Poster: Bidimensional Relative Localization Leveraging Interference among Passive Tags

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Abstract

Passive Radio Frequency IDentification (RFID) technology has been widely deployed in many applications, such as retailing, warehousing, supermarket, *etc.*. Knowing the relative localization of tagged items can significantly facilitate automatic processing flows. However, existing RFID based solutions that provide relative locations are either too costly or incompatible with the deployed infrastructures. In this paper, we propose an RFID **B**idimensional **R**elat**I**ve **L**oca**L**ization (BRILL) system. The basic idea of BRILL is to utilize the interference among nearby tags. By moving two interfering tags over a target tag array, the reader can obtain the RSS values of each tag over time. By analyzing the RSS variation accompany with temporal information, the reader can determine the tags' order in the array. The experimental results show that BRILL achieves high accuracy, *i.e.*, nearly 90%.

1 Introduction

Ultra-low power Radio Frequency Identification (RFID) system has been widely used in a variety of applications, such as warehousing, library, and supermarket. The benefit of UHF RFID tags is that they are small, battery-free, and cheap, enabling fast access on tagged items. In general scenarios, RFID reader has a considerable read range (*e.g.*, even 10 meters in indoor environments). In this region, the reader is able to know whether the target is within its inventory range, yet difficult to acquire its location information. Without the location information, it is hard to support auto-management or processing in many applications, such as supply chain, inventory, or manufacture, etc.

Besides the absolute location, relative location, which contains the order or sequence information of tags in a certain layout, is also of importance for modern automatic processing. Recent research efforts have adopted many techniques to estimate the location of RFID tags. Those approaches, either for absolute localization [3, 4], or relative localization [2], raise specific requirements, such as dedicated hardware or reader movements, resulting in a significant challenge in practical implementation.

Inspired by above issues, in this paper we propose an RFID **B**idimensional **R**elat**I**ve **L**oca**L**ization (BRILL) system. Our BRILL system has several attractive features. First, BRILL leverages the off-the-shelf commercial RFID readers and tags, which have already been deployed. Second, BRILL does not need any extra devices. Last but not the least, BRILL does not require to move the reader, which is noninvasive to existing infrastructure. BRILL achieves relative localization based on one observation derived from our preliminary experiments: *when two tags are placed very close and parallel to each other, the currents and charges of one tag will affect the electric fields on other tag antennas, yielding a decrease on its Radio Signal Strength (RSS).* Based on this observation, we implement BRILL by moving two passive tags over a grid of target tags. By analyzing the RSS variation of each target tag accompanied with the temporal information, we can derive the tag location as well as the tags' order in two dimensions.

2 System Design

2.1 Observation and theoretically analysis

UHF RFID systems operate using the backscatter communication technique. The passive tags have no battery, and harvest energy from the RF signals transmitted by readers. The induced current flow in a tag's antenna enables the tag's IC to operate. However, the current inevitably affects the electric fields in the tag's nearby area. If another tag is nearby, they may interfere with each other.

We conduct experiments to test such interference. We place two tags very close and parallel to each other and observe that the two tags with mutual interference become unreadable. The reason behind is that in this case, two dipole antennas (*i.e.*, two wires) of the two tags form a new structure, which is very similar to the folded dipole antenna [1]. The structure looks like a transmission line with an open-circuited end (due to the end of two antennas are not connected). Since the length of the tags' antennas is half of their working wave length, this open-circuited load shall be transformed into a short-circuit at the center of the transmission line, making those tags unreadable. This phenomenon exists only when two tags are close enough (*i.e.*, the distance between two tags is shorter than 0.05λ (say $\approx$1.5cm)). Furthermore, when tags are with a certian larger in-between distance, even they can be read, the interaction effect is still non-negligible. As a consequence, the RSS of tags will vary. We conducted preliminary experiments and test the interference region of one tag to another. We deploy the target tag on the

International Conference on Embedded Wireless
Systems and Networks (EWSN) 2017
20–22 February, Uppsala, Sweden
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ISBN: 978-0-9949886-1-4

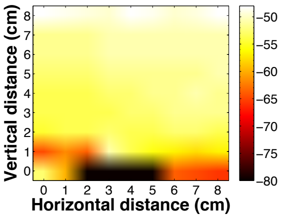

Figure 1: Interference region of one tag to another.

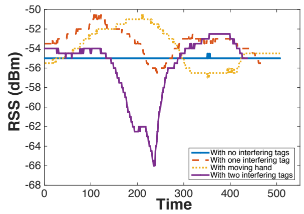

Figure 2: RSS variation of the target tag under different situations.

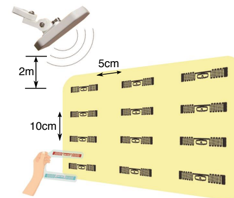

Figure 3: The deployment of BRILL.

