Coverage and Lifetime Optimization in Heterogeneous Energy Wireless Sensor Networks

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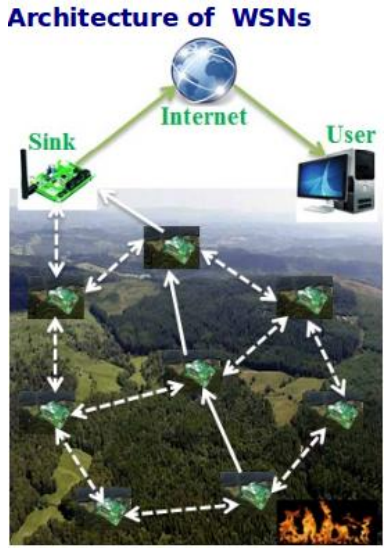
Outline

INTRODUCTION :WIRELESS SENSOR NETWORKS(WSNs)

DEVELOPMENT OF TECHNOLOGY

- Embedded micro-sensing MEMS.
- Wireless communications.



Sensor

- Electronic Low-cost tiny device.
- Sense, process and transmit data.
- Limited energy, memory and processing capabilities.

SOME APPLICATIONS OF WSNs

COVERAGE PROBLEM IN WSNs :PROBLEM DEFINITION

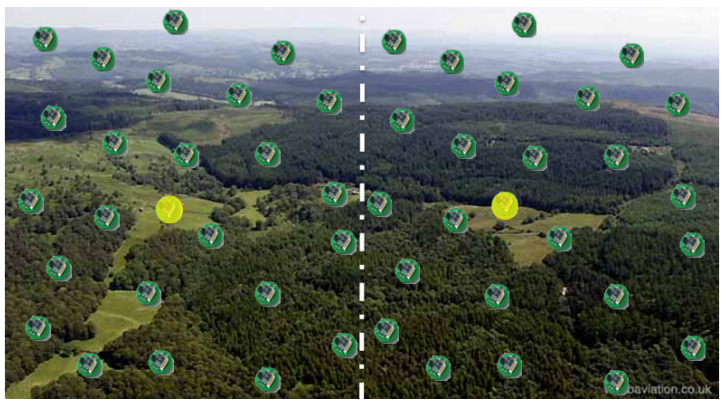
MAIN QUESTION ?

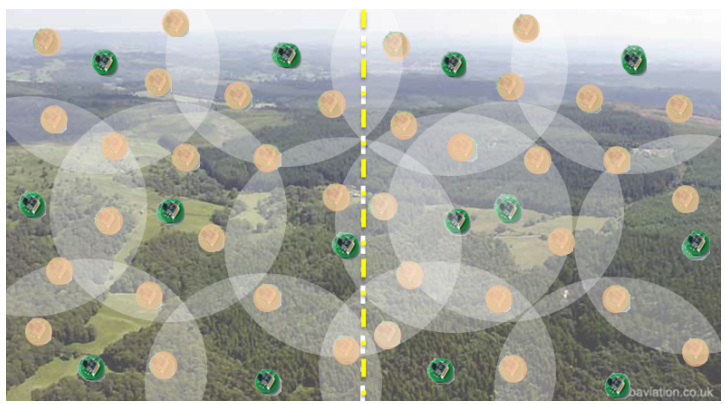
How to reduce the redundancy while coverage preservation for prolong the network lifetime continuously and effectively when monitoring a certain area (or region) of interest ?

OUR SOLUTION

The area of interest is first divided into subregions using a divide-and conquer method and then combine two efficient techniques :

- Leader Election for each subregion.
- Activity Scheduling based optimization is planned for each subregion.





LITERATURE REVIEW :COVERAGE PROTOCOLS IN WSNs

Characteristics

Some Proposed Protocols	Distributed	Centralized	Area coverage	Target coverage	k-coverage	Heterogeneous nodes	Homogeneous nodes	Disjoint sets	Non-Disjoint sets	Time-Expensive	Work in Rounds
D. Tian and N. D. Georganas(2002)	✓		✓			✓					✓
S. K. Prasad and A. Dhawan (2007)	✓			✓		✓		✓			
C. T. Vu (2007)	✓		✓		✓	✓	✓		✓		✓
Z. Abrams et. al. (2004)	✓	✓	✓		✓		✓				
M. Cardei et.al.(2002)		✓	✓				✓	✓		✓	
Cardei et al. (2005)		✓		✓			✓	✓		✓	
Our Protocol (2013)	✓		✓			✓	✓		✓		✓

LITERATURE REVIEW :OUR CONTRIBUTION

QUESTION 1

How must the phases for information exchange, decision and sensing be planned over time ?

