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Priority Based Resource Allocation for MIMO-Cooperative Cognitive Radio Networks

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Cognitive radio technology is an emerging technology which is very promising and hence is being developed at a rapid rate. In Multi Input Multi Output Cooperative Cognitive Radio Networks (MIMO-CCRN) primary users (PUs) recruit some secondary users (SUs) to cooperatively relay the primary traffic. Considering networks with heterogeneous services, it will be difficult to allocate the resources and assign the channel. The selection of secondary users (SU) as relay nodes should satisfy the rate and delay constraints of respective SUs. To overcome these issues, in this paper we develop an efficient resource allocation technique which uses very reliable nodes for data transmission. The resources are allocated only after ensuring that the nodes satisfy the specified constraints. This leads to successful data transmission and hence good network performance.

Keywords: Minimum Rate Guarantee, Minimum Delay Guarantee, Best effort

Introduction

MIMO-Cognitive Radio Network

Cognitive radio is an emerging technology suitable for the dynamic communication technique of the coming generation. The shortage of the resources in the frequency spectrum can be overcome by adopting this technology. The functionalities performed by the cognitive radio technology are spectrum sensing, spectrum access, cooperative communicating method and reducing the interference. This technology is explored in department and is determined to be suitable to be deployed in various networks like WLAN, MANET, broadcasting television networks, etc. [1]. In enhancing the spectrum usage and attaining proficiency, techniques such as Cognitive radio (CR), MIMO communications, and cooperative communications are very reliable [2]. MIMO is new technology developed in the physical layer and it has several advantages since it uses many antennas and follows enhanced signal processing techniques. MIMO antenna can be utilized to send and receive several different data streams and also to reduce interference [3].Increasing the capability of the secondary network is the highly focused area during the exploration of the MIMO cognitive radio networks. [4] Dynamic allocations of resources to maximize the spectrum utilization, Multichannel power allocation, Selection of secondary users based on their QoS requirements are some of the methods of increasing the capability of the secondary networks.

Objectives and Proposed Contributions

A MIMO-CCRN is designed in [3] where primary users (PUs) recruit some secondary users (SUs) to cooperatively relay the primary traffic. SUs equipped with MIMO antennas, cooperatively relay the traffic for the PUs while concurrently accessing the same channel to transmit their own traffic. However, the selection of SU as relay nodes should satisfy the rate and delay constraints of respective SUs. In energy efficient transmission technique for MIMO cognitive radio networks [4], it is a hard task to find a proper solution to the joint time scheduling technique and the beam forming technique since these techniques are non-convex. In [5], finding a satisfactory solution for the uplink subcarrier and power assignment problem is very difficult and is called as Mixed Integer Nonlinear Programming (MINLP) problem. Resource allocation issue is presented [7] in multiple-input multiple-output–orthogonal frequency division multiplexing-based cooperative cognitive radio networks. A two-stage distributed mechanism is proposed [8] based on the subcarrier assignment

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and power allocation. In this paper, we propose to develop a dynamic resource allocation technique for heterogeneous services in MIMO-CCRN.

Priority Based Resource Allocation

Overview

In this paper, the basic system model of MIMO-CCRN [3] is assumed in which the SU can be categorized as SU with minimum-rate guarantee (MRG) [9], SU with minimum delay guarantee (MDG), SU with minimum rate and delay guarantee (MRDG) and SU with best effort service (BE). While selecting the set of SUs as relay nodes, the objective function should satisfy the following constraints:

- For MRG, the transmission rate for SU should be greater than the minimum-rate threshold.[9]
- For MDG, the transmission delay for SU should be less than the deadline threshold.
- For MRDG, the transmission rate should be greater than the minimum-rate threshold and the transmission delay should be less than the deadline threshold.
- For BE, fairness constraint should be satisfied.

The Network Topology

Within the heterogeneous network, the intermediate nodes which are capable of forwarding the data between the primary users form the secondary network (SN). Each node in the secondary network is called as the secondary user (SU). The nodes located at a close distance from the PT are considered as secondary transmitter (ST), and the nodes located close to the PR, are called as secondary receiver (SR). The ST and SR are together considered as Secondary Users (SU) and the number of SU in the SN is assumed to be SU_{total}. The nodes in the SN are equipped with two MIMO antennas. Each SN consists of a Base Station (BS). A PU is linked to the SU through M channels.

