ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

Volume 3, Special Issue 3, March 2014

2014 International Conference on Innovations in Engineering and Technology (ICIET'14)
On 21st & 22nd March Organized by

K.L.N. College of Engineering, Madurai, Tamil Nadu, India

Modeling and Analysis of Sensing Schemes in Multichannel Cognitive Radio Networks

P. Jaya Rengaleela[#1], G. Pandeeswari[#2]

[#1] Department of ECE, K.L.N. College of Information Technology, Madurai, TamilNadu, India.

[#2] Department of ECE, K.L.N. College of Information Technology, Madurai, TamilNadu, India.

***Abstract*—** The current spectrum allocation policy adopted by communication agencies around the globe mandates for the static licensing of the available spectrum to various technologies and organizations. This non overlapping part of the spectrum reduces interference and guarantees exclusive spectrum use of licensed users. However, nearly all useful spectrum is now allocated to different entities, without provision for accommodating new wireless technologies. More specifically, a model for the single user case is introduced and its performance is validated through analytical analysis. Since the scheme utilized experiences a high level of collision among the seas, to overcome the problem appropriately, p-persistent random access (PPRA) protocol is considered, which offers higher average throughput for SUs by statistically distributing their loads among all channels. The structure and performance of the proposed schemes are discussed in detail, and compare the performance of the proposed sense access strategies.

***Keywords*—**Cognitive radio, spectrum handover, sequential channel sensing, queuing networks, secondary user's throughput.

I. INTRODUCTION

Wireless communication in which the transmission or reception parameters are changed to communicate efficiently without interfering with licensed users. A cognitive radio is an intelligent radio that can be programmed and configured dynamically. Its transceiver is designed to use the best wireless channel in its vicinity. Such a radio automatically detects available channels in wireless spectrum, its transmission or reception parameters allow more concurrent wireless communications in a given spectrum band at one location. This process is a form of dynamic spectrum management. Although cognitive radio was initially thought of as a software-defined radio extension (full cognitive radio), the most research work focuses on spectrum-sensing cognitive radio (particularly in the TV bands). The chief problem in spectrum-sensing cognitive radio is designing high-quality spectrum-sensing devices and algorithms for exchanging spectrum-sensing data between nodes.

Spectrum sensing to detect unused spectrum and sharing it, without harmful interference to other users; an important requirement of the cognitive-radio network to sense empty spectrum. Detecting primary users is the most efficient way to detect empty spectrum. Applications of spectrum-sensing cognitive radio include emergency network and W-LAN higher throughput and transmission distance extensions. A CR can intelligently detect whether any portion of the spectrum is in use, and can temporarily use it without interfering with the transmissions of other users. According to Bruce Fette, "Some of the radio's other cognitive abilities include determining its location, sensing spectrum use by neighboring devices, changing frequency, adjusting output power or even altering transmission parameters and characteristics.

II. RELATED WORKS

Sequential channel sensing problems for single and multiple secondary users (SUs) networks are effectively modeled through finite state Markovian processes [1]. This model for the single user case is introduced and its performance is validated through analytical analysis. Though the available spectrum resources seem to not meet the ever-growing demand, many investigations reveal that the spectrum is grossly under-utilized in time, space, and other dimensions [2]. Sequential spectrum sensing algorithms which explicitly take into account the sensing time overhead, and optimize a performance metric capturing the effective average data rate of CR transmitters. A constrained dynamic programming problem is formulated to obtain the policy that chooses the best time to stop taking measurements and the best set of channels to access for data transmission, while adhering to hard "collision" constraints imposed to protect primary links [3].

Cognitive radio (CR) is an enabling technology for numerous new capabilities such as dynamic spectrum access, spectrum markets, and self-organizing networks. To realize this diverse set of applications, CR researchers leverage a variety of artificial intelligence (AI) techniques. To help researchers better understand the practical implications of AI to their CR designs, this paper reviews several CR implementations that used the following AI techniques: artificial neural networks (ANNs), math heuristic algorithms, hidden Markov models (HMMs), rule-based systems, ontology-based systems (OBSs), and case-based systems (CBS) [4]. A false alarm event in spectrum sensing in a frequency channel causes the secondary user currently using the frequency channel to execute spectrum handoff to another channel. Although determination of optimal spectrum sensing time has been studied, there has been little research addressing the optimal sensing time considering spectrum handoff [5]. The optimal sensing other problem in multi-channel cognitive medium access control with opportunistic transmissions. The scenario in which the availability probability of each channel is known is considered first. In this case, when the potential channels are identical (except for the availability probabilities) and independent, it is shown that, although the intuitive sensing order [6].

