A Novel and Simple MAC Protocol for High Speed Passive Optical LANs

Chuan Heng Foh and Moshe Zukerman

ARC Special Research Center for Ultra-Broadband Information Networks
EEE Department, The University of Melbourne
Parkville, Vic. 3010, Australia
{chuanhf,m.zukerman}@ee.mu.oz.au

Abstract. In this paper, we propose a new MAC protocol for Gigabit Local Area Networks, called the Request Contention Multiple Access (RCMA) protocol. RCMA is proposed to operate in the 10BASE-FP Ethernet network topology at a gigabit data rate. It does not require the sophisticated WDM technology. Unlike the current IEEE 802.3z Gigabit Ethernet MAC protocol, RCMA is efficient and stable for a wide range of user numbers. Furthermore, it can support service differentiation with no additional overhead. Its performance under the saturation condition is analyzed and compared with performance of the current IEEE 802.3z Gigabit Ethernet MAC protocol, and significant performance advantage is demonstrated for RCMA.

1 Introduction

The challenge in developing Medium Access Control (MAC) protocols in Gigabit local area networks (LANs) is not only to achieve a simple as well as efficient protocol, but also to ensure that its efficiency is not affected as the number of shared users increases. This paper proposes a new MAC protocol for Gigabit LANs that overcomes the drawbacks of it predecessors in the Gigabit LAN environment and achieves efficient scheduling with minimum overhead and complexity.

MAC protocols can be classified to collision based, reservation based, and collision/reservation hybrid. Collision based protocols are simple but inefficient, reservation protocols are efficient but relatively complex. Since the introduction of the carrier sense multiple access with collision detection (CSMA/CD) protocol a quarter of a century ago, efforts have been made to develop protocols that are both efficient and simple by using both collision and reservation schemes. CSMA/CD has been considered one of the first MAC protocols that in some sense is a collision based as well as a reservation based protocol (see page 317 in [1] which views "the first portion of a packet as making a reservation for the rest"). However, interestingly, in Gigabit networks, where the transmission time of data frames become "small" relative to the propagation delay, CSMA/CD looses its reservation "affiliation" and it becomes a pure collision protocol in some cases.

There have been many protocols, such as IEEE 802.14 or DOCSIS, that use intelligent Central Controller (CC) to receive requests for bandwidth from multiplicity of stations. These requests are transmitted to the CC using contention minislots. In other words, these requests may collide and then retransmitted. After receiving the requests, the CC transmits scheduling information to the stations, which then transmit

E. Gregori et al. (Eds.): NETWORKING 2002, LNCS 2345, pp. 467-478, 2002.

their data frame collision free. Other reservation protocols are based on the distributed control principle. Examples are the IEEE 802.5 token ring and the IEEE 802.6 Distributed Queue Dual Bus (DQDB). These protocols achieve collision free transmission at the cost of complex transceivers.

The CSMA/CD protocol has been retained by the IEEE 802.3z working group as the MAC protocol for access arbitration in shared Gigabit Ethernet [2]. Due to the high data rate, to achieve backward compatibility and guarantee the proper operation of CSMA/CD, the IEEE 802.3z working group introduced *carrier extension* operation. If a data frame is too short for collision detection purposes, senders must append predefined carrier signals to the short data frame for a period of time that is long enough for collision detect. Another modification to the protocol is the slot time parameter. It is increased by almost 10 times from 512-bit time in 10 or 100 Mb/s Ethernet to 4096-bit time. Consequently, each collision in Gigabit Ethernet results in a loss of 10 times more data than in the 10 or 100Mb/s Ethernet.

In this paper, we propose a new MAC protocol for Gigabit LANs. We call it the *Request Contention Multiple Access* MAC protocol (RCMA). RCMA has the following traits: (i) it is simple and based on distributed control principle, synchronization between stations is not required; (ii) it achieves efficient scheduling and fairness with minimum overhead, intelligence and complexity; (iii) it is more efficient than IEEE 802.3z, and unlike IEEE 802.3z that suffers from efficiency degradation as the number of stations increases, the performance of RCMA remains stable; and (iv) RCMA can easily accommodate service differentiation.

