Energy-Efficient Continuous and Event-Driven Monitoring

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Outline

- Maximum Sensor Network Lifetime Problem
- CONTINUOUS AND EVENT-DRIVEN SENSOR NETWORK MODEL
- (DEEPS) General overview
- Cluster-Based Communication
- LEACH Communication Protocol
- (LBP) Load-Balancing Protocol for Sensing
- (LBP) Bottleneck
- Deterministic Energy-Efficient Protocol for Sensing
- NS2+LEACH Monitoring Simulations
- Simulation Results

Maximum Sensor Network Lifetime Problem

A formal definition of the energy preserving scheduling problem

- ✓ **Sensor cover :** A set of sensors C covering R.
- ✓ **A monitoring schedule:** a set of pairs $(C_1, t_1), \ldots, (C_k, t_k)$.
  - — C_i is a sensor cover;
  - — t_i is time during which C_i is active.

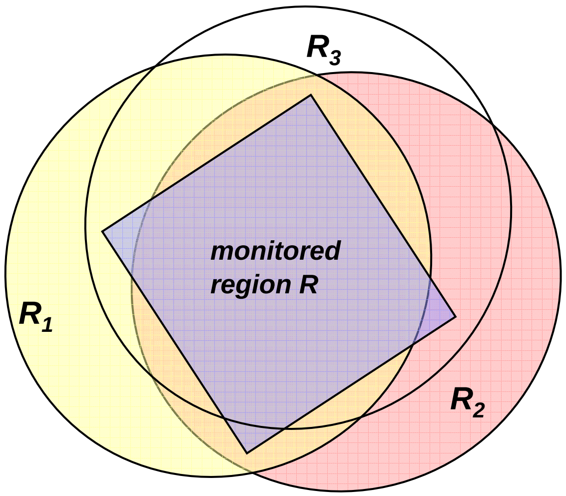
Maximum Sensor Network Lifetime problem

Given: a monitored region R, a set of sensors $p_1, \ldots, p_n$, and monitored region R_i ,and energy supply b_i for each sensor

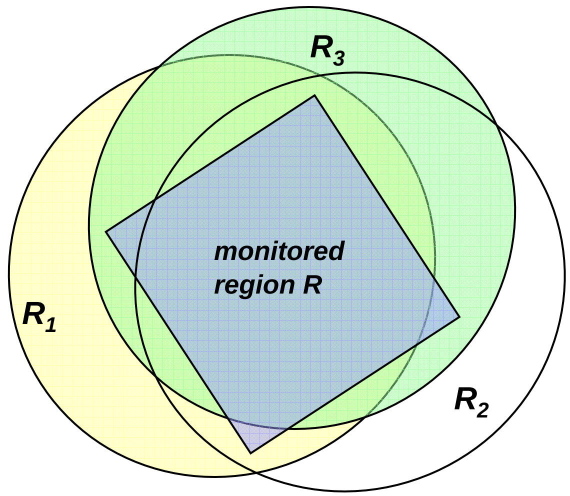
Find: a *monitoring schedule* $(C_1,t_1), \ldots, (C_k, t_k)$ with the *maximum length* $t_1 + \ldots + t_k$, such that for any sensor p_i the total active time does not exceed b_i.

Example of Maximum Sensor Network Lifetime Problem

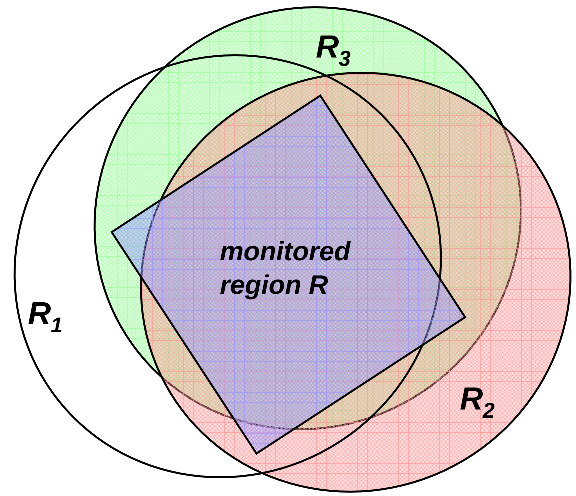
Advantage of switching between sensor covers:



sensors p1 and p2 for 1 time unit



sensors p1 and p3 for 1 time unit



sensors p2 and p3 for 1 time unit

Non-disjoint set covers:

— the schedule $(\{p_1, p_2\}, 1), (\{p_2\ p_3\}, 1), (\{p_{3,} p_1\}), 1)$;

— **3 units of time**.

