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# Simulation and Application of ISMA as Anti-collision Algorithm in RFID System to Improve its Performances by Capture Effect

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## ABSTRACT

In this article we are interested of the study of the influence of capture effect to improve the performance of RFID systems, especially the time of detection of tags and collision avoidance, and by taking a comparison between four algorithms we concluded that ISMA seems to be the best one to avoid collision. Here we simulated the whole system by a direct projection of the communication systems, by considering user terminals as tags and the access point as reader. If the capture effect is not taken into account, the system is modeled under wired communication and considered as wired system. We used here four algorithms of TDMA method: Aloha, Slotted Aloha, CSMA and ISMA as stochastic methods. The results illustrate better performance when using capture effect in both throughput of system and delay time, and ISMA shows the best performances compared to others.

**Key words:** RFID, anti-collision, Capture effect, ISMA.

## 1. INTRODUCTION

Agreement of set and rules among users for successful transmission of information using a common medium is called multiple access protocols. Whenever a resource is used and accessed by more than one independent user, the need for a multiple access protocol arises. In the absence of such protocols, conflicts occur if more than one user tries to access the resource at the same time as in RFID systems where we define this problem as collision problem which can be divided mainly on two categories: tag collision and reader collision.

The multiple access protocols addressed here are those used in wireless communication systems in which the resource to be shared is the communication channel [1]. When using a common medium with an access point (reader) for each user (tag) by a direct projection into an RFID system [2], [3], the point-to-point links can be simultaneously shared by many users; thus, a multiplexing technique is needed.

This article is organized as the following: section II talk about the system modeling, section III: details of anticollision algorithms that we used: ALOHA, Slotted Aloha, non-persistent Carrier Sense Multiple Access (CSMA) and slotted and non-persistent Inhibit Sense Multiple Access (ISMA) to evaluate the characteristics of delay time and throughput of the system in section IV and a conclusion in section V.

## 2. RFID SYSTEM MODELING

To perform RFID system simulation accurately and effectively, we must take into consideration several parameters such as [2], [3]: packet generation, collision problem, the capture effect which is mainly the key word of this work which makes the difference in evaluation parameters.

The throughput and the average transmission delay are the principle parameters by which we can evaluate and judge the efficiency of an RFID system (Figure 1).

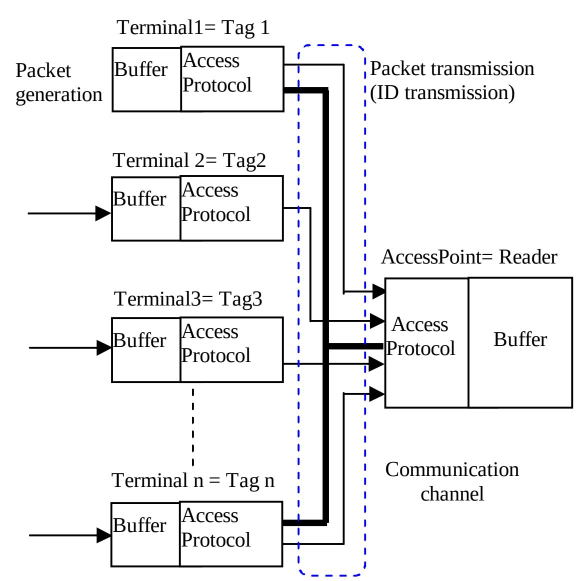


**Figure 1**: Configuration of our RFID system

### 2.1 Collision

Collisions of packets occur when several packets collide on the communication channel.

In wired communication system: All collided packets are destroyed, and the transmission of a packet is regarded as a failure, because the signal levels of all packets are the same. If no collisions occur, the generated packet is successively transmitted to the destination.

In wireless communication system: The received power of each packet is dependent on the position of the access terminal and the condition of communication channel. Therefore, even if several packets come into collision, the packet that has the largest received power sometimes survives, this is called capture effect.

- **Capture effect**

The phenomenon of capture effect is one of the key parameters to be taken in consideration while evaluating the overall performance of RFID systems.

For this article, it is possible to take advantage of the capture effect and increase the performances of the stochastic anti-collision algorithms by choosing the appropriate threshold (T) in the reader, which acts as a filter for the weak signals. As a result, the reader identifies the tag even if collision has occurred. The value of T which is called capture ratio indicates the amount by which a data packet must be stronger than others to be detected by the receiver without error [4]. For example, the throughput S in the Slotted Aloha algorithm with the capture effect is given by:

$$S = G * e^{-\left(\frac{T*G}{1+T}\right)} \qquad (1)$$

### 2.2 Offered Traffic

The total amount of packets, including newly generated packets and retransmission packets at the reader in a time interval, is called offered traffic. The normalized offered traffic by a transmission data rate is stated as G.

