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Efficient Algorithm for Redundant Reader Elimination in Wireless RFID Networks

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Abstract

Radio Frequency Identification (RFID) systems, due to recent technological advances, are being deployed in large scale for different applications. However, this requires a dense deployment of readers to cover the working area. Without optimizing reader's distribution and number, many of the readers will be redundant, reducing the efficiency of the whole RFID system. The problem of eliminating redundant readers has motivated researchers to propose different algorithms and optimization techniques. In this paper, the authors presented a new and efficient redundant reader elimination technique based on weights associated with reader's neighbor and coverage. Simulation results demonstrate that the proposed algorithm eliminates more redundant readers than those of other well-known techniques like Redundant Reader Elimination (RRE), Layered Elimination Optimization (LEO) and LEO+RRE algorithms while preserving the coverage ratio quite close to those obtained by RRE, LEO and LEO+RRE.

Keywords: *Large Scale, LEO, Reader, Redundancy, RFID, RRE.*

1. Introduction

Radio Frequency Identification (RFID) is based on radio communication for tagging and identifying an object [1]. It consists of two blocks namely, RFID transceivers (readers) and RFID transponders (tags). The RFID tag consists of a small integrated circuit for storing information and an antenna for communication. A basic RFID system is based on wireless communication between a reader and a tag. RFID readers can read information stored in no-line-of- sight RFID tags and communicate information to central database system through wired or wireless interface [2]. Over the last few years, RFID has drawn a great deal of attention and now is widely believed that RFID can bring revolutionary changes [3]. Indeed, applications of RFID systems include supply chain automation, security and access control, cold chain management (temperature logging) and identification of products at check-out points, to name a few. Some of the major retailors have already invested significantly in RFID and mandated their manufacturers to place tags on cases and pallets, which resulted in mass production of inexpensive RFID tags [4].

Integration of RFID systems with wireless sensors has broadened the scope of RFID applications. RFID tags can be interfaced with external sensors such as shock, temperature, and light sensors. Similar to wireless sensor networks, RFID systems can be deployed on-line instead of pre-installed statically [2].

To accurately monitor the area of interest, dense deployment of RFID readers and tags is sometimes required. However, this dense deployment of RFID systems in large scale results in unwanted effects. In fact, when multiple readers share the same working environment and communicate over shared wireless channels, a signal from one reader may reach other readers and cause frequency interference. This frequency interference occurs when a reader transmits the communication signal to read a tag and its signal interferes with signals from other readers who are trying to read the same tag. A reader may also interfere with other reader's operation even if the interrogation zones do not overlap because the back-scattered signal from a tag is weak enough to be easily affected by any interference. Thus, signals transmitted from distant readers may be strong enough to hamper accurate decoding of the communication signals back-scattered from adjacent tags. Therefore, frequency interference in the interrogation zones results into inaccurate reads and long reading intervals. Hence, the effect of reader interference on the RFID interrogation range should be analyzed before any large scale deployment of readers in a RFID system [5, 6]. Indeed, unnecessary readers in the network may consume power which can be wasteful. Therefore, finding redundant readers is of great importance for an optimal deployment of a large-scale RFID network. This ensures a user that the minimum number of readers should be used to cover all the tags in a specified zone.

The problem of redundant reader elimination has been studied extensively in [2, 7, 8, 9]. In this paper, we proposed an efficient redundant reader elimination algorithm based on weights assigned to reader's neighbor and coverage. In this algorithm, a reader that has more neighbors and minimum or no coverage is a potential candidate for elimination. To validate the performance of the proposed technique, we have also implemented other well-known methods like RRE [2] and LEO [7]. The proposed technique's performance proves that more redundant readers are removed than those of RRE, LEO and LEO+RRE.

The remainder of this paper is organized as follows: Section 2 examines the existing redundant reader elimination techniques and presents a brief survey of related works. Section 3 details the proposed algorithm. Section 4 presents results and discussions. Finally, Section 5 concludes the proposed work.

