Enhanced MAC Scheme to Support QoS Based on Network Detection over Wired-cum-Wireless Network

Moon Kim, Hwi-Jin Ye and Sung-Joon Cho, *Member, KIMICS*

Abstract**—**In these days, wireless data services are becoming ubiquitous in our daily life because they offers several fundamental benefits including user mobility, rapid installation, flexibility, and scalability. Moreover, the requests for various multimedia services and the Quality of Service (QoS) support have been one of key issues in wireless data communications. Therefore the research relative to Medium Access Control (MAC) has been progressing rapidly. Especially a number of QoS-aware MAC schemes have been introduced to extend the legacy IEEE 802.11 MAC protocol which has not guaranteed any service differentiation. However, none of those schemes fulfill both QoS features and channel efficiency although these support the service differentiation based on priority. Therefore this paper studies a novel MAC scheme, referred to as Enhanced Distributed Coordination Function with Network Adaptation (EDCF-NA), for enhancements of both QoS and medium efficiency. It uses a smart factor denoted by ACK rate and Network Load Threshold (TH). In this paper, we study how the value of TH has effect on MAC performance and how the use of optimal TH pair improves the overall MAC performance in terms of the QoS, channel utilization, collision rate, and fairness. In addition, we evaluate and compare both the performance of EDCF-NA depending on several pairs of TH and the achievement of various MAC protocols through simulations by using Network Simulator-2 (NS-2).

Index Terms**—**QoS, MAC, WLAN

I. INTRODUCTION

In these days wireless services such as WLAN, Bluetooth, and home network are getting popular all around the world. Because of its already well organized network architecture, IEEE 802.11 WLAN services are most successful and becoming important. Therefore the interests and researches of WLAN technologies are increasing. Especially, the requests for various multimedia services and the Quality of Service (QoS) support for these services are expanding so that the research relative to Medium Access Control (MAC) is progressing rapidly.

A number of QoS-aware MAC schemes have been introduced to extend the legacy IEEE 802.11 MAC protocol which has not guaranteed any service differentiation. However, none of those schemes fulfill both QoS features and channel efficiency although these support the service differentiation based on priority [1-5]. In this motivation, a distributed and contention-based MAC protocol, called Enhanced Distributed Coordination Function with Network Adaptation (EDCF-NA) is proposed in this paper. It employs dynamic procedures to suit both the Contention Window (CW) and the Inter Frame Space (IFS) depending on the acknowledgement (ACK) rate and the current network load state. In addition, the current network load state is divided into four states taking into account Network Load Threshold (TH) and the differential procedure is adopted in accordance with the state. So EDCF-NA can significantly decrease the collision rate, hence the total system throughput and the channel utilization increase as well. Moreover, fairness is enhanced since EDCF-NA elevates the throughput of lower priority traffics via minimizing the size of IFS under light traffic loads. This paper further investigates how the value of TH has effect on the QoS performance, the channel efficiency, and the fairness via simulations using Network Simulator-2 (NS-2).

The remaining of this paper is organized as follows. In the next section, we describe the promising EDCF-NA scheme in detail. Then, both the performance of EDCF-NA depending on several pairs of TH and the achievement of some MAC protocols including DCF, EDCF, and AEDCF are evaluated and compared through simulations by using NS-2 in Chapter 3. Finally, Chapter 4 concludes this paper via summarizing results.

II. ENHANCED MAC SCHEME : EDCF-NA

The proposal MAC protocol in this paper called EDCF-NA adopts two main methods, i.e. one is backoff procedure and the other is IFS control, of which purpose is to provide QoS efficiently. Both methods employ dynamic process to adapt MAC parameters, such CW and Arbitrary IFS (AIFS), based on network condition determined by ACK rate and TH as shown in Fig. 1. Further operation of EDCF-NA is presented below.

Manuscript received November 13, 2006.

