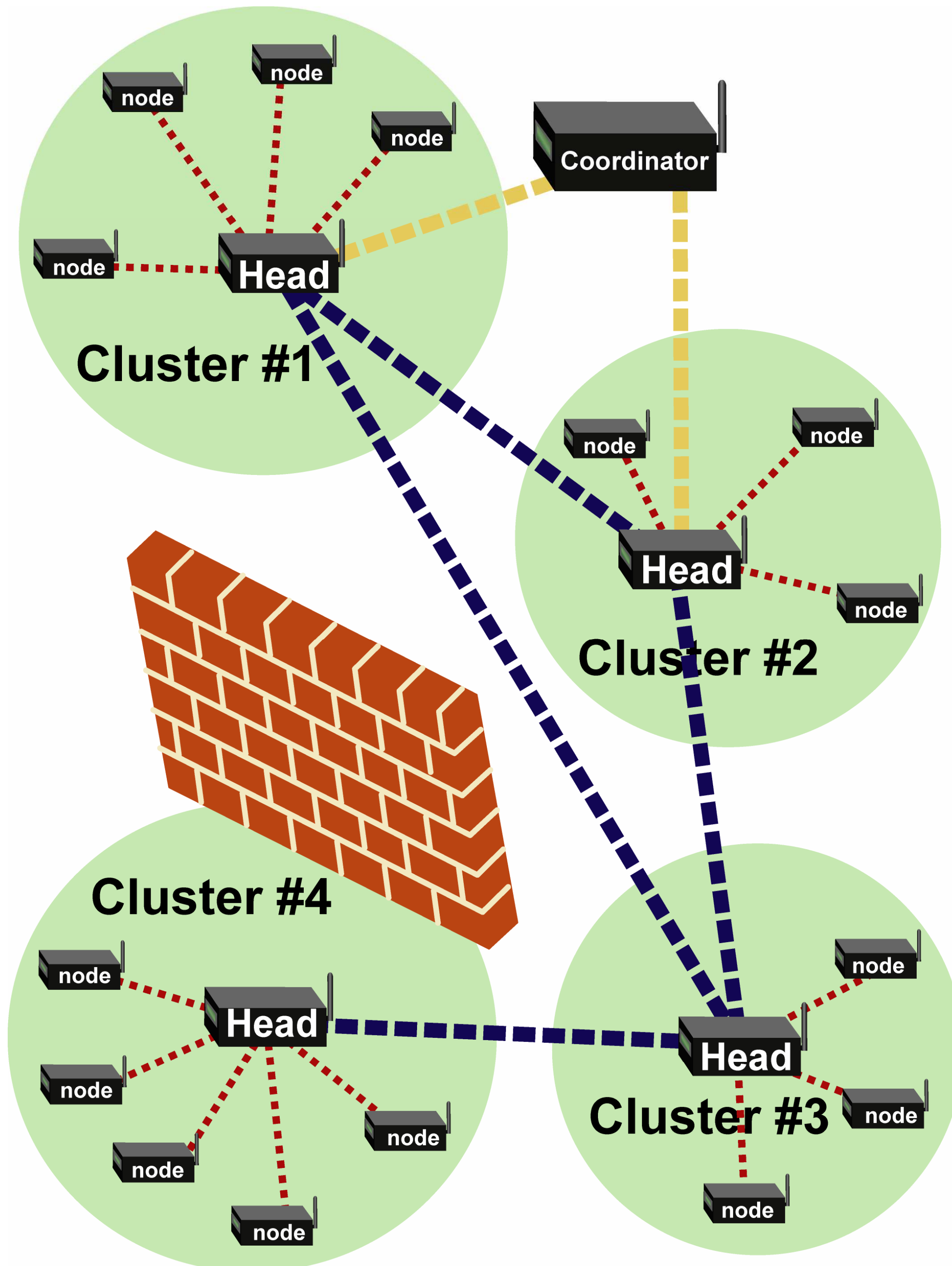
- framework for highly distributed, intelligent wireless control networks
- The nodes in WACNets locally execute many tasks such as: sensor/actuator control, data conditioning and processing while constantly communicating with each other
- The overall network structure is ad-hoc.

