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A REVIEW ON MIMO SYSTEM USING COGNITIVE RADIO BASE STATION

by

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ABSTRACT

With the speedy development of wireless communication, the confliction between the scarce frequency resources and therefore the low spectral potency caused by the stationary spectrum sharing ways seriously restricts the evolution of the longer term mobile communication. For this purpose, psychological feature radio (CR) emerges collectively of the foremost promising inventions which may overcome the spectrum shortage. Because the key technology and main objective of CR, spectrum sharing will fill use of the restricted spectrum, alleviate the scarceness of frequency resources and improve the system utilities, playing thereby a vital role in up the system performance of psychological feature radio networks (CRNs).This paper surveys techniques and benefits of MIMO in the spectrum sharing in CRNs is mentioned in terms of the sharing method, thought sharing technologies and spectrum sharing models. Particularly, comparisons of various spectrum sharing ways, furthermore as that of various spectrum sensing schemes in sharing procedure. This survey report consolidates the various schemes proposed and demonstrated on CR network with diversity scheme is presented.

Keywords: Cognitive radio, spectrum underlay, user selection, MIMO broadcast channel.

INTRODUCTION

With growing demands for the amount of data transferred in tactical wireless networks, spectrum shortage problems become more imminent. Mechanisms are needed to avoid interference, improve system-wide spectral efficiency and allow more flexible spectrum resource utilization. Cognitive Radio (CR) is widely considered as a promising technology for providing the mechanisms to solve the spectrum resource challenge on the modern battlefield, caused by the current inflexible spectrum allocation policy[1].

Tactical communications networks are operated in a dynamically changing environment, where interference and sudden changes in the network configuration and radio parameters take place. CRs, which have environment sensingvand transmission adaptation capabilities, can address the dynamic nature of the network, offering new possibilities to enhance the performance of a modern tactical communication system [1]. CR communications platforms may be ideal candidates for future tactical networks.

Many nations and organizations have put forward a roadmap for applying Cognitive Radio Networks (CRN) to tactical communications. Some Canadian defence R&D programs exist in this area; however, to date we have not documented our perspectives and plans for future research. We attempt to address this gap[2].

COGNITIVE RADIO AND DYNAMIC SPECTRUM ACCESS (DSA)

DSA is the real-time adjustment of spectrum utilization in response to changing circumstances and objectives [9]. In particular, DSA allows a group of radios to share spectrum, as a radio may locate

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vacant frequency bands and occupy them for the duration of a transmission, then release the spectrum resource. When the available spectrum is already licensed for use by a particular set of radios, DSA allows unlicensed (secondary) users to exploit the spectrum in an opportunistic manner, under the condition that the secondary users vacate the spectrum within a predetermined time if the primary user needs it.

A cognitive radio may or may not be capable of DSA. The sufficient aspects for cognitive radio are the context-awareness and decision-making, not a particular algorithm, such as fixed vs. dynamic spectrum access. Conversely, a radio capable of DSA may or may not be cognitive.

Insofar as spectrum access is a fundamental piece in a radio’s functioning, a cognitive radio will be more capable if it performs DSA. Thus DSA is viewed as a key component of CR. One issue of concern for military radio users is the ability to guarantee service in a DSA environment where spectrum access is not predictable.

OODA LOOP FOR COGNITIVE RADIO

A useful way to think about the cognition cycle for cognitive radio is to view it as an OODA loop (Figure 1.) [1-2]. The OODA loop refers to the decision cycle of Observe, Orient, Decide, and Act, and is widely used in combat operations process , often at the strategic level in military operations. Cognitive radio has the ability to sense the environment in which it is operating, measure the performance it is achieving, and assess whether it is able to perform additional tasks to better accomplish the user’s or the network manager’s objectives. To use the OODA loop terminology, we refer to the ability of the radio to:

- Observe the electromagnetic environment,
- Orient to the user’s objectives, by learning and organizing what has been learnt (planning). Note that the learning could be an evolving process with the CR, which can consider the impact of the previous actions and experiences,
- Decide whether there is an adaption that is possible / practical to enhance performance, and then,
- Act on the decision.

