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The Approaches in Solving Passive RFID Tag Collision Problems

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1. Introduction

Radio Frequency Identification (RFID) systems are being intensively used recently for automated identification. Every object can be detected as one form of an electronic code. At the beginning, the main purpose of RFID tag usage is meant to be an improvement of barcodes. Besides the fact that an RFID tag does not need line of sight to obtain its ID, the tag is also water and dirt resistant. Moreover, it also has a read-and-writable memory chip, which can store much more data than a barcode, and is difficult to be imitated. The above are the main factors that many enterprises and government associations consider to extensively apply the RFID technology to many applications.

An RFID tag is composed of two major components: an IC to store data and to handle communication processing and an attached antenna to transmit and receive radio signal. There are several types of RFID tags based on the differences of their power sources and communication methods. In general, a passive RFID tag does not have an internal power supply, and cannot work without collecting continuous wave from a reader. Oppositely, an active RFID tag has an attached battery and can communicate with other tags or reader on its own. A semi-passive tag is a mixed of above two types, which has an external battery for its operating power and yet communicates with reader in the same way as a passive tag does.

In an RFID system, a reader is able to communicate with many tags within its coverage. However the tag identification process may fail when multiple tags are sending their data simultaneously. The signals from the tags may interfere with each other and hence the reader may not receive any correct data at all. If this happens, the tags will have to retransmit their data, which wastes the tag reading time and hence degrades the system performance. Such a problem is often called "tag collision" in an RFID system.

To overcome the tag collision problem, researchers are still looking for the most effective anti-collision method to achieve high speed detection with nearly 100% data accuracy ID retrieval. The collision problems are usually classified into two types: the reader collision problems and tags collision problems (Burdet 2004; Dong-Her Shih 2006; Okkyeong Bang 2009). In this chapter, we focus on the latter one.

The tag collision problems are in conjunction with the anti-collision protocols used in various RFID systems, of which the objective is to retrieve a tag's ID accurately with low transmission power, low computational complexity, and minimum time delay. In the

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following we will overview a variety of anti-collision methods in solving RFID tag collision problems. Unlike many other surveys of RFID anti-collision methods that are mostly focusing on Time Division Multiple Access (TDMA) schemes, this work elaborates more details of applying other multiple access technologies to the passive RFID systems.

2. Review of anti-collision schemes for passive RFID systems

Multiple access technologies are extensively used to allow multiple communications to coexist in the communication channel with little interference with each other in modern communication systems. In an RFID system, a reader usually communicates with many tags within its read range, which means that all the reader and tag communications share the same air medium as their communication channel. Thus a variety of multiple access technologies have been used in recent RFID systems, such as Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Spatial Division Multiple Access (SDMA), Frequency Division Multiple Access (FDMA), and the hybrid multiple access technologies. In the following, we overview the multiple access technologies that have been proposed. Fig. 1 illustrates the category of multiple access schemes used in different RFID systems.

