A New Broadcast Method to Prevent Packet Collisions over Biased Terminal Arrangement

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Abstract: IEEE802.11DCF is widely used wireless LAN standard. But, packet delivery ratio of broadcast transmission is much lower than unicast transmission because the IEEE802.11DCF executes broadcast transmission without RTS/CTS exchange and ACK process. Hence, many protocols have been proposed to improve reliability of the broadcast transmission. Most of these protocols are proposed based on collision recovery policy using ACK signal or NACK signal instead of ACK frame. Then, transmission overhead is increased by retransmission under the condition that network contains some hidden terminals since ACK or NACK signal could not prevent transmission of hidden terminals. This paper proposes a new broadcast protocol based on collision prevention policy using modified RTS/CTS exchange, and clarifies that our proposed protocol achieved highly reliability even in the biased and nobiased distributed terminals arrangement.

1. Introduction

Throughput performance of IEEE802.11DCF with CSMA/CA (Carrier Sense Multiple Access / Collision Avoidance) is degraded when hidden terminals exist. RTS/CTS (Request To Send / Clear To Send) exchange is used for unicast transmission as an option for reducing effect of hidden terminals[1]. On the other hand, for broadcast transmission, packets will be transmitted with simple CSMA/CA without the RTS/CTS exchange and ACK method[2]. Hence, successful receive ratio in broadcast is much lower than unicast under the situation where hidden terminals exist.

Several papers have been proposed to improve broadcast receive ratio [3], [4], [5], [6], [7], [8]. For example, the paper [6] proposed BACK (Broadcast ACK) method which allocates mini slots for the verification of BACK signals returned from broadcast receivers. The paper [7] proposed ARB (Announce Reception of Broadcast) method which uses ARB and NACK (Negative ACK) pulse signal for solving unneeded re-broadcasting on the BACK method. And also, for the same purpose, the paper [8] proposed BEAM (Broadcast Engagement Ack Mechanism) as a modified version of the BACK method. The BEAM reduces the unneeded re-broadcastings by employing BACK order algorithm which allocates the order of transmitting BACK signal for avoiding collision.

These proposed methods can be categorized as *a collision recovery method* which improves broadcast receiving ratio by re-broadcasting. Though the collision recovery method improves broadcast receiving ratio by re-broadcasting, this method may not work well and increases transmission overhead when a network contains several hidden terminals since the method does not destined to reduce probability of collision.

Hence, in this paper, we propose a new method for improving broadcast receive ratio solving the above mentioned problems. The rests of this paper are organized as follow. Firstly, we discuss about methods categorized as *collision prevention type*. Our new method effectively suppresses the effect of hidden terminals by exchanging RTS/CTS with a terminal that connects to high-risk hidden terminals. High-risk hidden terminal is a terminal where a large number of broadcast receivers are connected. Lastly, we clarify that our method achieves higher broadcast receive ratio than IEEE802.11DCF even in the biased and no biased distributed terminals arrangement.

2. Transmission procedure of IEEE802.11DCF

2.1 Basic unicast procedure of IEEE802.11DCF

Fig. 1 shows packet format of IEEE802.11DCF (DCF). As shown in this figure, RTS and DATA frame contains transmitter (TA) and receiver (RA) address. In DCF, any terminal having a packet to transmit checks channel state by carrier sense. According to this result, a terminal will defer its transmission until a channel becomes idle when the channel is busy, otherwise, the terminal starts to decrement its back-off timer after DIFS (DCF Inter Frame Space) period. While decrementing back-off timer, a terminal suspends the timer if the channel becomes busy. After back-off timer becomes zero, a terminal starts to transmit a packet immediately. When DATA received correctly without error, a receiver transmit ACK to transmitter to notify that successive procedure of DATA transmission has succeeded.

2.2 RTS/CTS handshake procedure for suppressing hidden terminals

As described the above section, decision of packet transmission will be made only according to the result of carrier sense. Packet collision may occur and it decreases throughput performance significantly by existence of hidden terminal; a terminal that is in the range of receiver but is not in the range of transmitter[9].

