QTDFS-ALOHA: A Hybrid Collision Resolution Protocol for Dense RFID Tag Environment

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ABSTRACT

Proposed protocols work clumsily in resolving the collisions occurred in dense RFID tag environment. QTDFS-ALOHA, a hybrid protocol which combines the query tree protocol and the dynamic frame slot ALOHA protocol, is proposed. In each frame of this protocol, only tags in the active set are allowed to answer in randomly selected slots. Afterwards, the population of tags in the active set is estimated. According to the identification accuracy required, the protocol may choose to continue the identification of the active set with delicately calculated frame length, or to divide the active set into multiple subsets using some binary prefix strings and identify each subset subsequently in the following frames. This process is performed recursively for all tag sets until the required accuracy is achieved. Proposed tag population estimation methods are summarized and evaluated. Numeric simulation verifies that this hybrid protocol outperforms other frame slot ALOHA based protocols.

Keywords: Collision Resolution, Frame Slot ALOHA, Population Estimation, Query Tree, RFID

INTRODUCTION

RFID (Radio Frequency Identification) enables the contactless and simultaneous identification of multiple uniquely tagged items and bridges the physical object world with the virtual digital space. As the replacement of the barcode system and a de-facto standard object identification technology, RFID is regarded as the main enabler of the upcoming pervasive computing (Standford, 2003).

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Collisions (Viehland & Wong, 2007; Wu, Nystrom, Lin & Yu, 2006), which is caused by that multiple readers and tags try to transmit their commands and data simultaneously through the air interface. Collisions result in unsatisfactory identification accuracy and long identification delay. It is observed that due to collision and other issues, in a typical RFID system, the identification accuracy of RFID tags is usually about 60-70% (Jefferyn, Franklin & Gaorfalkis, 2008; Laurie, 2005). The collisions occurred in the RFID system can be categorized as the reader collision and the tag collision (Shih, Sun, Yen, & Huang, 2006). Reader collision is caused by that multiple RFID readers try to broadcast commands simultaneously and their radio frequency signals interfere in the air interface. Due to that the RFID readers can possess abundant resources and can be equipped with carrier sensing devices, they can detect the reader collision in advance and coordinate with each other to resolve the collision using some devised protocols, for example, the Colorwave (Waldrop, Engels, & Sarma, 2003).

The tag collision is caused by that multiple RFID tags try to transmit their identifiers back to the reader through the air interface simultaneously. Due to the extreme constraints on computation and communication put on the RFID tags, especially due to that the passive RFID tag can only get energy supply from the magnetic induction or electronic-magnetic waves emitted from the reader, RFID tags can neither detect the collision nor coordinate with each other in advance to avoid the collision. Tag collision brings significant challenge to the RFID adoption. Proposed collision resolution protocols for RFID tag can be classified as the deterministic tree based protocols and probabilistic frame slot ALOHA based protocols (Shih, et al., 2006). However, all protocols in both categories suffer from scalability and do not perform well in resolution the collisions occurred in dense RFID tag environment, in which case the RFID reader is required to identify hundreds or even more than a thousand RFID tags with satisfactory accuracy as soon as possible. For example, in the case of a warehouse, when a truck loaded with hundreds of even thousands tagged items passes the entrance/exit, the RFID reader mounted there is required to identify these tags in seconds with adequate accuracy.

In order to enable the rapid resolution of collisions occurred in such environment, a hybrid protocol, QTDFS-ALOHA (Query Tree Dynamic Frame Slot ALOHA), a combination of the query tree protocol and the dynamic frame slot ALOHA protocol, is proposed. In this protocol, the collisions occurred in a tag set are firstly resolved using the dynamic frame slot ALOHA protocol, according to the information gathered and the population estimation of tags in the set, the tag set may be divided into multiple subsets and the dynamic frame slot ALOHA protocol is again adopted to resolve the collisions occurred in each subset. The same process is repeated for each subset until the required identification accuracy is achieved in the subset.

The remaining sections are organized as follows. Section II reviews proposed RFID tag collision resolution protocols. Section III describes the mathematical preliminaries for RFID tag collision resolution, summarizes some proposed tag population estimation methods and presents the detail of the QTDFS-ALOHA protocol. Section IV evaluates the accuracy of every tag population estimation method and the performance of the QTDFS-ALOHA protocol. And finally, in section V, we conclude.

**RELATED WORK**

The resolution of collisions happened in communication channel has been studied for a long time (Rom & Sidi, 1990), and a lot of protocols have been devised. To resolve the collisions caused by multiple RFID tags, proposed protocols can be categorized as the probabilistic frame slot ALOHA based protocols, the deterministic tree based protocols, and some hybrid protocols, such as the tree slot ALOHA protocol (Bonuccelli, Lonetti & Martelli, 2006) and others. In all these protocols, an interaction between the application system and the RFID reader is called a cycle, in which the reader is required...
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