Two suboptimal algorithms, namely, the greedy search algorithm and the incremental algorithm, which have comparable performance with that of brute-force search and have much less computational complexity [7]. It is shown that, with a high probability, either suboptimal algorithm can reach an optimal point if a buck off mechanism is used for contention resolution. When adaptive modulation is adopted, it is observed that the traditional stopping rule does not lead to an optimal point in the two-user case [8]. The lower the probability of false alarm, the more chances the channel can be reused when it is available, thus the higher the achievable throughput of the secondary network. We formulate the sensing-throughput tradeoff problem mathematically, and use energy detection sensing scheme to prove that the formulated problem indeed has one optimal sensing time, which yields the highest throughput for the secondary network [9]. CSMA/p^*, is the non persistent carrier sense multiple access (CSMA) with a carefully chosen non uniform probability distribution p^* that nodes use to randomly select contention slots. We show that CSMA/p^* is optimal in the sense that p^* is the unique probability distribution that minimizes collisions between contending stations [10].

III SYSTEM MODELING AND VALIDATION

A. SYSTEM MODEL

We consider a time slotted CRN with *NS* SUs, which attempt to opportunistically transmit on the channels dedicated to the *Np* PUs. The SUs are synchronous in time-slots with other SUs as well as the PUs. The PUs start their transmissions only at the beginning of the slot whenever they have data for transmissions. Therefore, in order to find the transmission opportunities appropriate and to protect the PUs from a harmful interference, the SUs sense the channels at the beginning of each time-slot, by which the channels can be established as occupied or vacant. The SUs utilizes narrowband Spectrum sensing, i.e., They sense only one spectrum (out of *no* spectrums) at a time. The secondary network is considered saturated, meaning that the SUs always have packets to transmit; therefore they will start their transmissions when an opportunity is found.

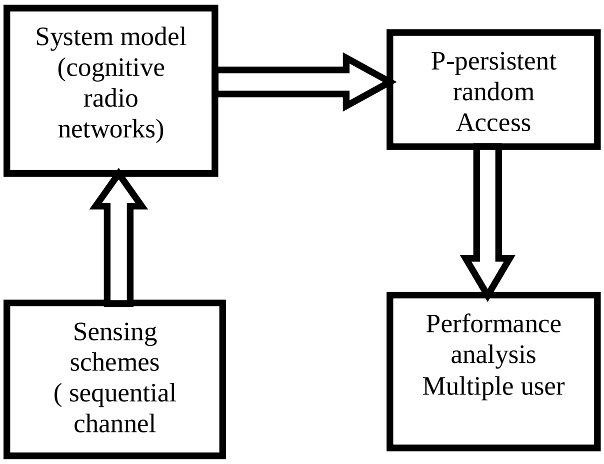

Fig 1. Block diagram for proposed system

Each SU senses the channels according to its SS sequentially, i.e., The SU senses the first channel that is assigned to its SS for a predetermined time duration τ (channel sensing time), and then starts sensing the second channel if and only if the first channel is sensed busy. This procedure will be continued until a transmission opportunity is found. If an SU starts transmitting on the *i*-th channel of its SS, the time length left in the slot for the transmission is,

$$RTi = T - \tau - (i - 1)(\tau + \tau ho) \quad \text{---- (1)}$$

B. MODEL VALIDATION

In order to compute the average throughput of the SU, the probability of transmitting data from each of the transmitter nodes in Fig. 1 as well as they're offered data rates must be derived. Let αx represent the packet arrival rate at node x. Considering the traffic equations of the proposed queuing network can be:

$$\alpha HO1 = \lambda + \alpha Wait, \alpha HOi = qi - 1\alpha Si - 12 \le i \le \delta \quad \text{------- (2)}$$

$$\alpha TxLPi = Pi,1(1 - Pd,i))\alpha si,1 \le i \le \delta \quad \text{------(3)}$$

$$\alpha TxHPi = (pi,0(1 - Pfa,i))\alpha si,1 \le i \le \delta \quad \text{------(4)}$$

