Random Access Method of the Wibro System

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ABSTRACT

Random access method for Wibro system is proposed using the Bayesian Technique, which can estimate the number of bandwidth request messages in a frame only based on the number of successful slots. The performance measures such as the maximum average throughput, the mean delay time and the collision ratio are investigated to evaluate the performance of the proposed method. The proposed method shows better performance than the binary exponential backoff algorithm used currently.

Key Words : random access, Wibro, Bayesian, exponential backoff algorithm

Ⅰ. Introduction

Wibro system provides the contention-based bandwidth request (BR) opportunity to the terminal using nrtPS or BE service. It uses the binary exponential backoff algorithm for conflict resolution. Conflict resolution in the binary exponential backoff can be done using the initial backoff window and maximum backoff window, which are controlled by the base station. The terminal which requests bandwidth gets the values of the initial backoff window size and the maximum backoff window size from the UCD (Uplink Channel Descriptor) message. These values represent the exponent of 2. If the value is 4, the window size becomes between 0 and 15. The terminal randomly selects one number within the window size. It represents the number of contention slots, after which the terminal can transmit the BR messages. After transmitting BR message the terminal waits for the bandwidth permission message in the MAP. If the permission message is received, bandwidth request is completed. Otherwise, bandwidth request is considered to be failed. Then the terminal doubles the backoff window size within the maximum backoff window and the process is repeated. If the bandwidth request is not successful until the maximum number of repetition is reached, the PDU (Protocol Data Unit) is abandoned.

There has been a need to improve the performance of the binary exponential backoff method. Oh[1] proposed the method which can determine the optimal initial backoff window size of the binary exponential backoff algorithm. In [2] he also proposed the method which can determine the optimal contention period considering the throughput and the delay. Kwak[3] provided the analytical methods which determine the throughput and the delay time of the binary exponential backoff algorithm. Je[4] showed how the throughput and the delay time change depending on the window size and the number of terminals. Kobliakov[5] proposed multi-FIFO-by-sets ALOHA technique to enhance the performance of the binary exponential backoff algorithm. Molle[6] proposed a random access method, which controls the number of messages transmitted in a frame based on the number of messages waiting for transmission. To estimate the number of messages transmitted in a frame, the number of idle slots and the number of successful slots are used. Kook[7] proposed a random access method based on conflict resolution algorithm and showed that its performance is better than that of the binary exponential backoff algorithm.

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In this study we propose a new random access method which controls the number of messages transmitted in a frame. In Wibro system only one BR message can be perceived in one contention slot and more than two BR messages in one contention slot cannot be identified. Therefore, the idle slot and the collision slot cannot be differentiated in Wibro system. So, only information used to estimate the number of messages transmitted in a frame is the number of successful slot, which is unlike the previous works[6,7]. Bayesian technique is used to estimate the number of messages transmitted in a frame given the number of successful slots.

In section 2 a random access method controlling the number of messages transmitted in a frame is reviewed. In sections 3 and 4 we propose a new random access method using Bayesian technique and provide some adjustment procedure. The performance of the proposed method is analyzed using the simulation and compared with the performance of other methods in section 5. Conclusion is in the section 6.

Ⅱ. Random Access Method Controlling the Number of Messages Transmitted in a Frame

In this section a random access method is reviewed, which controls the number of messages transmitted in a frame based on the number of messages waiting for transmission. This method provides the basis for our study.

Notation;

N the number of contention slots in a time frame available for BR messages

$\widetilde{n}_i$ the number of BR messages waiting for transmission in the i-th frame

n_i the number of BR messages transmitted in the i-th frame

P_i the probability that each message is transmitted in the i-th frame

$c_{o,i}$ the number of idle slots in the i-th frame

$c_{1,i}$ the number of successful slots in the i-th frame

$n_{a,i}$ the number of BR messages arriving newly in the i-th frame

The optimal number of BR messages transmitted in each frame, which maximizes the average number of successful BR messages, turns out to be N[6]. Therefore, if $\widetilde{n}_i$ is less than N all the BR messages are transmitted ($\widetilde{n}_i = n_i$ and $P_i = 1$). If $\widetilde{n}_i$ is greater than N, each BR message is transmitted with probability $P_i(N/\widetilde{n}_i)$. To implement this method we need a method which can estimate $\widetilde{n}_i$, the number of BR messages waiting for transmission in the i-th frame.

