Mobile Information Systems 5 (2009) 21–32
DOI 10.3233/MIS-2009-0070
IOS Press

A new MAC protocol for reducing effect of needless transmission deferment induced by missed RTS/CTS handshake

Tetsuya Shigeyasu[a], Daishi Inoue[b], Hiroshi Matsuno[b] and Norihiko Morinaga[c]
[a]*Faculty of Engineering, Hiroshima International University*
[b]*Graduate School of Socio-Infrastructural Technologies, Hiroshima International University*
[c]*Graduate School of Science and Engineering, Yamaguchi University*

Abstract. IEEE802.11DCF employs RTS/CTS (Request To Send/Clear To Send) mechanism for mitigating effect of hidden terminals. The RTS/CTS mechanism sets transmission deferral timer to neighbor terminals by exchanging RTS and CTS between transmitter and receiver. Then, in the case that RTS/CTS exchange succeeds, effect of hidden terminals could be suppressed, otherwise, any neighbor which received RTS and/or CTS defers its new transmission needlessly although DATA packet corresponding to the previous RTS/CTS exchange will not be transmitted. In this paper, we propose Cancel CTS, procedure in order to cope with the unnecessarily transmission deferment. Results of computer simulation confirms that our method well improves the throughput performance of IEEE802.11DCF.

1. Introduction

IEEE802.11DCF which is the most widely used wireless LAN standard employs CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) as its fundamental MAC (Media Access Control) protocol.

In order to address the hidden terminal problem, the DCF equips the virtual carrier sensing function in addition to the traditional carrier sensing function, CSMA. The virtual carrier sensing is realized by the RTS/CTS short packets exchange and the NAV. The RTS/CTS exchange can keep terminals other than the sender and the receiver silent for ensuring a data packet transmitted correctly. The NAV is a timer that indicates the amount of time that the medium will be reserved.

RTS/CTS mechanism could reduce the effect of hidden terminals when the RTS and CTS are exchanged successfully. However, in the opposite case, terminals which hears RTS and/or CTS sets NAV and defers its new transmission needlessly although DATA packet corresponding to the RTS and/or CTS will not be transmitted.

In order to cancel the needless NAV, IEEE802.11DCF+CRTS [2] proposes CRTS (Cancel RTS) mechanism in which a sender cancels NAVs by transmitting CRTS to neighbors if the sender senses that its RTS/CTS exchange has missed. Moreover [3], proposes the method of RTS validation which cancels unneeded NAVs, when the actual DATA transmission could not be detected by carrier sense at the expected time for receiving DATA. In addition [4], proposes a new method for avoiding unnecessary transmission deferment without any new control packet and large modification of MAC protocol. Although above

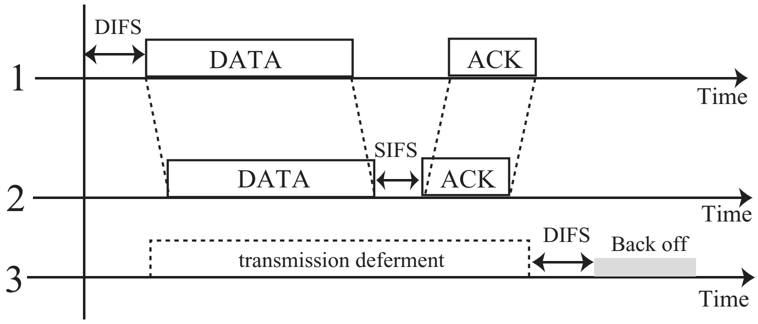

Fig. 1. IEEE802.11DCF mechanism.

these protocols can solves unneeded NAV set by RTS, the other unneeded NAV set by CTS is not be solved.

On the other hand, it has been reported that RTS/CTS mechanism works effectively when the sender transmits longer DATA [5,6]. However, it is also known that negative effect of unneeded NAV timer set by missed RTS/CTS exchange become large if DATA length becomes longer.

Therefore, in order to clarify the effect of unneeded NAV timer, this paper investigates the situation that the number of missed RTS and CTS transmission under the various traffic environment. We clarify that missed CTS induces negative effect by setting unneeded NAV to its neighbors under the high traffic environment. Therefore, for cancelling the unneeded NAV timer set by CTS, this paper propose a new MAC protocol, namely, IEEE802.11DCF with CCTS (Cancel CTS). Next, in order to evaluate effect of proposed protocol, we show the results of computer simulations. These results confirm that our proposed protocol improves throughput performance and brings out the essential performance of RTS/CTS mechanism reported by [5,6].

