VOL. 11, NO. 12, JUNE 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

REVIEW OF RFID OPTIMAL TAG COVERAGE ALGORITHMS

Adel Muhsin Elewe, Khalid bin Hasnan and Azli bin Nawawi
Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
E-Mail: adelmuhsin2@gmail.com

ABSTRACT

Radio Frequency Identification (RFID) system is a technology that use large number of tags communicates with small number of readers. This situation leads to the problem of determining the readability of Passive RFID Transponders based on the limited range of the reader-to-tag communication. For this reason several algorithms have been developed in order to optimize RFID tag coverage for improving functional procedures. Nature Inspired Algorithms applied to find RFID Optimal tag coverage. Particle Swarm Optimization (PSO) algorithm is used as an optimization technique because its fast in operation speeds, easy to implement and fewer parameters need to be adjusted. To improve accuracy, maximize the tracking precision and minimize the reader consumption it's hybridized with many techniques. The artificial bee colony algorithm (ABC) is another optimization algorithm which is distinguished as a simple algorithm with high flexibility, strong robustness, few control parameters, ease of combination with other methods, ability to handle the objective with stochastic nature, fast convergence, and both exploration and exploitation. Finally the bacterial foraging optimization (BFO) as a global optimization algorithm optimizes the local minima, direction of movement, randomness, swarming and attraction/ repelling. All these algorithms presented in this paper.

Keywords: tag coverage, nature inspired algorithms.

INTRODUCTION

RFID systems are a revolutionary element. It can read multiple tags at the same time with a large data storage capacity whereas the system can store a tag serial number which is used to identify the objects globally and uniquely.

An RFID stand for "Radio Frequency Identification" is a communication medium with non-light sight and employs the radio frequencies to transmit or receive signals. Radio Frequency Identification (RFID) tag is electronic piece characterized as a noncontact automatic identification technology. RFID tags utilize the RF signal to use it as an information transfer medium and energy source to exchange the information with the measured objects (Hasnan et al. n.d.).

An RFID system consists of three main components: a tag (or transponder), a reader (or interrogator) and a middleware. The transponder usually located on the object to be identified. It is made of a chip and an antenna with a unique code to provide unique object identification. The interrogator or reader emits radio signals and receive signal in return from the tag. A reader typically contains a transmitter and receiver (radio frequency module), a control unit and an antenna. Additional interface (RS 485, RS 232, etc.) are fitted with readers to enable them to forward the data received to other systems such as PC, robot control system, etc... The last component is the middleware which can provide the primary link between RFID readers and databases (Nawawi *et al.* 2011).

There are two types of RFID tags: Active and Passive. An active tag is an expensive circuit because it equipped with a battery. Its size is large but it can perform complicated processing for this reason it used for large goods such as container in port or cars in parking area. While passive tag is small, light, cheap, and powered by the radio from reader. It has no storage for processing history for this reason it is used for small items such as goods in a retail warehouse to identify the ID and some embedded information.

RFID Network Planning (RNP) is very crucial in deploying the RFID system which is present an acceptable Quality of Service (QoS) by accomplish several objectives such as maximizing tag coverage, maximizing economic efficiency, minimizing reader's interference and achieving equal load balance in all readers. Therefore enhancing readability of tag coverage represents the most crucial among other RNP objectives. For this reason RNP optimization can be formed by investigating the best location and power setting for each reader. As a result, many algorithms were employed in order to determine the best locations for readers (Nawawi *et al.* 2015).

TAG COVERAGE

Tag density and structure of tag distributions represent an effective Factors which affect read range for RFID. Its primarily depends on the properties of the underlying RFID technology. The range in the reader-to-tag communication and the signal from tag to reader play a major role in tag coverage function. The objective function for minimizing tag coverage is as follows (Nawawi *et al.* 2015).

$$C_{\min} = \sum_{i=1}^{Np} (P_i^r - P_d) \quad (1)$$

But there is no obvious correlation related to the position and power of readers. This problem Friis equation; (Nawawi *et al.* 2015). Applied for determining the power received at tag:

ARPN Journal of Engineering and Applied Sciences

$$P_r = (P_r.G_t.P_r)/(4\pi\frac{d}{\lambda})^2 \quad (2)$$

RFID TAG COVERAGE OPTIMIZATION

Optimal tag coverage consists of identifying a minimal set of readers that cover all tags present in the system, detecting maximum number of tags with the correlation of the cost consideration (Hasnan et al. 2012) the Optimal tag coverage minimizing redundant reports from multiple readers by using a minimal set of readers in the system which is cover all presented tags. For this reason this objective occupy the highest priority and weighting (Nawawi et al. 2015) (Ma et al. 2014), (Nawawi et al. 2015) proposed mathematical model for RFID tag coverage optimization as shown in equation below, the main issue in this equation is to minimize the difference between the threshold power and the power receives at tag. the function is formulated as the sum of the difference between the desired power levels Rq and the actual received power Pri j of each tag in each element:

$$f_1 = \sum_{i=1}^{P\times Q} \sum_{j=1}^{Ni} (P_{ij}^r - P_q) \quad (3)$$

Where Ni is the number of tags in the ith element. All the power levels in this function are expressed in dBm. Using this objective function the algorithm tries to locate the RFID readers close to the regions where the desired coverage level is higher, whereas the areas where a lower coverage is requested are taken into account by a proper increase of the radiated power.

OPTIMIZATION TECHNIQUES

Optimization is a process, or methodology for improving functional procedures such as finding the maximum or minimum of a function in order to highest achievable performance under the given constraints. Artificial Intelligence (AI) techniques introduced an interesting application in engineering. Optimization techniques represent a powerful set of tools which can be used to find optimal solutions of many kinds of problems. In RFID system, optimization and search technique was very helpful in solving problems of large search spaces, high complexity, searching ill-structured spaces. For this reason Nature Inspired Algorithms applied in this area. This study will present overview of the nature inspired algorithms used in RFID tag coverage optimization. Nature inspired computation techniques include evolutionary algorithm (EA) and swarm intelligence (SI). SI includes four different algorithms, namely artificial bee colony (ABC), ant colony optimization (ACO), particle swarm optimization (PSO), bacterial foraging optimization (BFO) and (Hasnan et al. 2013)

a) Particle swarm optimization (PSO) algorithm

Particle Swarm Optimization (PSO) algorithm is an optimization technique that is based on a population system. This algorithm is inspired by the movement of birds and fishes in their own groups PSO advantages is fast in operation speed, easy to implement and fewer parameters need to be adjusted working on various optimization problems and finally it is easy to modify/alter and uses less memory and parameter to work with in order to fulfill different needs. Algorithm (below) provides a pseudocode of the Particle Swarm Optimization algorithm:

pseudocode for the standard PSO Algorithm

```
  1 initialize particle...
for each particle x_i do
        x_i ← r
pl_i ← unknown
  2 starting main iteration...
        repeat
for each particle x_i do
y_i^k = f(x_i^k)
if y_i^k better than f(pl_i^k) then
pl_i^k ← x_i
pg^k ← best of all x_i^k
for each particle x_i do
v_i^{k+1} ← a v_i^k + b_1 r_1(pl_i^k − x_i^k)
                + b_2 r_2(pg^k − x_i^k)
x_i^{k+1} ← x_i^k + v_i^{k+1}
until k > maximum iterations or
pg unchanged many times
optimum ← pg
```

PSO is tends to fall easily into the local minima (Parsopoulos and Vrahatis, 2002), also it cannot adjust the velocity sufficiently. In order to overcome the PSO problems, the researchers proposed some modifications in parameters and hybridized PSO. Many researchers apply this method to improve tag coverage level. (Niu *et al.* 2007), presents a multi-swarm cooperative particle swarm optimizer MCPSO. The performances of the proposed algorithms are compared with the standard PSO and its variants demonstrated the superiority of MCPSO. (Chen and Zhu 2008) develop a mathematical model based on the application of two powerful optimization techniques known as Evolutionary Algorithms (EAs) and Swarm Intelligence (SI). It obtains a superior solution in terms of optimization accuracy and computation robustness. Dingyi, Yunlong, and HanNing, 2008, optimize RFID readers' deployment using Particle Swarm Optimization (PSO) algorithm for target tracking in Electronic Product Code (EPC). They maximize the tracking precision and minimize the reader consumption. (Bhattacharya and Roy 2010) proposed an RFID network based on Particle Swarm Optimization (PSO) for reader placement technique. The results show the effectiveness of this algorithm in achieving the optimal solution. (Di Giampaolo *et al.* 2010) apply the Particle Swarm Optimization algorithm in complex RFID readers for a system in large areas. The numerical results show the effectiveness of the method. Chen, *et al.*, and 2011present a novel multi-swarm particle swarm optimizer called