Note that the channel *I* will be chosen for the transmission if and only if (a) all ($I - 1$) previous channels are either not sensed due to the exploited p-persistent MAC protocol or sensed busy, (b) the channel *I* is sensed idle. So the *k*-th SU requires ($i-1$) times handovers with the probability of $c1c2$. $ci-1(1 - ci)$, where *ci*, the transition probability from the stage *i* to the stage i+1, is given in (4). The average number of handovers, denoted by *NHO*, is easily computed as,

$$NHO = \sum_{i=1}^{\delta} (i-1)(1-ci) \prod_{j-1}^{i-1} cj\,\delta \prod_{j-1}^{\delta} cj \qquad \text{-----(5)}$$

Where the last term is corresponding to the possibility of no transmission in any of δ transmission stages.

IV. P-PERSISTENT RANDOM ACCESS SCHEME

This is a sort of trade-off between 1 and non-persistent CSMA access modes. When the sender is ready to send data, it checks continually if the medium is busy. If the medium becomes idle, the sender transmits a frame with a probability *p*. If the station chooses not to transmit (the probability of this event is *1-p*), the sender waits until the next available time slot and transmits again with the same probability *p*. This process repeats until the frame is sent or some other sender starts transmitting. In the latter case the sender monitors the channel, and when idle, transmits with a probability *p*, and so on. P-persistent CSMA is used in CSMA/CA systems including Wi-Fi and other packet radio systems. The major disadvantage associated with the MPPA algorithm is that a high number of SUs (*pNp* SUs) intend to sense the first channel through the node *S*1. SUs' requests enter the node *S*2, and so forth. While this structure facilitates the network modeling and the performance evaluation, it imposes a high level of contention among the SUs to exploit the spectrum resources in each stage and consequently degrades the performance regarding the average SUs' throughput. In order to mitigate the aforementioned problem, we consider the p-persistent random access (PPRA) scheme, which equally distributes the load of the SUs within all channels, and hereby decreases the contention level and raises the throughput of each SU.

The average throughput of the single SU using sequential channel sensing scheme versus normalized sensing time (i.e., τ/T) based on both analytical and simulation results. From this Fig., it can be realized that the simulation results will coincide the analytical results, which further validates our analytical derivations.

First, as the number of primary channels increases, the SU throughput increases as well, but in a saturating manner. This is due to the fact that, though the average number of obtained transmission opportunities increases by the number of primary channels, but the average time left for the transmission reduces. Second, this figure clearly demonstrates the importance and efficiency of having multiple handovers. Interestingly, the improvement in the SU's maximum throughput when using multiple handovers is about 44.5% compared to the case of *Np* = 1, with no handover capability, for the example considered. For the example considered, the maximum throughput achieved by the PPRA scheme is about 3.63 times more than that of the MPPA scheme. Also, as less requests compete for accessing the same channel in the PPRA scheme, the breaking point of the PPRA's average throughput is greater than the MPPA protocol.

The SD algorithm well approximates the optimal value of the throughput for three different examples considered for its initial values. Albeit this algorithm cannot guarantee the global optimum values of *p*, its much lower computational burden is a key advantage. Finally, for the adaptive protocol proposed, the SUs throughput remains at an acceptable level while no information about other SUs (even *Ns*) is required. Intuitively, selecting a method to find a proper value highly depends on the information available and the tradeoff between the computational cost affordable and the optimality of the solution desirable.

In the first stages, the transmitter nodes face more collisions, and the probability of collision reduces as the requests intend to transmit in the higher stages. Again, the MPPA protocol leads to collision among the SUs with higher probability than the PPRA scheme. Finally, we investigate the performance of a simple improvement of the PPRA scheme, called improved-PPRA. Contrast to the PPRA scheme, in which in each random access stage, a sensing channel is selected uniformly from all the N_p channels, in the improved scheme, once an SU senses a PU channel occupied, the SU avoid sensing this channel in later random access stage.