Overview

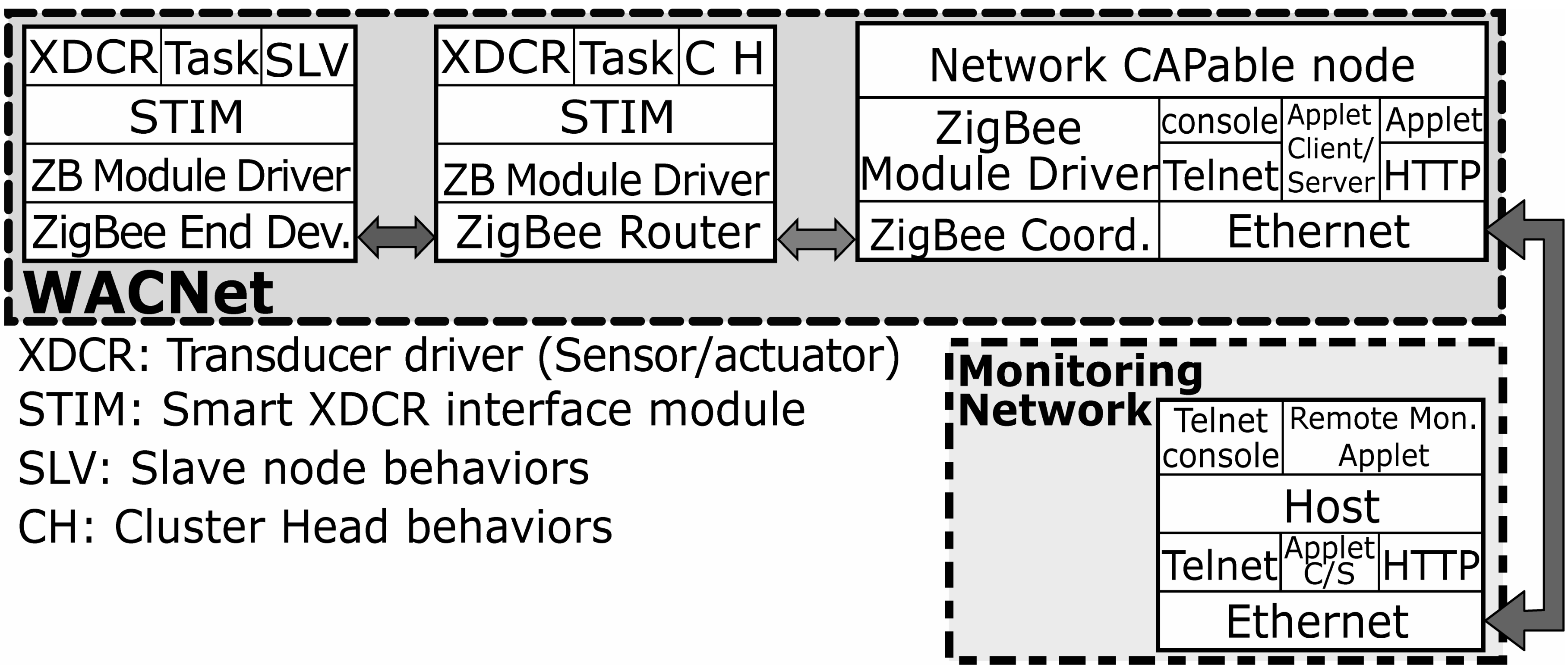
- WACNet description
- WACNet case study
  - →Description
  - →Results
  - →Analysis
- Conclusion
- Current and future work

WACNet Topology

- **In cluster** : Star topology
- **Cluster heads** : mesh network
- **Coordinator** : Network setup and WACNet-to-Ethernet bridge