CONTINUOUS AND EVENT-DRIVEN SENSOR NETWORK MODEL

- **Given the regions which are required to monitor (or, in general,set of required targets)**
- **sensors who can monitor these targets**
- **energy supply**
- **energy consumption**
- **rate for monitoring**
- **listening and idle modes**
- **energy consumption for receiving and transmitting a package**

- **we explore the problem of maximizing sensor network lifetime**

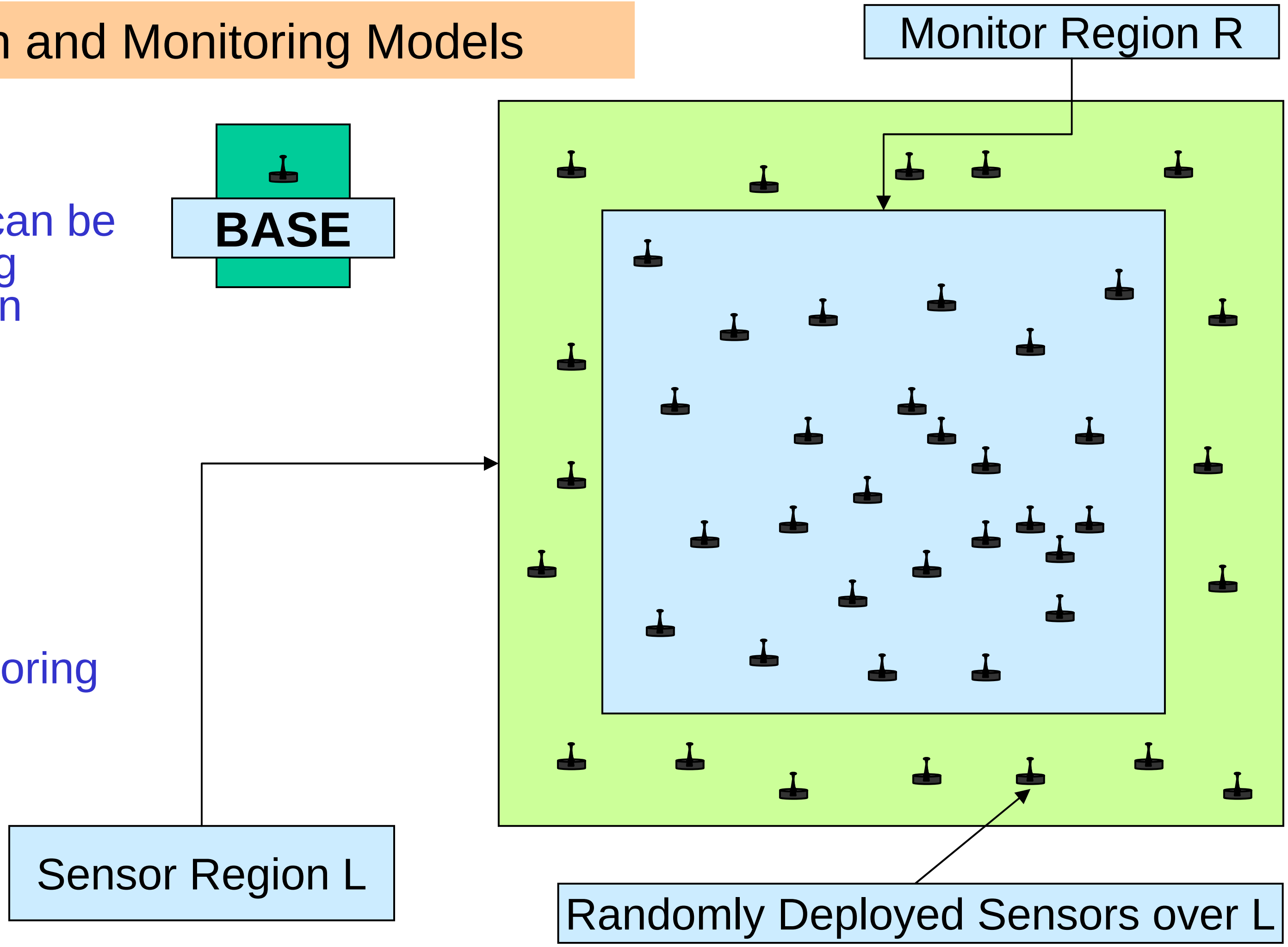
- **sensors can interchange idle and active modes both for monitoring and communicating.**

CONTINUOUS AND EVENT-DRIVEN SENSOR NETWORK MODEL

Communication and Monitoring Models

- Each sensor can be in the following communication modes:
- sleeping,
- listening,
- receiving and
- sending.

- and two monitoring modes:
- idle and
- active.

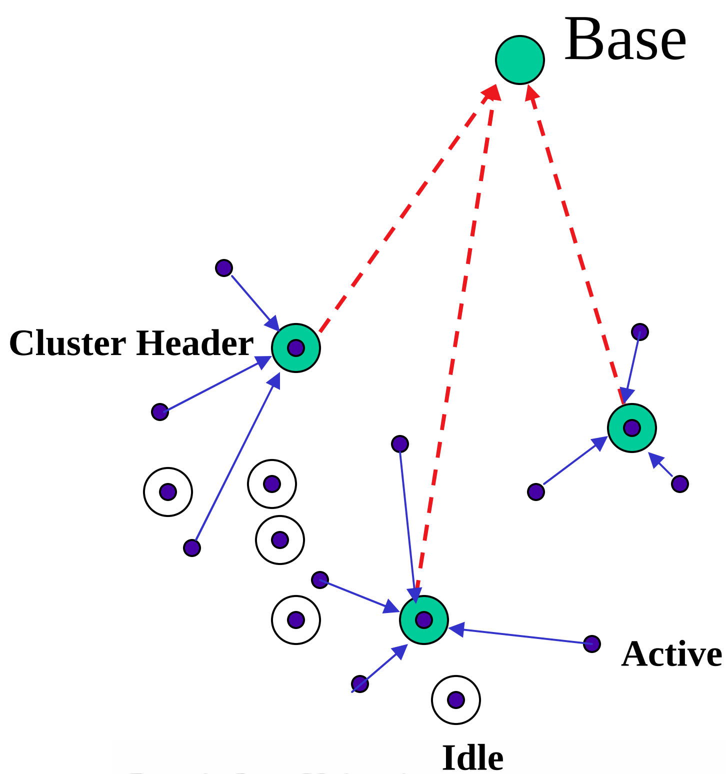


- The set of sensors largely exceeds the necessary amount to monitor ***R***

(DEEPS) General overview

(DEEPS) Deterministic Energy-Efficient Protocol for Sensor networks target-monitoring protocol, system lifetime increase in 2 times!!!