- The time line is divided into rounds. Each round contains 4 phases : Information Exchange, Leader Election, Decision, and Sensing.

QUESTION 2

What are the rules to decide which node has to be turned on or off ?

- Limit the Overcoverage and Prevent the Undercoverage.

QUESTION 3

Which node should make such a decision ?

- The decision is made by a leader in each subregion.

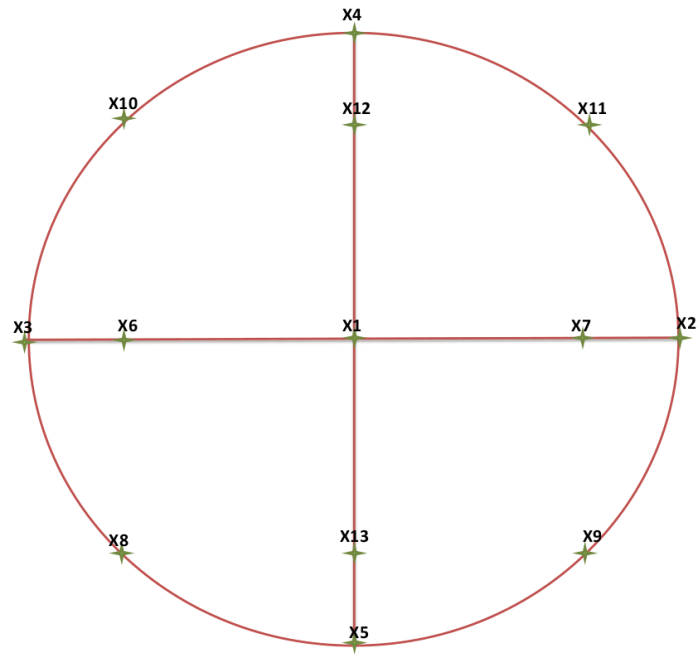
PROPOSED PROTOCOL :NETWORK MODEL

PROTOCOL ASSUMPTION

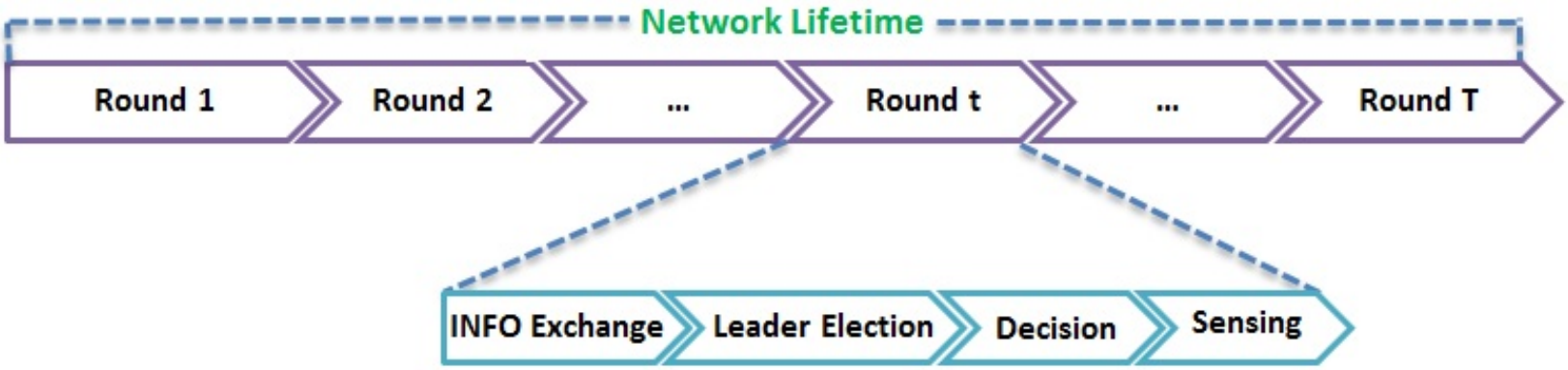
Static Wireless Sensors are :

- Randomly and uniformly deployed
- Deployed in high density.
- Homogeneous in terms of :
  - Sensing,Communication and
  - Processing capabilities
- Heterogeneous Energy.
- Its $R_C \geq 2R_S$.
- Know Its location by :
  - Embedded GPS or
  - Location Discovery Algorithm.
- Time synchronized.

DISK SENSOR COVERAGE MODEL



PROPOSED PROTOCOL :MULTI-ROUND COVERAGE PROTOCOL



Information Exchange Phase

The Information Exchanged :

- Sensor ID,
- Remaining energy,
- Sensor Position.