2. Related Work

During the last decade, the RFID collision problem has been extensively covered in literature. It can be categorized as reader to reader interference or reader to tag interference. Reader to reader interference occurs when the interrogation zones of two readers intersect and interfere with each other. Two readers may also interfere each other even if their interrogation zones do not overlap. This interference is due to the use of wireless radio frequencies for communication. Reader to tag interference occurs when more than one reader try to read the same tag simultaneously. In this type of interference, each reader may believe that it is the only reader communicating with the tag while the tag, in fact, is communicating with multiple readers at the same time. The reader collision problem not only results in incorrect operation but also results in reduction of overall read rate of the RFID system [6, 10, 11]. To separate the individual participant signal from one another, many procedures have been developed. Basically, there are four main procedures namely, the Carrier Sense Multiple Access (CSMA), the Frequency Domain Multiple Access (FDMA), the Time Domain Multiple Access (TDMA) and the Code Division Multiple Access (CDMA) [12].

CSMA enables individual data transmission by detecting whether the communication medium is busy. In CSMA, the interrogation zones of two readers do not overlap. However, the signals at particular tag from two readers can interfere each other that make carrier sensing ineffective in the RFID network. FDMA relates to techniques in which several transmission channels on various carrier frequencies are simultaneously available to the communicating participants. Since RFID tags do not have a frequency tuning circuit, tags cannot select particular frequency for communication. It can be achieved by the addition of a frequency tuning circuit, which adds to the cost of the RFID system. TDMA relates to techniques in which the entire available channel capacity is divided among the participants chronologically. In TDMA technique, each reader is allocated different time slot to avoid simultaneous transmissions. In a dynamic RFID system, time slot should be reshuffled adaptively to get better read rate. In case of mobility, reader may come closer and start interfering. CDMA uses spread spectrum modulation techniques based on pseudo random codes to spread the data over the entire system. To implement CDMA, a tag requires extra circuitry which will increase its cost. Moreover, assignment of codes to all tags at the development site may be complicated. Therefore, CDMA may not be a cost effective solution.

There are many algorithms, which cover reader collision problem available in literature [11, 13, 14, 15, 16]. Colorwave [13] is a TDMA based distributed algorithm with no guaranteed method of communication between neighboring nodes. In this technique, each reader monitors the percentage of successful transmissions and this procedure also assumes that the readers are able to detect collision in the RFID system. HiQ [14] is an online algorithm based on Q-learning to solve the reader collision problem. Q-learning is a form of reinforcement learning, which allocates resources to maximize the number of readers communicating at a single time period. At the same time, it also minimizes the number of collisions among communicating readers. The Pulse [11] is a distributed algorithm based on a beaconing mechanism in which a specific reader while reading a tag periodically broadcasts a beacon on a separate control channel. Any other readers in the network sense the control channel for a beacon before it starts communicating with the tag. If a reader does not receive any beacon at a given time, it starts transmitting a beacon and begins communicating with the tag. This process is expected to achieve fairness among all readers.

The DiCa [15] is a distributed and an energy efficient anti-collision algorithm similar to the Pulse. The DiCa contains both a data channel and a control channel. Each reader contends through the control channel for the use of data channel. The reader who wins reads the tags through the data channel. This algorithm adjusts the control channel's range at twice the radius from the first reader to address the hidden and exposed terminal problem. The DiCa algorithm consumes less dissipated energy than that of CSMA, ALOHA and Pulse algorithms. The Gentle [16] is a CSMA based protocol that uses RFID multi-channel and beacon messages to mitigate reader collision. In this algorithm, readers can also put tag information in their beacon messages in order to forward the information to their close readers. Therefore, readers using Gentle algorithm can avoid reader collision more efficiently and reduce waiting time to get tag's information.

Another approach to avoid collision is to reduce the number of redundant readers in the RFID network. In a RFID network, a reader is redundant if all of its tags are also covered by at least one of the other readers in the network. Figure (1) shows a typical example of the redundant reader in a RFID network. It consists of three readers R1 to R3 and five tags T1 to T5. The tags T2, T3 and T4 that are covered by R2 are also covered by R1 and R3, respectively. Therefore, R2 is a redundant reader, which can be safely removed without violating the full coverage of tags. Eliminating redundant readers from a RFID network has two-fold advantages; First, it increases the lifetime of the overall RFID network by saving the wasteful power used by redundant readers. Second, it improves the RFID network service quality by alleviating the interference among readers.

