Channel and Rate Selection in Cognitive Radio Network

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Abstract— *Now a days with tremendous growth of wireless technology, spectrum resources become more and more scare. For improving quality of service (QoS) and capacity of network, it is necessary that available spectrum is utilized effectively. Cognitive radio is one of solution to meet this requirement by Spectrum reuse (Dynamic spectrum access). There are three distinct phase in cognitive radio networks (CRNs) that is spectrum sensing, channel selection and data transmission. Channel selection is one of the basic mechanisms that controls interference in a wireless network. As soon as licensed user came back, it vacant the band and hence improve spectrum efficiency. In this paper, different channel selection techniques at CRN terminals and optimization of average throughput maximization with objective to reliable performance is summarized which jointly address issues such as channel scheduling order, channel selection, no of reports transmitted by Secondary user(SU) and channel sensing order while estimating channel through wireless media. Also the different channel selection schemes are discussed in this literature. Channel and corresponding transmission rate selection for throughput maximization in CRNs.*

***Keywords*—Cognitive radio network ,Throughput maximization ,optimization,Channel selecion, Transmission rate,successful transmission Probability.**

1. Introduction

Due to wide growth of wireless communication technologies and services there is tremendous demand for radio spectrum resources. Compared to wired technology, wireless technology have limited spectrum and Number of users are increased day by day. The limitation of spectrum resources has caused a bottleneck in wireless communication development. To alleviate such limitation, spectrum resources need to be reused to enhance capacity of network. Most of radio spectrum has been managed by government agencies such as Federal communication commission (FCC).In conventional wireless communication systems, radio spectrum resources are usually governed by license holders (Primary users) which is not always used by them hence spectrum is underutilized. Cognitive radio is promising solution which allow opportunistically sharing of ideal spectrum (Spectrum Hole) with Unlicensed users to dynamically access the spectrum with no or minimal interference [1].

Cognitive Radio (CR) first proposed in [1] is an adaptive, intelligent radio and network technology that can automatically detect available channels in wireless spectrum and tune transmission parameters enabling better communications by enhancing data communication experience (throughput and reliability), exploiting spectrum holes.

The main functionality of Cognitive radio is depicted in Figure 1. In CRN, there are two types of users are available. Primary user (PU) that are authorized user which have licensed to use specific portion of spectrum. Second is Secondary users (SU) which are unlicensed one. They opportunistically try to access both licensed and unlicensed spectrum and are allowed to use licensed band if it is detected empty without causing interference for licensed Pus[3].

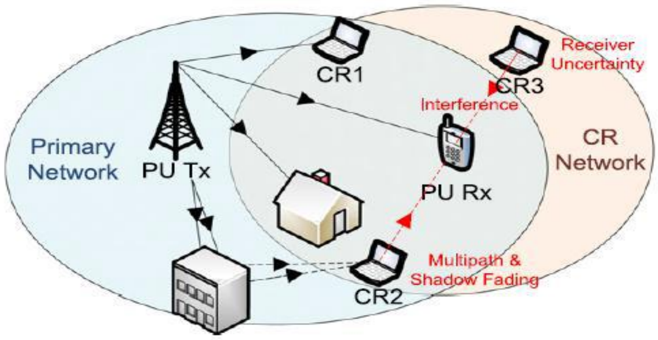

Figure 1.Basic Cognitive Cycle [3]

Cognitive Radio Functions:

- Spectrum Sensing: In order to avoid interference the spectrum holes (bands not being used by the PUs) need to be sensed. PU detection technique is the most efficient way in this respect. The spectrum sensing techniques are basically divided into three categories, which are transmitter detection, cooperative detection and interference based detection[11].

- Spectrum Management: There is a need to capture the best available spectrum to meet the user communication requirements. CRs should decide on the best spectrum band to meet quality of service requirements over all spectrum bands. The management function is classified as spectrum analysis and spectrum detection [11].

- Spectrum Mobility: It is the process where a CR user exchanges the frequency of operation. They target to use the spectrum in a dynamic manner by allowing the radio terminals to operate in the best available frequency band. The shift to a better spectrum must be seamless [11].

- Spectrum Sharing: It is of utmost importance to provide a fair spectrum scheduling policy. It is also one of the most important challenges in open spectrum usage. In the existing systems it corresponds to the existing MAC problems [11].

Among many areas of wireless systems that can be improved via CR, existing literature primary focuses on throughput maximization during channel and rate selection.

There are three basic types of channel selection algorithms which are used in CRNs. The first is fixed channel, second is hybrid channel and last one is dynamic channel.

Channel selection is the process of allocating available channels to radio interfaces on a node to enhance network capacity and reduce the interference.

