Title:

New MAC Protocol for Reducing the Effect of Needless Transmission Deferment Induced by Failed RTS/CTS Handshake

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Abstract:

IEEE802.11DCF employs the RTS/CTS (Request To Send/Clear To Send) mechanism for mitigating the effect of hidden terminals. This mechanism sets the transmission deferral timer for the neighbor terminals by exchanging RTS and CTS between the transmitter and the receiver. Therefore, when the RTS/CTS exchange is successful, the effect of hidden terminals can be suppressed. Otherwise, any neighbor that receives RTS and/or CTS defers its new transmission needlessly, although the DATA packet corresponding to the previous RTS/CTS exchange will not be transmitted. In this paper, we propose the Cancel CTS procedure in order to cope with unnecessary transmission deferments. The results of a computer simulation confirm that our method effectively improves the throughput performance of IEEE802.11DCF.

Key words:

Wireless LAN, IEEE802.11DCF, Failed RTS/CTS handshake

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Abstract

IEEE802.11DCF employs the RTS/CTS (Request To Send/Clear To Send) mechanism for mitigating the effect of hidden terminals. This mechanism sets the transmission deferral timer for the neighbor terminals by exchanging RTS and CTS between the transmitter and the receiver. Therefore, when the RTS/CTS exchange is successful, the effect of hidden terminals can be suppressed. Otherwise, any neighbor that receives RTS and/or CTS defers its new transmission needlessly, although the DATA packet corresponding to the previous RTS/CTS exchange will not be transmitted. In this paper, we propose the Cancel CTS procedure in order to cope with unnecessary transmission deferments. The results of a computer simulation confirm that our method effectively 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 uses the virtual carrier sensing function in addition to the traditional carrier sensing function CSMA. Virtual carrier sensing is realized by the exchange RTS/CTS of small packets and the NAV. The RTS/CTS exchange renders terminals other than the sender and the receiver to remain silent for a data packet transmitted correctly. The NAV is a timer for which indicates the amount of time that the medium will be reserved.

The RTS/CTS mechanism can reduce the effect of hidden terminals when RTS and CTS are successfully exchanged. However, in the opposite case, terminals that receive the RTS and/or CTS set the NAV and defer their 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 a CRTS (Cancel RTS) mechanism in which a sender cancels NAVs by transmitting CRTS to its neighbors when it senses that its RTS/CTS exchange has failed. Moreover, [3] proposes a method of RTS validation in which the unneeded NAVs are canceled when the actual DATA transmission can 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 packets and without any significant modification of the MAC protocol. Although the above mentioned protocols can solve the unneeded NAVs set by RTS, the other unneeded NAVs set by CTS cannot be solved.

It has been reported that the RTS/CTS mechanism is effective when the sender transmits long DATA packets [5], [6]. However, it is also known that the negative effect of the unneeded NAV timer set by a failed RTS/CTS exchange increase with the length of the DATA packet.

In order to clarify the effect of an unneeded NAV timer, in this study, we investigate the number of failed RTS and CTS transmissions under the various traffic environments. We clarify that failed CTS induces negative effect by setting unneeded NAV to its neighbors in a high-traffic environment. Therefore, for cancelling the unneeded NAV timer set by CTS, this paper proposes a new MAC protocol, namely, IEEE802.11DCF with CCTS (Cancel CTS). Next, in order to evaluate the effect of the proposed protocol, we show the results of computer simulations. These results confirm that our proposed protocol improves throughput performance and highlights the performance of the RTS/CTS mechanism, reported by [5] and [6].