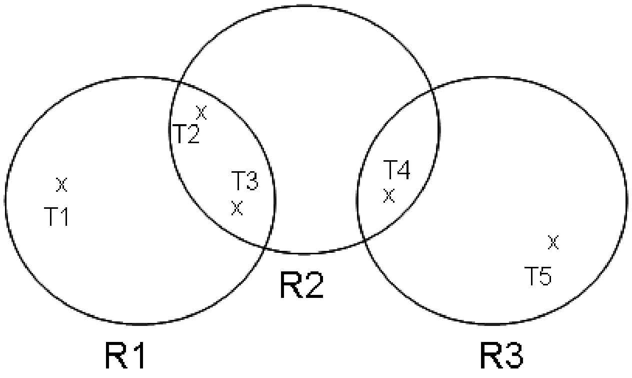

Fig. 1 Redundant reader example in RFID network.

A simple approach to remove redundant reader is that all readers broadcast query messages simultaneously to all tags in their interrogation zones. Each tag may reply by signaling its ID. So, if a reader covers no tags in its interrogation zone or receives no reply from any tags due to reader colllision, it may be called as a redundant reader.

There are some major drawbacks to the above approach. First, it requires strict time synchronization among readers, which is not practical in most RFID systems. Second, by turning all redundant readers, the network coverage may be violated.

The redundant reader elimination (RRE) problem was first introduced by [2]. The RRE algorithm is based on greedy method. The main idea of this algorithm is to record “tag count", i.e., the number of tags a reader covers into RFID tag's memory. The reader, which has the maximum number of tag-count, will be the holder of the corresponding tag. This procedure iterates the above steps until all the tags in a network are assigned to readers. Finally, readers with no tags assigned are eliminated as redundant readers. In [7], the authors illustrated that RRE algorithm failed to eliminate redundant readers from some specific RFID network topologies. Therefore, they introduced the LEO algorithm, which uses a layered approach. The term "layered" represents the relationship between early query readers and later query readers. The later query readers may have higher probability to be a redundant reader. The fundamental approach of this procedure is "first read first own". In a RFID network, all readers send command signals to RFID tags in their coverage zones to get the record of the tags. The reader that first sends its signal is the owner of the tag. If this tag already has other reader ID as its owner, then tags ID cannot be changed. Finally, the readers in the network with no tags in their coverage zones are eliminated as redundant readers.

The authors have also shown that LEO and RRE algorithms can be combined for better performance. In LEO+RRE scheme, first LEO is implemented to eliminate redundant readers. Then, for all the remaining readers, RRE is implemented to eliminate some more redundant readers. The authors have shown that the LEO algorithm can reduce the number of readings and writings effectively. On the other hand, the LEO procedure determines the owner of the tags in a random way. Therefore, the quality of owner selection for a tag is unreliable. Moreover, if a wrong reader is eliminated from the RFID network in the beginning, it may cause unsatisfactory results.

In [8], the authors have proposed an algorithm, which takes the advantage of the concept of neighboring reader density to assess the priority of reading. In this algorithm, the priority value of a reader depends on the number of its neighboring readers. Two readers are considered neighbors when they have at least one tag covered by both the two readers. At first step, all readers in the RFID network send commands to tags in their interrogation zones to read them. The readers then increase the *reader_num* stored in the tag's memory by 1 and write their IDs as well as the new value of *reader_num* into the covered tags. Secondly, all readers communicate with tags to obtain the number of neighboring readers and holder information by virtue of *reader_num* and *Rid* (reader ID) respectively. Then, each reader calculates the priority in

terms of *reader_num* and writes its ID as a new owner according to the priority comparison. Finally, any reader owing no tag is eliminated as a redundant reader.
The density based algorithm works on "first arrive first serve" methodology, i.e., the time delay required by a reader to read a tag defines the priority of that reader among its neighbors. Consider a simple scenario in a RFID network with readers R_1, R_2 and tags T_1, T_2. If the delay time in reading a tag T_1 by the reader R_1 is smaller than R_2, then R_1 owns T_1. However, if R_2 reads both T_1 and T_2, but the delay time in reading T_1 is greater than R_1, R_2 can not own T_1. In this way, both readers are kept in the network. In our proposed work, since both coverage and neighbors are taken into consideration, R_2 will own T_1 and T_2, whereas R_1 will be eliminated.