Leader Election Phase

The selection criteria priority :

- Larger number of neighbours,
- Larger remaining energy,
- Larger index.

PROPOSED PROTOCOL :MULTI-ROUND COVERAGE PROTOCOL

Decision Phase

The Leader will solve an integer program(see next slide) to :

- Select which sensors will be activated in the sensing phase.
- Send Active-Sleep packet to each sensor in the subregion.

Sensing Phase

Based on Active-Sleep Packet Information :

- Active sensors will execute their sensing task.
- Sleep sensors will wait a time equal to the period of sensing to wakeup.

PROPOSED PROTOCOL :MULTI-ROUND COVERAGE PROTOCOL

The integer program solves a coverage optimization problem at each round according to following formulation :

$$\begin{cases} \min \sum_{p \in P} (w_\theta \Theta_p + w_U U_p) & \\ \textit{subject to :} & \\ \sum_{j \in J} \alpha_{jp} X_j - \Theta_p + U_p = 1, & \forall p \in P \\ \Theta_p \in \mathbb{N}, & \forall p \in P \\ U_p \in \{0,1\}, & \forall p \in P \\ X_j \in \{0,1\}, & \forall j \in J \end{cases}$$

- X_j : indicates whether or not the sensor j is actively sensing in the round (1 if yes and 0 if not) ;
- Θ_p : *overcoverage*, the number of sensors minus one that are covering the primary point p ;
- U_p : *undercoverage*, indicates whether or not the primary point p is being covered (1 if not covered and 0 if covered).

PERFORMANCE EVALUATION

Simulation Parameter

- The simulations were conducted using OMNeT++ simulator.
- Experimental results were obtained from randomly generated networks and for five different densities : 50,100, 150, 200 and 250 nodes.
- The nodes are deployed over a $(50 \times 25)\ m^2$ sensing field.
- The results are the average of 10 simulations.
- A simulation ends when :
  - All the nodes are dead, or
  - The sensor network becomes disconnected

Performance Metrics :

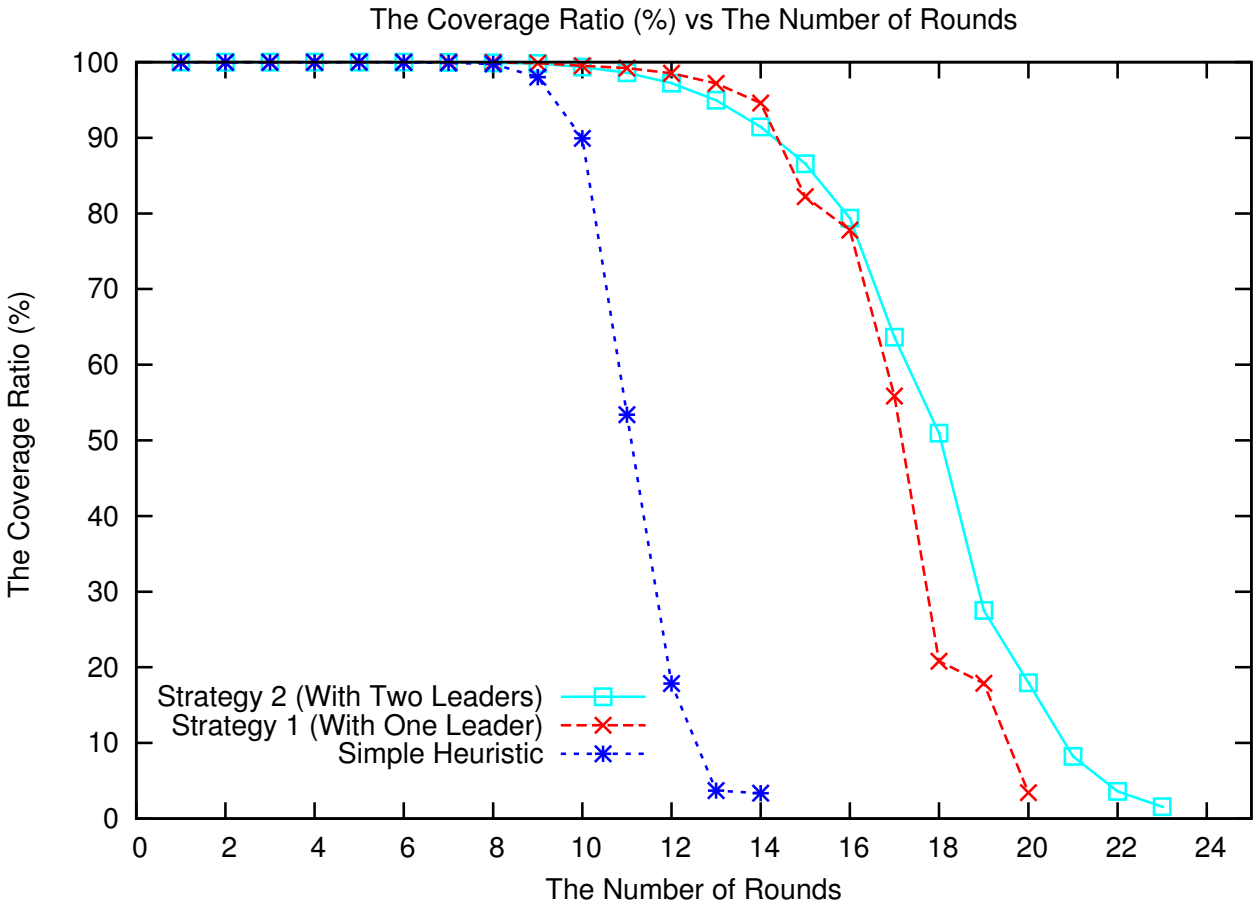
- Coverage ratio, Number of active nodes ratio, Energy saving ratio, Energy consumption,Number of stopped runs , Execution time,and Network lifetime.