full-fledged simulation of the monitoring protocols on NS2 combined with LEACH as a communication protocol



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Cluster-Based Communication

A Simple Algorithm

The problem: Select j cluster-heads of N nodes without communication among the nodes

The simplest solution:

- Each node determines a random number x between 0 and 1
- If $x < j / N$ → node becomes cluster-head

...it‘s good, but:

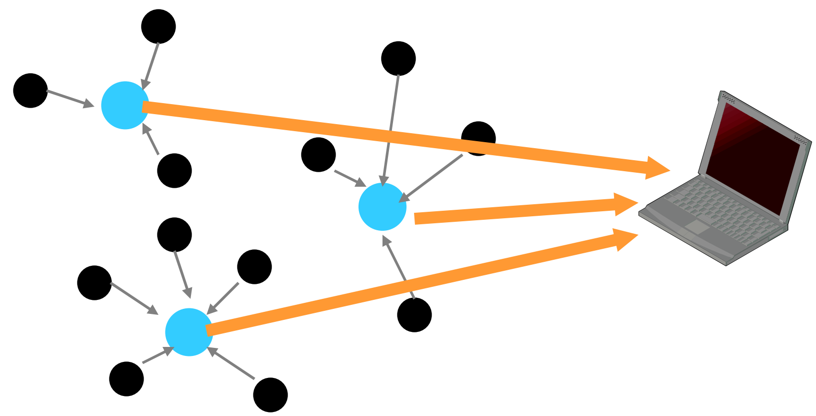
Cluster-heads dissipate much more energy than non cluster-heads!

How to distribute energy consumption?

LEACH Communication Protocol

Low-Energy Adaptive Clustering Hierarchy

- Cluster-based communication protocol for sensor networks, developed at MIT
- Adaptive, self-configuring cluster formation



- The operation of LEACH is divided into rounds
- During each round a different set of nodes are cluster-heads
- Each node n determines a random number x between 0 and 1
- If $x < T(n)$ → node becomes cluster-head for current round

(LBP) Load-Balancing Protocol for Sensing

(1) (*on-rule*)

whenever a sensor *s* has a target covered solely by itself (no alert- or on sensor covers it), *s* switches itself on, i.e., changes its state to ”on”.

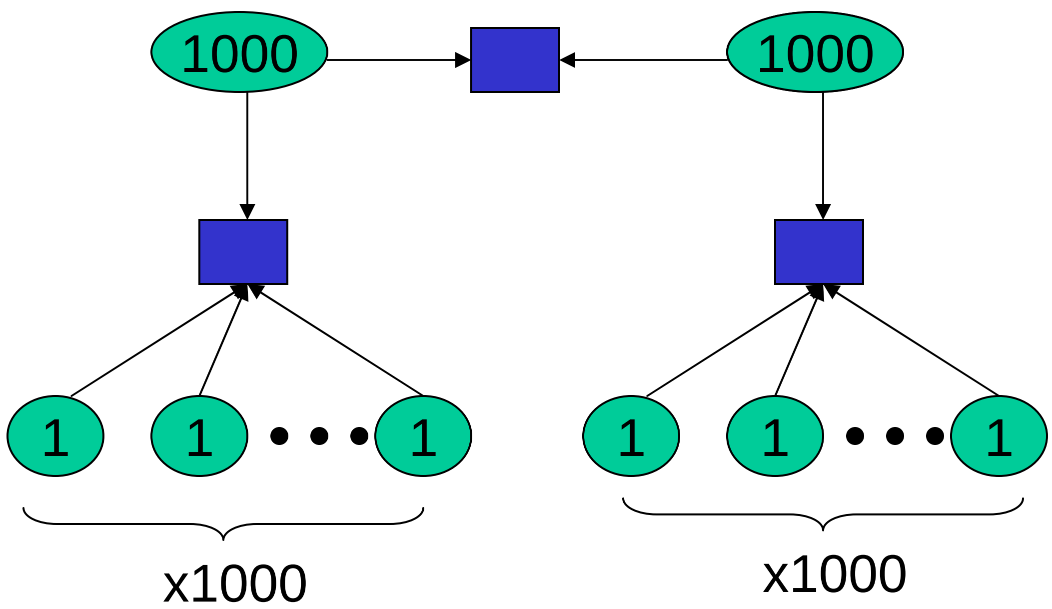
(2) (*off-rule*)

whenever each target covered by a sensor *s* is also covered either by an on sensor or an alert-sensor with a larger battery supply, *s* switches itself on, i.e., *s* changes its state to ”off”.

Each global reshuffle of LBP needs 2 broadcasts (to the neighbors) from each sensor and the resulted set of all active sensors form a minimal sensor cover.

The LBP is a reliable protocol.

