An Efficient RFID Reader Network Planning Strategy Based on P2P Computing

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Abstract. Radio Frequency identification (RFID) technology has been used in many areas, which needs to deploy many readers in the RFID network. Extra readers in the network will consume more power, resulting in a waste of RFID network resources. Therefore, the elimination of redundant readers is important to optimize an RFID network deployment. RFID reader redundant deployment optimization can ensure that users use the minimum number of readers to cover a specific range of all tags. Peer-to-peer (P2P) computing or networking is a distributed application architecture that partitions tasks or workloads between peers. P2P based RFID network is a novel distributed systems. In this paper, an efficient redundant reader elimination strategy is discussed, which is based on the P2P-based RFID reader network.

Key Words. RFID, Network Planning, P2P, Internet of Things

1 Introduction

Radio-frequency identification (RFID)[1-3] is one method for automatic identification and data capture, which uses electromagnetic fields to automatically identify and track tags attached to objects. RFID are used in many areas, for example, an RFID tag attached to an automobile during production can be used to track its progress through the assembly line; RFID-tagged pharmaceuticals can be tracked through warehouses; and implanting RFID microchips in livestock and pets allows positive identification of animals. RFID technology has been widely used in supply chain, electronic toll collection system or passive key-less entry, location services, medical industry and other fields.

Peer-to-peer (P2P) computing or networking is a distributed application architecture that partitions tasks or workloads between peers. P2P systems had been used in many Internet applications[4-8], and the P2P architecture was popularized by the file sharing

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system. Due to the distributed RFID information system need to real-time update the information, integration of P2P and RFID technology has gained a great interest by researchers[9-14]. The advantage is that peers can communicate each other in P2P network.

RFID system usually includes the following parts: RFID tag, RFID reader and back-end application and database system. In order to accurately monitor a working area, it needs dense deployments of RFID readers and tags in RFID-based application system. In fact, when multiple readers in the same working environment communicate through a common wireless channel, a signal from a reader may produce frequency interference on other readers. This frequency interference occurs when a reader sends a communication signal to read the tag, and the communication signal is interfering with other reader reading the tag. Even if the reader does not overlap the interrogation zone it will interfere with the operation of other readers. The backscatter signal from the tag is so weak that it is vulnerable to interference. Thus, frequency interference of the coverage area can cause inaccurate reading and also lengthening the reading interval. Consequently, for the large-scale deployment of the reader in RFID system, the impact caused by interference of readers in RFID coverage area should be analyzed[15,16]. Extra readers in the network will consume more power, resulting in a waste of reader resources. Therefore, the elimination of redundant readers is important to optimize an RFID network deployment. RFID reader redundant deployment optimization can ensure that users use the minimum number of readers to cover a specific range of all tags. Although redundant readers improve the tracking accuracy, they increase the energy consumption and additional write overhead[17]. When multiple readers share the same perception of the area and the communication channel, a signal from a reader can interfere with other readers[18]. In addition, the redundant data generated by the redundant readers take up more computing resources to achieve the purpose of data gathering. Therefore, effective algorithm to detect and minimize redundant readers is essential to developing RFID network.

Over the past few years, researchers have done extensive research on RFID collision, among which the most important issue is the signal collision. Signal collision is divided into two categories: tag signal collision and reader signal collision[19-25]. Another way to solve the anti-collision problems is to reduce the number of redundancy readers in RFID network. This approach not only increases the effectiveness of RFID systems, but also saves power consumed by redundancy readers. Technology of eliminating redundant readers has been widely used in large warehouses, production lines and large retailer areas. Some research has been done related to this issue [26,27]. RRE algorithm[26] and LEO algorithm[27] is the most representative algorithms of the method. RRE algorithm is a greedy algorithm. the main idea is to record "tag number" that the maximum number of tags a reader can cover. The reader having the maximum number of tags will become the holder of the corresponding tag. Repeat the above steps until all the tags have corresponding readers in the network. In the end, if there is no tag assigned to a reader, it will be eliminated as a redundant reader. Reference[27] pointed out that RRE algorithm is difficult to eliminate redundant readers in some certain RFID network, in order to deal with it, the authors proposed LEO algorithm using a layered approach. The main idea of the LEO algorithm is “first read first own” and all readers send requests to the tags within their coverage's to obtain records of tags. The first reader that sends a quest to the tag will become the holder of the tag. If the tag

already has other reader's ID, the ID can not be changed. Finally, eliminate readers which have no tags.

