Full Duplex MAC Protocol Based on Neighbor Node Information

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Abstract—**Full duplex communication and device-to-device (D2D) communication are key technology to provide high efficiency in wireless networks. Compared to distributed wireless MAC protocol, centralized wireless MAC protocol has advantages in terms of retransmission reduction and transmission overhead such as RTS/CTS packets exchanges. Therefore, we propose a novel centralized full-duplex MAC (CT-FDMAC) protocol considering D2D communications. In the proposed protocol, an AP schedules the transmission opportunity for each node using the information of the number of neighbors. The simulation result shows that the throughput of the proposed CT-FDMAC protocol increases 51% and 75%, compared to those of CSMA/CA and D2D with half duplex protocols, respectively. The proposed CT-FDMAC also show better delay performance. Moreover it is more appropriate for the edge dense network environments.**

.Keywords— Centralized, Full Duplex, MAC protocol, WLAN

I. INTRODUCTION

As one of the key technology for the next generation wireless networks with high efficiency and performance, the full duplex communication technology is being spotlighted [1]. Because the full duplex communications enables the simultaneous transmission and reception, it can double the channel capacity in theory. In order to implement the full duplex communication in real world, self-interference should be handled. Thanks to some researches, enough level of self-interference cancellation techniques has achieved at physical layer [2]-[7].

The CT-FDMAC protocol could be one of solutions to handle packet collisions by scheduling each transmission. In addition, it can solve hidden node problem without RTS/CTS handshaking procedure, while it also avoid the exposed node problem. However, throughput of CT-FDMAC can be limited due to link capacity between nodes and AP. The D2D communication can increase link capacity by reducing the traffic load of backhaul link. With the same reason, [8] proposed efficient networking and cost saving D2D communication schemes. Therefore, we propose centralized full duplex MAC protocol considering D2D communication.

The rest of this paper is organized as follows. The related works will be introduced in section II. A proposed MAC protocol will be introduced in section III. In section IV, the scheduling algorithm will be introduced. In section V, the simulation results will be given. Finally, section VI concludes this paper.

II. RELATED WORKS

In case of distributed full duplex MAC protocol, each node competes with others to access channel and transmit data. Most of distributed full duplex MAC protocols are adopting the carrier sense multiple access with collision avoidance (CSMA/CA), which is standardized in IEEE 802.11. However, full duplex protocols based on CSMA/CA still suffer from packet collision problems. The authors of [9] proposed a cross layer protocol for carrier sense multiple access with collision detection (CSMA/CD) in WiFi networks. In order to minimize collision time, they adopted the concept of CSMA/CD to stop transmission when it detects collision. Even if the result of [9] showed better performance, it still suffers from collision problem and also did not consider D2D communication. Furthermore, it only considered the uplink traffic. In [10], the authors proposed distributed type of full duplex MAC protocol without using busy tone. Busy tone is the signal without information to let other nodes know transmission. In most distributed scheme, busy tone is used to prevent collisions when uplink and downlink transmission time are not same. Since it has no information, busy tone could be a waste of power, which causes the deterioration of power and channel efficiency. The research of [10] had solved busy tone problem, but still suffers from collision. To solve the collision problem, centralized type could be a solution.

In case of CT-FDMAC, the AP controls the transmission of every nodes in a network. As the one of the typical CT-FDMAC, Janus was introduced in [11]. In Janus scheme, the AP schedules every transmissions for each cycle to maximize the network throughput. Because all of the transmission has been scheduled by the AP, CT-FDMAC protocols does not suffer from collision. However, CT-FDMAC such as [11], still did not consider D2D communication. In centralized type, AP needs to collect information for scheduling the requested transmissions. Thus, each nodes, which has data to transmit, should send information such as data size or channel conditions. This

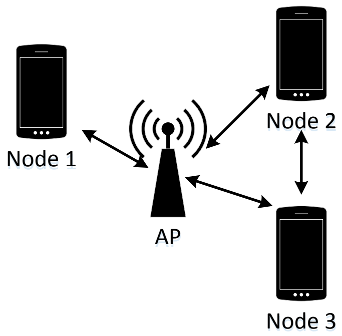


Fig. 1. Example of network topology

procedures could be overhead of CT-FDMAC. To minimize the overhead of centralized protocols, collecting information and scheduling time should be reduced. In [11], authors show that CT-FDMAC protocol has better performance in terms of overhead compared to the distributed ones. The authors of [12] proposed a CT-FDMAC protocol with three new protocol elements: shared random back-off, virtual contention resolution and snooping. However, it also did not consider the capability of D2D communications. Therefore, we propose a novel CT-FDMAC considering D2D communications.