Moon Kim and Hwi-Jin Ye are Ph.D course student in Department of Information and Telecommunication Engineering, Gradute School of Hankuk Aviation University, Goyang, Korea (Email: {moonkim, haua97}@hau.ac.kr)

Sung-Joon Cho is a professor in Hankuk Aviation University, Goyang, Korea (Email: sjcho@hau.ac.kr)

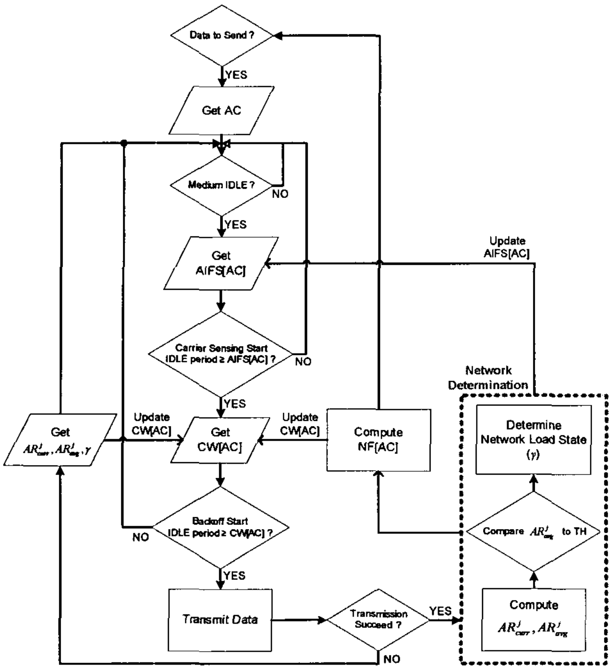

Fig. 1 Flow chart describing the operation of EDCF-NA mechanism.

A. Network Determination

After the MAC layer of a station transmits packet, it computes the ACK rate (AR^i_{curr}) affected with whole transmission fail due to collision, drop, and so on. The number of ACK received ($E(ack\_recv_i)$) and the total number of packets sent ($E(data\_sent_i)$) during a period i are adopted to estimate AR^i_{curr} as shown at equation (1), where the period i indicates terms from the moment of former ACK rate determination to this moment. The average ACK rate (AR^i_{avg}) is then calculated as denoted by equation (2) where the value of α, which indicates the weight, is used as 0.8 in this paper [4].

$$AR^i_{curr} = \frac{E(ack\_recv_i)}{E(data\_sent_i)} \tag{1}$$

$$AR^i_{avg} = (1-\alpha)\times AR^i_{curr} + \alpha \times AR^{i-1}_{curr} \tag{2}$$

Table 1 shows that the values of average ACK rate and TH are used to determine current network load divided into four states that are BUSY, HIGH, LOW, and IDLE; BUSY means heavier load on network, on the other hand IDLE means the lighter load on network. Especially, the value of THs such as THbusy, THnormal, and THidle performs as criterion to arrange the network load state. If the value of THbusy is allocated too small, data transmissions are not repressed even though the amount of network load is very high. It causes burst collisions and degradation of network state. In addition, if the value of THidle is designated too high, data transmissions are suppressed as if medium is crowded. It induces unnecessary delay so that the medium efficiency is aggravated. Therefore, it is essential to consider the measurement of reasonable TH values. In this purpose, several pairs of TH are assumed and considered through NS-2 simulations under various network environments in the next section. Each of four network load states is bound to its own network load factor (γ) which weights MAC parameters.

Table 1 Determination of the network load state

AR^i_{avg}	Network Load State	γ
$AR^i_{avg} <$ THbusy	BUSY	3
THbusy $< AR^i_{avg} <$ THnormal	HIGH	2
THnormal $< AR^i_{avg} <$ THidle	LOW	1
THidle $< AR^i_{avg}$	IDLE	0

B. AIFS Control

EDCF-NA adjusts the size of AIFS taking into account the amount of network load. In heavily loaded network, e.q. the network load state is BUSY, the network obstacles including collision and drop occur frequently. In other words, the medium access to transmit a packet in overloaded network causes additional collisions or drops; hence it is required for MAC algorithm to throttle the medium access. In this manner, Table 2 defines how to control the size of AIFS over four states of network load. For instance, when the network load state is HIGH, EDCF-NA increases the size of AIFS for the traffic of Access Category (AC) 1 by a slot time unless the AIFS value reaches 5.

