# Report 2 for Cooperative MAC Design

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## Abstract

**MAC layer is one of the most important parts of wireless communication network,since it is directly above the physical layer and controls the media access.There are now lots of Cooperative MAC designs to increase the throughput and quality of wireless communications.Based on the legacy of 802.11, people have presented some basic ideas such as using hopping and relay method,combined with relevant control mechanism.Others take advantage of the broadcast nature of the wireless channel and spatial diversity.In this paper,we extend these ideas to make an optimal cooperative MAC protocol,simply we call it OpMAC ,into the ad hoc network environment.The new protocol is based on the idea of involving in an ongoing communication several intermediate stations that are located between the transmitter and the receiver. The intermediate stations act as helpers to forward the traffic to the destination as well as compensating for the potential error.The way to find them will be novel and flexible.Thus,we can adapt the communication to all kinds of situations to achieve its best performance,including improved transmission rate,lower transmission error and delay.Simulations are needed to implement and check the new protocol,which is our future work.**

## 1 Introduction

Since wireless communication suffers from so many things that has very limited rate and bandwidth and is also prone to error,the 802.11b standard has tried its best to enhance it with CSMA/CA mechanism in the MAC layer.However,people are constantly seeking for all kinds of new methods to make it function better.Cooperative MAC design is one of the most appealing fields and so far has obtained very productive results.

Among these,the notion of hopping is of great importance in that it gives us a good solution to the unfairness problem as well as availability problem. In general,in the ad hoc environment,not all nodes can see each other,if a node want to transmit a packet to another node beyond its range,then it has to turn to a possible neighbor node.What's more,sometimes the source can see the destination but the distance is still a bit long and the channel is bad,the rate has to be low if the source wants to transmit its packets directly,thus it will take the channel more and cause unfairness to other high-rate nodes.The best solution to this is to use a helper which can achieve high- rate performance.Such a method has been talked by many people,who denote it the CoopMAC protocol.

The MAC design has also been introduced to take full advantage of the broadcast nature of the wireless channel and create spatial diversity, thereby achieving tremendous improvement in system robustness, capacity, delay, a significant reduction in interference, and extension of coverage range.People have denoted it C-MAC,that is: source would invite a relay node into data trans-

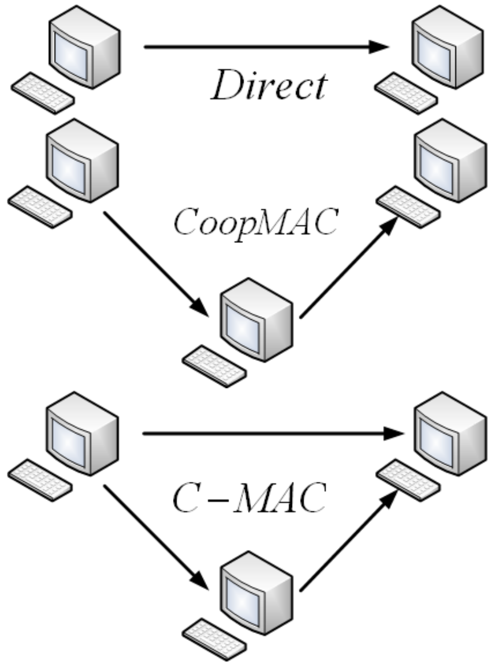


Figure 1: "Different MAC diagram"

mission if there exists an available one. During data transmission, source sends the signal to destination at first. The relay node will retransmit the overheard information to the destination at the second time slot.The destination combines two signals from source and helper,thus creating spatial diversity and robustness against channel fading.

However,there exists some problems.In this paper,we are going to talk about them in detail for the next section,and in section III we are going to analyze these schemes.In section IV ,we'll envisage our own protocol.Finally,in section V,we'll declare our future work.

# 2 Related Work

In this section we first present the IEEE 802.11b standard,then talk about others'work on CoopMAC and C-MAC .

## 2.1 the IEEE 802.11 b

IEEE 802.11 is a standard that defines the MAC and Physical layer protocol for wireless LANs. The MAC layer is based on a distributed mechanism that is called the Distributed Coordination Function(DCF).It is a CSMA/CA scheme under which every station contends for the medium by sensing if it is idle for a specific period of time called the DIFS interval followed by a random interval to avoid collision.If the station succeeds in getting control of the medium, it transmits its frame and waits for an acknowledgment (ACK) from the receiver. There is also an optional feature of using Request To Send (RTS) and Clear To Send (CTS) frames before the data transmission, in order to ensure that all nodes within hearing range of the sender and receiver are informed about the impending data transmission. The exchange of the four frames is known as the four-way handshake. The time period that the medium remains idle between the frames of the four-way handshake is a constant called the SIFS interval. By defining SIFS to be smaller than DIFS, 802.11 MAC design ensures that the exchange of these frames is not interrupted by a transmission from any other neighboring station.The band that 802.11b uses is the 2.4GHz band. In the Physical layer, it deploys three different modulation schemes to support 4 different transmission rates,1,2,5.5 and 11Mbps.All the control frames use the base rate,thus nodes can overhear each other.

