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Manipulating Multichannel Diversity for Cooperative Multicast in Cognitive Radio Mesh Network

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ABSTRACT

A cognitive radio network is composed of wireless users, referred to as secondary users, which are allowed to use a given licensed spectrum band as long as there are no primary, licensed, users occupying this band in their vicinity. Heterogeneity in channel availability forms a significant source of performance degradation for cognitive radio networks, and it degrades the multicast throughput since the link level broadcast may reach only a small set of destinations in the same channel. And it also increases the multicast time because it sends the same frame multiple times over multiple channels based on the channel availability. In this dissertation, we propose HAMS algorithm that take this heterogeneity property and its effect on the network performance into consideration. Our objective is reducing the multicast time and improving the multicast throughput to compensate for the performance degradation caused by the heterogeneity in channel availability. We proposed a scheduling algorithm that schedules multicast transmissions over both time and frequency. This algorithm achieves a significant gain, measured as the reduction in the total multicast time, as the simulation results prove.

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INTRODUCTION

In general terms, a "cognitive radio" is defined as a radio that can change its transceiver parameters based on interaction with the surrounding environment. A wireless mesh network is a communication network that consists of a number of wireless nodes organized in a mesh topology. These wireless nodes are usually classified into three major categories based on their roles in the network: mesh routers (MRs), mesh clients (MCs), and gateway routers. Gateway routers connect the wireless mesh network to a backbone network, or the Internet. Each mesh router, on the other hand, manages a number of mesh clients in its cell and connects them with the backbone network over multiple hops of mesh routers, and eventually through gateway routers. Lastly, mesh clients are end-users' equipment, like desktop computers, laptops, cell-phones etc., used to connect the user to the mesh network. Below diagram shows a general architecture of a wireless mesh network.

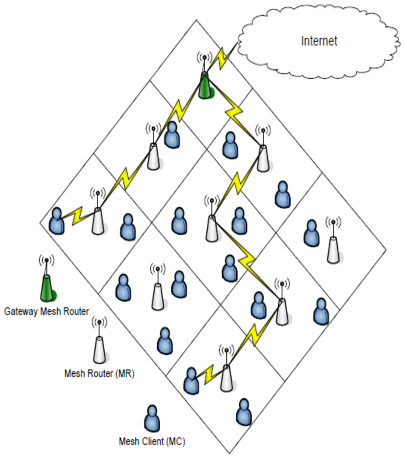

Fig. 1: General Architecture of Wireless Mesh Network.

Performance degradation due to channel heterogenity:

Depending on the activity of the PUs in their vicinity, different SUs may observe different channel availabilities. This heterogeneity in channel availability leads to the following problems that affect all modes of communication, i.e., unicast, multicast, and broadcast:

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1. Broadcast deformation: when an SU has neighbors that do not (all) share a common channel with this SU, it cannot broadcast a data unit to all neighboring SUs in one transmission. Therefore, a broadcast might become a number of multicast transmissions, or in the worst case a number of unicast transmissions. This leads to excessive reduction in network capacity and significant increase in the end-to-end delay especially in multicast applications.

2. Switching delay: another source of capacity wastage and delay increase is channel switching. Assume that SU i receives from SU j and forwards the data to SU k. If i cannot find a common channel with j and k together, then it has to use two different channels for transmission over the two links j ! i and i ! k. Depending on how separated the two channels are, the switching delay could be significant. The problem worsens when an SU has to receive from and/or transmit to multiple SUs.

In traditional multichannel wireless networks, the use of multiple radio interfaces was widely adopted as a solution to make full use of the capacity provided by the multiple channels and to avoid the switching delay problem. However, it is usually the case in traditional multichannel wireless networks that the same set of channels is available to all nodes in the network, which is not the case in cognitive radio networks. Therefore, new solutions are needed for cognitive radio networks.

