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Robust Cross Layer Design for Cognitive MIMO Ad Hoc Network for Optimal Resource Allocation

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***Abstract* – *Cognitive Radio* (CR) is an intelligent wireless communication technique in order to increase the spectrum efficiency and fairness issues. Cognitive radio has been considered as an efficient means to opportunistic spectrum sharing between primary users (licensed users) and cognitive users. Cross layer design provides cooperation between multiple layers to combine the resources. Multiple Input Multiple Output (MIMO) is a potential solution to minimize the Co channel interference where cognitive radio operating in coexisting environment. Due to unique physical layer characteristics associated with MIMO, network performance is tightly coupled with mechanisms at physical, link, and routing layers. So far, research on MIMO-based wireless ad hoc networks is still in its infancy and few results are available. So resource allocation at each node and multi hop/multipath routing in a MIMO-based wireless Ad Hoc network is needed. This paper describes the novel approach of robust cross layer design for cognitive MIMO ad hoc network for optimal resource allocation.**

***Keywords* – Cognitive Radio, MIMO, Cross Layer Design, Ad Hoc Network, Antenna Selection Algorithm.**

I. INTRODUCTION

Cognitive radio which automatically detect the available channels in wireless medium. The four main tasks of cognitive radio are spectrum sensing, spectrum sharing, spectrum mobility and spectrum management. Cognitive radios apply two distinct approaches for concurrent spectrum access, viz., spectrum overlay and spectrum underlay. In the underlay scheme, secondary users occupy the whole bandwidth and transmit at lower power than the noise floor of the primary user. As power is very low in these schemes, secondary users' communication appears as white noise as the primary user. On the other hand, in the overlay scheme, secondary users use opportunistic or adaptive techniques to determine when and where to transmit [1]. In this study, we will only focus on overlay communications of cognitive users. Determining spectrum opportunity is one of the key challenges for the overlay scheme. Cognitive radios are envisioned to have sensing and learning capability for this purpose .It is worthwhile to mention that cooperation among cognitive node

Can further improve spectrum sensing capability of cognitive radios. However, for this study, we assume cognitive nodes have perfect knowledge of available frequency channels and respective bandwidths. After successful detection of opportunity, unutilized frequency channels are assigned to cognitive radios. One of the prominent techniques to improve spectrum utilization is through Multiple-Input and Multiple-Output (MIMO) techniques. As the cognitive radios are able to access very small amount of wireless resources, this high spectrum efficiency makes MIMO systems extremely valuable for cognitive devices. CR operating in a coexisting environment so co-channel interference occurs. An effective MIMO technique to improve the spectral efficiency of the CR system and to provide flexible spectrum management, which makes the CR systems effectively reuse the frequency resources and Multiple Input and Multiple Output (MIMO), is a potential solution to avoid Co channel interference. MIMO uses space diversity and offer multiplexing gain, diversity gain, and co-channel interference suppression to the wireless system.

A Cross-Layer Design (CLD) is particularly important for any network using wireless technologies, since the state of the physical medium can significantly vary over time. CLD is the way of achieving information sharing between all layers. A recent emerging paradigm shift that is beginning to take place as wireless communications are evolving from circuit switched to packet switched infrastructure. The paradigm shift evolves around a principle known as Cross-Layer Design (CLD). The three main tasks of cross layer design are direct communication between layers, A shared database across the layers, Completely new abstractions. CLD provides a cooperation between multiple layers to combine resources. The ad has network is a self organizing multi-hop wireless network, which relies neither on fixed infrastructure nor on predetermined connectivity. Ad Hoc network decrease the infrastructure dependent and give a speed of deployment, ease of deployment process. The ad has network is an infrastructure less network and it does not have any base station. Ad Hoc network support peer to peer communication and give a full support for some time

And anywhere communication and Ad Hoc network decrease the administrative cost. The changing spectrum environment and the importance of protecting the transmission of the licensed users of the spectrum mainly differentiate classical ad hoc networks from CR ad hoc networks. In CR Ad Hoc networks (CRAHNs), the available spectrum bands are distributed over a wide frequency range, which vary over time and space. Thus, each user shows different spectrum availability according to the primary user (PU) activity. With the growing proliferation of wireless devices, these bands are increasingly getting congested. A CR user can communicate with other CR users through ad hoc connection on both licensed and unlicensed spectrum bands. Thus CRAHNs require collaboration between routing and spectrum allocation in establishing the routes.

