Improving Quos Parameter by Eliminating Hidden Terminal Problem

W. U. Khan and Ashutosh Mishra

Abstract—**In this paper, the basic idea of PCF is applied to solve hidden terminal problem and improve the QoS parameter. When collisions occur at a node, the node considers that there is more than one node means to transmit data to it. Then this node gets control of the channel. It polls all of the one-hop neighbor nodes in its polling list to enquire whether it has data to transmit. This mechanism greatly decreases the unnecessary contending time in bakeoff mechanism. More time is used to transmit useful payload. As a result, channel utilization is enhanced greatly.**

***Index Terms*—hidden terminal; MACA; polling**

I. Introduction

The hidden terminal situation has become a classic problem significantly affecting network performance in wireless network, especially in adhoc networks where a node may communicate directly with other node in range or use intermediate nodes as relays. In hidden terminal situation, both A and C can hear from B, but they cannot hear from each other. Thus collisions may occur at B.

There has been a significant amount of research on designing efficient medium access control (MAC) protocol avoiding or alleviating hidden terminal problem for wireless network, such as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

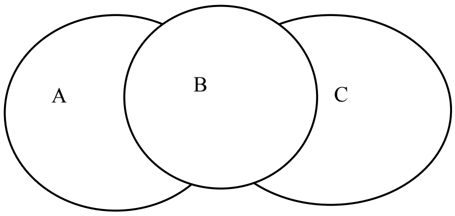

Fig. 1. An example of hidden terminal situation

There has been a significant amount of research on designing efficient medium access control(MAC) protocol avoiding or alleviating hidden terminal problem for wireless network, such as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and Multiple Access Collision Avoidance (MACA) which is derived from CSMA/CA. MACA is proposed by Kern[1]. There are also some improvements of MACA. The most famous one is called MACAW [2]. In this case, the three-way handshake for Multiple Access Collision Avoidance (MACA) is expanded to five-way handshake. MACAW mainly focuses on two aspects of medium access control (MAC) mechanism: bakeoff algorithm and the exchange between essential messages. Unfortunately, the additional path in handshake adds additional cost, which clearly reduces the channel utilization. The common point between MACA and MACAW is that they both use bakeoff algorithm when collisions occur between control packets. In this paper, a new mechanism called MACARPOLL is proposed when control packets collide. When control packets collide at Receiver node, the Receiver node will carry out a polling mechanism other than senders carry out bakeoff algorithm.

This paper is organized as follows. In section II, a specification on Multiple Access Collision Avoidance (MACA) is summarized explaining how it can mitigate hidden terminal problem. Following after this, mechanism proposed in this paper is specified. Intuitive comparison between the two of them is made with the conclusion that the mechanism proposed in this paper has better performance than bakeoff algorithm in MACA. In section III, theoretical analysis on the performance of newly proposed mechanism and MACA is presented. It is validated that the mechanism proposed in this paper has better channel utilization than MACA in some scenarios. Finally the paper is concluded in section IV.

IEEE 802.11 standard covers the MAC sub-layer and the PHY layer of the OSI network reference model for WLANs. The MAC sub-layer defines two medium access coordination functions, the basic DCF and the optional PCF. 802.11 can operate both in contention based DCF mode and contention free PCF mode. A group of station's (STA's) coordinated by DCF and PCF is called as a Basic Service Set (BSS). It is also considered as the coverage area provided by a single access point (AP). In which the AP and mobile stations can communicate using the radio channel with an acceptable minimum quality. The quality can be determined based on the Signal to Noise Ratio (SNR) and other derived matrices such as Frame Error Ratio (FER). In an extended service set (ESS) all or part of these coverage areas can overlap so that a mobile station can select the AP to use; these regions are called re-association or hand off area. The area covered by BSS is known as basic service area (BSA). The core of the IEEE 802.11 standard is the BSS. In 802.11 there are two ways to organize stations of WLAN's: the infrastructure and ad hoc mode.

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II. Turning MACA Into MACA-RPOLL

A. Multiple Access Collision Avoidance (MACA)

Multiple Access Collision Avoidance (MACA) is derived from Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). In CSMA/CA, when a sender S wants to send data to a receiver R, it has to firstly listen to the channel for a predetermined amount of time so as to check for any activity on the channel. If the channel is sensed "idle" then the sender S is permitted to transmit. If the channel is sensed "busy" then the sender S has to defer its transmission for a "random" interval. When the channel has maintained "idle" state for a period of time, the sender S will firstly send a short Request to Send (RTS) packet to the receiver R. Then the receiver R will respond with a short Clear to Send (CTS) packet. When the sender S has received CTS packet from the receiver R then it can initiate sending of data to the receiver R. Thus RTS packet is always much shorter than data packet, it will encounter less cost when collisions occur [3].

When CSMA/CA is used to solve hidden terminal problem, there is an issue that the result of carrier listening may mislead the node whether it can send data or not. Take figure 1 as example. When node A sends RTS to node B, node C will not hear node A using carrier listening. Then node C will consider that the channel is idle and send RTS to node B. Actually, node C cannot initiate any operation right now. Collisions

occur at node B. According to this problem, MACA boldly discards the carrier listening mechanism, using handshake mechanism entirely. Discarding the letters CS in CSMA/CA, it becomes MACA.