Contributions of our research:

Our objective in this study is to propose a scheduling approach that can overcome the degradation in multicast throughput due to the channel heterogeneity problem. we propose a receiver-assisted multicast scheduling algorithm to reduce the effect of the channel heterogeneity problem on the multicast process. We also exploit network coding to further enhance the performance of the proposed scheduling algorithm. We propose a scheduling strategy that exploits diversity in channel availability in enhancing multicast throughput. Second we propose centralized implementation of the proposed scheduling strategy within a single cell. The centralized user is allowed to keep track of the changes which are made by the client. The proposed system which we are concluding in the project is that the centralized user will always have the updates from the clients.This makes the centralized user to be aware of multiple connected client process and it can also monitored.

Cooperative multitasking:

- MCs which receive packets, assist MR in delivering packets to other receivers which have not received packets yet (i.e., Receiver Assisted Multicasting - RAM):
- Within the same multicast group (intra-group assistance)
- Between different multicast groups and using overhearing (inter-group assistance)
- Packet overhearing (between multicast groups) in order to reduce time to deliver packets:

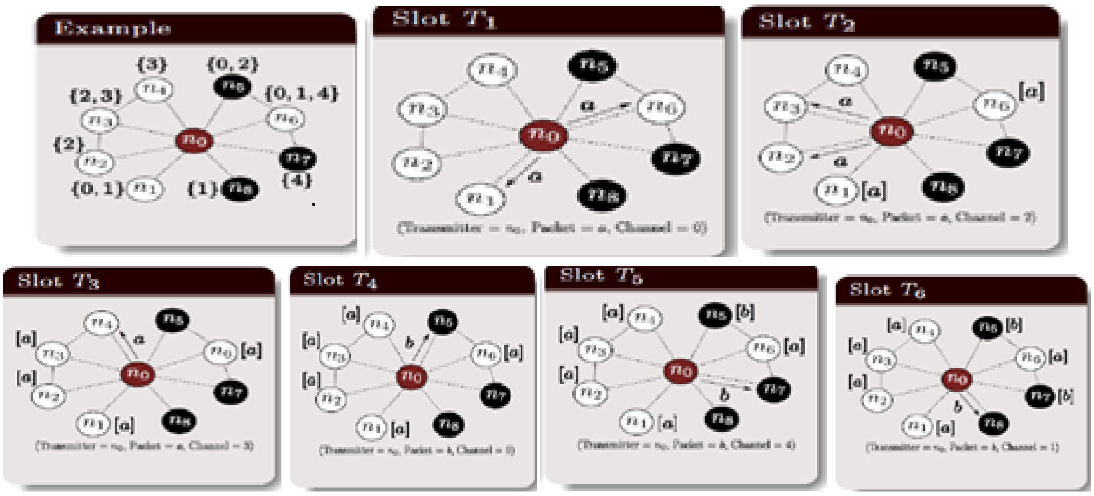


Fig. 2: Unassisted Multitasking.