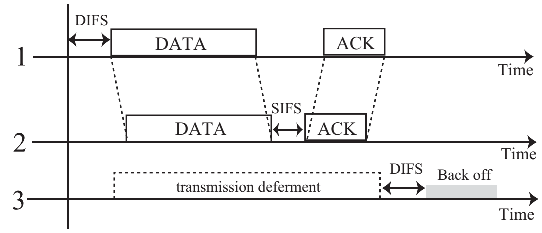

Figure 1. IEEE802.11DCF mechanism

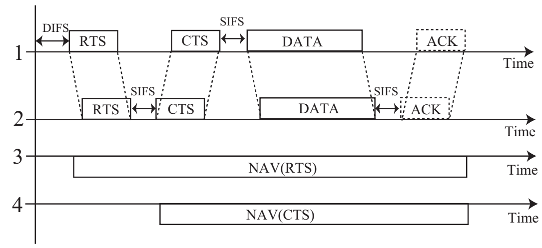

Figure 2. RTS/CTS procedure of IEEE802.11DCF

2 Transmission procedure and transmission problems of IEEE802.11DCF

2.1 Transmission procedure of IEEE802.11DCF

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

In DCF, a terminal employing the basic carrier sense procedure cannot check the state of terminals located out of its transmission range. Therefore, packet collisions may occur frequently in DCF when the network contains several terminals located the out of transmission range of the sender [1]. In order to reduce such packet collisions, the RTS/CTS handshake is defined as an option of basic carrier sense procedure in DCF. The RTS/CTS handshake transmits RTS and CTS packets between a transmitter and a receiver. Neighbouring terminals of the transmitter and receiver could prevent a new transmission by overhearing the RTS and/or CTS. Fig. 2 shows the transmission procedure involving the RTS/CTS handshake in DCF. In this procedure, terminal 1 checks the channel by carrier sense when it has a newly packet for transmission. On the basis of the result of the carrier sense procedure, the terminal 1 transmits RTS to terminal 2 during the DIFS period when no other terminal transmits a packet. After receiving RTS from terminal 1, terminal 2 replays CTS to terminal 1 during the SIFS period if terminal 2 is in a receivable state. During the same period, on receiving RTS and CTS, terminals 3 and 4 set the transmission deferral timers 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 packet is received correctly.

2.2 Needless transmission deferment in 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 R, and R will not return CTS to terminal S when hidden terminal I transmits any packet in parallel with the RTS transmitted by terminal S. Then, the terminals Xs set

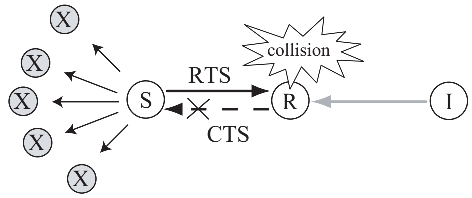

Figure 3. missing RTS/CTS handshake situation

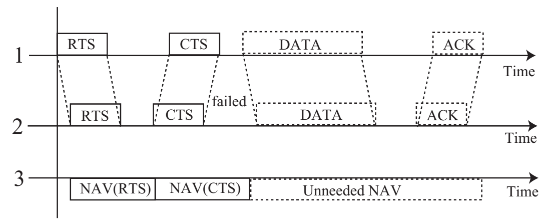

Figure 4. Failed situation of CTS transmission

unneeded NAV(RTS), although, the RTS/CTS handshake fails terminal S and terminal R. Fig. 4 shows the length of the above mentioned unneeded NAV(RTS) period. As shown 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, as shown in Fig. 4.

The length of needless transmission deferment increases in proportion to the length of the DATA packet, although it has been reported that the RTS/CTS handshake is advantageous in enhancing the throughput performance [6], [7].

3 Related works

3.1 RTS/CTS + CRTS

RTS/CTS+CRTS [2] is a method in which a transmitter cancels unneeded NAV(RTS) by transmitting CRTS (Cancel RTS) to its neighbouring terminals. Fig. 5 shows the transmission procedure of RTS/CTS + CRTS. Terminal 2, which is the neighbouring terminal of the sender sets, NAV(RTS) by overhearing RTS from sender terminal 1. If terminal 1 (the sender) cannot receive CTS from its receiver, it sends CRTS to its neighbouring terminals in order to cancel unneeded NAV(RTS) of its neighbors (including terminal 2). Overhearing terminals of CRTS cancel their NAV(RTS), and enter into an idle state. Fig. 5 shows the length of cancelled unneeded NAV period.

