Advanced Science and Technology Letters
Vol.139 (FGCN 2016), pp.34-38
http://dx.doi.org/10.14257/astl.2016.139.07

Efficient Topology Design in RFID Networks

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Abstract. To pursue more desirable reader deployment for RFID networks, we present an efficient new topology design in this paper. We brief the new method NOP because it involves a non-optimization practice to avoid the tedious long heuristic search in existing optimization-based methods and meanwhile provides proper sequential considerations of objectives to avoid their improper objective utilization. As the collected simulation results demonstrate, our non-optimization new method is able to generate better reader deployment with less complexity in contrast to existing optimization methods, or more specifically, we can turn over better fitness values at significantly shorter processing time.

Keywords: RFID (Radio Frequency IDentification) networks, topology design, optimization-based and non-optimization-based methods, reader deployment, experimental evaluation.

1 Introduction

In a Radio Frequency IDentification (RFID) network, unguarded reader deployment (e.g., readers are largely/randomly deployed) may incur tremendous deployment cost. Specifically, unplanned reader deployment may generate over-crowded readers in the network which can cause reader-to-tag or reader-to-reader interferences to decrease the percentage of successful tag detection [1-3]. In such an RFID network, creating an efficient topology design for all to-be-deployed readers becomes particularly important. Current methods taken to achieve favorable topology designs for RFID networks are all optimization-based methods involving different optimization techniques – including the Genetic Algorithms (**GA**) [4], the Genetic Annealing Algorithms (**GAA**) [3,5] and the Improved Genetic Annealing Algorithms (**IGAA**) [3]. We observe that, in the heuristic search for optimal or sub-optimal solutions, these optimization-based methods will take remarkable complexity. Besides, they are likely to produce unfavorable results due to improper utilization or concurrent consideration of the objectives covered by the multi-objective fitness function [3-4]. To improve the situation, i.e., to attain more desirable reader deployment, we present an efficient new RFID network topology design in this paper. Our new design is distinct in using a non-optimization-based method to avoid the tediously long heuristic search in optimization-based methods. It is also distinct in enacting proper sequential considerations of the objectives to avoid the improper utilization or

ISSN: 2287-1233 ASTL
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concurrent consideration in optimization methods. Simulation results show that our non-optimization (**NOP**)-based method can generate desirable reader deployment with reduced complexity, i.e., our **NOP** method practically outperforms optimization-based **GA**, **GAA** and **IGAA** by yielding higher fitness values at much shorter processing time.

2 The Proposed Method

Recent optimization-based methods [4] usually evaluate possible RFID topology designs by a defined linear weighted multi-objective fitness function which covers six objectives: the overlap of the reading area, the number of useless readers, the number of redundant readers, the number of tags located in the overlap reading areas, the number of tags covered and the deployment cost. (Here, we take in "the deployment cost" in [3] to replace "the number of readers located out of the deployment area" in [4] because it is unreasonable in practice to deploy readers "out of" a pre-specified deployment area.) Note that other than its ability to avoid the lengthy heuristic search in previous optimization-based methods, our new method will also enact proper sequential consideration on the above six objectives to avoid unfitting utilization or concurrent consideration in previous methods.

The practice of our non-optimization-based method consists of the following three phases:

1. Initial reader deployment: to find the best initial deployment of each reader.
2. Reader power increment: to cover more tags after initial deployment.
3. Reader power decrement: to further reduce the deployment cost without affecting the number of covered tags.

In the **initial reader deployment** phase, we record three items – possible reader positions (Pt[i]), covered tags (St[i]) and the number of covered tags (Ci) – to compare the deployment alternatives properly and, based on the result, to pursue desirable initial deployment of the preset number (N) of available readers one by one. Pt[i], St[i] and Ci are respectively denoted below.

*Pt[i]=1 indicates the position in the ith tag (of the n tags) is not a possible reader position due to certain reasons (e.g., the position has been occupied by another reader).

*St[i]=1 indicates the ith tag has been covered.

*Ci of a reader indicates the number of tags covered exclusively by this reader when it is deployed on the position of the ith tag.

Besides, we use count to calculate the number of deployment failures for each reader in the initial deployment phase. When the count of a reader exceeds a preset threshold, we will decrease the power of the reader (P) to avoid possible deployment failures. The steps for the phase are given below.

Step 1: Initialize Pt[i], St[i] and the count for a reader.

Step 2: Calculate the reader's Ci for all n tag positons according to Pt[i] and St[i].

Step 3: Select Max Ci and check if such a deployment breaks the preset limits (25% overlap reading area and 2 tags in the overlap reading area).

Step 4: If the deployment works, set Pt[i]=1 and {St[i]}=1; otherwise, set Pt[i]=1, count++ and perform power adjustment according to the count value.

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Step 5: Loop again to Step 2 until the number of deployed readers reaches N.

In the **reader power increment** phase, we maximize the power of each deployed reader to increase the covered tags for each reader and also the total covered tags in the network. The steps for the phase are listed below.