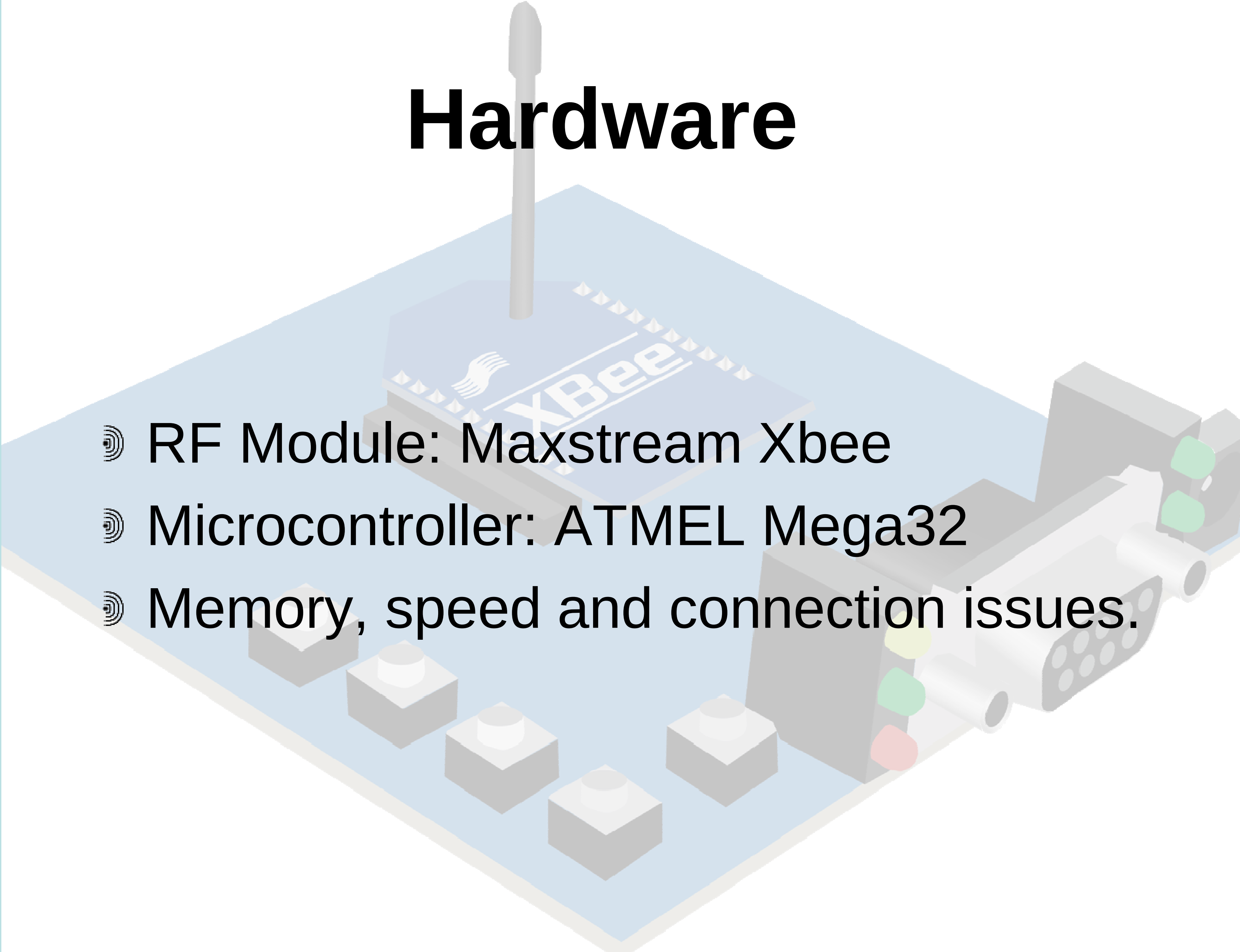


Node Structure



Hardware

- RF Module: Maxstream Xbee
- Microcontroller: ATMEL Mega32
- Memory, speed and connection issues.



Case Study

Home Ambient Intelligence system

- Totally Autonomous, no setup.
- Reduce the consumption of electricity & water in a non-intrusive way.

