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A New Dual Channel Based Medium Access Control Protocol for Ad Hoc Networks

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Abstract—Ad hoc networks are widely researched and applied on various fields. To implement Ad Hoc Networks, the IEEE 802.11 standard Medium Access Control(MAC) protocol are widely applied. However, there are some problems which decrease the transmission efficiency of wireless networks at the standard MAC layer. The standard use 4-way handshake procedure(RTS/CTS/DATA/ACK) to overcome the MAC layer problems. But some problems cannot be solved if only a single channel is used in MAC Layer. Therefore, many multi-channel based MAC protocols were proposed to prevent MAC layer problems. But, those scheme either cannot solve MAC layer problems perfectly. This paper proposes New Dual Channel based Medium Access Control(NDCMAC) protocol for ad hoc networks. This protocol requests just one additional channel and perfectly solves most of MAC layer related problems. For this scheme, busy tone and Negative ACK(NACK) concepts are applied. Using NDCMAC, the channel utilization is significantly increased. Result of the simulation show how NDCMAC is better than the standard.

Keywords—ad hoc network, medium accecc control, MAC, busy tone, dual channel

I. Introduction

In recent years, wireless network is widely used due to it has a lot of advantages compared to wired networks. Especially, ad hoc networks are widely researched and applied on many fields such as industry, and military. Because it can be performed without infrastructure and it may consist of many different types of nodes. To implement Ad Hoc Networks, the IEEE 802.11 standard MAC protocol are widely applied. However, there are some problems which decrease the transmission efficiency of wireless networks at the standard MAC layer. Because IEEE 802.11 standard is developed for supporting based wireless Local Area Network(LAN) and not suitable for multi-hop networks[1]. Hidden terminal problem, exposed terminal problem, unfairness problem and etc. can occur at MAC layer in the standard protocol.

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The IEEE 802.11 standard use 4-way handshake procedure[2]. RTS is used to inform that a sender wants to send data before transmitting. CTS is used to inform that a receiver can receive some data. And ACK is used to inform that a receiver has received the data correctly. Using 4-way handshake procedure can overcome MAC layer problems such as hidden and exposed terminal problem. However, in some cases, 4-way handshake procedure cannot solve those problems.

Many solutions to overcome those MAC layer problems were developed. But those problems cannot be solved if only a single channel is used in MAC Layer. Therefore, many multi-channel based MAC protocols were proposed to prevent MAC layer problems. And most of them used busy tone channel that was implemented on narrow-bandwidth medium. Also some scheme used control channel to communicate control message such as RTS/CTS. But, those scheme either cannot solve MAC layer problems perfectly or request more than one additional channel. Using additional channel is easy to solve problems but it request more Network Interface Card(NIC) and bandwidth.

This paper proposes New Dual Channel based Medium Access Control protocol for ad hoc networks. This protocol requests just one additional channel and perfectly solves most of MAC layer related problems. For this scheme, busy tone and NACK concepts are applied.

Rest of this paper is organized as follows. In section Ⅱ, problems in the standard MAC protocol and solutions which already had been researched are stated. In section Ⅲ, Operation of proposed scheme is described and simulation result of this scheme is described in section Ⅳ. Finally conclusion is stated in section Ⅴ.

II. Related Works

A. *Problems in Standard MAC Protocol*

In this section, well known problems in wireless networks such as hidden terminal problems and exposed terminal problems are described. Also additional problems occurred on IEEE 802.11 standard MAC protocol are introduced by simple examples.

Hidden terminal is the node located outside of the transmission range of the sender, but inside of the sensing range of the receiver. This causes well known problems and 4-way handshake procedure is used to overcome it. But, in some cases, 4-way handshake procedure cannot solve this problem. In Fig 1, node E is a hidden terminal when node C is sending data to node D. Node E cannot initiate transmission because it

already heard RTS from node D and it blocks transmission from other nodes. But another problem can occur. For example, if node F send RTS to node E to send DATA after RTS/CTS exchange between node C and node D, node E cannot reply as CTS because CTS from node D block to use medium. But the transmission from node F to node E dose not interfere the current transmission between node C and node D. So, medium utilization on hidden terminal is decreased by 4-way handshake procedure.