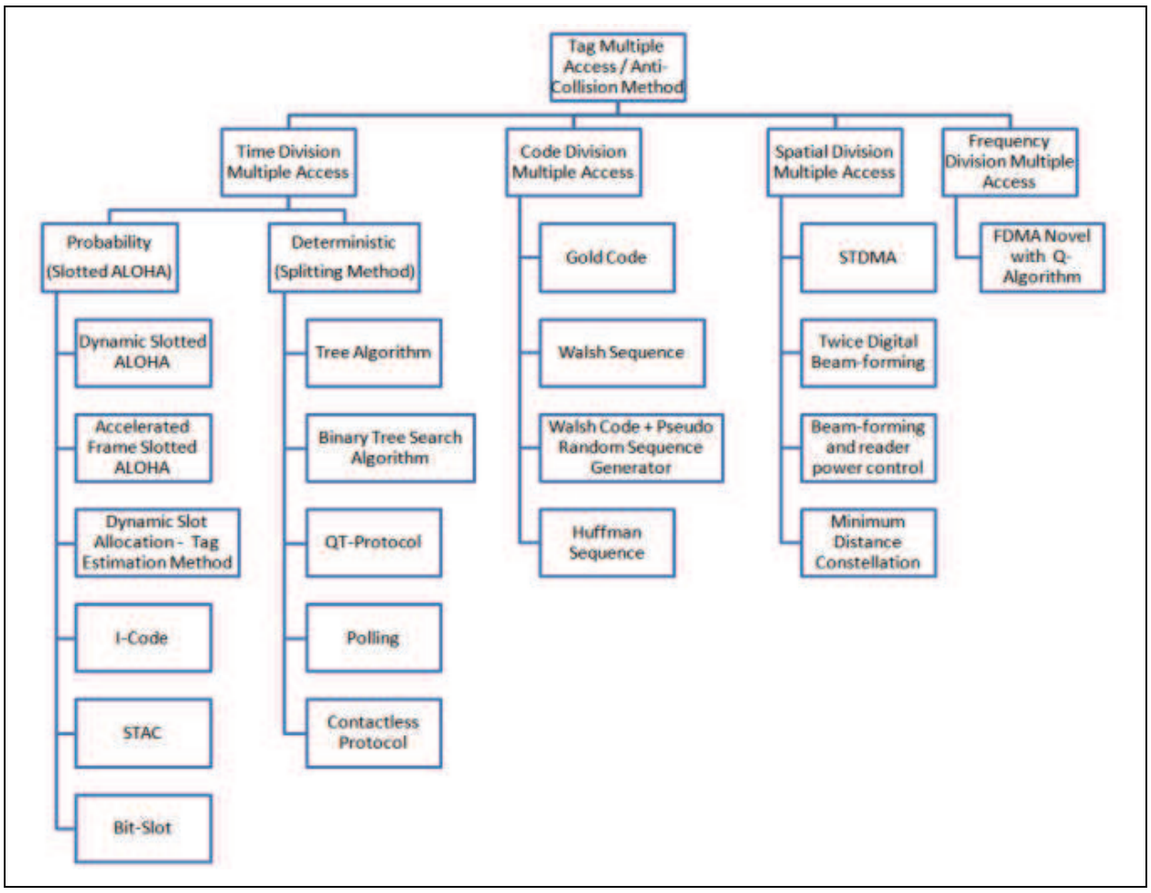


Fig. 1. Map of tag anti-collision schemes in RFID system

2.1 Time Division Multiple Access (TDMA) based schemes

With the TDMA technology, the reader and tag communications can use the same frequency in the same reader coverage, and each tag response can be differentiated by the time interval that it used. This kind of multiple access technology is the most popular RFID tag anti-collision schemes and can easily jointly incorporate with other multiple access technologies. As seen in Fig. 1, the RFID tag anti-collision schemes using TDMA technologies can be divided into two categories, the deterministic schemes and the probabilistic schemes (V. Sarangan 2008). The deterministic schemes are usually referred to as binary tree-search based schemes. The schemes are deterministic because each root-to-leaf path denotes a unique tag ID and all IDs can be retrieved once all branches are completely searched. On the other hand, the probabilistic schemes are usually referred to as slotted ALOHA based schemes. Each tag ID in the probabilistic schemes will have a chance to be retrieved successfully; however, there is a possibility that some tags may not be accessed due to recurrent collisions. Other than the above two categories, some hybrid schemes are also proposed; for instance, Bonuccelli et al. proposed a tree slotted ALOHA (TSA) is proposed in (Bonuccelli et al. 2006), and Shin et al. also proposed another hybrid tag anti-collision scheme (Shin et al. 2007).

Because the fundamental binary tree-search scheme interrogates one branch completely to obtain a tag ID, it is naturally slow. Let $L(N)$ denote the average number of iterations that are required to retrieve one tag ID among N tags. The $L(N)$ can be calculated as Eq. (1) (Finkenzeller 2004).

$$L(N) = \log_2 N + 1 \tag{1}$$

Obviously the value $L(N)$ becomes large when there are many tags in the reader's coverage. Hence, a variety of tree-search schemes have been proposed to mitigate this problem. The tree-search schemes are further categorized into two major types: Binary Tree Walking schemes and Query Tree schemes (Dong-Her Shih 2006; Okkyeong Bang 2009).

