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Anti-collision Scheme Analysis of RFID System

Zhongxiang Wang, Dan Liu, Xiaofang Zhou, Xi Tan, Junyu Wang, Hao Min

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Zhongxiang Wang
M.S. student
Auto-ID Lab at Fudan University

Dan Liu
M.S. student
Auto-ID Lab at Fudan University

Xiaofang Zhou
Research Director
State Key Lab at Fudan University

Xi Tan
Ph.D. student
Auto-ID Lab at Fudan University

Junyu Wang
Associate Director
Auto-ID Lab at Fudan University

Hao Min
Research Director
Auto-ID Lab at Fudan University

Contact:

No. 825 Zhang Heng Road,
Zhangjiang High-Tech Park,
Shanghai,
China ,
201203

Phone: +86 21 5135 5188

E-Mail: dliu@fudan.edu.cn
Internet: www.autoidcenter.cn

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Abstract

Anti-collision algorithms are very important to solve the anti-collision problem in multi-tag and multi-reader environment. The anti-collision algorithm is divided into the anti-collision algorithm for multiple tags and the anti-collision algorithms for multiple readers. The anti-collision algorithms for multiple tags are largely divided into tree-based deterministic algorithms and slot aloha-based probabilistic algorithms. In this paper, different multi-tag anti-collision algorithms compatible with the EPC Gen2 protocol (ISO 18000-6C protocol) are analyzed and simulated under different conditions, and the latest UHF frequency allocation regulation of China is taken into consideration.

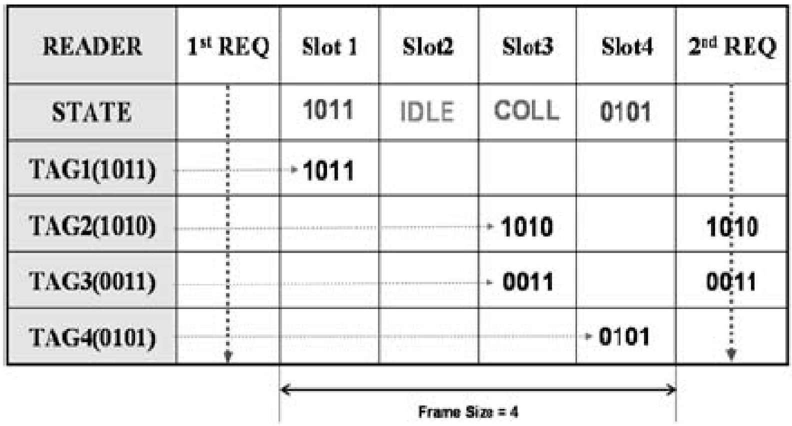
1. Introduction

In the RFID system, tag identification is performed by the reader's query to a tag and then the tag's backscattering its identifier as its response, but if there are multiple tags in the area, some of them might respond simultaneously and leads to collisions which decreases throughput. Besides, in many applications there would be more than one reader in which case most of them might read simultaneously, signals from one reader will interfere with other reader ‘s query to the tag population. Specifically, in large-scale electronic supply chain systems that process a large amount of objects in real time, anti-collision algorithm is essential to perform multiple tag identification (Auto-ID Center, 2003). Our paper mainly presents analysis and comparison of different anti-collision algorithms compatible to EPC GEN2 protocol.

The structure of this paper is organized as follows: Sect. 2 generally reviews previous researches on anti-collision algorithms. Sect. 3 introduces the mathematic fundamentals used in the anti-collision algorithms. Sect. 4.1 explains the tag collision problem in EPC GEN2 protocol; Sect. 4.2 introduces existing 9 transmission schemes, and of which the performance are evaluated; Sect.4.3 evaluates the performance of existing dynamic anti-collision algorithms. Sect. 5 introduces our simulation platform. Sect. 6 discusses the advantages and disadvantages of the algorithms in previous section and our future work.

2. Related work

Anti-collision algorithms for multiple tag identification are largely divided into tree-based deterministic algorithm and slot aloha-based probabilistic algorithms. Deterministic algorithms form a binary tree with tag identifiers expressed in binary bits and identify tags through browsing the nodes in the tree. In this type of algorithms, we can predict the process of tag identification. This type of algorithm is again divided into memory algorithms and memoryless ones. In memory algorithms, the response of a tag is determined by the query to the tag and the current state of the tag and thus each tag must remember its state. Representative memory algorithms are Splitting Tree (Hush, D.R., Wood, C., 1998) and Bit-arbitration (Jacomet, M., Ehrsam, A., Gehrig, U., 1999). In memoryless algorithms, on the other hand, the response of a tag is determined only by the query to the tag. This type of algorithms is a good approach for simple implementation of tags as well as for low cost, low power and small size. Representative memoryless algorithms are Tree-walking algorithm (Juels, R.L. Rivest, 2003), Query Tree (Law, C., Lee, K.,Siu, K.-Y., 2000) and Collision Tracking Tree (Quan, C.-H., Hong, W.-K., Lee, Y.-D., Kim, H.-C., 2004).



READER	1st REQ	Slot 1	Slot2	Slot3	Slot4	2nd REQ
STATE		1011	IDLE	COLL	0101	
TAG1(1011)		1011				
TAG2(1010)				1010		1010
TAG3(0011)				0011		0011
TAG4(0101)					0101	

Figure 1: The basic slot aloha-based probabilistic algorithm

Probabilistic algorithms are based on aloha protocol. Each of tags in a reader's identification area selects one of given N slots to transmit its identifier; all tags will be recognized after a few frames. Probabilistic algorithms are again divided into ID-slot algorithms and Bit-Slot (Kim, C.-S., Park, K.-L., Kim, H.-C., Kim, S.-D., 2004). In ID-slot algorithms each tag sends its identifier in a slot while in Bit-Slot algorithms each tag sends segment of its identifier. Representative ID-slot algorithms are I-Code (Vogt, H., 2002) and STAG (Slotted Terminating Adaptive Collection). All the algorithms in this paper belong to ID-slot algorithm.

3. Mathematic fundamentals in anti-collision algorithm

In the probabilistic model to estimate the number of present tags to approximate in the number of actuality tags, Binomial distribution becomes good method by a probabilistic model. The distribution (Su-Ryun Lee,Sung-Don Joo, Chae-Woo Lee, 2005) applies to all L slots, thus the expected value of the number of slots with occupancy number r is given by a_r .

$$a_r = L \times C_x^r \left(1/L\right)^r (1-1/L)^{x-r}$$

So the expected number of empty slot, representative by h, singly-occupied slot, s, and collided slots c are given by following equations:

$$\begin{cases} h = a_0 = L(1-\dfrac{1}{L})^x \\ s = a_1 = x(1-\dfrac{1}{L})^{x-1} \\ c = c_k = L - a_0 - a_1 \end{cases}$$

The system efficiency is defined as the ratio of successful slot -s- compared to the frame size -L. Here, we assume that every slot is of the same length.

$$P = \frac{s}{L} = n\frac{1}{L}\left(1-\frac{1}{L}\right)^{n-1}$$

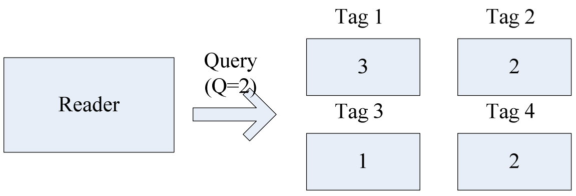
It is proved that the highest efficiency can be obtained if the frame size (means the total number of slots in a frame) is equal to the number of tags provided that all slots have the same fixed length:

