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Active Cognitive Radio for Wideband Spectrum Sensing

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***Abstract*—In this paper, active cognitive radio system is studied. This makes the perfect tradeoff between exploration and exploitation in optimum channels. This system is implemented by multi-armed bandit algorithm and it is essential one to achieve lossless data transmission even in fading channel**.

Keywords*—*Cognitiv Radio,POMDP,MEA,Multi Armed Bandit(MAB).

I. INTRODUCTION

Cognitive Radio (CR) is a exciting technology to avoid the spectrum scarcity problem. In wireless communication, energy consumption continues to grow rapidly along with applications for high data-rate transmission, leading to an increasing large gap between available battery sources and energy demands. Machine Learning (ML) plays essential role in spectrum sensing. Using the machine learning algorithm, system learns the environment and adopt to its parameter such as modulation, transmission power, code rate. System learns the radio environment from past status of channel and select the best channel as quick as possible in future. The focus of this paper is to implement the multi armed bandit algorithm which is one of the field of ML. There are different learning algorithm can be used in cognitive raadio systems such as genetic algotithm, Hidden Markov Model (HMM), Nural networks. Reinforcement learning divides the process as two phase which are exploration and exploitation. Detecting new optimum channel and transmission through that selected channel can be performed through exploration and exploitation respectively. Every learning algorithm takes an specific amount of time to get knowledge about radio environment. Multi-armed Bandit (MAB) algorithm is used for exploration and exploitation process. In wideband spectrum, there may be more number of channels to be idle. If the statistical information about channel status is known in advance, secondary user (SU) selects the best channel as soon as possible. If there is no information available for secondary user, learning process plays a vital role for obtain statistical information about the status of channel. In such situation, learning process requires some amount of energy. The energy loss in the learning process is referred as regret. The objective of this paper is to minimize the regret and maximize the throughput of data transmission. This can be obtained through limiting the energy for exploring the idle channel and allowing most of the energy for transmission purpose. This process leads to high throughput. So the scope of proposed paper is to improve the throughput by allowing optimal energy for exploration and exploitation.

II. ORGANIZATION

Contributions of the paper is organized as follows. Section III describes the related work and role of learning algorithm is provided in the section IV. System model is studied in section V. Correct policy and channel state information are explained in section VI and VII respectively. Active sensing and simulation results are described in the section VIII and IX respectively. Finally future work and conclusions are given by sections X and XI respectively.

III. RELATED WORK

The multi-arm bandit algorithm utilized in [2] for decentralized spectrum sensing. Multiarmed bandit senses the status of number of channel in each slots. Dynamic spectrum access deals problems such as whether to sense and where to sense with help of Partially Observable Markov Decision Process (POMDP) in [2]. Assuming that the spectrum occupancy state of each channel is independent from one time block to another, dynamic programming solutions for determining optimal sensing orders were provided for a single secondary user [3] and two secondary users [4]. In these papers, the secondary user not only senses a channel to decide whether it is idle but also checks the channel coefficient to decide the transmission rate. If the channel is sensed as idle but its quality is not satisfactory, the secondary user skips this channel and keeps sensing other channels.

IV. LEARNING ALGORITHMS

Generally three types of learning techniques such as reinforcement, supervised, and unsupervised learning are used in cognitive radio field. In order to maximize the throughput and avoid the interference, different learning algorithms can be used. Common goal of all learning algorithm is to maximize the channel capacity. Using the learning system, there is possible to estimate channel statistics and thereby we can select the optimum channel. This paper mainly focus the learning algorithm of multi-armed bandit. If channel found to be unoccupied and optimum SNR that channel is selected for transmission.

V. SYSTEM MODEL

The simple methods for spectrum sensing is hypothesis technique. One is null hypothesis and other one is alternative hypothesis. Channel model and occupancy status Channels are modeled as i.i.d Rayleigh fading. The entire frame is assumed to have same occupancy status. i.e. if a portion of frame is occupied means entire frame is assumed as to be occupied. The occupancy state of each frame is considered as independent. Every frames are splited into 10 blocks. Each blocks have different fading coefficient. The length of the each block time is T_c. The primary user (licensed user) spectrum occupancy is modeled as Bernoulli process which contains two state. One is "0" to represent the idle state and another one is "1" to represent the busy state. The number of blocks in a single frame is assigned as L. So length of the time for each frame can be estimated by the LT_c. Let assume q_i is probability to be spectrum as occupied status. The channel arranged as order of occupancy probability as follows