Approach

Multi agent system

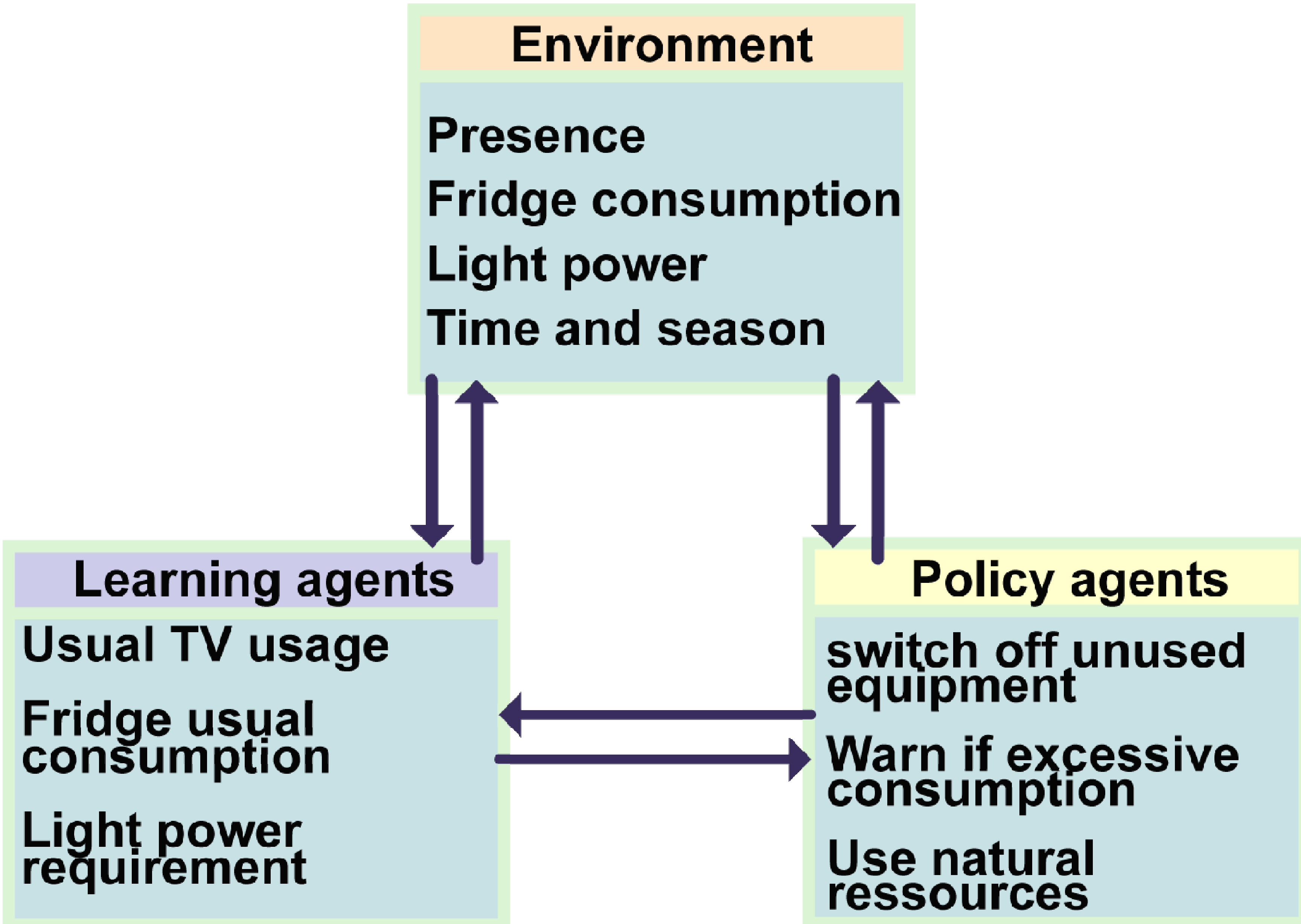
- **Learning agents**

learn how resources are consumed : what are the triggers and amounts consumed.

- **Policy agent**

Knows general rules which save ressources (policies). Collaborates with the learning agents to create rules which apply policies.

Approach Multi agent system



Method for knowledge building

- Poll the whole network, periodically or event-driven.
- Run a fuzzy learning algorithm
- Progressively eliminate unrelated sensors

→Acquire knowledge on when an appliance will consume, and how much.

Challenges

- **High-peak network traffic**

At each polling, every single node replies the query

- **Lack of memory**

Lots of memory available all over the network, but relatively few in a given node

- **Synchronisation**

The data must be acquire at the same time across the whole network

Outcomes

Learning algorithm

- Learning algorithm validated

→precision depends on memory allocated

- Uses a lot of memory

→For rule storage and redundancy

- Badly handles unrelated inputs

→Redundant rules

- Requires optimisation…

Outcomes

Learning algorithm

- **Rule table in memory**

→Using a single format for all the rules saves space, but lacks flexibility : all sensors are involved

→Redundant rules

O_{ccur}	W_{height}	S_1	S_2	S_3	S_4	S_5
3200	95%	1	3	1	1	1
356	75%	1	3	1	1	2
1750	40%	1	3	1	2	1

Outcomes

Learning algorithm

- **Rule table in memory**

→Creation of variable rules adds flexibility at the cost of memory (name of the sensor and address

O_{ccur}	W_{height}	Rule							
3200	95%	$@S_1$	1	$@S_4$	9	$@S_7$	3	$@S_4$	2
356	75%	$@S_6$	4	$@S_3$	7	$@S_1$	4	$@S_9$	1
1750	40%	$@S_4$	1	$@S_5$	2				