L(optimal)=n

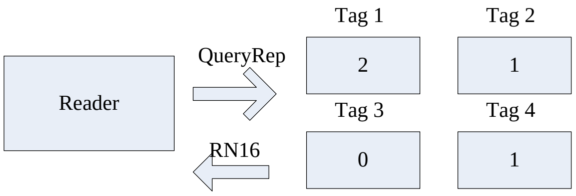
4. Anti-collision scheme for multi-tags

4.1. Tag collision problem in EPC GEN2

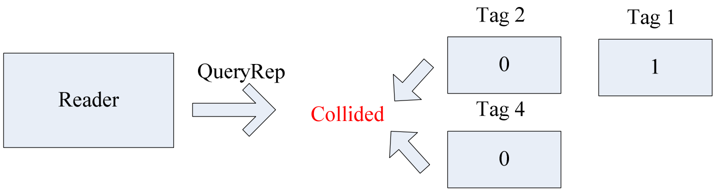
EPC GEN2 protocol (EPCglobal, 2005) is fundamentally the framed slotted ALOHA, in which reader “selects” a portion of the tag population firstly, then issues “QUERY(Q)” to announce the frame size to the tags (Q is the index of frame size, $L = 2^Q$), then each selected tag will pick a random number within 0 to $2^Q - 1$ as its slot counter which is decremented every time it receives a QueryRep command, and it shall backscatter an 16-bit random number (RN16) when its slot counter reaches 0, and it will not transmit its EPC until it has received a valid “ACK” from the reader. Figure 2 exhibits successful, empty and collided slot



a) Empty slot



b) Successful slot



c) Collided slot

Figure 2: Empty slot, successful slot, collided slot diagrams in EPC GEN2 PROTOCOL

What we should do to improve the identification efficiency is to choose an optimal frame size. It is proved that the system efficiency will reach the maximum value, e.g. $1/e$ (Cheng-Hao Quan, Won-Kee Hong, Hie-Cheol Kim, 2006), when the frame size ($L = 2^Q - 1$) is equal to the number of tags in the read area. As a result, the problem of anti-collision is the problem of estimating the number of tags in the work range of the reader. In section 4.2 and 4.3, we will present different anti-collision algorithms to solve this problems and corresponding simulation results.

4.2. Static environment

4.2.1. Introduction to static algorithms

1) Schoute

In (F. C. Schoute,1983), a backlog (means the total number of tags that have not been read) estimation algorithm is developed for framed ALOHA. In this algorithm, the frame size is chosen by assuming that the number of stations which transmit in each time slot is Poisson distributed. The backlog after the current frame Bt is then simply given by:

$$Bt = 2.39c$$

Where c represents the number of collided slot in the current frame.

2) Lower Bound

The estimation function is obtained through the observation that a collision involves at least two different tags. So backlog after the current frame Bt is then simply given by:

$$Bt = 2c$$

Where c is the number of collided slot in the current frame.

3) Vogt

In (H. Vogt, 2002), a procedure to estimate backlog is presented by minimizing the difference between the observed value, including number of empty slot h, singly-occupied slot s, and collided slot c, and the expected value E(H),E(S),E(C): In order to find the comparative precise backlog, the reader needs to resolve the equation below.

$$\min_N \left| \begin{pmatrix} h \\ s \\ c \end{pmatrix} - \begin{pmatrix} E_N(H) \\ E_N(S) \\ E_N(C) \end{pmatrix} \right|$$

4) Q Frame-by-frame Algorithm

The Q frame-by-frame Algorithm (EPCglobal, 2005) represents another transmission control strategy. It keeps a representation of the current frame size which is multiplied by a constant β whenever a collision occurs and which is divided by β whenever an empty slot is detected. While the Q algorithm requires only modest computational resources, it does not specify a method to compute the crucial control parameter β. It only provides a range of suitable values (1.07 ≤ β ≤ 1.41).

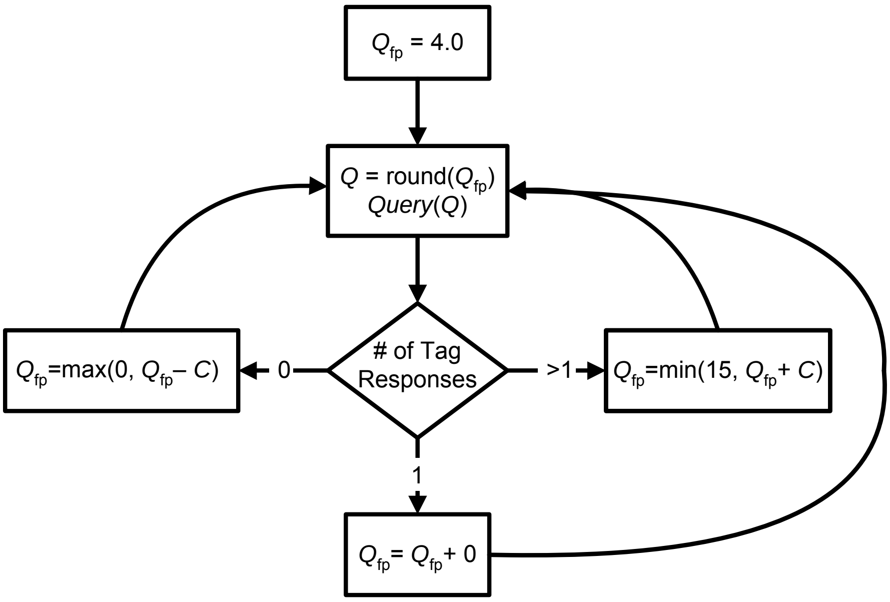


Figure 3: The block diagram of Q Frame-by-frame Algorithm in EPCglobal C1G2 protocol

The performance of Q Frame-by-frame Algorithm can, however, be significantly improved when changes to Q are restricted to incremental changes (denoted incremental) (Christian Floerkemeier, 2007). Under these conditions the oscillations of the Q algorithm are damped and the simulated throughput is similar to the other frame-based transmission schemes.

5) C-ratio (Collision)

In order to estimate the number of tags, the collision ratio (C-ratio) is introduced (Jae-Ryong Cha, Jae-Hyun Kim, 2005), which means the ratio of the number of the slots with collision to the frame size, is given by

$$C_{ratio} = 1 - \left(1 - \frac{1}{L}\right)^{n}\left(1 + \frac{n}{L-1}\right)$$

After a round, we know the frame size and the collision ratio. Based on this information, we can estimate the number of tags.

6) Chen1

Most of the static algorithms estimate the backlog with the number of collided slot. But here Chen1 (Wen-Tzu CHEN, 2006) estimate the backlog based on the empty slot information, through the probability of finding h empty slots after completing a frame.

$$P(h) = \frac{(-1)^h L!n!}{h!L^n} \sum_{j=h}^{L} \frac{(-1)^j (L-j)^n}{(j-h)!(L-j)!n!}$$

For a given L and h, a number n to make the above probability maximum will be calculated. It is straightforward using the number as the estimate of tag quantity because in this situation (a known frame size L, and the number of empty slots, h), choosing the n has maximum conditional probability.

