**CHAPTER 2**

**LITERATURE SURVEY**

**2.1 Interference Efficiency: A New Metric to Analyze the Performance of**

**Cognitive Radio Networks**

**Author:** Mohammad Robat Mili and Leila Musavian.

A framework to maximize the interference efficiency of a CRN with multiple Secondary users while satisfying target constraints on the average interference power, total transmit power, and minimum ergodic rate for the SUs. In doing so, we formulate a multi objective optimization problem that aims to maximize ergodic sum rate of SUs and to minimize average interference power on the primary receiver. We solve the MOP by first transferring it into a single objective problem using a weighted sum method. Considering different scenarios in terms of channel state information availability to the SU transmitter, we investigate the effect of CSI on the performance and power allocation of the SUs. When full CSI is available, the formulated SOP is non convex and is solved using augmented penalty method. When only statistical information of the channel gains between the SU transmitters and the PU receiver is available, the SOP is solved using Lagrangian optimization. Numerical results are conducted to corroborate our theoretical analysis.

**DRAWBACKS**

* It is in the simulation only there is no working model.

**2.2** **Route Selection for Multi-hop Cognitive Radio Networks using**

**Reinforcement Learning: An Experimental study**

**Author:** Aqeel Raza Syed, Kok-Lim Alvin Yau1, Junaid Qadir, Hafizal

Mohamad, Nordin Ramli, Sye Loong keoh.

Cognitive radio enables unlicensed users to explore and exploit underutilized licensed channels. While multi-hop CR network has drawn significant research interest in recent years, majority work has been validated through simulation. A key challenge in multi-hop CR network is to select a route with high quality of service and lesser number of route breakages. In this article, we propose three route selection schemes to enhance the network performance of CR networks, and investigate them using a real test bed environment, which consists of universal software radio peripheral and GNU radio units. Two schemes are based on reinforcement learning , while a scheme is based on spectrum leasing .

RL is an artificial intelligence technique, whereas SL is a new paradigm that allows communication between licensed and unlicensed users in CR networks. We compare the route selection schemes with an existing route selection scheme in the literature, called highest-channel, in a multi-hop CR network. With respect to the QoS parameters the experimental results show that RL approaches achieve better performance in comparison with the HC approach, and also achieve close to the performance achieved by the SL approach.

**DRAWBACKS:**

* Processing delay can be affect the network layer performance.

**2.3 Channel-Adaptive Spectrum Detection and Sensing Strategy for Cognitive**

**Radio Ad-Hoc Networks**

**Author**: Yuan Lu, Alexandra Duel-Hallen.

Cognitive Radio networks, multiple secondary network users attempt to communicate over wide potential spectrum without causing significant interference to the Primary Users. A spectrum sensing algorithm is a critical component of any sensing strategy. Performance of conventional spectrum detection methods is severely limited when the average SNR of the fading channel between the PU transmitter and the SU sensor is low. Advanced detection techniques only partially remedy this problem. Cooperative sensing can combat channel fading, but requires a large number of cooperating SUs and diversity branches. A key limitation of conventional approaches is that the sensing threshold is determined from the miss detection rate averaged over the fading distribution.

In this paper, the threshold is adapted to the instantaneous PU-to-SU Channel State Information under the prescribed collision probability constraint, and a novel sensing strategy design is proposed for an overlay CR ad hoc network where the instantaneous false alarm probability is incorporated into the belief update and the reward computation. It is demonstrated that the proposed sensing approach improves SU confidence, randomizes sensing decisions, and significantly improves SU network throughput while satisfying the collision probability constraint to the PUs in the low average PU-to-SU SNR region. Moreover, the proposed adaptive sensing strategy is robust to mismatched and correlated fading CSI. In addition, threshold adaptation at a single SU sensor outperforms conventional cooperative sensing unless the number of cooperating SUs is very large. Finally, joint adaptation to PU channel gain and SU link CSI is proposed to further improve CR throughput and reduce SU collisions.

**DRAWBACKS:**

* The signal from the primary user transmitter to the secondary user detector is weak.
* Conventional cooperative sensing is not feasible for small networks. E.g. rural areas.