V. SIMULATION RESULTS

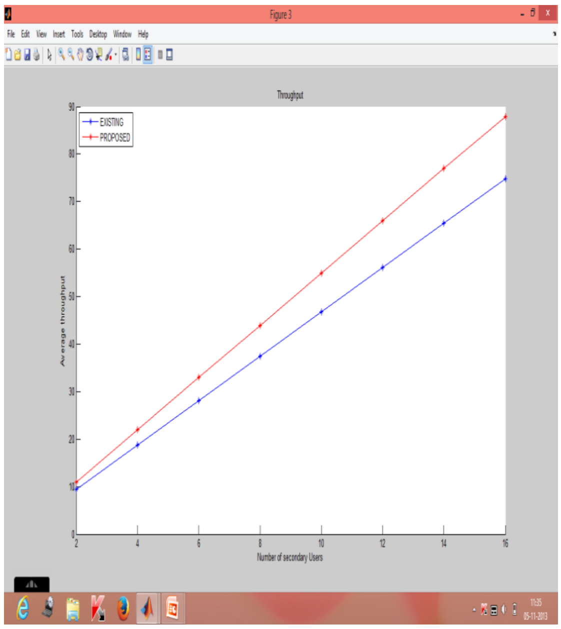

Fig 2. Secondary user normalized throughput versus Normalized sensing time for a CRN with single secondary Users.

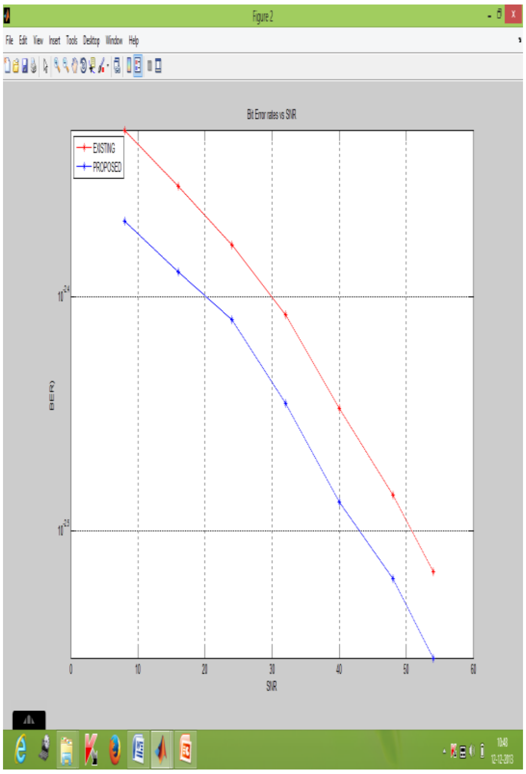

Fig 3. Bit Error rate vs SNR

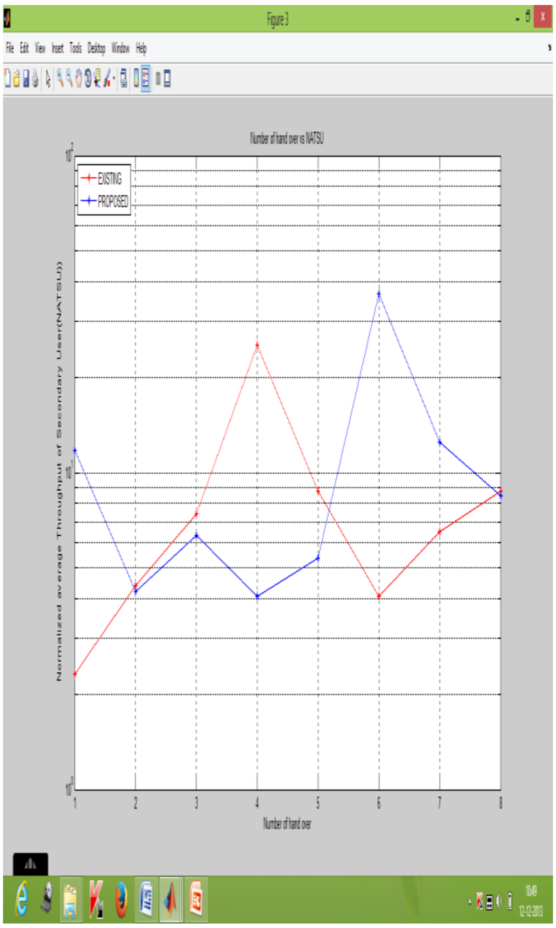

Fig 4. Average secondary user normalized throughput versus average number of handovers