Performance Comparison :

- Strategy 2 (Our approach distributed on several subregions).
- Strategy 1 (Our approach applied on all the region).
- Simple heuristic(without optimization).

PERFORMANCE EVALUATION

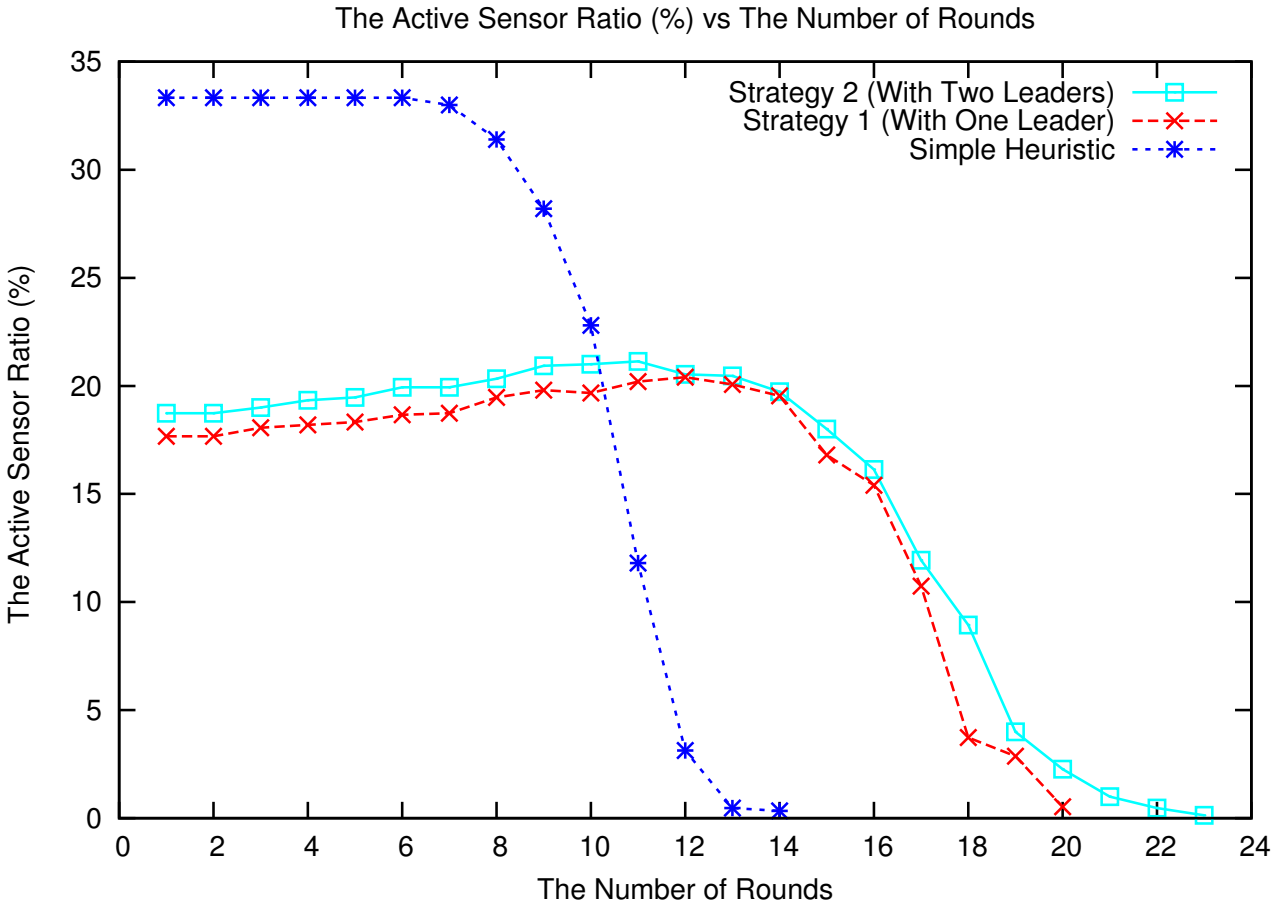
▶The Coverage Ratio(150 deployed nodes)