If we know the outcome of the BR message transmission in the i-th frame, both $c_{o,i}$ and $c_{1,i}$ can be immediately determined. And n_i can be obtained using the following equation[6].

$$n_i = \frac{(N-1)}{c_{0,i} / c_{1,i}} \tag{1}$$

Now, the number of BR messages waiting for transmission in the (i+1)-th frame can be estimated using the following recursive equation (2).

$$\widetilde{n}_{i+1} = \widetilde{n}_i(1-p_i) + n_i - c_{1,i} + n_{a,i+1} \tag{2}$$

$\widetilde{n}_{i+1}$ is calculated as the summation of 1) the number of BR messages which cannot be transmitted in the i-th frame ($\widetilde{n}_i(1-p_i)$), 2) unsuccessful transmission (n_i-$c_{1,i}$) and 3) the number of BR messages arriving newly in the (i+1)-th frame $n_{a,i+1}$.

Now the random access method can be implemented as follows.

i) $\widetilde{n}_{i+1}$ is estimated using the equation (2)

ii) If $\widetilde{n}_{i+1}$ is greater than N, each terminal selects the random number between 0 and 1. If the random number is less than transmission probability $P_{i+1}(=N/\tilde{n}_{i+1})$, the BR message is transmitted. Otherwise transmission is deferred to the next frame. If $\tilde{n}_{i+1}$ is less than N, all the BR messages are transmitted.

Ⅲ. Random Access Method Using Bayesian Technique

To estimate the number of bandwidth request messages transmitted in a frame using equation (1) both $c_{o,i}$(the number of idle slots) and $c_{1,i}$(the number of successful slots) should be known. However, Wibro system can perceive only one BR message in one contention slot and more than two BR messages in one contention slot cannot be identified. Therefore, the idle slot and the collision slot cannot be differentiated. Since only $c_{1,i}$ can be known in Wibro system, equation (1) cannot be used any more. In this section we propose the Bayesian method which can estimate the number of bandwidth request messages transmitted in a frame only based on the number of successful slots.

3.1 Occupancy Problem

The occupancy problem of reference[8] provides some mathematical tools we will use in section 3.2. The allocation of bandwidth request messages to slots within a time frame belongs to a class of problems that are known as occupancy problem[9,10].

Given N time slots in a frame and n bandwidth request messages, the number of r messages in one slot is binomially distributed with parameter n and $1/N$.

$$B_{n,1/N}(r)=\binom{n}{r}\left(\frac{1}{N}\right)^{r}\left(1-\frac{1}{N}\right)^{n-r} \tag{3}$$

Let us denote by c_r the random variable that equals the number of slots being filled with exactly r bandwidth request messages, r=0, 1, 2, ⋯, n. The distribution of c_r can be obtained as follows[8].

$$P(c_r=m_r)=\frac{\binom{N}{m_r}\prod_{k=0}^{m_r-1}\binom{n-kr}{r}G(N-m_r,n-rm_r)}{N^n} \tag{4}$$

where

$$G(M,m)=M^m+\sum_{k=1}^{\lfloor m/r\rfloor}\left\{(-1)^k\prod_{j=0}^{k-1}\left\{\binom{m-jr}{r}(M-j)(M-k)^{m-kr}\frac{1}{k!}\right\}\right\} \tag{5}$$

Bandwidth request message becomes successful only if one message is allocated in one slot. Therefore, the probability distribution of number of successful bandwidth request messages (c_1)in one frame can be obtained from the equation (4) by setting r=1.