In [9], the authors have proposed the algorithm TREE which is very similar to LEO. In TREE, reader R_i, with its identifier, sends query packet to all tags in its interrogation zone. When tags respond to the query message, the stored reader identifier is returned by them. The tag can respond to a query of a reader with two possible replies i.e. it may reply NULL reader identifier or stored reader identifier. If a NULL reader identifier is returned by the tag, it indicates that the tag is not identified by other readers and the tag writes the reader identifier R_i on it. If the tag returns identifier R_k and $R_k \neq R_i$, then the reader R_i will ignore this query. In this algorithm, if a reader identifier R_i never receives the tag's response as a NULL identifier, this reader is redundant and will be eliminated from the network.

Similar to LEO algorithm, TREE also works on the principle of "first read first own". Since TREE has fewer write operations, it reduces the time and communication complexity than that of RRE. As TREE and LEO works in a similar manner, the shortcomings of LEO mentioned above are also applicable to TREE.

3. Proposed Algorithm

In any arbitrary RFID network, any reader that covers more tags and has fewer number of neighbor readers must be given priority. A reader with more neighbors has higher probability of getting its operation interfered by the neighbor readers. It is known that a reader interferes other reader's operations if it intersects each others interrogation zones. Even though, readers do not overlap other reader's interrogation zones, they can still interfere [6]. Therefore, selecting readers with fewer numbers of neighbors will have higher probability of not interfering one another and results in an efficient working of RFID system. With above stated fact, the proposed algorithm assigns weights to each reader based on its number of neighbors and the number of covered tags. In this way, the algorithm ensures that the best possible readers are selected for the efficient working of any RFID network.

Some of the assumptions of the proposed technique are:

- Reader coordinates are easily available.
- Coverage information i.e. the number of tags each reader has covered in initial round can easily be obtained by data processing subsystem.

It can be noted that the second assumption of collecting coverage information i.e. the total number of tags covered by each reader at central host system does not require new setup to RFID systems. Indeed, such processing system is already included in existing RFID setup. Therefore, this assumption adds no extra cost to the RFID systems.

The normal read range for a 1W reader to read a passive tag whose IC consumes about 10 - 30µW to operate when being read is about 3 meters [17]. Since proposed work is based on the number of neighbors to a reader, the neighbor is defined as: Reader A is a neighbor to reader B if (*d>0 meter & d< 2D meters*), where *d* is the distance between readers A and B whereas *D* is the read range of a reader.

Total weights assigned to a reader are a function of cost functions and multiplication factor. Cost function of a reader is defined in terms of its coverage and the number of neighbors. Cost function of a reader due to its coverage and number of neighbors is given by Eq. (1) and (2) respectively. The equations are as follows:

$$f_c = \frac{\text{coverage}(r)}{\alpha \times max\ (\text{coverage}(\boldsymbol{R}))} \tag{1}$$

$$f_n = 1 - \frac{(\text{neighbor}(r))}{max\,(\text{neighbor}(\boldsymbol{R}))} \tag{2}$$

where r defines each individual reader in a network and $\boldsymbol{R}$ is the list of all readers in the network with their individual tag counts and neighbor counts, respectively. A user-defined multiplication factor α, usually between 1 and 3, is used so that the cost functions due to coverage and neighbors are in proportion and can influence each other.

$$TW_{reader} = l_c \times f_c + l_n \times f_n \tag{3}$$

where l_c and l_n are the load factors assigned to a cost function of a reader for coverage f_c and the number of neighbors f_n, respectively. Load factors l_c and l_n are user defined that satisfy the criteria $l_c + l_n = 1$.