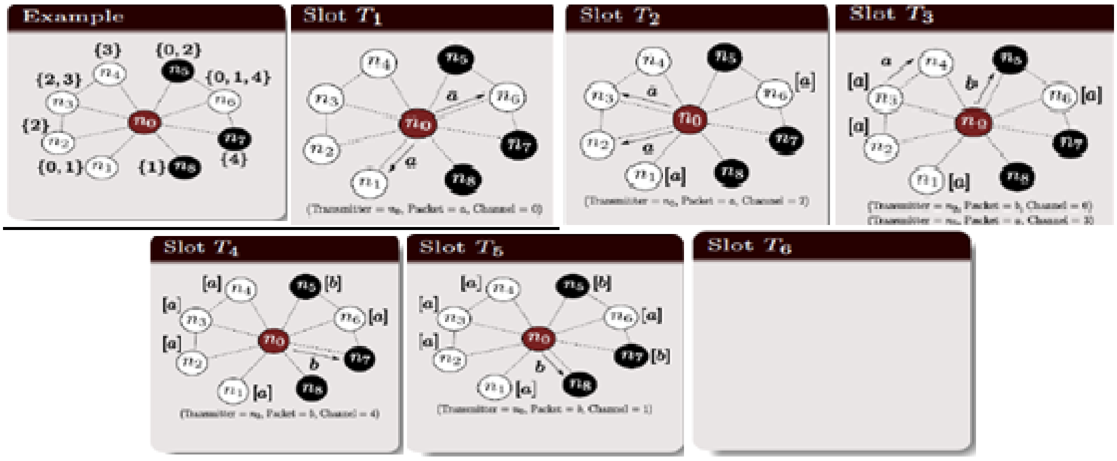


Fig. 3: Assisted multicast within a group (intra group)

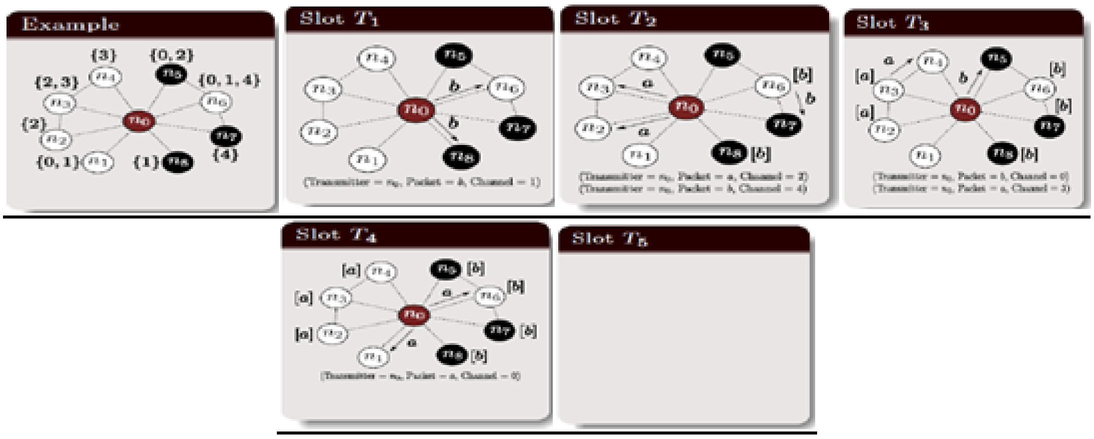


Fig. 4: Assisted Multicast within a group (Inter group)

Related works:

Creating a centralized User:

It is the main module of all the modules used in our project, creating a centralized server using the sockets. For the security purposes, the server has to register or log in to open with the server. And there are some sub modules related to the server to monitor the Clients which are connected to the network.

The main server will have the available network lists which are connected to the network. The clients who are connected will produce the IP address of the system and the clients who are in standby will not available with the IP address. The primary motivation for centralizing path computation was manageability. An efficient message-dissemination solution was proposed to minimize signaling overhead and avoid the formation of transient loops in such an environment. This is the basic process which is done at server side.

Creating an individual Receiver:

This module consists of the Client side application; here the basic task which has to be done is to connect the network with the help of the server, so it has to be connected to the centralized server. We are using the sockets to connect with the server. The IP address of the server has to be entered by the individual clients, so that it can then be connected to the server using the local host IP address.

As the client has been connected with the centralized server, the latter part of sending the packets to other clients can be done if any other multi clients are connected to the server. So, the packets can be transferred between the clients in an efficient way without any loss of data. The clients or nodes which are connected to the centralized server can send messages and files to other connected clients. The transfer which has been made by local host to the other clients can be checked again with the help of the Inbox and Sent items. The inbox carries the packets which are received from other clients and the sent item consists of the packets which have been sent to other clients with the help of the centralized server.