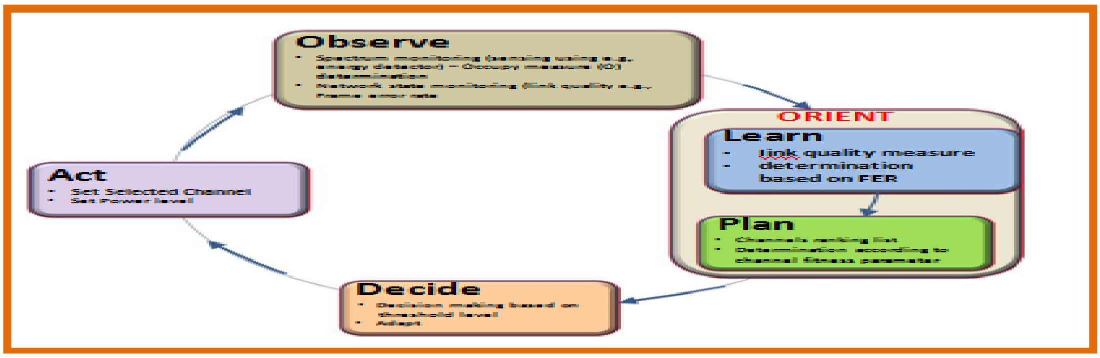

Figure 1: Simplified cognitive cycle - OODA loop[2]

LITERATURE SURVEY

Karama Hamdi et.al. [2009] have studied cognitive users whose channels are nearly orthogonal to the primary user channel are pre-selected so as to minimize the interference to the primary user. Then, *M* best cognitive users, whose channels are mutually near orthogonal to each other, are scheduled from the preselected cognitive users. A lower bound of the proposed cognitive system capacity is derived. It is then shown that opportunistic spectrum sharing approach can be extended to the multiple input/multiple-output (MIMO) case, where a receive antenna selection is utilized in order to further reduce the computational and feedback complexity. Simulation results show that our proposed approach is able to achieve a high sum-rate throughput, with affordable complexity, when considering either single or multiple antennas at the cognitive mobile terminals. [1]

Lu Yang et.al. [2014] have studied multiuser diversity of uplink MIMO cognitive radio network and proposes a two-stage opportunistic user scheduling scheme. In the first stage, a cognitive beam forming design is proposed to ensure the interference caused by secondary signals is canceled or minimized on the spatial dimensions occupied by primary MIMO system. Then, some secondary users that cause minimal interference leakage at primary system are pre-selected as candidate users. In the second stage, some candidate users that produce maximum sum secondary rate are further selected for uplink scheduling. The proposed scheme enables the secondary link to take advantage of multiuser diversity while ensuring that the interference on primary link is within a certain threshold. Analytical results show that the sum rate of secondary uplink scales as *Ns* log log*K*for *K* secondary users and *Ns* antennas on secondary receiver for very large *K*.[2].

WenhaoXiong et.al. [2015] have studied user selection strategies for downlink of multiple input and multiple output (MIMO) cognitive radio (CR) network. Underlay CR secondary users (SUs) are selected by cognitive base station (CBS) to share sub channel with primary users (PUs). It is assumed that the cross interference channel from cognitive radio base station to PUs is not known. CBS select underlay SUs based on the knowledge of SUs transmission channels in order to reduce the interference from base station to PUs. We propose and evaluate user selection schemes with low computational complexity and best-effort interference mitigation to PUs.[3].

Duoying Zhang et.al. [2016] have studied the spectrum sharing multiple-input multiple-output (MIMO) cognitive interference channel, in which multiple primary users (PUs) coexist with multiple secondary users (SUs). Interference alignment (IA) approach is introduced that guarantees that secondary users access the licensed spectrum without causing harmful interference to the PUs. A rank constrained beam forming design is proposed where the rank of the interferences and the desired signals is concerned. The standard interferences metric for the primary link, that is, *interference temperature*, is investigated and redesigned. The work provides a further improvement that optimizes the dimension of the interferences in the cognitive interference channel, instead of the power of the interference leakage. Due to the non convexity of the rank, the developed optimization problems are further approximated as convex form and are solved via choosing the transmitter precoder and receiver subspace iteratively. Numerical results show that the proposed designs can improve the achievable degree of freedom (DoF) of the primary links and provide the considerable sum rate for both secondary and primary transmissions under the rank constraints. [4].

