Co-Operative Communication using Cross Layer Designing Approach

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Abstract

Exploding demand for a growing number of wireless applications has fueled significant development of wireless network, especially several generations of cellular voice & data networks & more recently ad-hoc data networks for wireless computer, home & personal networking. To overcome the problem of wireless medium like fading and interference MIMO system can be used but due to size, cost or hardware limitations, a wireless node may not be able to support multiple transmit antennas. so the co-operative communication can be used as an alternative to MIMO. In this paper, we have discussed CO-OPMAC, cross layer protocol used for cooperative communication. Here, comparison between CO-OPMAC & IEEE 802.11 is presented. The CO-OPMAC protocol performs better than its legacy IEEE 802.11 in terms of throughput, delay & achieves higher spatial diversity.

Keywords: Co-operative communication, comparison of results of IEEE 802.11 & Co-op.MAC protocol, Cross layer approach.

1. Introduction

The CO-OPMAC protocol

Wireless network that provide multi-rate support give the stations the ability to adapt their transmission rate to the link quality in order to make their transmissions more reliable. Thus, stations that experience poor channel conditions tend to use lower transmission rates and vice versa. There are two cases where station will decide to transmit at a low transmission rate. 1. When a station experiences a bad channel due to its distance from the access point. 2. In an indoor environment with strong shadowing and fading effects, a station may experience a low quality channel at some spots in the coverage area. The CO-OPMAC protocol is based on a simple, but efficient cooperative scheme where intermediate stations between the low speed station and the Access point can act as helper in the transmission process. Instead of having a slow station transmitting its frame directly to the access point (Yan Zhang et al), an alternative route through a high speed station is used for sending the frame in a two-hop manner. Thus instead of using one low data rate transmission, two high data rate transmissions are used, decreasing the amount of time the channel is occupied for that particular transmission. The cross layer protocol, which is called CO-OPMAC, enables cooperation in 802.11 networks. There are two potential costs for the helper stations introduced by the CO-OPMAC protocol. It is shown in paper that for helping nodes participating in CO-OPMAC protocol, there is substantial saving of energy. This is due to fact the amount of cooperation which is idle time of helper node before this get access to channel for its own transmission. The CO-OPMAC protocol maintains backward compatibility with the legacy IEEE 802.11 distributed coordination function describe this protocol. Since, the CO-OPMAC protocol is based on IEEE 802.11, so first we describe it shortly and then we will describe this protocol (Aria Nosratinia et al, 2004).

Fig. 1 NAV Mechanism in IEEE 802.11

The IEEE 802.11 protocol: It employs carrier sense multiple access with collision avoidance (CSMA/CA) as its medium access protocol for the distributed coordination function mode. In this mode, each station can initiate a data transmission by itself. Channel sensing before packet
transmission is essential to avoid collisions. If one station
has any packet to send it will sense the channel to make
sure the channel is clear before the actual transmission
starts. Thus virtual carrier sensing is also employed with
the use of the Request To send (RTS) and Clear To Send
(CTS) frame to reserve channel time for the transiting
stations. The band that 802.11b uses 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 11 Mbps (A. Sendonaris et al, 2003).

Multi rate capability

In order to deliver an acceptable frame error rate (FER),
packets in IEEE 802.11 can be transmitted at different bit
rates, which are adaptive to the channel quality. In general,
the transmission rate is essentially determined by the path
loss and instantaneous channel fading conditions. For
IEEE 802.11b, in particular, four different rates are
supported over the corresponding ranges, as depicted in fig
2.Another key observation conveyed by fig 2. Is that a
source station that is far away from the destination may
persistently experience a poor wireless channel, resulting
in rate as low as 1Mbps for direct transmission over an
extended period of time. It there exists some neighbour
who in the meantime can sustain higher transmission
rates(11 Mbps and 5.5 Mbps in fig 2between itself and
both the source and the intended destination, the source
station can enlist the neighbour to cooperate and forward
the traffic on its behalf to the destination, yielding a much
higher equivalent rate. With the simple participation of
neighbouring station in the cooperative forwarding, the
aggregate network performance would witness a dramatic
improvement, which justifies and motivates the
introduction of cooperation into the MAC layer. Thus to
enable cooperation in the IEEE 802.11 MAC layer, the
RTS/CTS signalling defined in IEEE 802.11 can be
extended to a 3 way handshake in COOPMAC to further
facilitate the ensuring the data exchange(A. Sendonaris et
al, 2003).

