Computers and Electrical Engineering 65 (2018) 1–17

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

An optimized Bidding-based coverage improvement algorithm for hybrid wireless sensor networks☆

Ayda Vatankhah, Shahram Babaie*

Department of Computer Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran

ARTICLE INFO

Article history:
Received 19 July 2017
Revised 14 December 2017
Accepted 15 December 2017

Keywords:
Wireless sensor network
Area coverage
Sensing radius
Delaunay Triangulation
Optimized Bidding

ABSTRACT

The positioning techniques and adjusting sensing radius of nodes have an important role in improving the network coverage of hybrid wireless sensor networks. In this paper, we propose a novel optimized bidding-based algorithm that able to identify the coverage holes after deploying the stationary sensor nodes, also adjust sensing radius of nodes effectively based on the Delaunay triangulation. In addition, if necessary, an endeavor is made to relocate a portion of mobile nodes at the appropriate positions to cover the holes and reduce the overlapping area. Furthermore, the structure of created triangles i.e. acute and obtuse, layout vertices, region coverage status in before and after the relocation are considered in moving strategy of the proposed algorithm. Extensive simulations have been performed to validate the effectiveness of the proposed algorithm in terms of the coverage ratio, number of moved nodes, number of alive nodes and average of nodes movement.

1. Introduction

Recent advances in micro-electro-mechanical systems technology, wireless communications, and digital electronics lead to the development of low-cost, low-power, tiny, and multifunctional sensor nodes. Each sensor node is capable of the sense of surrounding, aggregates data, and forwards own collected data and neighboring nodes data to the base station, which is known as sink node for further processing [1]. In general, sensor nodes are placed in a hard-to-reach location and are equipped with a limited power source, and given that recharging the energy of these sensor nodes is impossible, costly, and inconceivable in most applications so that efficient management of energy consumption is an essential to prolong the WSN lifetime [2]. However, designing energy efficient algorithms and managing the activities of the sensor nodes become important for enhancing the network lifetime and improving network coverage. In addition, it should be pointed out that there are many problems and challenges in WSNs applications, including energy limitation, hardware bottlenecks, dynamic topology, scalability, security, reliability and the vulnerability and prone to failure [3].

It is proven that among sensor activities, idle and transceiver modes require more energy consumption than processing mode. Moreover, it should be considered that the amount of energy consumption depends on the layout of sensor nodes and their communication strategy. The clustering is a well-known technique that due to decreasing the number of transmission packets can reduce the energy consumption [4]. In addition, applying simple and low overhead software, middleware, and operating system alongside the QoS-aware traffic management techniques have an important role in reducing the en-

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Associate Editor Dr. M. H. Rehmani.

* Corresponding author.
E-mail addresses: ayda.vatankhah2014@gmail.com (A. Vatankhah), sh.babaie@iaut.ac.ir (S. Babaie).

https://doi.org/10.1016/j.compeleceng.2017.12.031
0045-7906/

ergy consumption. Therefore, Tiny Operating System (TinyOS) due to its features is most suitable for applying in resource constraint systems such as wireless sensor networks [5].

One of the major issue in relation to the placement of sensor nodes in WSNs is the strategy of their deployment, which depends on the application of network [6]. In general, deployment strategy of sensor nodes can be classified into pre-determined and random schemes. In pre-determined or deterministic deployment, the position of each sensor node is pre-defined and this scheme is applicable to small and medium-sized networks and friendly environment. This type of deployment is a proper choice for applications that their sensor nodes are expensive and their operations are significantly affected by sensor nodes position [7]. Whereas, sensor nodes are accidentally deployed in an inaccessible large-scale area in random strategy so that may lead to lack of exhaustive coverage in some regions that are referred as coverage holes [8]. Coverage holes refer to the positions, which are not covered through any sensor nodes, and no reports will be received from them.