Compared with the tree-search scheme, the slot ALOHA schemes usually interrogate tags faster. Because slotted ALOHA scheme segments the reader and tag communications into many time slots. Each time slot can be empty (which means no tag response in the time slot), collided (which means multiple tag responses in the time slot), or successful (which means exactly one tag response in the time slots). Because using a pure TDMA scheme, only one tag response can be read by the reader in a time slot. The performance of the schemes is hence determined by the probability of occurrence of a successful time slot. The probability of observing a successful time slot P_{succ} can be written as Eq. (2).

$$P_{succ} = n_{tag}\left(\frac{1}{n_{frame}}\right)\left(1-\frac{1}{n_{frame}}\right)^{n_{tag}-1}, \tag{2}$$

where the n_{tag} denotes the number of tags in the reader's coverage, and n_{frame} denotes the number of slots that a tag can select, which is also called as a frame size. When the number of tags in the reader's coverage is large, it is reasonable to assume that the distribution of the probability of receiving a tag response is a Poisson distribution. Under such a circumstance, the optimal system performance (or throughput) of a slotted ALOHA scheme can achieve as 36.8% (that is, $MAX(P_{SUCC})$= 36.8%) when n_{frame} = n_{tag} (Proakis 1995; Finkenzeller 2004). Apparently, the ratio of the frame size to the number of tags in the reader's coverage determines the system throughput. As the amount of tags that needs to be read is unknown

in advance for most cases, to choose a proper frame size is a key factor that can determine the system performance. Moreover, the proper frame size is usually time-variant because the number of unread tags decreases in an inventory process, which gives a challenge on choosing the most suitable frame size (Wang & Liu 2006). Since several papers have addressed this kind of research comprehensively (Dong-Her Shih 2006; Okkyeong Bang 2009), we will not describe further details on the TDMA schemes in this chapter but refer readers to those papers.

2.2 Code Division Multiple Access (CDMA) based schemes

As mentioned earlier, the TDMA based anti-collision schemes can only retrieve one tag's ID at one time slot. In order to significantly increase the system throughput, incorporating the TDMA technology with other multiple access technology is necessary.

The CDMA technology has been extensively used in many modern communication systems. The CDMA schemes allow multiple communications to coexist in the same medium using the same time and frequency resources. The CDMA technology is usually categorized into two types: frequency hopping CDMA (FH-CDMA) and direct sequence spreading CDMA (DS-CDMA). Because a passive tag is unable to select the communication frequency actively but only backscatters the radio signal emitted from a reader, the FH-CDMA technology is hence not suitable for the passive RFID system. The DS-CDMA technology however uses a spread sequence as the signature of a signal source. Different signal sources can transmit their signals at the same time, and the receiver is able to separate each signal from the received signals by dispreading the received signals with its corresponding signature.

There are a variety of spreading sequences for different DS-CDMA applications. The sequences are generally separated into two groups. One is called "orthogonal sequences", and the other is called "pseudo random sequences". For instance, the well-known Walsh code is one of the orthogonal sequences and another well-known Gold code is one of widely used pseudo random sequences. Most orthogonal sequences require perfect synchronization (that is, each code should arrive at the receiver at the same time) to preserve their mutual orthogonality. On the other hand, the perfect synchronization is not required for pseudo random sequences to be low cross-correlated; however, the pseudo random sequences are not mutually orthogonal. Due to the low cross-correlation value, a near-far problem can be caused if the received powers from the signal sources are different. Another kind of spreading sequence is called shift-orthogonal sequences. A shift-orthogonal sequence can maintain orthogonality with a different shift-orthogonal sequence and with a delayed version of itself. Thus, the sequences do not require synchronization and can resist the near-far effect. A Huffman sequence is one example of the shift-orthogonal sequences.