Basic operations of the proposed work can be summarized as follows:

1. All readers in the RFID network send commands to all tags in their interrogation zones.
2. Each reader coverage information is sent to the central host station, i.e., how many tags (with IDs) each reader has read.
3. For each tag in the RFID network, the proposed algorithm checks how many readers have read it. Further, the algorithm compares the weights of readers that have read the tag. The reader having the maximum weight owns the tag.
4. All the readers of the network with no assigned tags are eliminated as redundant readers.

After eliminating the redundant readers with no assigned tags, the algorithm switches to its second part which is optimization of the network. In the optimization mode, the algorithm picks a reader from the remaining readers based on minimum coverage and maximum neighbors and then eliminate it. Based on the number of readers left and total tags covered by the remaining readers, the algorithm again assigns weigts using Eq. (1), (2) and (3) respectively. Further, the algorithm follows step 2 of its operation to reorder the readers based on total weights assigned to each remaining reader. The procedure iterates until all readers have a number of neighbors equals or less than 3.

4. Simulation Setups and Results

4.1 Simulation Setups

To evaluate the performance of the proposed redundant reader elimination technique, we implemented two experimental setups. In the first setup, we demonstrated the performance of the proposed algorithm in a similar type of experimental setup as presented in [2, 7, 8]. The experimental area of 100 × 100 sqm was taken with 500 readers placed randomly and the numbers of tags were increased from 1000 to 4000. Initially, we compared the maximum coverage obtained by all remaining readers in the RFID network. This step was undertaken to ensure that the coverage attained by the proposed work is in close relation with RRE, LEO and LEO+RRE algorithms. Figure (2) shows the comparison of coverages obtained by proposed technique to RRE, LEO and LEO+RRE. It can be easily observed that the obtained coverage relates very well with the above algorithms.

After insuring that the coverage of the proposed algorithm is very close with the other algorithms, the number of redundant readers eliminated by each algorithm was compared. Figure (3) demonstrates that the proposed algorithm eliminates more redundant readers than those of RRE, LEO and LEO+RRE. We obtained these results by varying the number of neighbor readers from 0 to 8 for any particular reader. In fact, for any particular reader, more number of neighbor readers could be required because the considered experimental RFID network is very dense.

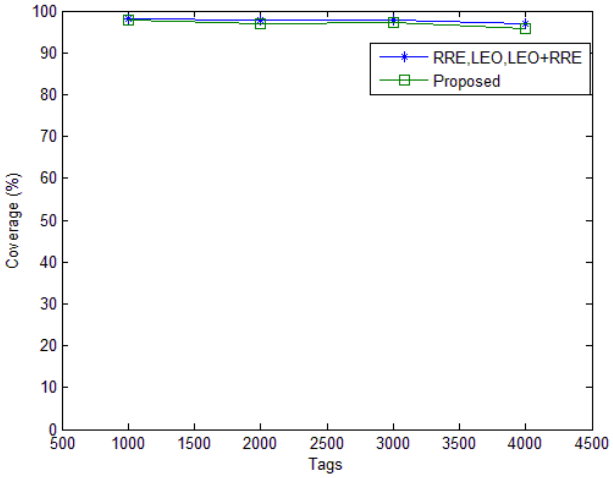

Fig. 2 Comparison of coverage of the proposed technique vs. RRE, LEO and LEO+RRE (first setup).

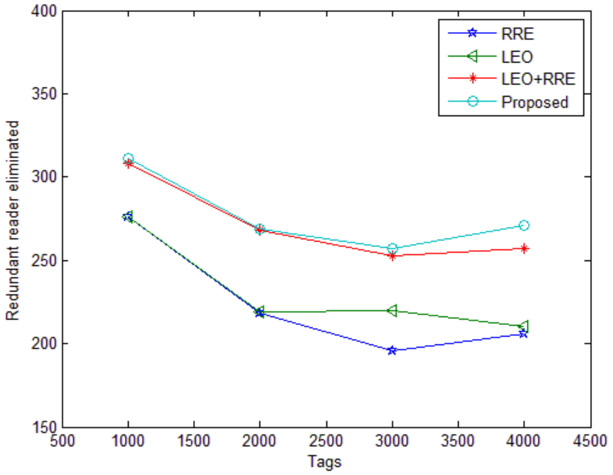

Fig. 3 Performance comparison of the proposed technique vs. RRE, LEO and LEO+RRE (First setup).