7) Chen2

Chen2 algorithm (Wen-Tzu CHEN, 2006) is a simple way to estimate the number of tags, which is illustrated as follows: after completing a frame, the n will be computed by the following equation:

$$n = (L-1) \cdot \frac{s}{h}$$

If h=0, n is set to a certain upper bound for the tags estimate.

8) Frame-by-Frame Bayesian Updating

The individual steps of the broadcast scheme are adapted to suit the nature of framed Aloha and RFID (Christian Floerkemeier, 2006):

1. Compute the frame size L based on the current probability distribution of the random variable N that represents the number of tags transmitting.

2. Start frame with L slots and wait for tag replies.

3. Update probability distribution of N based on evidence from the reader at the end of the frame. The evidence comprises the number of empty, singly-occupied, and collision slots in the last frame.

4. Adjust probability distribution N by considering newly arriving tags and departing tags including the ones which successfully replied and do not transmit in subsequent slots.

Let H, S, and C denote random variables indicating the number of empty, success (single-occupied), and collision slots in a single frame with L slots and N tags. After the frame is completed and the feedback in terms of H, S, and C is available, the number of tags that replied is estimated. According to Bayes' rule, the probability that N tags have been transmitting in the frame at time t, given all evidence z1:t including that from the past frame, is then given by

$$P_r(N \mid z_{1:t}) = \alpha P_r(N \mid z_{1:t-1}) \cdot P_r(z_t \mid N)$$

$$= \alpha P_r(N \mid z_{1:t-1}) \cdot P_r(C, H, S \mid N)$$

where α is a normalizing constant.

Computing the Conditional Probability Distributions Pr(C,H, S|N) :

Let us first consider the problem of determining the number of ways T (n, c, h, s, L) to distribute n distinguishable tags into L distinguishable slots 1, 2, 3, ..., L with the first c slots containing at least 2 tags , the next s slots containing exactly a single tag, and the remaining h slots with no tag reply. The exponential generating function1 for T (n, c, h, s, L) is given by

$$G(x) = (e^x - (1+x))^c x^s$$

T (n, c, h, s, L) is given by the coefficient of $\frac{x^n}{n!}$ in the expansion of G(x). The number of ways V (n, c, h, s, L) to distribute n distinguishable tags into L distinguishable slots 1, 2, 3... L with c slots containing at least 2 tags, the s slots containing exactly a single tag, and the remaining h slots with no tag reply, is then simply given by the equation as follows.

$$V(n, c, h, s, L) = T(n, c, h, s, L)\frac{L!}{c!s!h!}$$

Since there are $\frac{L!}{c!s!h!}$ different permutations of the collision, successful, and empty slots, the conditional probability distribution Pr(C,H, S|N) is given by the ratio of the number of outcomes in the event space -V (n, c, h, s, L) - and the number of outcomes in the sample space- the number of ways to distribute n tags in L slots

$$P_r(C, H, S \mid N) = \frac{V(n, c, h, s, L)}{L^n}$$

Modeling Newly Arriving and Departing Tags

Once the posterior tag number distribution $P_r(N \mid z_{1:t-1})$ is calculated, we still need to incorporate the successful transmissions of the last frame. This only applies to RFID protocols where tags transition to a quiet state after successful identification. Under these circumstances, successful transmissions result in a reduction in the number of tags which reply in the next frame. This means that we simply need to drop the first s entries of the posterior tag distribution in order to compute $P_r(N_{t+1}=n \mid z_{1:t})$:

$$P_r(N_{t+1}=n \mid z_{1:t}) = P_r(N_t=(n+s) \mid z_{1:t})$$

The number of tags that transmit their ID in the next frame can also change because new tags arrived and others disappeared during the last frame. The exact probability distribution of newly arriving and departing tags, PA(n) and PD(n), depends on the application characteristics and technology parameters as mentioned earlier. We will consider two extreme cases. If a number of tags are placed within the range of a reader and no tags are removed or added until all tags are identified, there is no need to update the probability distribution at all. Here, new tags arrive because they leave a deep fade or are powered for the first time; some tags depart because they lose power as they enter a deep fade or disappear from the vicinity of the reader all together. We can compute the probabilities for N'_{t+1} then as:

$$P_r(N'_{t+1}=n) = \sum_{j=0}^{n} P_r(N_{t+1}=j) P_A(n-j) + \sum_{j=0}^{n_{\max}} P_r(N_{t+1}=j) P_D(j-n)$$

Where the conditioning evidence z1:t is omitted.

4.2.2. Simulation result

In our static model, the mobility of tags is not considered, and our simulation model uses the actual slot length in terms of R->T data rate and T->R data rate. All transmission schemes are on a frame-by-frame basis. The performance of aloha-based anti-collision is mainly determined by efficiency (or throughput) and No. of frames. The No. of frames is taken into considerations because the process of transmission scheme causes delay in RFID system, the less frame number, the better.

4.2.2.1. System efficiency

Fig. 5 shows the system efficiency of different schemes. We know that the theoretical system efficiency is 1/e, according to figure 5, most algorithms are close to the theoretical system efficiency. But the system efficiency of Q FBF drops dramatically when total number of tags increases. Its system efficiency is relatively high when tag number is small. At most

240 tags are simulated in Chen1 and Bayesian FBF algorithms because tag population more than 240 exceeds the range of simulation tool.