Generally, creation the coverage holes in the network leads to decreasing the packet delivery ratio and degrading connectivity that determines the importance of identifying and taking the appropriate decision to reduce these points even eliminating these holes as possible. Therefore, selected approaches to deal with this problem in order to detection of holes, calculating their span, and resolving them directly affect network performance. Hence, covering all points of the surveillance circumference is one of the main challenges of randomly distributed networks such as WSNs. In traditional approaches, deploying a high number of stationary sensor nodes is performed as a solution to improve the network coverage. In the initial assessment, it might seem that expanding the number of sensor nodes can enhance the network coverage. However, it should be noted that increasing the number of deployed sensor nodes might be no significant change in the coverage rate but it may have adverse consequences, including increasing the overlapping rate, energy consumption, and network cost [9].

In general, coverage rate is defined as the proportion of the covered area by the sensor nodes to the total network area. The coverage objectives of WSN can be classified into three types such as area coverage, target coverage and barrier coverage [10]. The major objective of sensor nodes in area coverage is to fulfill complete observation of the surveillance circumference. Whereas, in the target coverage, an attempt has made to guarantee the coverage of only specific points of the area. Barrier coverage is concerned with finding a penetration path across the sensor field with some desired properties to apply in special applications such as tracing a mobile target [11]. Eventually, considering the application of WSN at the initialization phase of sensor nodes deployment is necessary to choose the most appropriate objective of coverage that affects directly to the network performance [12].

In some algorithms, mobile nodes can be applied alongside the stationary nodes to improve the coverage rate and the resulting network is called Hybrid Wireless Sensor Networks (HWSN). These nodes are randomly deployed at initialization phase similar to the stationary nodes so that applying a proper replacement technique is a requirement to find an optimal position for the mobile nodes. However, it should be noted that only a portion of sensor nodes could able to move that this property is a constraint of HWSN. In addition, some issues are addressed in the HWSN as challenges such as finding appropriate interest points, motion management to achieve the minimum moving distance, selecting a worthy mobile node between candidate nodes, and adjusting the sensing radius to minimize the overlapping areas.

In this paper, in line with the purpose of reducing the mobility dependency of the network, an attempt has made to introduce a novel cost-effective algorithm that is called CADTA (Coverage enhancing Algorithm based on Delaunay Triangulation with Adjustable rages) to improve the coverage of HWSN. In the proposed algorithm, stationary sensor nodes are able to identify the coverage holes and sort them based on their extents in the descending order. Then, an attempt is made to keep a few sensor nodes in active mode as possible and adjust the sensing radius of the sensor nodes to reduce the overlapping areas and consequently reduce the energy consumption and enhance the coverage rate. In addition, an optimized bidding-based movement strategy is applied to cover the uncovered points via the mobile sensor nodes if coverage rate is less than the respective threshold after the radius adjustment. Eventually, to validate the proposed algorithm its efficiency is compared with counterpart algorithms in terms of the coverage rate, number of alive nodes, number of moved nodes, and average moving distance.

The rest of the paper is organized as follows. Section 2 overviews the related works. Section 3 clarifies and describes basic concepts of the CADTA algorithm as well as some relevant definitions and mathematical models. A detailed description of the CADTA algorithm is given in Section 4. In Section 5, the results of the simulations are reported and analyzed. Finally, Section 6 concludes the paper and unfolds a number of noteworthy directions for future research.

2. Related works

In general, coverage issue refers to ensuring that sensor nodes of WSN should completely cover occurred events of the monitoring area. In fact, coverage is generally defined as the degree of supervision, observation, and how well each point of the monitoring area is covered by the deployed sensor nodes [13].

Coverage problem in WSNs in the most common case is classified into three types including blanket coverage, barrier coverage, and sweep coverage. The objective of WSN in blanket coverage is to maximize the detection rate of targets by the static arrangement of sensor nodes. Minimizing the probability of getting lost the target despite the obstacle through the static arrangement of sensor nodes is referred as barrier coverage. In sweep coverage, the purpose is to achieve the maximum detection rate and minimum getting lost the target using the mobile sensor nodes. Generally, in the setup phase of WSN network, one of the above-mentioned types of coverage is considered with regard to the respective application, needs, and requirements. Furthermore, some factors such as sensor deployment strategy (random and deterministic), type