In the second setup, we implemented RFID networks of different sizes. We took five different experimental areas in which the location of readers and tags were randomly generated. When random locations for readers and tags in a RFID network were generated, it was ensured that no reader or tag was located at the same position. Table (1) shows the parameters selected for simulation. Figure (4) shows one of the experimental areas taken in second setup i.e. the area of 55 × 55 sqm , 100 readers and 334 tags.

Table 1: Parameters for experimental area

Working Area (Square Meter)	Number of Readers	Number of Tags
30 x 30	50	200
55 x 55	100	334
75 x 75	150	475
85 x 85	200	662
100 x 100	250	775

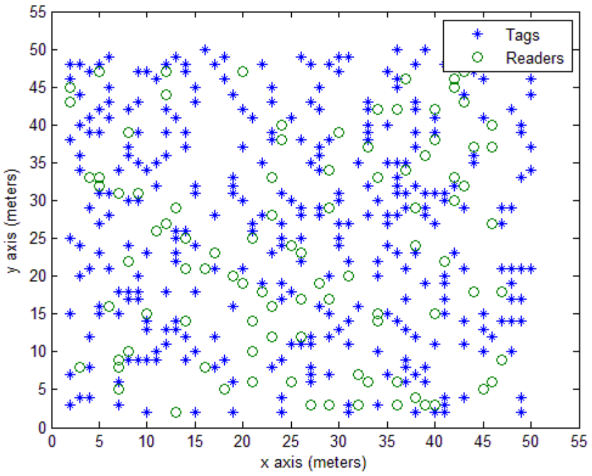

Fig. 4 Network topology of a RFID network.

4.2 Results and Discussions

In this section, we will discuss the performance of our algorithm and compare our results with those obtained by the state-of-the-art approaches such as RRE, LEO and LEO+RRE. Performance evaluation of proposed work was done in two different ways:

- In setup A, performance of proposed work was evaluated for different experimental areas as shown in Table (1).
- In setup B, the same experimental area was kept fixed but the read range of readers was varied.

In setup A, we compared the number of redundant readers eliminated by our algorithm to those obtained by the other existing techniques. Figure (5) shows that the number of redundant readers eliminated by the proposed procedure outperforms the other compared algorithms. Redundant readers eliminated by our work are (26.09 - 78.26 %) more than RRE, (29.85 - 62.5 %) more than LEO and (8.75 - 21.05 %) more than LEO+RRE.

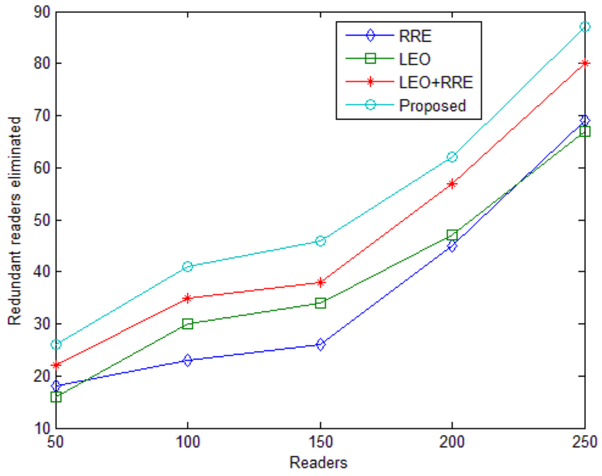

Fig. 5 Performance comparison of the proposed technique vs. RRE, LEO and LEO+RRE (setup A).

Read range is one of the key parameters that define the performance of passive RFID systems. This is the maximum distance at which the power received by the transponder is strong enough to work efficiently. It is also the maximum distance at which the backscattered power received by the reader is strong enough to be detected and properly demodulated [18]. To evaluate the effect of read range on a RFID network, second setup was implemented selecting the experimental area of 55 ×55 sq m, 100 readers and 334 tags.