$$q_{[1]} \leq q_{[2]} \leq q_{[3]} \leq \ldots\ldots\ldots \leq q_{[i]}.$$

VI. PROBABLY APPROXIMATELY CORRECT LEARNING

To select the maximum reward channel, probably approximately correct learning is a essential method. This is used to find out the optimal and sub-optimal reward channel. This process is achieved by applying the confidence bound on the cardinality of channel. The reward of the each channel is stored and compared with reward of other channel. Then channels are sequenced in the order of reward availability. This is obtained by forming reward as stochastic process. The available reward of channel i is assumed as "i". A is considered as set of available channel and "i" is the one of the channel from set of channel A. The index of best machine arm can be represented as "i¨". The index of optimal channel is defined by below equation.

$$i^{*} = \arg\max_{i \in \mathcal{A}} \bar{\Psi}_i .$$

A. Definition of Parameters

Some important parameters which are used in this paper are sensing energy figure, transmission energy figure.

Defenition 1 (Sensing Energy Figure):

The ratio of unit energy and frame energy is called as sensing energy figure. The sensing energy is represented as ς. measures the effectiveness of a sensing mechanism in terms of the energy cost relative to the frame energy ε_{tot}, while the TEF η, reflects the exploitation energy proportion in the active sensing OSA. In particular, η = 1 corresponds to *aggressive* spectrum access of the secondary user without sensing and probing phases. For reliable sensing quality with certain levels of p_m and p_f . the time duration and energy required to sense a channel depend on a specific sensing algorithm. When the energy cost for sensing is assumed to be linear in the sensing duration or the number of samples used for sensing, the unit sensing energy can be written as ε_0. The sensing energy figure is defined as follows,

$$\zeta = \frac{\mathcal{E}_0}{\mathcal{E}_{\rm tot}}.$$

Definition 2 (Transmission Energy Figure):

The ratio of total transmission energy and frame energy is called as transmission energy figure. This is denoted as η. The transmission energy figure is defined as follows,

$$\eta = 1 - \frac{\mathcal{E}_{\rm s} + L\mathcal{E}_{\rm p}}{\mathcal{E}_{\rm tot}}.$$

Definition 3 (Probability of Missed Detection):

If busy channel is mistakenly detected as idle channel, that event can be declared as missed detection. The probability of missed detection should be low. Probability of missed detection is represented as P_m. In this paper, the value of P_m is assumed as 0.1.

Definition 4 (Probability of False Detection):
If the idle channel is mistakenly detected as busy channel, that event is called false detection. The probability of false detection is represented as P_f. P_f is measured as efficient spectrum sensing. In this paper, value of P_f is set as 0.1.

Definition 3 (Average Regularity Throughput):
The average regularity throughput $R_{rt}(\eta)$ regulates the achievable rate R for data transmission by the exploitation energy proportion η. Hence, the total average OSA throughput achievable for every frame is equal to $R_{rt}(\eta)\, \varepsilon_{tot}$ /P. nats/Hz. For example, with aggressive access to the i^{th} channel (no exploration energy), the average regularity throughput is $R_{rt}(1) = \mathbf{E}\{C_i\}$. The average regulatory throughput is defined as follows,

$$R_{rt}(\eta) = \eta R \quad \text{nats/s/Hz.}$$

VII. EXPLORATION OF CHANNEL STATE INFORMATION

In the probing phase, the secondary user sends the sequence of unit-energy testing signals X_{test} over each channel of probing set in for channel probing, where X_{test} subset of probing channel is a binary phase-shift keying signal known to the receiver. Then, in the presence of phase CSI, the receiver duplicates X_{test} using maximum likelihood detection. Then it compares received signal and transmitted signal, if both signal is found to be same, cognitive radio system considers the probed channel to be idle state "0", otherwise probed channel considered as busy state "1". We further consider the following channel state information (CSI) model at the secondary transceiver pair: i) the transmitter does not know all the channel coefficients ii) before identifying an access channel, the receiver knows only the phases of channel coefficients iii) with channel training after access decision making, the receiver has perfect CSI on the channel chosen to access. The learning process is divided into exploration and exploitation. Both of channel's status and interference can be determined through the MAB. To maximize the throughput, energy is traded