2. Transmission procedure and Its problem of IEEE802.11DCF

2.1. Transmission procedure of IEEE802.11DCF

Figure 1 shows fundamental transmission procedure of IEEE802.11DCF. The IEEE802.11DCF defines several IFSs (Inter Frame Space) as inter transmission period to fix an order of priority between packet types. Each packet will be transmitted with designated IFS while the IFS has an adequate fixed length for holding its priority. On the IEEE802.11DCF, a transmitter which has a transmission request senses channel, and waits in DIFS (DCF Inter Frame Space) period and transmits DATA packet if the channel is detected as an idle state. After receiving DATA, a receiver waits in SIFS (Short Inter Frame Space) period and returns ACK (Acknowledgement) to a transmitter when the DATA is received without any collision and error. The transmitter terminates transmission sequence by receiving ACK in an expected time. Otherwise, the transmitter retransmits the DATA to the receiver.

In DCF, a terminal employing basic carrier sense procedure could not check the state of terminals locating out of its transmission range. Then, collisions may occur frequently in DCF when network contains several terminals locating out of transmission range of sender [1]. In order to reduce such packet collisions, RTS/CTS handshake is defined as an option of basic carrier sense procedure in DCF. The RTS/CTS handshake transmits RTS and CTS among a transmitter and a receiver. Neighbor terminals of the transmitter and receiver could prevent its new transmission by overhearing the RTS and/or CTS.

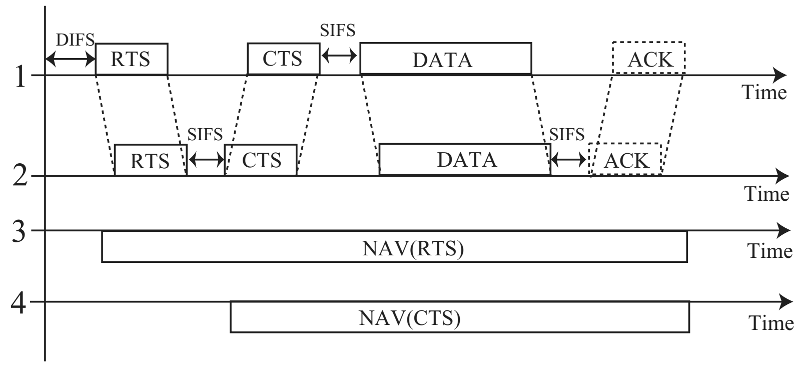

Fig. 2. RTS/CTS procedure of IEEE802.11DCF.

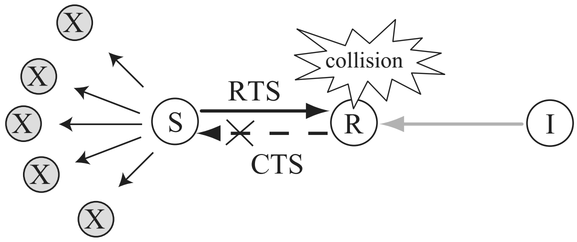

Fig. 3. missing RTS/CTS handshake situation.

Figure 2 shows transmission procedure using RTS/CTS handshake in DCF. In this procedure, terminal 1 which has a newly packet to transmit checks channel by carrier sense. According to the result of the carrier sense, the terminal 1 transmits RTS to terminal 2 in DIFS period when no other terminal transmits packet. The terminal 2 receiving RTS from terminal 1 replays CTS to terminal 1 in SIFS period if the terminal 2 is in a receivable state. At the time, by receiving RTS and CTS, terminals 3 and 4 set transmission deferral timer NAV(RTS) and NAV(CTS), respectively. Terminal 1 starts DATA transmission to terminal 2 after receiving CTS from terminal 2. Terminal 2 replays ACK to terminal 1 when the DATA is received correctly.

2.2. Needless transmission deferment on IEEE802.11DCF

In DCF, a transmitter S sends RTS to a receiver R in order to prevent transmissions from hidden terminals (see Fig. 3). However, the RTS may collide with a packet from a hidden terminal at the R and R will not return CTS to the terminal S when the hidden terminal I transmits any packet in parallel with the RTS transmission of terminal S. Then, terminals Xs set needless NAV(RTS) although RTS/CTS handshake among the terminal S and the terminal R is missed. Figure 4 shows the length of the above mentioned needless NAV(RTS) period. In this figure, terminal 3 sets NAV(RTS) by overhearing RTS from terminal 1. When the RTS/CTS handshake does not succeed, terminal 3 defers its new transmission in needless NAV period shown in Fig. 4.

The length of needless transmission deferment becomes large in proportion to growing length of DATA although it is reported that RTS/CTS handshake increases its advantage in throughput performance [6, 7].