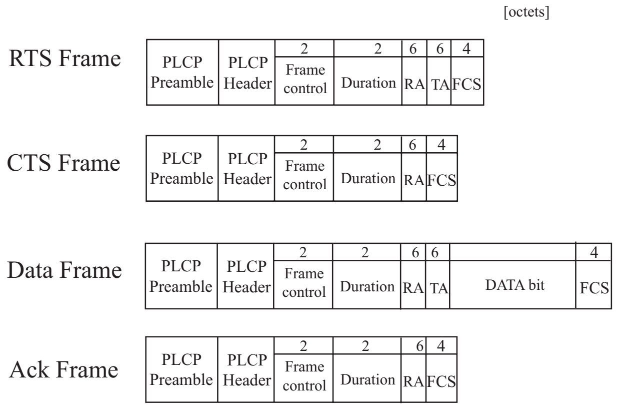

Figure 1. Packet format of IEEE802.11DCF

Therefore, DCF employs RTS/CTS handshake procedure to suppress the effect of hidden terminals as option of unicast procedure (MACA was the first protocol to propose the RTS/CTS handshake[10]).

In the procedure of RTS/CTS handshake, before DATA transmission, RTS (CTS) which is provided with time duration required for DATA transmission are exchanged among a transmitter and a receiver, and neighbor terminals of both the terminals are prohibited their new transmission for the duration recorded in RTS (CTS). RTS/CTS is called virtual carrier sense because the handshake could reduce packet collision caused by hidden terminals which is in the out of carrier sense range of a transmitter.

2.3 Broadcast procedure of IEEE802.11DCF

In broadcast transmission, packet will be transmitted without RTS/CTS handshake and ACK since transmitter could not recognize CTSs and ACKs returned by its neighbors at the same time. Then, the broadcast procedure of DCF is a best effort transmission procedure.

3. Related works

3.1 Type of collision recovery broadcast protocol

BACK[6] is a broadcast protocol improving broadcast receive ratio by employing retransmission schema using BACK (Broadcast ACK) signal.

As shown in Fig.2, BACK prepares BACK window for receiving BACK signal notifying successful receipt of broadcast. Receivers receiving broadcast correctly return BACK signal to a slot selected randomly from the BACK window. After receiving BACK signals, transmitter counts number of slots detected by BACK signal, and compare it with the number of broadcast receiver. When both the numbers are equal, the transmitter ends procedure of successive broadcast schema, otherwise, transmitter retransmits broadcast to recover the lost packet. However, BACK signal is defined as just pulse signal, then, it could not detect that multiple receiver replies BACK signal at the same slot. For example, the sender counts the number of successful receiver is three when the two BACK signals sent in same slot despite actual number of receiver transmitting BACK signal is four in Fig.2. It has been reported that this problem caused by missing count of successful receiver induces unneeded retransmission and degrades the system performance[7], [8].

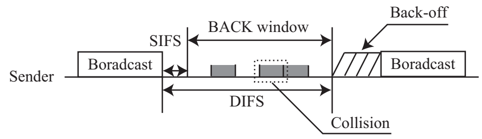

Figure 2. Broadcast procedure of BACK

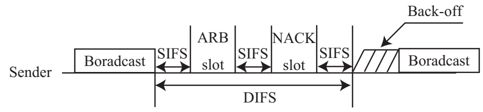

Figure 3. Broadcast procedure ARB with NACK

ARB with NACK[7] has been proposed as the method employing ARB (Announce Reception of Broadcast) signal and NACK (Negative ACK) signal in order to reduce unneeded retransmission. ARB with NACK uses two slots for ARB and NACK, respectively (Fig. 3). Any terminal receiving broadcast successfully sends ARB signal to the ARB slot. And any terminal which could not receive broadcast can perceive that broadcast had been done by receiving ARB signal. Then, broadcast receiver which could not receive broadcast correctly transmits NACK signal to the sender in order to request rebroadcasting to the sender.

The sender keep trying rebroadcasting while the NACK signal is detected or retransmission count is smaller than maximum retransmission count. In this manner, ARB with NACK can solve the unneeded retransmission.

On the other hand, BEAM (Broadcast Engagement Ack Method)[8] solves unneeded rebroadcast on BACK by assigning the BACK slot to the each receiver with no overlap to avoid collision of BACK signals. In the BEAM, sender will rebroadcast a packet immediately when the any BACK slot is detected as empty. Therefore, the method continues rebroadcast until retransmission count reaches the maximum retransmission count when at least one receiver moves out the transmission range of the sender.