C. Backoff Algorithm

When a packet transmission is achieved, each AC computes a novel factor denoted by Network Factor (NF). It is derived from not only the AC's priority level and but also the network conditions as shown at equation (3), in order to offer both priority and network based QoS.

$$NF[AC] = \min\{(1+(AC\times\gamma))\times(1-AR^i_{avg}), \frac{\gamma+6}{10}\} \tag{3}$$

Table 2 AIFS control depending on network load

AC	AIFS	State of Network Load			
		BUSY	HIGH	LOW	IDLE
0	Variation	Incr.	Incr.	Decr.	Decr.
	Limit	10	8	7	5
1	Variation	Incr.	Incr.	Decr.	Decr.
	Limit	6	4	2	2
2	Variation	Incr.	Decr.	Decr.	Decr.
	Limit	4	2	2	2
3	Variation	No	No	No	Incr.
	Limit	2	2	4	5

Incr.: Increase, Decr.: Decrease

This equation allows that higher priority AC and better network conditions, e.q. bigger ACK rate and lighter network load, induce smaller NF value. It is used to update the value of CW as following equation (4).

$$CW_{new}[AC] = \max\{CW_{\min}[AC], CW_{old}[AC]\times NF[AC]\} \quad (4)$$

After each unsuccessful transmission, the size of CW is increased with the ACK rate and the network load factor as it is denoted at equation (5). Therefore, it is assured that lower value of CW is derived from superior network conditions.

$$CW_{new}[AC] = \min\{CW_{\max}[AC], (CW_{old}[AC]+\gamma)\times(2-AR^{j}_{avg})-\gamma\} \quad (5)$$

III. SIMULATION ANALYSIS

This section evaluates the performance of proposed MAC protocol, EDCF-NA, through NS-2 simulations. So it is analyzed how the value of TH pair has effect on both QoS performance and channel efficiency. Moreover, we compare and examine the performance of legacy MAC protocols with EDCF-NA employing the optimal TH pair determined by various simulations.

A. Simulation Properties

We use the simulation topology shown in Fig. 2 that is composed of wireless and wired network. The simulation is performed in terms of throughput, collision rate, ACK rate, and medium utility. Table 3 shows several pairs of TH used in simulations.

In simulation, we employ three of MAC modules; DCF methods implemented in NS-2 release 2.26, EDCF methods introduced from Telecommunication Network Group, and AEDCF described in [6]. In addition, we assume that all stations used in simulation adopt the IEEE 802.11a PHY mode-6 specification as listed in Table 4. Also, the MAC parameters for three ACs used in simulations are addressed at Table 5 [7].

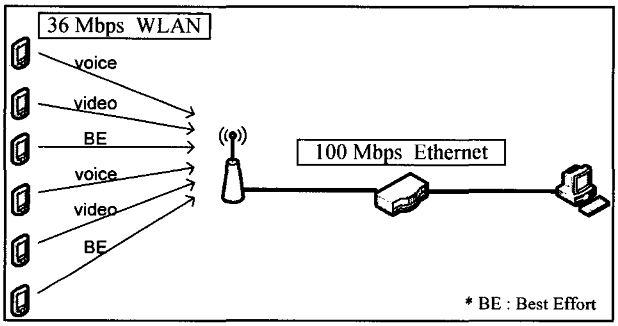

Fig. 3 Simulation topology.

Table 3 AIFS control depending on network load

	TH#1	TH#2	TH#3	TH#4	TH#5	TH#6
TH_{busy}	0.80	0.75	0.75	0.70	0.70	0.70
TH_{norm}	0.85	0.85	0.80	0.75	0.80	0.75
TH_{idle}	0.90	0.90	0.90	0.85	0.90	0.90

Table 4 IEEE 802.11a PHY/MAC parameters

Parameters	Value
Slot Time	9 us
SIFS	16 us
DIFS	34 us
Data Rate	36 Mbps
Modulation	16-QAM

Table 5 MAC parameters for three different AC

Parameters	High	Medium	Low
AIFSN	2	3	4
AIFS (us)	34	43	52
CWmin	7	15	31
CWmax	31	63	1023
Packet Size (bytes)	160	1280	200

B. Simulation Discussion

Fig. 4~6 shows the comparison of throughput performance according to some pair of TH as listed in Table 3 under different priority. In Fig. 4, it is confirmed that the throughput performance of High priority traffic according to TH is almost same when the traffic load is less than 10000Kbps. However, if the traffic load is very high, the throughput is different depending on TH. All the TH pairs except TH#4 allow better throughput performance than AEDCF. Particularly, it is shown that the adoption of TH#1, TH#2, TH#3, and TH#5 increases the throughput of High priority traffic significantly.