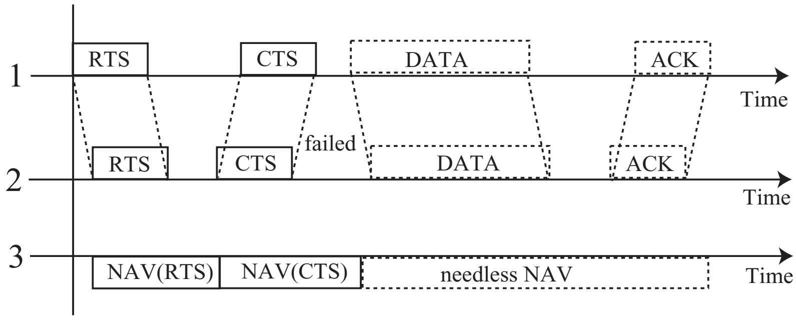

Fig. 4. Failed situation of CTS transmission.

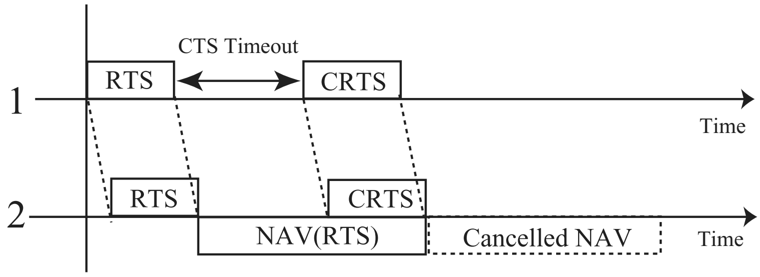

Fig. 5. RTS/CTS+CRTS mechanism.

3. Related works

3.1. RTS/CTS+CRTS

RTS/CTS+CRTS [2] is a method in which a transmitter cancels needless NAV(RTS) by transmitting CRTS (Cancel RTS) to its neighbor terminals. Figure 5 shows the transmission procedure of RTS/CTS+CRTS. In this figure, terminal 2 which is a neighbor terminals of sender sets NAV(RTS) by overhearing RTS from the sender terminal 1. If the sender terminal 1 could not get CTS from its receiver, terminal 1 sends CRTS to its neighbor terminals in order to cancel needless NAV(RTS) of its neighbors (including terminal 2). Overhearing terminals of CRTS cancels its NAV(RTS) and it turns into an idle state. Figure 5 shows the length of cancelled needless NAV period.

3.2. RTS validation

Figure 6 shows the control procedure of RTS validation proposed in the paper [3]. RTS validation is a method which avoids needless transmission deferment by validating the adequacy of allocated NAV.

In the RTS validation, any terminal deferring its new transmission by NAV checks DATA transmission corresponding the NAV to carrier sensing after RTS Defer time (RTS Defer time equals CTS transmission time $+ 2 \times$ SIFS periods). According to the result of carrier sensing, if no carrier is detected, the terminal cancels the NAV and it returns to idle state. Otherwise, the terminal keeps its transmission deferment in order to avoid collision with ongoing transmission.

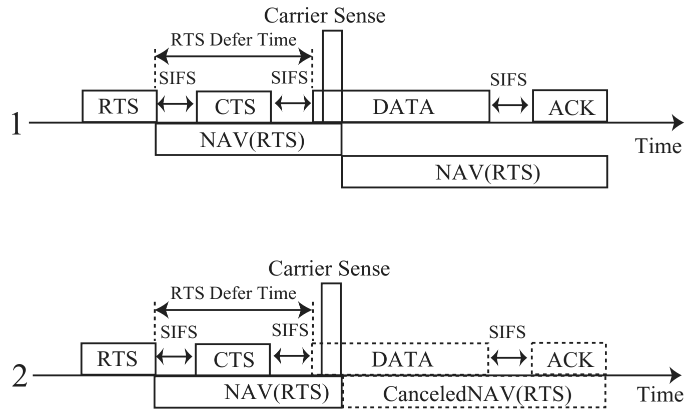

Fig. 6. RTS validation mechanism.

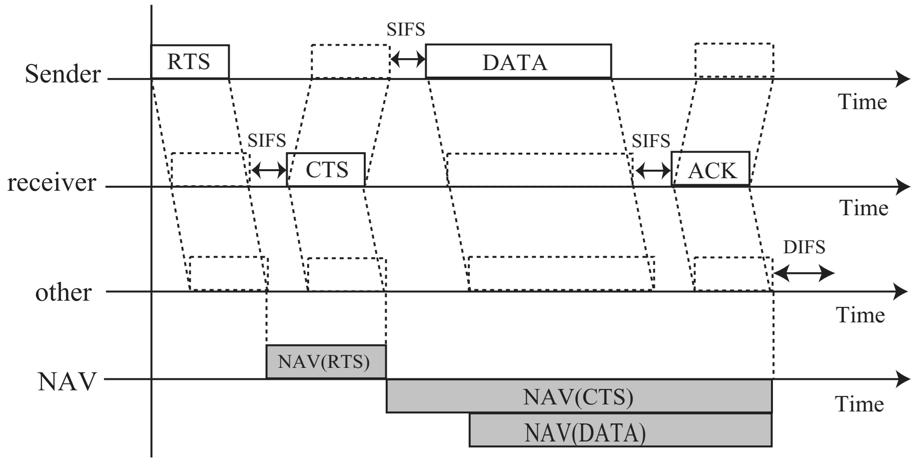

Fig. 7. NAV omitted mechanism.