A passive tag can generate a desired signal by changing its antenna reflection coefficient to produce the proper backscatter signal. This is usually referred to as backscatter modulation. Using the backscatter modulation, the tag can easily produce a desired coded signal.

Several studies on using CDMA technology onto RFID systems have been revealed (Fukumizu et al. 2006; Rohatgi 2006; Wang et al. 2006; Maina et al. 2007; Liu and Guo 2008). Rohatgi and Wang et al. both proposed methods of applying Gold sequences to RFID systems. However, due to the non-zero cross-correlation of each spreading sequence, the performance of this method deteriorates when there exists power inequality amount the tag backscatter signals. In general, a passive tag merely returns its response by backscattering the incident continuous wave, which is emitted from a reader. The strength of a received tag backscatter signal is determined by a variety of factors, including the power of the incident

continuous wave, the radar cross section (RCS) of the tag, the polarization of the tag antenna, the propagation loss in the tag-to-reader link, and so on. In order to mitigate the near-far problem, a sophisticated power control scheme is required. Unfortunately, the implementation of power control mechanism on each individual tag is impractical due to the limitations of the tag power and cost.

Maina et al. apply Walsh codes to spread the tag backscatter signals (Maina et al. 2007), which allows multiple tags to respond simultaneously. However, the paper does not reveal how to assign the spreading sequences to the tags, which reply in the same time slot. In addition, the demodulation and decoding process are not clearly mentioned in the paper.

Fukumizu et al. presents a scheme by applying both Walsh code and pseudo random sequence to solve the tag collision (Fukumizu et al. 2006). The approach is very similar to a modern wireless transmitter, such as a mobile phone. However, the scheme may not be suitable for a RFID system with passive tags due to the complexity constraint of the passive tags.

Liu and Guo proposed a method by applying Huffman sequences, which is nearly orthogonal to its delay version, to passive backscatter signals (Liu & Guo 2008). The Huffman sequences are more near-far resistant and can preserve code orthogonality without precise synchronization of received signals. Unlike aforementioned system, where each tag uses a unique spreading sequence, the proposed RFID anti-collision scheme uses only one Huffman sequence system for all tags. Consequently the reader can have the knowledge of the Huffman sequence used to spread the tag backscattering signal *a priori*, which can significantly reduce the complexity of reader design. Furthermore the tag backscatter signal spread by the sequence can be easily generated using a set of preset circuit with corresponding reflection coefficients, because only a Huffman sequence is used in a RFID system. However, no experimental results but simulation results are provided in (Liu & Guo 2008). In practice, in order to recover the backscatter Huffman sequence, the reader requires high sensitivity and low phase noise, which is quite a challenge in reader design.

It is noteworthy that all CDMA based anti-collision methods (in physical layer) need to incorporate with proper TDMA methods (in Media Access Control layer) to optimize the performance of the system throughput. Up-to-now scant researches dedicating in this issue have been found, which makes it an interesting future research topic. The details of the cross-layer design, however, are beyond the scope of this chapter.

2.3 Space Division Multiple Access (SDMA) based schemes

SDMA is a relatively new technology in modern communication systems compared with the rest three multiple access schemes. Typically, the SDMA architecture is capable of providing a collision-free access to the wireless channel and a qualitative delay-bounded communication in real time for delay sensitive applications. Because the SDMA method divides the available channels in spatial domain, the system can significantly increase the channel capacity of the same frequency and the same time slot.

In general, a SDMA scheme separates the coexisting transmission sources via the angle of arrival (AOA) of each signal source, which is also called as spatial signature. In the passive RFID system, this property is especially useful because it does not require any change of the physical communication protocol but use a reader with array antennas.