ARPN Journal of Engineering and Applied Sciences

PS2O. This algorithm extends the single population PSO to the interacting multi-swarms model and enhances dynamical update equations. It proves to be superior for planning RFID networks than PSO and multi-swarm cooperative PSO (MCPSO). (Gong *et al.* 2012) developed a novel particle swarm optimization (PSO) algorithm with a tentative reader elimination (TRE) operator. The mechanism of this algorithm is to delete readers during the search process of PSO and recover it in order to adjust the number of readers used to enhance the overall performance of RFID network. Experimental results show that the proposed algorithm is capable of achieving higher coverage and using fewer readers than the other algorithms. Han and (Feng and Qi 2012) present a novel optimization algorithm, namely the multi-community GA-PSO. It applied on the complicated RFID network planning problem of large-scale system. The proposed algorithm enhances PSO algorithm work. (Suriya 2013) apply PSO and genetic algorithm (GA) to the model formulations to search for feasible solutions to the coverage RNP problem. (Kuo *et al*. 2013) proposed a hybrid of artificial immune system (AIS) and particle swarm optimization (PSO)-based support vector machine (SVM) (HIP–SVM) for optimizing SVM parameters. They indicated that HIP–SVM can achieve highest accuracy compared to those of AIS–SVM and PSO–SVM. (Chen *et al*. 2014) used multiobjective EA and SI algorithms to find all the Pareto optimal solutions and to achieve the optimal planning solutions. The multiobjective particle swarm optimization (MOPSO). Simulation results show that multiobjective artificial bee colony algorithm MOABC proves to be more superior for planning RFID networks than NSGA-II and MOPSO in terms of optimization accuracy and computation robustness. (Nawawi *et al.* 2015) developed a method to determine the optimum setting for PSO parameters. Two sessions of Design of Experiment (DOE) analysis were embedded in the optimization process. It manages to generate high quality results for this reason the proposed method (PSO and DOE combination) cause to become as a robust and efficient optimization system.

b) Bee colony algorithm (ABC)

The artificial bee colony algorithm (ABC) is an optimization algorithm based on the intelligent foraging behavior of honey bee swarm, proposed by Karaboga in 2008-2009. Algorithm (below) provides a pseudocode of the Bee colony algorithm:

The pseudocode for the standard Bees Algorithm

```
1 for i=1,…,ns
   i scout[i]=Initialise_scout( )
   ii flower_patch[i]
=Initialise_flower_patch(scout[i])
2 do until stopping_condition=TRUE
   i  Recruitment( )
   ii  for i =1,…,nb
        1 flower_patch[i]
=Local_search(flower_patch[i])
        2 flower_patch[i]
=Site_abandonment(flower_patch[i])
        3 flower_patch[i]
=Neighbourhood_shrinking(flower_patch[i])
   iii  for i = nb,…,ns
        1 flower_patch[i]
=Global_search(flower_patch[i])}
```

The main advantages of the ABC algorithm over other optimization methods for solving optimization are simplicity, high flexibility, strong robustness, few control parameters, ease of combination with other methods, ability to handle the objective with stochastic nature, fast convergence, and both exploration and exploitation (Le Dinh *et al*. 2013). both of exploration and exploitation are necessary for the population-based optimization algorithms to investigate the various unknown regions in the solution space in order to discover the global optimum. To find better solutions based on exploration and exploitation in order to achieve good optimization performance by keeping the two abilities in good balance. For this reason (Zhu and Kwong 2010) modify ABC algorithm and present a new algorithm named Gbestguided ABC (GABC) algorithm. (Ma *et al*. 2014) applied a novel optimization algorithm, namely, hierarchical artificial bee colony optimization, called HABC on RFID tag coverage. The proposed algorithm applied with multilevel model. The higher-level species can be aggregated by the subpopulations from lower level. Each subpopulation in the bottom level employs the canonical ABC. They approved that this algorithm superior, in terms of optimization accuracy and computation robustness. (Bacanin *et al*. 2015) perform multi-objective RFID optimization with the ABC algorithm hybridized with heuristic. This approach uses a form of collaborative hybrid. This hybrid type has three possible structures: multi-stage, where first algorithm acts as the global optimizer, whereas the second algorithm performs the local search, sequential, where both algorithms are run alternatively until one of the convergence criteria is met and parallel, where two or more algorithms are run simultaneously searching on the same population. The results find excellent quality solutions. (Tuba *et al*. 2015) also presents a new hybrid ABC algorithm for RFID tag coverage. They incorporated genetic operator into the basic artificial bee colony algorithm (GI-ABC) which is produce a superior results.

c) Bacterial foraging optimization (BFO)