3.3. *NAV omitted*

Figure 7 shows control procedure of NAV omitted proposed in the paper [4]. The NAV omitted is a method which applies NAV setting to the original IEEE802.11DCF according to the NAV setting of MACA which is the first method proposing RTS/CTS handshake. In the NAV omitted, any terminal receiving RTS sets NAV(RTS) and defers its new transmission until expected time for receiving CTS in response to corresponding the RTS. On receiving the CTS, the terminal extends NAV to NAV(CTS) until expected time for receiving ACK. When the CTS is not received, the terminal returns to the idle state in short period by expiring the NAV(RTS).

4. A new method for avoiding needless transmission deferment caused by missing both RTS and CTS

As described in the previous section, several methods for avoiding needless transmission deferment by missing RTS/CTS handshake has been proposed. However, these methods are only destined for

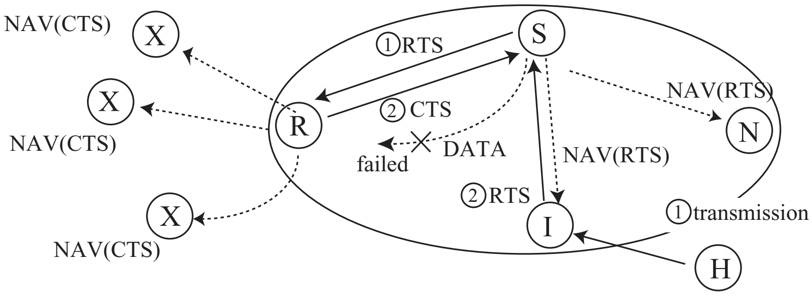

Fig. 8. missing CTS situation.

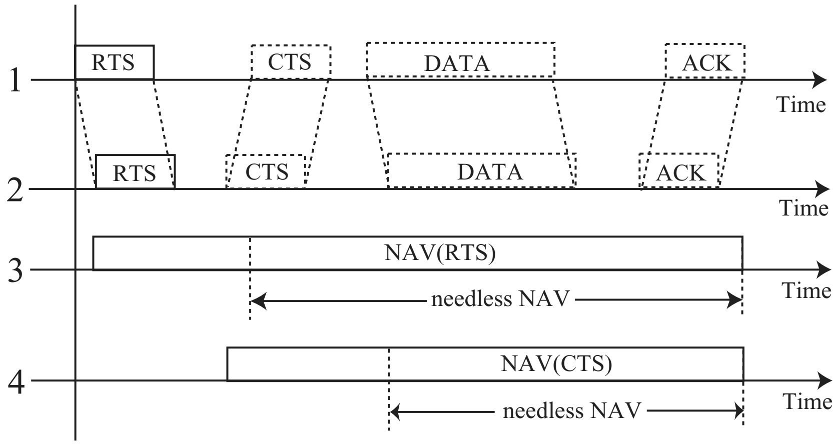

Fig. 9. Lengths of needless NAVs induced by RTS and CTS.

cancelling needless NAV(RTS). Then, none of these method could eliminate the effect of needless NAV(CTS).

Figure 8 shows an example of missing CTS transmission on IEEE802.11DCF.

Let us consider the situation that terminal S has a new packet destined to terminal R. First, terminal S transmits RTS to terminal R. The RTS reaches all neighbors of terminal S. But, terminals connected to hidden terminals H of terminal S could not receive the RTS correctly due to collision when the terminal H transmits any packet in parallel with the RTS (this is shown in Fig. 8 as 1). Then, NAV(RTS) is not set at terminal I, and terminal I may interfere with a reception of CTS at terminal S. The DATA is not transmitted from terminal S if the interference occurs by terminal I although terminals marked X in Fig. 8 defers its new transmission needlessly by receiving CTS from terminal R correctly (this is shown in Fig. 8 as 2).

Figure 9 shows lengths of needless NAV periods of RTS and CTS. As shown in Fig. 9, both lengths of needless NAV depends on the DATA length. Therefore, these needless NAV much degrades throughput performance on the long DATA transmission.

Therefore, in this paper, we propose IEEE802.11DCF with CCTS as a new method for avoiding needless transmission deferment induced by missing both RTS and CTS transmissions.

Our new method employs CCTS procedure to cancel needless NAV(CTS) in addition to the NAV omitted method destined for cancelling needless NAV(RTS). The reason for employing NAV omitted to cancel needless NAV(RTS) is that the NAV omitted method does not need any new additional packet

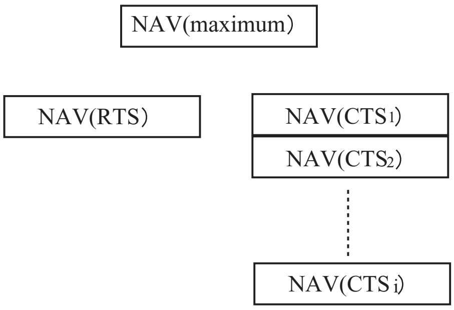

Fig. 10. NAV information.