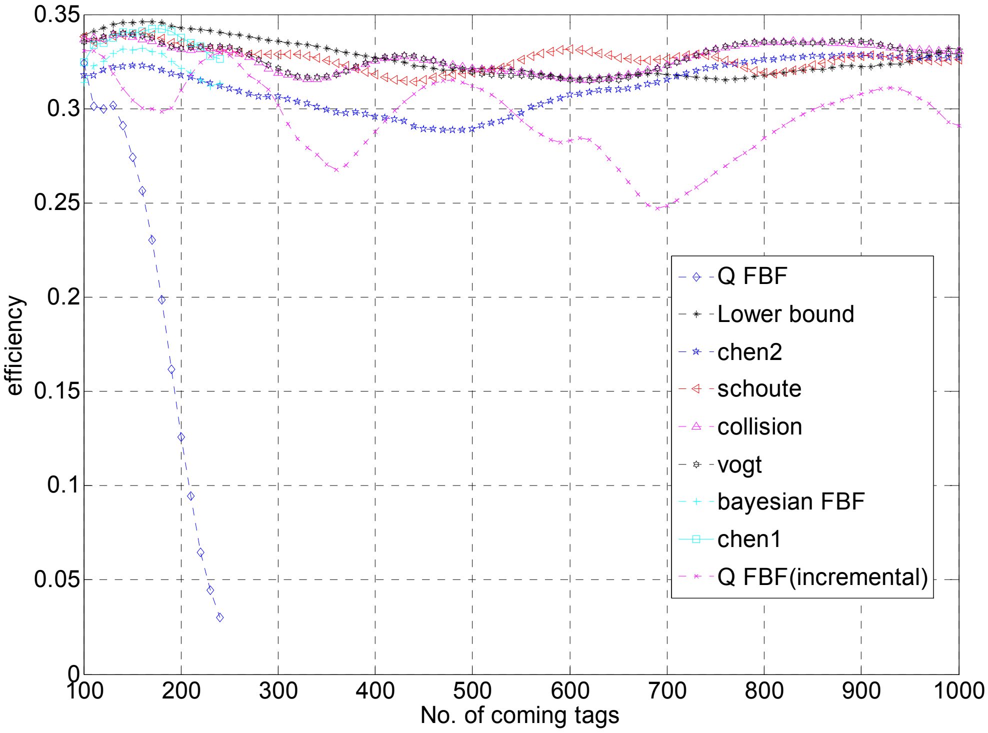


Figure 5: System efficiency vs. different schemes

4.2.2.2. Throughput

Simulation parameter

Q =6 (initial value), R->T=80 kbps, R->T=80 kbps

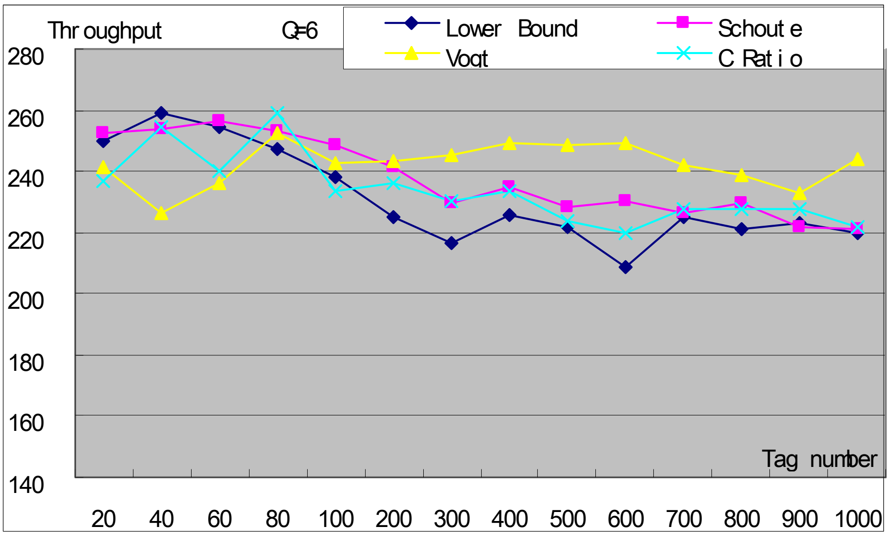
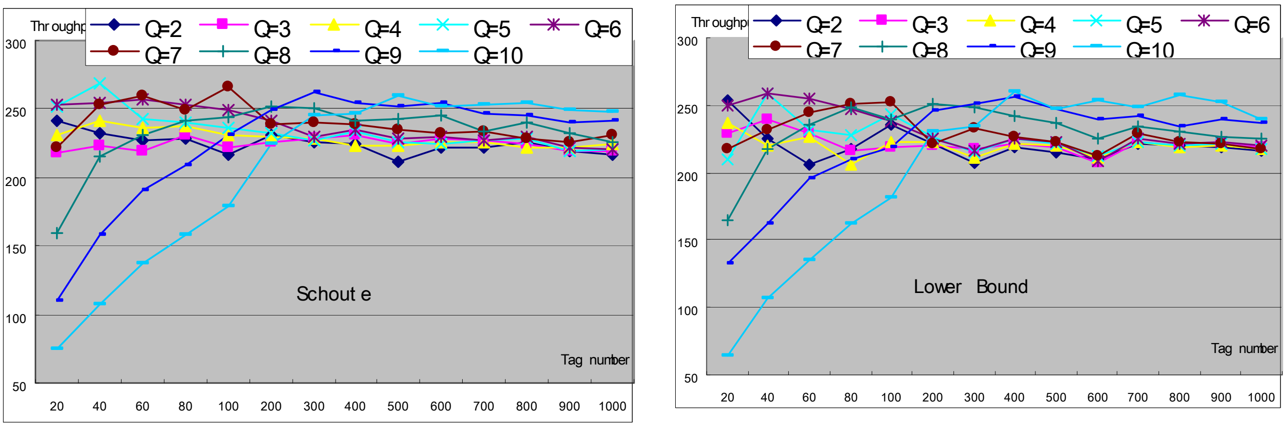


Figure 6: Throughput vs. different number of tags

The average speed for all schemes is about 200-260 tags per second when forward link frequency and backward link frequency are both 80 kbps.

Throughput vs. different initial Q value



a) Schoute b) Lower Bound

Figure 7: Throughput vs. different initial Q

Taking Schoute and Lower Bound for example, roughly speaking, the initial value of Q doesn't affect the throughput very much, especially when the total tag number is more than 300.

Throughput vs. different transmission error rate

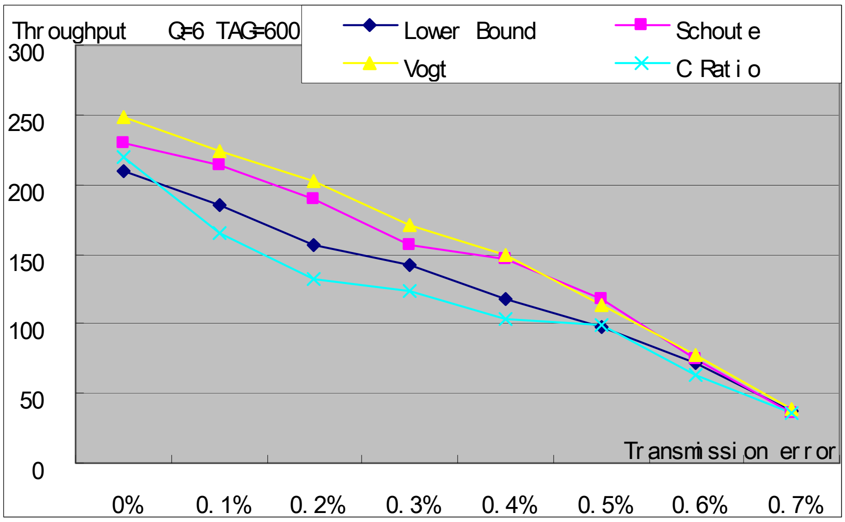
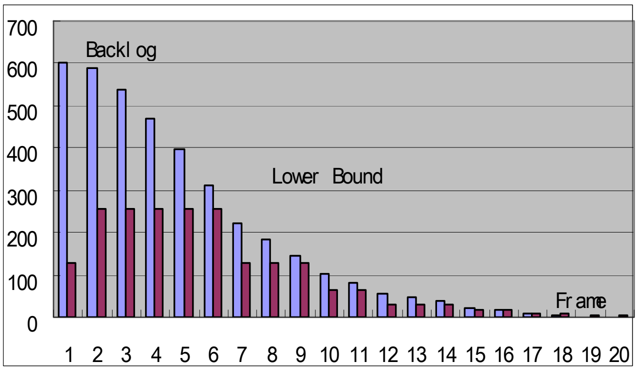


Figure 8: Throughput vs. different transmission error rate

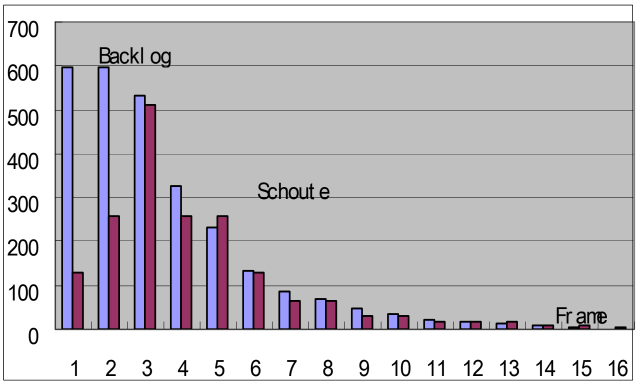
Our simulation model takes the transmission error rate into consideration. From the simulation results (figure 8), It is clear that the throughput decreases to 100 tags per second and below if the transmission error rate increases to 0.5% and above.

