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Development of an Enhanced Scheduler Algorithm for Radio Frequency Identification in a Dense Reader Environment (RFID-DRE)

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### ABSTRACT

*This research work presents an enhanced Scheduler Algorithm using a Modified Searching of Time Slot and Frequency Assignment Approach for Radio Frequency Identification Dense Reader Environment (RFID-DRE). The problem of RFID in a Dense Reader Environment (DRE) is interference between readers as a result of collision between the frequencies of the different readers operating concurrently. This interference prevents the correct identification of tags, which causes degradation of the system performance. To resolve this impairment, a scheduler algorithm had been proposed in literature as an interference mitigation technique in RFID-DRE. This algorithm has a slow convergence problem because of the random search of time slot and frequency allocation processes. It takes a longer time to assign the network resources due to the random search of time slot and frequency allocation processes, which delay the overall system. This work used simulated annealing solver (SAS) which is expected to minimize the problem of the random search of time slot and frequency allocation processes with a view to improve the convergence time and increase network throughput. The enhanced scheduler algorithm was modified and computer simulations were carried out using MATLAB/SIMULINK R2017a, the performance of the enhanced scheduler algorithm was compared with that of the conventional scheduler algorithm using throughput and convergence time as performance metrics. The enhanced scheduler algorithm had a better throughput and decrease in convergence time compared to the conventional scheduler algorithm scheduler with the overall average percentage improvements of 6.58% and 33.86% respectively for number of tags ranging from 20-200 distributed to 12 readers for full mesh scenario.*

### INTRODUCTION

The term Radio Frequency Identification (RFID) is used to describe a system of identification based on storing and remotely recovering information or data. It consists of: a reader, tag and a back-end server. RFID tags store important identification information of objects, and readers communicate with the tags in order to allow remote recovery of their Identification (ID). The end user communicates with the RFID reader to access the tag information through antennas (Nikitin & Rao, 2008). Unlike its legacy counterparts such as magnetic stripe and barcode which suffer numerous drawbacks such as requiring human intervention before scanning of a tagged object, line of sight communications and low storage capacity (Munkailu *et al.*, 2018). From the above shortcomings in its legacy counterparts, the RFID technology has the following advantages over the others, which are (Incel *et al.*, 2011):

- i. High penetrability
- ii. Repeated use of tags
- iii. Rapid scanning or high speed of detection
- iv. No barrier to reading ability
- v. Endurance ability
- vi. High security
- vii. High reading accuracy
- viii. Labels volume miniaturization

However, RFID technology which is better than other technologies, has the following shortcomings (Kumar *et al.*, 2018; Wang *et al.*, 2011):

- i. Interference
- ii. Limited transmitting power
- iii. Complex technology
- iv. Affected by metals
- v. High cost (more expensive)
- vi. Unauthorized reading of tags

Several researchers have addressed issues that are related to RFID reliability, interference, capacity, efficiency and throughput. RFID is gaining popularity because it increases efficiency and provides better service to stakeholders. RFID technology has been recognized as a performance differentiator for a variety of commercial applications, but its capability is yet to be fully harnessed (Ahsan *et al.*, 2010). RFID technology has been used in tracking delivery of goods, courier services and baggage handling. Other applications include departmental access control in large buildings, automatic toll payments, safety of items which should not leave the area, equipment tracking in engineering firms, hospital filing systems and personal and vehicle control in a particular area (Klair *et al.*, 2010). RFID systems consist of tags that are attached to the objects to be identified. Each tag has its own “read-only” or “rewrite” internal memory depending on the application and type. Typical configuration of this memory is to store product information, such as an object’s unique ID, manufactured date, serial number etc. The RFID reader generates a magnetic field that allows the RFID system to trace the objects (via the tags) that are within its range (Wei *et al.*, 2014). The high-frequency electromagnetic energy and query signal generated by the reader triggers the tags to reply to the query; the query frequency could be up to 50 times per second. As a result of this, communication between the main components of the system i.e. reader and tags was established, due this, a large quantity of data were being generated by the reader and the data are routed to the back end server for further processing (Ahsan *et al.*, 2010).