In RCMA, we propose that a station wishes to access the medium, if the medium is free, will first broadcast a very short request by which it will make a reservation for further data transmission. More importantly, the channel assignment task in RCMA will be performed in a distributive manner without the need for an intelligent CC. Because the RCMA request is much shorter than an IEEE 802.3 frame, the probability of collisions is significantly reduced. A new operation called non-contention channel assignment operation is introduced to exploit the short requests for further performance improvement in RCMA. In addition, service differentiation can be achieved by prioritizing the request. For some low priority services, stations can request for the channel access right with a lower request priority number so that delay sensitive services can be served first.

The paper is organized as follows. In Section II, we describe our proposed MAC protocol, RCMA, in detail. The performance analysis of RCMA is given in Section III. In Section IV, we compare RCMA with the IEEE 802.3z MAC protocol.

2 The RCMA Protocol

2.1 Network Topology

Our RCMA protocol is proposed to operate in a tree topology with a passive optical repeater similar to the 10BASE-FP Ethernet [3]. The data rate is expected to be 1Gb/s. The main advantage of this configuration is its cost effectiveness due to the use of passive optical repeaters.

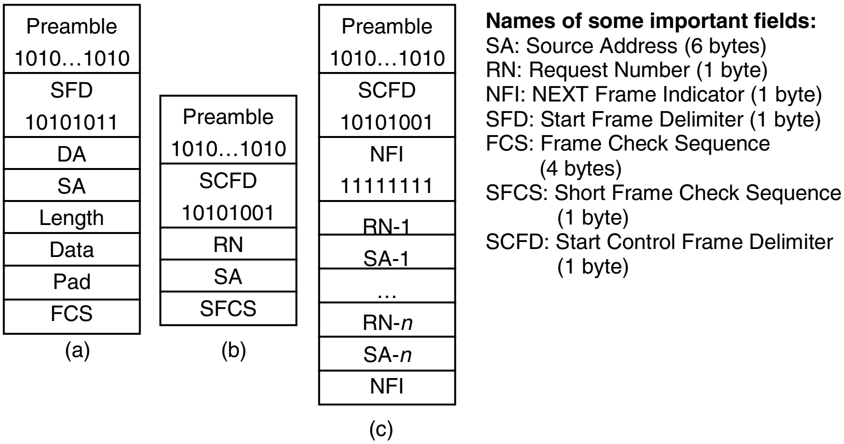


Fig. 1. The frame structure. (a) IEEE 802.3 frame; (b) RCMA Request Frame; (c) RCMA NEXT Frame

The main difference between the 10BASE-FP Ethernet and other Ethernet variations is the signal repeating mechanism. In 10BASE-FP, two optical fibers are connected to the passive optical repeater from each station, one for incoming, and another for outgoing traffic. When optical signals arrive at one port of the passive repeater, the signals will be repeated to all stations, including the originated station. Since the sender will receive its own transmission during its data frame transmission, collision detection is somehow difficult for the CSMA/CD protocol. Therefore, in Ethernet, a special transceiver is designed to allow the sender to detect collisions in the presence of its return signals.

However, in RCMA, a station is required to request access right before its actual data frame transmission can take place. Once the channel is reserved, the data frame is transmitted free of collision, thus collision detection operation is not required.

2.2 The RCMA Protocol

The key idea of our proposed protocol is that it makes use of the return signals repeated by a passive optical repeater to allow each sender to verify that its earlier transmission was successful. To make the operation more efficient, we introduce the use of a very small request frame for each sender contending for the channel access right to reserve the channel for longer data frame transmissions.

Let τ be the maximum signal propagation delay between any pair of the stations. When a station is ready for a data transmission, henceforth called a *ready station*, it is required to perform a *request contention* operation. It first prepares a request frame. The proposed request frame structure is depicted in Fig. 1(b). The station must randomly generate a 6-bit *request number* and store it in the *Request Number* (RN) field of the request frame. Its MAC address is also included. The request frame ends with an 8-bit *short frame check sequence* (SFCS) for error detection.

