An important problem addressed in literature is the *sensor coverage problem*. This problem is centered around a fundamental question: "*How well do the sensors observe the physical space ?*" As pointed out in [13], the coverage concept is a measure of the quality of service (QoS) of the sensing function and is subject to a wide range of interpretations due to a large variety of sensors and applications. The goal is to have each location in the physical space of interest within the sensing range of at least one sensor.

In this paper we address the *target coverage problem*, with the objective of maximizing the network lifetime of a power constrained wireless sensor network deployed for monitoring (coverage) of a set of targets with known locations. We consider that a large number of sensor nodes are dispersed randomly in close proximity of a set of objectives (targets) and send the sensed information to a central processing node. We define the sensor network lifetime as the time interval each target is covered by at least one sensor node.

In this paper we propose to extend the network lifetime by dividing the sensor nodes into a number of sets, such that each set completely covers all the targets. These sensor sets are activated successively, such that at any time instant only one set is active. The sensors from the active set are in the *active* state (e.g. transmit, receive or idle) and all other sensors are in the *sleep* state. If, while meeting the coverage requirements, sensor nodes alternate between the active and sleep mode, this will result in increasing the network and application lifetime compared with the case when all sensors are active continuously. Also, as a consequence, the spatial density of active nodes is lowered, thus reducing contention at the MAC layer. The contributions of this paper are the following:

1) introduce a new model of maximizing the network lifetime of the target coverage problem by organizing the sensor nodes in non-disjoint set covers; we define the maximum set covers (MSC) problem and prove that MSC is NP-complete
2) design two target coverage heuristics for efficiently solving the MSC problem using linear programming and greedy techniques, and
3) analyze the performance of our approach through simulation.

The rest of the paper is organized as follows. In section II we present energy efficient and coverage related works. Section III describes the target coverage problem. Next, in section IV, we introduce the maximum set covers (MSC) problem and prove that MSC problem is NP-complete. We propose a linear programming based heuristic in section V-B and a greedy solution in section V-C. Section VI presents the simulation results for our heuristics, and section VII concludes our paper.

II. Related Work

Sensor nodes have size, weight and cost restrictions, with direct impact on resource availability. They have limited battery resources, processing and communication capabilities. As replacing the battery is not feasible in many applications, low power consumption is one of the most important requirements of a sensor network [8]. Various power efficient schemes have been proposed in literature [7], not only at the hardware and architectural design, but also when designing algorithms and protocols at all layers of the network architecture.

In sensor coverage problems, the goal is to have each location in the physical space of interest within the sensing range of at least one sensor. Cardei and Wu [3] survey recent sensor coverage problems proposed in literature and categorize them according to the following design criteria:

1) objective of the problem: maximize network lifetime or minimize the number of sensors deployed
2) sensor deployment method: deterministic versus random
3) relationship between sensing R_s and communication R_c ranges (e.g. $R_c = R_s$?; Do all sensors use the same R_c and the same R_s (homogeneous network)?)
4) additional critical requirements, such as energy-efficiency and connectivity
5) algorithms characteristics: centralized versus distributed and localized.

The coverage problems can be classified in the following types [3]:

- area coverage [4], [16], [17], [19], [15], where the main objective is to cover (monitor) an area,
- point (or target) coverage [2], [9], where the objective is to cover a set of points (targets) and
- coverage problems that have an objective to determine the maximal support/breach paths that traverse a sensor field [13], [10].

An important method for prolonging the network lifetime for the area coverage problem is to determine a localized and distributed protocol for selecting the set of active sensor nodes. To be distributed and localized are important properties of a node scheduling mechanism, as they better adapt to a scalable and dynamic network topology. The network activity can be organized in rounds, and the set of active sensor nodes is decided at the beginning of each round. Active node selection is determined based on the problem requirements (e.g. area monitoring, connectivity, power efficiency). Different techniques have been proposed in literature [4], [16], [17], [19] for efficiently deciding the eligibility rule, that is, to determine if a node will be in sleep mode for the next round. The basic idea is to design a mechanism such that each node can determine if its sensing disk is collectively covered by other nodes which