### 2.3 Throughput

The total amount of the packet successfully transmitted to the reader in a time interval is called *throughput,* and the normalized throughput by the data transmission data rate is shown as S.

### 2.4 Average Transmission Delay

The period for which a packet is generated in a tag, transmitted to the reader, and received at the reader is called the average transmission delay. The average transmission delay is dependent on the length of packet. Therefore, the normalized average transmission delay with regard to the length of the packet is shown as D. Originally, the average transmission delay is dependent on the period when a packet is generated and transmitted from a tag, and the distance between the reader and a tag and signal processing time at reader [1]-[5].

### 2.5 Evaluation of the Access Protocol

The most fundamental elements used to evaluate the access protocol are offered traffic G, throughput S, and average transmission delay D. In the ideal access protocol, the throughput refer to "(2)," [1]:

$$S = \begin{cases} G & \text{for} \quad G < 1 \\ 1 & \text{for} \quad G \geq 1 \end{cases} \qquad (2)$$

## 3. ANTICOLLISION PROTOCOLS

The Figure 2 describes the procedure used to evaluate the throughput and delay time of an access protocol. The simulation process ends when the number of successfully transmitted packets is equal to the required user-defined number. To achieve simulations, appropriate protocols should be selected. Among those widely used in wireless systems, pure ALOHA, slotted ALOHA, non-persistent pure CSMA, and slotted and non-persistent ISMA protocols need to be evaluated to further determine the transmission delay. Table1 shows the simulation conditions to model our RFID communication channel.

**Table 1**: Simulation conditions

| | | |
|---|---|---|
| R | Service area radius | 10m |
| Bxy | Height of the access point | 5m |
| Mnum | Number of terminals | 100 |
| Srate | Symbol rate | 256 symbols/s |
| Plen | Length of the packet | 128 symbols |
| Alfa | Distance attenuation fixed number | 3 |
| Sigma | Standard deviation of the logarithm normal distribution | 6dB |
| Mcn | *C/N* in the access point when transmitted from the area edge | 30 dB |
| tcn | Capture ratio | 10 dB |

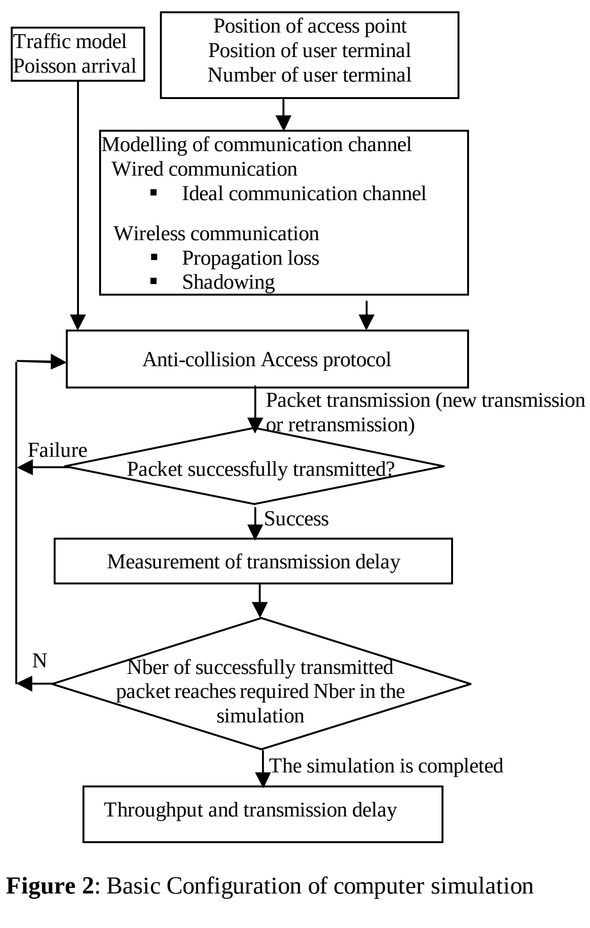


**Figure 2**: Basic Configuration of computer simulation

### 3.1 Pure ALOHA

Pure ALOHA is a protocol in which tags transmit their packets randomly, so all the tags do not mind whether the communication channel is busy or not. If the length of each packet is fixed and the period to transmit a packet is T, a packet can be successfully transmitted to the reader when other packets do not start to transmit during 2 T. Therefore, the throughput S of pure ALOHA for the offered traffic G is shown as follow [1], [2]:

$$S = G \cdot e^{-2G} \quad (3)$$

Where the maximum throughput is 0.184 when G=0.5.