Before the request frame transmission, the station activates a timer called the *request-waiting timer* (RWTimer). RWTimer=$w \cdot T_s$, where w is a uniformly distributed random integer between zero and k-1, and T_s is the minislot time which is the time required to transmit the entire request frame plus a short guard time. The station waits and monitors the incoming channel after activated RWTimer. Detection of a request or data frame from the incoming channel generated by another station during that period will cause the station to abort its request frame transmission. This will ensure that the station which has requested the channel earlier has the priority to transmit based on first come first served principle.

When RWTimer expires, if the incoming channel remains idle, the station may transmit its request frame. The station is required to monitor the incoming channel during its request frame transmission. If a carrier is detected on the incoming channel, the request frame transmission must also be aborted immediately. We assume that the cable between a station and the repeater is long enough (in the case of 1Gb/s and 16 bytes request frame, the cable must be at least 19.2m) so that the request frame will not return back to the originated station while transmitting that request frame. However, the request frame transmissions are subject to collisions. If two stations transmit the request almost at the same time such that the request frames meet at the passive repeater, these request frames are corrupted due to the overlapping signals. Otherwise, the request frames are considered successfully transmitted and can be read correctly by all stations.

After the very last bit of the request frame is transmitted, the station activates another timer called the *request-collection timer* (RCTimer). This timer is set to 2τ plus a short guard time. During this time interval, the station monitors the incoming channel and collects any request frame including its own request frame transmitted earlier. Any incorrect or incomplete request frames are discarded. When RCTimer expires, the station can be sure that all transmitted request frames have arrived and no further request frame is still propagating in the network. The station then compares all the collected requests. One of these requests will be the *winning request*. The winning request is the one with the largest request number among all collected requests. The station that originally sent the winning request will gain the channel access right. This station will henceforth be called the *winner*.

All stations contending for the channel access right, including the winner can identify the winner by comparing the request numbers, and identifying the MAC address of the largest request number. No collision detection is required during the data frame transmission. The choice of data frame structure is optional; here we propose to use the IEEE 802.3 frame [3] shown in Fig. 1(a).

It is possible that two or more stations may choose the same request number. There are many ways to break this tie. Under one simple option, the station of a larger numerical MAC address always has the advantage to transmit its data frame first. This will not affect the fairness significantly because this event is very rare.

Since the station, which has given the exclusive right to access the channel, is also aware of other requests while competing for the channel access right, after its data frame transmission and an *interframe gap* (IFG) period similar to its Gigabit Ethernet counterpart, it may transmit a special control frame, called the NEXT frame. The proposed frame structure for the NEXT frame is given in Fig. 1(c). The NEXT frame generally contains a list of successful requests that the station collected earlier, sorted by request number.

