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Persistent Q Anti-collision Algorithm for RFID

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Abstract—In passive Radio Frequency Identification Systems (RFIDs), the interrogator should energise clients within range and use their backscattered replies to identify an inventory as quickly as possible. However, at the interrogator replies from two or more energised clients may collide and collided clients may not be identified. Therefore, collisions increase the number of timeslots needed to record an inventory. Reducing the number and frequency of collisions is an important and topical area research in RFID. Previously for passive Ultra High Frequency RFID the problem of collisions has been addressed using an ALOHA based protocol called the Q-Selection Algorithm. In this paper, a more efficient algorithm is presented that is shown to reduce the number of timeslots needed to record an inventory by approximately 30% when compared to the existing Q algorithm.

Index Terms—Collision Resolution, RFID, tag anti-collision, frame ALOHA, Q algorithm, tag identification, low power tags, Electronic Product Code, UHF RFID.

I. INTRODUCTION

Radio-frequency identification (RFID) is the wireless use of electromagnetic fields to transfer data over distance, for the purposes of automatically identifying and tracking tags attached to objects. Such technology may provide an efficient and low cost way to stock take even in poor propagation environments such as shopping areas with many diffracting and reflecting edges and surfaces. RFID systems have two components, RFID transponders (tags) and RFID readers (interrogators). Typically, the interrogators are active (powered by batteries) and the clients are passive and gain their energy from the interrogator. Generally, in a system there are many more clients than interrogators. At the receiver, signals from more than one clients may collide wasting power and bandwidth. An optimal RFID interrogator should identify the maximum number of tags in the shortest period. Client collision avoidance algorithms (CCAs)[1] are therefore an important research topic. CCA algorithms can be divided into three main groups, those using a binary tree algorithm [2][3] and those using an ALOHA method[2][4] and hybrids between the two[5].

Several types of interrogator with differing radio methods exist. These include interrogator enabled smart phones, SD Card Interrogators, Bluetooth and ZigBee Interrogators. A client will have a unique EPC code. The EPC code consists of an EPC type, Manufacturer code, product type and serial number.

The process begins with when the interrogator takes an inventory. An inventory is typically a partial set of addresses from a larger set. For example, the whole set may consist of

clothing clients but a subset may consist of a type of clothing such as socks or shoes. The subset is chosen by masking bits. At start the interrogator broadcasts a query command. All clients within range will be energized by energy from the interrogator and, if their ID is within the inventory set, will attempt to send their backscattered replies. The number of clients in range cannot be known in advance and therefore the number of slots in a frame may need to be adjusted from an initial guess so that all clients can be served. In 2006, to deal with multiple clients in range, the ISO adopted the standard ISO 18000-6 Type C that includes an anti-collision called the Q-algorithm [5][7]. The Q algorithm allows interrogators to adjust frame time to any number of time slots. Slots are typically adjusted according to $(2^Q - 1)$ with $Q \pm 1$. An initial guess for Q typically being 4. When a client receives a query, it will internally generate a random 16bit random number (RN16). If $Q=4$ then the last 4 bits of this RN16 number will be used by the client as a slot counter (SC). Figure 1 shows the model we have used for our simulations with exchanges between an interrogator and the first three clients. In the figure client 1 randomly selected 1 as a slot counter. The interrogator acknowledges client 1 which transmits its EPC. Having been served, client 1 is then killed and all other energised clients decrement their slot counter by one.

Fig. 1. Q Algorithm Schematic Model

In the figure clients 2 and 3, having randomly chosen the same start value for their SC collide in the next slot. In this work we do not consider the capture effect therefore neither client receives an acknowledgement. The interrogator senses the collision and the Q-algorithm increases Q by 1 and this increases the number of slots in the next frame by a power of 2 reducing the probability of further collisions but increasing the frame length and increasing the time needed to complete the inventory.

We propose an alternative to the Q-algorithm that converges to a completed inventory more quickly.

II. PERSISTENT Q ALGORITHM

To reduce the frequency of changes to Q value and therefore lower the power requirements of the system this paper puts forward a novel algorithm we have called the Persistent Q algorithm (PQA).