**2.4** **Spectrum Map Empowered Opportunistic Routing for Cognitive Radio Ad**

**Hoc Networks**

**Author:** Shih-Chun Linand Kwang-Cheng Chen.

Cognitive radio emerges as a key technology to enhance spectrum efficiency by creating opportunistic transmission links. Supporting the routing function on top of opportunistic links is a must to transport packets in a cognitive radio ad hoc network consisting of cooperative relay multi-radio systems. However, there lacks thorough understanding of these highly dynamic opportunistic links and a reliable end-to-end transportation mechanism over the network. Aspiring to meet this need, with innovative establishment of the spectrum map from local sensing information, we first provide mathematical analysis to deal with transmission delay over such opportunistic links. Benefited from the theoretical derivations, we then propose.

Spectrum map empowered opportunistic routing protocols for regular and large-scaled CRAHNs with wireless fading channels, employing a cooperative networking scheme to enable multipath transmissions. Simulations confirm that our solutions enjoy significant reduction on end-to-end delay and achieve dependable communications for CRAHNs, without commonly needed feedback information from nodes in CRAHN to significantly save the communication overhead at the same time.

**DRAWBACK:**

* Powercontrol produces the reciprocal interference.

**2.5** **Spectrum map aided multi-channel multi-hop routing in distributed**

**cognitive radio networks**

**Author:** Saptarshi Debroy and Mainak Chatterjee

A spectrum map aided routing protocol for a distributed cognitive radio network. We assume the presence of dedicated sensors that capture the spatio-temporal spectrum usage statistics to create the radio environment map. We exploit the map to find not only the best hops along a route but also the best available channel in terms of the expected performance. Through the use of edge nodes, which lie in the intersection of more than one sensors’ domain, inter-domain routing is facilitated.

The selection of each hop, the channel to be used per hop, and the transmitting power to be used considers i) protection of primary receivers, and ii) maximization of desired performance metric. In this context, we propose a novel power control mechanism that computes just enough power to maintain the desired signal-to-noise ratio for secondary communication but at the same time protects the primary receivers in the vicinity. We analyze and compute the probability of network connectivity by finding the minimum spanning tree of the graph formed by the over-lapping domains. Through simulations, we show how the proposed routing scheme

works in terms of route capacity, connectivity of the network, reachability among the nodes, and number of primary receivers protected.

**DRAWBACK**:

* A over-conservative primary contour protection scheme decreases the achievable secondary throughput.

**2.6** **Spectrum Assignment in Cognitive Radio Networks: A Comprehensive**

**Survey**

**Author**:Elias Z. Tragos, Sherali Zeadally, Alexandros G. Fragkiadakis and

Vasilios A. Siris

The fixed spectrum allocation of governmental agencies results in unused portions of spectrum, which are called spectrum holes. CR technology overcomes this issue, allowing devices to sense the spectrum for unused portions and use the most suitable ones, according to some pre-defined criteria. Spectrum assignment is a key mechanism that limits the interference between CR devices and licensed users, enabling a more efficient usage of the wireless spectrum. Interference is a key factor that limits the performance in wireless networks.

The scope of this work is to give an overview of the problem of spectrum assignment in cognitive radio networks, presenting the state-of-the-art proposals that have appeared in the literature, analyzing the criteria for selecting the most suitable portion of the spectrum and showing the most common approaches and techniques used to solve the spectrum assignment problem CR technology enables the reuse of the available spectrum resources. The basic limiting factor for spectrum reuse is interference, which is caused by the environment.

**DRAWBACK**:

* Interference is a key factor that can lead to reduced capacity because it reduces the achievable transmission rate .

**2.7 Channel-Aware Spectrum Sensing and Access for Mobile Cognitive Radio**

**Ad Hoc Networks**

**Author:**Elias Z. Tragos, Sherali Zeadally, Alexandros G. Fragkiadakis and

Vasilios A. Siris

Hardware-constrained cognitive radio ad hoc networks, secondary users with limited sensing capabilities strive to discover and share available spectrum resources without impairing primary user transmission. Sensing strategy design objectives include high CR network throughput, resolved SU competition, distributed implementation, and reliable performance under node mobility. However, these objectives have not been realized by previously investigated sensing strategies. A novel sensing strategy is analyzed where the reward is adapted to the SU link channel state information prior to sensing, thus randomizing sensing decisions and boosting the network throughput. Moreover, CSI-aided sensing is combined with a novel first-come-first-served medium access control scheme that resolves SU competition prior to sensing. Finally, a pilot-based CSI prediction method is developed to enable the proposed CSI-aided sensing strategies for mobile scenarios. Analytical and numerical results demonstrate that the proposed sensing and access methods significantly outperform non adaptive sensing strategies for practical mobile CR scenarios with CSI mismatch and pilot overhead.