The CO-OPMAC protocol

The CO-OPMAC protocol is a protocol based on cross
layer approach. It also exploits the concept of cooperative
communication. Fig 3 shows the message flow
(Handshaking signalling and data transfer) and Fig 4
shows the NAV (Network Allocation Vector) setting with
helper and without helper.

The message flow in COOPMAC protocol

When a source node has a new MAC protocol data unit
(MPDU) to send, it can either transmit directly to the
destination, or use an intermediate helper for relaying,
whichever consumes less total air time. The feasible data
rate is the largest data rate that guarantees a predetermined
average error rate threshold for an average channel SNR.
Beyond its normal function, a request to send (RTS)
message is also used by CO-OPMAC to notify the node
that has been selected for cooperation. Moreover CO-
OPMAC introduces a new message called helper ready to
send (HTS), which is used by helper to indicate its
availability after its receive the RTS message from the
source. If HTS and CTS are received at the source,
the data packet should be transmitted to the relay first,
and then forwarded to the destination by the relay. A normal
ACK is used to acknowledge a correct reception,
regardless of whether the packet is forwarded by the relay,
or is directly transmitted from the source. The CO-
OPMAC protocol deals with this issue mainly through
maintaining a table called CO-OP Table in its
management plane. Here frame format has been depicted
in fig 5 (G. Kramer et al, 2006).
modification is needed to existing MAC protocols, like 802.11 DCF mechanism, to enable such cooperation. This cross layer protocol is based on IEEE 802.11 DCF mechanism (A. Sendonaris et al., 2003).

For simulation of COOPMAC protocol, we have modified the custom event-driven simulator-Network simulator-2. In this we have mainly modified the header file mac_80211.h and mac_80211.cc files to enable cooperation at mac layer. It generates events faithfully following every state transition of the 802.11 MAC including the head of line arrival, back off count down, DIFS time, individual transmissions, RTS/CTS transmission for both legacy and COOPMAC protocol. As shown in Table 1 and Table 2, the set of core parameters used in simulation assume the default values of specified in 802.11b standard.

Table 1 Parameters used in simulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC header</td>
<td>272 bits</td>
</tr>
<tr>
<td>PHY header</td>
<td>192 bits</td>
</tr>
<tr>
<td>CTS</td>
<td>301 bits</td>
</tr>
<tr>
<td>ACK</td>
<td>301 bits</td>
</tr>
<tr>
<td>Data rate for MAC and PHY header</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Slot time</td>
<td>20ms</td>
</tr>
<tr>
<td>SIFS</td>
<td>10mus</td>
</tr>
<tr>
<td>DIFS</td>
<td>50mus</td>
</tr>
<tr>
<td>acWmin</td>
<td>31 slots</td>
</tr>
<tr>
<td>acWmax</td>
<td>1028 slots</td>
</tr>
<tr>
<td>retryLimit</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 2 Mode Table (Path loss exponent=3)

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 Mbps</td>
<td>48.2 m</td>
</tr>
<tr>
<td>5.5 Mbps</td>
<td>67.1 m</td>
</tr>
<tr>
<td>2 Mbps</td>
<td>74.7 m</td>
</tr>
<tr>
<td>1 Mbps</td>
<td>100 m</td>
</tr>
</tbody>
</table>

We will see performance of each approach based on the protocol aspect as listed below

1. Throughput performance.
2. Delay performance. (Average end-to-end delay & transmission delay)
3. Impact of cooperation on the helper station that helps the source transmit to the destination.

*Simulation scenario for the CO-OPMAC and performance results*

Fig. 6 Simulation scenario for CO-OPMAC protocol with three nodes. Fig 6 shows the simulation scenario for CO-OPMAC protocol with three nodes, in which one node act as a source node, second node act as a destination and third node act as a helper. In this simulation, the data rate for the simulation is as shown in the Fig 6.

