บันทึกข้อความ

ส่งงานวิจัย ด่วน

ส่วนราชการ หน่วยสนับสนุนการวิจัยและบริการ คณะวิศวกรรมศาสตร์ มหาวิทยาลัยอุบลราชธานี **โทร.** 3319

ที่ ศธ 0529.8./ 4372 **วันที่** 8 ก.ย. 2557

เรื่อง ขออนุมัติรับทุนค่าลงทะเบียนการเสนอผลงานวิจัย/ผลงานทางวิชาการระดับนานาชาติ แบบ Oral Presentation ที่จัดในประเทศไทย ปีงบประมาณ 2558

1) เรียน รองอธิการบดีฝ่ายวิจัยและนวัตกรรม (ผ่านคณบดี)

ด้วยข้าพเจ้า ดร.อธิพงศ์ สุริยา ได้รับการตอบรับให้นำเสนอผลงานวิจัย/ผลงานทางวิชาการ เรื่อง Genetic Algorithm Based Approach for RFID Network Planning **แบบ Oral Presentation** ในการประชุมวิชาการระดับนานาชาติ IEEE Region 10 Conference 2014 (IEEE TENCON 2014) ระหว่างวันที่ 22-25 ตุลาคม 2557 ณ ประเทศไทย จึงใคร่ขออนุมัติรับทุนค่าลงทะเบียนการเสนอผลงานฯ จำนวน 10,000 บาท

ข้าพเจ้าขอรับรองว่าผลงานเรื่องดังกล่าว ไม่เป็นส่วนหนึ่งของผลงานระดับบัณฑิตศึกษา **และเป็นการนำเสนอผลงานในรูปแบบ Oral Presentation** และจะมีการตีพิมพ์บทความของข้าพเจ้าใน Proceeding ทั้งนี้ หากตรวจสอบทราบในภายหลัง ข้าพเจ้า**ยินดีคืนเงิน**ที่ได้รับการสนับสนุนทั้งหมด

พร้อมได้แนบหลักฐานประกอบการพิจารณา จำนวน 1 ชุด ตามลำดับ ดังนี้

- ☑ 1. สำเนาหลักฐาน/หนังสือตอบรับการเข้าร่วมเสนอผลงาน แบบ Oral Presentation
- ☑ 2. สำเนาหลักฐานการรับผลงานเพื่อตีพิมพ์ใน Proceeding
- ☑ 3. หลักฐานการจัดประชุม
- ☐ 4. กำหนดการนำเสนอผลงานแบบ Oral Presentation
- ☑ 5. บทความที่จะนำไปเสนอต่อที่ประชุม

จึงเรียนมาเพื่อโปรดพิจารณา

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(ดร.อธิพงศ์ สุริยา)
ตำแหน่ง อาจารย์

(ลงชื่อ)........................
(ผู้ช่วยศาสตราจารย์ดร.อดุลย์ จรรยาเลิศอดุลย์)
รองคณบดีฝ่ายวิจัยและบริการวิชาการ
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ปฏิบัติราชการแทนคณบดีคณะวิศวกรรมศาสตร์

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2) เรียน รองอธิการบดีฝ่ายวิจัยและนวัตกรรม ผ่านหัวหน้างาน
ตรวจสอบแล้ว เห็นควร ☐ เสนออธิการบดีเพื่อพิจารณา อนุมัติทุน ☐ แจ้งกลับต้นสังกัด เนื่องจากขัดประกาศฯ ....

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3) เรียน รองอธิการบดีฝ่ายวิจัยและนวัตกรรม
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(ลงชื่อ)........................
(นางสาวนาวินี สุตัญตั้งใจ)
ตำแหน่ง ตำแหน่งหัวหน้าสำนักงานส่งเสริมบริหารงานวิจัยฯ
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☐ 4) แจ้งกลับต้นสังกัด **☐ 4) เรียน อธิการบดี**
เพื่อโปรดพิจารณาเห็นควรอนุมัติให้ทุนจากกองทุนวิจัย ตามจ่ายจริงไม่เกิน 10,000 บาท

(ลงชื่อ)........................
(ผู้ช่วยศาสตราจารย์ ดร.อินทิรา ชาฮีร์)
ตำแหน่ง รองอธิการบดีฝ่ายวิจัยและนวัตกรรม
วันที่........................