$$P(c_1=m_1)=\frac{\binom{N}{m_1}\prod_{k=0}^{m_1-1}\binom{n-k}{1}G(N-m_1,n-m_1)}{N^n} \tag{6}$$

where

$$G(M,m)=M^m+\sum_{k=1}^{m}\left\{(-1)^k\prod_{j=0}^{k-1}\left\{(m-j)(M-j)(M-k)^{m-k}\frac{1}{k!}\right\}\right\} \tag{7}$$

3.2 Bayesian Technique

Given the number of bandwidth request messages n_1 in one frame, the probability of $c_1=m_1$ ($P(c_1=m_1 \mid n=n_1)$ can be obtained from the equation (6) by setting $n=n_1$. Now Given $c_1=m_1$, the probability of $n=n_1$ ($P(c_1=m_1 \mid n=n_1)$ can be obtained using Bayesian technique.

$$\begin{aligned}P(n=n_1 \mid c_1=m_1)&=\frac{P(n=n_1,c_1=m_1)}{P(c_1=m_1)}\\&=\frac{P(c_1=m_1 \mid n=n_1)P(n=n_1)}{\sum_{n_1=m_1}^{\infty}P(c_1=m_1 \mid n=n_1)P(n=n_1)}\end{aligned} \tag{8}$$

To calculate the probability ($P(n=n_1 \mid c_1=m_1)$ using above equation we need to determine $p(n=n_1)$, which is the probability that the number of bandwidth request messages transmitted in one frame is n_1. Considering the optimal number of bandwidth request messages transmitted in each frame is same as the number of random access slots

N, the number of terminals n_s waiting for the bandwidth request in each frame is assumed to follow Poisson distribution with mean N, $p(n_s)$. In this study, the number of bandwidth request is also controlled to be N on the average. Therefore, if n_s is less than N all the messages are transmitted (p_i = 1). If n_s is greater than N, each bandwidth request message is transmitted with probability $p_i(= N / n_s)$.

Now $p(n = n_1)$ can be obtained as follows.

$$p(n=n_1)=\sum_{n_s=n_1}^{\infty} p(n=n_1 \mid n_s)p(n_s)$$
$$=\begin{cases} \dfrac{e^{-N}N^{n_1}}{n_1!}+\displaystyle\sum_{n_s=N}^{\infty}\frac{e^{-N}N^{n_s}}{n_s!}\binom{n_s}{n_1}\left(\frac{N}{n_s}\right)^{n_1}\left(1-\frac{N}{n_s}\right)^{n_s-n_1} & if \quad n_1<N \\ \displaystyle\sum_{n_s=N}^{\infty}\frac{e^{-N}N^{n_s}}{n_s!}\binom{n_s}{n_1}\left(\frac{N}{n_s}\right)^{n_1}\left(1-\frac{N}{n_s}\right)^{n_s-n_1} & otherwise \end{cases} \tag{9}$$

3.2.1 Using the Maximum Value of Bayesian Probability

Given $c_1 = m_1$ the number of bandwidth request messages transmitted in a frame (n) can be determined so as to maximize the Bayesian probability. That is,

$$n = \max_{n_1} p(n = n_1 \mid c_1 = m_1) \tag{10}$$

3.2.2 Using the Average Value of Bayesian Probability

Given $c_1 = m_1$ the number of bandwidth request messages transmitted in a frame (n) can be obtained as the average value of Bayesian probability. That is,