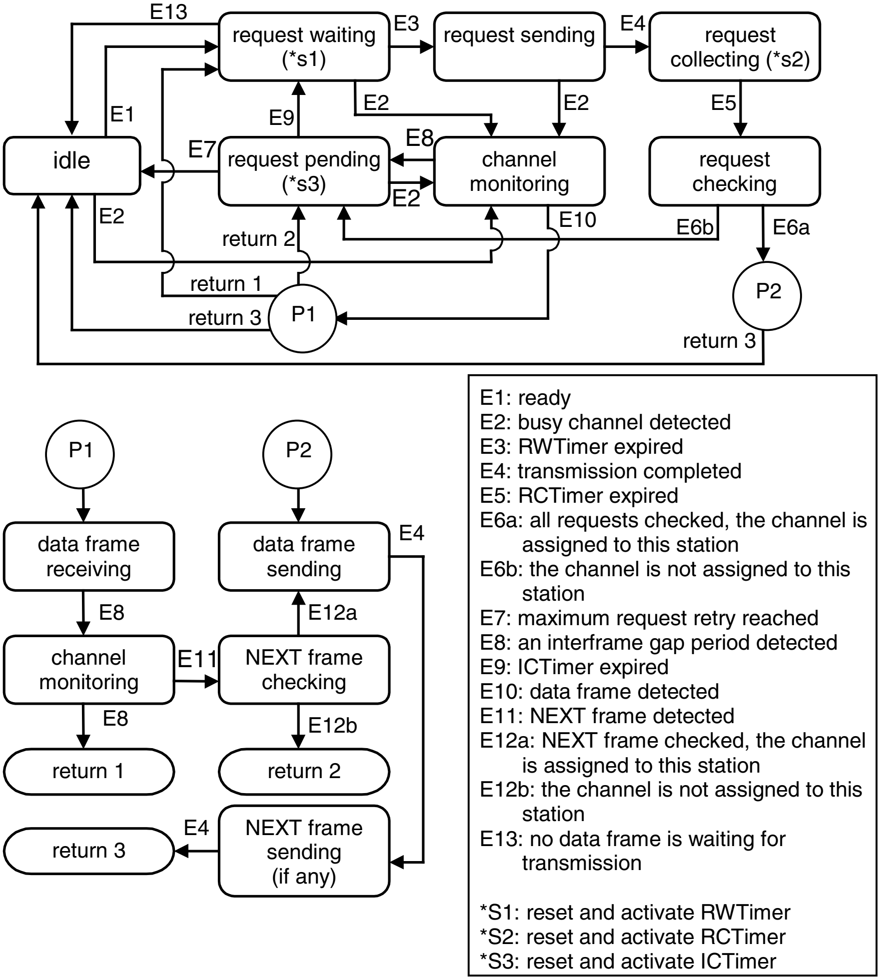
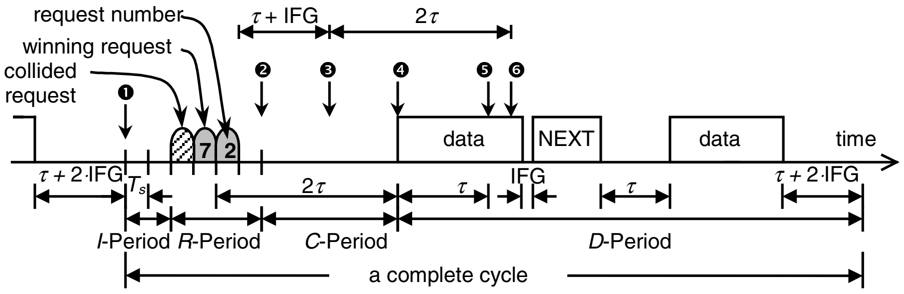


Fig. 2. The finite state machine of a RCMA transceiver

When the NEXT frame is transmitted, RCMA enters a *non-contention channel assignment* operation. Each station, after receiving the NEXT frame, compares its MAC address with the first MAC address in the NEXT frame. If matched, that station may transmit its data frame after an IFG period. Again, the station removes its record from the NEXT frame and transmits the modified NEXT frame after it has completed its data frame transmission.

When the last station on the list in the NEXT frame completes its data frame transmission, no NEXT frame will follow. After an IFG period, all ready stations enter the request contention operation.

If all request frames collide, no data frame transmission will occur. After discovering that there is no data frame transmission, all ready stations immediately repeat the request contention operation to compete for the channel access right.



❶ all stations detects the end of the data frame transmission;
❷ all stations detects the first request frame transmission, the stations that have not transmitted their request frames must abort their request frame transmissions;
❸ the channel turns from busy to idle due to request frame of request number ‘2’. After detecting the channel to be idle for an IFG period, all stations, that do not participate in request contention, reset and activate their ICTimers which will expire at ❻;
❹ the RCTimer of the winner expires, it starts its data frame transmission immediately;
❺ all stations sense the busy incoming channel and will not access the channel at ❻;

Fig. 3. The snapshot of RCMA channel

A critical aspect of RCMA is its implicit channel assignment property. If the assigned station fail to initiate its transmit, a deadlock situation may occur. To avoid this problem, when the channel is assumed to be assigned to a winner, each station activates a timer called the *idle-channel timer* (ICTimer). The duration of ICTimer must be greater than the duration of RCTimer. ICTimer is reset if incoming channel is sensed busy. However, if the incoming channel remains idle after ICTimer expires, it is assumed that the winner forfeits its transmission right. Each ready station then repeats the request contention operation to compete for the channel access right.

Finally, before a newly started station can join the network, it must wait and monitor the channel for a time period longer than the duration of ICTimer plus T_s. This will ensure that the station does not disrupt any ongoing events.