Outcomes

Communications

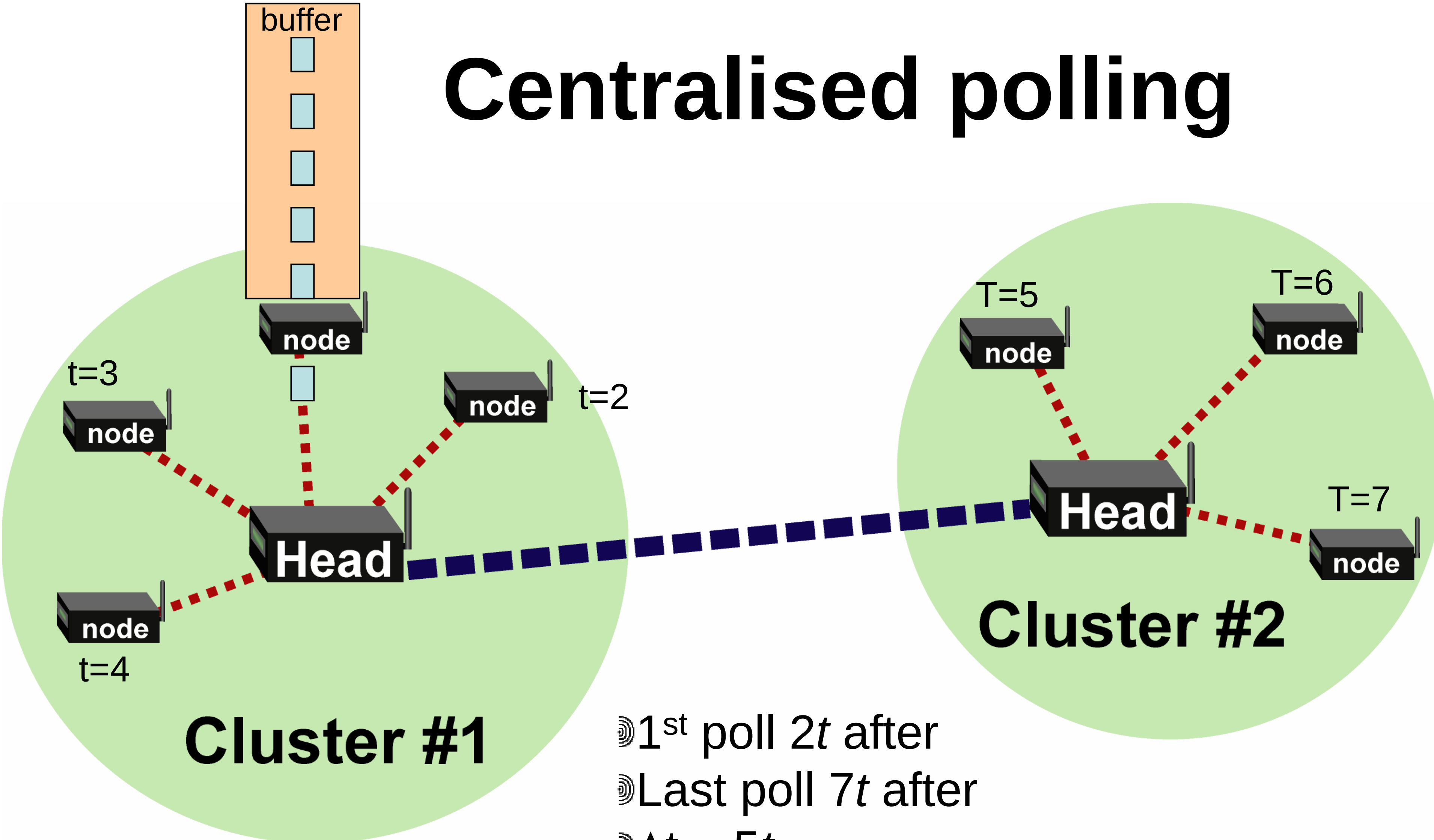
- **ZigBee standards adds large headers**.