$$\text{Coverage Ratio}(\%) = \frac{\text{Number of primary points covered during the current round}}{\text{Total number of primary points within the field}} \times 100.$$

PERFORMANCE EVALUATION

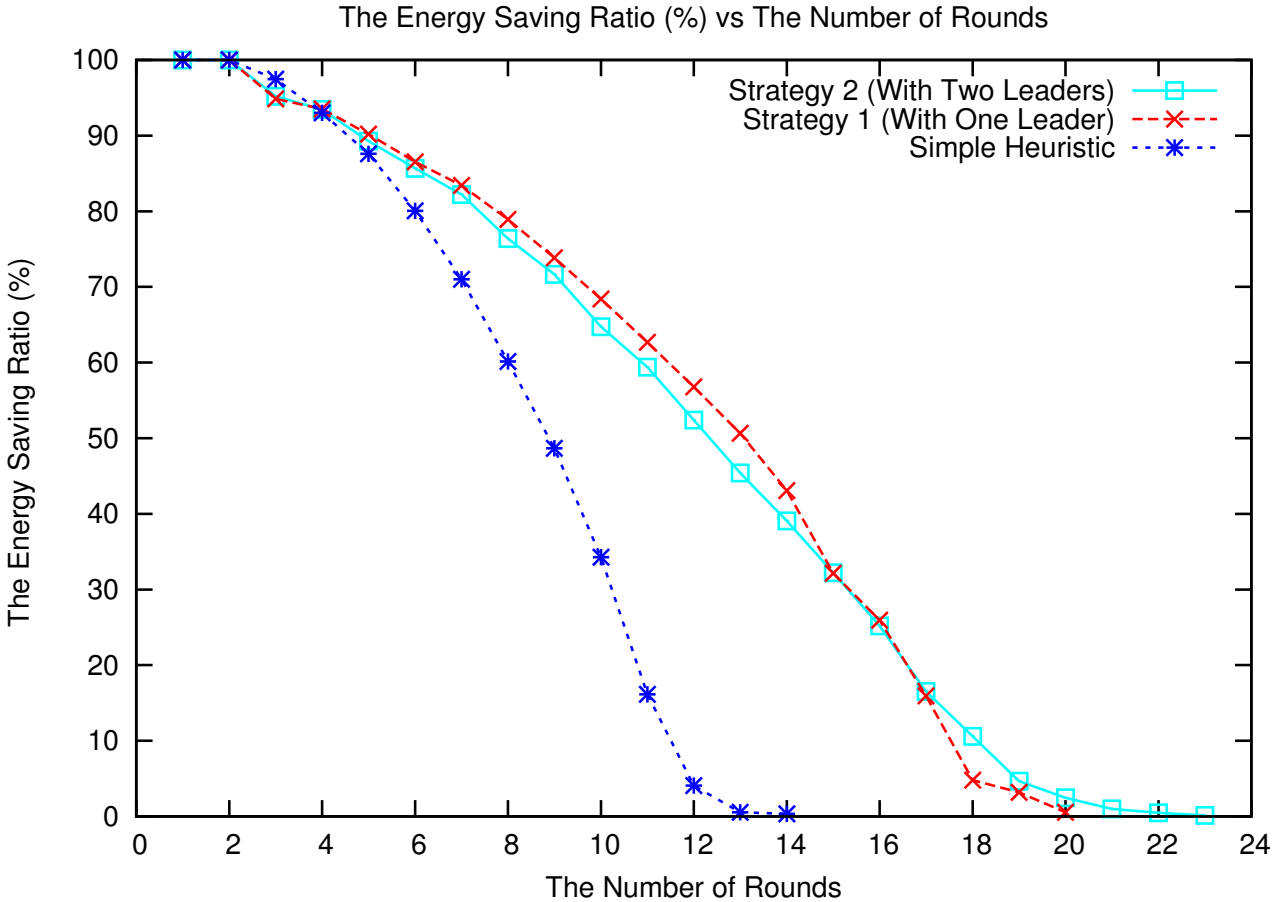
- The Active Sensor Ratio(150 deployed nodes)



$$\text{Active Sensor Ratio}(\%) = \frac{\text{Number of active sensors during the current sensing phase}}{\text{Total number of sensors in the network for the region}} \times 100.$$