In Fig. 2, we construct a finite state machine to describe the detail operation of a RCMA transceiver.

3 Performance Analysis

3.1 The Model

Let a network consist of *m* stations. Each station is saturated so that it always has data to transmit. In other words, the event E1 shown in Fig. 2 occurs as soon as the station enters “idle” state.

We assume that the distance between any two stations is the same. We consider a realistic data frame size distribution. We assume that 35% of the data frames carry 46 bytes of useful information and 65% of the rest carry 1500 bytes of useful information, corresponding to the minimum and the maximum sizes of IEEE 802.3 frames [3].

We consider a cycle on the channel of RCMA shown in Fig. 3. Each cycle consists of the following: (i) an *I*-period; (ii) an *R*-period; (iii) a *C*-period; and (iv) a

D-period; representing an idle, request transmission, request collection and data frame transmission periods respectively.

The *I*-period starts as soon as the previous *D*-period ends. According to Fig. 2, in the *I*-period, all ready stations, including the station just completed a data frame transmission, enter the "request waiting" state. At this state, each station may transmit its request if its RWTimer expires. As soon as the first transmission of the request frame appears on the channel, the *I*-period ends and the *R*-period begins.

During the *R*-period, each station is not aware of any request frames transmitted by other stations, hence whenever its RWTimer expires, that station transmits its request frame. When the first bit of the first request frame reaches all stations, the *R*-period ends, and the *C*-period begins.

When the *C*-period begins, no further request frame can be transmitted. During this period the stations collect the requests to determine the winner. The winner initiates its data frame transmission when its RCTimer expires. The *C*-period ends when the winner starts its data frame transmission.

Due to the non-contention channel assignment operation, During the *D*-period, several data frame transmissions may occur. The *D*-period ends when there is no NEXT frame transmission after a data frame transmission.

3.2 Saturation Throughput Analysis

Let B be the data rate of the network. Given m saturated stations, let the random variables I, R, C, D be the duration of the *I*-period, the *R*-period, the *C*-period and the *D*-period respectively. Let the random variable U be the duration of the actual data transmission, excluding all IEEE 802.3 frame overheads during a cycle, and H be the duration of the overhead transmission such that $D=H+U$. Then the RCMA saturation throughput for m saturated stations, S_{RCMA}, can be expressed by

$$S_{RCMA} = \frac{E[U]}{E[I+R+C+H+U]}. \tag{1}$$

As described earlier, RWTimer=$w \cdot T_s$, where w is a uniformly distributed random integer between zero and k-1, and T_s is the minislot time duration. The *I*-period ends when at least one request frame transmission appears. Hence the probability that the *I*-period lasts for x minislots is the probability that any of the m stations choose to transmit their request frames given that no request frame transmission appears in previous minislots. The probability density function (pdf) of I is thus

$$P\{I = x \cdot T_s\} = \begin{cases} q_x & ,x=0 \\ q_x\left(1-\sum_{i=0}^{x-1} P\{I = i \cdot T_s\}\right) & ,x=1,2,\ldots,k-1 \\ 0 & ,x=k \end{cases} \tag{2}$$

where $q_x = 1-\left(1-\frac{1}{k-x}\right)^m$ is the probability that any of the m stations choose to transmit its request frame after x idle minislots.

For the *R*-period, since the distance between any two stations is fixed, the duration for a signal to propagate from any station to all stations is constant. Thus

$$R = \tau. \tag{3}$$

When the R-period ends, no further request frame can be transmitted. Since the R-period is a constant, then the number of minislots, r, within the R-period is also a constant, and it can be obtain by

$$r = \lfloor \tau / T_s \rfloor \tag{4}$$

where $\lfloor x \rfloor$ is the floor of x, defined as the largest integer smaller than x.