### 3.2 Slotted ALOHA

Since the messages are required to be sent in the slot time between two synchronization pulses, if the sending started only at the beginning of a time slot, the rate of collisions can be reduced by half leading to slotted ALOHA [1]-[4]. In this protocol, the packet generated in a time slot is transmitted in the next time slot. If more than two packets are generated in a time slot, a collision occurs. Therefore, the throughput S of slotted ALOHA for the offered traffic G is given as [1]-[4]:

$$S = G \cdot e^{-G} \quad (4)$$

Where the maximum throughput is 0.368 when G=1.

### 3.3 Non-persistent CSMA

The name carrier stems from the fact that the existence of the carrier wave on the communication channel is sensed by tags. By using carrier sense, it is possible to judge whether other tags are transmitting their packets, because each tag does not transmit any carrier wave except for its packet transmission. If a carrier wave is sensed on the communication channel, the condition is called "**busy**"; otherwise, it is called "**idle**" The CSMA is a protocol that decides whether packet transmission should start as the result of a carrier sense. When the result is "**busy**" the next action to avoid collision is needed.

Non-persistent CSMA, presented in this section, is one of the protocols that avoid collisions. In the non-persistent CSMA, when packets are generated in a tag, the tag starts the carrier sense. If the result of a carrier sense is "**idle**" the packet is transmitted to the reader immediately. However, if the result of carrier sense is "**busy**" the tag stops the carrier sense, waits for a while, and then starts the carrier sense again. The waiting time is a key point to realize a system with high throughput.

In the CSMA, the collision of packets occurs although each tag performs carrier sense. One of the reasons is propagation delay time. In a real communication system, when a tag transmits its packets, other tags detect the transmission from the propagation delay time. If other tags transmit their packets during the propagation delay time, collisions occur at the reader. The propagation delay time is dependent on the distance between tags. In most cases, it is assumed that the propagation delay time is the same in the system and that the normalized propagation delay time that is normalized by the period is needed for packet transmission from a reader to each tag.

Moreover, in a wireless communication system, the carrier sometimes cannot be sensed at some tags even if a tag transmits packets, because some obstacles may exist between the tags. The problem is called the "**hidden terminal**" problem.

The throughput S of non-persistent CSMA for the offered traffic G is shown as follows [1]:

$$S = \frac{G \cdot e^{-\alpha G}}{G(1 + 2 \cdot \alpha) + e^{-\alpha G}} \quad (5)$$

Where $\alpha$ is the normalized propagation delay. The throughput S is obtained under an ideal communication environment where no hidden terminal exists

### 3.4 Slotted np- ISMA (Inhibit Sense Multiple Access)

ISMA is one solution that has been offered to solve this hidden access-terminal problem. The ISMA is a system that can solve hidden access-terminal problems by informing the communication channel of **busy** or **idle** conditions from the reader to the tag. In the ISMA, the reader sends a busy signal to all tags when the reader is receiving packets from tags. On the other hand, the reader sends an **idle** signal when the reader is not receiving any packets. When each tag receives the **idle** signal, each tag must decide whether to transmit packets to the reader or not.

By taking a normalized propagation delay *d*, the busy slot must be more than (1+d)*T and the **idle** slot must be at least more than d*T. The throughput S of slotted non-persistent ISMA for the offered traffic G and under an ideal communication channel is shown as [1]:

$$S = \frac{dG^{-dG}}{1 + d - e^{-dG}} \quad (5)$$

## 4. SIMULATION RESULTS

As shown in Figures 3 and Figure 4 for pure ALOHA, when the capture effect is not considered, the throughput is close to the theoretical value even if the number of tags is 100. On the other side, when the capture effect is considered, the throughput increases while the average transmission delay is reduced. This is due to the fact that in pure ALOHA, collisions often occur. Here, the normalized propagation delay $\alpha$ was set to 0.01 or 0.1. If $\alpha$ is small the maximum throughput of algorithm is higher than that when $\alpha$ is large, it means that we make less time to identify all data packets and the time of identification is increased rapidly**.**

The simulation results of throughput and average delay for the four protocols considered in this paper, i.e., ALOHA, np-ISMA, CSMA are shown in Figure 5 and Figure 6.

