Performance Analysis of Aloha Protocol for RFID Communication Systems

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Summary
Automatic identification systems (barcode, smartcard, RFID…) are a common and a useful tools in manufacturing, supply chain management, payment system…Due to the low cost and its flexibility, radio frequency identification technology (RFID) has emerged a lot of applications (access control, antitheft car systems…) This technology aims to uniquely identify physical object attached to a so called tag or transponder. When the reader attempts to identify more than one transponder, it may face up a simultaneous interfering transmission from transponders which may causes a collision as tags share the same communication channel. For this generic multi access communication problem, several algorithms have been proposed to identify tags. These protocols are classified into deterministic approach and probabilistic collision resolution. The main focus of this work is to analyze the performance of aloha protocol in the case of RFID communication system

Key words:
RFID, medium access, collision, slotted-Aloha.

1. Introduction

Due to the research and development progress of information technology, automatic identification and data capture (AIDC) systems have become popular in common places in security application, and manufacturing process. These systems aim to provide information about items or persons. These systems are based on many technologies like bare code, OCR and biometric procedures. The former is a traditional technology that requires the use of scanners handled by users. Despite its low cost, this system suffers from several drawbacks [1] a line of sight is required between such reader and a tagged object; an operator needs to point the scanner to every object individually and scan it, as a result this system is not suitable for fast multiple objects identification [2] adds to that it could be affected by physical constraint like dirt, abrasion, limit storing data space. OCR and biometric procedures don't Allow object identification. RFID is a good alternative to identify both human and object entity, besides to this fact this technology support multiple identification object based on a so called anti-collision algorithms.

2. RFID Basic

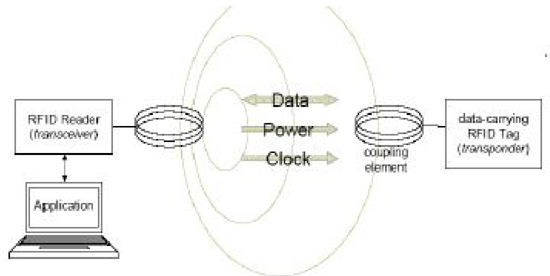

Fig.1 RFID system

RFID system is a kind of wireless communication it consists of three main parts:
- A base station (reader): this is the powerful entity which consists of a microcontroller and a modem designed to transmit energy to a transponder and to read information Back from it by detecting the backscatter modulation [3]
- One or more transponder: called also tag, it is composed of an antenna coil and a silicon chip that includes basic modulation circuitry with on board Rectification Bridge and a non volatile memory.

Management system: this is a data processing subsystem which can be an application or database depending on the application.

Passive tags are energized by a time-varying electromagnetic field (RF) wave (carrier) that is transmitted by the reader. When this RF field passes through an antenna coil, there is an AC voltage generated across the coil. This AC voltage is rectified to supply power to the transponder at the same time the tag divides down the carrier to generate an on board clock and begins

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clocking its data output transistor connected across the coil inputs [3].this amplitude fluctuation of the carrier wave is seen by the reader as an amplitude modulation hence it peak detects the amplitude modulated data and process the resulting bit stream according to the encoding and data modulation scheme used by the transponder.

3 Anti-collision Protocols

There are a lot of applications that requires a simple tag identification scenario, like access control and animal tagging. Due to the growth of new applications where multiple tag identification is a fundamental request, a problem called tag collision appears. When attempting to identify multiple RFID tags, the base station may faces up a simultaneous interfering transmission from transponders which may causes a collision as tags share the same communication channel. For this generic multi access communication problem, several algorithms have been proposed to identify tags efficiently, by reducing the number of read cycle [4] [5], or decreasing the collision probability. These protocols are classified as deterministic approach or probabilistic collision resolution [3] [4].
The first strategy aims to successively hold off subsets of tags that are involved in a collision until one tag sends its data. The second approach is inspired from aloha protocol which is a time-division multiple access [5], we distinguish a variant called slotted aloha where time is divided into discrete time intervals called slots and having the same size [5]. After the reader has sent a request indicating the available number of slots, each transponder selects randomly one time interval to transmit. When more then one tag selects the same time slot, a collision occurs and messages cancel each other. This situation leads to a retransmission which increases the identification delay. This paper aims to analyze the performance of Aloha protocol for RFID Communication Systems based on previous works.