The duration of the C-period depends on the position of the winner within the r minislots. The value of the random variable C is between $\tau + T_s$ and 2τ. Since in LANs, the signal propagation time, τ, is generally small compared to the data frame transmission time (for example in our case, the data frame transmission for a long frame is about six times larger than τ), hence this random variable has only little effect on the saturation throughput of RCMA. Therefore, we here consider the worst case where the winner always appears at the last position during the R-period, that is

$$C = 2\tau. \tag{5}$$

Given m saturated stations, r minislots and the k parameter, the pdf of the number of request frames successfully detected by all stations during the R-period, N, can be derived recursively to be

$$P\{N = x\} = \frac{N_b(x,r,k,m)}{N_a(k,m)}, x = 0,1,\dots,r \tag{6}$$

where

$$N_b(x,r,k,m) = \binom{m}{0} N_b(x,r,k-1,m) + \binom{m}{1} N_c(x-1,r-1,k-1,m-1) + \sum_{n=2}^{m} \binom{m}{n} N_c(x,r-1,k-1,m-n),$$

$$N_c(x,r,k,m) = \binom{m}{0} N_c(x,r-1,k-1,m) + \binom{m}{1} N_c(x-1,r-1,k-1,m-1) + \sum_{n=2}^{m} \binom{m}{n} N_c(x,r-1,k-1,m-n),$$

$$N_a(k,m) = k^m,$$

with $\binom{m}{n} = \frac{m!}{n!(m-n!)}$ and the following initial conditions,

$N_b(x=-1,r,k,m) = 0;$

$N_b(x=0,r,k \neq 1,m=0) = 1; N_b(x=0,r,k=1,m=1) = 0;$

$N_b(x=0,r,k=1,m \neq 1) = 1; N_b(x=1,r,k \neq 1,m=0) = 0;$

$N_b(x=1,r,k=1,m=1) = 1; N_b(x=1,r,k=1,m \neq 1) = 0;$

$N_b(x \geq 2,r,k \neq 1,m=0) = 0; N_b(x \geq 2,r,k=1,m) = 0;$

and

$$\begin{aligned}
&N_c(x=-1,r,k,m)=0;\\
&N_c(x=0,r=0,k,m)=N_a(k,m);N_c(x=0,r,k\neq 1,m=0)=1;\\
&N_c(x=0,r,k=1,m=1)=0;N_c(x=0,r,k=1,m\neq 1)=1;\\
&N_c(x=1,r=0,k,m)=0;N_c(x=1,r,k\neq 1,m=0)=0;\\
&N_c(x=1,r,k=1,m=1)=1;N_c(x=1,r,k=1,m\neq 1)=0;\\
&N_c(x\geq 2,r=0,k,m)=0;N_c(x\geq 2,r,k\neq 1,m=0)=0;\\
&N_c(x\geq 2,r,k=1,m)=0.
\end{aligned}$$

$N_c(x,r,k,m)$ is the total number of possible permutations, that x out of r minislots will carry successful requests, given m and k. $N_b(x,r,k,m)$ is similar to $N_c(x,r,k,m)$ but $N_b(x,r,k,m)$ is the number of possible permutations under the assumption that no idle slot appears in any of the previous minislots. $N_a(k,m)$ is the total number of possible permutations given m and k.

The duration of the D-period depends on the number of successful requests appear in the R-period given in (6). If there was no successful request, all ready stations will enter the "request pending" state in Fig. 2 due to the events E6b and E8. Not all stations discover the failure of channel assignment at the same time, but the difference between the time each station enters the "request pending" state is not significant. Therefore we assume all stations return to the "request pending" state at the same time after the C-period ends. In the case where there is no winner, if ICTimer lasts for 2τ, then it will take duration of 2τ before this cycle ends. With this assumption, the relationship between the number of successful requests, N, obtained in (6) and the duration of the D-period is

$$D=\begin{cases}2\tau & ,N=0\\ E[T_{FRAME}]+\tau+2\cdot T_{IFG} & ,N=1\\ \sum_{i=1}^{N-1}\left(E[T_{FRAME}]+T_{IFG}+T_{NEXT}(i)+\tau\right)+E[T_{FRAME}]+\tau+2\cdot T_{IFG} & ,2\geq N\geq r\end{cases} \quad (7)$$

with $T_{NEXT}(i)=8\cdot(10+7i)/B$, and T_{FRAME}, T_{NEXT} and T_{IFG} are the transmission time of the IEEE 802.3 frame, the NEXT frame and the IFG duration respectively. Knowing the distribution of a data frame, the mean of D can be computed.