5) อนุมัติตามเสนอ

(ลงชื่อ)........................
(รองศาสตราจารย์ ดร.นงนิตย์ ธีระวัฒนสุข)
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IEEE TENCON 2014 Bangkok Thailand

IEEE THAILAND SECTION

Paper ID : 00345
Paper Title : Genetic Algorithm Based Approach for RFID Network Planning
Author's : Atipong Suriya, David Porter

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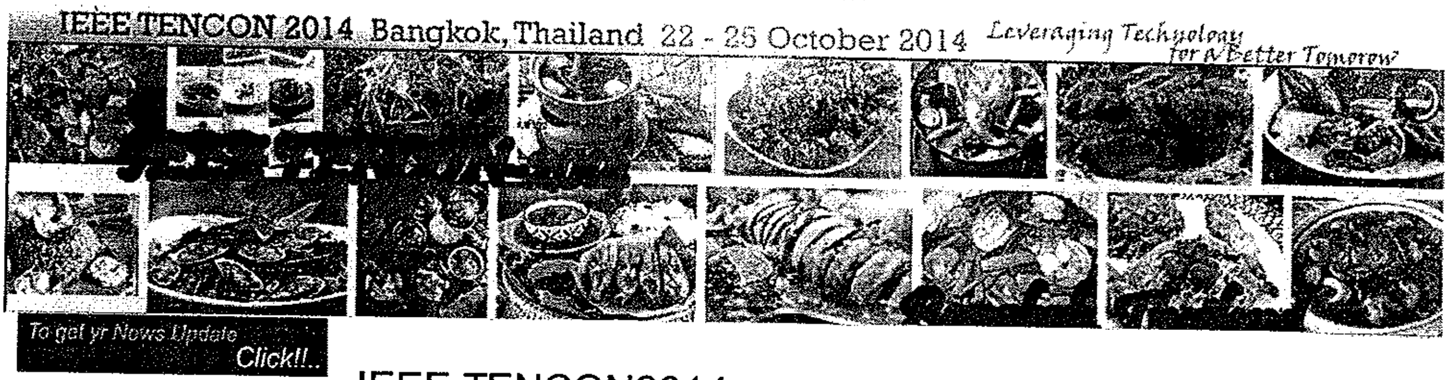

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[14-Mar-2014] Submission site is opened.
[1-Mar-2014] Keynote speakers are added.
[3-Oct-2013] Conference Dates changed from 19-22 November 2014 to 22-25 October 2014.
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	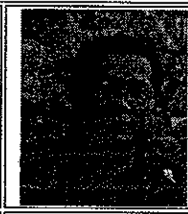		
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Genetic Algorithm Based Approach for RFID Network Planning

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***Abstract*—The design of a RFID network in a large-scale facility requires a placement of a large number of RFID readers to ensure the desired coverage. However, the placement of RFID readers is often done on a trial and error basis which is time consuming and results in less than optimal coverage. In this paper, a multi-objective function optimization model for the placement of RFID readers is proposed. Genetic algorithm (GA) is used to determine the optimal placement and number of RFID readers required in two simulations involving a 30m x 30m facility with 99 randomly placed RFID tags. The first simulation considered only 10 RFID readers and the results showed that 76 tags could be covered using the proposed model (compared to 72 tags covered in previous research). In the second simulation, the optimal number and location of RFID readers to cover all 99 tags in the facility was determined. The results showed that 21 RFID readers were necessary to cover all 99 tags, which is less than the 30 RFID readers derived from the concept of hexagonal packing.**

Keywords*—*radio frequency identification; reader antenna coverage; RFID network planning; genetic algorithm

I. Introduction

Radio frequency identification (RFID) is an automatic identification and data capture (AIDC) technology that has gained significant attention in recent years as a means of enhancing the traceability of items throughout the supply chain. Market trends indicate a rapid growth in the demand for RFID-based technologies, with an expected 18% compound annual growth rate for the three-year period 2011-2014, culminating in a projected $19.3 billion industry by the end of 2014 [1].

A basic RFID system includes four main components: a host computer system, a RFID reader, an antenna, and a transponder (or RFID tag). RFID technology, when properly implemented, has several benefits over more conventional AIDC technology (i.e., bar codes), including tracking physical objects in real time and reductions in process times, labor, and the amount of paperwork needed in day-to-day operations. Applications of RFID technology are becoming more common in the supply chain and healthcare applications (and particularly in large-scale facility such as warehouse and hospital) to enable physical objects tracking and to support inventory management systems (IMSs) [2-4].