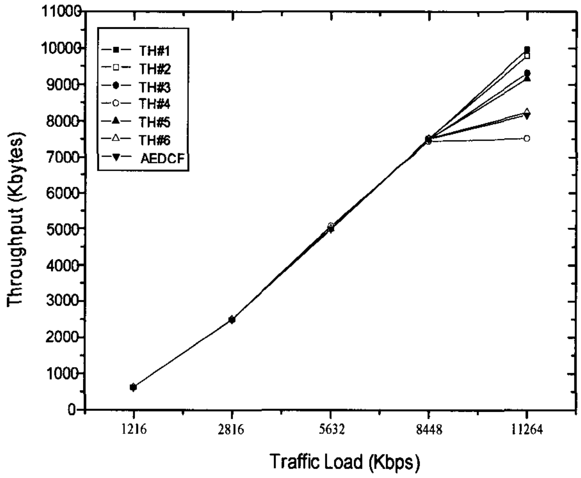

Fig. 4 Throughput of High priority traffics according to TH.

On the other side, the use of TH#1, TH#2, TH#3, and TH#5 conspicuously decreases the throughput of Medium priority traffic as described in Fig. 5. Consequently, we can figure out that in case the throughput of High priority traffics is increased, that of Medium priority traffics is decreased. This is because the value of THbusy is established too high so that the network load state is settled BUSY in all probability. Fig. 6 shows the throughput of Low priority traffic in accordance with TH pairs. It is sure that EDCF-NA using any of TH pairs improves the throughput performance of Low priority data regardless of network traffic load. Especially, EDCF-NA employing TH#2, TH#3, and TH#6 allows much more Low priority packets to be transmitted than AEDCF when traffic load is more than 5000Kbps.

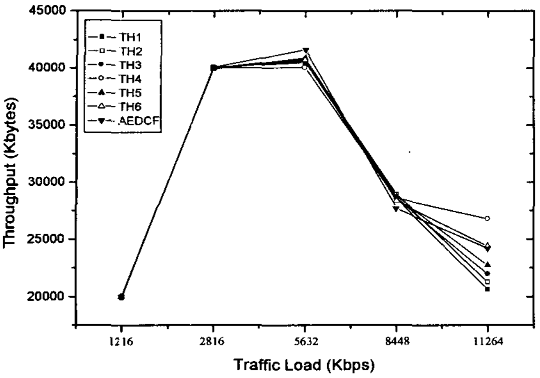

Fig. 5 Throughput of Medium priority traffics according to TH.

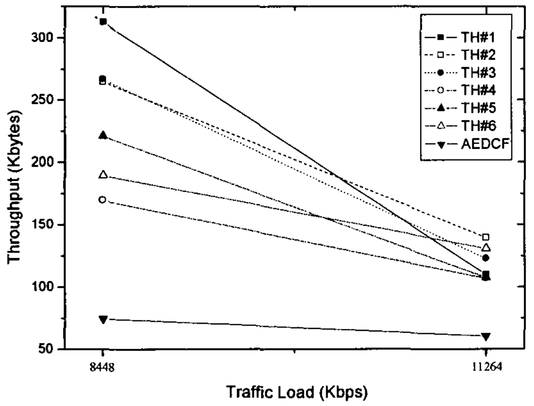

Fig. 6 Throughput performance of Low priority traffics according to TH pairs in heavy traffic load.

Total throughput performance depending on TH is described in Fig. 7. Note that we have performed the simulation in terms of the number of packets. This is because the packet size depending on priority is set differently, hence, we make sure how MAC mechanisms handle packets with distinguished priority via the number of packets to be transmitted successfully. The total throughput performance presented in Fig. 8 is remarkably enhanced if TH#1, TH#2, TH#3, and TH#5 are adopted for measuring the network load state. But when using TH#4, total throughput is degraded as compared with AEDCF at heavily loaded network.