3.1 ALOHA PROTOCOL

This protocol was originally developed in the University of Hawaii for use with satellite communication in the pacific. This is a simple protocol where once a tag gets in the powering field (base station interrogation area) it starts sending its ID according to "Tag talks first" behaviour. In the case of RFID systems this protocol is referred to the "Tag-Talks first" family; tag sends its ID upon entering a powering field. Due to the probabilistic behave of this protocol several tags could collide completely or partially. This state causes collided tag to retransmit after a randomly determined delay [6].the inability to detect or sense the channel make this protocol hard to implement in its simplest form.

3.2 SLOTTED ALOHA

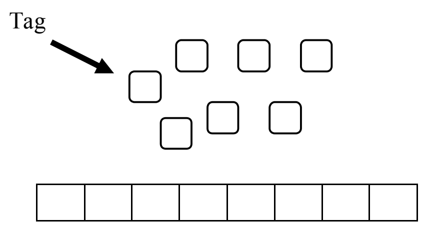

Fig.2 Slotted Aloha Example
Each tag selects randomly one slot to transmit, when more than one tag choose the same slot, collision occurs

Slotted aloha is a kind of pure aloha by adding a constraint to the later: time is divided into discrete time intervals called slot. Each slot has duration long enough for the reader to receive a tag response (tag's ID or any information) [7]. The reader generates a request to get tag serial number which consists of N slots. After receiving this information each transponder selects randomly one slot to send its ID. A successful identification means that a slot is occupied with exactly by one tag. Since slot allocation is a stochastic process multiple tags could select the same time slot, a collision occurs and data gets lost. Tag collision probability is closed to the number of transponder **T** and the amount of time slot **N**; in fact if the number of transponders (**T**) is small vs the number of slot (**N)** hence the probability of tag collision is low and the time required to identify all tags is short. But when the number of tags increases this probability increases and the time required identifying all tags becomes exponential.

4 Mathematical Model

In this section we describe a combinatorial model of the allocation of tags into slots. We denote by N the number of time slot in a time frame for one reading cycle, and by n the number of transponders. The read cycle starts

4.1Tag Model Distribution

The number t of tags in one slot is binomially distributed with parameters n and 1/N

$$B_{n,1/N}(t) = C_n^r \left(\frac{1}{N}\right)^t \left(1 - \frac{1}{N}\right)^{n-t} \quad (1)$$

By this distribution model we can give the expected number of tag by slot. This will be used to expect the numbers of transponders and hence to adapt dynamically the frame size.

4.2 Occupancy Problem

The allocation of tags to slots with in a time frame [8] belongs to the occupancy problem which was studied in the literature. This problem deals to the random allocation of balls to a number of bins where we are looking for the number of filled bins. Applying the distribution (1) to all the N slots we deduce the number of slots filled by t tags by the following equation:

$$a_t^{N,n} = N\, B_{n,1/N}(t) = N\, C_n^t \left(\frac{1}{N}\right)^t \left(1 - \frac{1}{N}\right)^{n-t} \quad (2)$$

Thus the number of empty slots is given by:

$$C0 = a_o^{N,n} = N\left(1 - \frac{1}{N}\right)^n \quad (3)$$

The number of slots filled with one transponder is given by:

$$C1 = a_1^{N,n} = n\left(1 - \frac{1}{N}\right)^{n-1} \quad (4)$$

Since the number of transponders is generally unknown, a scenario to identify all present tags within the base station interrogation area could be described as fellow:
- The base station sends the number of slots denoted N.
- receiving this information, each tag selects randomly one time slot to transmit.
- The base station estimates the number of tags.
- The number of slots is adapted to the number of tags.
- Successful identified tags move to sleep state hence they will note participate in the subsequent collection rounds
These steps are repeated until all tags are identified.

4.3Estimation tag function

Since in every collision, at least two tags are involved, a lower bound of the number of tag is given by: C1 + 2CK. Once this number is estimated the frame length could be adapted for the next reading cycle. Te following figure shows the error estimation for several frame length.