4.2.2.3. Backlog estimation

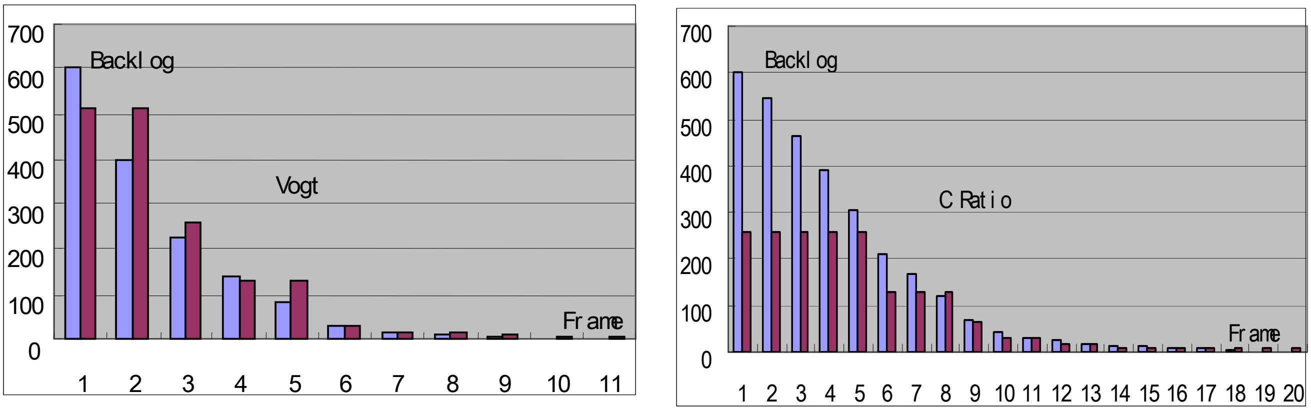
Figure 9 (a) shows Lower Bound uses 20 frames to recognize all 600 tags, the length of red and blue bars respectively denote frame sizes (2, 4, 8, …, 2^Q) and backlog at the end of frames. Figure 9 shows Vogt uses the fewest frames than other algorithms, so it is the most accurate estimation method.



a) Lower Bound



b) Schoute

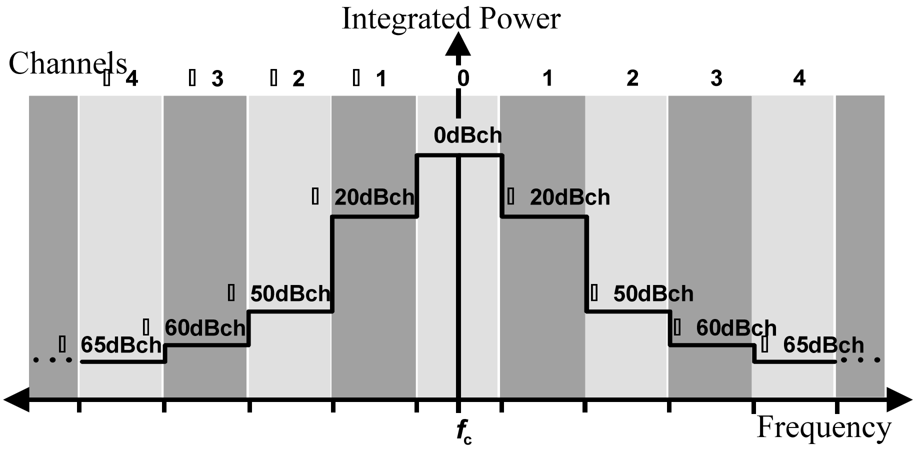


c) Vogt **d) C Ratio**

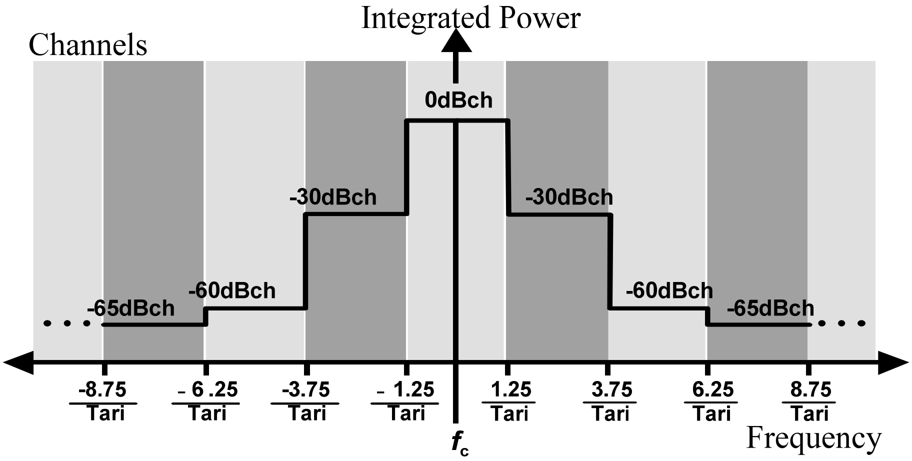
Figure 9: Backlog estimation

4.2.3. Simulation under UHF frequency allocation in China

Readers certified for operation in multiple-reader environments according to EPC GEN2 shall meet local regulations for out-of-channel and out-of-band spurious radio-frequency emissions. In addition to meet local regulations, Readers certified for operation in multiple- and dense-reader environments shall also meet the transmit mask defined in EPC GEN2 protocol, as figure 10 shows (EPCglobal, 2005):



(a)



(b)

Figure 10(a) Transmit mask for multiple-reader environments

(b) Transmit mask for dense-reader environments

In China, the frequency bands of 840-845MHz and 920-925MHz are allocated for RFID system. According to “Simulation report for frequency allocation for RFID system in China and other wireless communication interference”, DSB-ASK, SSB-ASK and PR-ASK modulated signals take: 4 times, 3 times and 2 times of the signals’ bandwidth for their channel bandwidth respectively. So 80 kHz DSB-ASK modulated PIE data uses a channel width of 320 kHz. We can use SSB-ASK modulated PIE data to reduce channel bandwidth (Xi Tan, Hao Min, 2006). The following figure shows PSD of 80 kHz SSB-ASK modulated PIE data, and Integrated power in 240 kHz channel. Compared to PIE data without Raise-cosine filtering (see figure 11), Raise-cosine filtered PIE data (see figure 12) suppresses the out-of-channel and out-of -band spurious radio-frequency emissions efficiently, which completely meets the transmit mask for dense-reader environments.