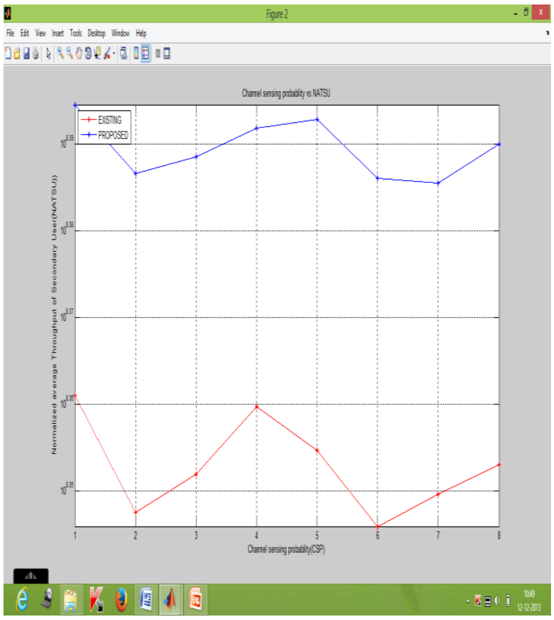

Fig 5. Average secondary user normalized throughput versus normalized sensing time.

Specifically, for *NHO* = 3.72, the throughput achieved by the PPRA is about 3.5 times more than the one achieved by the MPPA scheme. Figs.1and 2 further verify the advantages of the PPRA algorithm compared to the MPPA schemes. In addition, as Fig.5 shows, less collisions are imposed by the PPRA scheme compared to the MPPA due to the exploited load balancing method.

Fig.3 compares the average throughputs of the PPRA scheme versus the improved PPRA scheme. As can be observed, the average throughput is slightly raised. Hence, there exists a trade off between the average SU's throughput and its detection accuracy. As it can be seen in Fig. 4, first the SU throughput increases by τ (due to more accurate sensing); then after an optimum point Where *Pd* and *Pfa* are in an acceptable level, the throughput starts decreasing due to the reduction of the time left for the transmission

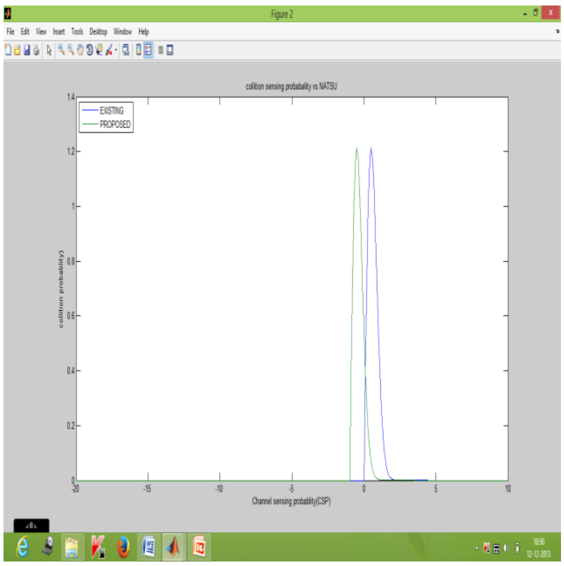

Fig 6. Normalized throughput of each secondary user versus The channel sensing probability