Several protocols manage the communication process between the reader and the tag. These protocols (ISO15693 and ISO18000-3 for HF or ISO18000-6, and EPC for UHF) begin the identification process when the reader is switched on (Wang *et al.*, 2011). These protocols work on selected frequency bands (e.g. 860 – 915 MHz for UHF or 13.56MHz for HF). When a reader is on and a tag arrives in the reader fields, it automatically wakes-up the tag and decodes the signal and replies to the reader by modulating the reader’s field (Wang *et al.*, 2011). All the tags in the reader range may reply at the same time, and in this case the reader must detect signal collision (indication of multiple tags). Signal collision is resolved by applying anti-collision algorithm which enables the reader to sort tags and select/handle each tag based on the frequency range (between 20 tags to 200 tags) and the protocols used. In this connection the

reader can perform certain operations on the tags such as reading the tag's identifier number and writing data into a tag. The reader performs these operations one by one on each tag. This will be accomplished with the aid of the simulated annealing solver (SAS), which is a probabilistic technique used for approximating the global optimum of a given function.

The rest of the paper is outlined as follows, section 1 discusses the introduction, while section 2 presents the network topology. Section 3 introduces the proposed algorithm, the results and discussion are presented in section 4, and the conclusion is given in section 5.

### Network Topology

In this research work, the network topology used is the full mesh topology.

#### i. Full Mesh Topology

This topology represents a case where all the readers exhibit reader to reader interference (RRI). This can occur in many RFID installations if no counter measures (e.g. screening the readers) have been taken to reduce interferences (Vales-Alonso *et al.*, 2016). This is shown in Figure 2.1.

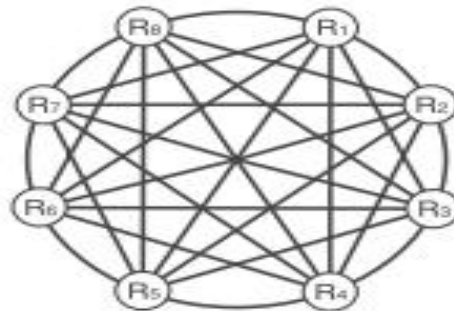


Figure 2.1: Full Mesh Scenario for RFID Network (Vales-Alonso *et al.*, 2016)

### Proposed Algorithm

The proposed algorithm used for this research is simulated annealing solver (SAS). SAS is a probabilistic technique for approximating the global optimum of a given function. Specifically, it is a meta-heuristic algorithm used to approximate global optimization in a large search space. It is often used when the search is discrete (e.g. all tours that visit a given set of cities). For problems where finding the precise global optimum is less important than finding an acceptable local optimum in a fixed amount of time. SAS may be preferable to alternatives such as gradient descent (Yüksel & Yüksel, 2011). SAS interprets slow cooling as a slow decrease in the probability of accepting worse solution as it explores the solution space. Accepting worse solution is a fundamental property of meta-heuristics because it allows for more extensive search for the optimum solution. SAS continuously tries random variations of the current solution and accepts new ones if they improve the current solution (in terms of throughput) or randomly if new solutions are worse (with a probability that slowly decreases as the algorithm progresses). This way of dealing with solution renewal allows the SAS to escape from local minima. Although there is no guarantee that the final solution will correspond to a global optima (just as with any other solver available), SAS is able to find good-quality solutions to many problems, given that a proper algorithm to generate new solutions is based on previous solutions is found (Vales-Alonso *et al.*, 2016).

## RESULTS AND DISCUSSION

The results of this research work was simulated using MATLAB 2017a using MATLAB/SIMULINK communication toolbox. The full mesh scenario was selected to run the algorithm, and the scenario represents the case where all the readers exhibits RRI. Table 4.1 gives the model parameters used for the implementation of the work.

**Table 4.1:** Model Parameters used.

Parameters	Units
Number of Readers (m)	12
Number of Tags	1-200
Number of Time Slots	512
Number of Frequencies (f)	2 and 4
Topology	Full mesh and Star

Also, Table 4.2 shows the throughput and convergence time for different number of tags in a full mesh scenario case when compared with the work of Vales-Alonso *et al.* (2016).

**Table 4.1:** Throughput and Convergence time for Different Number of Tags in a Full Mesh Scenario

Number of Tags present in each reader	Vales-Alonso <i>et al.</i> , (2016) Throughput	Enhanced Scheduler Algorithm Throughput	% Improvement in Throughput	Vales-Alonso <i>et al.</i> , (2016) Convergence time	Enhanced Scheduler Algorithm Convergence time	% Improvement In Convergence Time
20	240	240	0	473.49	464.50	1.96
40	390	480	18.75	750.46	556.39	25.89
60	500	624	19.87	870.06	651.55	25.12
80	600	694	13.54	1000.49	659.55	34.68
100	680	741	7.42	1043.97	654.14	37.34
120	745	756	1.46	1100.17	655.37	40.43
140	750	758	1.20	1138.53	656.07	42.38
160	750	759	1.20	1200.12	746.09	37.88
180	750	759	1.19	1422.12	840.13	40.92
200	750	758	1.06	2085.85	1000.74	52.02