(LBP) Bottleneck



- LBP time schedule is twice shorter since it uses the 1000-battery sensors simultaneously for 999 time units

Deterministic Energy-Efficient Protocol for Sensing

Algorithm

(1) (*on-rule*)

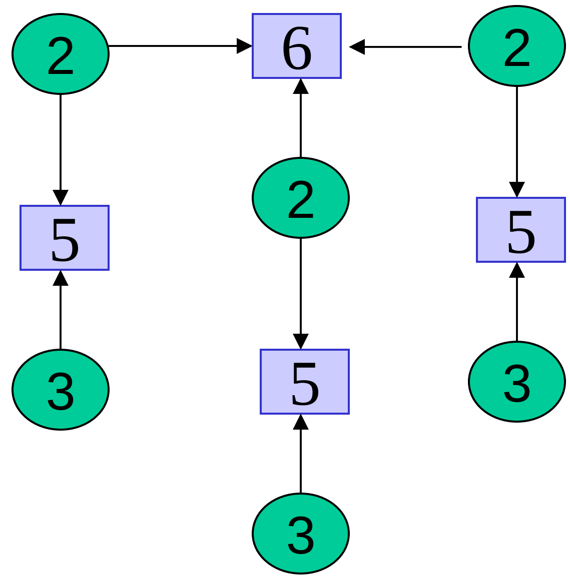
whenever a sensor *s* has a target covered solely by itself (no alert- or onsensor covers it), *s* switches itself on, i.e.,changes its state to ”on”.

(2) (*off-rule*)

whenever a sensor *s* is not in charge of any target except those already covered by on-sensors, *s* switches itself off, i.e., changes its state to ”off”.

DEEPS is a reliable protocol. Each global reshuffle of DEEPS needs 2 broadcasts (to the 2-neighbors) from each sensor and the resulted set of all active sensors form a minimal sensor cover.

(DEEPS) Bottleneck



An example of reliability violation (circles are sensors and rectangles are targets, numbers correspond to battery supply). 3 lower sensors have 3 batteries each and the 3 uppers sensors have 2 batteries each. Therefore, 3 lower targets are sinks with 5 batteries each. The upper target will be abandoned if all three upper poorer sensors will be switched off simultaneously.

NS2+LEACH Monitoring Simulations

Environment : NS2 – Network Simulator

LEACH communication protocol

DEEPS - Deterministic Energy-Efficient Protocol for Sensing

LBP – Load-Balancing Protocol for Sensing

1-DEEPS which is DEEPS but with a single reshuffle and local reparation on node die

EUPS - Energy Unaware Protocol for Sensing – where all sensors continuously monitor their targets

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Simulation Results

Results which are represented in this presentation are obtained for 3 scenarios:

Scenario-1:

- **Square territory*100m* x *100m* which is divided into the small square faces 1m x 1m, and each face is considered like a target with coordinates equals with the middle of the face.**
- **10.000 targets – good approximation for real area.**
- **Random distribution of sensors**
- **Faces are covered by one or more sensors, sensing radius is 5m.**

Scenario-3:

- **The same as Scenario-1, with additional restriction: All faces are covered by at least 3 sensors.**

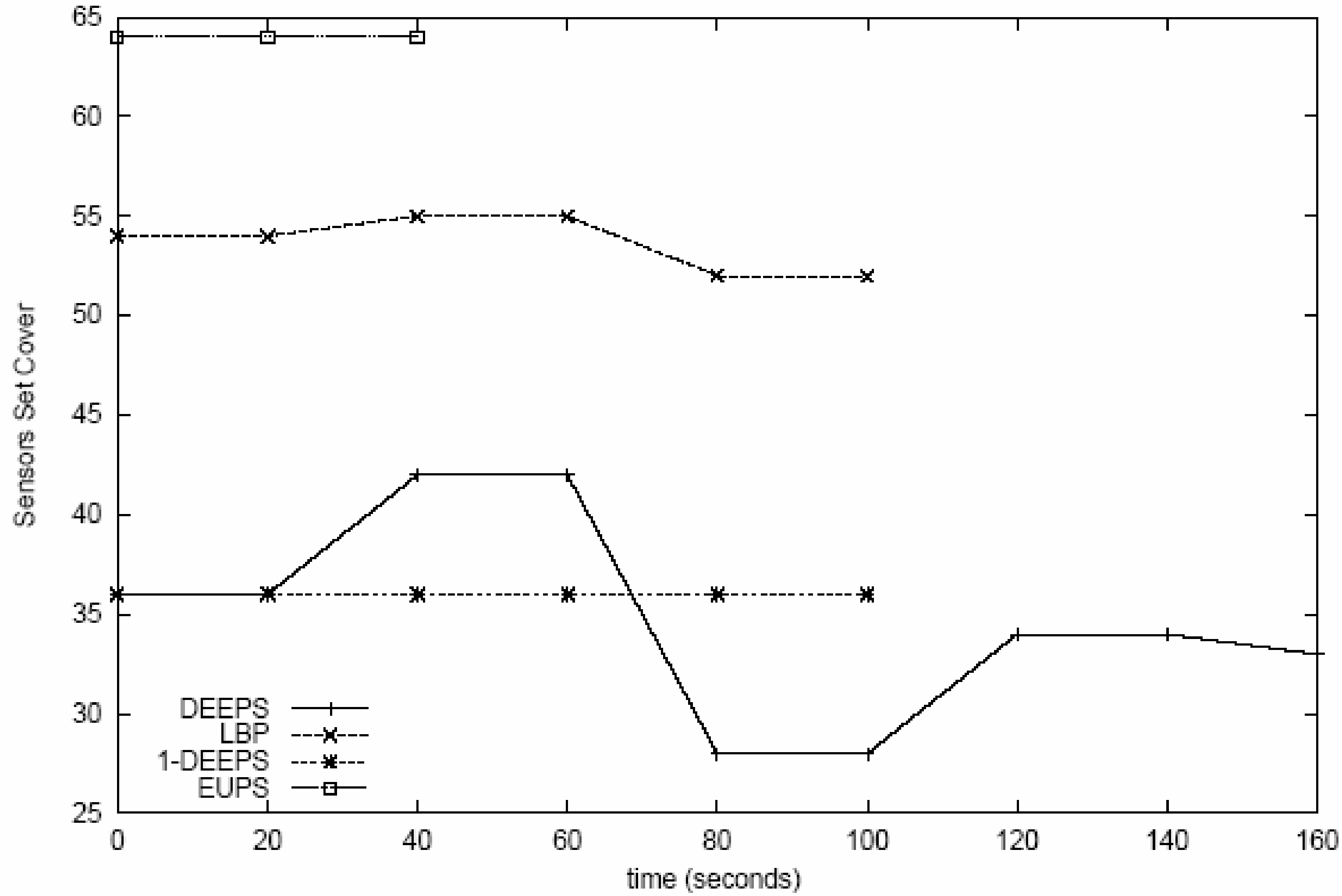
Scenario-2:

- **Random distribution of 100.000 targets in 100m x 200m.**
- **All others are the same as in Scenario-3**

Experimental results are for constant initial energy distribution 4(J) or random between 1 and 4(J).

Scenario-1

Number of active sensors



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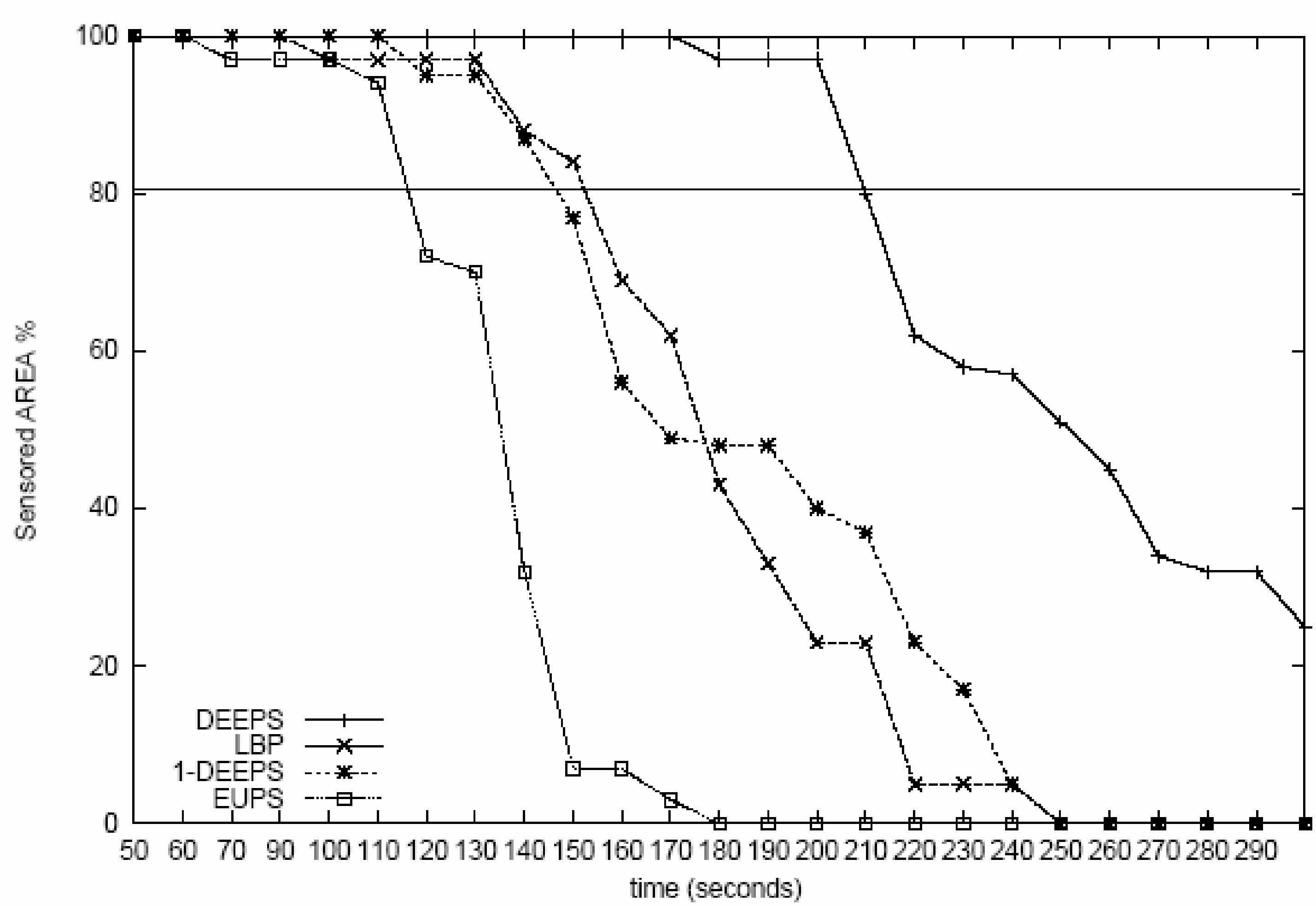
Scenario-1