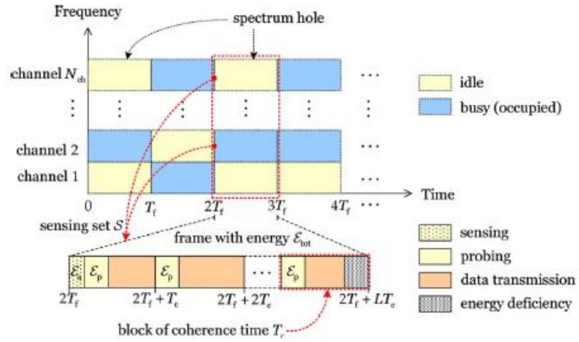

Fig.1 Frame structure

off between exploration and exploitation. Using exploration, status and quality of channel are tested. Data transmission takes place in the phase of exploitation. Every channel have different reward distribution. The parameter regret indicates the effectiveness of learning. The main objective is reduction of reduce the regret. Cardinality of set of channel is considered in exploration stage. Hence system explores only the highest reward channels. Thereby only least amount of energy is consumed for exploration and most of the energy is assigned for exploitation. By choosing cardinality, tradeoff between exploration and exploitation is performed. Exploration is process by which process all statistical information about reward can be learned. Reward of the each arm is updated with help of index of channel. Since the channel phases usually change very slowly and hence are easy to track (compared to the fading amplitudes), we consider this partial CSI obtained by coarse channel training for active sensing. This can reduce a overhead by precisely tracking only the single channel chosen to access for data transmission. In this paper, not included this training mode since it has no effect on our framework in the paper.Some backoff timing and acknowledging mechanism is also required to avoid collisions due to miss detection of primary occupancy and/or other secondary access.

VIII. ACTIVE SENSING AND OPPORTUNISTIC SPECTRUM ACCESS

Due to the nature of wireless channels, if the secondary user simply determines a channel based on the statistics in to access for data transmission without any probing mechanism, the secondary user may end up choosing an idle but "bad" channel to transmit data. Therefore, we now consider active sensing for intelligent spectrum access decision making. Specifically, we develop the energy-efficient OSA strategy with optimal active sensing by determining the sensing cardinality and and probing cardinality to maximize the achievable average throughput of the secondary user subject to the frame energy constraint ε_{tot} for sensing, probing, and data transmission. The accuracy of spectrum sensing and reliability of spectrum access can be determined using two parameters which are probability of missed detection and probability of false detection.

ALGORITHM 1

Step1: Probe all channel.
Step2: Store reward of channel and arrange all channel in order of reward.
Step3: Select the cardinality of channel which is depends on available energy and update reward of channel.
Step4: Repeat the step2 and step3 until get single optimal channel. finally access the that optimal channel.
Note
Cardinality determination is done by median elimination algorithm

Table 1 ABBREVIATIONS

CDF	Cumulative Distribution Function
CSI	Channel Side Information
i.i.d	Independent and Identically Distributed
MEA	Median Elimination Algorithm

The probability to i[th] channel to be idle can be found through following equation,

$$P_i(idle) = (1-P_f)(1-q_i) + p_m q_i \quad (2)$$

A. Singleton probing

In passive sensing without any probing mechanism which is used to assess the quality of channels in S_{idle}, the secondary user chooses a channel with the smallest q_i in S_{idle} to access for data transmission . This policy can be viewed as a special case of active sensing with a singleton probing set. In this singleton probing only one channel is taken to for data transmission. That is cognitive system scans for idle channel. If a channel is found to be free, system is not considered remaining channel and moreover it is not probe the quality of channel. Directly system starts to use that initially found idle channel. so this leads to occur the loss of data. So this paper is mainly concentrated on active sensing. Unlike singleton probing, this active cognitive radio system initially checks the status of channel, and with help of that result number of channel is reduced to form probing set. Secondly, channel quality is probed in the term of SNR of the channel and ultimately single optimum channel is used to exploit the available channel. The additive Gaussian noise is considered to be mixed in all independent channel. The quantities SNR_1 and SNR_2 denote the average received signal-to-noise ratios at the secondary receiver for the secondary and primary signals, respectively. Note that the second case icorresponds to the misdetection of the primary signal, which is likely to happen at a low level of the primary signal at the secondary transmitter in typical spectrum sensing. Due to limited available frame energy, we fix the secondary transmission power in both probing and data transmission phases such that the interference power at the primary receiver is controlled to be small for this miss detection case.