Table 4.2 show the results obtained using model parameters highlighted in Table 4.1 for the enhanced scheduler algorithm and the conventional scheduler algorithm. A different

number of tags present at each reader ranging from 20, 40, 60... 200; a total number of 12 readers were used; 4 frequency channels and 512 number of time slots for full mesh scenario. The throughput was recorded at each time the algorithm run; also the convergence time was recorded. From Table 4.2, it can be observed from the results that in the first and second run for the enhanced scheduler algorithm, all the tags present at the reader's environment were identified, but as the number of tags increases, some tags were not identified.

Figure 4.1 shows the results of throughput against the number of tags in a full-mesh scenario. The number of tags ranging from 20-200 at each reader, 12 readers were deployed, 4 frequency channels were used with 512 number of time slots. It was observed that, the enhanced scheduler algorithm had a better throughput compared to conventional scheduler algorithm with the total average percentage improvements of 6.58%. This shows that the proposed technique outperformed the conventional scheduler algorithm in terms of throughput in the network; with this it is evident that the RFID network performed better with the enhanced scheduler algorithm, but as we can observe in Figure 4.1 from tags 120-200 there is no exponential rising, which occurred because of the limited network resources distributed by the network coordinator.

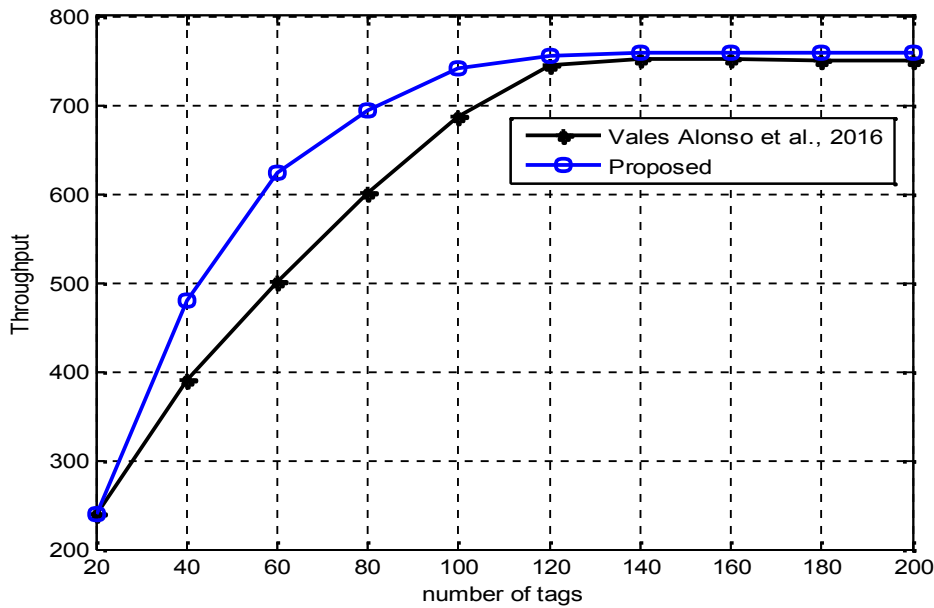


Figure 4.1: Plot of Throughput against the Number of Tags for a Full Mesh Scenario

Figure 4.2 shows the results of convergence time against the number of tags. The number of tags ranging from 20-200 at each reader, number of readers 12, 4 frequency channels and 512 total number time slots. It can be observed that from the results the enhanced scheduler algorithm had a better convergence time compared to conventional scheduler algorithm with the total average percentage improvements of 33.86% for full Mesh scenario This shows that the proposed technique outperformed the conventional scheduler algorithm in terms of convergence time, with this it is evident that there was an improvement in terms of efficiency in RFID network using the enhanced scheduler algorithm.