Several schemes using SDMA has been proposed (Abderrazak et al. 2006; Liu et al. 2007; Yu et al. 2008). In (Abderrazak et al. 2006; Yu et al. 2008), a reader employs multiple directive antennas (Abderrazak et al. 2006) or uses twice digital beam-forming (Yu et al. 2008) to

segment the reader coverage into several subsets. The tags in different subsets can be read in the same time; hence the throughput can be multifold of that of a conventional RFID system, where only one antenna is activated in the same time.
The trade-off between the system throughput and the complexity of the reader requires more attention, which is not well-addressed in the papers. Similar to CDMA methods, the technical challenge of seamlessly combining of TDMA and SDMA is remained unsolved. For instance, if the tags are not uniformly distributed in all subsets, the time slot allocation should be designed accordingly to optimize the system throughput. Thus it is expected that such a cross-layer anti-collision design will be an interesting research topic in the near future.

2.4 Frequency Division Multiple Access (FDMA) based scheme

The FDMA technology allows a number of transmission channels to work together at the same time by using different operating frequency. In a passive RFID system, the signal from the reader is usually broadcasted in some operating frequencies to provide power and reader's command to passive tags. A tag not only receives the power from the reader broadcasted signal but also utilizes the signal as the carrier of its modulated backscatter signals. Indeed, a tag can receive any signals within its operation frequency band and use the received signal as the carrier to backscatter its modulated signal. Thus it is possible to take the advantage of such a property to apply the FDMA technology to passive RFID systems.
The FDMA technology has been used in the ISO 18000-3 mode 2 HF RFID system (ISO/IEC18000-3 2004), which has 8 reply channels for simultaneous communication with 8 different RFID tags; however the FDMA technology has not yet been adopted in any passive UHF RFID standards.
(Liu et al. 2007) proposed a method that can allow a tag response happens in the different frequency band, which is called as multi-carrier backscatter. In (Liu & Ciou 2009) a feasible deployment similar to a cellular system is proposed as shown in Fig. 2. Each continuous wave emitter (CWE) occupies a different frequency which is different with that of its neighbor CWEs. Each tag in a CWE's coverage uses the continuous wave emitted from the CWE as the carrier of its modulated backscatter signal. In that way, a reader is able to correctly receive multiple tag response simultaneously by separating each individual tag response according to its carrier frequency.
Incorporating with the original framed slotted ALOHA scheme, the system throughput is nearly doubled because the idle time slots can be fully utilized as successful slots. However, the system still allows to retrieve one ID tag in a time slot. An optimal jointly combining TDMA and FDMA scheme, however, is not investigated in (Liu and Ciou 2009). With a proper protocol develop, it is reasonable to believe that the system throughput can be multi-fold faster than the current system. Another problem of the scheme is the system cost issue, which is expected to be reduced once the technology is more mature.

3. Conclusions

The RFID technology is a key technology toward the goal of internet of things. As RFID systems are pervasively deployed, our daily life will highly depend on the technology. High system reliability and performance will be demanded. Consequently the tag collision problems will keep drawing researcher's attention. Up-to-now most literatures use TDMA