One of the most important decisions when designing RFID networks to support large-scale facilities operations is where to locate the RFID readers. Locating RFID readers in a facility is referred in the literature as the *RFID network planning (RNP)* problem [5-8]. In practice, the placement of RFID readers is often done on a trial and error basis. This placement method is very time consuming and results in a less than optimal coverage of the facility area.

Providing an optimal solution to the RNP problem is a complex task that may be affected by several factors such as radio frequency (RF) signal coverage, RF signal propagation, and interference (i.e., both passive and active). Thus, a formal methodology to optimize the placement and number of RFID readers required to cover a facility is needed. Critical steps in such a methodology are the development of a mathematical formulation and the selection of an appropriate optimization technique to ensure that quality solutions are obtained within a reasonable computation time.

Several researchers have attempted to solve the RNP problem. For example, Guan et al. [9] developed a computer-based model aimed at optimizing the placement of RFID readers under the assumption that antenna coverage was omnidirectional (i.e., circular signal coverage). The free space propagation model was used and no obstacles were considered. Chen et al. [10] developed a model considering circular antenna coverage and a free space propagation model. They did not model obstacles or the uplink communications channel either. It is clear that there are still critical technical gaps and challenging issues to be addressed. In particular, this research will attempt to improve on the research done in [9] and [10].

In this manuscript, we propose a multi-objective optimization model for the placement of RFID readers in a large-scale facility. To validate the results obtained by the proposed optimization model, two simulations involving a 30m x 30m facility with 99 randomly placed RFID tags were performed. The first simulation used only 10 RFID readers and the results obtained are compared to prior research performed by Chen et al. [10]. The objective of the second simulation was to find the optimal number and location of RFID readers to cover all 99 RFID tags in the facility.

The remainder of this paper is organized as follows. Section 2 describes the characteristics of the problem to be solved (i.e., the RNP problem). Section 3 explains the features of the multi-objective optimization model and parameters used in the GA. The results of the two simulations are presented in Section 4. Finally, conclusions and future work are discussed in Section 5.

II. Problem Description

The main objective in producing a solution to the RFID network planning (RNP) problem is to determine the *number* and *location* of the RFID readers in a facility to maximize a specific objective (or set of objectives). To this end, an indoor test facility (ITF) with a height of 30 meters and a width of 30 meters was utilized. The ITF, depicted in Fig. 1, constitutes a free space environment with no obstructions. A total of 99 RFID tags (represented by the "x" marks in Fig. 1) are placed randomly within the boundaries of the ITF. The solid black circles located in the ITF represent potential locations for the RFID readers (i.e., centers of candidate grids) and correspond to the coordinate points (0.5,0.5) to (29.5, 29.5). Thus, there is a total of 900 individual coordinate points that represent potential locations for the RFID readers.

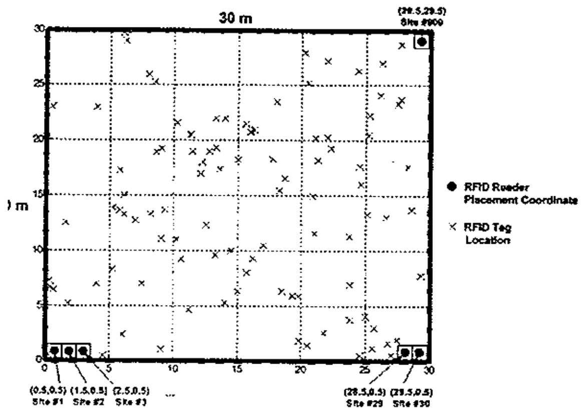

Fig. 1 The target facility area (Chen et al. [10])

Omnidirectional antennas with circular signal coverage were used to generate an initial set of RFID readers to cover the entire ITF. Assuming a transmission frequency of 915 megahertz (MHz), a transmitted power of 2 watts (W), and a received threshold power of 0.1 milliwatts (mW), the radius (in meters) of the omnidirectional antenna's circular coverage can be calculated using the simple free space propagation formula shown in (1).

$$P_r = P_t G_t G_r \times \left(\frac{\lambda}{4\pi r}\right)^2 \Rightarrow r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r}{P_r}} \qquad (1)$$

P_t : Power transmitted by the RFID reader (2 W)

P_r : Power received by the RFID tag (0.1 mW or -10 dBm)

G_t, G_r : Gain of reader and tag (both are assumed to be 1)

λ : Wavelength of the signal (0.3278 m)

r : Radius of the antenna's coverage area

Using the values shown above, the radius (r) of the coverage area for each omnidirectional antenna is 3.69 meters. This value of r translates in a total of 30 RFID readers needed to initially cover the ITF, as depicted in Fig. 2.