We can see clearly the best performance of throughput and average delay time for non-persistent ISMA by considering the capture effect. In the case of the non-persistent ISMA protocol, the normalized propagation delay *d* was set to 0.01 and 0.1. If the capture effect is considered, a transmitted packet sometimes survived because the received powers for arrival packets were different from each other. Therefore, the throughput increased. The maximum throughput of the slotted non-persistent ISMA was dependent on the normalized propagation delay.

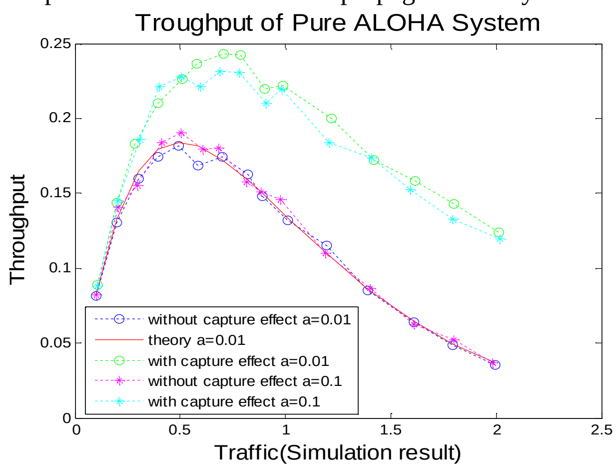


**Figure 3**: Offered traffic and throughput of pure ALOHA

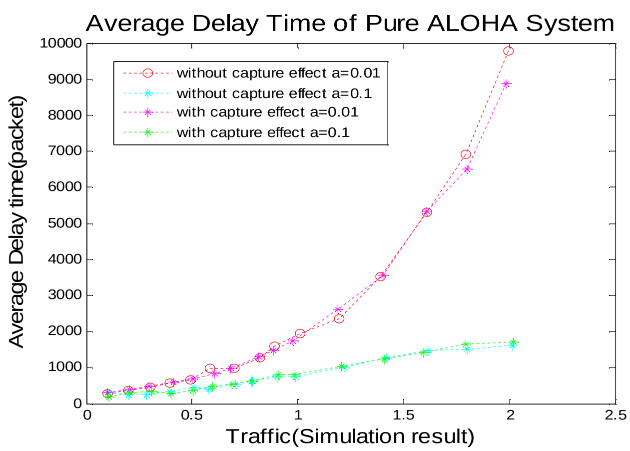


**Figure 4**: Offered traffic and delay time of pure ALOHA

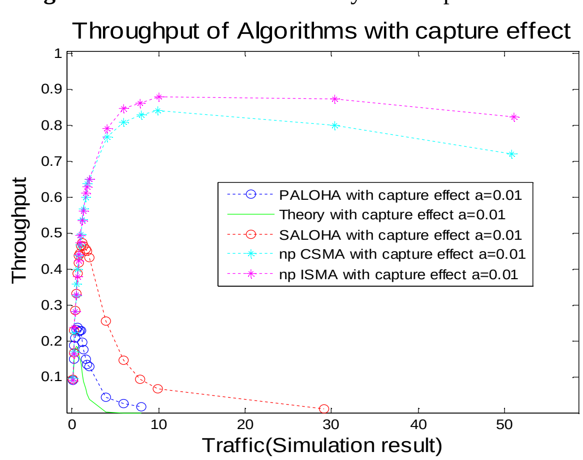


**Figure 5**: Throughputs of the 4 algorithms with capture effect

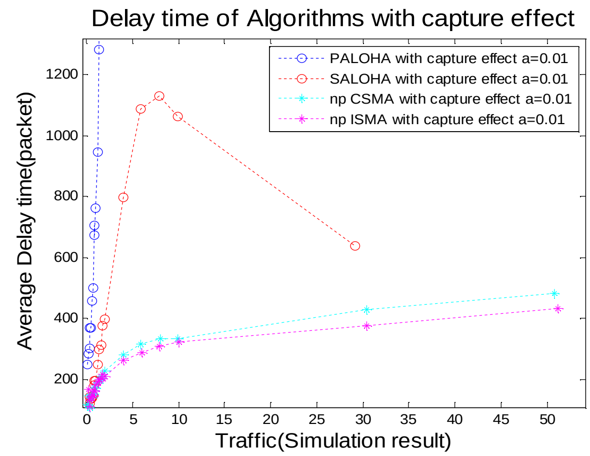


**Figure 6**: Delay time of the 4 algorithms with capture effect

Figures 7 and 8 illustrate a comparison between the four algorithms: ALOHA, Slotted ALOHA, CSMA and ISMA without capture effect and when using it. The graphics in Figure 7 shows best performance oh throughput when using capture effect because of the detection of signals having superior amplitude compared to others, so it can be used as a good factor to reduce the amount of tags in collision. The same remark is given for delay time throw Figure 8 where we see a good improvement in time to detect a given tag, so the tags having signals less than the threshold fixed by the capture effect can't be taken in consideration, and they can't be detected completely which reduce the number of tags entering in collision.