The bacterial foraging optimization (BFO) proposed by Passino in the year 2002. Bacterial foraging optimization algorithm (BFOA) as a global optimization algorithm has different set of advantages regarding local minima, direction of movement, randomness, swarming, attraction/ repelling and so on. Algorithm (below) provides a pseudo code of the Bacterial foraging optimization:

```
The pseudocode for the bacterial Algorithm
Require: Parameters: n;Nc;Nre;Ns;Ned
Ensure: Initialize randomly the bacterial colony
Ensure: Evaluate the fitness of the population.
  for i = 1 to Ned do
        {Elimination dispersal}
  for j = 1 to Nre do
        {Reproduction loop}
        for j = 1 to Nc do
              {Chemotaxis loop}
              for k = 0 to n do
                    Explore the neighborhoods defined
                    to get new solution compute its fitness
                    m ← 0
                    while m < Ns  do
                    if new solution < f(xi) then
                              Update solution
                              Move again
                    else
                              m ← Ns
                    end if
              end while
        end for
  end for
  for x = 1 to n do
        Sort bacteria
          Best half of the colony duplicates and
          replaces the worst part
  end for
end for
end for
```

It has been reported to surpass many powerful optimization algorithms in terms of convergence speed and final accuracy. (Chen *et al.* 2010) propose the multi-colony bacteria foraging optimization (MC-BFO) applied in complex RFID network planning problem. The mechanism of this approach is to extend the single population bacterial foraging algorithm based on relating the chemotactic behavior of single bacterial cell to the interacting multi-colony model by the cell-to-cell communication of bacterial community. The results show that the MC-BFO obtains superior solutions for RNP problem in terms of optimization accuracy and computation robustness. (Liu et al. 2011) developed a self-adaptive bacterial foraging optimization (SABFO) in which swim length of individual bacterium adjusts dynamically during search to balance the exploration/ exploitation trade off. The mechanism of bacterium which discovers a better fitness based on promising domain, swim length of bacteria is adapted to exploitation state as a smaller one. If a bacterium's fitness is unchanged, the swim length adjusts to larger one and this bacterium enters in exploration state. (Chen *et al.* 2011) also use the self-adaptive bacterial foraging optimization (SABFO) to optimize tag coverage problems in dynamic RFID networks. The results show that the SABFO obtains superior solutions than the original BFO method. Table-1 shows a summary of RFID Tag coverage algorithms:

Table-1. Summary of RFID tag coverage algorithms.

Year	Author (s)	Algorithm
2007	Ben, et al.	(MCPSO)
2008	Hanning Chen and Yunlong Zhu	(EAs-SI),
2008	Dingyi, Yunlong, and HanNing	(EPC-PSO)
2010	Indrajit Bhattacharya and Uttam Kumar Roy	(PSO)
2010	Di Giampaolo, et al.	(PSO)
2010	Guopu Zhu and Sam Kwong	(GABC)
2010	Hanning Chen et al.	(MC-BFO)
2011	Chen, et al.	(PS2O)
2011	Liu et al.	(SABFO)
2011	Hanning Chen et al.	(SABFO)
2012	Gong, et al.	(PSO-TRE)
2012	Han and Jie	(GA-PSO)
2013	Suriya	(GA-PSO)
2013	Kuo et al.	(PSO-SVM)
2014	Chen et al.	(MOPSO)
2014	Lianbo Ma et al.	(HABC)
2015	Nawawi	(PSO-DOE)
2015	Nebojsa Bacanin et al.	(HABC)
2015	Milan tuba et al.	(GI-ABC)

EVALUATION OF ALGORITHMS

Because of the complex and difficult engineering problems such as dimensions, variables, and time increases. nature inspired algorithms are designed to optimize numerical benchmark functions , multi objective functions and solve NP-hard problems for large number of variables, dimensions, etc. the big challenge for evaluating the performance of these algorithms is the high dimensions. This problem is termed as "curse of dimensionality" as shown in Table-2.

Table-2. Evaluation of algorithms.

Nature inspired algorithm	Max Dim.	Min Dim.	Number of benchmark functions
PSO	1000	100	6
ABC	30	10	5
BFOA	10	4	4

It is cleare that the portrays show the various existing of Evaluated Dimensions of Nature Inspired Algorithms used in RFID over continuous unimodal or multimodal benchmark test problems(Agarwal 2014).