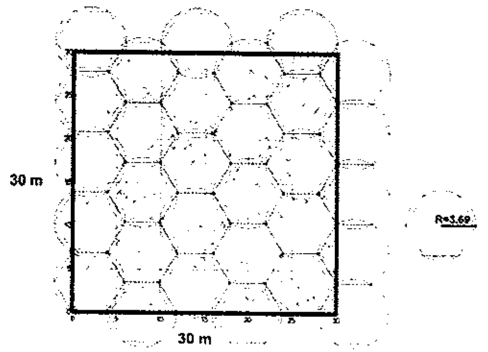

Fig. 2 Initial placement of RFID readers using the concept of hexagonal packing

This initial number of RFID readers was determined using the concept of a hexagon enclosed by a circle with radius r proposed by Huang and Chang [11].

Finding an optimal number of RFID readers and their location to cover the ITF based on the initial number of RFID readers shown in Fig. 2 is an NP-hard problem. Therefore, a procedure based on genetic algorithm (GA) and implemented as a software tool was used to solve this problem in a reasonable computation time. The previous research conducted by Guan et al. [9] used a genetic algorithm (GA) to deal the RNP problem, whereas Giampaolo et al. [5] and Chen et al. [10] used PSO. GA is known to deal very well with several types of combinatorial optimization problems. Furthermore, GA can lead the search to achieve the optimum solution very fast and deals effectively with multi-objective function problems.

III. Methodology

Several competing system requirements were considered when optimizing the number and placement of RFID readers in the ITF. These system requirements were the following:

- Maximize RFID reader antenna coverage within the ITF.
- Minimize the interference in the downlink communication channel, i.e., the communication from a RFID reader to an RFID tag. This objective also maximizes the signal-to-interference ratio of the downlink communication channel (*Downlink SIR*).
- Minimize the interference in the uplink communication channel, i.e., the backscattered signal from an RFID tag to a RFID reader, thus also maximizing the signal-to-interference ratio of the uplink communication channel (*Uplink SIR*).

- Minimize the number of RFID readers required in the system. This objective also minimizes the implementation cost.

Since all the system requirements have to be satisfied simultaneously, this problem can be formulated as a multi-objective function model. The next subsections present more details about how each system requirement was formulated and the parameters used in GA.

Three main objective functions were formulated that deal with coverage, signal to interference ratio of both uplink and downlink, and cost. All the objective functions have a value that can range between 0 and 1.

A. Coverage

The objective function for the RFID reader antenna coverage is expressed as the number of RFID tags covered ($\sum_{i=1}^{n} S_i$) by all RFID readers in the system divided by the total number of RFID tags in the system ($\sum_{i=1}^{n} T_i$) as shown in (2).

$$f_1 = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} T_i} \qquad (2)$$

S_i is a binary decision variable to identify whether or not the RFID tag i (T_i) is covered by at least one RFID reader. RFID tag i is covered by the RFID reader located at grid j ($S_i = 1$) if and only if the downlink communication from the RFID reader located at grid j to RFID tag i and the uplink communication from RFID tag i to the RFID reader located at grid j are successfully established.

B. Interference

The type of interference considered in this paper is that produced by the RFID tags located in the overlapped area of two or more RFID readers. This type of interference is known as reader-to-reader interference [12].The signal to interference ratio for the downlink, i.e. the communication from the RFID reader to the RFID tag, is the summation of the maximum signals received at RFID tag i from RFID reader located at grid j ($\sum_{i=1}^{n}\sum_{j\in N_i}(\max(D_{i,j}))$) divided by the summation of these aforementioned signals and the interferences from the other RFID readers ($\sum_{i=1}^{n}\sum_{j\in N_i}(\max(D_{i,j})) + \sum_{i=1}^{n}\sum_{j\in N_i}\sum_{k\in IS_i}((\max(D_{i,j}))_k)$). The objective function to quantify the amount of SIR for the downlink is shown in (3).