**DRAWBACKS**:

* The cognitive radio network , collision-avoidance medium access control scheme alone is not sufficient
* It results in poor spectrum utilization and low network throughput.

**2.8 Network Selection in Cognitive Heterogeneous Networks Using Stochastic**

**Learning**

**Author:**Li-Chuan Tseng, Feng-Tsun Chien, Daqiang Zhang, Ronald Y. Chang,

Wei-Ho Chung, and ChingYao Huang

The rapid increase of wireless applications has rendered the single-network wireless system insufficient in meeting the traffic demands due to the inefficient spectrum utilization. A heterogeneous network, where multiple radio access technologies coexist, has emerged as a viable alternative solution. In a heterogeneous network, users are allowed to access the spectrum licensed to different spectrum owners, which are called service providers, and as a result a more efficient spectrum utilization can potentially be achieved. In heterogeneous networks, one significant issue is the network selection where each user determines which network to associate with. Early works on heterogeneous networks primarily focused on the study of vertical handover procedures for mobile devices . The handover decision is made independently at each user according to the user’s received signal strength from different SPs and the predicted trajectory of movement. However, even a user is associated with an SP of good RSS, its achievable throughput may degrade when the total number of users served by the same SP increases.

**DRAWBACK:**

* Through put is very low and performance is very poor.

**2.9 Distributed Spectrum Sensing in Cognitive Radio Networks with Fairness**

**Consideration: Efficiency of Correlated Equilibrium**

**Author:**Sabita Maharjan, Yan Zhang, Chau Yuen and Stein Gjessing.

Cooperative spectrum sensing improves the reliability of detection. However, if the secondary users are selfish, they may not collaborate for sensing. In order to address this problem, Medium Access Control protocols can be designed to enforce cooperation among secondary users for spectrum sensing. In this paper, we investigate this problem using game theoretical framework. We introduce the concept of correlated equilibrium for the cooperative spectrum sensing game among non-cooperative secondary users and formulate the optimization problem for the case where secondary users have heterogeneous traffic dynamics. We show that the correlated equilibrium improves the system utility, as compared to the mixed strategy Nash equilibrium. While maximizing system payoff is important, fairness is also equally important in systems with dissimilar users. In order to address fairness issue, we propose a new fair social welfare correlated equilibrium, which maximizes

the system utility and ensures that the less well-off users do not starve. We employ a no-regret learning algorithm for distributed implementation of the correlated equilibrium. A neighborhood based learning algorithm and show that it achieves better performance than the no-regret algorithm.

**DRAWBACKS**:

* Secondary users are selfish , they may be collaborate for sensing.
* Game theory non cooperative the secondary user.

**2.10** **Dynamic Spectrum Leasing in Cognitive Radio Networks via Primary-**

**Secondary User Power Control Games**

**Author:**Sudharman K. Jayaweera, and Tianming Li

Hierarchical dynamicspectrum access has received the most attention in recent years as the solution for better spectrum utilization. In this paper, on the other hand, we develop a framework for dynamic spectrum leasing. Power control in hierarchical DSA networks only involves that of controlling secondary user transmissions. Thus, in game theoretic formulations of power control in cognitive DSA networks only secondary users are considered as players of the game. In proposed dynamic spectrum leasing, on the other hand, the primary users are rewarded for allowing secondary users to operate in their licensed spectrum. Thus, in the proposed DSL networks the primary users have an incentive to allow secondary users to access the spectrum whenever possible to the maximum extent. We develop a game theoretic framework for such dynamic spectrum leasing in which primary users actively participate in a non-cooperative game with secondary users by selecting an interference cap on the total interference they willing to tolerate. We establish that the proposed primary-secondary user power control game has a unique Nash equilibrium. Performance of a DSL system based on the proposed game model is compared through simulations under different linear receivers at the

secondary base station.

**DRAWBACK**:

* When the primary user do not use their spectrum, Interference mainly placed on the secondary users