PERFORMANCE EVALUATION

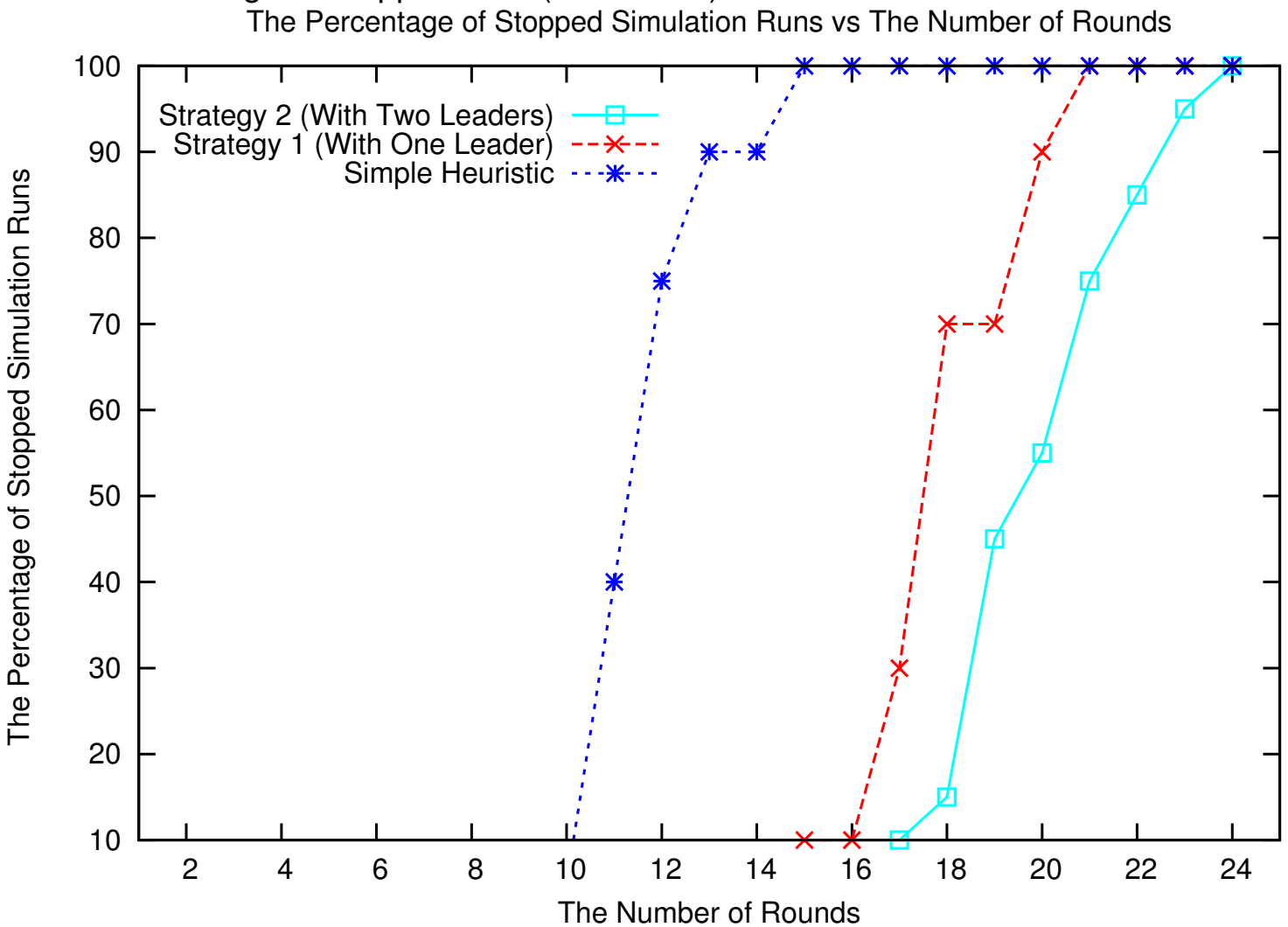
- The Energy Saving Ratio(150 deployed nodes)



$$\text{Energy Saving Ratio}(\%) = \frac{\text{Number of alive sensors during this round}}{\text{Total number of sensors in the network for the region}} \times 100.$$