IX. SIMULATION RESULTS

Simulation results illustrate that energy tradeoff is performed by multi-armed bandit problem with median elimination algorithm. Because of most amount of energy is used for data transmission purpose, cognitive radio user can use the spectrum even in deep fading condition. Therefore there is less chance to occur the data loss and error. By optimizing the upper confidence bound of average regulatory throughput R_{rt}, the cardinality of testing and probing channels are determined. This is shown by simulation result. In the simulation, totally 200 channels are considered. But only 16 channels are taken for probing set. This shows that sensing energy is consumed as efficient. Hence most of the remaining energy is utilized for data transmission.

A. Channel Status

The channel status is uncertainty one. This property shown in the fig. 2. This fig.2 illustrates the current status of channel which is varying one. The status have property to vary depends on usage of the spectrum. For example, if primary user exploits the spectrum for transmit text message, it occupies only small portion of channel whereas primary user utilizes spectrum for MMS, more amount of

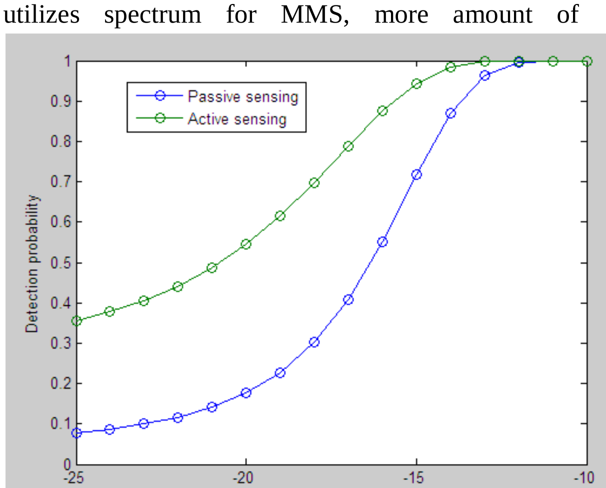

Fig.2 Detection probability

spectrum needs to be occupied.

B. Tradeoff between Exploration and Exploitation

For improve the throughput, there is need of efficient energy consumption. This can be achieved by exploring the limited number of channel. In this simulation, initially 200 channels are assumed to check the status of channel and gradually the cardinality of channel is reduced to get single optimal channel. This process is possible by the median (action) elimination algorithm. The sensing energy figure is assigned as less than $\eta = 10^{-4}$ (in the case of $P_{busy} = 0.1$).

C. *Optimal Sensing Cardinality*

Fig. 2 shows the optimal sensing cardinality as 16. In this simulation, considered total idle channels are 20. The graph shows that four channels which are not optimal are eliminated. Two values for occupancy probability are given. They are $P_{busy} = 0.2$ (Sparse primary spectrum occupancy) and $P_{busy} = 0.9$ (densed primary occupancy). Fig.3 shows the cumulative distribution function of the optimal cardinalities as the fuction of optimal cardinlities. This occupancy status is given for both of passive sensing and active sensing. In simulation assigned values are $N_{ch} = 100$, $SNR_1 = 15$ dB, $SNR_2 = 10$ dB, $\varepsilon_0 = 50000$ energy units, L=10, $P_m = 0.1$ and $P_f = 0.1$. In active sensing, different values for sensing energy is assumed.

D. *Performance Comparison*

This proposed spectrum sensing leads to efficient energy consumption. But the most of the previously published paper which are using greedy algorithm and softmax, mainly concentrate on detecting the optimal channel without considering the energy consumption.

I. FUTURE WORK

To make the possibility to exploit the same channel simultaneously by all user without any compromise in interference and throughput in the channel.