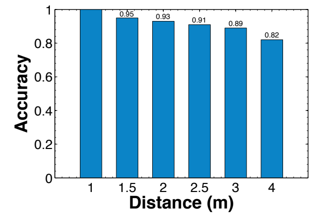

Figure 4: Accuracy vs. reader-to-tag distance

carton, and put another tag (namely *interfering tag*) around it with different horizontal and vertical distances. Fig. 1 shows the RSS values (in dBm) of the target tag. Without the interfering tag, its RSS is -48dBm. When introducing the interfering tag at different positions, the target tag's RSS decreases accordingly. Specifically, the black points in the figure represent that the target tag is unreadable (*e.g.*, its RSS is lower than the minimum power necessary to activate its IC). This phenomenon inspires us utilizing the interference among tags to localize the target tag.

2.2 Realizing BRILL

To strengthen above interference, we set up BRILL using two interfering tags, oriented in opposite directions (as shown in Fig. 3). The benefits are two folds. First, the antenna orientation of interfering tag has uncertain effect on its influence to the target tag. Utilizing two interfering tags can eliminate the impact of antenna orientation of target tags, since each of them shall always suffer from joint influences induced by two interfering tags with same and opposite directions. Second, as shown in Fig. 2, the RSS decrease is not obvious enough when there is only one interfering tag moving by. The induced influence is not distinguishable from that of ambient variations, such as a moving hand. However, when utilizing two interfering tags, RSS of the target tag decreases significantly.

BRILL realizes relative localization of tagged object as follows. Two interfering tags are moved over a set of target tags, during which the RFID reader continuously interrogates the tags and obtains their RSS values over time. By analyzing the sharp RSS decrease of each tag in time, BRILL can obtain the approximate location of current target tag (*e.g.*, close to interfering tags). Furthermore, accompanying with the temporal information of the variations, BRILL can obtain the bidimensional spatial orders of those target tags. A simple prototype of BRILL is shown in Fig. 3. We deploy a 4×3 tag array on a carton, and move two interfering tags across the fourth row. For comparison, we also collect the RSS variation when only moving the hand without interfering tags. The results shown in Fig. 5 proves the effectiveness of BRILL. According to the sequential relationship of detected decrease (*e.g.*, marked with grey boxes) in Fig. 5(d)(e)(f), we can deduce the horizontal order of three tags in the fourth row. Similarly, by moving the interfering tags along the colomn, we can derive the vertical tag order, hence achieve the bidimensional relative localization.

3 Preliminary evaluation

We evaluate the performance of our BRILL system over a prototype. We move the interfering tags along different lines and columns of a 5×5 tag array and check whether BRILL can distinguish the tags' orders correctly. Each test

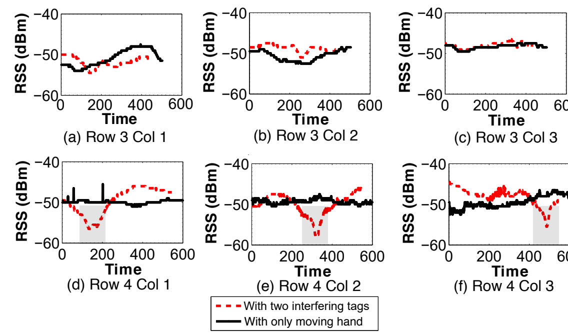

Figure 5: RSS variation of tags in the 4×3 tag array.

case is repeated 30 times. We also vary the reader-to-tag distance. Fig. 4 shows the detection accuracy. We can observe that with the increasing distance, the accuracy of BRILL decreases slightly. The reason may lie in that multipath interference become more serious when the reader-to-tag distance is enlarged. In this case, the power of tag is vulnerable to complicated ambient factors. However, when the distance is shorter than 2.5m, the accuracy is always above 90%, which proves the effectiveness of BRILL.

4 Conclusions

In this paper, we propose a bidimensional relative localization system, called BRILL. BRILL leverages the interference among nearby tags and determines the tag ordering by analyzing the RSS variations of each tag. BRILL is easy to implement and compatible with deployed commercial RFID systems. The experimental results prove that BRILL can achieve high detection accuracy.

5 Acknowledgements

This work was supported by NSFC Grant No.61190112, 61325013, 61572396, 61402359, China 863 Grant 2013AA014601, and National Science and Technology Major Project of the Ministry of Science and Technology of China JZ-20150910.

6 References

[1] D. Dobkin. *The RF in RFID: Passive UHF RFID in Practice*. Elsevier Inc, 2008.

[2] L. Shangguan, Z. Yang, A. X. Liu, Z. Zhou, and Y. Liu. Relative Localization of RFID Tags using Spatial-Temporal Phase Profiling. In *Proceedings of USENIX NSDI*, 2015.

[3] J. Wang and D. Katabi. Dude, Where's My Card?: RFID Positioning That Works with Multipath and Non-line of Sight. In *Proceedings of ACM SIGCOMM*, 2013.

[4] L. Yang, Y. Chen, X. yang Li, C. Xiao, M. Li, and Y. Liu. Tagoram: Real-time Tracking of Mobile RFID Tags to High Precision Using COTS Devices. In *Proceedings of ACM MobiCom*, 2014.