$$n = \sum_{n_1=0}^{\infty} n_1 \times p(n = n_1 \mid c_1 = m_1) \tag{11}$$

Ⅳ. Adjustment Method

In section 3 we proposed the Bayesian method which can estimate the number of bandwidth request messages in a frame only based on the number of successful slot. Now the number of BR messages waiting for transmission can be estimated using the equation (2). Due to the limited information which can be used for estimation there can be a difference between the real number of BR messages waiting for transmission and the estimated one by equation (2). Once the difference becomes large it does not lessen, but becomes larger and larger. For example, assume there are 500 BR messages waiting for transmission in the i-th frame and the estimated number by equation (2) is 1000. If we assume N = 50, each message is transmitted with probability 0.05(= 50/1000). Since the average number of transmitted messages 25(= 0.05x500) is well below the optimal number 50, the performance goes down. For the opposite example, assume there are 1000 BR messages waiting for transmission in the i-th frame and the estimated number is 500. Then each message is transmitted with probability 0.1(= 50/500). Since the average number of transmitted message 100 is well above the optimal number 50, the performance goes down also.

However, there is no way to know when the difference between the real number and the estimated number becomes large. If the number of BR messages transmitted successfully is below a certain level in the i-th frame, we can think that this is due to the poor estimation accuracy and need to make some adjustment of the estimated number. However, this might be due to the small number BR messages transmitted in the i-th frame.

In this section we propose the method which can identify the poor estimation performance by comparing the average number of BR messages successfully transmitted in relatively short term period of 5 frames ($\overline{n}_{i,s}$) and the average number of BR messages successfully transmitted in relatively long term period of 20 frames ($\overline{n}_{i,l}$). $\overline{n}_{i,s}$ and $\overline{n}_{i,l}$ can be obtained using exponential smoothing method with α=0.2 and β=0.05, respectively.

$$\overline{n_{i,s}} = (1-\alpha)\times\overline{n_{i-1,s}} + \alpha \times n_i(s)$$

$$\overline{n_{i,l}} = (1-\beta)\times\overline{n_{i-1,l}} + \beta \times n_i(s)$$

where $n_i(s)$ is the number of BR messages successfully transmitted in the i-th frame.

If $\overline{n}_{i,s}$ is less than $\overline{n}_{i,l}$ by more than 10% ($\overline{n}_{i,s}$ / $\overline{n}_{i,l} < 0.9$), we judge that the difference between the real number of messages waiting for transmission and the estimated one becomes large and decrease the estimated number by 20%. After time elapse of 20 frames we again compare the updated values of $\overline{n}_{i,s}$ and $\overline{n}_{i,l}$. If $\overline{n}_{i,s}$ is greater than $\overline{n}_{i,l}$ by more than 10%, we judge that the adjustment is reasonable and further decrease the estimated number by 20%. If $\overline{n}_{i,s}$ is less than $\overline{n}_{i,l}$ by more than 10%, we judge that the adjustment was made in wrong direction and increase the estimated number by 20%. If $\overline{n}_{i,s}$ is neither less nor greater than $\overline{n}_{i,l}$ by more than 10%, we go to the initial step of the adjustment method and investigate if $\overline{n}_{i,s}$ is less than $\overline{n}_{i,l}$ by more than 10%.

If we increase the estimated number by 20%, we again compare the updated values of $\overline{n}_{i,s}$ and $\overline{n}_{i,l}$ after time elapse of 20 frames. If $\overline{n}_{i,s}$ is greater than $\overline{n}_{i,l}$ by more than 10%, we judge that the adjustment is reasonable and further increase the estimated number by 20%. If $\overline{n}_{i,s}$ is less than $\overline{n}_{i,l}$ by more than 10%, we judge that the adjustment was made in wrong direction and decrease the estimated number by 20%. If $\overline{n}_{i,s}$ is neither less nor greater than $\overline{n}_{i,l}$ by more than 10%, we go to the initial step of the adjustment method and investigate if $\overline{n}_{i,s}$ is less than $\overline{n}_{i,l}$ by more than 10%.

This recursive procedure can be summarized as follows.

1. $\overline{n}_{i,s}$ and $\overline{n}_{i,l}$ are updated in every frame. If $\overline{n}_{i,s}$ is less than $\overline{n}_{i,l}$ by more than 10%, we decrease the estimated number by 20%.

