A Parallel Identification Protocol for RFID Systems

Linghe Kong*†, Liang He*, Yu Gu*, Min-You Wu†, Tian He‡
*Singapore University of Technology and Design, Singapore
†Shanghai Jiao Tong University, China
‡University of Minnesota, USA
*{linghe_kong, he_liang, jasongu}@sutd.edu.sg, †{linghe.kong, mwu}@sjtu.edu.cn, ‡tianhe@cs.umn.edu

***Abstract*—Nowadays, RFID systems have been widely deployed for applications such as supply chain management and inventory control. One of their most essential operations is to swiftly identify individual tags to distinguish their associated objects. Most existing solutions identify tags sequentially in the temporal dimension to avoid signal collisions, whose performance degrades significantly as the system scale increases. In this paper, we propose a *Parallel Identification Protocol* (PIP) for RFID systems, which achieves the parallel identification paradigm and is compatible with current RFID devices. Uniquely, PIP encodes the tag ID into a specially designed pattern and thus greatly facilitates the reader to correctly and effectively recover them from collisions. Furthermore, we analytically investigate its performance and provide guidance on determining its optimal settings. Extensive simulations show that PIP reduces the identification delay by about $25\% - 50\%$ when compared with the standard method in EPC C1G2 and the state-of-the-art solutions.**

I. Introduction

Radio Frequency IDentification (RFID) systems are rapidly changing our lives with their low costs and ubiquitous characteristics. They have been widely deployed in various applications such as inventory control [4], supply chain management [8], and object tracking [21]. In order to identify the associated object for each tag, one essential operation in RFID systems is for the reader to acquire the unique IDs of individual tags through the communication between them, known as the *tag identification* [24]. The performance of the identification process is normally evaluated by the time for it to be accomplished, referred to as the *identification delay*.

In RFID systems, the communication starts with the reader transmitting a high power waveform query, and the tags modulate the received signal by changing the impedance match on its own antenna and reflect back to the reader [3]. Due to this special property of RFID communication, it is not feasible for tags to detect whether other tags are communicating with the reader, *e.g.*, through channel sensing as in traditional wireless communications [4]. Thus to avoid the collisions caused by the simultaneous transmission of multiple tags, tag identification is traditionally accomplished by assigning individual tags with different time slots to inform the reader of their IDs, and the identification process is carried out in a sequential manner [13], [15]. These existing sequential identification solutions demonstrate great efficiency for RFID systems with small and medium scales. However, their performance degrades dramatically in large-scale RFID systems because the tags need to be identified one-by-one.

To improve the identification performance in large-scale RFID systems, two kinds of parallel solutions have been designed: the conventional CDMA-based identification solutions [12], [19] and the Buzz code proposed in [18]. The CDMA-based RFID systems are known to be expensive and power hungry [6], while Buzz imposes additional requirement on system to accurately differentiate the signal strength, which is beyond the hardware requirement of EPC Class-1 Generation-2 (C1G2) [3] standard or current off-the-shelf RFID readers.

To efficiently achieve the parallel identification while guaranteeing its compatibility with current off-the-shelf RFID devices, we propose a novel *parallel identification protocol* in this paper. The motivation of our design is simple: although the collisions from multiple tags are normally considered undesirable for communications, partial original information is conserved in the collision. Our main contributions of this paper are four-fold.

- We design a novel *L-K code*, which encodes the tag ID into a bit string with a specially designed pattern. This pattern facilitates the reader in recovering part of the ID information from collided signals.
- As only partial information can be recovered if tag ID is encoded by the *L-K code* and responded to the reader, we further propose a *randomized mapping scheme*, with which the *L-K code* can be applied to the same tag multiple times with different inputs. As a result, multiple partially recovered ID information can be jointly utilized to recover the full information.
- Combining the *L-K* code and the randomized mapping scheme, we propose a *Parallel Identification Protocol* (PIP) for RFID systems to identify tags in a parallel manner, which significantly reduces the identification delay especially for large-scale RFID systems.
- We analytically investigate the performance of PIP and provide guidance on identifying its optimal settings. Our evaluation results show that PIP can achieve about $25\% - 50\%$ reduction of the identification delay when compared with classic identification solutions.

The rest of this paper is organized as follows. The related work on tag identification is presented in Section II. We formulate the problem in Section III. The detailed design of PIP is presented in Section IV, and we investigate the optimal protocol setting in Section V. A few practical issues are discussed in Section VI. We present the evaluation results in Section VII, and conclude this paper in Section VIII.

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