Practical Key Tag Monitoring in RFID Systems

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Abstract—With rapid development of radio frequency identification (RFID) technology, ever-increasing research effort has been dedicated to devising various RFID-enabled services. The key tag monitoring, which is to detect anomaly of key tags, is one of the most important services in such important Internet-of-Things applications as inventory management. Yet prior work assumes that all tags are armed with hashing functionality and a reader would report channel states in every slot, which is not supported by commercial off-the-shelf (COTS) RFID tags and readers. To bridge this gap, this paper is devoted to enabling key tag monitoring service with COTS devices. In particular, we introduce two anomaly monitoring protocols to detect whether there is any key tag absent from the system. The first protocol employs Q-query that works in an analog frame slotted Aloha paradigm to interrogate tags and collect tag IDs. An anomaly event will be found if at least one key tag ID is not present in the collected ones. To reduce time cost of the first protocol resulted from tag collisions, we present a collision-free method that uses select-query to specify a key tag to reply in each slot. Once there is no response in a slot, the specified key tag is regarded as a missing tag. We conduct experiments to evaluate two protocols.

I. INTRODUCTION

Recent years have witnessed an unprecedented development of the radio frequency identification (RFID) technology. An RFID system typically consists of readers and tags. A reader is a device equipped with a dedicated power source and an antenna, and can collect and process information sent by tags in its interrogation region. A tag, on the other hand, is a low-cost microchip labeled with a unique serial number (ID) to identify an object. The core characteristic of a tag is that it is battery-free and can capture energy from the radio wave of its nearby reader to backscatter messages. As a promising technology, RFID is widely used in various applications ranging from inventory control, supply chain management and logistics [3] to object tracking and location [2].

In an RFID system, one may be more interested in partial tags instead of the whole tag population. We define these tags as key tags. Here, we present two examples to motivate the presence of key tags in practice.

• In a retail store with expensive and inexpensive goods, an RFID system is deployed to monitor them. Staffs more care about expensive ones due to higher value, thus the tags on these objects are expected to be detected more frequently.

• Consider a warehouse rented to multiple companies, when a company requests tag anomaly service, warehouse management only needs to detect tags attached on products from this company instead of all tags in the region.

In this paper, we study key tag anomaly monitoring problem which is to detect whether some key tags are no more present in the coverage of RFID system. A large body of work has been proposed to address this problem. The nature of these work is that the reader predicts response slot of each tag and could find an absent one if a slot expected to be single does not see any reply. Although technical tools, such as multiple-seed method and sampling method, are very promising in accelerating the detection process, the reality is that the tag response slot cannot be predicted a prior due to the lack of hashing functionality in COTS tags. Therefore, monitoring key tag anomaly while being compatible with COTS RFID devices is still an open problem.

In this paper, we introduce two protocols that are able to find key tag anomaly while being compatible with existing COTS RFID devices. Specifically, in the first protocol named Q2, we employ Q-query to interrogate the tags. Q2 works in an analog frame slotted Aloha paradigm, which is the de facto random access protocol in the Gen2 standard [1]. To avoid tag collisions as well as interferences of non-key tags in Q2, we then design a select-query based protocol (SQ) that can singularize the tags in each slot with a selective bitmask and ensures successful communication in all slots. We implement Q2 and SQ with COTS RFID devices.

II. PROBLEM DEFINITION AND PROPOSED SOLUTIONS

Consider an RFID system composing of a reader and n tags containing k key tags. The reader knows all tag IDs 1. The key tag anomaly monitoring problem is to detect the existence of key tag absence. Here, execution time that is measured as the time spent achieving the task is the most important metric.

A. Q2: Q-query based solution

The reader conducts Q-query to collect tag IDs. The query can stop when the reader reads all key tags, meaning there is no absent key tag; otherwise, the query process continues until the execution of the whole frame. At the end, the reader compares the collected key tag IDs with those recorded in the

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1In this paper, each tag is assigned an electronic product code (EPC) that is stored in the tag memory and is used to distinguish different tags.
The core of SQ is Select function, which is used to inform tags of which bit string in their individual memory should be compared with the received mask. There are six mandatory fields in the Select command that is shown in Figure 2, we will mainly introduce the four fields. 1) Field MemBank: This field indicates the memory model where a tag will search for a target bit string to compare with the received mask. The EPC memory bank is used in this paper, i.e., MemBank = 1.

B. SQ: Select-query based solution

Since Q2 is a random protocol, multiple tags may reply with RN16 simultaneously leading to the failure of decoding RN16 at the reader side. To deal with tag collisions in Q2, we turn to SQ that is able to singularize tags in every slot. The difference of Q2 and SQ are shown in Figure 1.

SQ operates as follows: The reader first sends a Select command that specifies a bitmask. On receiving Select, each tag checks whether it matches the reader-to-tag bitmask. Only the matching tags will wait for the further query of the reader. We will explain shortly how to choose the bitmask such that only one tag can pass the bitmask comparison in a slot. Then the reader transmits a Query that specifies the matching tag to reply. Because only one tag meets the requirement in SQ, this tag is the only one responding in this slot with its RN16. After that, the reader issues an ACK with the decoded RN16 and waits to receive the ID of this tag. The reader will repeat the above process until all key tags are probed.

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