Now, first we assign the TCP traffic between the source & destination and the throughput is calculated for both COOPMAC protocol & its legacy IEEE 802.11 as shown in Fig 7. In second simulation, we assign the UDP traffic between the source and destination and then calculate the throughput for both CO-OPMAC protocol and its legacy IEEE 802.11 as shown in Fig 8. The increase in throughput for CO-OPMAC is due to cooperation enabled between these three nodes. As the source forwards its data to destination as well as to the helper. Now as the distance between the helper and destination is lower than that of direct path so throughput is more for CO-OPMAC protocol as compared to its legacy IEEE 802.11 standards for both TCP (Transmission Control Protocol) as well as UDP (User Datagram Protocol) (J. N. Laneman et al., 2004).

As seen from the results, the throughput for UDP is higher than that of TCP. The reason for this is that TCP is connection-oriented services i.e. in TCP, an ack signal is required while in UDP, an ack signal is not required. The Fig 9 shows the results for Throughput V/S packet size. As seen from the fig. 9 the throughput increases as the packet size increases. As the packet size increases, total no of packet decreases and hence no of drop-out in packet is also decreases and hence the increase in throughput. The maximum packet length of MPDU is of 8192 bytes.

Fig. 7 Throughput for TCP

Fig.8 Throughput for UDP
Fig. 10, Fig.11, Fig.12 shows the comparison of throughput for both IEEE.802.11 and CO-OPMAC protocol with different packet length of 512 bytes,1024 bytes and 2048 bytes respectively. As the packet length increases the total no of packet decreases and hence increase in throughput. Now, Fig.13 shows the simulation results for delay for both 802.11 and CO-OPMAC protocol. The delay for CO-OPMAC protocol is lower than that of IEEE 802.11. Because as IEEE 802.11 provides the multirate capability. In CO-OPMAC protocol, helper station forward source station data to the destination and distance between helper and destination is small as compared to direct between the source and the destination and hence higher rate and lower delay than its legacy.

Now we change the data rate between source, destination and helper. As shown in the Table 3 and then calculate the throughput for the same (P. Liu et al, 2006).

Table 3 Different Data rate for CO-OPMAC

As seen from the result of Fig.14, the throughput for different data rate increases as data rate increases. For higher throughput both data rate must be same and high. Table 4 shows data rate settings for study of end to end delay between the stations. Fig.15 shows results of end to end delay for different packet rate for both 802.11 and CO-OPMAC protocol. As the packet rate increases, more no of packets have to be sent by the helper or source to the destination and hence it increases the delay. The delay for CO-OPMAC protocol is 50% less than that of 802.11 as seen in Fig.15 (P. Liu et al, 2005).

Table 4 Setting for study of end to end delay
Fig. 17 shows the results of transfer time required for sending packets from source to destination with 802.11 for direct link of 2 Mbps and with CO-OPMAC protocol. The CO-OPMAC with rate 11-11 Mbps performs better than all others as shown in Fig. The transfer time for CO-OPMAC with (11-11 Mbps rate) is about 50% less than that of direct 802.11 with 2 Mbps due to cooperation between the nodes (Thanasis Korakis et al, 2009).

Fig 18 CO-OPMAC V/S 802.11 with a 2Mbps direct link

So, here various results (Throughput, Delay) of simulations with three nodes for CO-OPMAC protocol are presented and discussed. The comparison between various results of IEEE 802.11 and CO-OPMAC are also presented. All results have been obtained using NS-2 simulator.

Conclusion

The aim of this paper is to explore the cooperation at the medium access control (MAC) layer and do the performance analysis of a protocol called CO-OPMAC, which is based upon the existing IEEE 802.11 DCF mode. The various simulations have been done for IEEE 802.11 for throughputs and delay with different network scenario. We have developed custom event-driven simulator for CO-OPMAC protocol. The various simulations have been done for CO-OPMAC protocol while keeping the number
of nodes limited to 3. At last, the comparison between the IEEE 802.11 and CO-OPMAC protocol is presented. From comparison it is concluded that the throughput for CO-OPMAC protocol is higher than its legacy IEEE 802.11. The reason behind this is incorporation at the MAC layer. The end-to-end delay from source to destination decreases as data rate between source to helper and helper to destination is higher than the direct transmission. The Cooperation at MAC layer enables high data rate stations to assist low data rate station to help them in forwarding their data to the station. The data rate between source to helper and helper to destination should be high and same.

In Future, Cooperation can be implemented at the Medium access control layer with more no. of nodes and can be done various performance analysis of it and comparison between CO-OPMAC protocol and IEEE 802.11 protocol.

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