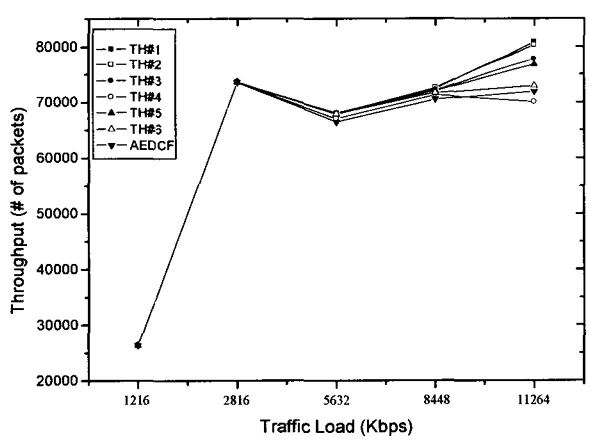

Fig. 7 Total throughput performance according to TH pairs as compared with AEDCF

In Fig. 8, it is shown that EDCF-NA employing any of TH pairs alleviates collision rate in case network traffic load is more than 8000Kbps. In particular, the adaptation of TH#1 and TH#2 brings notable improvement of channel efficiency, thus collision rate significantly decreases. Moreover the use of these TH pairs enhances total throughput performance remarkably compared with other TH pairs and AEDCF. Consequently, it is confirmed that the adaptation of TH#1 and TH#2 gives solid enhancement of both QoS features and channel efficiency. However, it is also told that the throughput performances of Medium priority and Low priority are much degraded when using TH#1. On the other hand, the use of TH#2 increases the throughput of both Medium priority and Low priority significantly too. Therefore, EDCF-NA employing TH#2 pair provides notable enhancement of both QoS and channel efficiency without any starvation of lower priority traffics as compared with other TH pairs.

Each of Fig. 9~11 shows the comparison of throughput according to both the MAC algorithm and the amount of network load under differential priority when TH#2 pair is adopted by EDCF-NA. In these figures, the network is capable of entire traffic demands when the traffic load is less than 3000 Kbps. Thus, all the MAC schemes provide similar performance of throughput without any difference according to traffic priority.

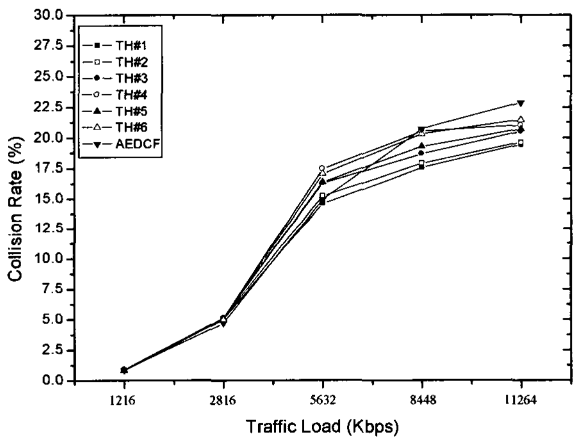

Fig. 8 Comparison of collision rate according to TH.

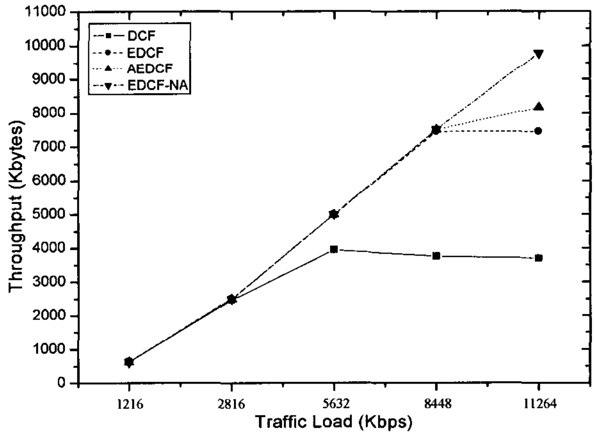

Fig. 9 Throughput performance of High priority traffics according to MAC protocols.

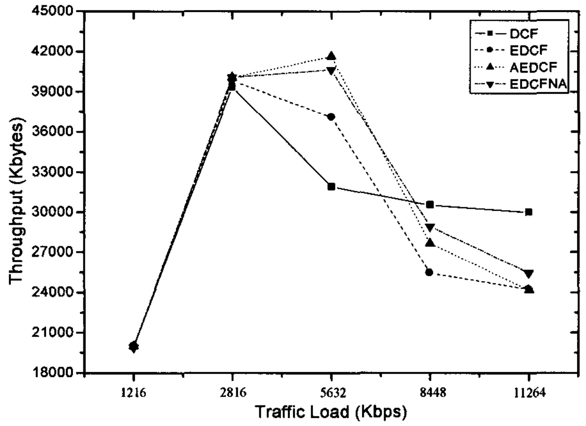

Fig. 10 Throughput performance of Medium priority traffics according to MAC protocols.