WenhaoXionget.al. [2016]have studied user selection strategies for a multiple-input multiple-output (MIMO) cognitive radio (CR) downlink network, where the r-antenna underlay CR secondary users (SUs) coexist with a primary user (PU), and all terminals are equipped with multiple antennas. Two main scenarios are considered: (1) the t-antenna cognitive base station (CBS) has perfect or partial channel state information at the transmitter (CSIT) from the CBS to the PU receiver (RX), and (2) the CBS has absolutely no PU CSIT. For these scenarios, we propose and evaluate multiple SU selection schemes that are applicable to both best-effort PU interference mitigation and hard interference temperature constraints. The computational complexity of the proposed schemes can be significantly smaller than that of an exhaustive search with negligible performance degradation. For the selection of C SUs out of K candidates, They proposed sliding window scheme for example is of complexity O(Krt2), whereas an exhaustive search is of the order of O(K_CC4r3). When t and r are of the same order, the computational complexity of the proposed scheme can be K_C C4=K times smaller. Mathematical complexity analysis and numerical simulations are provided to show the advantage of our schemes.[5]

COGNITIVE RADIO TECHNIQUE IN WIRELESS NETWORK

Early idea of Cognitive Radio (CR) is proposed by Mitola and Maguire [29]. In [29], the software radios are defined as the platforms for multiband multimode personal communication systems. Cognitive radio extends the software radio with radio-domain model-based reasoning about the set of RF bands, air interfaces, protocols, and spatial and temporal patterns that moderate the use of the radio spectrum. Cognitive radio enhances the flexibility of personal services through a Radio

Knowledge Representation Language (RKRL). Since then, the idea of cognitive radio has evoked much enthusiasm.

There is no agreement on formal definition of Cognitive Radio because meaning of the CR varies in different contexts [30]. In essence, common feature of the cognitive radio is the awareness of its environment. Following is the definition of the cognitive radio extracted from Federal Communications Commission (FCC): "A cognitive radio (CR) is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. This interaction may involve active negotiation or communications with other spectrum users and/or passive sensing and decision making within the radio." [30]. Therefore, the long term vision of cognitive radio technology is that the user terminals would automatically make use of underutilized spectrum across a broad frequency range.

A typical cognitive radio cycle [29] is illustrated in Figure 2. The cognitive radio cycle involves three main steps: spectrum sensing, spectrum analysis and spectrum decision. The spectrum sensing stage involves examining the radio environment and obtaining the spectrum holes information. Then in the spectrum analysis stage, the characteristics of the spectrum holes are determined, the channel state information is estimated and the channel capacity is predicted for the transmitter to use. In the spectrum decision step, the transmit strategy is decided, such as transmit power control, data rate, transmission mode and dynamic spectrum management.

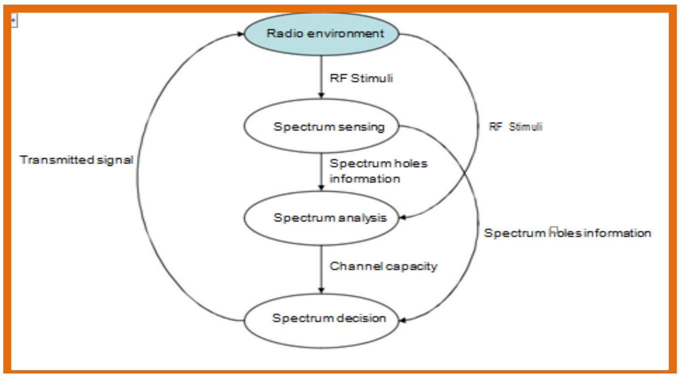

Figure 2. Cognitive radio cycle.[22]

In early research on cognitive radio [31], dynamic spectrum access (DSA) networks as well as cognitive networks is predicted as the next generation wireless communication networks in view of solving scarcity of spectrum and utilizing the unused band. The heterogeneous wireless network architectures are designed for the future networks to provide high bandwidth to mobile users. It is considered that the key technology of the next generation networks is the cognitive radio which enables the unlicensed (secondary) users to use and share the spectrum with the licensed (primary) users in an opportunistic manner.

With the research development on cognitive radio, there are other ways to utilize the licensed band where both licensed and unlicensed users operate on the same band when the interference constraint to the licensed user is satisfied. In general, there are three main cognitive radio network paradigms [31]: underlay, overlay, and interweave described as follows.

INFRASTRUCTURE-BASED ARCHITECTURE

In this architecture, illustrated in Figure 2, the secondary user network is infrastructure-based, which means that the network consists of cells; each cell is managed through a central Base Station (BS) or Access Point (AP) which controls the medium access and the secondary mobile station (MS) . The MSs are synchronized with their BS. The observations and analysis performed by each MS feeds the BS, so that it can make decisions such as how to avoid interfering with primary users. According to the decision, each MS reconfigures its communication parameters.