Covered area %



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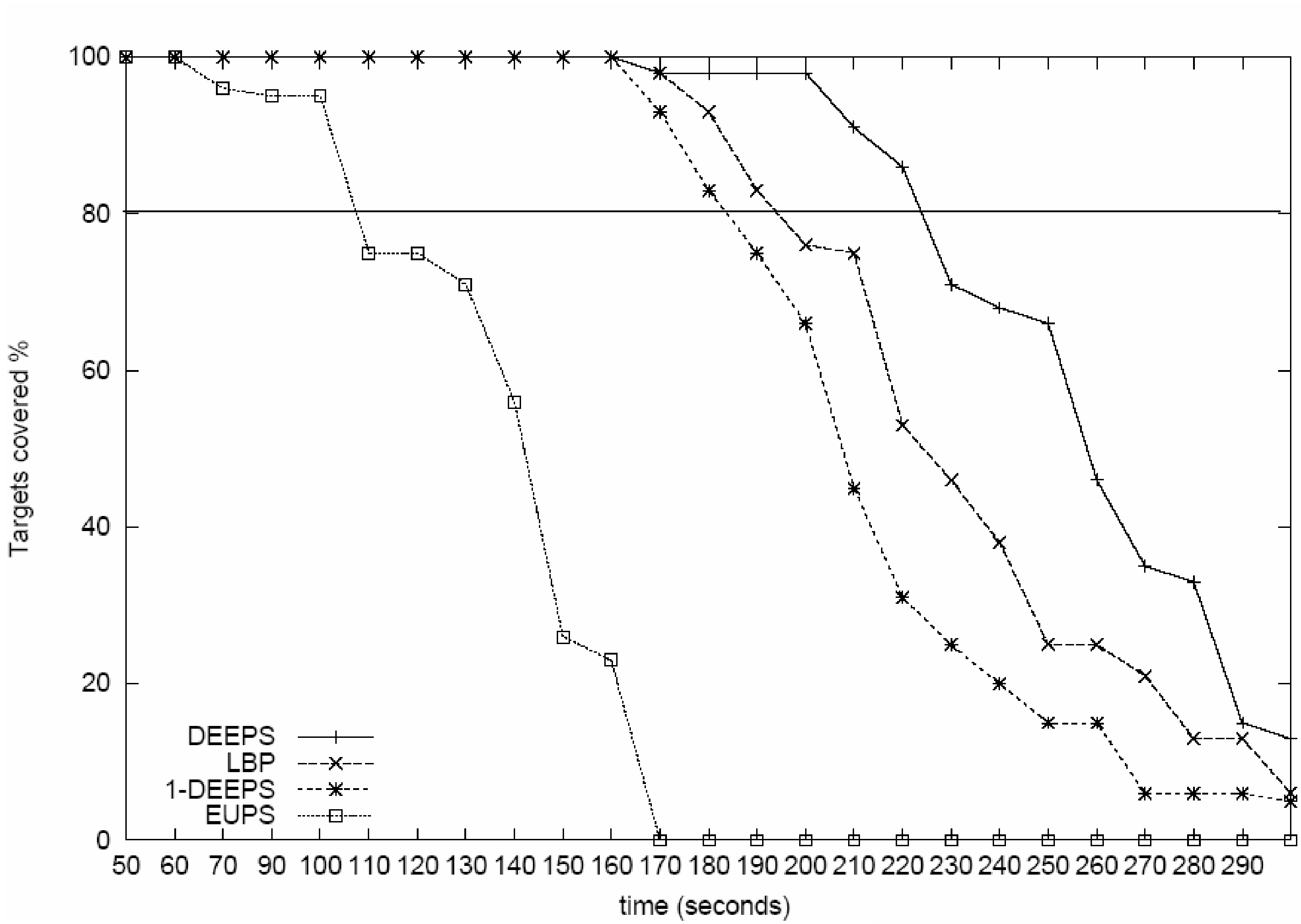
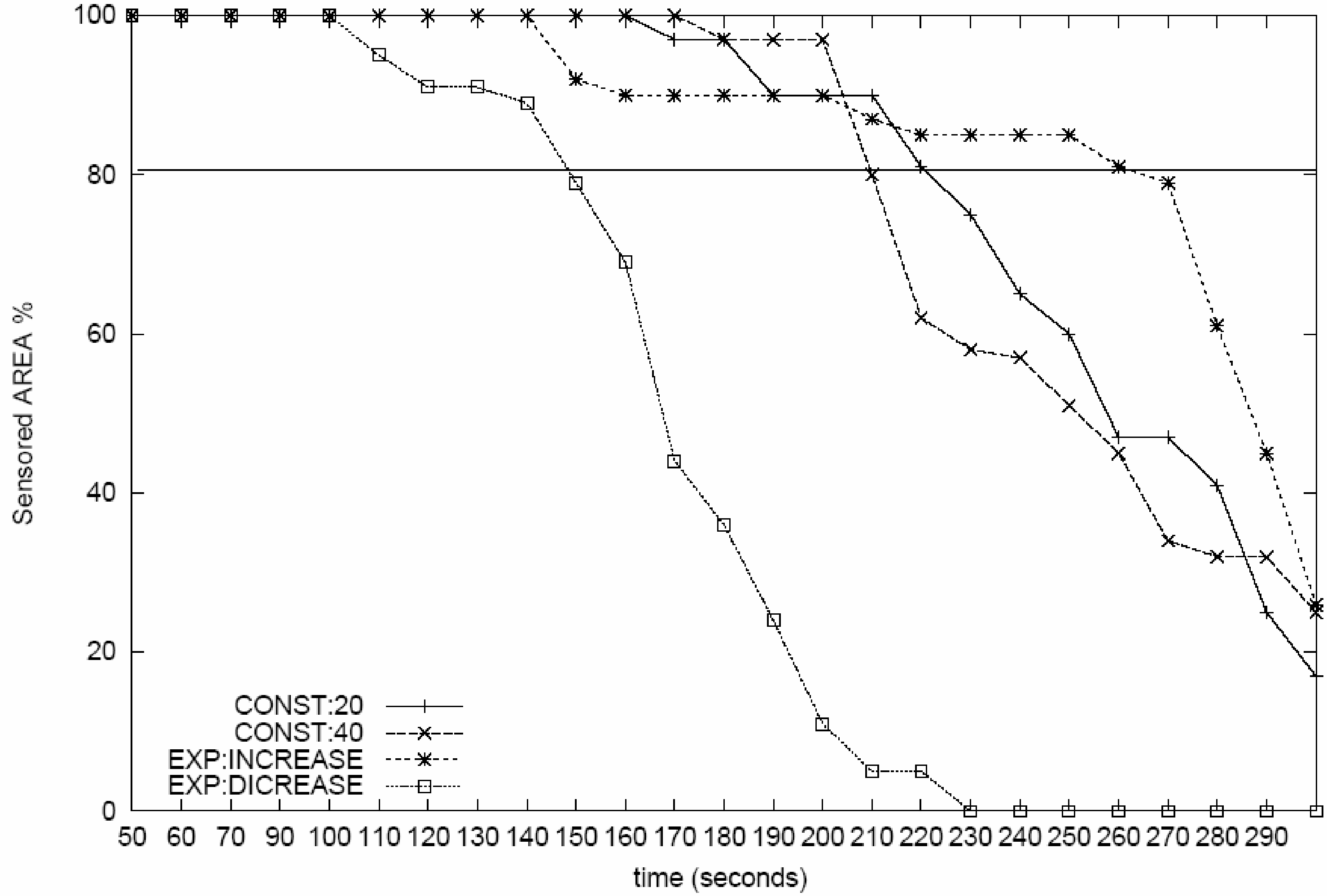
Scenario-3 TARGET