CONCLUSIONS

RFID tag coverage objective is the most crucial among other RNP objectives because it's a very complex optimization problem due to the high dimensional characteristic. This paper presents different algorithms which developed to quick convergence of the optimal solution and reduction of the computational time. It has been solved successfully various constrained and unconstrained multi-objective optimization problems. The optimization progress concerns with the investigating of a satisfactory criterion to assess the performances of the tag coverage readability.

REFERENCES

Agarwal, P., 2014. Nature-Inspired Algorithms : State-of-Art, Problems and Prospects. , 100(14), pp. 14-21.

Bacanin, N., Tuba, M and Strumberger, I. 2015. RFID Network Planning by ABC Algorithm Hybridized with Heuristic for Initial Number and Locations of Readers.

Bhattacharya, I. and Roy, U.K., 2010. Optimal Placement of Readers in an RFID Network Using Particle Swarm Optimization. International journal of Computer Networks & Communications, 2(6), pp. 225-234.

Chen, H. et al. 2011. Dynamic RFID network optimization using a self-adaptive bacterial foraging algorithm. International Journal of Artificial Intelligence, 7(A11), pp.219–231.

Chen, H. *et al*., 2014. Multiobjective RFID network optimization using multiobjective evolutionary and swarm intelligence approaches. Mathematical Problems in Engineering, 2014.

Chen, H. and Zhu, Y. 2008. RFID networks planning using evolutionary algorithms and swarm intelligence. In Wireless Communications, Networking and Mobile Computing, 2008. WiCOM'08. 4th International Conference on. pp. 1-4.

Chen, H., Zhu, Y. and Hu, K. 2010. Multi-colony bacteria foraging optimization with cell-to-cell communication for RFID network planning. Applied Soft Computing, 10(2), pp. 539-547.

Le Dinh, L., Vo Ngoc, D. and Vasant, P. 2013. Artificial bee colony algorithm for solving optimal power flow problem. The Scientific World Journal, 2013.

Feng, H. and Qi, J. 2012. Optimal RFID networks planning using a hybrid evolutionary algorithm and swarm intelligence with multi-community population structure. In Advanced Communication Technology (ICACT), 2012 14th International Conference on. pp. 1063–1068.

Di Giampaolo, E., Fornì, F. and Marrocco, G. 2010. RFID-network planning by particle swarm optimization. In Antennas and Propagation (EuCAP), 2010 Proceedings of the Fourth European Conference on. pp. 1-5.

Gong, Y.-J. *et al*. 2012. Optimizing RFID network planning by using a particle swarm optimization algorithm with redundant reader elimination. Industrial Informatics, IEEE Transactions on, 8(4), pp.900–912.

Hasnan, K. et al. 2012. Implementation of RFID System for Improving the Inventory Management System in Unijoh Sdn Bhd. Planning (RNP), 2013.

Hasnan, K. *et al*. 2013. Optimization of RFID real-time locating system.

Kuo, R.J. et al. 2013. Hybrid of artificial immune system and particle swarm optimization-based support vector machine for Radio Frequency Identification-based positioning system. Computers and Industrial Engineering. 64(1), pp. 333-341.

Liu, W.. B. et al. 2011. RFID network scheduling using an adaptive bacterial foraging algorithm. Journal of Computational Information Systems, 7(4), pp.1238–1245. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-79955742873&partnerID=40&md5=4d5ccd66a01d76621ede81c21a75ca89.

Ma, L. et al. 2014. Hierarchical artificial bee colony algorithm for RFID network planning optimization. The Scientific World Journal, 2014, p.941532. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3921959&tool=pmcentrez&rendertype=abstract.

Nawawi, A., Hasnan, K. and Ahmad Bareduan, S. 2011. The application of RFID technology to capture and record product and process data for reverse logistics sorting activity. Proceeding of the 12th International Conference on QiR (Quality in Research). (July), pp. 4-7.

Nawawi, A. 2015. A Modified Technique in RFID Network Planning and Optimization.

Niu, B. *et al*., 2007. MCPSO: A multi-swarm cooperative particle swarm optimizer. Applied Mathematics and Computation. 185(2), pp. 1050-1062.

Suriya, A. 2013. Modeling and optimization of radio frequency identification networks for inventory management.

Tuba, M., Bacanin, N. and Beko, M., 2015. Multiobjective RFID Network Planning by Artificial Bee Colony Algorithm with Genetic Operators. In Advances in Swarm and Computational Intelligence. Springer. pp. 247-254.

Zhu, G. and Kwong, S., 2010. Gbest-guided artificial bee colony algorithm for numerical function optimization. Applied Mathematics and Computation. 217(7), pp. 3166-3173.