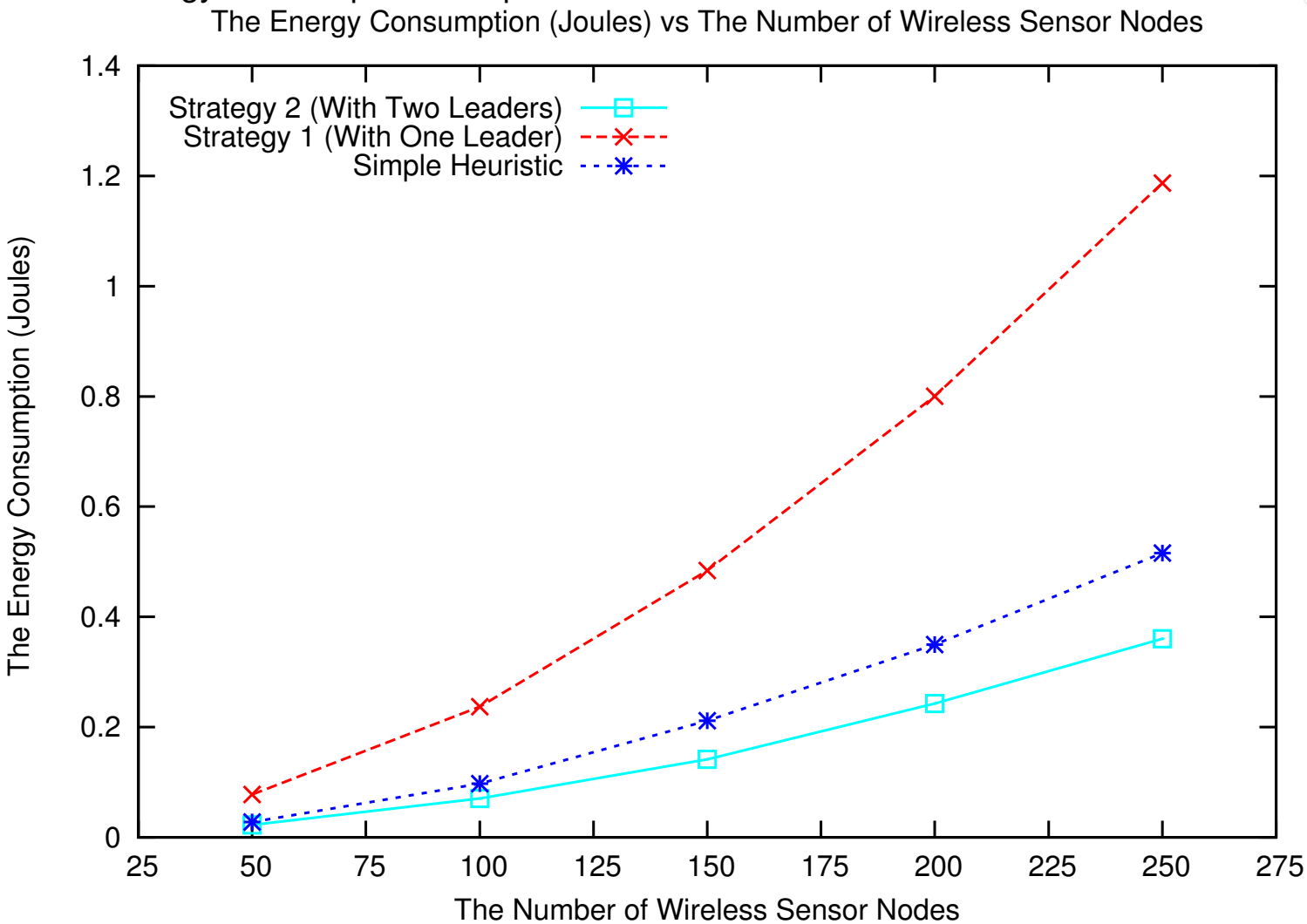
PERFORMANCE EVALUATION

- The Percentage of Stopped Runs(150 nodes)