Targets covered %



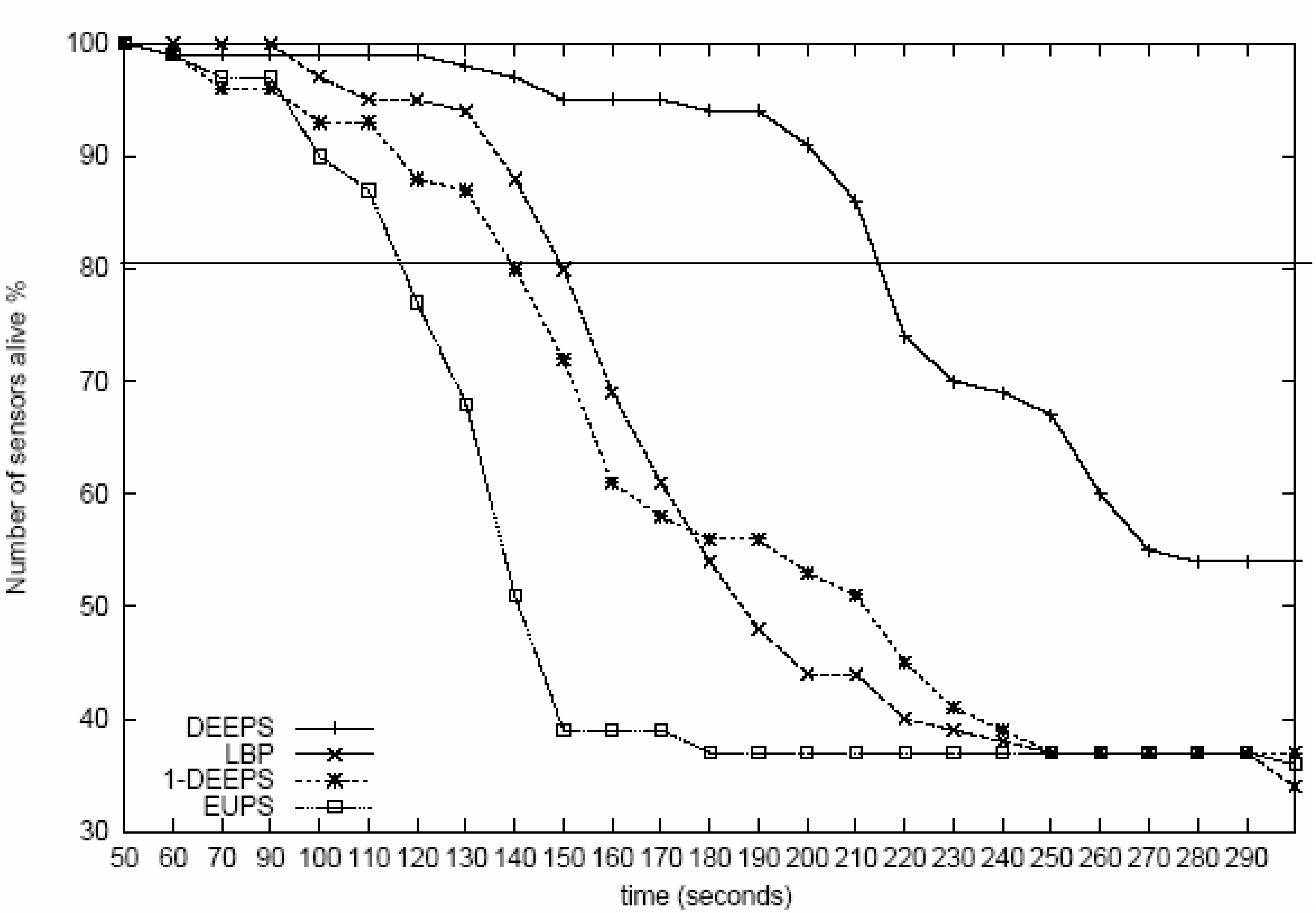
Scenario-1

Covered area for different # of reshuffles



Scenario-1

Number of sensors alive %