In setup B, the number of redundant readers eliminated by the proposed work is compared to RRE, LEO and LEO+RRE. It is clear from figure (6) that the number of redundant readers eliminated by the proposed procedure outperforms the other algorithms. Redundant readers eliminated by our work are (42.85 - 78.26 %) more than RRE, (36.67 - 68.75 %) more than LEO and (17.14 - 42.22 %) more than LEO+RRE.

Furthermore, all redundant reader elimination techniques presented in literature have many read-write operations [2, 7, 8, 9]. The LEO procedure presented in [7] has minimum write operations (reader writing or updating information on the tag) and the density based procedure [8] has the maximum write operations. Compared to other algorithms, our work has no write operation and has only one read operation.

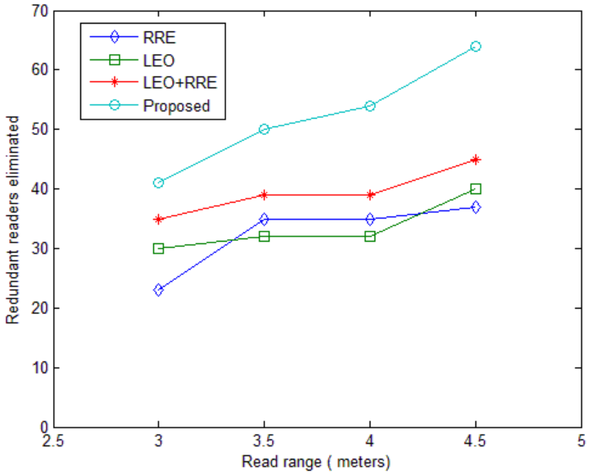

Fig. 6 Performance comparison of the proposed technique vs. RRE, LEO and LEO+RRE (setup B).

Since the existing algorithms [2, 7, 8, 9] require write operations, these procedures are only suitable for tags which have both read and write options. There are mostly three types of tags namely, passive, active and semi-active. Passive tags are lower functionality tags that take power from reader for its operation. Active and semi-active tags have batteries to provide power to tag's operation. Passive Read-Only tags are similar to bar codes in that once they are programmed by a product manufacturer cannot be altered. Read-Write tags are often called "smart" tags. These tags give users much more flexibility than Read-Only tags. These tags can store large amount of data and have an addressable memory, which can be easily changed. Data on Read-Write tag can be erased and re-written thousands of times [19]. Read-Write operations are only available on tags of EPC Class-2 generation and above [20]. However, since tags have extra-functionality i.e. support read-write operations, which adds to the cost of RFID system. Since proposed work requires no write operations, it is suitable for any type of tags.

RRE procedure focuses on the maximum number of tags each reader covers for its operation. The LEO and TREE algorithms works with first read first own basis whereas density based procedure focuses on the number of each reader’s neighbor for its operation. In contrast, our work takes total tags covered by each reader, i.e. individual coverage and the number of each reader’s neighbors. The advantage of this approach is that it not only eliminates the maximum possible redundant readers but also optimizes the RFID network for an efficient operation. In the proposed technique, maximum neighbors for any reader in a RFID networks is set equal or less than 3. The probability of interfering will be lower since readers do not have much neighbor readers to interfere with. We have taken 3 as a lower bound number to ensure that the coverage of tags in a RFID network may not be reduced below appreciable limit.

5. Conclusions

In this paper, we presented a redundant reader elimination technique based on weights related to reader's neighbor and coverage. This algorithm optimizes the RFID network by giving importance to a reader who has fewer numbers of neighbors and more coverage. This work can be used by any arbitrary RFID network. The proposed work needs only one read and no write operation. The simulation results had proved that the proposed algorithm outperformed other state of the art techniques presented in literature such as RRE, LEO and LEO+RRE by eliminating more redundant readers. It also kept coverage close to that of RRE, LEO and LEO+RRE.