III. PROPOSED FULL DUPLEX MAC PROTOCOL

In this section, the proposed CT-FDMAC considering D2D communications will be introduced. In section III-A, a considered network topology will be introduced. In section III-B, the entire procedure of the proposed full duplex MAC protocol will be introduced.

A. Network topology

A network with one AP and *N*-nodes is considered. The proposed protocol not only considers the communication between AP and each nodes, but also considers D2D communications. Fig. 1 shows the example of network topology that is considered. We assume that the position of the AP and each nodes is fixed. And the AP can assure that the collected neighbor node information of each node will not change until new node join or leave the network. Therefore, AP just needs to collect the neighbor information just one time at first transmission cycle.

B. Proposed CT-FDMAC protocol

The proposed CT-FDMAC protocol is consists of 5 phases. For each transmission, same procedure will be repeated. Fig. 2 shows the example flow of proposed CT-FDMAC protocol. The procedure of the proposed full duplex MAC protocol is as follows.

1) Request phase

In request phase, the AP broadcasts a request packet to every node which are connected to the AP. The request packet includes information about a transmission round for each node. The size of the node address and transmission time fields changes depending on the number of the nodes in the network.

2) Information phase

In information phase, when nodes receives the request packet, each of them transmits information packet to the AP if it has a data to transmit. Information packet include sender node's and destination node's id. If and only if it is the first