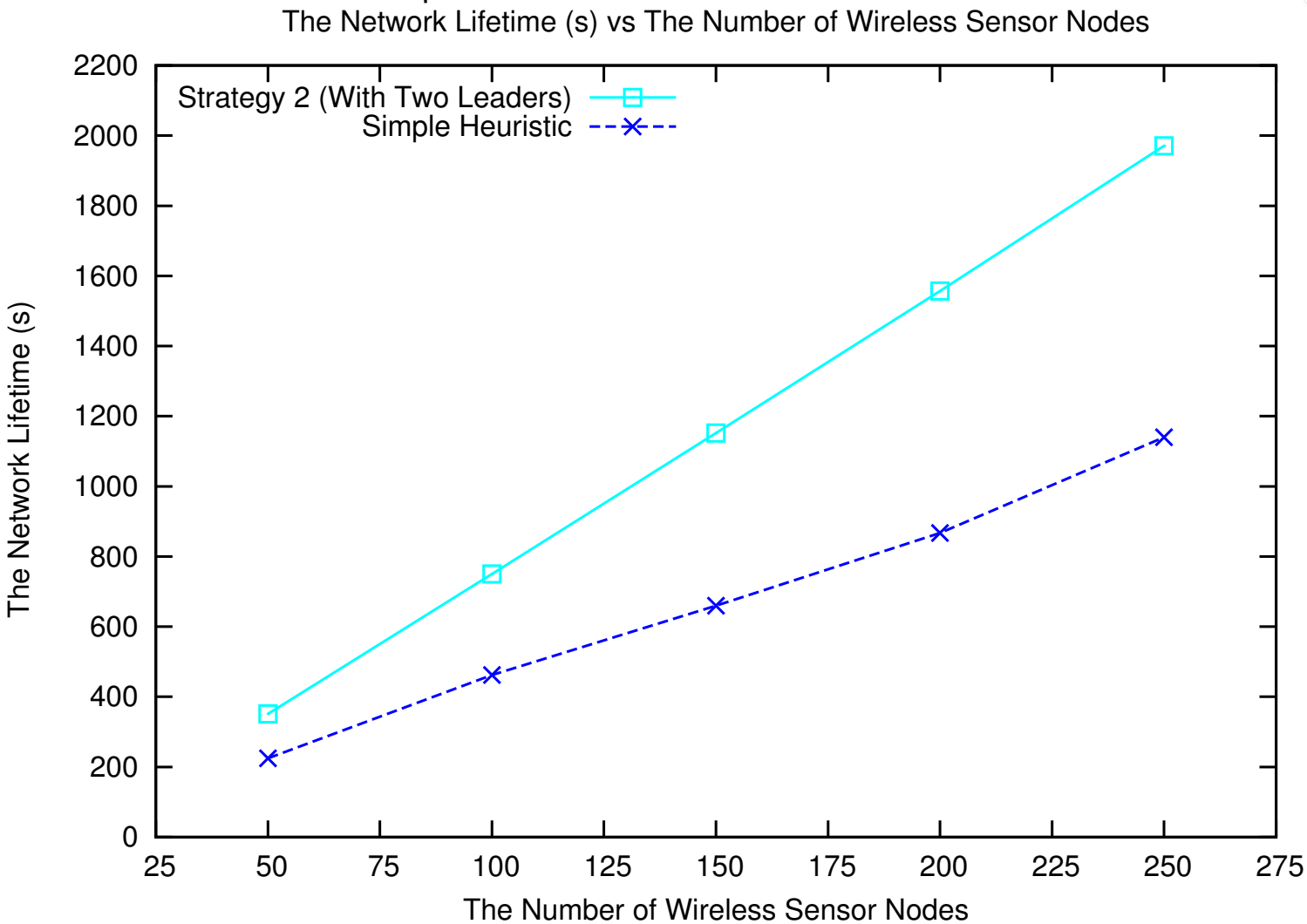
PERFORMANCE EVALUATION

- The Energy Consumption Comparison



PERFORMANCE EVALUATION

- The network lifetime Comparison



PERFORMANCE EVALUATION

TABLE: The execution time(s) vs the number of sensors

Sensors number	Strategy 2 (with two leaders)	Strategy 1 (with one leader)	Simple heuristic
50	0.097	0.189	0.001
100	0.419	1.972	0.0032
150	1.295	13.098	0.0032
200	4.54	169.469	0.0046
250	12.252	1581.163	0.0056

CONCLUSION AND FUTURE WORKS

CONCLUSION

- A distributed multi-rounds coverage protocol to optimize coverage and lifetime is proposed.
- Our Protocol maintain the coverage for a larger number of rounds with less active nodes allow to save energy efficiently and prolong the network lifetime.
- Our protocol is more powerful against network disconnections and less energy consumption during communication .It performs the optimization with suitable execution times.

FUTURE WORKS

- Currently, we are applying the fully distributed approach that proposed by C. T. Vu (2007) to compare it with our approach.
- We plan to study and propose a coverage and lifetime optimization protocol which computes all active sensor schedules in one time.

THANK YOU FOR YOUR ATTENTION

QUESTIONS AND COMMENTS