Transferring packets between the Multiple Receiver:

This is considered to be the key module of our project because of the transfer of packets from a client to other connected clients in the network with the help of the centralized server. The process which has been done here is that, whenever the data or a packet has to be transferred between the clients, the important part is about how well the data which is transferred is protected. The clients can send data as message or as a file to other clients who are online respectively.

The client will predict the shortest path to transfer the packets with the help of ARQ protocol, this will avoid data losses and also the output will be so efficient. As the packets which are going to be sent as a message or a file. We had provided the option to browse any data from your system to be sent to the other clients. It makes it easier for the client. Each individual client will be allocated with the IP address, thus the transfer which are happening here is with the help of the local host address. After the process is finished, the notification will be sent to the centralized server.

Updating the notifications in User:

The centralized server which has been formed here will carry all the updates which are done at the client side. This helps the server to be aware of the situation within the clients initially. For e.g.: whenever a client has log on to the server, then the notification saying that a client has been logged in to the network. So we have to create various databases has to maintain the history which has been done at the client side.

Likewise, we are maintaining the notifications for the Client information and also for transferring messages. This makes the centralized server to be aware of the Client side at all times. The notifications which are maintained in the server side will have every detail about the Clients who are in the network. The history which is maintained can be cleared by the server at any time. The updates which are being held in the server side are just for maintaining the client side. Because of the security issues, the history which is maintained by the server side has to be cleared at least once a day. So that the messages which are also been monitored is for the transfer of messages. The centralized is responsible for updating the Client history.

Transferring the packets without data losses:

This module plays a big role in our project, as our main concern is all about avoiding the data losses between the clients in the centralized server when transferring the data or the packets. As we are using the algorithm to find the shortest path between the nodes, it allows us to make sure that the data losses are controlled. With the help of ARQ Protocol the data loss has been protected efficiently, whenever the file has been transferred from a client to client. Automatic repeat request (ARQ) is a protocol for error control in data transmission. First we send a request to the entire available path. Based on the request received from the client we set primary and secondary path. Basically all the data send via Primary path. If the primary path fails the client can automatically sends the data to secondary path. So data can send or receive very safely. Thus we can prove that while transferring a file or a packet, the data has not been lost and it has been protected very efficiently.

Heuristic assisted multicast solution (hams) algorithm:

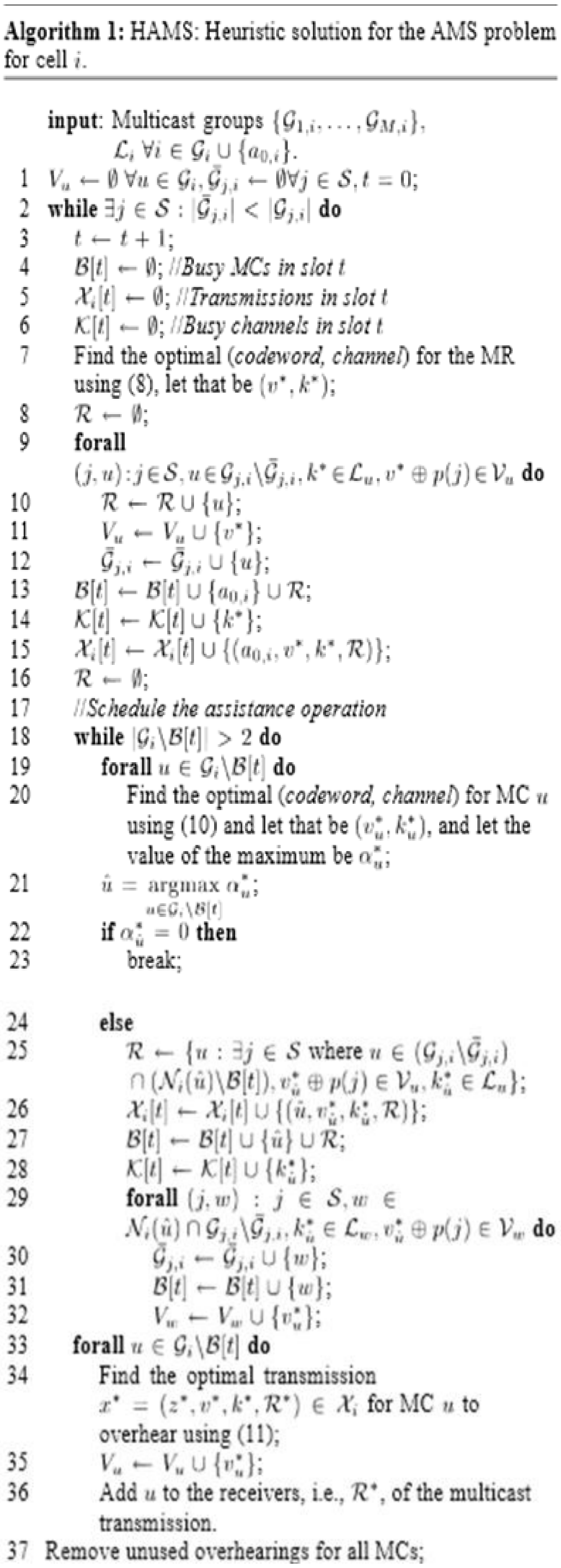
Heuristic algorithm to solve the problem with multiple multicast groups. The algorithm is greedy-based in the sense that it deals with each slot independently and tries to make the optimal decision at this slot. However, finding this optimal decision in each time slot is not an easy task. In fact, it can be shown that in the case of a single multicast group, scheduling the transmissions of the MR and covered MCs in a time slot t (those which have received the multicast packet in $[1, t-1]$) in a slot t such that the packet is delivered to the maximum number of uncovered MCs is NP-hard (assuming of course that covered MCs may *assist* uncovered ones). Therefore, we divide the scheduling task in *a single time slot* it into three phases.

Phase-1: Scheduling the MR transmission (what code word to transmit, and on which channel).

Phase-2: Scheduling the assistance operation for each assistance candidate (what code word to transmit and on which channel). An *assistance candidate* is an MC that was not scheduled to receive data in the first phase, and has received at least one code word in
$[1, t - 1]$.

Phase-3: Scheduling overhearing opportunities for overhearing candidates. An *overhearing candidate* is an MC that was not scheduled as a transmitter (assistant MC) or a receiver in the first two phases. Such an MC has the choice to overhear any of the scheduled code word transmissions it can. It shall overhear the code word transmission that has the highest potential of being beneficial to the MC itself or any of its neighbors.

Hams algorithm:



Algorithm 1: HAMS: Heuristic solution for the AMS problem for cell i.

```
input: Multicast groups $\{\mathcal{G}_{1,i}, \ldots, \mathcal{G}_{M,i}\}$,
       $\mathcal{L}_i\ \forall i \in \mathcal{G}_i \cup \{a_{0,i}\}$.
$V_u \leftarrow \emptyset\ \forall u \in \mathcal{G}_i, \bar{\mathcal{G}}_{j,i} \leftarrow \emptyset \forall j \in \mathcal{S}, t = 0$;
while $\exists j \in \mathcal{S} : |\bar{\mathcal{G}}_{j,i}| < |\mathcal{G}_{j,i}|$ do
    $t \leftarrow t + 1$;
    $\mathcal{B}[t] \leftarrow \emptyset$; //Busy MCs in slot t
    $\mathcal{X}_i[t] \leftarrow \emptyset$; //Transmissions in slot t
    $\mathcal{K}[t] \leftarrow \emptyset$; //Busy channels in slot t
    Find the optimal (codeword, channel) for the MR
    using (8), let that be $(v^*, k^*)$;
    $\mathcal{R} \leftarrow \emptyset$;
    forall
    $(j, u) : j \in \mathcal{S}, u \in \mathcal{G}_{j,i} \backslash \bar{\mathcal{G}}_{j,i}, k^* \in \mathcal{L}_u, v^* \oplus p(j) \in \mathcal{V}_u$ do
        $\mathcal{R} \leftarrow \mathcal{R} \cup \{u\}$;
        $V_u \leftarrow V_u \cup \{v^*\}$;
        $\bar{\mathcal{G}}_{j,i} \leftarrow \bar{\mathcal{G}}_{j,i} \cup \{u\}$;
    $\mathcal{B}[t] \leftarrow \mathcal{B}[t] \cup \{a_{0,i}\} \cup \mathcal{R}$;
    $\mathcal{K}[t] \leftarrow \mathcal{K}[t] \cup \{k^*\}$;
    $\mathcal{X}_i[t] \leftarrow \mathcal{X}_i[t] \cup \{(a_{0,i}, v^*, k^*, \mathcal{R})\}$;
    $\mathcal{R} \leftarrow \emptyset$;
    //Schedule the assistance operation
    while $|\mathcal{G}_i \backslash \mathcal{B}[t]| > 2$ do
        forall $u \in \mathcal{G}_i \backslash \mathcal{B}[t]$ do
            Find the optimal (codeword, channel) for MC $u$
            using (10) and let that be $(v_u^*, k_u^*)$, and let the
            value of the maximum be $\alpha_u^*$;
        $\hat{u} = \underset{u \in \mathcal{G}_i \backslash \mathcal{B}[t]}{\operatorname{argmax}}\ \alpha_u^*$;
        if $\alpha_{\hat{u}}^* = 0$ then
            break;

        else
            $\mathcal{R} \leftarrow \{u : \exists j \in \mathcal{S}$ where $u \in (\mathcal{G}_{j,i} \backslash \bar{\mathcal{G}}_{j,i})$
            $\cap (\mathcal{N}_i(\hat{u}) \backslash \mathcal{B}[t]), v_{\hat{u}}^* \oplus p(j) \in \mathcal{V}_u, k_{\hat{u}}^* \in \mathcal{L}_u\}$;
            $\mathcal{X}_i[t] \leftarrow \mathcal{X}_i[t] \cup \{(\hat{u}, v_{\hat{u}}^*, k_{\hat{u}}^*, \mathcal{R})\}$;
            $\mathcal{B}[t] \leftarrow \mathcal{B}[t] \cup \{\hat{u}\} \cup \mathcal{R}$;
            $\mathcal{K}[t] \leftarrow \mathcal{K}[t] \cup \{k_{\hat{u}}^*\}$;