A exposed terminal is the node located outside of the sensing range of the receiver, but inside of the transmission range of the transmitter. Same as hidden terminal problem, 4-way handshake procedure cannot solve this problem. In Fig 1, node B is an exposed terminal. Node A cannot initiate transmission to exposed node B because node B cannot receive RTS from node A caused by collision with current transmission. Another problem is when node B want to send DATA to node A. Node B cannot send RTS because RTS from node C blocks initiating new transmission from other nodes. So, medium utilization on exposed terminal is decreased by 4-way handshake procedure.

B. Multi-Channel Based MAC Protocols

Various researches have been done to solve the those problems. But standard MAC protocol has essential problems that it uses a single medium channel. In this section, the solutions that have been already researched using multi-channel to solve MAC layer related problems in ad hoc networks are described.

Busy Tone Multiple Access (BTMA)[3] used busy tone to solve the hidden terminal problem. Only the base station can transmit busy tone when there is current communication with one of child nodes. Busy tone signal can guarantee current transmission from medium access by other nodes. However, this protocol was based on centralized infrastructure and not suitable for ad hoc networks.

In [4], [5], Dual Busy Tone Multiple Access(DBTMA) used a formal communication channel and two additional busy tone channels. One busy tone channel was used for transmission function named BT_t, and the other was used for receiving function named BT_r. There was no CTS message because BT_r acts as CTS and informs current transmission to other nodes. This scheme prevented initial transmission on hidden nodes and permit response from RTS on it. Exposed nodes also initiated transmission. Therefore, DBTMA can handle the traditional hidden/exposed terminal problems. However, it does not use ACK message, so it cannot control unforeseen collision or loss of packet.

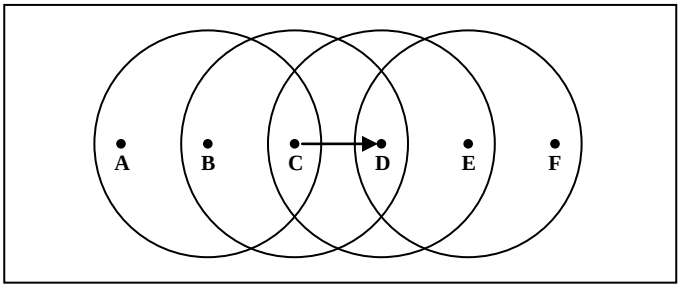


Figure 1. Simple nodes topology

A New Dual-Channel MAC Protocol(DUCHA)[6], [7] used three channels, one for busy tone signal, one for control frames and another one for data frames. Also it used RTS, CTS and Negative CTS(NCTS) through control channel. Receiver transmits the busy tone signal during it is receiving DATA. NACK is continuing busy tone that occurs if the receiver has not received the correct DATA packet. It looks like perfectly prevent the hidden/exposed terminal problems and additional problems such as receiver blocking problem, intra/inter-flow contention. But It requested a lot of additional channel, so it was so expensive and complicated to be implemented.

Dual Channel MAC protocol(DCMAC)[8] used just two channels, one for data frames, and the other for control frames. And there were three Network Allocation Vectors(NAV) for scheduling transmitting function, receiving function, and control channel. Also this scheme used Delay to Send(DTS) and NACK to prevent collision and blocking receiver. This protocol can solve MAC layer problems by using three NAV timer. Also channel reservation is possible. But, it is hard and complicated to handle a lot of NAV timer and additional message such as DTS.

All of introduced schemes use common methods as follow to solve MAC layer problems and increase utilization of medium.

- In spite of current transmission, new handshake procedure for new transmission can be initiated to increase channel utilization using other channel.
- Initiating new transmission from hidden terminal is not allowed to prevent collision. However, hidden terminal can receive new transmission from other nodes for increasing channel utilization.
- Initiating new transmission to exposed terminal is not allowed because exposed terminal is already in the range of current transmission. However, exposed terminal can initiate new transmission in spite of current transmission for increasing channel utilization.

Additionally, aforementioned schemes used more than one additional channels, and those were divided into control channel and busy tone channel. Control channel can deliver a lot of information but it requests more bandwidth and computability. Busy tone channel is more simpler to implement because it just senses whether the medium is busy or not. So, busy tone channel does not request high level computation. Furthermore, very narrow bandwidth is required to implement less than 10KHz[3]. But, Busy tone channel cannot deliver additional information such as sender/receiver identity, data length.

