Dynamic Deployment Optimization in Wireless Sensor Networks

Xue Wang, Sheng Wang, and Junjie Ma

State Key Laboratory of Precision Measurement Technology and Instruments, Department of Precision Instruments, Tsinghua University, Beijing 100084, P.R. China
wangxue@mail.tsinghua.edu.cn
wang_sheng00@mails.tsinghua.edu.cn
mjj@mails.tsinghua.edu.cn

Abstract. Sensor deployment is one of the key topics addressed in wireless sensor networks (WSNs) study. This paper proposes a self-organizing technique for enhancing the coverage of WSNs which consists of mobile and stationary nodes. The mobile nodes will relocate themselves to find the best deployment under various kinds of situations for covering largest area. The new locations of mobile nodes are determined by parallel particle swarm optimization (PPSO) which is suitable for solving multi-dimension function optimization in continuous space. Especially, the mobile nodes deployment with PPSO is useful in situations where some area need cooperative measuring with multiple nodes, and can be adjusted dynamically according to the requirement of environment. The experimental results verify that mobile nodes deployment with PPSO has good performance in quickness, coverage, and connectivity.

1 Introduction

In WSNs, dynamic deployment optimization has become one of the key topics addressed. T. Wong et al. [1] and S. Zhou et al. [2] proposed the “Virtual Forces” algorithm which can effectively enhance the coverage and connectivity of WSNs in single measurement, but little attention has been focused on the dependability and precision of sensor nodes. Actually, because of the high robust and precision requirement, cooperative measurement is required in most applications. The proposed PPSO based dynamic deployment optimization algorithm is useful in deployment of cooperative measurement with the effective coverage performance taken as criterion while precision and speed of optimization is satisfied.

2 Detection Model and Evaluation Method

2.1 Sensor Node Deployment

Proper deployment can improve performance of WSNs. We assume that all nodes know their location and have the same detection range $r_d$, detection dependability $r(t)$ and communication range $r_c$. We define that a circle with original point $(x, y)$ and radius $r_d$ can be monitored by the sensor sitting on location $(x, y)$ with the probability $r(t)$ at time $t$. Fig. 1(a) shows an example of initial random sensor deployment.
2.2 Performance Evaluation for WSNs

If an area is in detection range of \( n \) nodes at time \( t \), the area’s synthesis detection dependability can be calculated directly as:

\[
R(t) = 1 - \prod_{i=1}^{n} (1 - r_i(t))
\]  

where \( r_i(t) \) is the detection dependability of \( i \)th sensor nodes.

Effective coverage performance can be represented by the proportion of effective area where synthesis detection dependability can satisfy the detection acquirement. As shown in Fig. 1(b), gridding algorithm divides the area into grids and calculates the proportion of effective detected grids. The simulation results verify that the error is between 0.5% and 0.1% while granularity is between 4% and 0.25%. Unfortunately, the execution time increases fast when granularity decreases. For reducing the execution time, we can analyze the effective detection area formed by stationary nodes at first, and then solve the remaining area during dynamic adjustment.

As illustrated in Fig.1, sensors are divided into two connected groups. In WSNs, if a node cannot be connected to the sink node, its information will not be received. For grouping, each node detects its neighbors and all connected nodes label them in the same group. We define the group connected with sink node as the activated group. The number of connected nodes and coverage are focused. The coverage ratio is as follows:

\[
C_i = \frac{\cup_{i} c_i}{A}, i \in S
\]  

where \( c_i \) is the coverage of a sensor \( i \), \( S \) is the set of nodes, and \( A \) is the total size of the area to be monitored. Let \( N_m \) denotes the number of sink-connected nodes after placing mobile nodes. To represent the improvement, we define:

\[
N_{im} = \frac{N_m - N_0}{N_0} \times 100\%
\]  

where \( N_0 \) is the number of connected nodes before placing any mobile nodes. We also define \( c_{im} \) as the improvement of coverage with \( m \) mobile nodes, as:

\[
c_{im} = \frac{C_m - C_0}{C_0} \times 100\%
\]