## 2.2 CoopMAC scheme

Just now we have given some conceptions for this scheme,there are so-called unavailability and unfairness problems in direct transmission for some cases. In [8],the author has formally presented the notion of CoopMAC and do some analysis. In[6]the same author continued to introduce the scheme of CoopMAC into infrastructure network environment.In that scheme,every node maintains a table of all the possible helpers around itself,which is called "CoopTable".Each row of this helper table corresponds to a potential helper and has four fields.The first field is the ID(MAC Address)of the potential helper followed by the time that the last packet from that station was heard. The third field is the direct transmission data rate from that station to the AP,denoted by $R_{hd}$.The last field is used to record the data rate that can be used to send data packet to that potential helper from the current station, which is denoted by $R_{sh}$. This table is updated constantly.

When a station $S_s$ has L octets of data to send to a destination station $S_d$,it will choose a best helper with the transmission time $8L/R_{sh} + 8L/R_{hd} < 8L/R$, ignoring contention time and overhead.If none is suitable,the packet will be delivered directly,the same as in the IEEE 802.11b standard.In the helping case,four-way handshake is used,including the source's RTS,the helper's HTS(Help To Send),the destination's CTS,and the final ACK from the destination,the author has also suggested an alternative scheme without HTS frame.

In[2]the author also presented the CoopMAC scheme,but into ad hoc network environment.A big issue of these two schemes is how to find the helper,as they have depicted,we can use overhearing,that is whenever a packet is overheard from a neighboring station $S_h$, if that neighbor has no corresponding entry in the CoopTable,a new entry is created and inserted into the table with the rate $R_{hd}$ being seized and $R_{sh}$being calculated.The CoopMAC scheme can achieve high throughput and other improvements in delay and error rate as the authors have shown,it is reintroduced and referred in many other papers like[4],[5],[7].The diagram of control frame,data frame and the scenario of transmission are shown in figure 2.

## 2.3 C-MAC scheme

C-MAC is something evolving from CoopMAC,the special advantage of it as depicted previously is the spatial diversity gain since it combined two signals from the source and the helper.[1]has advanced this scheme and the author has given a very detailed analysis of such a scheme,including the new frame format and the handshake procedures for both the control plane and data plane.The simulation results are heart-stirring,for the transmission error rate has few effects the throughput for this scheme while severely damages that for direct transmission.The paper doesn't talk about the issue of finding the helper.However,the same method as in CoopMAC can be adopted.The C-MAC scheme has also been talked in[3],which advises more partners involved in help.The diagram and scenario of C-MAC can be the same as CoopMAC.

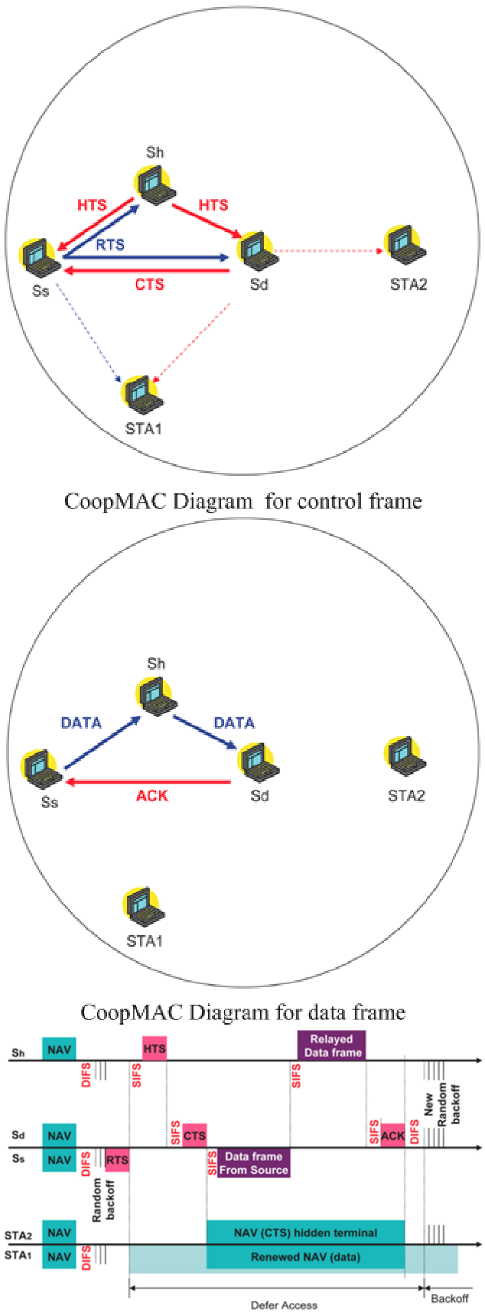


Figure 2: "The diagram of control frame,data frame and the scenario of transmission of CoopMAC"