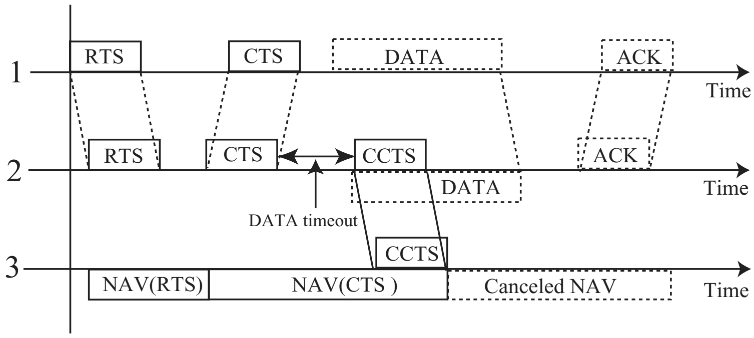

Fig. 11. Cancel CTS procedure.

and new operation to the legacy IEEE802.11DCF. For CCTS procedure, our method keeps three types of NAV information as shown in Fig. 10. NAV(RTS) keeps NAV value by receiving RTS from all neighbors. NAV(CTS$_i$) is a NAV information for keeps NAV value set by CTS from terminal i. NAV(maximum) keeps maximum NAV value among NAV(RTS) and NAV(CTS$_i$)s. NAV(maximum) will be updated when any NAV value is changed. In our method, sender determines whether it is in a transmittable state or not according to the value of NAV(maximum).

Figure 4 shows the control procedure of our method. By using this figure, let us consider the situation that terminal 2 transmits CTS to terminal 1, and terminal 1 can not receive the CTS (due to collision or any other interference) although terminal 3 receive the CTS correctly and sets NAV(CTS$_2$). After the transmission of CTS, terminal 2 waits for DATA time out and transmits CCTS in order to cancel needless NAV(CTS$_2$) on its neighbor terminals when terminal 2 could not recognize DATA transmission with carrier sensing. On receiving CCTS from terminal 2, terminal 3 cancels its NAV(CTS$_2$) and avoids needless transmission deferment induced by missing CTS.

5. Performance evaluation

In this section, we evaluate the effect of our proposed method by comparing with the protocols of legacy IEEE802.11DCF and NAV omitted. Simulation parameters are shown in Table 1.

Table 1
Simulation parameters

Data rate	1 Mbps
Communication range	100 m
Payload	1024 bytes
Packet arrival process	Poisson
Simulation field	500 × 500 m
Number of terminals	50
Terminals initial location	random placed
Simulation period	50 seconds

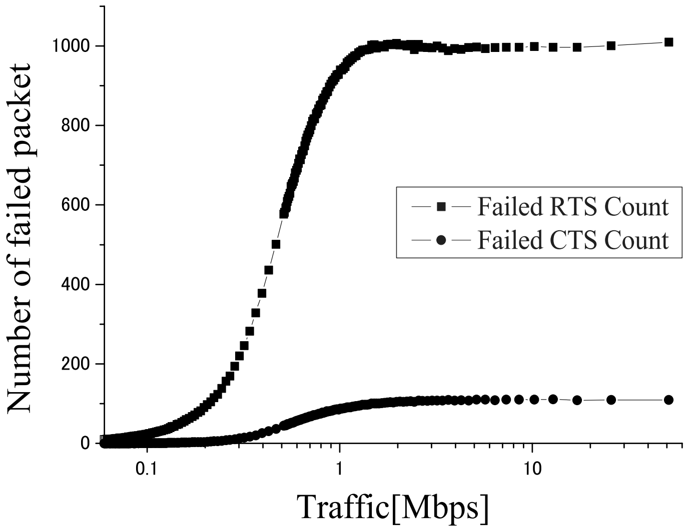

Fig. 12. RTS/CTS~@Failed Count.

5.1. The number of failed transmissions of RTS and CTS

In order to keep track of occasions of needless transmission deferment induced by missed RTS and CTS, we examine the number of missing RTS and CTS under the various traffic situations. Figure 12 shows results of the number of missing packets on various traffic condition. In this figure, failed RTS count indicates the number of RTS transmissions with no corresponding CTS transmission. Failed CTS also indicates the number of CTS transmissions with no corresponding DATA transmission. From the figure, these results confirm that both number of failed counts increase in proportion to growing traffic. Although the failed CTS count is always lower than the failed RTS count, the results clarify that the number of failed CTS increases and it might induces unneeded transmission deferment under the high traffic environment.

