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PEAS-LI: PEAS with Location Information for coverage in Wireless Sensor Networks

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HIGHLIGHTS

- An improved PEAS protocol, to improve the coverage and connectivity is presented.
- First, PEAS is run as Vieira et al. (2003), and then, state and location information are exchanged.
- Second, nodes make their decision to be active, based on the gathered information.
- PEAS-LI supposes that each node knows its location in the area of interest.
- Our algorithm performs better than DecovPDS, CCSID, and PEAS.

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ABSTRACT

Probing Environment and Adaptive Sleeping (PEAS) is one of the most cited protocols in the literature for coverage in Wireless Sensor Networks (WSNs). PEAS maintains only two variables: the number of received messages N and the period of time T necessary to receive these messages. Sensor nodes do not keep any information about their neighbors. In this paper we present PEAS-LI an extension of PEAS to improve the coverage and connectivity. PEAS-LI operates in two steps, initially we apply PEAS as described in Ye et al. (2003) then the neighbors exchange their state and location information in order to estimate precisely the coverage and to make their decision basing on the gathered information. The alone additional requirement is that PEAS-LI supposes that each node knows its position in the monitored area of interest (AI). PEAS-LI performance evaluation proves that it is a robust protocol with high coverage ratio and that it outperforms PEAS and a set of other protocols.

1. Introduction

Technological advances allowed an excess in the miniaturization of the electronic components leading a few years ago to the creation of entities (sensors) having a size of a coin equipped with capacities for computation, sensing, and communication the all generally fed by a battery. The advantage is that these sensors are cheap providing their use in mass to form networks called Wireless Sensor Networks (WSNs) useful for many kinds of applications including battlefield

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surveillance, healthcare, environmental and home monitoring, industrial diagnosis and so on [1].

WSNs are characterized by the deployment of thousands inexpensive sensors energetically constrained, able to sense within a well-defined zone called Sensing Range (SR). Even with the high nodes density (more than 20 nodes/m^2 [2]), both random deployment and different sensing ranges (in the case of heterogeneous networks) lead to the occurrence of sensing holes in the area of interest. In order to improve the coverage ratio and the connectivity, the coverage and connectivity schemes [3,4] try to affect nodes into the maximum number of disjoint groups called cover sets, making sure that the nodes of a given cover set provide less holes than possible and remains connected.

Our paper focuses mainly on the improvement of the PEAS [5] protocol. This is the reason why we developed an algorithm which will take into account the location parameter of each deployed sensor. This algorithm is called PEAS-LI for PEAS with Location Information. When designing the PEAS-LI, our goals were to achieve high coverage and connectivity ratio. In the literature many solutions to the coverage and connectivity problem were presented [5–21] but they still suffer from some weaknesses. The proposed algorithm reaches its goal by probing the local environment, allowing the nodes to awake while following an exponential distribution, and evaluating the coverage relying on the nodes position. Taking into account the nodes position improves significantly the coverage ratio as proven by our experiments.

The remainder of this document is organized as follows, in Section 2 we will talk about the protocols which are close to our solution. Section 3 describes the assumptions made and which are necessary to run PEAS-LI. The description of PEAS-LI is detailed in Section 4. Then, Section 5 is dedicated to the performances evaluation of PEAS-LI according to a set of metrics and to make a comparison with a set of similar protocols. We will conclude this paper in Section 6 by presenting our future perspectives.

2. Related work

A good survey on the existing solutions for coverage problem in wireless sensor networks, including the centralized, distributed, and localized ones, can be read in [6]. In this section we are focusing on some algorithms that are similar in their scheme and assumptions, precisely on localized approach in which each node makes its activity status decision solely based on the decisions made by its communication neighbors.

An efficient algorithm called PEAS was proposed by Ye et al. in [5]. It assumes like us an asynchronous network. Initially, all nodes are in the sleeping mode. PEAS has two components: *Probing Environment* and *Adaptive Sleeping*. Following a Poisson process, each sensor wakes up and sends a probe. All neighbor nodes within the probing range (which is defined by the application) receive this message. If there are any active nodes among neighbors, they must advise the probing sensor accordingly by a REPLY message, to allow it to continue sleeping for another carefully selected duration. Otherwise, no message is sent and the probing node decides to be active. Once activated, it remains active until consuming all its energy. This protocol is highly fault tolerant with constant overhead level under various deployment conditions ranging from sparse to a very dense network. However it does not present a sophisticated coverage evaluation scheme instead it is satisfied with a probing range quite selected.

Connected Cover Set based on IDentity of nodes (CCSID) [7] is a solution proposed for the problem of cover set construction. It is based on analytical approach and uses the concept of Minimum Connected Dominating Set (MCDS) deduced from graph theory. The network is modeled by a graph $G(V, E)$, where V represents the vertices set and E the set of edges CCSIDS [7] is composed of two steps. The first phase is to determine a Minimum Dominating Set (MDS) as a cover set for assuring the coverage in the network. In the second phase, CCSIDS [7] connects the MDS obtained previously to form a so-called Minimum Connected Dominating Set (MCDS) ensuring both area coverage and connectivity.

Gallais et al. [8] approach is fully localized and can be applied on networks formed from heterogeneous time-synchronized sensors knowing their position and having arbitrary sensing and communication radii. Since devices were synchronized, the activity scheduling is designed as rounds. Within the duration of each round nodes set a time out, a node can take its time out according to one of the tree following methods, random scheme, on fly coverage estimation, or the activity history. The decision to be active or not is taken while waiting for the expiration of time out relying on the received decisions from neighbors which have had a smaller quantum of time. If a node will be active it must announce it. The protocol allows too the *withdrawal* message for passive nodes which have previously sent a message to be active but they are not yet and the *retreat* message for the already working nodes but which wish to be withdrawn when discovering that they are not needed for the full coverage and the connectivity. This protocol has very low communication overhead, indeed, no neighbor discovery phase is needed here and neighbor knowledge is brought by activity messages.

Distributed Coverage Preserving based on Dominating Set (DCovPDS) [9] is a distributed protocol for coverage in synchronous WSNs. DCovPDS [9] divides the process into equal rounds and then each round in two steps called *decision* and *sensing* phases. The duration of the decision phase should be much smaller than the sensing one. Initially, each sensor computes a timeout inversely proportional to its residual energy and according to its state in the previous round. During this time, the sensor listens to messages sent by neighbors. If the timeout expires without receiving any message, the node then concludes that it is dominating and decides to be in *active* state. It broadcasts a message announcing its domination to one-hop neighborhood. Upon receiving the domination message, a neighbor in *listen* state decides to save its energy by switching directly to the *passive* mode without sending any message. Note that the lower a node's time out it is, the higher is the probability to become dominating node. Furthermore, dominating nodes form a Dominating Set (DS). At the end of