3.2 Type of collision prevention broadcast protocol

BSMA[3], [4] is a method preventing collision by RTS broadcasting before broadcasting. In the BSMA, sender broadcasts RTS to its neighbor. Receiver (sender's neighbors) replies CTS at the same time. After this procedure, the sender can make broadcasting safely since its hidden terminals have been suppressed by CTS from sender's neighbors. However, BSMA works only in the condition that sender can recognize the at least one CTS by capture ability of physical layer.

On the other hand, BMW[5] employing unicast RTS has been proposed as a method which does not consider such an unrealistic condition. In the BMW, a RTS receiver is selected by sender based on round robin. Sender transmits RTS with latest sequence number of broadcast packet to the RTS receiver. RTS receiver replies CTS with sequence num-

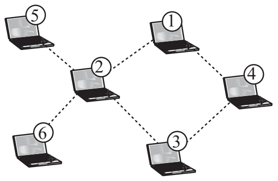

Figure 4. A network topology example

ber which has not been received smaller than or equal to the sequence number recorded in RTS. After receiving CTS, sender broadcasts or rebroadcasts according to the replied CTS. Sender transmits RTS to the same RTS receiver continuously until the RTS receiver received broadcast packet with latest sequence number. After this procedure, sender make same procedure with next ordered RTS receiver. In the BMW, the sender must store any broadcast packet to its retransmission buffer. Then, the sender must be provided with enough memory for the retransmission buffer. In addition, transmission delay may increase due to retransmissions after $n - 1$ times broadcast procedures in the worst cast when the sender has n neighbors.

4. A collision preventing broadcast protocol

In order to improve broadcast receive ratio without rebroadcasting, we propose a method employing unicast RTS for suppressing effect of hidden terminals effectively without rebroadcasting schema. Proposed protocol uses a neighbor list and a hidden terminal list configured by overhearing DATA (RTS) destined for the other terminal. By using Fig.4, following sections give detailed constructing procedure of these lists.

4.1 Constructing procedure of neighbor list

When terminal 2 in the transmission range of terminal 1 transmits DATA (RTS), terminal 1 could know that terminal2 is its neighbor by referring the sender's address (TA) field in overheard DATA (RTS) from terminal 2. In this case, terminal 1 adds terminal 2 and NULL to Terminal ID field and to degree of risk field of its neighbor list, respectively. After overhearing DATA (RTS) from terminal 4, neighbor list of terminal 1 is updated as shown in TABLE 1.

4.2 Constructing procedure of hidden terminal list

Hidden terminal list is constructed by overheard DATA (RTS) and neighbor list. When terminal 1 overhears DATA (RTS) transmitted to terminal 3 from terminal 2, the terminal 1 could know that terminal 2 is connected to terminal 3 and distance to terminal 3 is less than 2 hops from terminal 1[1]. At the same time, terminal 1 recognizes that terminal 3 is its hidden terminal if terminal 3 is not recorded at neighbor list. Then, if the terminal 3 is not recorded at its hidden terminal list yet, terminal 1 and terminal 2 will be add to Terminal ID and Corresponding terminal ID field of the list,

[1] It should be noted that a terminal that is 2hops apart from the sender terminal is the neighbor terminal or the hidden terminal of the sender terminal

Table 1. Neighbor list

Terminal ID	Reducing risk
2	NULL
4	NULL

Table 2. Hidden terminal list

Terminal ID	Corresponding terminal ID	Risk
3	2, 4	2
5	2	1
6	2	1

Table 3. Neighbor list (2)

Terminal ID	Reducing risk
2	4
4	2

otherwise, only the Corresponding terminal ID filed will be updated. Every Risk field records total number of corresponding terminals of each hidden terminal. The value of Risk field means the number of broadcast receivers which could not receive broadcast packet correctly if the hidden terminal transmits any packet while broadcasting. Updating procedure of hidden terminal list will be done at any time the neighbor list is updated. On the updating procedure of hidden terminal list, any terminal ID recorded at both neighbor and hidden terminal lists will be removed from hidden terminal list.

4.3 Selection procedure of RTS receiver

Before broadcasting, the proposed method makes RTS/CTS handshake with receiver which could suppress the effect of hidden terminals effectively by one CTS transmission. More specific description of selection procedure of RTS receiver is provided below.