5.2. Characteristics of traffic – throughput performance

Figure 13 shows characteristics of traffic – throughput performance. From this figure, the results show that differences among three protocols grow up in proportion to increasing traffic. Our proposed method shows higher performance than the other two protocols in all ranges. Our protocol effectively mitigates the effects of needless NAV(RTS) and NAV(CTS) induced by failed RTS and CTS in contradiction to increasing the number of failed RTS and CTS transmission.

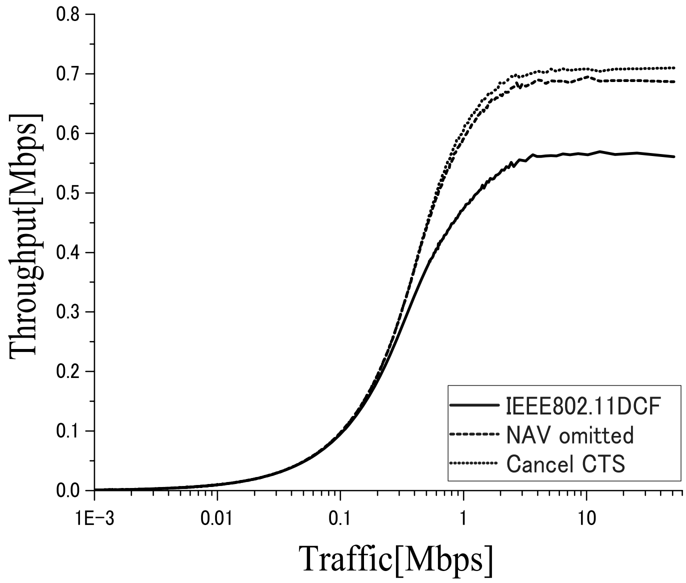

Fig. 13. Traffic-Throughput performance.

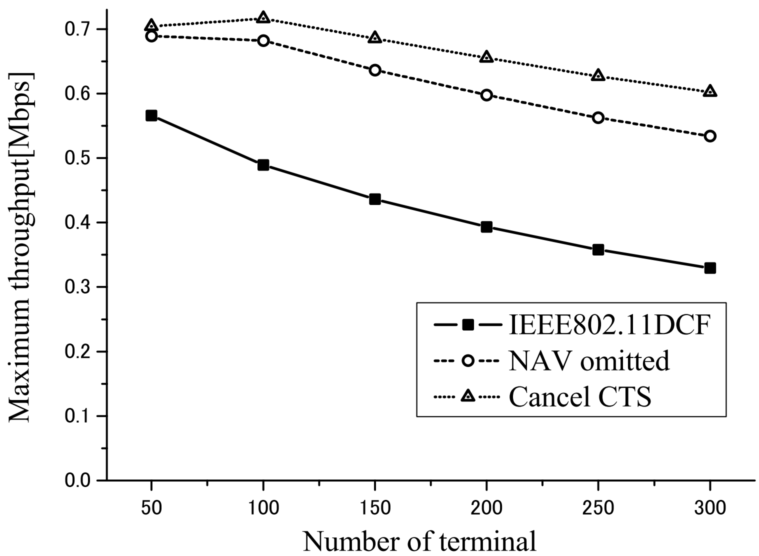

Fig. 14. Characteristics of number of terminals – throughput performance.

5.3. Characteristics of the number of terminals – throughput performance

Figure 14 shows characteristics of the number of terminals – throughput performance. In this evaluation, number of terminals varies 50 terminals to 200 terminals. The other parameters are set as the same listed in Table 1. In order to make the differences clear among these protocols, we derived maximum throughput performance on each protocol and show this in Fig. 14. From the figure, differences of maximum throughput between proposed method and legacy IEEE802.11DCF increases in proportion to

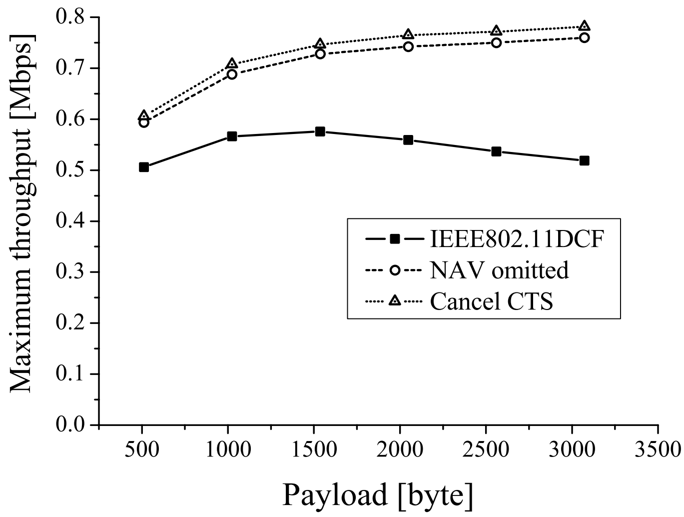

Fig. 15. Characteristics of DATA length – throughput performance.

the increase number of terminals.