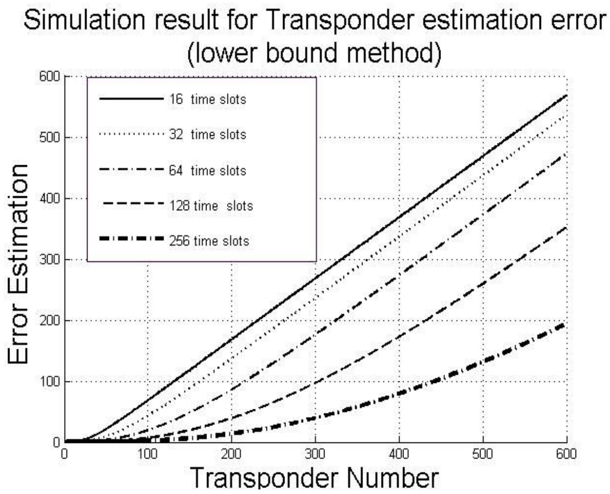

Fig.3 Error Estimation

The system utility (Figure 4) is defined as the channel efficiency which is the number of singly occupied slots divided by the frame size [9]. This parameter is an interesting metric to characterize the efficiency of the protocol. The frame size must be dimensioned to maximize the system utility. This could be a parameter to adapt the frame length to the number of transponder. In the literature this established when the number of tags equals the frame length.

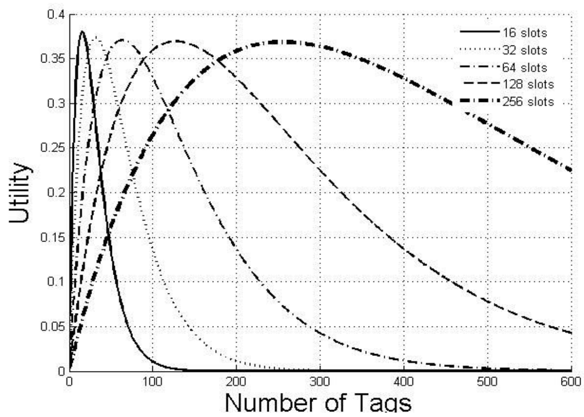

Fig.4 System Utility

The collision ratio is defined as the number of slot with collision divided by the frame length. An efficient protocol has to decrease this parameter. Figure 5 shows this parameter for different slot number.

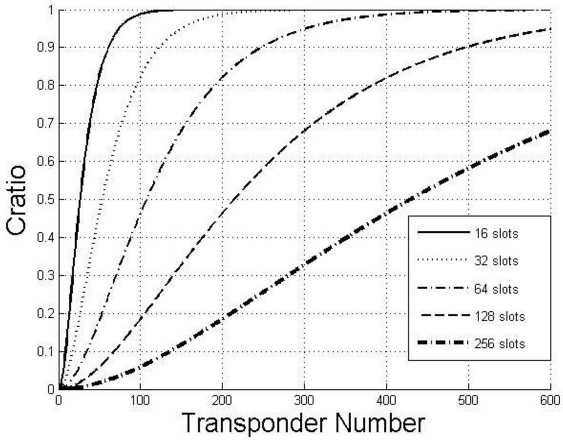

Fig.5 Collision ratio

3 Conclusion

Radio frequency identification (RFID) is an emergent technology that requires efficient protocols to enhance tag identification in the fastest delay. In this paper we described a simple scenario for multiple identification tags under the umbrella of slotted aloha protocol. Essential Performance metric (utility, collision ratio) was studied. For the next step we will start to use DSP technique to analyze colliding slots. We hope that this simple work could enhance the RFID studies..

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Hachani Abderrazak was borne in 1979 in Nabeul, Tunisia. He received the M.Sc. Degree in telecommunication in 2004 from the National School of engineer of Tunis (ENIT), and the M.Sc. Degree in Instrumentation from the National Institute of applied Science and Technology (INSAT). He is currently preparing his Ph.D. in 6'TEL laboratory / SUP'COM and the Electronic and Digital Communication Team, Faculty of Bizerte. His current research interests RFID systems, Access technique and pervasive computing Domain.