$$f_{21} = \frac{\sum_{i=1}^{n}\sum_{j\in N_i}(\max(D_{i,j}))}{\sum_{i=1}^{n}\sum_{j\in N_i}(\max(D_{i,j})) + \sum_{i=1}^{n}\sum_{j\in N_i}\sum_{k\in IS_i}((\max(D_{i,j}))_k)} \qquad (3)$$

The SIR for the uplink can be formulated as the same way as the downlink one which is shown in (4).

$$f_{22} = \frac{\sum_{i=1}^{n}\sum_{j\in N_i}(\max(U_{i,j}))}{\sum_{i=1}^{n}\sum_{j\in N_i}(\max(U_{i,j})) + \sum_{i=1}^{n}\sum_{j\in N_i}\sum_{k\in IS_i}((\max(U_{i,j}))_k)} \qquad (4)$$

N_i is the set of all possible RFID readers that can cover the RFID tag i and IS_i is the set of RFID readers that generate interferences at the RFID tag i.

C. Cost

The objective function for cost is calculated by subtracting the implementation cost, i.e. cost of one RFID reader (C_i) by the number of installed RFID readers (t), from the implementation budget and then dividing this result by the implementation budget, as shown in (5). The higher the value of cost objective, the greater the implementation cost to be saved.

$$f_3 = \frac{Budget - (C_i \times t)}{Budget} \qquad (5)$$

All three objective functions are combined into a fitness assignment using a weighted sum. No prior evidence was found that suggested a specific method to assign weights to the different objectives. In most cases, the suggestion was that this decision is the responsibility of the modeler and relies heavily on prior experience with and knowledge of the system being modeled. In this research, the coverage objective was considered the most important objective and therefore was assigned a larger weight. After assigning a weight to the coverage objective, the remaining two objectives were assigned weights with equal values to respect the constraint that the summation of the weights must be equal to one.

To find the most appropriate setting for the weight value of the coverage objective, its value was varied starting at 1.0 and then lowered in decrements of 0.1 until the GA could no longer cover all 99 RFID tags in the ITF. By using this approach, the GA could still ensure the entire coverage of the ITF, while also improving (i.e., reducing) interference and cost. Using this procedure, it was found that 0.6 was the lowest weight value of the coverage objective that allow the GA to still cover 99 RFID tags in the ITF. Thus, the interference and cost objectives were assigned equal values of 0.2, as shown in (6).

$$Fitness = 0.6 \times f_1 + 0.2 \times (f_{21} + f_{22}) + 0.2 \times f_3 \qquad (6)$$

D. Genetic Algorithm

Table 1 shows the parameters (and their values) used in the GA to find good solutions to the RNP problem.

TABLE I. PARAMETERS FOR SIMULATION OF THE DEVELOPED GA

Parameters	Values
Number of RFID Readers	10[†] or 21
Number of RFID Tags	99
Radius of Signal Coverage	3.69 m
Number of Populations	50
Parent selection	Proportional to fitness
Crossover	One-point crossover
Mutation rate	0.05
Next generation selection	Strong child or parents
Stopping Criteria	1000 generations

[†] Number of RFID readers used to compare to results from Chen et al. [10]

IV. RESULTS AND DISCUSSIONS

A. Comparison to Results in Chen et al.[10]

Satisfying coverage is typically the most important objective in the RNP problem. Good algorithms should result in the coverage of as many RFID tags in the system as possible or coverage of the entire facility in the best case. Therefore, a preliminary simulation was conducted to assess the effectiveness of the developed GA by comparing it to the results obtained in Chen et al. The modeling parameters shown in Table 1 were used in this preliminary simulation. It is also important to note that the number of RFID readers used was 10 (same as Chen's). Fig. 3 shows that 72 tags can be covered with 10 RFID readers using the algorithm proposed by Chen et al.

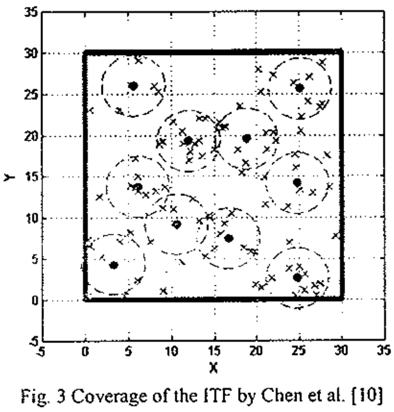

Fig. 3 Coverage of the ITF by Chen et al. [10]

Fig. 4 shows the results obtained with the developed GA. In this case, 76 tags were covered and the solution is obtained in 221.31 seconds (no computation time was provided in [10]). This represents an improvement of 5.56% in terms of the number of RFID tags covered in the system. The optimum value of fitness was 0.7940 and was reached after the algorithm ran approximately 392 generations. The objective of coverage, SIR, and cost were 0.7677, 1.0, and 0.6667, respectively.