2. After 20 frames we compare $\overline{n}_{i,s}$ and $\overline{n}_{i,l}$.

   (1) If $\overline{n}_{i,s}$ is less than $\overline{n}_{i,l}$ by more than 10%; 20 frames ago if we decreased the estimated number by 20%, we increase it by 20%. If we increased the estimated number by 20%, we decrease it by 20%. And we repeat step 2.

   (2) If $\overline{n}_{i,s}$ is greater than $\overline{n}_{i,l}$ by more than 10%; 20 frames ago if we decreased the estimated number by 20%, we decrease it by 20%. If we increased the estimated number by 20%, we increase it by 20%. And we repeat step 2.

   (3) If $\overline{n}_{i,s}$ is neither less nor greater than $\overline{n}_{i,l}$ by more than 10%, we go to step 1.

Ⅴ. Performance Analysis

The performance of the random access method discussed in sections 3 and 4 is analyzed using the simulation software ARENA. We use the following performance measures.

- Mean delay time : It is the average of the elapsed time from the arrival of the BR message to the service completion and expressed as the number of slots.

- Maximum average throughput : Average throughput is defined as the ratio of the number of message transmitted over a long term period to the number of successful messages. In this study maximum average throughput is represented as the maximum input load, under which the ratio of messages whose delay time exceed 0.5 sec is less than 1%. The input load represents the number of BR messages transmitted in one random access slot. For example, when $N = 50$, 10% load represents that number of BR messages transmitted per frame is 5.

- Collision ratio : It is defined as the ratio of the number of transmitted messages transmitted over a long term period to the number of collided messages.

The number of contention slots in a frame is assumed to be 50.

5.1 Random Access Method Using Bayesian Technique

The number of messages waiting for transmission in the (i+1)-th frame $\tilde{n}_{i+1}$ can be estimated using equation (2). And the number of messages transmitted in the i-th frame (n_i) can be determined using equation (9) or (10). Once we know the outcome of the BR message transmission in the i-th frame, $c_{1,i}$ can be immediately determined. For the number of BR messages arriving newly arriving in the i-th frame ($n_{a,i}$) we use the product of the number of random access slot in a frame (N) and the input load.

In estimating n_i we can use the maximum value of Bayesian probability or average one. The simulation results are summarized in Table 1 and 2, respectively.

Table 1. Performance Results (Maximum Value)

Input Load (%)	Mean Delay (Slot)	Ratio Exceeding 0.5 Sec(%)	Collision Ratio (%)
30%	143.23	0.00%	39.25%
31%	152.54	0.00%	41.68%
32%	174.67	0.00%	43.93%
33%	218.01	0.00%	46.76%
34%	380.14	0.09%	50.89%
35%	1054.50	3.42%	50.99%
36%	1422.30	10.29%	59.82%

Table 2. Performance Results (Average Value)

Input Load(%)	Mean Delay (Slot)	Ratio Exceeding 0.5 Sec(%)	Collision Ratio (%)
30%	84.49	0.00%	39.20%
31%	87.87	0.00%	41.45%
32%	91.56	0.00%	43.73%
33%	242.92	0.88%	55.43%
34%	942.20	4.90%	74.70%
35%	1388.60	6.41%	78.33%
36%	1829.34	52.49%	92.19%

5.2 Comparative Analysis

In this section we derive the maximum throughput of the random access method controlling the number of messages transmitted in a frame.

Using simulation, we can know the real number of transmitted BR messages (n_i) given the number of successful BR messages ($c_{1,i}$). When the random access is controlled based on this information, although impossible in reality, we can expect the highest performance measures, which can be the upper limit of the performance measures of the random access method presented in this study. The performance measures of the random access method using the binary exponential backoff algorithm are also compared.