The essential idea of MACA is as follows. In MACA, a sender S having data to send to a receiver R will first send a RTS packet to receiver R. Then it waits for CTS packet from receiver R. Sender S begins to send data to the receiver R after it has received CTS from receiver R. The action of other nodes, sending or backing off, decides on whether they have received a RTS or CTS packet correctly other than the result of carrier listening. For example, if the one-hop neighboring nodes of sender S receive RTS packet addressing to receiver R, they will carry out bakeoff mechanism in order to ensure that CTS packet from receiver R arrives at sender S correctly. If the one hop neighboring nodes of receiver R receive CTS packet addressing to sender S, they will also carry out the bakeoff mechanism which is much longer than the bakeoff to RTS, for

they must ensure receiver R receives all of the data correctly [1].

The collided senders use contention window to decide their bakeoff interval. Contention window is divided into slots. Slot length is medium-dependent: higher-speed physical layers use shorter slot times. Senders pick a random slot and wait for that slot before attempting to access to the medium; all slots are equally likely selections. The sender that picks the first slot wins [4] [5]. The most famous bakeoff algorithm is called binary exponential bakeoff (BEB). But there is a "fair" problem using BEB. Every time one of the senders fails to access to the medium, the contention window will increase by binary exponential. So the failure has less and less possibility to access to the medium and will lead to the phenomena of starving to death. The algorithm of bakeoff has a significant influence on the performance of MACA. Thus many modified algorithms have been studied. Now the mechanism of polling we propose in this paper will evade the bakeoff algorithm.

B. MACA-RPOLL

The idea in this paper is inspired by point coordination function (PCF). In 802.11, PCF is designed upon DCF. PCF is limited to apply in infrastructure network. The point coordination function is taken by Access Point (AP). AP maintains a polling list containing the privileged mobile stations solicited for packets forwarding. Polling packets are often abbreviated as CF-Poll. Each CF-Poll is a license to transmit one packet. Multiple packets can be transmitted only if the AP sends multiple poll requests. AP has four major tasks. In addition to the "normal" task of relaying data and acknowledging packets from mobile stations, as the point coordinator, it also needs to poll mobile stations on the polling list to enable them to send data [4]. The detailed specification of MACA-RPOLL is as follows.

Before the detail of MACA-RPOLL is discussed, some reasonable assumes are brought forward first.

Firstly, all of the mobile nodes have the same transmission range; second, the channel is ideal. In other word, all of the packets lost in transmission have no business with the performance of the wireless channel;

Third, all of the mobile nodes maintain a polling list containing its entire one-hop neighboring nodes.

Now let us consider the following scene. Receiver R has three neighboring mobile nodes: S1, S2 and S3. S1 and S2 send RTS to R exactly at the same time. Then RTS packets will collide at R. Then R will control the use of the channel and poll every mobile node in its polling list enquiring whether it has any data to transmit. If the enquired node has data to transmit, receiver and sender are deemed to begin the process of transmitting data. If the node does not have any data for R, it will answer with an ACKP packet containing this message. Then R will continue to poll the next mobile node. The general algorithm of MACA-RPOLL is as follows.

First, a mobile node having data to transmit sends RTS packet to receiver node. Then it waits for receiver R's answering packet. Second, if receiver R receives RTS packet correctly, it will answer the sender with CTS packet and then they will begin the process of transmitting data. If collision of RTS packets occurs at receiver R, R will poll all of the mobile nodes one by one with RP packet.

Third, if a sender receives a RP packet addressed to it, it will send data to the receiver directly other than answer the receiver with ACKP packet.

Fourth, if the addressing node of the RP packet does not have any data to transmit, it answers receiver R with ACKP packet informing R this message. However, collisions may occur at the enquired nodes. For example, RP packet from receiver R may collide with other types of packet at S1, S2 or S3. Some mechanism is needed to figure out this situation.

Just like mechanism in MACA, all of the sender's one-hop neighbors hearing the RTS packet should wait until the sender transmit its data completely. This mechanism ensures that no collisions occur at the senders. Receiver R wills startup its timer after sending a RP packet. If the receiver R does not receive any packet from the enquired node, it will consider that collisions occur at the enquired node. Because mechanism has been taken to ensure that no collisions occur at the senders. Receiver R considers the enquired node does not have any data to send. Then receiver R turns to the next mobile node in its polling list

III. Performance Evaluation of MACA-RPOLL

Intuitively it is believed that MACA-RPOLL has larger saturation channel utilization ratio than MACA. There have been many papers analyzing saturation throughput of Distributed Coordination Function (DCF) with different bakeoff algorithm. In this section, it will be evaluated that the channel utilization ratio of both MACA-RPOLL and MACA. Then comparing these two parameters it is concluded that our proposed protocol MACA-RPOLL does better than MACA to some extent.