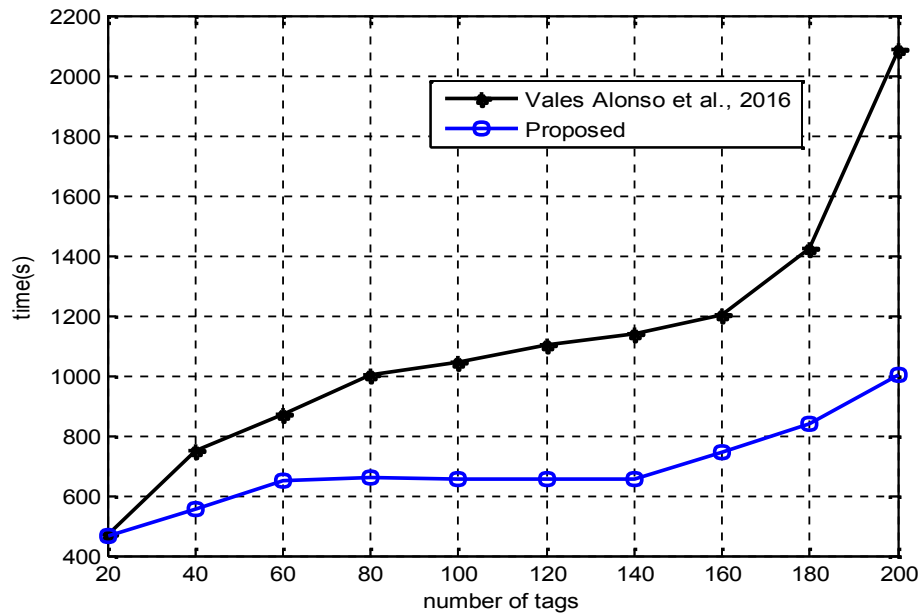


Figure 4.2: Plot of Convergence Time against Number of Tags for a Full Mesh Scenario

## CONCLUSION

RFID technology is a term that defines a system of identification based on storing and remotely retrieving information or data. It consists of Tags, Readers and a Back end server. RFID tags store unique identification information of objects and communicate the tags to allow remote retrieval of their ID. The drawback of RFID in a DRE is interference between readers as a result of collision between frequencies of different readers operating concurrently. This interference prevents the correct identification of tags, which caused degradation of system performance. To solve this problem, scheduler algorithm has been proposed in literature as an interference mitigation technique in RFID-DRE. But this algorithm has a slow convergence problem because of the random search of time slot and frequency allocation process. It took a longer time to assign network resources due to the random search of time slot and frequency allocation process, which delay the overall system. Therefore this research article was able to enhance scheduler algorithm for RFID in DRE with a view to improve the convergence time and increase network throughput.

Computer simulations were carried out using MATLAB R2017a and performance of the proposed scheduler algorithm was compared with that of Vales-Alonso *et al.*, (2016) using throughput and convergence time as performance metrics. It could therefore be concluded that the enhanced scheduler algorithm has output performed that of Vales-Alonso *et al.*, (2016) based on the results presented.

## REFERENCES

- Ahsan, K., Shah, H., & Kingston, P. (2010). RFID applications: An introductory and exploratory study. *arXiv preprint arXiv:1002.1179*.
- Incel, O. D., Van Hoesel, L., Jansen, P., & Havinga, P. (2011). MC-LMAC: A multi-channel MAC protocol for wireless sensor networks. *Ad Hoc Networks*, 9(1), 73-94.

- Klair, D. K., Chin, K.-W., & Raad, R. (2010). A survey and tutorial of RFID anti-collision protocols. *IEEE Communications Surveys & Tutorials*, 12(3), 400-421.
- Kumar, A., Aggarwal, A., & Gopal, K. (2018). A Novel and Efficient Reader-to-Reader and Tag-to-Tag Anti-Collision Protocol. *IETE Journal of Research*, 1-12.
- Munkailu, M., Sani, S., & Tekanyi, A. (2018). Development of a sparse RFID reader deployment algorithm for effective RFID network planning. *Nigerian Journal of Technology*, 37(3), 779-785.
- Nikitin, P. V., & Rao, K. S. (2008). *Antennas and propagation in UHF RFID systems*. Paper presented at the 2008 IEEE International Conference on RFID
- Vales-Alonso, J., Parrado-García, F. J., & Alcaraz, J. J. (2016). OSL: An optimization-based scheduler for RFID Dense-Reader Environments. *Ad Hoc Networks*, 37, 512-525.
- Wang, Z., Kang, W., Zhang, G., & Zhang, Y. (2011). *A novel reader anti-collision protocol using Priority Cluster for dense reader RFID system*. Paper presented at the IEEE 13th International Conference on Communication Technology, 2011
- Yüksel, M. E., & Yüksel, A. S. (2011). RFID Technology in business systems and supply chain management. *Journal of Economic & Social Studies (JECOSS)*, 1(1).