References

[1] M. Jo, and C.-G. Lim, "RFID Tag Detection on a Water Content Using a Back-Propagation Learning Machine", KSII Transactions on Internet and Information Systems, Vol. 1, No. 1, 2007, pp. 19-32.
[2] B. Carbunar, M. K. Ramanathan, M. Koyuturk, C. Hoffmann, and A. Grama, "Redundant-Reader Elimination in RFID Systems", in Second Annual IEEE Communications and Networks (SECON), 2005, pp. 176-184.
[3] Y. Bendavid, S. F. Wamba, and L. A. Lefebvre, "Proof of Concept of an RFID-Enabled Supply Chain in a B2B e-Commerce Environment", in Proceedings of the 8th International Conference on Electronic Commerce (ICEC’06), 2006, pp. 564-568.
[4] S. E. Sarma, "Towards the Five-Cent Tag", Technical Report MIT-AUTOID-WH-006, MIT AUTO ID Center, 2001.
[5] D.-Y. Kim, B.-J. Jang, H.-G. Yoon, J.-S. Park, and J.-G. Yook, "Effects of Reader Interference on the RFID Interrogation Range", in Proceedings of the 37th European Microwave Conference, 2007, pp. 728-731.
[6] D. W. Engels, "The Reader Collision Problem", White Paper MIT-AUTOID-WH-007, MIT AUTO ID Center, 2001.
[7] C.-H. Hsu, Y.-M. Chen, and C.-T. Yang, "A Layered Optimization Approach for Redundant Reader Elimination in Wireless RFID Networks", in IEEE Asia-Pacific Services Computing Conference, 2007, pp. 138-145.
[8] K.-M. Yu, C. W. Yu, and Z.-Y. Lin, "A Density-Based Algorithm for Redundant Reader Elimination in a RFID Network", in Proceedings of the Second International Conference on Future Generation Communication and Networking, 2008, Vol. 1, pp. 89-92.
[9] Z.-Y. Yang and J.-L. Chen, "The Simulation and Analysis of Algorithms for Redundant Reader Elimination in RFID

System", in Third UKSim European Symposium on Computer Modeling and Simulation, 2009, pp. 494-498.
[10] D.-H. Shih, P.-L. Sun, D. C. Yen, and S.-M. Huang, "Taxonomy and Survey of RFID Anti-Collision Protocols", Computer Communications, Vol. 29, No. 11, 2006, pp. 2150-2166.
[11] S. M. Birari, and S. Iyer, "Mitigating the Reader Collision Problem in RFID Networks with Mobile Readers", in 13th IEEE International Conference on Networks, 2005, Vol. 1, pp. 463-468.
[12] K. Finkenzeller, RFID Handbook Fundamentals and Applications in Contactless Smart Cards and Identification, Chichester, UK: John Wiley and Sons Ltd., 2003.
[13] J. Waldrop, D. W. Engles, and S. E. Sarma, "Colorwave: A Mac for RFID Reader Networks", in IEEE Wireless Communications and Networking Conference, 2003, pp. 1701-1704.
[14] J. Ho, D. W. Eagles, and S. E. Sarma, "HiQ: A Hierarchical Q-Learning Algorithm to Solve the Reader Collision Problem", in International Symposium on Applications and the Internet Workshops (SAINT), 2006, pp. 88-91.
[15] K.-I. Hwang, K.-T. Kim and D.S. Ecom, "DiCa: Distributed Tag Access with Collision-Avoidance Among Mobile RFID Readers", in EUC Workshops, 2006, pp. 413-422.
[16] J. Yu and W. Lee, "GENTLE: Reducing Reader Collision in Mobile RFID Networks", in The 4th International Conference on Mobile Ad-hoc and Sensor Networks, 2008, pp. 280-287.
[17] D. M. Dobkin, The RF in RFID Passive UHF RFID in Practice, Oxford, UK: Elsevier Inc., 2008.
[18] I. Mayordomo, R. Berenguer, and A. G. Alonso, "Design and Implementation of a Long-Range RFID Reader for Passive Transponder", IEEE Transactions on Microwave Theory and Techniques, Vol. 57, No. 5, 2009, pp. 1283-1290
[19] V. D. Hunt, A. Puglia, and M. Puglia, RFID-A Guide to Radio Frequency Identification, Hoboken (N.J.), USA: John Wiley and Sons Inc., 2007
[20] M. A. Khan, M. Sharma, and R. B. Prabhu, "A Survey of RFID Tags", International Journal of Recent Trends in Engineering, Vol. 1, No. 4, 2009, pp. 68-71.

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