            forall $(j, w) : j \in \mathcal{S}, w \in$
            $\mathcal{N}_i(\hat{u}) \cap \mathcal{G}_{j,i} \backslash \bar{\mathcal{G}}_{j,i}, k_{\hat{u}}^* \in \mathcal{L}_w, v_{\hat{u}}^* \oplus p(j) \in \mathcal{V}_w$ do
                $\bar{\mathcal{G}}_{j,i} \leftarrow \bar{\mathcal{G}}_{j,i} \cup \{w\}$;
                $\mathcal{B}[t] \leftarrow \mathcal{B}[t] \cup \{w\}$;
                $V_w \leftarrow V_w \cup \{v_{\hat{u}}^*\}$;
    forall $u \in \mathcal{G}_i \backslash \mathcal{B}[t]$ do
        Find the optimal transmission
        $x^* = (z^*, v^*, k^*, \mathcal{R}^*) \in \mathcal{X}_i$ for MC $u$ to
        overhear using (11);
        $V_u \leftarrow V_u \cup \{v_u^*\}$;
        Add $u$ to the receivers, i.e., $\mathcal{R}^*$, of the multicast
        transmission.
Remove unused overhearings for all MCs;
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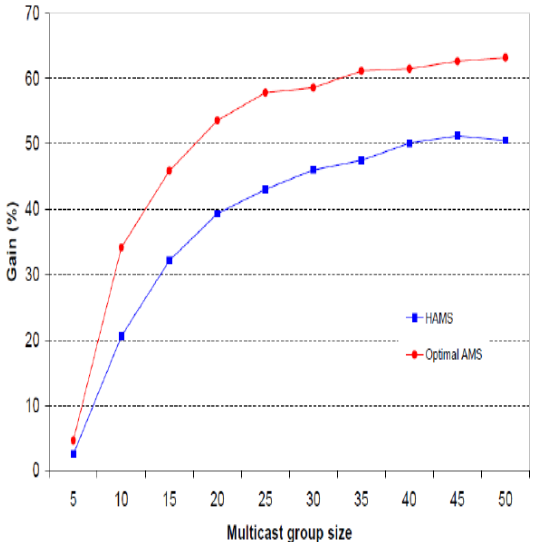
Hams performance (single group):

Gain=100*(Unassisted-Assisted)/ Unassisted



Gain of different assistance level

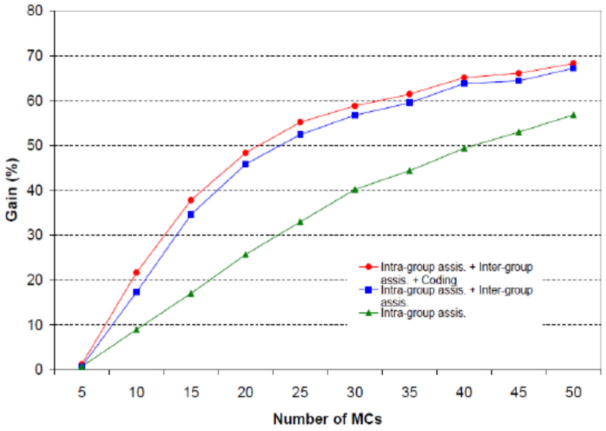
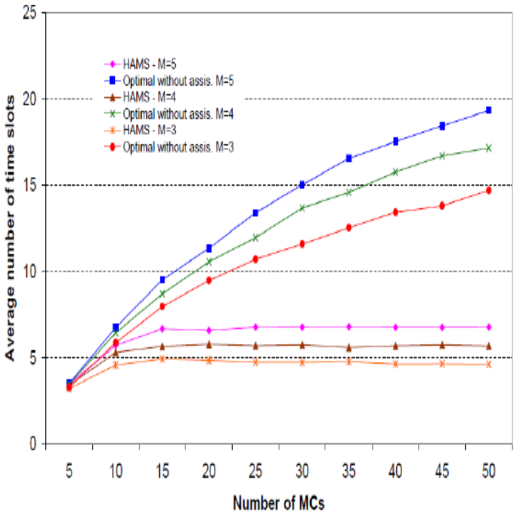


Figure 4.8: Average gain of assisted multicast using different levels of assistance ($M = 3, Pa = 0.25$).

HAMS PERFORMANCE (Multiple Groups):



Future enhancements:

Decreased need for internet gateway.

Collaborative redundant backup technology which ensures data security in the event of disk failure.

The ability to configure routes dynamically.

Lower power requirements which would potentially be met by low cost or renewable energy sources.

Increased reliability: Each node is connected to several other nodes and if one drops out of the network, its neighbors simply find another route.

Summary:

We introduced an assistance paradigm that relies on receiver nodes to forward the multicast data to other receivers that have not yet received their own data.

- Intra-group assistance
- Inter-group assistance

Introduced exact and heuristic solutions within a single cell

Introduced heuristic approaches for scheduling between cells

Conclusion:

Thus we have studied the problem of assisted multicast scheduling in wireless cognitive mesh networks. We have proposed an assistance paradigm that is intra group assistance, inter group assistance using HAMS algorithm that relies on receiver nodes to forward the multicast data to other receivers to overcome the effect of heterogeneity problem and to increase the multicast throughput and to reduce the multicast time.

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