However, spectrum efficiency of the MIMO system can be further improved by using antenna selection schemes and antenna selection algorithm used increase the transmission efficiency.

II. System Model

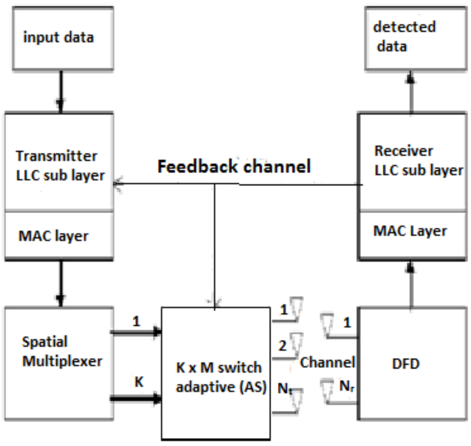

Fig.1. System Model Cognitive nodes

Consider a cognitive ad-hoc network coexists with licensed primary users (PU) in the same area. The ad-hoc network contains M pairs of cognitive users (CU) and any node can listen to all other nodes in the network. For wireless resource allocation purposes, we consider cognitive nodes that can make use of C unused frequency bands of the primary users. Also, the number of available channels for cognitive radios are less than the number of cognitive users. The ad-hoc network contains M pairs of cognitive users (CU) and any node can listen to all other nodes in the network. For wireless resource allocation purposes, we consider cognitive nodes that can make use of C unused frequency bands of the primary users. So, the number of available channels for cognitive radios is less than the number of cognitive users. On the other hand to improve the wireless resource utilization, cognitive source-destination pairs use *nor* transmit and *not* receive antennas. Nodes also use the Decision Feedback Detection (DFD) to cancel interference and improve detection. In the Logical Link Control (LLC) sub-layer, nodes use Go-Back-N (GBN) protocol, and Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol in the Media Access (MAC) sub-layer of the data link layer.

Cognitive radios in ad-hoc networks encounter few more challenges: such as, lack of cooperation between nodes, unstable user statistics, resource management, etc. In that sense, game theory can mathematically model the ad-hoc network to address these challenges [2]. In some recent works, game theory is used to determine the achievable capacity or transmit power of cognitive networks. In [3], game theory is used to reduce the interference on primary users due to concurrent communication of cognitive and primary users in the same frequency band. In [4], a cross-layer approach to transmit antenna selection capable of adapting the number of active antennas to varying channel conditions. The selection of antenna subsets is the maximization of link layer throughput which takes into account characteristics both at the physical and link layers. In order to enhance system performance, adaptive modulation is included to jointly perform antenna selection and rate adaptation from both cross layer and physical layer approach. Future work in this field will encompass an extension to multi-user scenarios with the derivation of cross-layer scheduling techniques in combination with antenna selection methods.

In [5], a dynamic spectrum sharing algorithm for cognitive radio network presented and consider a cognitive radio network that consists of multiple cells and the system throughput is defined as the total number of subscribers that can be simultaneously served. Consider a cognitive radio network as self-organizing network. Furthermore, the throughput is defined as the average probability of success transmission. For each available channel, TDMA frame is divided into *N* time slots, and each active cognitive user is assigned one transmission slot different from those of other active cognitive users in each frame. It allows an active cognitive user utilize the slots pre assigned to the other active cognitive users under a range of values for accessing probability. Then evaluate the performances of the dynamic spectrum sharing algorithm for a different average number of active cognitive users and different number of available channels.

III. Antenna Selection Algorithm

The advantage of MIMO systems is that better performance can be achieved without using additional transmit power or bandwidth extension. However, its main drawback is that additional high-cost RF modules are required as multiple antennas are employed. In general, RF modules include low noise amplifier (LNA), frequency down-converter, and analog-to-digital converter (ADC). So to reduce the cost associated with the multiple RF modules, antenna selection techniques can be used to employ a smaller number of RF modules than the number of transmit antennas

The channel capacity of the system depends on a number of selected antennas. The goal of antenna selection is to find a trade-off between capacity maximization and pairwise error probability minimization. In [1], the antenna selection algorithm works as at first, the cognitive source node determines the combination of maximum possible usable antennas for a given transmit power and primary users' interference constraint. Then, source nodes consult with respective receivers on the optimum combination of $K \leq not$ transmit antennas.