A. The performance evaluation of MACA

Different with other performance analysis, the average contending time (ACT) which is the interval before a packet is successfully transmitted is used to evaluate the performance of MACA. For example, node A and node B are contending on the channel and both of them begin to bakeoff when collision occurs. Before one of them accesses to the channel successfully, the average bakeoff time they have waited for is called average contending time (ACT) [5].

Just as DCF, MACA employs a discrete-time bakeoff model. A mobile node is allowed to transmit only at the beginning of each slot time. The slot time, σ, is set equal to the average time that a node needs to detect the transmission of a packet from other node. MACA adopts an exponential bakeoff scheme. At each packet transmission, the bakeoff time is uniformly chosen in the range (0, w-1). The value w is called Contention Window. It depends on the times the node has tried for transmitting the packet. At the first transmission attempt, w is set equal to a value CWmin which is called minimum contention window. After each unsuccessful transmission, w is doubled until it is up to the maximum value CWmax which is equal to 2m CWmin. The values CWmin and CWmax are determined by the physical protocol PHY used. The specific standard is summarized in Table I .

TABLE I. BACKOFF PARAMETERS

PHY	Slot Time	CWmax	CWmin
FHSS	50µs	1024	16
DSSS	20µs	1024	32
IR	8µs	1024	64

The bakeoff counter decreases by one when each slot lapses. When a packet is transmitted successfully, the receiver will send a positive acknowledgement (ACK) packet to the sender to signal the successful packet reception. ACK packet is transmitted immediately after the packet has been received for a period called Short Inter Frame Space (SIFS) [3]. SIFS is used to ensure that other nodes hearing RTS/CTS packet have enough time to retreat their transmission and thus the transmission between the receiver and the sender is correct. In the analysis, it is assumed that the number of the nodes contending on the channel is fixed, which means that every node has a packet for transmission at any time. The analysis of performance is operated in saturation conditions. In other word, the transmission queue of each node is assumed to be always non-empty.

The values of the parameters used to obtain numerical result are summarized in Table Ⅱ. The system values are those specified for the FHSS (Frequency Hopping Spread Spectrum) PHY layer.

TABLE II. PARAMETERS USED IN ANALYTICAL MODEL

PHY header	128 bits
ACK header	112 bits + PHY header
RTS	160 bits + PHY header
CTS	112 bits + PHY header
Channel Bit Rate	1Mbit/s
Propagation Delay	1 µs
Slot Time	50 µs
SIFS	28 µs

It is assumed that the number of the nodes contending on the channel is n. At first, all of the nodes set their bakeoff counter to CWmin, according to FHSS the value of CWmin is 16. For simplicity, a tough model is used to estimate the average contending time (ACT). In this analysis, the contention widow of each contending node is fixed to the value 520, which is calculated from the average of CWmin and CWmax. ACT can be calculated by the following equation

$$ACT = \sigma\Sigma\ i*n*(1/520)*((520-i)/520)^{n-1} \qquad (1)$$

In this equation, the range of parameter i is from 1 to 520.

The parameter i present the shortest bakeoff counter among all of the n nodes. So the node which sets its bakeoff counter to i will access to the channel successfully after i slots lapse. According to the equation, it can be seen that ACT changes with the number of nodes n.

B. The performance evaluation of MACA-RPOLL

It is assumed that the number of the one-hop neighboring nodes of the receiver is n. The most ideal situation in MACARPOLL is that all of these n nodes have packet to send to the receiver. In this case, there will be no channel wastage. For being more general, a variable i is used to indicate the number of the nodes having data to transmit. Intuitively it can be seen that the larger variable i is, the less wastage there will be. It is assumed that the size of RP packet is equal to CTS and the size of ACKP is equal to ACK. Then we can calculate the total time in a round of polling. The time includes transmission time and propagation time. All of the parameters used for numerical calculation is summarized in Table II.

According to Table II, it can be calculated that the transmission time of CTS packet is 240 µs, which is the same as ACKP packet. So the total time TT used for transmitting control packet in a round polling is calculated as the following equation.

TT = 240*n+240*(n-i).

For each node has packet to transmit, the average time TTA= TT/i= (240*n+240*(n-i))/i.

We can turn this equation into a simplifier form:

TTA = 240*2*n/i – 240.

TTA represent the average time spending for exchange between the control messages before a data packet is transmitted successfully.

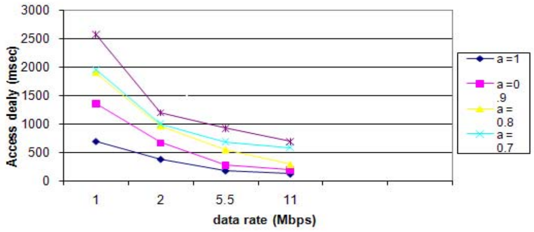

Fig. 2. Effect of hidden terminals on access delay

IV. CONCLUSION

Unfairness is a common issue in MAC protocol design. MACA-RPOLL proposed in this paper has larger channel utilization and also settles the unfairness problem commendably. In general, using the receiver-polling mechanism 'hidden terminals' effect on the performance of the channel is mitigated.

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