5.2.1 Theoretical Maximum Throughput

Theoretical maximum throughput is obtained for the random access method which controls the number of BR messages transmitted in a frame to be N. The theoretical maximum throughput $\hat{\rho}_{\max}$ can be obtained as follows.

$$\hat{\rho}_{\max} = \sum_{n=0}^{\infty}\sum_{n_t=0}^{n}\sum_{c=0}^{n_t} m_1 \times P(c_1 = m_1 \mid n) \times p(n \mid \tilde{n}) \times p(\tilde{n})$$

(13)

In above equation $p(\tilde{n})$ is the probability that number of BR messages waiting for transmission is $\tilde{n}$, which is assumed to follow Poisson distribution with mean N. $p(n \mid \tilde{n})$ is the probability that the number of BR messages transmitted is n given that the number of BR messages waiting for transmission is $\tilde{n}$, which follows Binomial distribution. And the $p(c_1 = m_1 \mid n)$is the probability m_1 messages are successfully transmitted when n messages are transmitted, which can be obtained using equation (6). That is,

$$P(\tilde{n}) = \frac{e^{-N} N^{\tilde{n}}}{\tilde{n}!}$$

$$P(n \mid \tilde{n}) = \binom{\tilde{n}}{n}\left(\frac{50}{m}\right)^{n}\left(1-\frac{50}{m}\right)^{\tilde{n}-n}$$

$$P(c_1 = m_1 \mid n) = \frac{\binom{N}{m_1}\prod_{k=0}^{m_1-1}\binom{n-k}{1} G(N-m_1, n-m_1)}{N^n}$$

When $N = 50$, maximum throughput $\hat{\rho}_{\max}$ becomes 36.7%.

5.2.2 Performance using the real number of transmitted messages

Using simulation, we can know the real number of transmitted BR messages given the number of successful BR messages. Since these are not the estimated values but the real ones, we can expect higher performance than that of the random access method proposed in this study. The results are summarized in Table 3.

Table 3. Performance Results Using the Real Number of Transmitted Messages

Input Load(%)	Mean Delay (Slot)	Ratio Exceeding 0.5 Sec(%)	Collision Ratio (%)
30%	82.69	0.00%	39.32%
31%	85.76	0.00%	41.49%
32%	89.34	0.00%	43.84%
33%	93.43	0.00%	46.24%
34%	99.64	0.00%	49.33%
35%	109.99	0.00%	53.04%
36%	134.29	0.00%	57.21%
37%	607.66	0.27%	62.69%
38%	1231.70	2.74%	63.12%

5.2.3. Performance using the binary exponential backoff algorithm

Random access method using the binary exponential backoff is a traditionally used one. The initial backoff window and maximum backoff window sizes are determined as 32 and 1024, respectively, which shows the best performance in our simulation. In case of collision retransmission is allowed up to 16 times. The messages which are not transmitted after 16 collisions are assumed to start again from the beginning, which makes the traffic load same as that of the Bayesian method. The performance results are summarized in Table 4.

Table 4. Performance Results Using the Binary Exponential Backoff Algorithm

Input Load (%)	Mean Delay (Slot)	Ratio Exceeding 0.5 Sec (%)	Collision Ratio (%)
30%	160.47	0.00%	50.68%
31%	179.35	0.01%	52.98%
32%	207.58	0.02%	55.82%
33%	247.22	0.04%	58.97%
34%	357.04	4.01%	70.26%
35%	1560.2	76.95%	98.16%
36%	1796.3	82.90%	98.72%

5.2.4 Comparison

The performance measures of the following three random access methods are compared.

- Using the Bayesian technique (Method 1)
- Using the binary exponential backoff algorithm (Method 2)
- Using the reall number of transmitted messages (Method 3)

For the Bayesian technique we can use the maximum value of Bayesian probability or average one. Since the maximum value gives better performance than the average one as shown in Tables 1 and 2, we use the maximum value only in method 1.

A. Mean delay time

The mean delay times of the above 3 methods are shown as the function of input load in the Figure 1. Since the theoretical maximum throughput is 36.7%, we change the input load between 30% and 36%. As expected, method 3 gives the lowest mean delay time. Method 1 proposed in this study shows less mean delay time than method 2 over entire input loads between 30% and 36%.