The time duration of useful information transmitted during a cycle, U, also depends on N in (6). It can be expressed as

$$U=N\cdot E[T_u]\,,N=0,1,...,r \quad (8)$$

where T_u is the transmission time of the useful information. Having obtained the pdf of I, R, C, D, and U, their mean values can be computed, as well as the saturation throughput of RCMA given in (1).

4 Performance Comparison of RCMA and IEEE 802.3z

4.1 Saturation Throughput of IEEE 802.3z

The saturation throughput of Ethernet has been performed in [4]. Some modifications are made here to include the carrier extension operation of Gigabit Ethernet. From [4], the saturation throughput of IEEE 802.3z protocol, S_{CSMA}, is

$$S_{CSMA} = \frac{E[U_{CSMA}]}{E[I_{CSMA} + C_{CSMA} + H_{CSMA} + U_{CSMA}]}. \tag{9}$$

where the random variables I_{CSMA}, C_{CSMA}, H_{CSMA}, U_{CSMA} are the idle, contention, overhead transmission, and the useful information transmission periods respectively in CSMA/CD. Let D_{CSMA} be the frame transmission period including the overhead, thus $D_{CSMA}=H_{CSMA}+U_{CSMA}$. By [4]

$$\begin{aligned} E[I_{CSMA}] &= 0 \\ E[C_{CSMA}] &= (L_m - 1) \cdot T_{SCSMA}. \end{aligned} \tag{10}$$

where L_m, given in [4], is the mean number of slots required to resolve a collision caused by m stations and to obtain a successful transmission, and T_{SCSMA} is the slot time.

Given T_{IFG}, $T_{CARRIER}$, T_{FRAME} and T_u to be the duration of the IFG, the duration of carrier extension, the IEEE 802.3 frame transmission time, and the useful information transmission time respectively, the mean values of D_{CSMA} and U_{CSMA} are

$$\begin{aligned} E[D_{CSMA}] &= E[T_{FRAME}] + E[T_{CARRIER}] + T_{IFG} + \tau \\ E[U_{CSMA}] &= E[T_u]. \end{aligned} \tag{11}$$

By substituting (10) and (11) into (9), the saturation throughput of IEEE 802.3z can be obtained. It is important to note that due to the capture effect in the Ethernet protocol that results in temporary unfairness, a minor modification of the Ethernet protocol has been applied in [4] to eliminate the transient effect influencing the steady state results of the saturation throughput. The results here represent the worst case of the actual Gigabit Ethernet saturation throughput.

4.2 Performance Comparison

In this subsection, we compare the saturation throughput of RCMA and the IEEE 802.3z MAC protocol at 1Gb/s. The parameters used for numerical computations as well as computer simulations are based on [2, 3]. They are listed in Table 1.

We assume that the data frames consist of a mix of long and short frames with 35% of the frames being short, and 65% being long. Note that in IEEE 802.3z, if the data frame transmission duration (excluding preamble bits and SFD) is less than a slot time, the transmission will be extended with carriers until the duration of a slot time is reached. E[$T_{CARRIER}$] represents the average time wasted due to carrier extension for each data frame transmission with the assumed data frame distribution.

The saturation throughput of RCMA and the IEEE 802.3z MAC protocol are compared in Fig. 4. The analytical results (shown in lines) are also verified by the simulation results (shown in symbols). The analytical results for RCMA are slightly below the simulation results because we consider the worst case in the analysis.

Table 1. The parameters of RCMA and the IEEE 802.3z MAC protocol

Parameter	Value
Data rate, B	1Gb/s
Station numbers, m	1,2,…,50
Propagation delay, τ	2μsec
The IEEE 802.3 frame overhead including preamble and SFD	0.208μsec (26 bytes)
The useful transmission duration for a short IEEE 802.3 frame	0.386μsec (46 bytes)
The useful transmission duration for a long IEEE 802.3 frame	12μsec (1.5kbytes)
The IFG time duration, T_{IFG}	0.049μsec
The slot time in IEEE 802.3z, T_{SCSMA}	4.096μsec
The minislot time duration in RCMA, T_s	0.128μsec (16 bytes)
The minislot numbers in RCMA, r	15
The parameter k for RCMA	20

Comparing the throughput of the two protocols, the saturation throughput of IEEE 802.3z drops quickly when the number of saturated stations increased from one to five, and its throughput continues to drop as the number of saturated stations increases. The throughput even drops below 10% when there are over 32 saturated stations sharing the 1Gb/s bandwidth. In other words, each saturated station only receives at around 3.125Mb/s bandwidth on average under this condition.