Each MS connects to a BS/AP with a direct link. MSs in the transmission range of the same BS/AP (one cell) communicate with each other through the BS/AP. Communications between different cells are routed through backbone/core networks. A good example of a cognitive, infrastructure-based network is that of the IEEE 802.22 standard [24] which follows a cellular architecture.

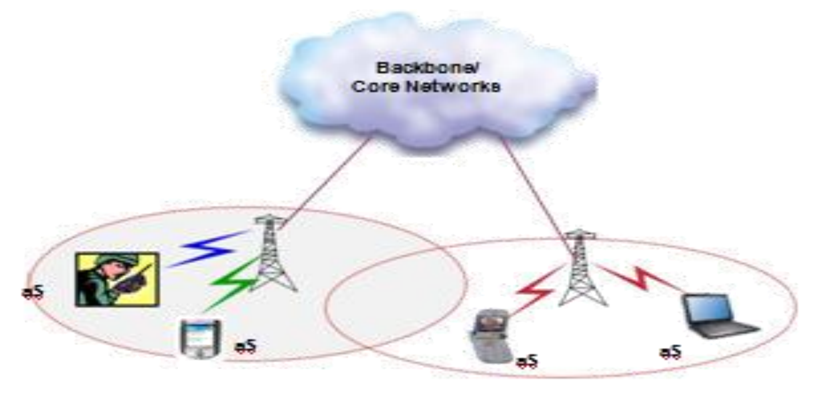

Figure 3. Infrastructure-based network architecture[22]

Table 1: Aspects of infrastructure-based network architecture for CRNs.

Pros	Central control, central decision making
Cons	Single point of failure, if the BS is down, may take too long time to for MS to communicate. Time consuming to set up the infrastructure.
Possible Remedies	Redundant (back-up) base station
Comments	Suitable for stable secondary spectrum, e.g., IEEE 802.22 is expected to provide broadband wireless access over unused TV bands in rural areas.

MIMO

In radio communications, MIMO refers to the technology where multiple antennas are employed at both the transmitter and receiver sides to improve performance. MIMO technology offers significant increases in data throughput and link range without additional bandwidth or transmit power [10,11]. That is MIMO systems are known to provide higher spectral efficiency and better link quality. Because of these properties, MIMO is an important part of modern wireless communication standards [43, 44] such as IEEE 802.11n (Wifi), 4G, 3GPP Long Term Evolution, WiMAX and HSPA+.

MIMO techniques can be sub-divided into three main categories, pre-coding, spatial multiplexing, and diversity.

➢ Pre-coding: In (single-layer) beam forming (Fig. 3.4), the same signal is emitted from each of the transmit antennas with appropriate phase (and sometimes gain) weighting such that the signal power is maximized at the receiver input. The benefits of beamforming are to increase the received signal gain, by making signals emitted from different antennas add up constructively, and to reduce the multi path fading effect. In the absence of scattering, beamforming results in a well defined directional pattern, but in typical cellular conventional beams are not a good analogy. When the receiver has multiple antennas, the transmit beamforming cannot simultaneously maximize the signal level at all of the receive antennas, and pre-coding is used (Fig. 2.7) [11]. This spatial processing occurs at the transmitter, and requires knowledge of channel state information (CSI) at the transmitter.

➢ Spatial multiplexing In spatial multiplexing, a high rate signal is split into mul-tiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals arrive at the receiver an-tenna array with sufficiently different spatial signatures, the receiver can separate these streams into parallel channels (Fig. 2.8 [11]). Spatial multiplexing is used to support higher data rate applications. The maximum number of spatial streams is limited by the lesser in the number of antennas at the transmitter or receiver [11].