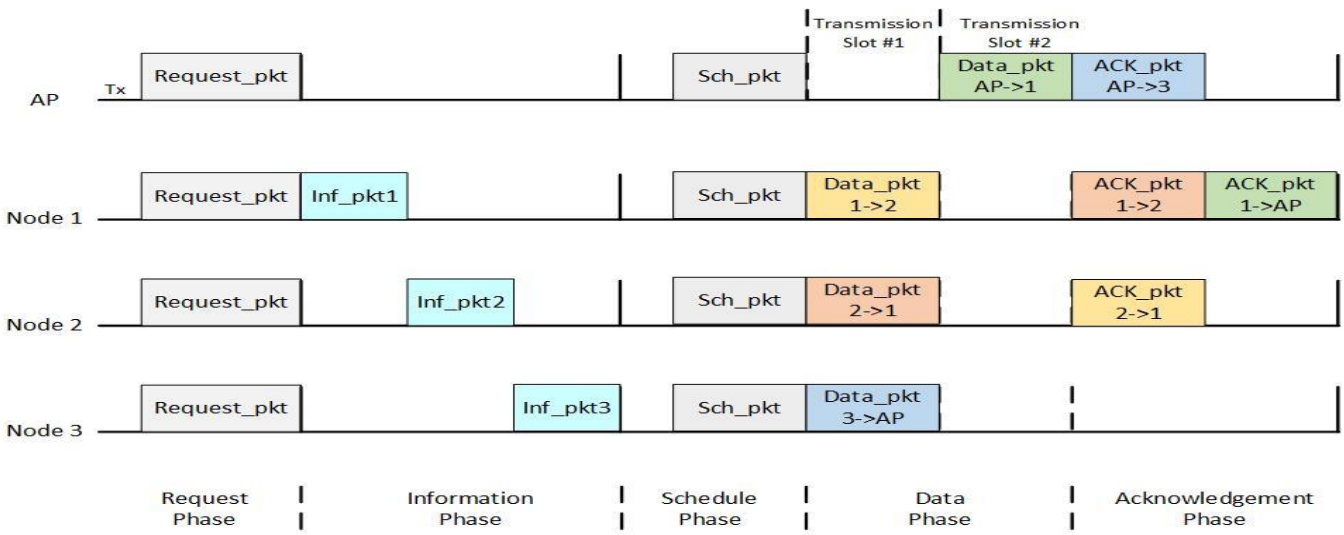


Fig. 2. Example flow of proposed full duplex MAC protocol

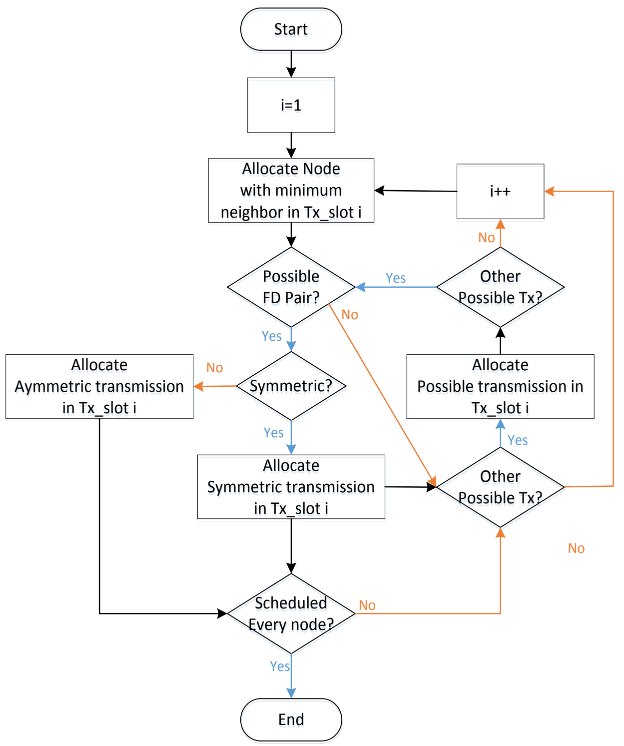


Fig. 3. Flow chart of scheduling algorithm

transmission cycle, each node can obtain neighbor node list by listening information packets in information phase. When the information phase has started, each node will keep listening the channel and if they can receive other nodes information packet, it can consider the nodes is neighbor nodes to itself.

3) Scheduling phase

In scheduling phase, The AP schedules the transmissions based on collected information. Detail of the scheduling procedure will be explained in section IV. After scheduling, AP broadcasts the schedule packet to every nodes to inform transmission schedule.

4) Data phase

In data phase, each nodes and the AP transmit data in the allocated transmission as scheduled by AP. Since all of the transmission in the cycle has scheduled, any collision will not occur during data phase.

5) Acknowledgement phase

In acknowledgement phase, each of them sends acknowledgement packet with same order after entire scheduled transmission have done.

IV. The Scheduling Algorithms

After collecting information from each node, the AP schedules them based on information about transmissions and neighbor nodes of each node. Fig. 3 shows a procedure of scheduling. The procedure of the scheduling algorithm is as follows.

1) Step 1

Once the AP collects the transmission information, it chooses the first transmission on the basis of neighbor node information. The AP checks all destination node of the requested transmissions. Then the AP allocates a transmission opportunity by selecting the node with the fewest neighbor nodes among the destination nodes.

2) Step 2

For secondary transmission, if there is a transmission which destination node try to transmit to transmission node, AP allocates it in the current transmission round. Otherwise, AP looks for transmission which can be paired with first one, and allocates it in the current transmission if possible.

3) Step 3

Whether the AP finds secondary transmission which can be paired or not, it keep looking for other transmission which can be transmitted simultaneously until all of the possible transmissions are allocated.

Table 1. System Parameters

Parameters	Values
Data rate of channel	18 Mbps
Data packet size	1500 bytes
Request packet size	3 bytes
Information packet size	4 bytes
Schedule packet size	9 bytes
SIFS(Short Interframe Space)	16 µs

V. Performance Evaluations

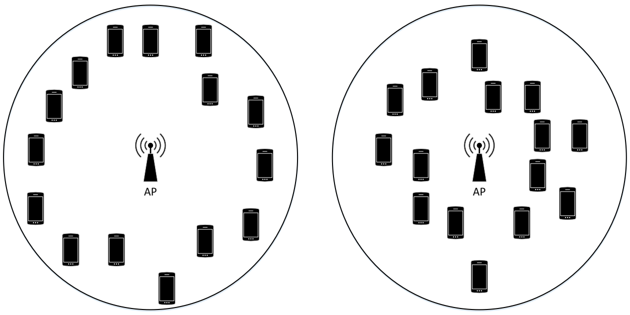
In this section, the simulation results will be presented to show the performance of a proposed full duplex MAC protocol. The simulator develops with OPNET. We consider average throughput and delay as the performance metric. The system model and other parameters will be introduced in section V-A and V-B.

A. System models

For the system model, one AP and N-nodes are considered. The number of nodes are changed from 5 to 40 with 5 intervals for each scenario. Each node is added to the inside of the coverage area of AP with circular uniform distribution. Fig. 4 shows the example of edge dense and center dense networks.

B. System parameters

We assumed that the coverage area of AP and each nodes are same. For comparison we are considered CSMA/CA and D2D with half duplex protocol. For CSMA/CA parameters, we apply general parameters [1]. Due to the randomness of destination node of each packet, we simulate 100 times and take average values for each protocol. Other simulation parameters are shown in Table 1.



(a) Edge dense (b) Center dense

Fig. 4. System Model of edge dense and center dense networks.