5.4. Characteristics of DATA length – throughput performance

Figure 15 shows the characteristics of DATA length – throughput performance. In this evaluation, the length of DATA varies 512 bytes to 3072 bytes. From this figure, the result of the legacy IEEE802.11DCF confirms that throughput performance decreases in contradiction to increasing of DATA length when the DATA length is larger than 1500 bytes, although throughput performance increases in proportion to increasing of DATA length when the DATA length is lower than 1500 bytes.

As against the result of the legacy IEEE802.11DCF, throughput performances of the NAV omitted and the proposed method increases in proportion to increasing of DATA length under the all DATA lengths.

In the papers [6,7], it has been reported that essential performance of RTS/CTS handshake increases when DATA length grows lager. Therefore, we can conclude that NAV omitted and our proposed method well educe performance of RTS/CTS handshake of IEEE802.11DCF.

Figure 16 shows results of more characteristics of DATA length – throughput performance under various number of terminals situation. This result confirms that the above mentioned throughput feature becomes strong in response to increase number of terminals.

6. Conclusion

This paper discussed needless transmission deferment induced by missed RTS/CTS handshake. Based on the survey of related works, we proposed a new MAC protocol for avoiding needless transmission deferment induced by missed both RTS and CTS. Our proposed method is employing NAV omitted and CCTS procedure for cancelling needless NAV set by RTS and CTS, respectively.

For the effect evaluations of three protocols, we clarified that our proposed method achieves highest throughput performance on all evaluations. In addition, from the result of evaluation for DATA length – throughput performance, our proposed method well educes essential throughput performance of RTS/CTS handshake on IEEE802.11DCF.