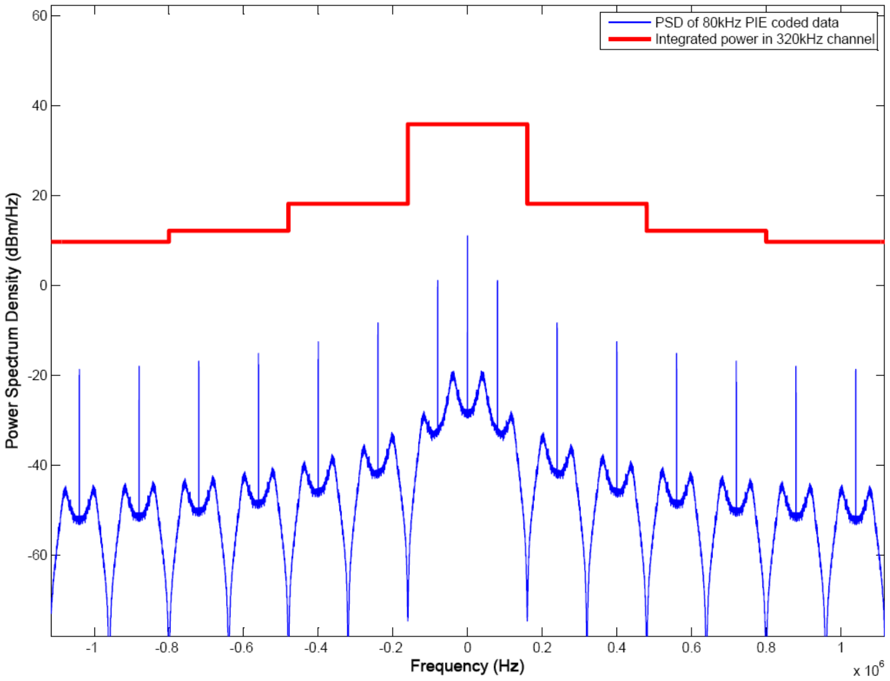


Figure 11 PSD of 80 kHz PIE data, and Integrated power in 320 kHz channel

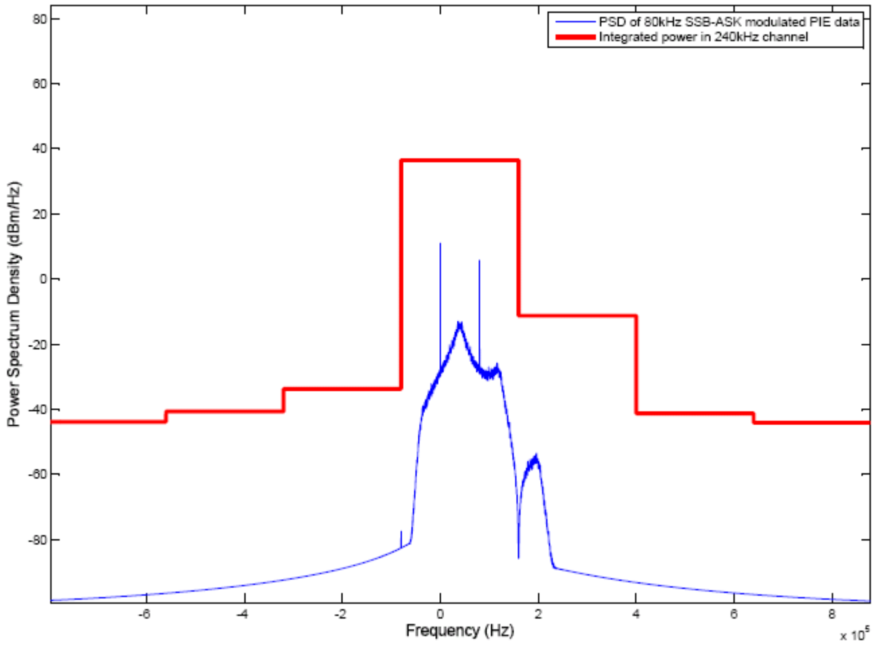


Figure12: PSD of 80 kHz SSB-ASK modulated PIE data，Integrated power in 240 kHz channel

Here we give the simulation results for the available band of 920-922MHz. The total bandwidth is 5MHz, which can be divided into 20 channels of 250 kHz for each. The highest data rate of DSB-ASK modulated PIE data allowed by 250 kHz channel is 250 kHz/4 = 62.5 kHz. We use 60 kHz in our simulation.

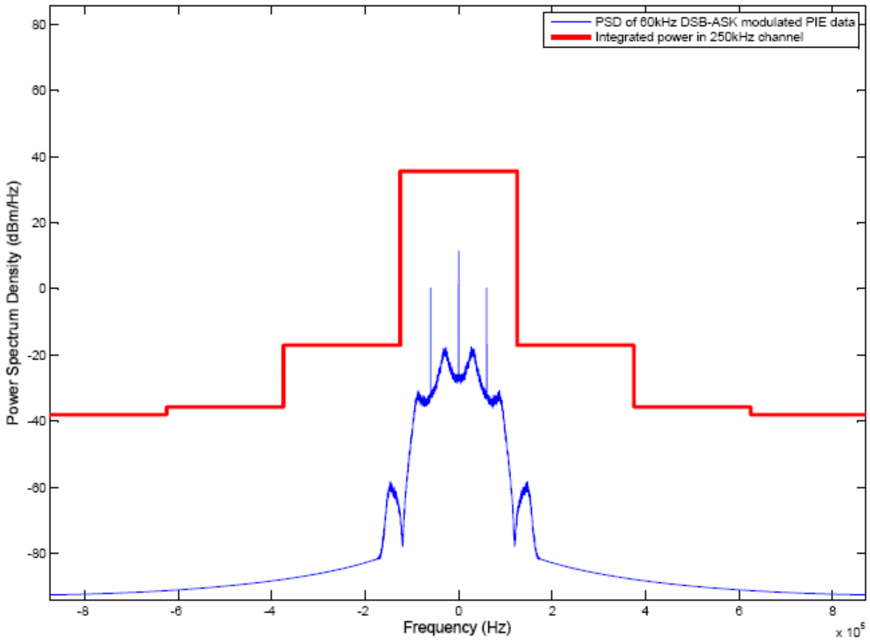


Figure13: PSD of 60 kHz DSB-ASK modulated PIE data，Integrated power in 250 kHz channel

Figure 13 shows PSD of 60 kHz DSB-ASK modulated PIE data，and Integrated power in 250 kHz channel. According to Figure 9, this simulating results shows that it completely meet the transmit mask for multiple-reader environments. The suggested 250kHz maximum channel width has been accepted by State Radio Regulation of china 205 (dated 2007).

Accordingly, in China, Figure 14 simulate all transmission schemes using the maximum forward link frequency 80 kbps and maximum backward link frequency 60 kbps. It shows that most schemes could reach 220 -240 tags per second except Chen1.