In the remainder of this paper, we first discuss the RFID data features (section 2). In section 3, we describe related definitions that are used in proposed strategy. The section 4 presents the proposed strategy based on P2P-RFID network in detail. Finally, the section 5 concludes our paper and future work is given.

2 RFID Data Features

Not every successful reading of a tag (an observation) is useful for business purposes. A large amount of RFID data may be generated that is not useful for managing inventory or other applications. Data Cleaning refers to a program which can detect and correct the identifiable error in data files[28]. RFID data have the following features[29]: Temporarily, dynamic and association; Semantic richness; Inaccuracy and heterogeneity; Flow, bulk and mass.

In earlier RFID application, the RFID data were directly sent to the application, then the raw data were processed by applications. The current trend is to provide RFID application with RFID middleware platform, while middleware shields the reader hardware and the upper system, shares the processing of data, and preprocess the raw data (Data Cleaning).

Taking from the angle of readers, inaccuracies of RFID raw data can result in the following errors[30] : (1)Positive error: tag data that should not be recognized is read for some reasons (such as noise) by readers;(2)Negative error: tag data should be the recognized is not read by readers;(3)Read redundancy: tag data is read by multiple times.

3 Related Definitions

There are some classical data cleaning algorithms, such as SMURF model which combines statistical knowledge based on a sliding window cleaning the tag data. Online pipe cleaning frame (ESP) does data cleaning after five stages processing of point, smoothing, merge, decision and blurring. In this paper, RFID reader redundancy problems have been discussed. Reader repeatedly reads the tag data and the reader's identification range overlapping causes a lot of redundant data in RFID system, thus seriously affecting the identification accuracy and efficiency. In the real environment the readers and tags are often very dense so the redundant data read simultaneously by tags and multiple readers cannot be ignored. In the following paragraph, we will describe the methods of redundant reader elimination in detail. The following definitions are given for redundancy readers and the elimination of redundant readers.

Suppose RFID(R, T) denotes an RFID system, where R represents a set of readers, and T represents a set of tags. Suppose Coverage (R, T) represents tag covering domain of the RFID system.

Definition 1 : R^1 is a set of redundant readers set.

Definition 2 : R^2 is a process set of looking for the R^1, which connections is $R^1 \geqslant R^2$.

Definition 3 : Let the read range radius of a reader is M, if the distance L between two readers L<2M, the two readers are called neighboring readers.

Definition 4 : Suppose R_{iN} is a set of neighboring readers of R_i, the neighboring coverage density(NC_i) of R_i is $NC_i = \sum_{j=1}^{n} Coverage\ (R_{ij})$.

Definition 5 : Suppose R_{iN} is a set of neighboring readers of R_i, the weight of reader R_i is $Wi = \frac{Coverage\ (\mathrm{Ri})}{NCi}$.

Figure 1 is an example for reader redundancy in RFID system. Reader R_1 and R_2 cover the same tag T_1, so they are neighboring readers. And the like, R_2 and R_3 are neighboring readers, and R_3 and R_4 are neighboring readers.

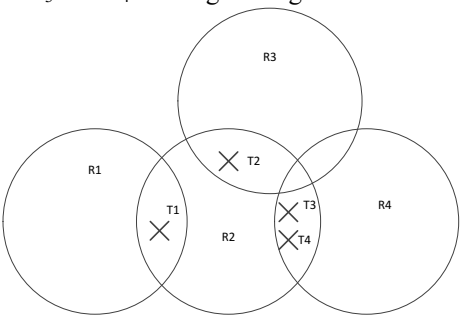

Figure 1. Example for Reader redundancy in RFID system

4 Proposed Strategy

The redundancy elimination algorithm for the reader proposed in this paper is based on the P2P-RFID network system, where one reader can have the ability to communicate with each other among readers, therefore, the following is introduction of P2P-RFID reader network. P2P network is a distributed network of application layer on the IP network, participants in the network i.e. Peers share a portion of the hardware resources (such as processing power, storage capacity, network connectivity, etc.) they have. P2P-RFID reader network system[31] is a new way of P2P-based RFID reader network systems. The P2P-RFID reader network takes advantage of P2P technology, which can work as client and server mode. Embed ZigBee (ZigBee is a short-range, low-power wireless communication technology based on the IEEE802.15.4 standard) technology in the reader, compose P2P network between them, and they can communicate with each other. P2P-RFID reader network architecture proposed in literature[31] is shown in Figure 2.