As shown in Fig. 2, there are three basic types of channel allocation algorithms, fixed, hybrid and dynamic. Channel allocation schemes can be divided into,

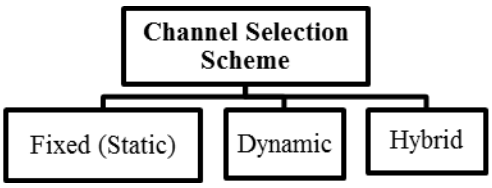

Figure 2 Classification of Channel Assignment [5]

The reminder of the paper is organized as follows: In section II, we present literature survey of existing approaches. In which we represent summary of different channel and rate selection techniques. In section III, we compare this algorithm based on techniques they are used, parameters which is to be considered, and channel being used. Finally we draw our conclusion in section IV.

2. Channel selection techniques

A. CRs Channel Assignment Algorithm

The algorithms are categorized based on the following characteristics: Coordination Mechanisms, Objectives, Solving Approaches, Network Types, and Number of Radios [5].

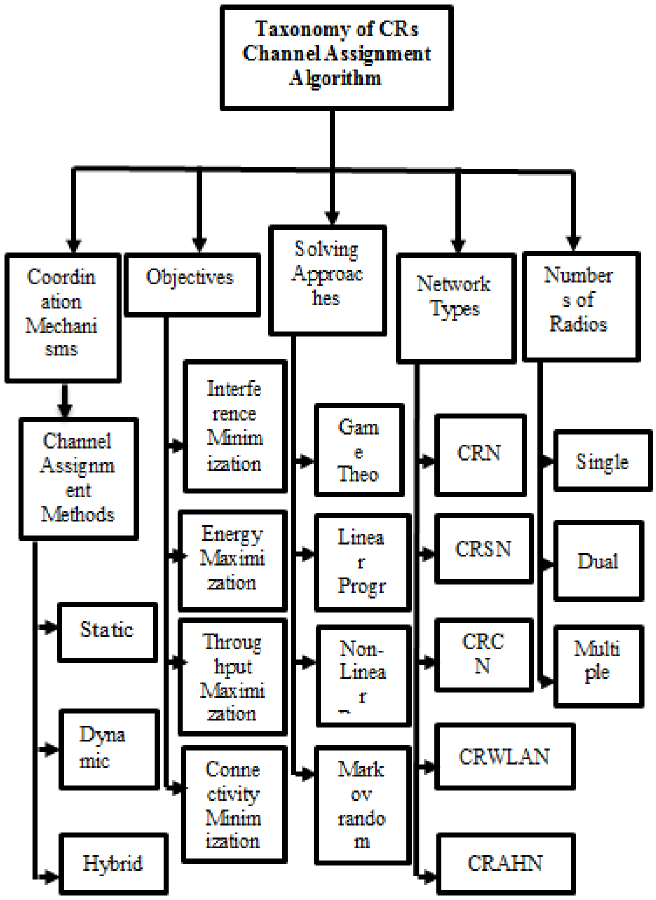

Figure 1 Thematic taxonomy of channel assignment algorithms [5].

B. Channel and Rate selection using Multiarm Bandits

In MAB problems, a decision maker sequentially selects an action (also called an "arm"), and observes the corresponding reward. Rewards of a given arm are random variables with unknown distribution. The objective is to design sequential action selection strategies that maximize the expected reward over a given time horizon. In Cognitive radio network, first, consider the systems exploiting channels known to be free from primary users. For the transmission of each packet, transmitters can select a coding rate from a finite predefined set and a channel from the set of available channels. The outcome of a packet transmission is random, and the probabilities of successfully transmitting a packet using the various (channel, rate) pairs are a priori unknown at the transmitter; they need to be learnt based on trial and error. These probabilities can vary significantly and randomly over time and across channels; they also strongly depend on the chosen coding rate [6].

Second is, formulate the design of the optimal sequential (channel, rate) selection algorithms as an online stochastic optimization problem. In this problem, the objective is to maximize the number of packets successfully sent over a finite time horizon [6].

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1) Example of Multiarm Bandits Problem [12]

An example: A gambler faces a row of slot machines and decides,

- which machines to play,
- how many times to play each machine
- in which order to play them

Goal: of the gambler is to maximize the sum of rewards earned through a sequence of lever pulls.

Figure 2 Row of slot machine [12]

2) Algorithm for Multi arm bandits

[1] For the i-th packet transmission on channel c at rate k, a binary random variable $X_{ck}(i)$ represents the success $X_{ck}(i) = 1$ or failure $X_{ck}(i) = 0$ of the transmission.

[2] $\mathbb{E}[X_{ck}(i)]$ refers to as the packet successful transmission probability on channel c at rate k (i.e., it is the packet reception rate).