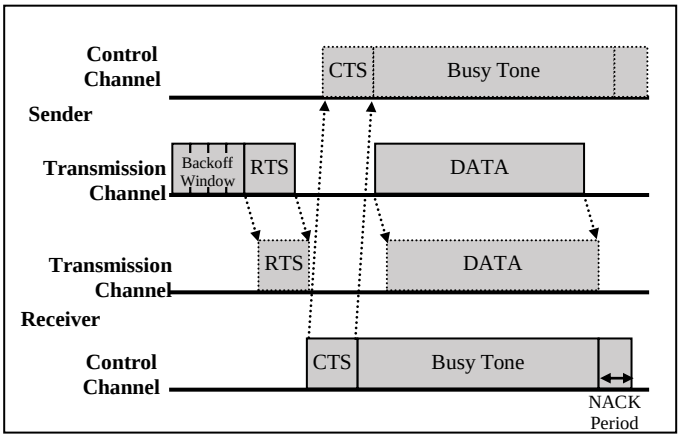


Figure 2. Basic diagram of NDCMAC

III. Proposed Scheme

A. *Assumptions*

- Transmission ranges of all nodes are the same.
- Transmission ranges of all channels are the same.
- All nodes have two Network Interface Cards(NIC).

B. *New Dual Channel Based Medium Access Control(NDCMAC)*

This paper proposed NDCMAC for ad hoc networks. NDCMAC use two channels, one is named transmission channel, and the other is named control channel. Transmission channel is similar with traditional data channel, but there is not any CTS, ACK message. CTS message and busy tone signal are flowed in control channel. NACK is applied to guarantee the correct transmission instead of normal ACK message. Fig 2 is a basic diagram of NDCMAC. Detail procedure of NDCMAC is as follow.

- RTS : Before initiating a new transmission, sender node must initiate backoff procedure. If not any signal is sensed on the control channel during backoff procedure, the sender sends RTS packet on transmission channel. If sender sense any signal on the control channel during backoff procedure, it defers its transmission until no more signal is sensed and restart backoff procedure. After transmitting RTS, sender set timer for waiting response. Detail action of the sender according to channel condition is described in TABLE Ⅰ.

TABLE I. ACTIONS OF SENDER

Channel Conditions of Sender		Actions of Sender
Transmission Channel	*Control Channel*	
Busy	Busy	Wait for the end of current tranmission on control channel
Idle	Busy	
Busy	Idle	Send RTS
Idle	Idle	

TABLE II. ACTIONS OF RECEIVER

Channel Conditions of Receiver		Actions of Receiver
Transmission Channel	*Control Channel*	
Idle	Idle	Send RTS and busy tone
Idle	Busy	
Busy	Idle	X (Cannot receive RTS because collision with current data transmission)
Busy	Busy	

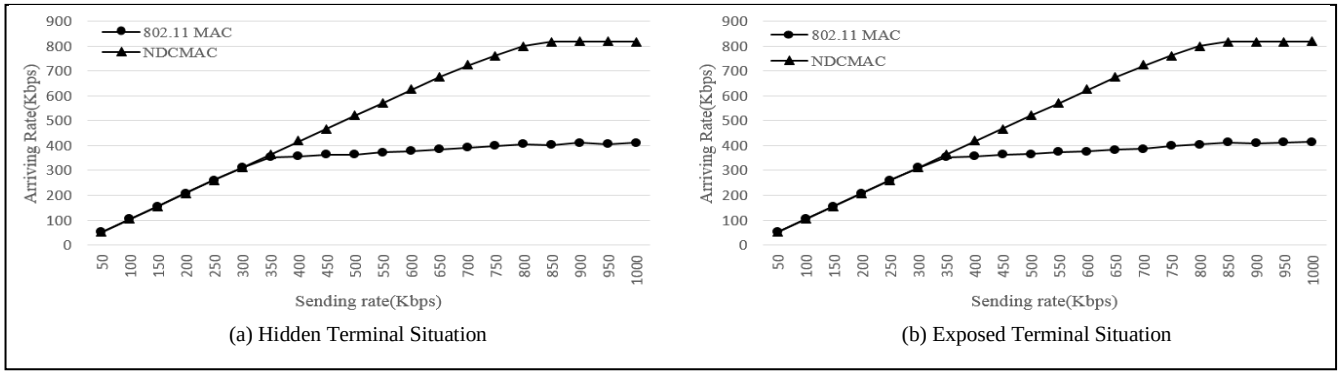
- CTS, Busy tone : When the receiver node received RTS, it senses its transmission channel. If transmission channel is idle, it sends CTS and busy tone continuously. Busy tone is transmitted until all of data reception is completed. If receiver node has already received RTS from other nodes, it ignores the belated RTS. Detail action of receiver according to channel condition is described in TABLE Ⅱ.
- DATA : If sender node cannot receive CTS until its timer reaches 2τ [1], sender node retries first step. When sender node receives CTS before the end of its timer(If the sender nodes receives CTS before the expiration of the timer), it transmits its data.
- NACK : The receiver node has a timer to calculate when the receiving should finished according to the duration field of RTS. If the receiver has not received the data correctly when the timer is expired, it assumes the data transmission is failed. So, the receiver node send NACK by continuous additional busy tone signal for an appropriate period. If sender node senses NACK, it assumes its data transmission is failed and retries first step.