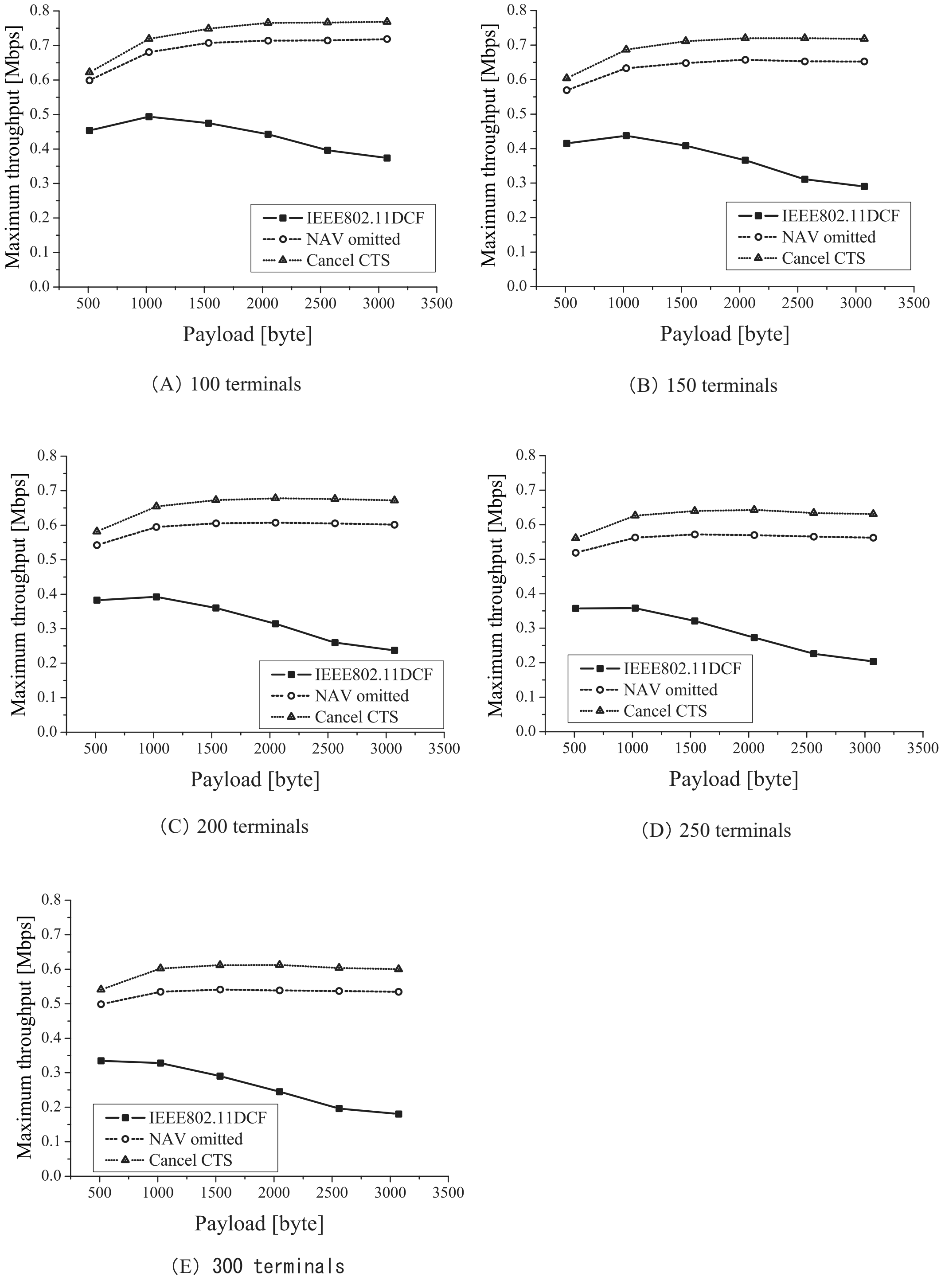

Fig. 16. Characteristics of DATA length – throughput performance under various number of terminals.

Acknowledgement

This research was partially supported by the Grant-in-Aid for Young Scientists (B) No. 18700075 from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

References

[1] F.A. Tobagi and L. Kleinrock, Packet switching in radio channels: Part – The hidden terminal problem in carrier sense multiple-access and the busy tone solution, *IEEE Trans Commun* **COM-23**(12) (1975), 1417–1433.
[2] T. Harada, C. Ohta and M. Morii, Improvement of TCP Throughput for IEEE 802.11DCF in Wireless Multi-hop networks, *IEICE Trans Commun* **J85-B**(12) (2002), 2198–2208.
[3] Saikat. ray et al., On false Blocking in RTS/CTS-Based Multihop Wireless Networks, *IEEE Trans. Vehicular Technology* **56**(2) (March 2007), 849–862.
[4] T. Shigeyasu, T. Hirakawa, H. Matsuno and N. Morinaga, Two simple modifications for improving IEEE802.11DCF throughput performance, WCNC 2004 *IEEE Wireless Communications and Networking Conference* **1**(March 2004), 1445–1450.
[5] F. Karn, MACA – A new channel access and protocol for packet radio, ARRLS/CRRL Amateur Radio Ninth Computer Networking Conf., pp. 134–140, 1990.
[6] H. Matsuno, H. Ishinaka and T. Shigeyasu, Effect of propagation delay and RTS packet recognition time on MACA, *Electronics and Communications in Japan* (*Part I: Communications*) **88**(1) (2005), 21–31.
[7] T. Shigeyasu, H. Matsuno and N. Morinaga, Performance evaluation of media access control protocols using an algorithm generating graphs for effect estimation of hidden terminals, *Electronics and Communications in Japan* (*Part I: Communications*) **90**(4) (2007), 46–55.

Tetsuya Shigeyasu graduated from the Department of Physics, Biology and Informatics at Yamaguchi University in 2000, completed the preliminary doctoral training program in 2002, and became a assistant professor in the Department of Infrastructural Technology at Hiroshima International University. His research interests concern methods for improving and evaluating the characteristics of communications media control protocols in wireless environments, particularly in network environments that do not depend on a specific base station. He is a member of IEEE IEICE and IPSJ.

Hiroshi Matsuno graduated from Faculty of Engineering at Yamaguchi University in 1982 and completed the master's program in 1984. From 1984 to 1987 he worked at Yamaguchi Junior College and from 1987 to 1994 at Oshima National College of Maritime Technology. In 1995 he became an associate professor at Faculty of Science, Yamaguchi University. In 2005 he was appointed a professor. His research interest includes computer network construction technology and systems biology. He holds a Ph.D. degree (Science), and is a member of IEEE, IEICE and IPSJ.

Norihiko Morinaga completed the doctoral program at Osaka University in 1968. He was a research associate, lecturer, associate professor, and professor (1987) in the Department of Engineering at Osaka University. In 2003 he became an emeritus professor at Osaka University and a professor of information technology at Hiroshima International University and since 2005 he has been a Dean at the same university. He holds a D.Eng. degree. His research interests are in wireless communications, satellite communications, mobile communications, free space optical communications, and other communications schemes; in addition, he is interested in strategies for dealing with interference noise in communications systems. He is a former Vice-Chairman of IEICE; former Head of the West Japan Chapter of IEICE; member of the Japan Aerospace Exploration Agency; board member of the Local Authorities Satellite Communications Organization of Japan; committee member of the Telecommunications Business Dispute Settlement Commission of the Ministry of Internal Affairs and Communications of Japan (Deputy Chairman). He received the Best Paper Award of the Society in 1995, the Achievement Award of the Society in 1998, and the Merit Award of the Society in 2004. In 2005 he was made an emeritus fellow of the Society; in 1998 he received a Computerization Award from the Ministry of International Trade and Industry of Japan. He is a fellow of IEEE.