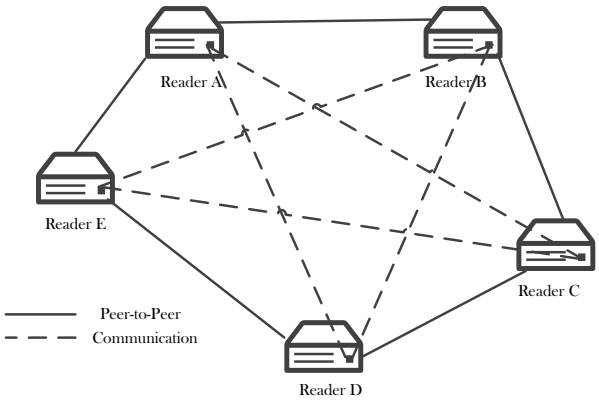

Figure 4

Figure 2. P2P-based RFID reader network system

LEO is applied for high-density wireless RFID network as a distributed optimization technology of wireless RFID network[27], which can eliminate most of the redundant readers, and greatly reduce the "write-to-tag" operation, but LEO relies on RFID reader query sequence. The result is different when query sequence is different. NCD algorithm improves accuracy relative to other distributed algorithms, but the calculation is more complicated, so it does not apply to RFID network in high-density environments.

NCD algorithm is divided into four steps:

(1) Each reader inquiries near readers and tags to calculate the tag covering domain, and writes the reader ID in all the coverage lists of tags it covers.

(2) According to the coverage list and according to the Definition 5, calculate the weight of the reader.

(3) All readers will write the command containing their reader ID and weight into tags they cover. Each tag chooses a holder which has the largest weight in its neighboring areas.

(4) Reader inquiries its covered tags and read the tag holder. A reader having no tags will be eliminated as a redundant reader.

This paper combines the advantages of LEO and NCD algorithm, and proposes a redundant RFID reader algorithm in an environment of high-density readers. First, we make the following assumptions:

(1) The covering domain tag of the reader is known;

(2) P2P-RFID reader network as mentioned in literature[31] are use, by using P2P communication to know whether two readers are neighboring readers.

Query-Response process of reader Ri (i=1…n, the algorithm will be executed in parallel for n times, n is the total number of reader, total number of tag T is m) is listed as the following step:

(1) Reader broadcasts an "inquiry message "(Do you have a holder?) to tags in coverage domain.

(2) Tags in coverage domain of Ri reply to Ri.

(3) If tag's holder = "NULL", reader Ri will write its ReaderID to the tag, else Ri will ignore this reply.

(4) If there is no NULL in all the replies of tags in coverage domain of reader Ri, then Ri will be eliminated as a redundant reader.

(5) Reader Ri broadcast a "query message" to query neighboring reader Rj (j=1…n, n is the number of neighboring readers of Ri).

(6) Reader Ri's neighboring reader Rj replies the tag value.

The above is the entire query response process of the reader and the neighboring reader and tag. After the end of the process, Ri calculates Neighboring Coverage Density Di and Weight Wi according to definition 4 and definition 5. If the neighboring coverage density Dj of reader Rj is 0 and the number of the coverage domain tag Tj is not 0, then reader Rj must not be a redundant reader. List the weight of Ri and Tag Ti, Ti chooses the reader that has the largest weight to be its "holder", finally the readers which are not chosen by any tag are redundant readers.

5 Conclusions

In this paper, an efficient redundant reader elimination strategy is discussed, which is based on the P2P-based RFID reader network. The P2P-RFID reader network takes advantage of P2P technology, which can work as client or server mode, and can communicate with each other. In the P2P-RFID network, through using P2P communication to identity whether the two readers are the neighboring readers. Because LEO relies on RFID reader query sequence, and NCD algorithm improves accuracy relative to distributed algorithms, but the calculation of NCD algorithm is more complicated. This paper makes use of the advantages of LEO and NCD algorithm, and proposes the redundant reader elimination strategy in an environment of high-density readers, which can eliminate redundant readers. The future work includes deployment and refinement of the proposed strategy in realistic environments.

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