On the other hand, the performance of RCMA is stable, it offers over 65% efficiency for up to 50 stations, except when the number of saturated stations is below three. This is because when the number of saturated stations is low, the channel assignment overhead for each data fame transmission is slightly higher due to the need for requests prior to data frame transmissions. However, as the number of saturated stations increases, the non-contention channel assignment operation of RCMA becomes effective, more data frame transmissions can be assigned during a request contention period, thus the channel assignment overhead for each data frame transmission becomes relatively small. In the case of 32 saturated stations, RCMA achieves around 70% throughput, which is equivalent to 21.875Mb/s bandwidth for each station on average, seven times higher than that in the IEEE 802.3z protocol.

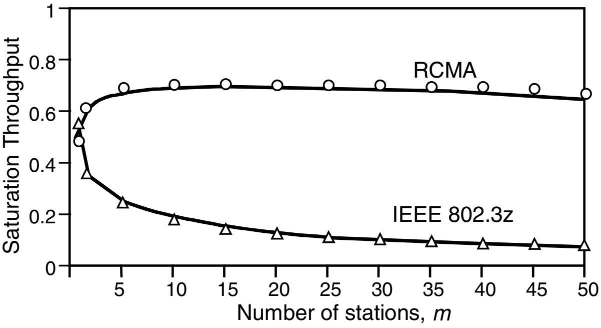


Fig. 4. The saturation throughput of RCMA and the IEEE 802.3z MAC protocol

Table 2. The duration of mean transmission time

Variable	Value
The mean frame transmission time, E[T_{FRAME}]	8.1368μsec
The mean useful information transmission time, E[T_u]	7.9288μsec
The mean duration of carrier extension in the IEEE 802.3z MAC protocol, E[$T_{CARRIER}$]	1.2544μsec

5 Conclusion

We have proposed a new MAC protocol for Gigabit LANs called RCMA. In RCMA, a sender uses the return signals repeated by a passive optical repeater as an acknowledgement to determine if its earlier transmission is successful. To make the protocol more efficient, the sender is required to contend for a channel access right for its data frame transmission using a very short request frame. This leads to a small bandwidth loss due to collisions of the request frames which is significantly small compared with the loss of bandwidth due to data frame collisions in IEEE 802.3z.

To further improve the performance of RCMA, the non-contention channel assignment operation was introduced. Under the non-contention channel assignment operation, the channel assignment information is explicitly passed by a sender to others to minimized the overhead of the channel assignment task. Moreover, RCMA can easily support service differentiation.

Finally, comparing the performance of RCMA and the current IEEE 802.3z MAC protocol, RCMA offers relatively stable and efficient performance under traffic saturation conditions while the performance of the IEEE 802.3z MAC protocol drops below 20% in the case of merely 10 saturated stations.

Since the performance of RCMA remains stable and efficient even if the number of saturated stations is as many as 50, we believe that the use of our proposed RCMA protocol in Gigabit LANs for the network access from a group of shared end users is not only cost efficient, but also far more reliable than the currently available standards and solutions.

References

1. Bertsekas, D., Gallager, R.: Data Networks, 2nd edition. Prentice Hall (1992).
2. Kadambi, J., Crayford, I., Kalkunte, M.: Gigabit Ethernet: Migrating to High-Bandwidth LANs. Prentice Hall (1998).
3. IEEE 802.3/ISO 8802-3: Information Processing Systems - Local Area Networks - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications, 2nd edition, New York (1990).
4. Foh, C.H., Zukerman, M.: Performance Comparison of CSMA/RI and CSMA/CD with BEB. Proceeding of IEEE ICC 01, Helsinki (2001).