C. Simulation Results

Fig. 5 presents the average throughput of each protocols depending on the number of nodes. The proposed protocol shows that the throughput of the proposed CT-FDMAC protocol increases 51% and 75%, compared to those of CSMA/CA and D2D with half duplex protocols, respectively. The comparison of average throughput performance between CSMA/CA and D2D with half duplex protocol shows that if we just consider D2D communications without the proposed CT-FDMAC protocol, it would result the throughput decrement. Therefore for efficient D2D communication, proper protocol is needed. The proposed CT-FDMAC protocol always shows improved throughput. Since the proposed CT-FDMAC protocol is based on full duplex communication, it can have better channel capacity. Therefore, the proposed protocol show better performance regardless of the number of nodes.

Fig. 6 shows the average delay of each protocols depending on the number of nodes. The average delay means the average time between two successful transmissions. For legacy half duplex based on CSMA/CA, the collision ratio also increases as the number of nodes increases. Therefore, the increment of retransmission ratio causes the increment of average delay. If the D2D communication is added in CSMA/CA, the probability of collision increases because of the increment of average delay. On the other hand, since the proposed protocol is centralized type, it can efficiently control the communication between nodes. As we mentioned before, it also has better channel capacity with full duplex manners. Therefore, the proposed protocol shows better performance in terms of average delay.

Fig. 7 shows the performance comparison in terms of nodes distribution. For this result, we considered the network with 15 nodes. In addition, we considered two types of distribution; center dense network and edge dense network. The results show that the proposed protocol has better performance when the nodes are distributed in edge dense manner. Because the proposed protocol is based on the spatial information, as the distance between nodes increases, the probability of the other possible transmission node also increases. Therefore the proposed protocol can show better performance both in throughput and delay with edge dense network

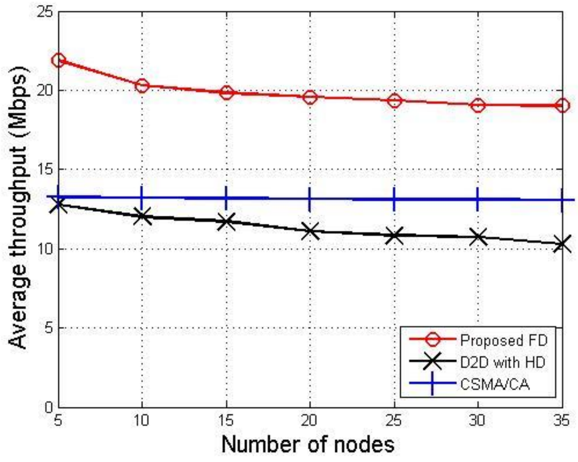


Fig. 5. Throughput depending on the number of nodes

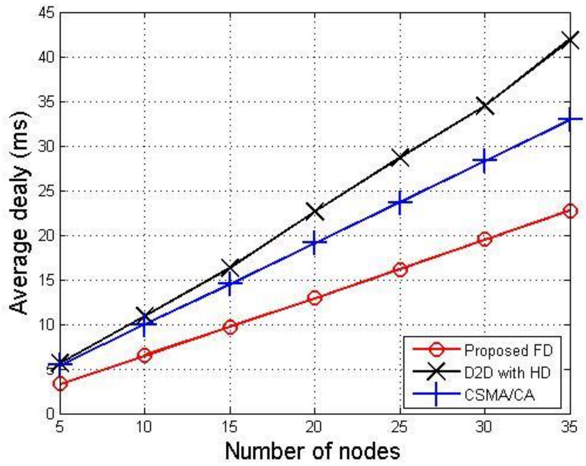


Fig. 6. Average delay depending on the number of nodes

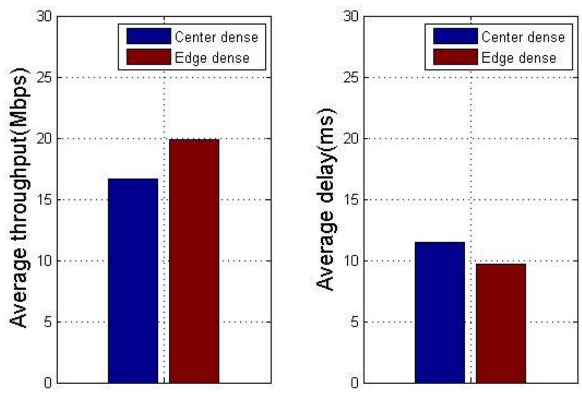


Fig. 7. Performance depending on the node distribution

VI. CONCLUSIONS

The CT-FDMAC protocol based on neighbor node information proposed in this paper. Since the proposed full duplex MAC protocol is based on scheduling phase, it can efficiently handle the D2D communications. Moreover, due to the increment of channel capacity with full duplex communications, the throughput and successful transmission delay performance improved. The simulation results also show better performance in edge dense network. Therefore, it is more appropriate for the edge dense network environments.

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