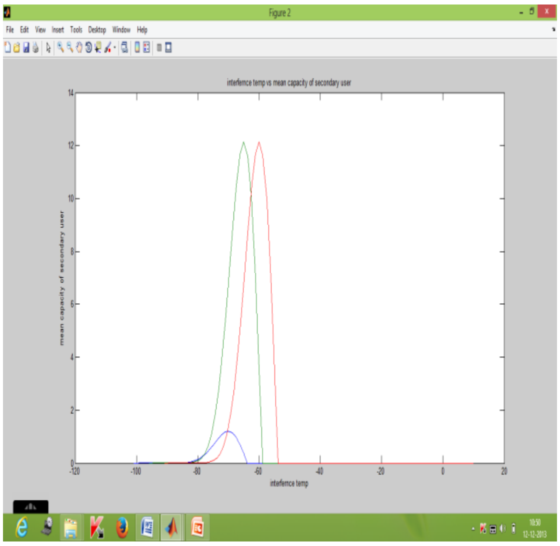

Fig 7. Interference temp vs mean capacity of secondary user

VI. CONCLUSIONS

In this paper, we proposed a cognitive radio system that significantly improves the achievable throughput of opportunistic spectrum access cognitive radio systems by performing data transmission and spectrum sensing at the same time. First, finite state Markov process-based structure has been exploited to effectively model the behavior of a single secondary user (SU) in the CRN. This model has been validated by analytical analysis and simulations, and then extended to a multiuser CRN. Modified p-persistent access (MPPA) has been introduced, and its performance in terms of the average SUs' throughput and the average number of handovers has been evaluated. In order to appropriately mitigate the problem associated with the MPPA scheme, a distributed sensing access policy, called p-persistent random access (PPRA), has been proposed, which statistically distributes the Busload among all channels. Future work is to reconfigure PPRA schemes and get more accurate average throughput.

REFERENCES

[1] Hossein Shokri-Ghadikolaei, Fatemeh Sheikholeslami, and Masoumeh Nasiri Kenari,"*Distributed Multiuser Sequential Channel Sensing Schemes in Multichannel Cognitive Radio Networks*" IEEE Trans.Wireless commun., Vol. 12, no. 5, pp. 2055-2067, MAY 2013

[2] L. C. Wang, C. W. Wang, and C. J. Chang, "*Modeling and analysis for spectrum handoffs in cognitive radio networks*," *IEEE Trans. Mobile Comput.*, Vol. 11, no. 9, pp. 1499–1513, Sept. 2012.

[3] R. Fan and H. Jiang, "*Optimal multi-channel cooperative sensing in cognitive radio networks*," *IEEE Trans. Wireless Commun.*, Vol. 9, no. 3, pp. 1128–1138, Mar. 2010.

[4] A. He, K. K. Bae, T. R. Newman, J. Gaeddert, K. Kim, R. Menon, L. Morales, J. Neel, Y. Zhao, J. H. Reed, and W. H. Tranter, "*A survey of artificial intelligence for cognitive radios*," *IEEE Trans. Veh. Technol.*, Vol. 59, no. 4, pp. 1578–1592, May 2010.

[5] S. Kim and G. B. Giannakis, "*Sequential and cooperative sensing for multi-channel cognitive radios*," *IEEE Trans. Signal Process.*, Vol. 58, no. 8, pp. 4239–4253, Aug. 2010.

[6] Y. Chen, V. K. N. Lau, S. Zhang, and P. Ciu, "*Protocol design and stability/delay analysis of half-duplex buffered cognitive relay systems*," *IEEE Trans. Wireless Commun.*, Vol. 9, no. 3, pp. 898–902, Mar. 2010.

[7] R. Fan and H. Jiang, "*Channel sensing-order setting in cognitive radio networks: a two-user case*," *IEEE Trans. Veh. Technol.*, Vol. 58, no. 9, pp. 4997–5008, Nov. 2009.

[8] N. Arulselvan, V. Ramachandran, and S. Kalyanasundaram, "*Distributed power control mechanism for HSDPA femtocells*," in *Proc. IEEE VTC*, 2009.

[9] H.-S. Jo, C. Mu, J. Moon, and J.-G. Yook, "*Interference mitigation using uplink power control for two-tier femtocell networks*," *IEEE Trans.Wireless Commun.*, Vol. 8, no. 10, pp. 4906-4910, Oct. 2009.

[10] V. Chandrasekhar and J. G. Andrews, "*Uplink capacity and interference avoidence for two-tier femtocell networks*," *IEEE Trans. Wireless Commun.*, Vol. 8, no. 7, pp. 3498-3509, July 2009.