## 3 Analysis of these schemes

In summary,we can owe MAC schemes to three categories.They are:direct link,multi-hop and decode-and-forward. CoopMAC belongs to the multi-hop method,it has four questions must be answered as depicted in[9]:

1. ? Cooperate or not cooperate;

2. ? If cooperate, who should be the helper(s) and how to do the selection;

3. ? How to solve the new hidden and exposed terminal problem in cooperation scenarios;

4. ? Rate maximization or interference minimization.

Among these,the second may be the most vital,one of the solution to this is illuminated above,but it may be not good or practical,since in dynamic environment,the helper's parameters are always in change while the information stored previously goes stale.Though the mechanism has some way to preserve the transmission,yet the HTS handshake is executed in vain and large overhead is appended. As to the C-MAC,it belongs to the decode-and-forward method,the same four question also have to be answered by it.Overall,we can have the knowledge that C-MAC is better then direct method because the QoS is more guaranteed.Therotically,as depicted in [3],if we suppose the error rate is $p_e$ for each direct transmission,then the transmission number is$\frac{1}{1-p_e}$for the direct case,while for the C-MAC case,the transmission number is$1 - p_e + p_e + p_e = 1 + p_e$,the former subtracts the latter and we get$\frac{{p_e}^2}{1-p_e}$,which is always positive,showing the QoS of C-MAC is better.However,the transmission rate for C-MAC can't be higher than the direct method,since interference becomes easier when there are more transmissions,the two data packets must have enough intervals.So what's left for us to think ? There's always the lower rate problem if we want to use a helper and thus transmit the data packets twice,the left we can do is to reduce the overhead and transmission error.

## 4 Blueprint of OpMAC

OpMAC combines the schemes above and also has other characteristics.In [3]the author has suggested multi-partners as potential helpers,each help should relay the overheard packets after a random back-off time regardless of the media,until the ACK is received from the destination.Such a scheme is rather crude that collision is probable,even the ACK signal can be corrupted and the source must retransmit,in addition to the waste of the media for such a period.In our OpMAC,we decide to extract some legacy from it.

One thing that must be declared earlier is that our OpMAC is a flexible one.That is: the source can switch between normal MAC and cooperative MAC,such information is contained in an appended control packet.When the source sends a RTS ,the destination should respond with a CTS ahead of the potential partners'HTS frame.Then the source will send another signal,here we just call it RFH(request for help).If the source thinks the channel is good,it will tell all the partners that they are declined.Otherwise,the potential partners will compete to respond to the source with a HTS frame after a small random back-off time(such a method to find partners is discussed in[5],the potential partners must also meet with some demand such as what we have already talked above,here the partners overhear the RTS and CTS and sense both the channel to the source and the destination,we suppose the channel is symmetric),the random window must be designed carefully and delicately,we plan that one unit last SIFS ,the window is twenty units and and after twenty-three units,it will send another signal called HOK,tell all the neighbors to be silent and declare the selected partners,then it will start the data packet after SIFS .The selected partners will overhear the source's transmission.The source will allocate an order for the partners to transmit their packets in case of no ACK received from the destination. These partners should wait for the ACK from the destination and listen to other partners'transmission.They hold the packets until timeout or the ACK is received,or when they have sent them out. A crude scenario is shown in figure 3.

The scheme listed above is a bit complicated

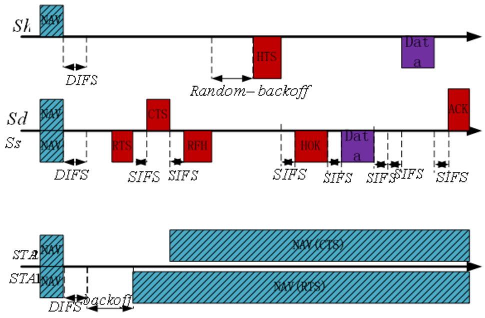


Figure 3: The OpMAC scenario

and not backward-compatible to 802.11b while very suitable for 802.11e to provide QoS .For the first glimpse,it should be very accommodated to bad-channel and dynamic environment,but internally it is prone to interference and suffering of delay.

## 5 Future Work

We 'll continue to keep an eye of new Cooperative MACs and try to strengthen our OpMAC . We will also try to validate the protocol by means of a simulation using NS-2.

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