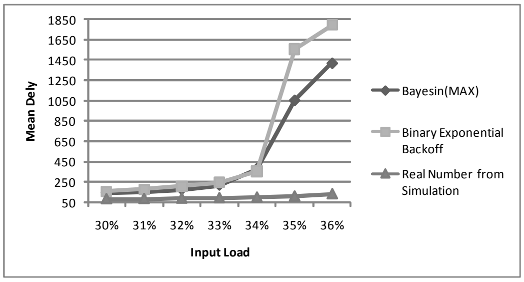

Fig. 1. Mean Delay Time

B. Ratio exceeding 0.5sec delay time

The ratio of messages whose delay time exceed 0.5 sec is compared and shown in Figure 2. Using method 3 this ratio is 0% even under the input load of 36%. This tells us that the maximum throughput of method 3 is almost same as the theoretical maximum throughput obtained through the equation (13). This is natural result since method 3 uses the real number of transmitted messages, which can be

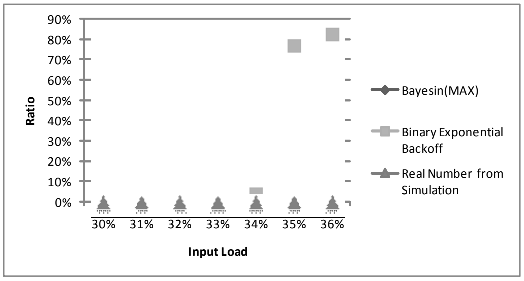

Fig. 2. The Ratio Whose Delay Time Exceeds 0.5 Sec.

known only through simulation. Using method 1 the ratio is 0% until the input load 33%, increases little under the input load 34% and becomes 3.42% under the input load 35%. Method 2 shows the highest ratio, which becomes 4.01% under the input load 34% and sharply increases to 76.95% under the input load 35%. The ratio goes above 1% when the input load is 34.5% in method 1 and 33.3% in method 2. By the definition presented earlier the maximum average throughputs of the methods 1 and 2 are 34.4% and 33.2%, respectively.

c. Collision ratio

Method 1 and 3 show almost same collision ratios as shown in the Figure 3, while method 2 shows the highest collision ratio.

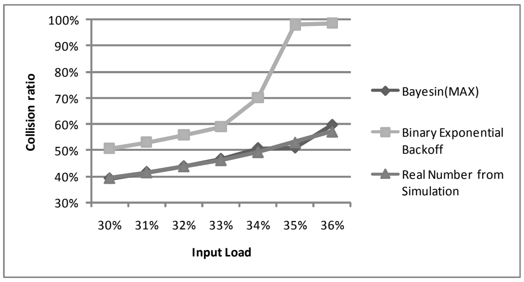

Fig. 3. Collision ratio

Ⅵ. Conclusions

In this study we propose the random access method using the Bayesian technique, which can estimate the number of bandwidth request messages in a frame only based on the number of successful slots. The proposed method has following advantages over the traditional binary exponential backoff algorithm.

- The maximum average throughput of the proposed method is 34.4%, which is 1.2% higher than that of the exponential backoff algorithm. The theoretical maximum throughput is 36.7%.
- In this study the maximum average throughput is defined as the maximum input load, under which the ratio of messages whose delay time exceed 0.5 sec is less than 1%. Considering that the system is usually operated below the maximum input load, the performances measures such as the mean delay time, the ratio exceeding 0.5 sec delay time and the collision ratio are investigated between the input load 30% and 36%. The proposed method shows better performance than the binary exponential backoff method below the maximum input load.

The parameter values used for the adjustment method in section 4 are obtained by trial and error method. It is found that the variation of the parameter values within a certain range does not affect the estimation accuracy. Therefore, even If we find the optimal parameter values, we can't expect much performance improvement of the random access method using Bayesian technique. It is not easy to determine the optimal combination of the parameter values, which will be a good topic for further study.

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