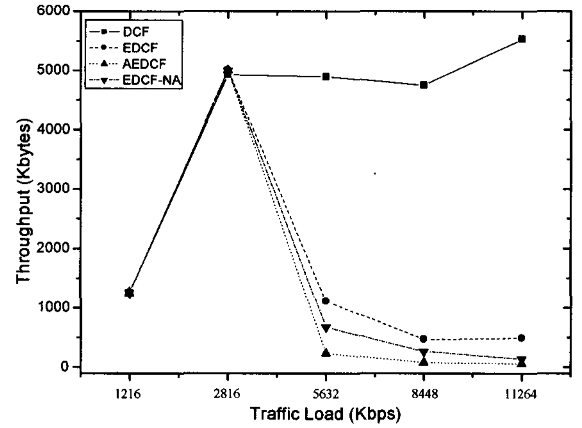

Fig. 11 Throughput performance of Low priority traffics according to MAC protocols.

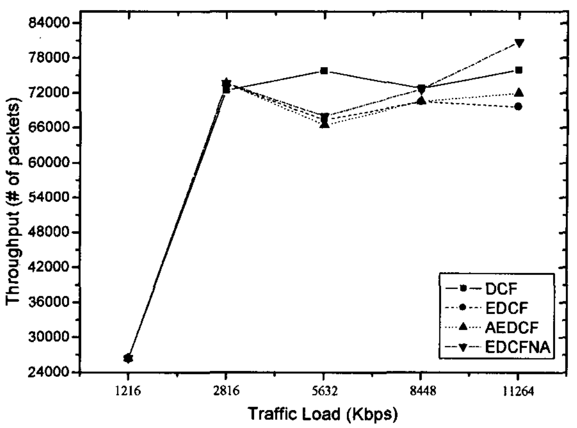

Fig. 12 Comparison of total throughput according to MAC protocols.

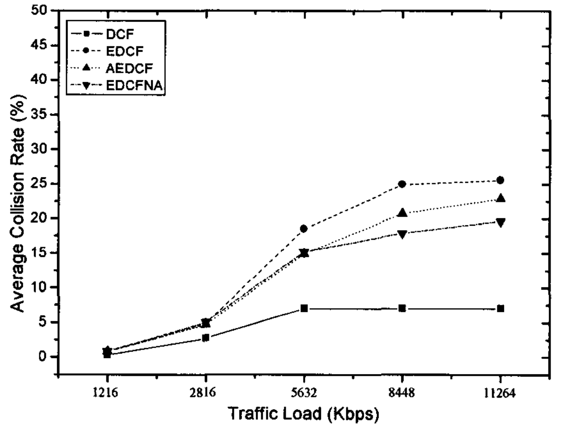

Fig. 13 Comparison of collision rate according to MAC protocols.

However, if the traffic load exceeds 3000 Kbps, MAC schemes show unlike throughput achievement depending on the priority and the feature of MAC algorithm. For instance, DCF does not guarantee any service differentiation although it represents better performance than other QoS-aware MAC algorithms on medium and low priority traffics. In QoS-aware MAC protocols, we confirm that the proposed MAC protocol, EDCF-NA, employing TH#2 provides significant improvement of throughput performance than other protocols when the network load is heavier. Particularly, in low priority traffics, EDCF-NA improves the starvation problem of AEDCF by using AIFS control mechanism which admits the low priority AC to get a chance to transmit packets, as shown in Fig. 11.

The performance of total throughput under variable traffic load is described in Fig. 12. Note that the total throughput performance and average collision rate represent the medium utilization. In the figure, it is seen obviously that EDCF-NA guarantees conspicuous enhancement of medium utility compared with any other MAC protocols such DCF, EDCF, and AEDCF. This is because the ACK rate adopting all the network errors represses the collision occurrence. Additionally, the average collision rate depending on network traffic load is compared in Fig. 13. In case of EDCF, it does not consider any network conditions so that average collision rate is worse than other MAC protocols. AEDCF which estimates network state using collision rate also shows poor collision rate although it offers better collision rate than EDCF. Accordingly, it is clear that EDCF-NA allows remarkable decrease of average collision rate hence channel efficiency is enhanced well.