C. *Solution to the problems*

In this section, how the aforementioned problems can be solved in NDCMAC is described using some examples.

The first example is for hidden terminal problems. In Fig 1, node E is the hidden terminal when C is sending data to D. If node E sends any data, collision occurs at node D. In NDCMAC, node E cannot initiate any data transmission because node E is sensing busy tone from node D during current transmission. But node E can receive new data transmission if new transmission does not interfere with current transmission. In Fig 1, data transmission from node F to node E does not interfere with current transmission. In NDCMAC, node F can send RTS to node E, because node F does not sense any signal on its both channels. Also, node E can responds by CTS and busy tone, because node E has been sensing just busy tone from node D. Additionally, CTS and busy tone from node E does not interfere with current

[1] 1τ is the maximum propagation delay between two nodes.



(a) Hidden Terminal Situation (b) Exposed Terminal Situation

Figure 3. Simulation Result

reception on node D, because CTS and busy tone signal use different channels with current data transmission.

Next example is for exposed terminal problems. In Fig 1, node B is an exposed terminal. Node B cannot receive any new transmission because it is already inside of current transmission. In NDCMAC, a new transmission to node B is not allowed because RTS from other nodes are collided on it. But node B can initiate new transmission to other nodes if new transmission does not interfere with current transmission. In Fig 1, when node B want to send data to node A, node B can initiate new transmission because there is no busy tone signal on it. After then, node A will respond with CTS and node B can sense it even if node B is on current transmission. Because the channel CTS message using is different from current data transmission. Finally, node B can send data to node A in NDCMAC.

IV. Simulation Result

We use NS-2 Simulator to prove performance of NDCMAC. Also, we simulate NDCMAC and the standard 802.11 MAC protocol for comparing each other. Simulation topology is same with Fig 1 and distance of each neighboring nodes is 150m.

First, we simulate hidden terminal situation. Node C is sending data to node D and node F is sending data to node E simultaneously. UDP agent is installed on node C to send data to node D. Also, other UDP agent is installed on node F to send data to node E. Loss Monitor agent is installed on node D and node E. Sending data rate on each UDP agents is 50, 100, 150, …, 950, 1000Kbps. We measure arriving packet rate on Loss Monitor Agent installed on node E. According to result of simulation[Fig 3(a)], NDCMAC should have much higher arriving rate comparing with the standard MAC.

Second, we simulate exposed terminal situation. Node C is sending data to node D and node B is sending data to node A simultaneously. Other UDP agent is installed on node B to send data to node A. We measure arriving packet rate on Loss Monitor Agent installed on node A. Result of simulation [Fig 3(b)] is similar with result of hidden terminal simulation.

On the standard MAC protocol, Arriving rate is not increased after certain sending rate because two packet flow is cannot flowed simultaneously. So, Maximum arriving rate on the standard MAC is approximately half of NDCMAC after certain sending rate.

V. Conclusion

In this paper, the problems on the standard MAC protocol and solutions which already had been researched are introduced. Also, we propose new MAC protocol named NDCMAC to solve those problems. Result of simulation show that proposed protocol can solve MAC layer related problems and it is better than the standard. Especially, Using NDCMAC, the channel utilization is significantly increased. In the future, we will simulate NDCMAC on more complicated topology and scenario to improve the protocol.

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