During this phase, a cognitive receiver searches for the subset p, from all possible combination set $P = \{\binom{Nt}{K},\ for\ K = 1..\ Nt\}$, that achieves the maximum transmission efficiency at the LLC sub layer. This information about

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the optimum subset p of transmitting antennas is relayed back to the cognitive transmitter through a feedback channel. At the transmitter side, cognitive nodes use this subset p to divide the incoming data into *K* parallel streams for spatial multiplexing and subsequent transmission from the K-selected antennas. If the cognitive node transmission probability is τ_i, then the total interference level of the primary user for *M* cognitive users can be written as,

$$I_{total} = \sum_{i=1}^{M} \tau_i \quad (1)$$

$$I = \sigma G_{i.} (GI)^H \quad (2)$$

II is an instantaneous interference power at thel^{th} Primary user. Stands for an $1xN_t$ channel vector representing the corresponding channels between a primary user and cognitive node.

By using *my* $_{total}$ measurements to calculate the maximum number of usable antennas during DIFS period of IEEE 802.11 standard. The DIFS value of this measurement is 128 microseconds. Then sends an RTS signal using antennas identified in previous steps. Considering binary-phase-shift-keying (BPSK) transmission, the bit-error rate (BER) of the j^{th} Layer provided that all previous layers are correctly detected and the data packet is divided into K-parallel streams before transmission, it used to find the packet error rate (PER). About GBN protocol with window size W the instantaneous transmission efficiency at the receiver side of the node I can be expressed as,

$$\eta i(Hp,\rho) = \frac{K}{Nt} \frac{1-PER(Hp)}{1+(W-1)PER(Hp)} \quad (3)$$

For the antenna selection algorithm, cognitive source nodes select the antenna combination that provides maximum transmission efficiency at the LLC sub layer for a given interference threshold at the primary user, that is

$$HP = argmax_{Hp}\, i(Hp, \rho) \quad (4)$$

Then, the calculation of *HP* on the receiver side is relayed back to the cognitive transmitter through feedback channel. On the transmitter side, cognitive nodes use this information to divide the incoming data into *K* parallel streams for spatial multiplexing and subsequent transmission from the *K*-selected antennas

IV. Channel Assignment Algorithm

The channel assignment algorithm for cognitive users competing for available frequency slots. This algorithm considers the interference threshold at the primary users and the bandwidth of the available frequency slots when assigning channels to cognitive users. By using previous method achievable data rate, *Xi*, at the LLC sub layer of any cognitive node is determined by multiplying transmission efficiency with bit rate $K R_{tr}$.

$$X_i = K R_{tr} \eta_i (H_p,\rho) \quad (5)$$

In order to maximize the transmission efficiency, the SNR is increased. However, the interference at the primary users also increases with the increase in SNR. For this reason, the average data rate of cognitive nodes is introduced.

This can be written as

$$(\rho) = \frac{\sum_{i=1}^{M} Xi}{M} \quad (6)$$

If available frequency slots can offer different bandwidths. That show the random channel assignment result in large difference in data rates between cognitive nodes, which as will be shown later results in some throughput degradation. To overcome this problem, a learning based channel selection algorithm for cognitive nodes produced. And this algorithm reduces the number of channel switching and give an equal utility to all cognitive users. Cognitive nodes then record the utility of the channels for a certain amount of time and use these utilities to compute the future channel selection probability.

V. Simulation Result

All nodes are equipped with four antennas (4 × 4 MIMO). The ad-hoc network contains 40 cognitive sources-destination pairs and consider cognitive nodes with perfect channel state information (CSI). Assume nodes use primary users pilot symbols to estimate the CSI of 'primary-to-cognitive' channels. Assume there exists a line-of-sight (LOS) component in the wireless link between the cognitive source and destination pairs. At this point, we consider nodes experience flat fading in all frequency channels. To build an above consideration MATLAB simulation tool is used.

