RADIO FREQUENCY (RF) ENERGY HARVESTING IN COGNITIVE RADIO NETWORKS USING A JOINED OPTIMAL TIME AND POWER ALLOCATION ALGORITHM

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ABSTRACT

A possible method for sustaining the operation of wireless networks is radio frequency (RF) energy harvesting. A secondary user in a cognitive radio network may be capable of harvesting RF energy. In this research, we take into account a network with channel access, where the secondary user can send a packet or harvest RF energy depending on whether the primary user is using the channel or not. For RF energy harvesting cognitive radio networks, a multichannel selection technique is suggested. In this case, there are several channels available, and each secondary user (SU) harvests RF energy from the channel that is currently being used by active primary users while transmitting data using other accessible but unoccupied channels. This nonconvex problem is first converted into a convex optimisation problem using an analogous transformation, and then it is resolved using the joint optimal time and power allocation (JOTPA) technique, which successively resolves a series of feasibility issues until convergence. According to comparison data, the buffer can greatly lower the likelihood of SU blockage and non-completion while just slightly increasing the likelihood of forced termination. Extensive simulation has been used to validate the analytical model.

Keywords: Radio frequency (RF), secondary user (SU), the joint optimal time and power allocation (JOTPA) algorithm, wireless networks

INTRODUCTION

The availability of unlicensed spectrum has recently decreased due to the sharp rise in the number and variety of wireless devices. A significant portion of licenced bands are underutilised in the time and space domains, according to studies [1], leaving empty spaces in the time-frequency grid. According to a Federal Communications Commission (FCC) assessment [2], the old fixed spectrum allocation approach causes regional and temporal variances in spectrum utilisation that range from 15% to 85%. The unused gaps (also known as white space) in licenced spectrum cannot be utilised again by unlicensed users due to fixed spectrum allocation laws. CR is a cutting-edge communication method that permits secondary users—unlicensed users who can take advantage of spectrum gaps when they arise—without impairing or compromising the performance of primary users, who are licenced users. [3] A network of unlicensed users with CR capabilities that compete with one another for spectrum access and take advantage of gaps in the spectrum is known as a cognitive radio network (CRN). The methods put forth so far to implement CR communication have shown to be effective in terms of taking advantage of the gaps in the spectrum for wireless transmission. To take advantage of the huge potential for the emerging next-generation radio communication technology to adopt CR, additional research endeavours are required because the methodologies to execute spectrum detection, power allocation, and channel allocation to make CR communication practicable are highly inefficient.

Today's frequency spectrum is comparable to real estate. Although it is a fixed-price commodity, the demand for it is growing dramatically every day. Authorities who have the only authority to govern radio spectrum access are in charge of regulating the usage of the spectrum. Most of the radio spectrum is restricted from public access and is distributed in a command-and-control manner to licenced radio services. [4] Only a very small portion of the radio spectrum, or unlicensed frequency bands, are openly accessible. It's exciting to note that numerous new wireless technologies, standards, and applications have emerged during the previous few decades. IEEE 802.11 Wireless Local Area Networks (WLANs), Wireless-Fidelity, Bluetooth for IEEE 802.15, and Wireless Personal Area Networks (WPANs) are a few of the most well-known ones. Therefore, it makes sense that the present focus of research is on systems that can manage the growing spectrum demand or achieve improved bandwidth utilisation.

II RELATED WORK

Accordingly, on the reception side, radio-scene analysis and channel identification are carried out, while DSA (Dynamic Spectrum Access) is carried out on the sender side to dynamically pick the free band and use it for transmission. Spectrum-hole identification and interference temperature calculation are the main topics of radio-scene analysis.[5] The identification of the channel, which deals with estimating channel state information and predicting channel capacity, is the second aspect on the receiver side. When performing activities that are somewhat cognitive, CR functions like a signal-processing and machine-learning system. CR functions as an SDR (Software Defined Radio) for operations like reconfiguration. They emphasised that CR must be able to adapt to the changing environment, making learning and adapting the two key components of CR. [6] [7] Intelligent algorithms must be used to assess the surrounding environment in order to learn the behaviour of the environment, and the sender must use the knowledge gathered to easily adapt to the best channel and channel parameters for transmission in order to increase performance.

A review of CR methods in various cognitive networks was conducted along with an alternative strategy to adaptation. Also discussed was a dynamic, opportunistic channel selection strategy for an IEEE 802.11 wireless network based on CR. They proposed a stochastic channel selection method [8] so that the unlicensed user may use it to select the best channel to utilise to reduce the likelihood of miss detection as opposed to adjusting channels consistently and randomly. By changing the probability of channel selection, an asymptotic ideal solution was produced. [9] Channel selection for both control and data transmission was carried out by estimating the frequency of the channel's availability in the future. [10] It was suggested to use a classification and learning technique to forecast the channel type and gather the data needed for wise channel selection. [11]The number of channel shifts required up to a time was decreased to 55%, resulting in a decrease in delay and an increase in throughput, which made the suggested model perform better than opportunistic random channel selection.