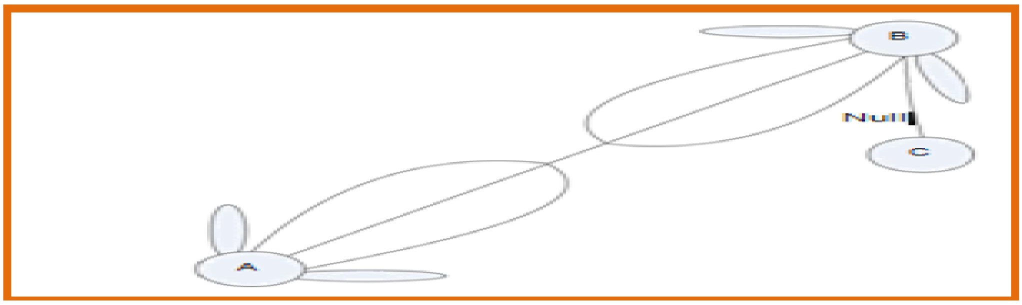

Figure 4: Beamforming to improve the signal-to-noise ratio and to reduce interference [11].

PROBLEM FORMULATION

In the research work abnormal behaviour detection I have studied the different problems that are given below:

- The first problem is the optimization problem that is occurred during the transmission of data.
- The second problem is the complexity problem on multiple cognitive base station and PU.
- Other problems such as to interference channel scenario with multiple CBSs and PUs are of interest.
- There is primary and secondary cognitive base station and User problem.
- Other problem is the transmission rank problem on multiple users.

COGNITIVE RADIO FOR DYNAMIC SPECTRUM MANAGEMENT (CORASMA)

The Cognitive Radio for dynamic Spectrum Management (CORASMA) program [14] is a joint program of research of seven European countries, and managed by the European Defence Agency (EDA). CORASMA is intended as a flexible framework for cognitive radio solutions being developed by a collection of nations. As such, there needed to be a common base of functionality upon which the cognitive radio components were built. Also, these solutions needed to be tested and evaluated in a common environment with enough detail to realistically model the costs and benefits of the cognitive solutions, for example in terms of the extra signaling required, and the sensitivity to a loss of signaling. These needs were met by :-

1) the basic waveform, which is a non-cognitive, reference waveform for comparison with the cognitive solutions, and
2) the HiFi simulator, which represents in some detail the behaviour of the first three layers of the OSI protocol stack, the physical layer (layer 1) through the network layer (layer 3).
The basic waveform, or common base of functionality which was the starting point for the cognitive solutions, is a clustered ad-hoc network. As there was interest from each of the

participating nations in the problem of dynamic frequency allocation (DFA), a basic DFA algorithm was implemented in the basic waveform for comparison against the cognitive solutions. The basic waveform supports a multiple -channel clustered ad-hoc network; each cluster is managed by a cluster head. The cluster head must choose the transmit channel in which its cluster must operate, and the power level at which all radio nodes inside the cluster must transmit. The adaptive algorithm which controls this is called Greedy-based Dynamic Channel Assignment (GBDCA) [14, 15]. The GBDCA algorithm assigns channels with a compact pattern for spatial re-use, but has the drawback that it is not based upon interference measurements.

One of the cognitive solutions studied was a learning algorithm for power and frequency allocation in clustered ad-hoc networks [16]. The learning algorithm finds a solution to the optimization problem wherein the cluster heads select cluster frequency channels and transmit powers that minimize the total transmit power of all the clusters. The cluster heads have available information acquired through sensing, and cooperation with other nodes within their cluster. The authors suggest a game theory based solution to the frequency and power assignment problem, based upon trial and error, which consists of a state machine implemented by each player in the game. The players are the cluster heads, and the actions in the game are the set of potential powers and frequencies. A per-player utility function was proposed which evaluates how well the constraints have been satisfied. The original trial and error algorithm was unstable, and the authors have proposed an enhanced version which avoids the problem of repeated channel switching. The algorithm was tested under some fixed and mobile cluster scenarios. The CORASMA HiFi simulator was used to analyze the performance of the algorithm at various layers, such as throughput at the MAC layer and IP layer, which compared favorably with respect to the basic waveform.

CONCLUSION

In a cognitive radio network, the common control channels of multiple secondary users are essential for effective network operations. In this the problem of assigning common control channels is modeled as a potential game. Each secondary user is a game player and its game strategy is to choose an available frequency channel as the control channel. The utility of each secondary user reflects its common interest and selfish benefit. A potential function is designed onto which the incentives of all the secondary users can be mapped. According to the characteristics of potential games, sequential and asynchronous strategy updates are developed that use the best response dynamic to reach a Nash equilibrium. Moreover, simulated annealing is adopted in the updating process in order to escape a Nash equilibrium which is not Pareto efficient. The proposed scheme has a better chance to obtain the optimal assignment of the common control channel within finite time.

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