IV. CONCLUSIONS

In this paper, it is analyzed that how the value of TH pair has effect on both QoS performance and channel efficiency through the simulations using NS-2. In result, the adaptation of TH#2 pair gives solid enhancement of both QoS features and channel efficiency. Moreover, it increases the throughput of both Medium priority and Low priority traffics significantly as well. Therefore, it is verified that EDCF-NA employing TH#2 pair provides remarkable improvement of both QoS and channel efficiency without any starvation of lower priority traffics as compared with other TH pairs. In addition, it is clearly seen that EDCF-NA adopting TH#2 has improved a number of MAC achievement. At first, it has strengthened the QoS property by increasing the throughput of higher priority traffics regardless of the network traffic load. Secondly, it has reduced the probability of collision occurrence according to the use of ACK rate which has adapted network conditions to both backoff parameters and IFS parameters dynamically. Moreover, the decreased collision rate has raised the channel utility. Finally, the proposed AIFS control mechanism has allowed lower priority ACs to have more transmission opportunities; thereby the starvation of lower priority traffics has been alleviated.

ACKNOWLEDGMENT

This research was supported by the Internet information Retrieval Research Center (IRC) in Hankuk Aviation University. IRC is a Regional Research Center of Gyeonggi Province, designated by ITEP and Ministry of Commerce, Industry and Energy.

REFERENCES

[1] IEEE Std. 802.11-1999, Information technology-Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific Requirements-Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, IEEE, 1999.

[2] He Dajiang, Shen, C.Q., "Simulation study of IEEE 802.11e EDCF," *IEEE Vehicular Technology Conf. (VTC 2003-Spring),* vol. 1, pp. 685-689, Apr. 2003.

[3] IEEE Std. 802.11e/D8.0-2004, Draft Supplement to Standard for Telecommunications and Information Exchange Between Systems-LAN/MAN Specific Requirements-Part 11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Medium Access Control (MAC) Enhancements for Quality of Service (QoS), IEEE, 2004.

[4] Romdhani, L., Ni Qiang, Turletti, T., "Adaptive EDCF: enhanced service differentiation for IEEE 802.11 wireless ad-hoc networks," *IEEE Wireless Communications and Networking Conf. (WCNC 2003),* vol. 2, pp. 1373-1378, Mar. 2003.

[5] Kim, S-M., Cho, Y-J., "QoS enhancement scheme of EDCF in IEEE 802.11e wireless LANs," *Electronics Letters,* vol. 40, No. 17, Aug. 2004.

[6] http://www-sop.inria.fr/planete/qni/Research/AED-CF

[7] IEEE Std. 802.11a-1999, Information technology- Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific Requirements-Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications -Amendment 1: High-speed Physical Layer in the 5 GHz band, IEEE, 2000.

Moon Kim
Received the B.S. and M.S. degree in telecommunication and inform-ation engineering from Hankuk Aviation University, Gyeonggi-do, Korea in 2004 and 2006. Since 2006, he has been Ph.D course student in information and telecommunication engineering at the same university. His research interests include QoS, Handoff, and heterogeneous network.

Hwi-Jin Ye
Received the B.S. and M.S. degree in telecommunication and inform-ation engineering from Hankuk Aviation University, Gyeonggi-do, Korea in 2002 and 2004. Since 2004, he has been Ph.D course student in information and telecommunication engineering at the same university. His research interests include system integration, IPv6 and heterogeneous network.

Sung-Joon Cho
Received the B.S. degree in telecommunication engineering from Hankuk Aviation University, Gyeonggi-Do, Korea in 1969, the M.S. degree in the telecommunication engineering from Hanyang University, Seoul, Korea in 1975 and the Ph.D. degree in telecommunication engineering from Osaka University, Osaka, Japan in 1981. Since 1972, he has been a professor in the School of Electronics, Telecommunication and Computer Engineering, Hankuk Aviation University, Gyeonggi-Do, Korea. His research interests are in the areas of wireless communication, mobile communication, and electromagnetic interference.