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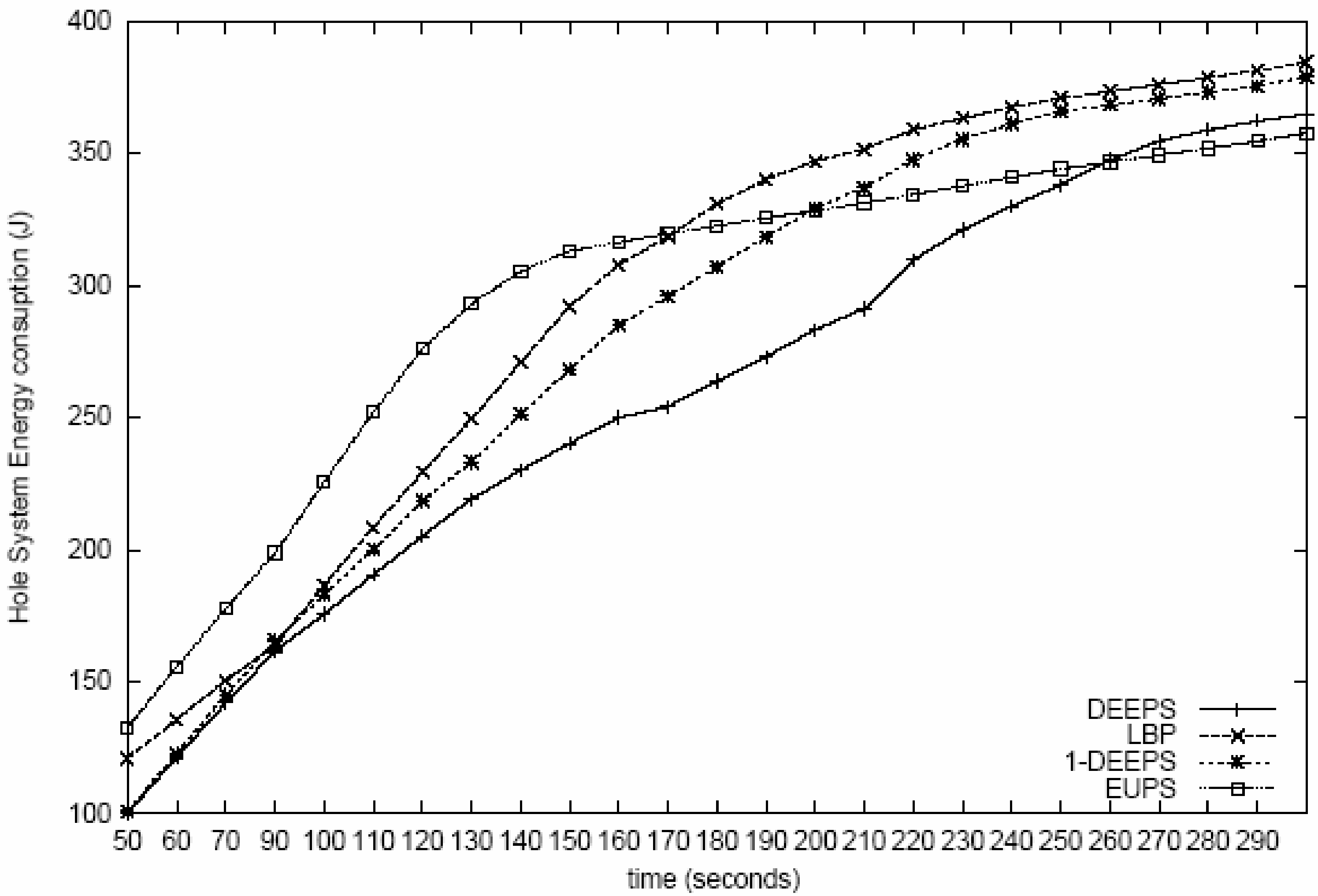
Scenario-1

Total energy consumption (J)



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