3.2 RTS validation

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

In RTS validation, any terminal deferring a new transmission by employing an NAV checks the DATA transmission corresponding to the NAV for carrier sensing after the RTS defer time (RTS defer time $=$ CTS transmission time + ($2\times$ SIFS periods)). On the basis of the result of carrier sensing, if no carrier is detected, the terminal cancels the NAV and it returns to the idle state. Otherwise, the terminal continues with the transmission deferment in order to avoid a collision with the ongoing transmission.

3.3 NAV omitted

Fig. 7 shows the control procedure of NAV omitted, as proposed in a previous paper [4]. NAV omitted is a method that applies an NAV setting to original IEEE802.11DCF on the basis of the NAV setting of MACA, which is the first method

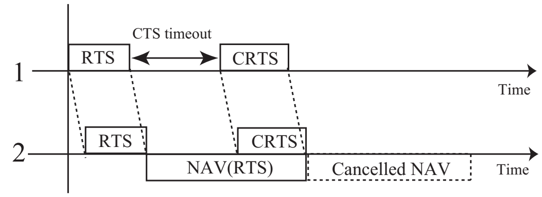

Figure 5. RTS/CTS + CRTS mechanism

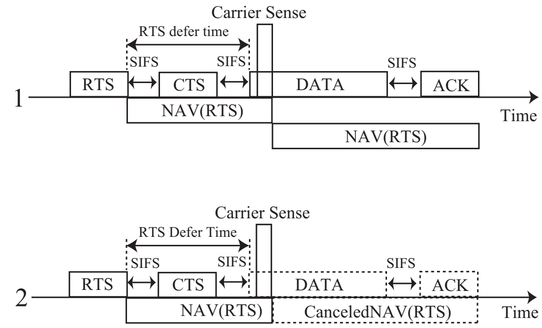

Figure 6. RTS validation mechanism

that proposed the 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 the corresponding RTS. On receiving the CTS, the terminal extends the NAV to NAV(CTS) until the expected time for receiving ACK. When the CTS is not received, the terminal returns to the idle state in a short period by expiring the NAV(RTS).

4 New method for avoiding needless transmission deferment caused by the failure of both RTS and CTS

As described in the previous section, several methods have been proposed for avoiding needless transmission deferment resulting from failed RTS/CTS handshakes. However, these methods are intended only for cancelling unneeded NAV(RTS). Further, none of these methods can eliminate the effect of unneeded NAV(CTS).

Fig. 8 shows an example of failed CTS transmission on IEEE802.11DCF.

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

Fig. 9 shows durations of needless NAV periods of the RTS and CTS. As shown, the lengths of both the unneeded NAVs, depend on the length of the DATA packet. Therefore, these unneeded NAVs degrade the throughput performance considerably for the transmission of long DATA packets.

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

Our new method employs the CCTS procedure to cancel unneeded NAV(CTS) in addition to the NAV omitted method that is used for cancelling unneeded NAV(RTS). The reason for employing NAV omitted to cancel unneeded NAV(RTS) is that the method does not require any new packets or operations in addition to that required for the legacy IEEE802.11DCF. For the CCTS procedure, our method uses three types of NAV information, as shown in Fig. 10. NAV(RTS) stores the NAV