Let us consider the case of broadcasting by terminal 1. Before broadcasting, terminal 1 knows terminals 2 and 4 are its neighbors by referring TABLE 1. Also, terminal 1 knows that terminals hearing CTS from terminal 2 are terminals 1, 3, 5 and 6 if terminal 1 succeeds RTS/CTS handshake with terminal 2. Then terminal 1 knows that RTS/CTS handshaking with terminal 2 could suppress hidden terminal effect from terminals 3, 5 and 6 by referring TABLE 2. As a result, terminal 1 stores total value of Risk field of those terminals in hidden terminal list to Reducing risk field of terminal 2 in neighbor list. After calculating of all Reducing risks for each neighbor, terminal 1 can get the neighbor list as shown in TABLE 3

In order to minimize the probability of collision, terminal 1 (broadcast sender) selects terminal 2 with maximum Reducing risk, as a RTS receiver.

5. Performance evaluation

Fig.5 depicts network topologies for performance evaluation. In this figure, every topology construct different biased arrangement of hidden terminals.

Fig.6 shows broadcast receive ratio of the proposed method. This result confirms that our proposed method

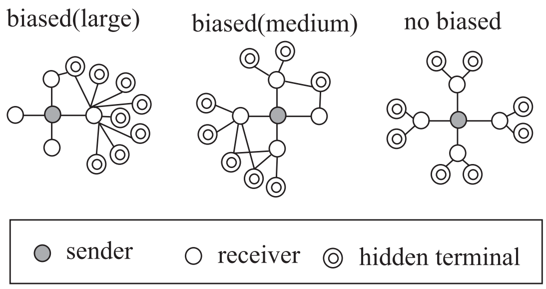

Figure 5. evaluation network topology

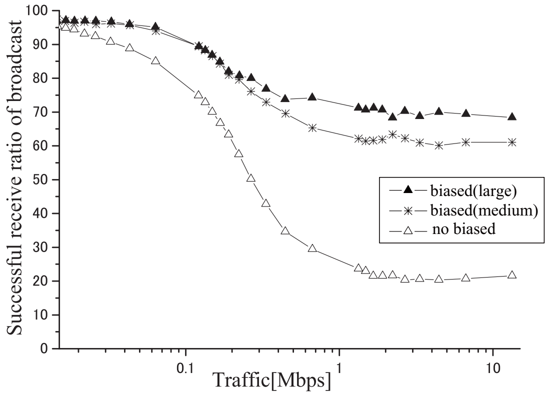

Figure 6. broadcast receive ratio of proposed method

achieved higher performance over the large biased network topology. This is because, in our method, many hidden terminals could overhear CTS over large biased network topology.

Fig.7 illustrates broadcast receive ratio of the proposed method and IEEE802.11DCF over the no biased topology, in which proposed method shows lowest performance shown in Fig.6.

From these results, we can see that our proposed method shows higher performance than IEEE802.11DCF even in the situation that a network is constitute by terminals with biased location.

6. Conclusion

This paper discussed about a method for improving broadcast receive ratio on IEEE802.11DCF. With considering to the fact that on the existing methods based on collision recovery policy, overhead and recovering delay of rebroadcasting degrade system performance, we proposed a new protocol without rebroadcasting schema based on collision prevention policy.

The results of performance evaluation, we clarified that our proposed method achieves higher performance than IEEE802.11DCF.

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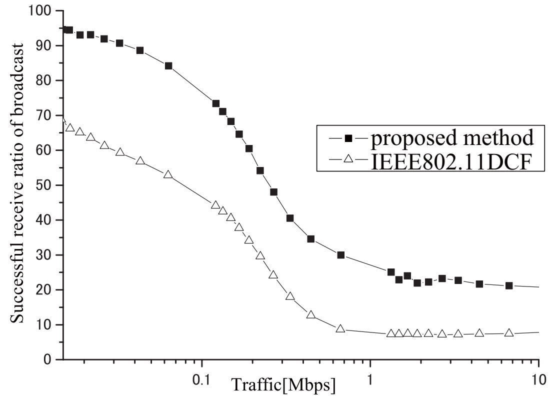

Figure 7. broadcast receive ratio over no biased network topology

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