Step 1: If the stop condition (when 90% of tags are covered) is not reached, go to the following steps.
Step 2: Calculate the reader's Ci for all n tag positons according to the increased power (P) of the reader and St[i].
Step 3: Select Max Ci and check if such a power increment breaks the preset limit.
Step 4: If the deployment succeeds, assign the new power to the reader and set {St[i]}=1; otherwise, keep the original topology.
Step 5: Return to Step 1.

We define the stop condition as "when 90% of tags are covered" based on the fact that optimization methods can cover less than 90% of tags only after convergence [3].

In the **reader power decrement** phase, we will maintain the same tag coverage but possibly decrease the power of each reader to save the deployment cost. In this power decrement phase, we can actually detect a reader to be useless or redundant after reducing its power to an extent that it covers no tags but we still maintain the same tag coverage as well. Such useless or redundant readers can then be removed due to their negligible performance. The steps of the phase are given below.

Step1: Select the next reader.
Step2: Do power decrement.
Step3: Return to Step 2 if the number of covered tags is unchanged.
Step4: Replace the power of the reader by the new minimum power which maintains the original tag coverage. Loop again to Step1 until all readers finish the power decrement.

The sequential consideration of the above six objectives are shown in Table 1, to display that we can avoid the improper utilization or concurrent consideration in optimization-based methods.

Table 1. Sequential consideration of the six objectives in our method.

Objectives	initial reader deployment phase	reader power increment phase	reader power decrement phase
Overlap reading area	✓	✓	
Number of useless readers	✓		✓
Number of Redundant readers			✓
Number of tags located in the overlap reading area	✓	✓	
Number of tags covered		✓	
Deployment cost			✓

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3 Experimental Evaluation

Extended simulation runs are conducted to compare the performance of our non-optimization method (briefed as **NOP**) and existing optimization methods **GA**, **GAA** and **IGAA**. In our simulation, we assume 30 tags are located in a 20m*20m tag area and 10 readers will be deployed to read the tags in a 32m*32m reading area. The preset limits in the initial reader deployment phase are, as mentioned, 25% overlap reading area and 2 tags in the overlap reading area. The reader power increment phase will stop when 90% of the tags are covered (the stop condition) and the preset threshold for a reader's deployment failures (count) is 2. We then evaluate these optimization methods and our non-optimization method under the above environments and by the same six objective functions. We collect the results of optimization methods around 200 iterations because convergence normally takes place at the time [3]. The performance measures of interest are ***the fitness value*** and ***processing time***. Fig. 1 depicts the fitness values of the four methods. As the result shows, our **NOP** yields better fitness values than **GA**, **GAA** and **IGAA** – mainly because we enact proper sequential considerations of the objectives to avoid improper utilization or concurrent consideration in the three optimization methods. Fig. 2 gives the processing time of the methods. In contrast to optimization methods, our **NOP** method takes significantly the least processing time because our non-optimization-based practice can avoid the tediously long heuristic search in optimization-based methods.

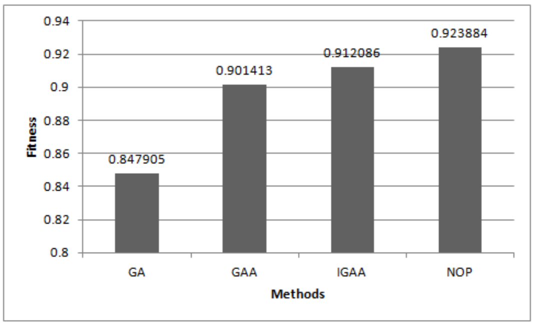

Fig.1. The fitness values for various methods.

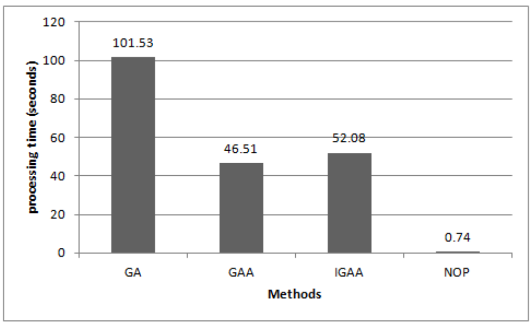

Fig. 2. The processing time for various methods.

4 Conclusions

We know that a desirable topology design for to-be-deployed readers can critically influence the performance of an RFID network and that current methods for such topology designs are all optimization-based methods whose heuristic search for optimal or sub-optimal solutions tends to incur remarkable complexity. The improper utilization or concurrent consideration of objectives covered by their multi-objective fitness function may also lead to unfavorable results. To attain better RFID network topology design, i.e., to ensure more desirable reader deployment, we provide an efficient non-optimization-based (**NOP**) method in this investigation. Our proposed **NOP** method is desirable in that its practice avoids the tedious lengthy heuristic search and the improper objective utilization in existing optimization methods. The obtained simulation results show that, in comparison to existing optimization methods, our non-optimization method is able to yield better fitness values at much less processing time, i.e., to turn over better reader deployment with less complexity.

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