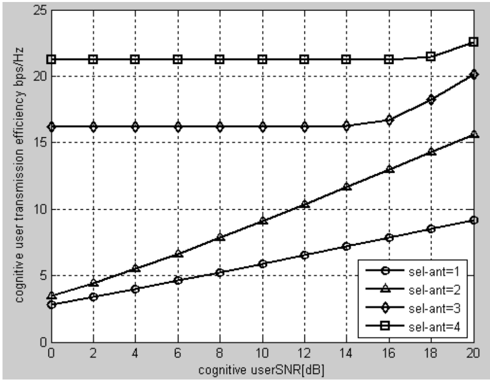

Fig.2. Transmission efficiency for cognitive nodes with different antenna selection algorithms

The main purpose of antenna selection techniques can be used to employ a smaller number of RF modules than the number of transmit antennas. so the end-to-end configuration of the antenna selection in which only K RF modules are used to support NT transmit antennas (K < NT). Since *K* antennas are used among *NT* transmit antennas. A set of *K* transmits antennas must be selected out of *NT* transmit antennas so as to maximize the channel capacity. In order to maximize the system capacity, one must choose the antenna with the highest capacity, Figure 2 shows the channel capacity with antenna selection for $NT = 4$ and $NR = 4$ as the number of the selected antennas varies by $K = 1; 2; 3; 4$. It is clear that the channel capacity increases in proportion to the number of the selected antennas.

V. Proposed Model

MIMO-based communications systems have great potential to improve network capacity for wireless ad hoc networks. Due to unique physical layer characteristics associated with MIMO, network performance is tightly coupled with mechanisms at physical, link, and routing layers. So far, research on MIMO-based wireless ad hoc networks is still in its infancy and few results are available. So resource allocation at each node and multi hop/multipath routing in a MIMO-based wireless Ad Hoc network is needed. Resource allocation is important to increase the end-to-end capacity. The use of combined antenna selection and channel assignment algorithm to increase the transmission efficiency and data rate is achieved. By using above mentioned methods optimal resource allocation for cognitive MIMO ad hoc network will achieve with the use of convergence distributed algorithm. Distributed algorithm is very suitable for MIMO ad hoc network because it is not a centralized authority. Ad hoc network does not have a base station so every node move to anywhere and nodes have self configuring capability.

With previous methods transmission efficiency and data rate is achieved by allocating equal power and uniform interference to all cognitive users. In proposing system we will allocate different power and different interference level to all cognitive users and select an antenna depends on power and minimum interference level from all possible combinations of antennas. After selecting an antenna, channels allocated to cognitive users to achieve maximum transmission efficiency and data rate than previous methods. In Cognitive Radios Secondary users opportunistically utilize the spectrum band of primary users without producing interference in primary users. For that opportunistic access of spectrum cognitive radios need perfect time slots .By using above mentioned algorithms resources allocated to cognitive MIMO ad hoc network by using convergence distributed algorithms.

VI. Convergence Distributed Algorithm

In wireless data networks, in which each node has a fixed set of resources (power and time slot fractions are normally node-level fixed resource) to be allocated to its incoming and outgoing links. Additionally, in node based wireless data networks, link capacity increasing function of resources allocated to it. So distributed algorithm for an individual node to allocate resources to its incoming and outgoing links and establish routing tables to minimize global cost Because the proposed distributed protocols require very limited cooperation among the participating network elements, they are particularly applicable to ad hoc cognitive networks, where centralized processing and control are certainly inaccessible. The algorithm is applied independently at each node: it iteratively updates the local resource allocation based on link data rates, and then updates the routing table based on information communicated between neighbour nodes about the marginal global cost to each destination. The marginal global cost is computed through the sensitivity analysis of the node cost with respect to the link data rates.

VI. Conclusion

Transmission efficiency is achieved by using an antenna selection algorithm at the same time interference on primary users also increased. To avoid the interference on primary users, the channel assignment algorithm is proposed; by using this algorithm data rate is achieved. Furthermore using above mentioned algorithm, resource allocation for cognitive MIMO ad hoc network will achieve using convergence distributed algorithms.

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