Centralized MAC Protocol for Wireless Full Duplex Networks Considering D2D Communications

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Abstract—The full duplex communication is a spotlighted technology as a most promising solution that can solve channel capacity problem in wireless network. In the future, the device to device(D2D) communication can be considered to reduce the load of network. Furthermore, the centralized network have advantages in collision ratio. For these reasons, we propose a novel centralized full duplex MAC protocol for wireless networks while considering D2D communications using spatial channel reuse algorithm. The proposed protocol can minimize the scheduling overhead while maximize the network throughput. Additionally, it can solve the hidden/exposed node problems without using the RTS/CTS mechanism. The simulation result shows better performance in dense networks with 190% improved average throughput compare to that of half duplex protocol. Based on simulation results, full duplex transmission can be applied to small dense networks such as internet of things (IoT) based networks.

Keywords—Centralized, Full Duplex, MAC protocol, WLAN

I. INTRODUCTION

As one of the most promising solution to solve lack of channel capacity for future dense networks, the full duplex communication is being spotlighted. Thanks to some research results which obtained enough self-interference cancellation, the full duplex communication can be implemented recently [1][2]. However, in order to implement full duplex communication in real world, appropriate MAC protocol is needed to handle MAC frames. Moreover, for extremely dense wireless networks in the future, the D2D communications can be considered to reduce the load of network. Some researches introduces D2D communication for half duplex networks in order to improve network throughput while reducing backhaul traffic [3]. However, proposed D2D MAC protocols are not optimized for full duplex networks. Therefore, full duplex MAC protocol for D2D communication is needed for future networks.

In case of D2D communication, using centralized full duplex MAC protocol can be a solution to future dense network, due to collision issues. Full duplex MAC protocols can be divided into two types such as distributed type and centralized type.

In distributed full duplex MAC protocol, each nodes compete each other to access channel and transmit data. In [4], authors had designed cross layer protocol for carrier sense multiple access with collision detection (CSMA/CD) in WiFi networks. They implemented the concept of CSMA/CD to reduce collision time. The authors of [5] had proposed distributed type of full duplex MAC protocol without using busy tone. Even if the research of [4] and [5] had solved overhead issues of overhead caused by collision and busy tone, they still suffer from collision issues. In current WLSN network, each nodes retransmit data when collision occurs. This may cause the high overhead when the network is dense. Therefore, reducing the collision ratio may the important issue for the future networks.

In order to solve the collision problem, centralized type could be a solution. The Janus scheme is one of the typical centralized type of full duplex MAC protocol [6]. In the Janus scheme the AP schedules every transmissions to maximize the network throughput. Because all of the transmission has been scheduled, centralized type the Janus does not suffer from collision. However, Janus is not optimized to D2D communications. Therefore, we propose a centralized MAC protocol for wireless full duplex networks, while considering D2D communications.

II. PROPOSED FULL DUPLEX MAC PROTOCOL

In this section, the entire procedure of proposed full duplex MAC protocol will be introduced in section II-A. A specific scheduling procedure will be explained in section II-B.

A. Procedure of Proposed full duplex MAC protocol

The proposed full duplex MAC protocol is consisted of 5 phases. Figure. 1 shows the timeline example of the proposed full duplex MAC protocol. In request phase, AP broadcasts request packet to each node which are connected to AP. The request packet contains information about transmission slot for each node. Figure. 2-a shows the format of the request packet.

In collect phase, when node receives request packet, each of them transmit information packet to AP if they has data to transmit. Information packet contains information about sender node’s address, destination node’s address and AP’s address. Figure. 2-b shows the format of the information packet.

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Algorithm 1. Scheduling procedure

1: while number of unscheduled transmission != 0
2: for i = 1~N
3: allocate min(num_of_neighbor[i]) in this slot.
4: end for
5: while number of possible transmission != 0
6: if tx_table[i][0] == rx_1 && tx_table[i][1] == tx_1
7: allocate tx_table[i][0] in this tx_slot
8: else if tx_table[i][0] == rx_1 || tx_table[i][1] == tx_1
9: allocate tx_table[i][0] in this tx_slot
10: end if
11: if (tx_table[i][0] && tx_table[i][1] possible)
12: allocate tx_table[i][0] in this tx_slot
13: end if
14: i++;
15: end while
16: schedule next slot
17: end while

In schedule phase, AP schedules the collected transmissions. Detail of Scheduling procedure will be explained in section II-B. After scheduling, AP broadcasts the schedule packet to let every nodes know their transmit schedule. Figure 2-(c) shows the format of the schedule packet. The size of schedule packet changes depend on the number of nodes in network.

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

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

B. Scheduling procedure

After collecting transmission information from each node, AP schedules them based on destination node of each transmission and neighbor nodes of each node. Algorithm 1 shows the procedure of scheduling. Once the AP gets the transmission information, it chooses the first transmitting node on the basis of neighboring node information. AP checks all of the requested transmissions, and allocate the transmission, which has the smallest number of neighbor node of destination node. For secondary transmission, if there is a transmission which can be paired symmetrically with the first transmission, AP allocates it in the current transmission slot. Otherwise, AP looks for transmission which can be paired with first one asymmetrically, and allocate it in the current transmission slot if possible. Whether 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 in the current transmission slot. For every transmission slots, the same procedure will be repeated until all of the requested transmissions are allocated.

III. PERFORMANCE EVALUATION

In this section, simulation results are presented to show the performance of proposed full duplex MAC protocol. The simulator had developed with MATLAB. Each scenario had simulated for 300 seconds of simulation time. Each scenario had simulated ten times to calculate the average. Proposed full duplex MAC protocol and existing CSMA/CA based half duplex protocol had been compared in the simulation.

A. System model

For the system model, 5 nodes and 1 AP topology had considered in each scenario. Fig. 3 shows the topology of each scenario. As the scenario number increases the connectivity between nodes are increases.

B. System parameters

For half duplex protocol, general simulation parameters for CSMA/CA half duplex protocol has applied [1]. In addition,
This protocol had been implemented using WiFi networks, as reported in[7]. The performance compared to half duplex protocol based on CSMA/CA, while having better performance increment with dense network. Therefore, the proposed full duplex MAC protocol can be applied to small dense wireless communication networks with heavy traffic load such as future IoT based sensor networks.

C. Simulation results

Figure 4 presents the average throughput of each scenario. For each scenario, throughput of the proposed protocol had increased about 190%, 189%, 196% respectively, compared to that of half duplex. Because the proposed protocol is based on full duplex, it shows improved throughput compared to half duplex. For proposed scheme, as the connectivity between nodes are increased, the probability of full duplex pair are also increased. In addition, the interference from neighbor node are also increased. Therefore, as the connectivity increased there are tradeoff between additional transmission probability and full duplex paired transmission. As the result, the proposed protocol can achieve highest throughput gain in well balanced network such as scenario 3.

IV. CONCLUSIONS

In this paper, we proposed a novel centralized full duplex MAC protocol considering D2D communications using spatial channel usage information which can maximize the number of concurrent transmission pairs. The simulation result shows the proposed protocol shows better performance compared to that of traditional half duplex protocol based on CSMA/CA, while having better performance increment with dense network. Therefore, the proposed full duplex MAC protocol can be applied to small dense wireless communication networks with heavy traffic load such as future IoT based sensor networks.

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