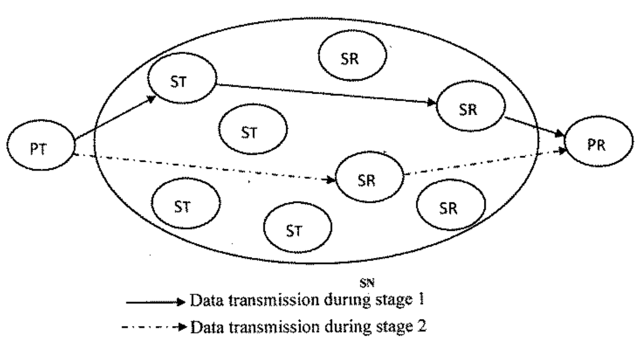

Fig. 1—Network Topology

Channel Assignment for Data Transmission

Initially, the PT determines idle channels and valid SU which may be either ST or SR to transmit its data to the destination. To determine the idle channels in the network, all the available channels are sensed by the SUs. Based on the sensing, the BS decides the status of the channels. The detection of the idle channels is described in algorithm 1.

Algorithm-1

1 The data transmission from the PT is carried out in frames with each frame duration equal to FD, as in the TDMA technique.

2 During the first FD, the channels are sensed and resource is allocated.

3 Initially, the SU sense the M channels to detect any idle channel.

4 The $Sensed_{info}$ is then transmitted to the BS in the SN.

5 On receiving the $Sensed_{info}$ from the SU, the BS processes it, since there are four cases possible.

i Channel is idle, and $Sensed_{info}$ indicates the channel to be idle.

ii Channel is idle, and $Sensed_{info}$ indicates the channel to be busy.

iii Channel is busy, and $Sensed_{info}$ indicates the channel to be idle.

iv Channel is busy, and $Sensed_{info}$ indicates the channel to be busy.

6 The BS compares the $Sensed_{info}$ with $Idle_{Threshold}$ and decides the channel condition based on the P_M^{FA} and P_M^D .

$$P_M^{FA} = P\{Sensed_{info} > Idle_{Theshold}|H_o\} \quad \dots (1)$$

$$P_M^D = P\{Sensed_{info} > Idle_{Theshold}|H_1\} \quad \dots (2)$$

7 Based on the probability, the BS detects the correct channel case, which is case (i) and (iv).

8 BS selects the channels, N≤M which fall into case (i), and decides these channels to be idle.

9 Thus the idle channels are assigned by the BS to the SU.

Dynamic Resource Allocation

After the detection of the idle channels, the resources are allocated to perform data transmission. Due to the dynamic nature of the wireless network, the resource allocation process should also be carried out in a dynamic way. The characteristics considered during resource allocation are data rate, delay and best effort service rate. The dynamic resource allocation process is described in algorithm 2.

Algorithm-2

1 Once the idle channels are detected, the nodes which transmitted the $Sensed_{info}$ corresponding to the idle channel are notified.

2 All the notified nodes, $K \leq N$ and $K \leq SU_{total}$ are accessed.

3 The nodes are tested to determine the MRG constraint as given below:

If $R_k > R_k^{\min}$, then

MRG constraint is satisfied

Else

a. MRG constraint not satisfied

End if

4 To check the MDG constraint of the node, initially the average D during the usage of the node is determined as given by (3) and compared with the network delay guarantee threshold.

$$D = N[d_{tran} + d_{proc} + d_{prop}] \quad \text{... (3)}$$

5 If $D \leq D\_Gurantee_{threshold}$, then

a. MDG constraint is satisfied.

Else If $D > D\_Gurantee_{threshold}$, then

b. MDG constraint is not satisfied.

End if

6 The nodes which satisfy the MRDG constraint i.e., step (3) and (5) simultaneously are determined.

7 To ensure the best effort service, the node should satisfy the fairness constraint. So, initially the throughput is determined using the equation (4) given below:

$$Fair = \frac{R_k}{\sum_{i=1}^{k} R_i} \quad \text{… (4)}$$

8 The estimated throughput is compared w.r.t the best effort threshold.

a. If Fair $\leq BE_{Threshold}$, then

b. BE service constraint is not satisfied.

Else If the Fair > $BE_{Threshold}$, then

c. BE service constraint is satisfied.

End if

9 The SU nodes which satisfy the MRG, MDG and MRDG and BE service constraints are selected for the resource allocation.

10 Based on the SU nodes selected, the FD is divided into two stages: Stage 1 uses the initial part of frame duration, αFD and Stage 2 which uses last part of the frame duration,

$$(1-\alpha)FD$$

11 During stage 1, the ST selected by the PT is allowed to access the channel.

12 So, the data transmitted by the PT is received by ST, and then it is forwarded to the SR, and is finally delivered at the PR.