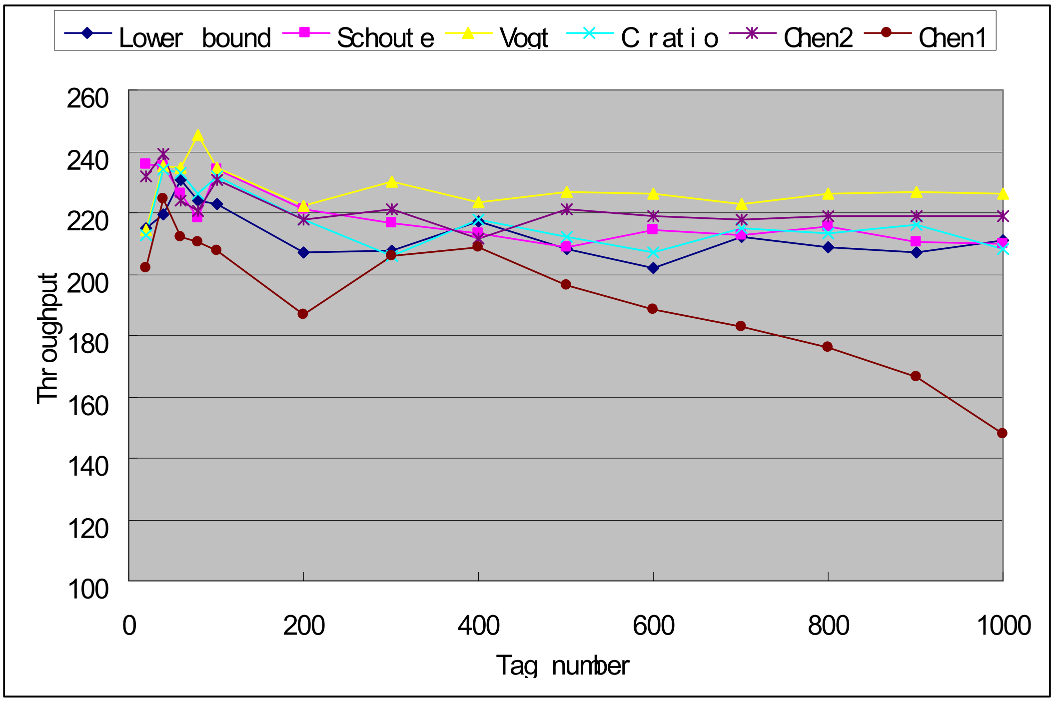


Figure 14: Throughput when FLF=80 kbps, BLF= 60 kbps

4.3. Dynamic environment

4.3.1. Introduction to dynamic algorithm

In the dynamic application, the number of tags in the range of reader is not a constant. There are two types of dynamic model. One model is that the newly arriving tags is Poisson distributed, The other model is that the newly arriving is two-dimension Poisson distributed, which means in the X*Y array of newly coming tags, the X and Y are both Poisson distributed. In our paper we will give the simulation results of the Poisson distribution model, including one dimension Poisson and two-dimension Poisson.

So far there is one algorithm which is designed specified for dynamic application Bayesian Slot by Slot Updating ,which differ from Bayesian Frame by Frame Updating in that the former updates the estimated probability distribution of tags present after each slot, while the latter updates the probability distribution after each frame only. The detailed steps are as follows:

1). Compute the frame size L based on probability distribution Pr (N).

2.) Start frame with L slots and wait for tag replies.

3.) Update Pr (N) based on evidence from the reader at the end of each slot.

4). Adjust Pr (N) for tags that are departing during the current frame because they lost power.

5). If the frame size L is optimal, given Pr (N), continue with the next slot and go back to step 3. Otherwise, cancel current frame.

6). Adjust Pr (N) by considering the arrival of “new” tags and the departure of tags that were successfully identified.

Steps 1) and 2) of the above procedure follow the same principles outlined in the previous section, where we discussed a Bayesian approach that updates Pr (N) at the end of each frame only.

Most of the static algorithms could also be used as the dynamic algorithm, when the newly departed and arrived tags are taken into consideration. Nevertheless, the arrival and departure of tags caused by the frequent nulls and tag movements will significantly increase the uncertainty about the true number of tags ready to reply in the next frame in applications such as the dock door scenario.

4.3.2. Simulation results

This section presents performance of tag anti-collision schemes in the applications with high mobility of tags. We modeled the supply chain application shown in Figure 15, where the movement and identification of two pallets carrying 300 UHF tags. The simulation parameters are listed in Table 1. The simulation engine (written in Matlab) supports the command set of the EPC global UHF GEN2 Protocol, and it produces a number of statistics that allow users to evaluate the performance of different transmission control strategies, settings in EPC GEN2 protocol.

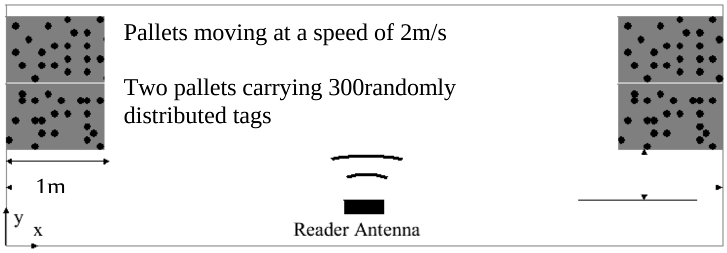
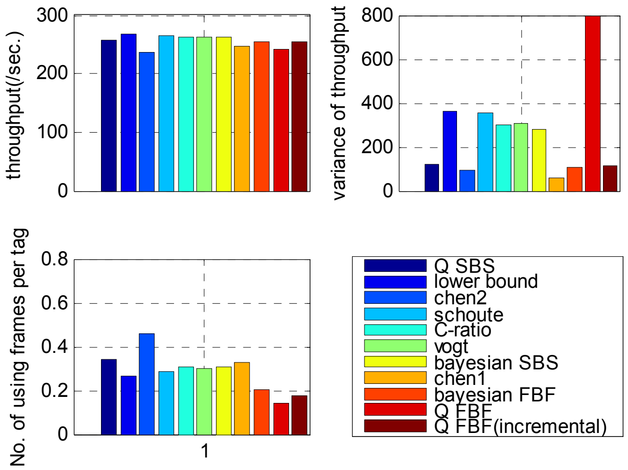


Figure 15: Simulation scenario: Loading dock application. Pallets containing 300 or 1280 randomly distributed RFID tags are moved past a single reader at a constant speed of 2 m/s.

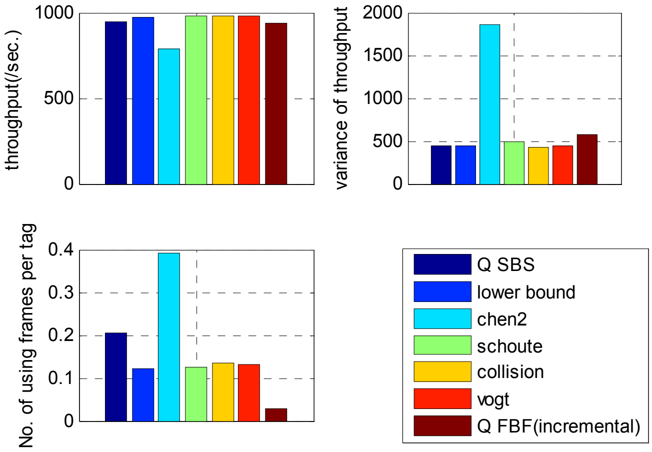
Parameter Name	Value 1	Value 2
Reader's read range	1.25m	1.25m
Length of pallets	1m	1m
Tari	12.5us	6.25us
R->T	80 kbps	160 kbps
T->R	80 kbps	400 kbps
Distribution of tags	Poisson	2-D poisson
Tag population	300	1280
Iteration	100	100

TABLE 1: Simulation parameters for the loading dock application.

In this subsection, we improve all frame-by-frame transmission schemes including Q Algorithm to be operated on a slot-by-slot basis. The slot-by-slot transmission scheme means interruption of the running frame when the current frame size is found to be suboptimal. The Bayesian FBF transmission scheme can also be applied in dynamic model, because it takes newly arriving tags and departing tags into considerations.