All performances are summarized in Table 2 for the four algorithms with and without capture effect with G=2 and d=0.01s.

**Table 2**: Performances summary of the four algorithms: Throughput and delay time with and without CE (without capture effect)

| | Throughput (%) | | | |
|---|---|---|---|---|
| **Algorithms** | **Aloha** | **SAloha** | **CSMA** | **ISMA** |
| Without CE | 0.18 | 0.36 | 0.81 | 0.82 |
| With CE | 0.24 | 0.48 | 0.84 | 0.85 |
| | **Delay time (µS)** | | | |
| **Algorithms** | **Aloha** | **SAloha** | **CSMA** | **ISMA** |
| Without CE | 25 | 3 | 1.5 | 1.4 |
| With CE | 6 | 1.8 | 1.1 | 0.9 |

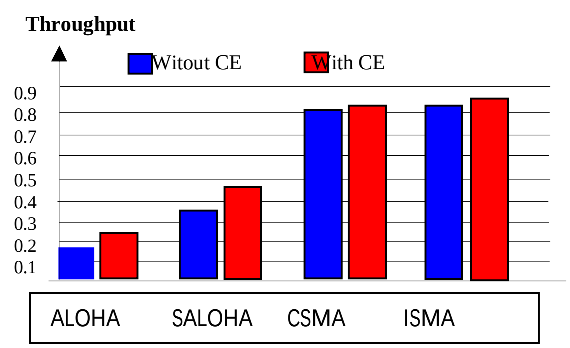


**Figure 7**: Comparison of the 4 algorithms throughput with and without capture effect

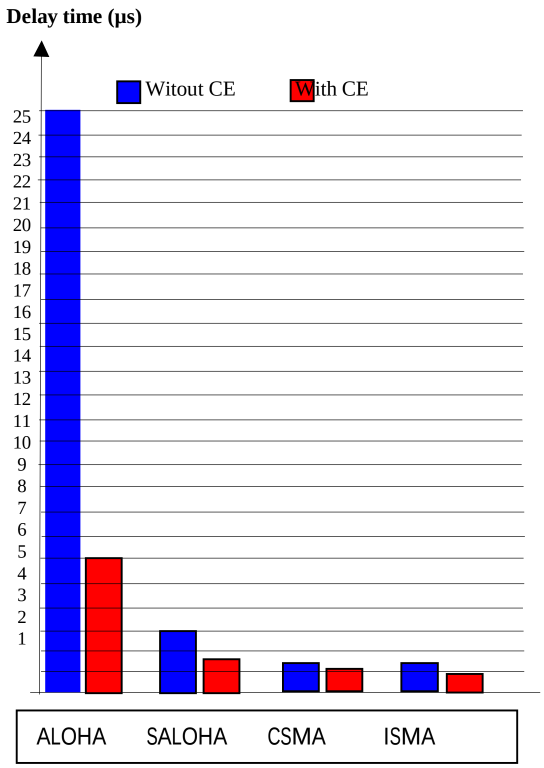


**Figure 8**: Comparison of the 4 algorithms delay time with and without capture effect

## 5. CONCLUSION

In this paper, we introduced some typical protocols used in communication systems that we have applied to RFID systems by considering tags as user terminals and reader as access point. By taking into account the capture effect, the overall system performance was efficiently evaluated with regard to the throughput and average transmission delay.

From the obtained results, np-ISMA looks to be the most efficient and thus, can be successfully applied to enhance the performance of RFID systems for fast tag detection and collision avoidance. The maximum throughput of the slotted non-persistent ISMA was dependent on the normalized propagation delay.

Moreover, if the capture effect is considered, a transmitted packet sometimes survived because the received powers for arrival packets were different from each other. Therefore, the throughput increased.
We have presented a humble contribution to evaluate the performances of the conventional ones and to study the capture effect influence in the case of RFID systems compared with the communication channel or communication systems.

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