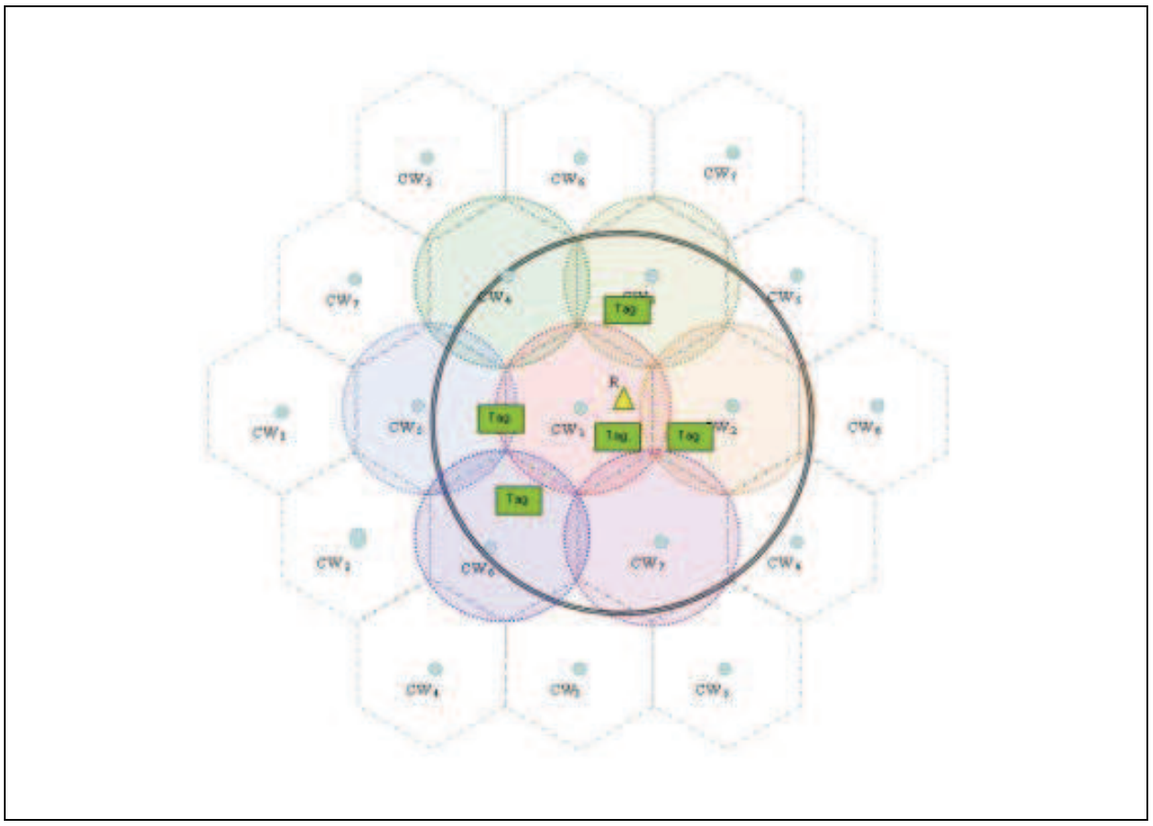


Fig. 2. A possible deployment of a multi-carrier RFID system, where R denotes the reader and CW*i* denotes that the CWE using the *i*-th frequency band.

based method to solve this problem. However, due to the nature of TDMA technology, only one tag ID can be retrieved in a time slot. In order to rapidly improve the system performance, similar to other modern communication systems, jointly using other multiple access schemes are required. So far, most papers deal with different multiple access schemes on RFID systems individually. To optimize the system throughput, it requires more advanced technologies such as cross-layer optimization technology. A passive RFID system, unlike other communication system, is an unbalanced client–server (tag-reader) structure, where the passive tag has power and cost constraints and hence can only perform low complexity anti-collision algorithm. The property results in the anti-collision scheme for passive RFID system a unique and challenging problem.

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5. References

Abderrazak, H., et al. (2006). A Transponder Anti-collision Algorithm Based on a Multi-Antenna RFID Reader, *Proceedings of 2nd Information and Communication Technologies, ICTTA '06.* , pp. 2684-2688.

Bonuccelli, M. A., et al. (2006). Tree slotted ALOHA: a new protocol for tag identification in RFID networks, *Proceedings of 2006 International Symposium on a World of Wireless, Mobile and Multimedia Networks*, pp. 603-608.

Burdet, L. A. (2004). RFID Multiple Access Methods, pp.15.

Dong-Her Shih, P.-L. S., David C. Yen, Shi-Ming Huang (2006). Taxonomy and survey of RFID anti-collision protocols, *Computer Communications*, Vol.29, pp.17.

Finkenzeller, K. (2004). RFID Handbook: Fundamentals and Applications in Contactles Smart Cards and Identification, Wiley.

Fukumizu, Y., et al. (2006). Communication Scheme for a Highly Collision Resistive RFID System, *IEICE TRANS. FUNDAMENTALS*, Vol.E89–A, No.2, pp.408-415.