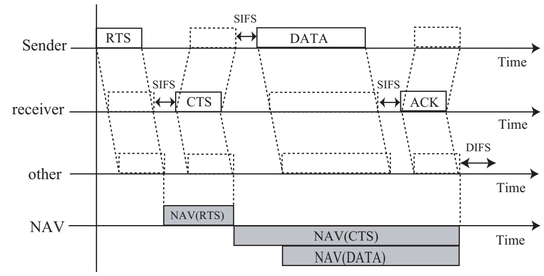

Figure 7. NAV omitted mechanism

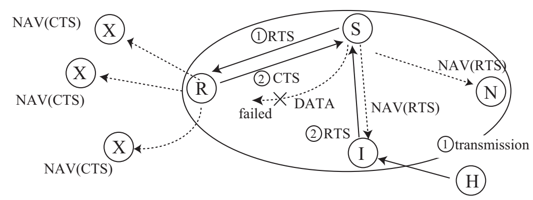

Figure 8. Failed CTS transmission

value on receiving RTS from all the neighbors. $\mathsf{NAV(CTS}_i)$ represents the NAV information that contains the NAV value set by the CTS from terminal i. $\mathsf{NAV(maximum)}$ stores the maximum NAV value among $\mathsf{NAV(RTS)}$ and $\mathsf{NAV(CTS}_i)$s, and it is updated when any NAV value is changed. In our method, the sender determines whether channel is in a transmittable state or not according to the value of $\mathsf{NAV(maximum)}$.

Fig. 11 shows the control procedure of our method. In this figure, let us consider that terminal 2 transmits CTS to terminal 1, and terminal 1 cannot receive the CTS (due to collision or any other interference), although terminal 3 receives the CTS correctly and sets $\mathsf{NAV(CTS}_2)$. After the transmission of the CTS, terminal 2 waits for DATA timeout and transmits CCTS in order to cancel the unneeded $\mathsf{NAV(CTS}_2)$ of its neighbor terminals when terminal 2 cannot recognize DATA transmission through carrier sensing. On receiving CCTS the from terminal 2, terminal 3 cancels its $\mathsf{NAV(CTS}_2)$ and avoids the needless transmission deferment induced by the missing CTS.

5 Performance evaluation

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

5.1 The number of failed transmissions of RTS and CTS transmissions

In order to keep track of the needless transmission deferment induced by failed RTS and CTS, we examine the number of missing RTS and CTS under various traffic environments. Fig. 12 shows the number of missing packets under various traffic conditions. In this figure, the 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. The results confirm that the number of failed RTS and CTS counts increases in proportion to the increase in the traffic. Although the failed CTS count is always lower than the failed RTS count, the results indicate that the number of failed CTS increases under a high-traffic environment and that this might induce unneeded transmission deferment.

5.2 Characteristics of traffic–throughput performance

Fig. 13 shows the characteristics of the traffic–throughput performance. In this figure, it can be observed that the differences among the three protocols increase with the increasing traffic. Our proposed method shows higher performance

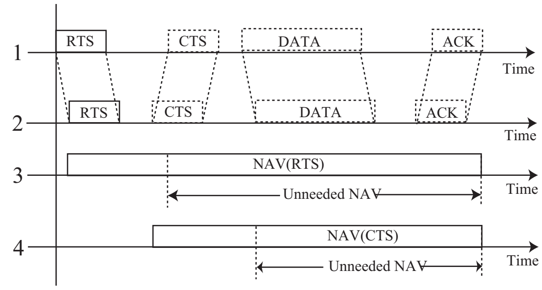

Figure 9. Lengths of unneeded NAVs induced by RTS and CTS

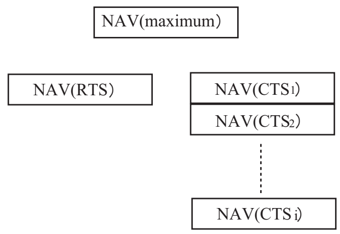

Figure 10. NAV information

than the other two protocols in all the ranges. Our protocol effectively mitigates the effects of unneeded NAV(RTS) and NAV(CTS) induced by failed RTS and CTS in contrast to the increasing number of failed RTS and CTS transmissions.

5.3 Characteristics of the number of terminals–throughput performance

Fig. 14 shows the characteristics of the number of terminals–throughput performance. In the evaluation, the number of terminals varies from 50 to 200. The other parameters are set to be the same as those listed in TABLE 1. In order to clarify the differences among these protocols, we have derived the maximum throughput performance for each protocol and have shown it in Fig. 14. From in this figure, the difference between the maximum throughput of the proposed method and that of legacy IEEE802.11DCF increases with the number of terminals.