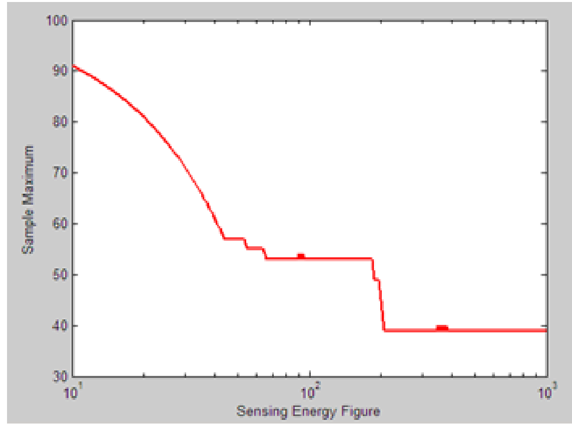

Fig.3 Sample reduction

II. CONCLUSION

From the simulation result it showed that optimum energy is utilized for exploration process and rest of the maximum energy is assigned for exploitation process which is used for data transmission purpose. These two process are implemented through multi-armed bandit which is class of machine learning algorithm.

REFERENCE

[1] R. Tandra and A. Sahai, "SNR walls for signal detection," *IEEE J. Sel. Topics Signal Process.*, vol. 2, no. 1, pp. 4–17, Feb. 2008.

[2] H. Jiang, L. Lai, R. Fan, and H. V. Poor, "Optimal selection of channel sensing order in cognitive radio," *IEEE Trans. Wireless Commun.*, vol. 8, no. 1, pp. 297–307, Jan. 2009.

[3] R. S. Sutton, A. G. Barto, "Reinforcement Learning: An Introduction", Cambridge, MA: MIT Press, 1998.

[4] R. Fan and H. Jiang, "Channel sensing-order setting in cognitive radio networks: A two-user case," *IEEE. Trans. Signal process.*, March 2012.

[5] E. Even-Dar, S. Mannor, and Y. Mansour, "Action elimination and stopping conditions for the multi-armed bandit and reinforcement learning problems," *J. Mach. Learn. Res.*, vol. 7, pp. 1079–1105, Dec.2006.

[6] S. Mannor and J. N. Tsitsiklis, "The sample complexity of exploration in the multi-armed bandit," *J. Mach. Learn. Res.*, vol. 5, pp. 623–648, Jun. 2004.

[7] T. V. Nguyen, H. Shin, and M. Z. Win, "Optimal sensing cardinality for cognitive radios," *IEEE Commun. Lett.*, vol. 15, no. 7, pp. 716–718, Jul. 2011.

[8] Z. Quan, S. Cui, A. H. Sayed, and H. V. Poor, "Optimal multiband joint detection for spectrum sensing in cognitive radio networks," *IEEE Trans. Signal Process.*, vol. 57, no. 3, pp. 1128–1140, Mar. 2009.

[9] A. Taherpour, S. Gazor, and M. Nasiri-Kenari, "Invariant wideband spectrum sensing under unkonwn variances," *IEEE Trans.Wireless Commun.*, vol. 8, no. 5, pp. 2182–2186, May 2009

[10] Q. Zhao, L. Tong, A. Swami, and Y. Chen, Decentralized cognitive MAC for opportunistic spectrum access in ad hoc etworks: A POMDP framework," *IEEE J. Sel. Areas Commun.*, vol. 25, no. 3, pp. 589–600, Apr. 2007.

[11] A. Rabbachin, T. Q. S. Quek, H. Shin, and M. Z. Win, "Cognitive network interference," *IEEE J. Sel. Areas Commun.*, ., vol. 29, no. 2, pp. 480–493, Feb. 2011.

[12] J. C. Park, J. S. Wang, H. G. Kang, S. Yoon, I. Song, and Y. H. Kim, "Detection of variable subband nulling mode for OFDM-based cognitive radio in narrowband interference channels," *IEEE Trans. Wireless ommun.*, vol. 10, no. 3, pp. 782–791, Mar. 2011.

[13] S.-J. Kim, E. Dall'Anese, and G. B. Giannakis, "Cooperative spectrum sensing for cognitive radios using Kriged Kalman filtering," *IEEE J. Sel. Topics Signal Process.*, vol. 5, no. 1, pp. 24–36, Feb. 2011.

[14] T. Yücek and H. Arslan, "A survey of spectrum sensing algorithms for cognitive radio applications," *IEEE Commun. Surveys Tuts.*, vol. 11, no. 1, pp. 116–130, Mar. 2009.