ISO/IEC18000-3 (2004). RFID for item management – Air interface, Part 3: Parameters for Air interface communications at 13.56MHz, ISO/IEC Std. 18000-3, 2004.

Liu, H.-C., et al. (2007). A Frequency Diverse Gen2 RFID System with Isolated Continuous Wave Emitters, *Journal of Network*, Vol.2, No.5, pp.54-60.

Liu, H.-C. and Ciou, J.-P. (2009). Performance Analysis of Multi-Carrier RFID Systems, *Proceedings of 2009 International Symposium on Performance Evaluation of Computer and Telecommunication Systems*, pp. 112-116, Istanbul, Turkey.

Liu, H.-C. and Guo, X.-C. (2008). A Passive UHF RFID System with Huffman Sequence Spreading Backscatter Signals, *The Internet of Things, LNCS 4952*, pp.184-195.

Liu, Z., et al. (2007). A Novel Passive UHF RFID Transponder with Space Division Anti-collision Algorithm, *Proceedings of 7th International Conference on ASIC, 2007. ASICON '07.* , pp. 878-881.

Maina, J. Y., et al. (2007). Application of CDMA for anti-collision and increased read efficiency of multiple RFID tags, *Journal of Manufacturing Systems*, Vol.26, No.2008 The Society of Manufacturing Engineers. Published by Elsevier Ltd. All rights reserved,pp.7.

Okkyeong Bang , J. H. C., Dongwook Lee ,Hyuckjae Lee (2009). Efficient Novel Anti-collision Protocols for Passive RFID Tags, *Auto-ID Labs White Paper WP-HARDWARE-050*,pp.30.

Proakis, J. G. (1995). *Digital Communications*, McGraw Hill, Malaysia.

Rohatgi, A. (2006). Implementation and Applications of an Anti-Collision Differential-Offset Spread Spectrum RFID System, *Georgia Institute of Technology*.

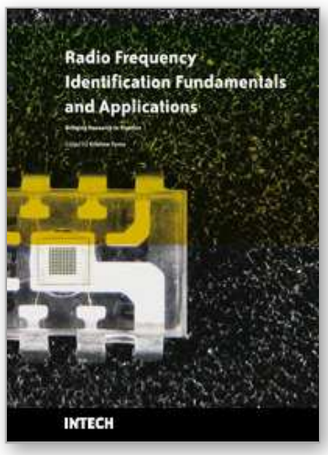
Shin, J.-D., et al. (2007). Hybrid Tag Anti- Collision Algorithms in RFID Systems, *Proceedings of ICCS, Part IV, LNCS 4490*,pp.693-700.

V. Sarangan , M. R. D., S. Radhakrishnan (2008). A framework for fast RFID tag reading in static and mobile environments, *Computer Networks*, Vol.52, No.2007 Elsevier B.V. All rights reserved, pp.16.

Wang, L.-C. and Liu, H.-C. (2006). A Novel Anti-collision Algorithm for EPC Gen2 RFID Systems, *Proceedings of 3rd International Symposium on Wireless Communications Systems (ISWCS'06)*, pp., Valencia, Spain.

Wang, P., et al. (2006). The Design of Anti-collision Mechanism of UHF RFID System based on CDMA, *Proceedings of IEEE Asia Pacific Conference on Circuits and Systems, 2006. APCCAS 2006.* , pp. 1703 1708.

Yu, J., et al. (2008). A Novel RFID Anti-collision Algorithm Based on SDMA, Proceedings of 4th International Conference on Wireless Communications, Networking and Mobile Computing, 2008. WiCOM '08. , pp. 1-4.



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The number of different applications for RFID systems is increasing each year and various research directions have been developed to improve the performance of these systems. With this book InTech continues a series of publications dedicated to the latest research results in the RFID field, supporting the further development of RFID. One of the best ways of documenting within the domain of RFID technology is to analyze and learn from those who have trodden the RFID path. This book is a very rich collection of articles written by researchers, teachers, engineers, and professionals with a strong background in the RFID area.

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