(a): simulation results using Value-1 parameters



(b): simulation results using Value-2 parameters

Figure 16: Performance of anti-collision algorithms in dynamic model

Fig. 16(b) doesn't include two Bayesian transmission and Chen1 schemes compared to Fig. 16(a), because they exceed the computing ability of the simulation engine, and Q FBF is also omitted, because it has the highest variance of throughput.

From Fig. 16(a) (b), we can see that Lower Bound outperforms in throughput, and Bayesian slot-by-slot updating algorithm outperforms Q FBF (incremental) algorithm and Bayesian SBS. The Bayesian slot-by-slot updating algorithm has the lowest variance, because it indirectly uses all available information, i.e. All past evidence, including The throughput of Bayesian slot-by-slot updating algorithm does not outperform as expected, but it has the lowest variance of throughput , because it indirectly uses all available information, including the evidence from the last slot and the current frame size, to compute the multiplicity of conflict. However, the Bayesian algorithm does require significant computing resources, although some of the computations can be pre-computed and stored in the memory of the reader device.

The two Bayesian schemes (Frame by Frame and Slot by Slot) do not outperform other schemes partly because the departed tags partly overlap with successfully identified tags, so we can not figure out the exact probability distribution of departing tags, PD (n).

Comparing Fig.16(a) with (b), we can also find that the Vogt and C-ratio algorithm exhibit better balanced performance among the three statistic anti-collision algorithms when tag population becomes larger, which shows that they provides more accurate backlog estimation than other algorithms.

5. Simulation platform

In many practical environments, reader needs to gain the information from a large tag population in a short period time. As mentioned earlier, there are about several types of algorithms for the “one reader and multi-tags” application, so evaluation on different schemes is necessary and of great importance.

We have established a simulation platform base on Verilog DHL and C language. Our simulation platform is compatible with EPC GEN2 protocol. Transmission process and timing control are realized with Verilog DHL, while the reader’s state control and anti-collision algorithm are completed with C language. We use Verilog-PLI to call the anti-collision algorithm in Modelsim (see figure 17).

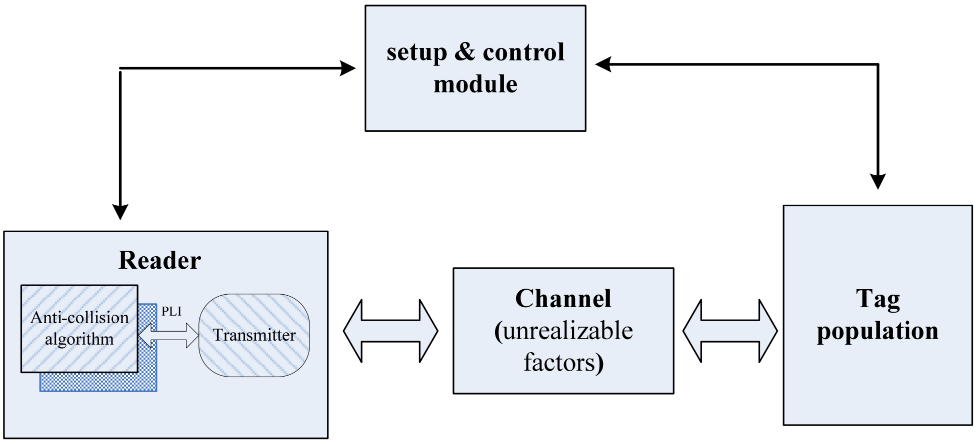


Figure 17: The block diagram of simulation platform for RFID anti-collision

The simulation platform consists of four main modules: setup and control module, reader module, tag population module, channel module. The platform presented in this paper focuses on simulation of the static anti-collision algorithm for the “one reader and multi-tags” case. The setup and control module initializes and setups the simulation process. You can set the number of tags, forward link frequency and backward link frequency in this module. The reader module simulates the behavior of the RFID reader, which can execute the basic protocol flow and complete different anti-collision algorithms. And the main purpose of the channel module is to simulate random error communication link.

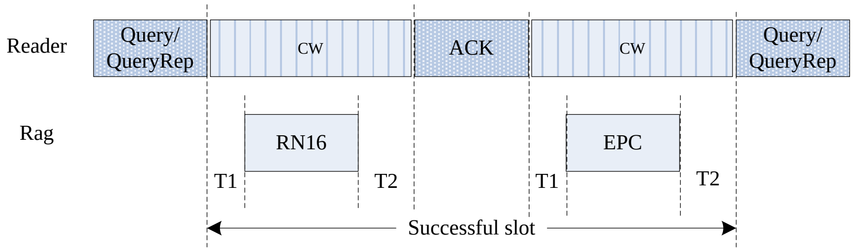
Apart from the throughput, this simulation platform could also output the collision information, which is very useful for evaluating the performance of different anti-collision schemes. With proper modification this simulation platform could also simulates dynamic anti-collision algorithm.

6. Discussion and Future Work

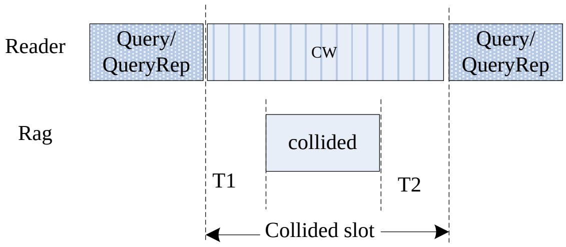
This paper mainly introduces several anti-collision algorithms based on EPC GEN2 protocol, and evaluates their performance. The principle of these schemes is to control the frame size to optimize the throughput by estimating the backlog in the read range on the feedback from the current frame, i.e. the number of collisions, single replies and empty slots. In static environment, according to the result of performance evaluation, Vogt, and C ratio show better performances with a collision detection technique. In dynamic environment , Lower Bound shows the highest throughput performance but high variance , which is opposite to the performance of Bayesian SBS, Vogt and C-ratio algorithm exhibit better balanced performance among three statistics (throughput, variance of throughput, average number of frames per tag) when tag population becomes larger.

Grouping is a potentially useful algorithm when Q value is restricted to a constant, or tag population is too large (2^{15}-1, in EPC GEN2 protocol); if the collided slots happen more than the reference level, the reader decides the limitation of response tags by means of adapting proper “Mask” and “Length” in “SELECT” command defined in EPC GEN2 protocol so as to select a portion of tags.

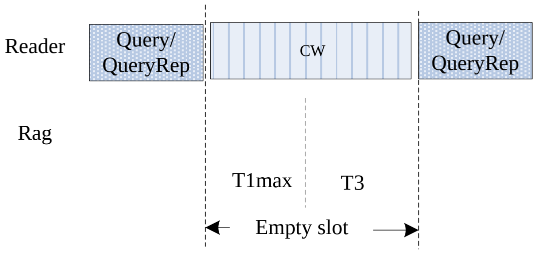
The frame size is calculated to optimize the system efficiency on the basis that all slots have the same fixed length, which is however, not true according to the following diagram, so in the future we are going to take actual slot length into consideration in efficiency expression to improve the throughput performance.



a) Successful slot length



b) Collided slot length



c) Empty slot length

Figure 18: Actual slot length

Besides, our future research will focus on mitigating the reader interference problem and applying the most efficient anti-collision algorithms to the RFID system.

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