5.4 Characteristics of DATA packet length–throughput performance

Fig. 15 shows the characteristics of DATA packet length–throughput performance. In the evaluation, the length of the DATA packet varies from 512 to 3072 bytes. In this figure, the result for legacy IEEE802.11DCF confirms that the throughput performance decreases with an increase in the length of the DATA packet when it is larger than 1500 bytes, although the throughput performance with the DATA packet length when it is smaller than 1500 bytes.

In contrast to the result of legacy IEEE802.11DCF, the throughput performance of NAV omitted and the proposed method increases with the DATA packet length for all DATA packet lengths.

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

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

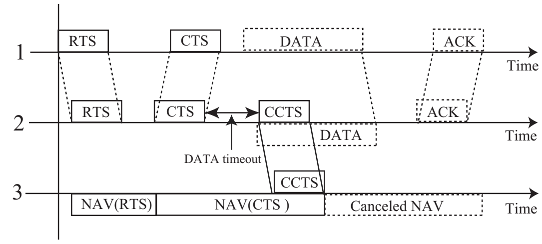

Figure 11. Cancel CTS procedure

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	Randomly placed
Simulation period	50 sec

6 Conclusion

This paper discussed the needless transmission deferment induced by missed RTS/CTS handshakes. On the basis of the survey of related studies, we proposed a new MAC protocol for avoiding the needless transmission deferment induced by both failed RTS and CTS. Our proposed method employs NAV omitted and the CCTS procedure for cancelling unneeded NAVs set by RTS and CTS, respectively.

We clarified that our proposed method achieves the highest throughput performance among the three protocols evaluated. In addition, from the evaluation of the DATA packet length– throughput performance, our proposed method effectively educes the throughput performance of the RTS/CTS handshake in IEEE802.11DCF.

Acknowledgement

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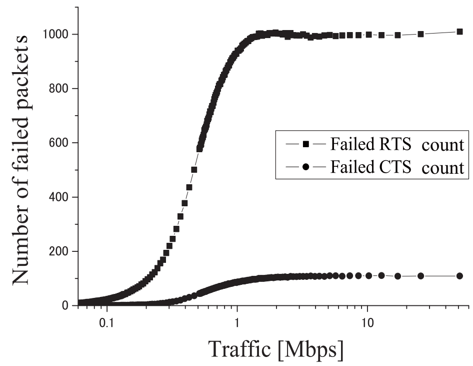

Figure 12. Failed RTS/CTS Count

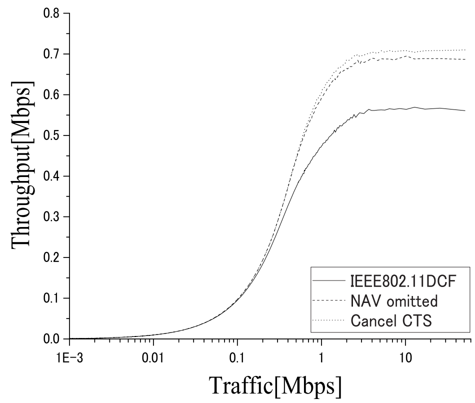

Figure 13. Traffic–Throughput performance

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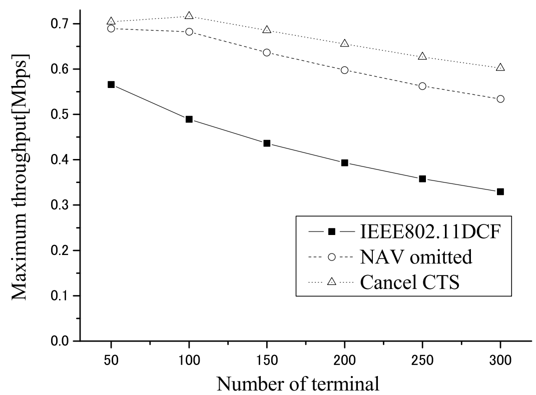