13 During stage 2, the SR selected by the PT is allowed to access the channel.

14 In stage 2, the data is transmitted by the PT towards the SR. On receiving the data, SR forwards it directly to the PR.

15 On receiving the data, the PR checks the path used to reach the destination and responds by transmitting an ACK message in two stages during the next FD.

16 During the stage 1 of response, the PR sends the ACK to the ST and during stage 2, the PR sends the ACK to the SR, which is then forwarded to the PT.

Thus, the data reception is confirmed by the PR, and on receiving the confirmation, PT transmits the next data to be transmitted.

Simulation Results

Simulation Parameters

We use NS2 (Network Simulator) to simulate our proposed Priority Based Resource Allocation (PBRA) protocol. We use the IEEE Maccon for wireless networks as the MAC layer protocol. The area size is 1500 meter x 300 meter square region for 50 seconds simulation time.

Results & Analysis

We compare the Cooperative Cognitive Radio Networks (CCRN) protocol [9] with our proposed PBRA protocol. The data sending rate of CBR and Exponential (EXP) traffic is varied as 100,200,300,400 and 500Kb. The results are shown in Fig. 2.1.When comparing the performance of the two protocols, we infer that PBRA outperforms CCRN by 5% in terms of cbr-bandwidth, 5% in terms of cbr-fairness, 13% in terms of exp-bandwidth, 13% in terms of exp-fairness, 29% in terms of video-bandwidth, 29% in terms of video-fairness, 21% in terms of delay and 3% in terms of delivery ratio.

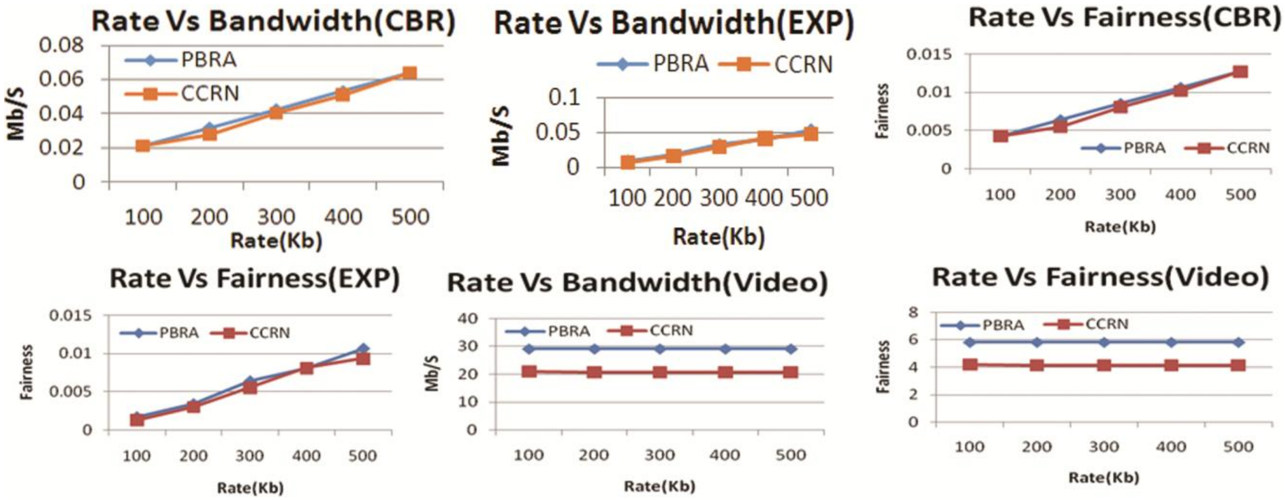

Fig. 2—show the results of cbr-bandwidth, cbr-fairness, exp-bandwidth,exp-fairness,video-bandwidth,video-fairness by varying the rate from 100Kb to 500Kb for the CBR,Exponential and Video traffic in PBRA and CCRN protocols.

Conclusion

In this paper, an efficient technique for Priority Based Resource Allocation in MIMO- Cooperative Cognitive Radio Networks is proposed. In this paper, whenever a primary user wants to transmit data to a destination, then initially the channels are sensed and assigned. Then, suitable nodes in the secondary network are selected based on the specific conditions like MRG, MDG, MRDG and BE service. Thus, the effective resource allocation technique used in this network aids in successful network performance. Future scope aims to develop effective channel sensing and scheduling algorithms for heterogeneous MIMO-CCRN.

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