[3] First assume that $X_{ck}(i), i = 1,2..$ are independent and identically distributed, and denote by θ_{ck} the success transmission probability on channel c at rate k: $\theta_{ck} = \mathbb{E}[X_{ck}]$ (1)

[4] Consider a rate adaption scheme $\pi \in \Pi$ that selects (channel, rate) pair $(c^{\pi}(t), k^{\pi}(t))$ for the t-th packet transmission. The number of packets $\gamma^{\pi}(t)$ that have been successfully sent under algorithm π up to time T is:

$$\gamma^{\pi}(t) = \sum_{c,k} \sum_{i=1}^{S_{ck}^{\pi}(T)} X_{ck}(i) \qquad (2)$$

Where, $S_{ck}^{\pi}(T)$ is the number of transmission attempts on channel c at rate k before time T.

[5] The $S_{ck}^{\pi}(T)$'s are random variables (since the rates selected under π depend on the past random successes and failures), satisfy the following constraint:

$$\sum_{c,k} S_{ck}^{\pi}(T) \times \frac{1}{r_k} \le T \qquad (3)$$

[6] Wald's lemma implies that the expected number of packets successfully sent up to time T is,

$$\mathbb{E}[\gamma^{\pi}(t)] = \sum_{c,k} \mathbb{E}[\sum_{i=1}^{S_{ck}^{\pi}(T)}]\theta_{ck} \qquad (4)$$

[7] Online Stochastic Optimization Problem,

$$max_{\pi \in \Pi} \sum_{c,k} \mathbb{E}[S_{ck}^{\pi}(T)]\theta_{ck} \qquad (5)$$

S.T

$$\sum_{c,k} S_{ck}^{\pi}(T) \times \frac{1}{r_k} \le T, \quad \forall c,k, S_{ck}^{\pi}(T) \in \mathbb{N} \qquad (6)$$

[8] online stochastic optimization problem can be divided into time slots written as:

$$max_{\pi \in \Pi} \sum_{c,k} \mathbb{E}[t_{ck}^{\pi}(T)] r_{k*}\theta_{ck} \qquad (7)$$

S.T.

$$\sum_{c,k} t_{ck}^{\pi}(T) \le T, \quad \forall c,k, t_{ck}^{\pi}(T) \in \mathbb{N} \qquad (8)$$

Where $t_{ck}^{\pi} = {S_{ck}^{\pi}}/{r_k}$ represents the amount of time (in slots) that the transmitter spends, before T, on sending packets on channel c at rate r_k.

[9] Find the throughput for given channel and rate pair,

$$\mu_{ck=r_k * \theta_{ck}} \qquad (9)$$

C. Channel Selection Based On Upper Confidence Bound (UCB) Algorithm

A secondary user gets the occupancy status X about the channel at each time $t = 1, \cdots, T$. X is the binary value that represents the channel occupancy: when the channel is not used by primary user, X is equal to one; otherwise zero. Based on the occupancy status, SU estimates the channel available probability $\bar{\mu}_m$ from the number of times m-th channel is sensed and that m-th channel is sensed idle as follows,

$$\bar{\mu}_m = \frac{N_m^I(t)}{N_m^S(t)} \qquad (10)$$

where $N_m^I(t)$ is the number of times m-th channel is sensed idle by t and $N_m^S(t)$ is that m-th channel is sensed. Secondary user selects the channel with the highest $\beta_{\bar{\mu}_m}$ UCB index given by

$$\beta_{\bar{\mu}_m} = \arg max_m \bar{\mu}_m + C\sqrt{\frac{logN^T(t)}{N_m^T(t)}}$$

where C is an exploration parameter. $N^T(t)$ and $N_m^T(t)$ is the number of times player transmitted successfully and that player transmitted successfully over channel m by time t, respectively. As the number of trials becomes larger, secondary user can get the correct channel occupancy.

3. Comparison

Table.1 Comparison of Techniques [6, 7, 8, 9, 10]

Method Used	Numbers of Radio used	Parameter Measured	Channel Type
Multi armed Bandit (MAB) Approach	Single	Throughput	Dynamic
Multi armed Bandit (MAB) Approach	Single & Multiple	Throughput	Fixed
Multi armed Bandit (MAB) Approach	Single	Capacity	Dynamic
Multi armed Bandit (MAB) Approach	Multiple	Throughput	Distributed

4. SUMMARY

In this Paper, the channel and rate selection issues in cognitive radio network are investigated. In cognitive radio network, the main issue is which channels should be selected first and how much resources are used for this channel (resources may be bandwidth, transmission rate, power etc.) Therefore channel selection is critical issue in CR which need to be considered. In particular different channel selection techniques are discussed in cognitive radio network while guaranteeing desirable performance of CRN. Different optimization problem with objective to maximize throughput of particularly SU while taking into account different constraints of existing algorithms. Also, comparison of algorithms by their optimization techniques parameters they taken into consideration, channel being used, and number of radio used they have used is given. Although there are still several outstanding issues that must be explored further related to cognitive radio network with existing approaches.

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