Figure 14. Characteristics of number of terminals–throughput performance

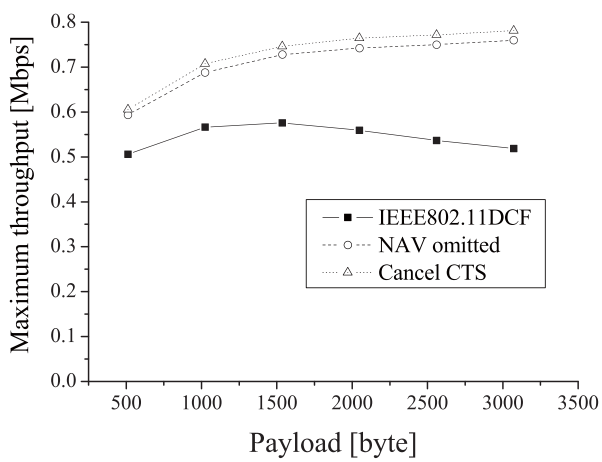
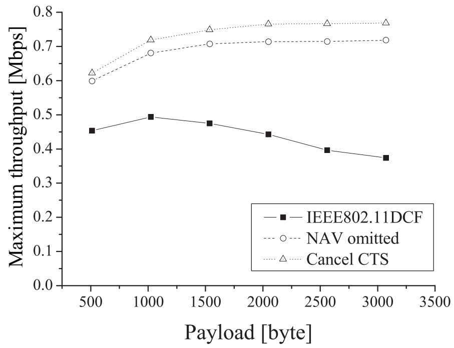
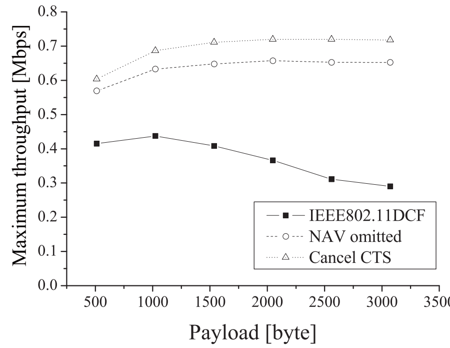


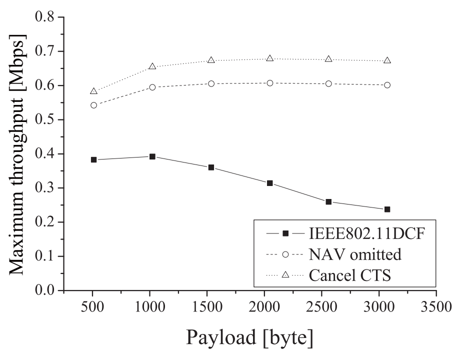
Figure 15. Characteristics of DATA packet length–throughput performance



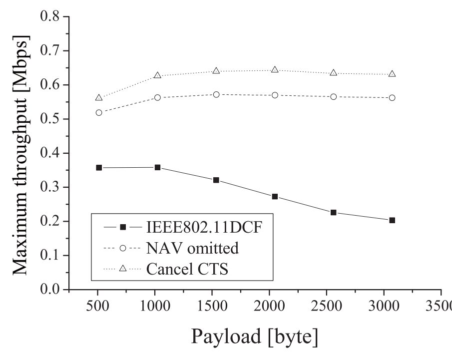
(A) 100 terminals



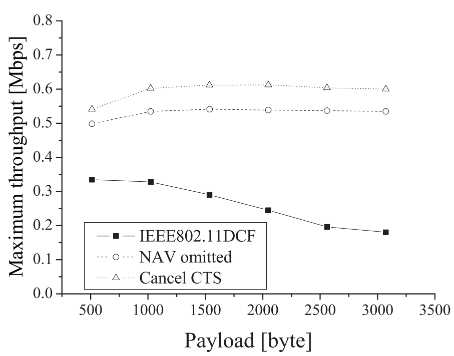
(B) 150 terminals



(C) 200 terminals



(D) 250 terminals



(E) 300 terminals

Figure 16. Characteristics of DATA packet length–throughput performance for various numbers of terminals