Sending small messages achieve better latency, but increases overhead/data ratio

- **Synchronisation**

distributing the polling process adds delay but increases synchronisation

Centralised polling



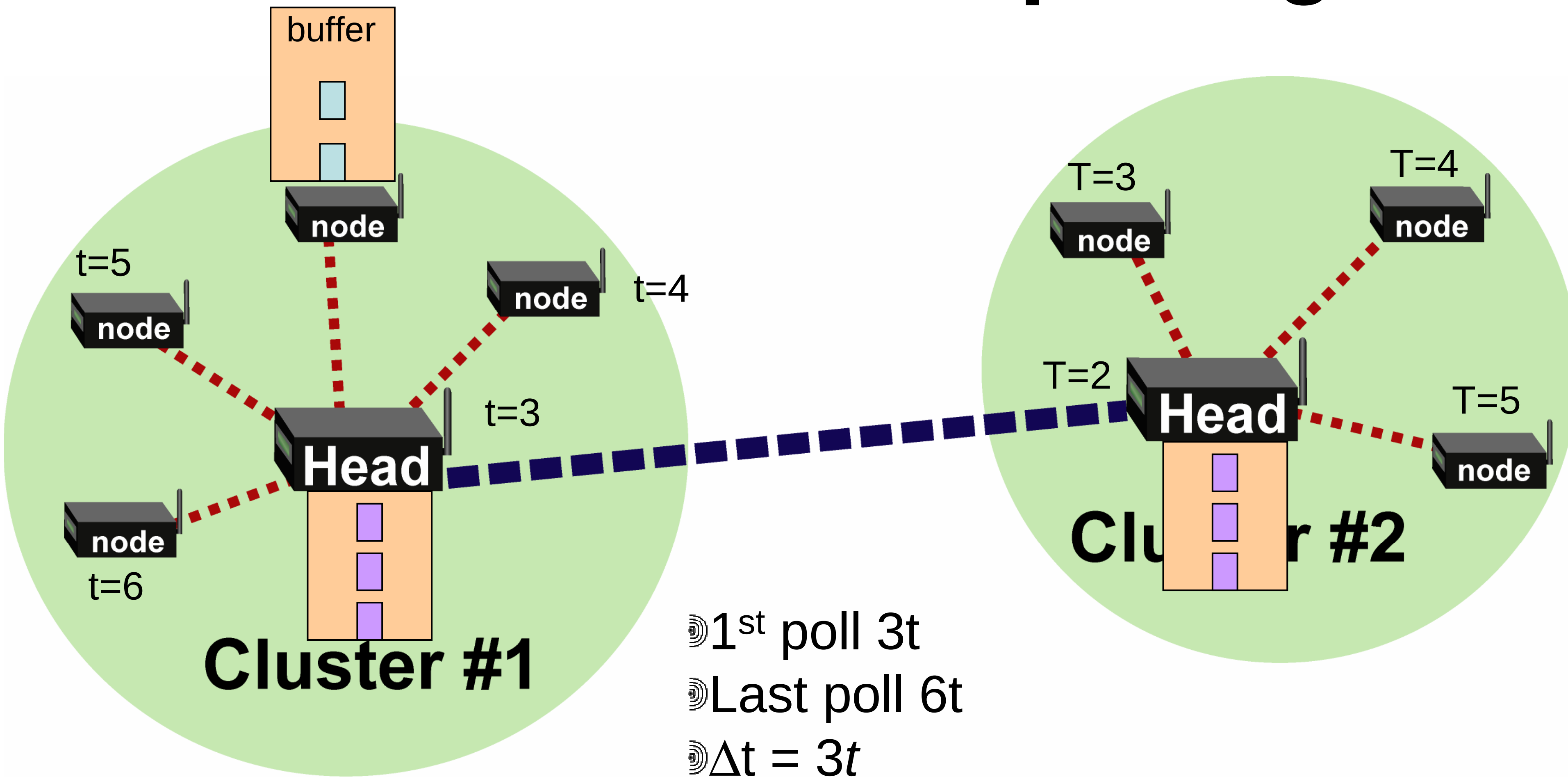
- 1^{st} poll $2t$ after
- Last poll $7t$ after
- $\Delta t = 5t$

→**Few delay**

→**considerable de-synchronisation**

→**Large TX buffer required**

Distributed polling



- 1^{st} poll 3t
- Last poll 6t
- $\Delta t = 3t$

→**More delay**
→**better synchronisation**
→**Many small TX buffers**

Current work

- Based on the small-scale tests, a simulator is being built.

→Amount of memory consumed

→Maximal frequency of polling

→Delays expected

→Large number of cluster

→Node failure

Conclusions

- Basic function of the task successful
- Microcontrollers' limitations
- ZigBee Standard and modules

Future work

- **Intelligent network self-organisation**

→Use the outcomes of the learning agents

→Regroup “functionally close” nodes in the same cluster.

→Change network configuration dynamically

- **Limitations**

→How far in complexity can we go before reaching the limits of the hardware ?

→Efficiency of the learning algorithm and optimiser on complex environments

Questions

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