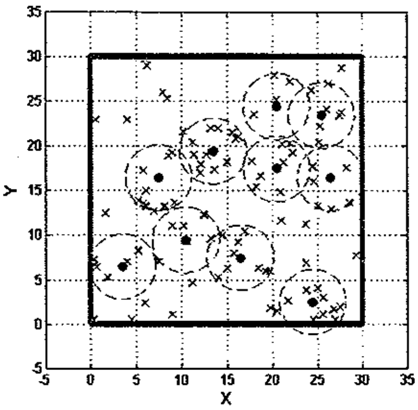

Fig. 4 Coverage of the ITF by proposed GA

B. Covering the entire ITF

As mentioned in section 2, 30 RFID readers are required to cover the entire ITF. The coverage provided by this number of RFID readers is very inefficient (i.e., large amounts of radio frequency energy is lost) as well as not cost-effective. Therefore, the optimum location and number of RFID readers needed to cover all 99 tags in the system were further investigated. Logically, the number of required RFID readers should be in the range between 10-30 RFID readers. To find the optimal solution, the number of RFID readers was varied in the GA from 10 to 30 to evaluate the resulting value of the fitness function. Using this procedure, it was determined that 21 RFID readers was the optimum number to cover all RFID tags in the ITF.

The graphical results are depicted in Fig. 5, where the coverage area of each RFID reader is represented by a dash-dotted line. The solid line represents the boundary of the ITF and the "x" marks represent RFID tags that were randomly added onto the ITF. Finally, the black circles in the center of the coverage areas indicate the optimum locations for the RFID readers, as determined by the proposed GA.

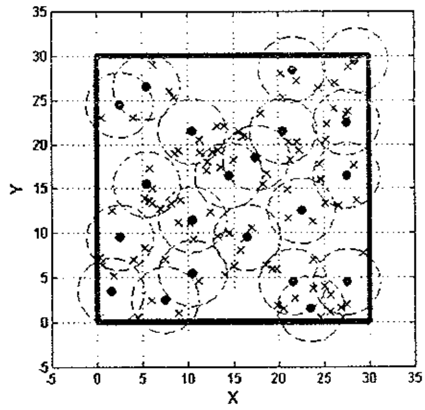

Fig. 5 The optimum location and number of RFID readers to cover all RFID tags in the ITF.

In terms of the objective functions, the coverage reached the maximum value of one. This means that all RFID tags are covered by at least one RFID reader in the system. The objective function for signal to interference ratio of both uplink and downlink was 0.799. The cost objective function, as calculated with (5), is 0.3. As a result, the fitness value obtained with (6) is high at 0.8198. The GA achieved the maximum value of fitness at generation 546. The GA was terminated after 1,000 generations with a computation time of 723.15 seconds.

V. Conclusions and Future Work

This paper presented the results obtained from applying a newly developed GA to solve the RFID network planning problem. To validate the developed GA, a preliminary simulation was conducted using 10 RFID readers and the results were compared to those reported in Chen et al. [10]. The optimal location of the RFID readers obtained with proposed GA provided coverage for 76 tags (compared to 72 tags) and obtained the solution in only 221.31 seconds.

A second simulation was conducted with the objective of determining the optimal location and number of RFID readers to cover all 99 tags located in the ITF. In this case, the proposed GA determined that 21 RFID readers were necessary to cover all 99 tags, which is less than the 30 RFID readers derived from the concept of hexagonal packing. A total of 1,000 generations were performed by the algorithm with a computation time of 723.15 seconds and the maximum value of fitness was achieved at generation 546. The proposed GA guided the search to a good solution with 100% coverage, and low level of interference. These result improved the reliability of reader-tag communication and the RFID tags reading process. Also, the lower number of RFID readers would translate into lower implementation and maintenance costs.

There are several modifications that will be made to the proposed GA to improve its efficiency and also to reflect more practical and realistic modeling aspects associated with the RNP problem. Among these modifications are the type of antenna coverage pattern, the assumed propagation model, the obstruction in the system and the addition of considerations associated with RFID reader elimination.

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