The process of the PQA shown in Table 1. Consider the inventory cycle in state k . Q_{k-1} is the Q value used for the previous Query command, Q_k is the Q value of the current Query command and Q_{k+1} is the Q value of the next Query command.

TABLE I PERSISTENT Q ALGORITHM(PQA) PROCESS

NO OF CLIENTS CHOOSING SC=0	0	1	>1
LIKELIHOOD	SC>No.Energised Clients	SC=Optimal	SC<No.Energised Clients
ACTION	$Q_{k+1}=Q_k$	$Q_{k+1}=Q_k$ IF $Q_{k+1}=Q_{k-1}$ then $Q_{k+1}=Q_{k+1}+1$	$Q_{k+1}=Q_k+1$ If $Q_{k+1}=Q_{k-1}$

Proof: at first, we assume that the frame size formula is

$$L = (m - 1) + 2^Q - 1 \quad (1)$$

Here m is the number of tags which select slot 0. Using the work of Schoute [11] the number of tags in a collision can be estimated. If m tags select slot 0 in a frame, we can estimate there are $(m-1)$ tags more than the number of slots. Therefore, in PQA, the Query Adjust command used for the next frame adds $(m-1)$ slots. Thus, rather than the coarse increase in frame length by powers of 2, the frame length is adjusted in proportion to an estimate of collisions.

In the estimation method [12], the lower bound is given as

$$N=S+2C \quad (2)$$

In which N is the total number of clients, S is the number of successes, and C is the number of collisions.

According to Schoute[11], clients are subject to Poisson Distribution of $\lambda = 1$ when choosing timeslots. Let P_s and P_c represent the probability of success and collision in a single slot respectively. So

$$P_s = P(k = 1) = \frac{\lambda^k}{k!} e^{-\lambda} |_{\lambda=1} = e^{-1} \quad (3)$$

$$P_c = P(k > 1) = 1 - P(k = 1) - P(k = 0) \quad (4)$$

$$= 1 - 2e^{-1}$$

$$N_c = \frac{N_t}{N_s} = \lim_{N \rightarrow \infty} \frac{(1-P_s) \times N}{P_c \times L} \quad (5)$$

Here N_c is the average number of clients in a collision slot, N_t is the number of collided clients in a frame, and N_s is the number of collision slots in a frame. L is the total number of

slots. $L=N$ concludes to the highest system efficiency. So, from Eq. 5, the number of tags within each collision slot is approximately 2.39.

$$N = S + 2.39C \quad (6)$$

Using this method, our PQA algorithm rounds 2.39 to 2 yielding $m=2$. This value is used in Eq. 1. The frame length adjustment formula is set to $L = 2^Q$.

III. PERFORMANCE ANALYSIS OF PQA

A numerical simulation was written in MATLAB to compare the performance of PQA with the original Q algorithm. The assumption was made that all commands and responses from the interrogator and the client were of an arbitrary but equal length. Further that the capture effect was not implemented at the receiver and that the clients were capable on incrementing their slot counter by values other than a power of two.

Fig. 2. Comparison in Q levels between the Q Algorithm (top) and PQA (bottom)

Fig. 3. Comparison of original Q versus PQA – changes of Q versus inventory size.

The results in Figure 2 compare the Q algorithm with PQA for an example inventory of 100 clients. The changes in

Q are plotted against communication times. It can be seen that PQA identifies the 100 clients in fewer communication times (cycles) and with fewer changes in the Q value.

From Figure 3, it can be observed that the rate of change of Q value in PQA has decreased significantly when compared with the original Q Algorithm. For example, to identify 100 clients PQA triggers only approximately 70% of the changes in Q required by the original algorithm. Since each change in Q requires an adjust command to be broadcast by the interrogator it is reasonable to state that PQA will be more power efficient than the original algorithm.

IV. CONCLUSIONS

In this paper, the PQA algorithm based on the C1G2 EPC Q algorithm is proposed. Simulation results show that the change frequency of Q value of the algorithm is reduced by 35%, the search timeslots decrease nearly 30%, the system efficiency is maintained at a 20% higher level peak throughput when compared to the original Q algorithm.

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