III METHODOLOGY

Spectrum sharing is the process of dividing up the available spectrum across all CR users according to their usage. One of the obligations of spectrum sharing is to access the channel in order to preserve the PU. In general, overlay, underlay, and interweave access strategies make up spectrum sharing based on access technology. The SU has access to a spectrum hole through the interweave access approach and is free to utilise it. If the PU enters the spectrum once more, the SU must exit the spectrum or switch to another open channel. The SU's ability to detect spectrum holes, which are a part of the spectrum band given to the PU but have not been utilised at a specific time or location, is hence its most crucial function. The capacity of an SU to perceive the spectrum using standard detection techniques like a coincident filter and an energy detector is known as spectrum sensing. A SU can collocate with the PU in overlay and underlay schemes without any interference or with very little disturbance.

The spectrum efficiency improves in the underlay access strategy if the SU modifies its transmission rate to prevent the PU from being destroyed. The most significant drawbacks of this method include the need to use the channel capacity and adjust the transmission power to be effective for both PUs and SUs while minimising interference levels. In overlay mode, the SU and PU can both communicate simultaneously. By using some of the SU's power to transmit the PU's message, the interference caused by the ST to the PR can be made up for. The SU serves as a relay for a PU, which in turn grants it access to a piece of its spectrum. A cognitive radio network (CRN) powered by RF energy can offer a spectrum- and energy-efficient solution for wireless networking, where the energy is gathered and used for data transmission as well as for channel sensing, both of which improve the performance of channel allocation. Therefore, cognitive devices need to look for occupied spectrum bands in addition to spectrum holes in order to harvest RF energy.

3.1 Cognitive Radio Network Powered By RF Energy

This study made the assumptions that the CR network had a centralised server and that node positions were unchanging. The spectrum server, also known as the location server, receives broadcasts from SUs about their positions, channels that are available, and energy levels. Flow routing and spectrum/energy management are hence simple and structured. SUs must interact with the spectrum server while the algorithm is running, and the centre must inform users of the results of the energy level and allocation. Since communication takes place in a band outside of the spectrum that is being hired, it is assumed that interactions between SUs and the spectrum server have no effect on spectral efficiency.

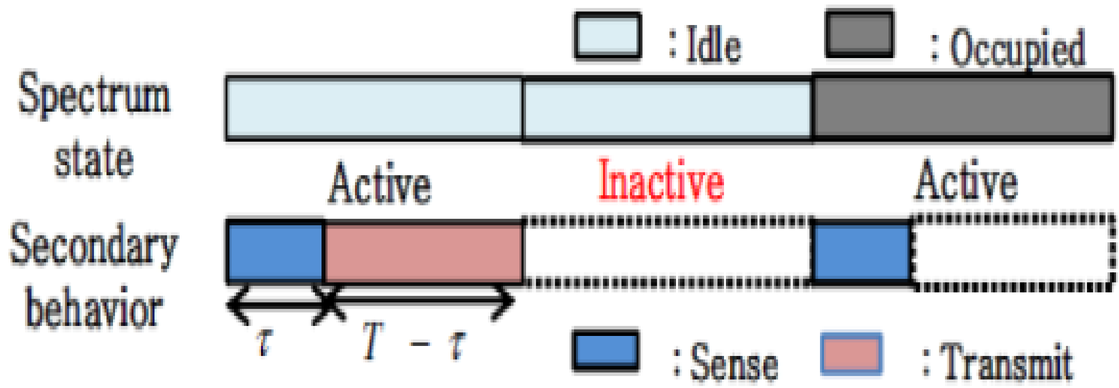

Figure 1. Opportunistic spectrum access of energy-harvesting cognitive radio (CR).

ST must accurately sense spectrum holes in order to avoid collisions with the primary pair. By synchronising with the primary pair, the secondary pair senses the spectrum using the battery's remaining energy. The energy needed for sensing for that ST is saved because it is not necessary to sense channels τ if the ST is outside of the PT's interference range because it can use that channel even if it is busy. The transmission period is represented as $T - \tau$ if the sensing period is defined as and the time slot as T, as shown in Figure 1.

3.2 JOINT OPTIMAL TIME AND POWER ALLOCATION ALGORITHM

In order to address problem (1), we first offer the thesis that follows, which establishes the connection between the best resource allocation and the greatest end-to-end throughput.

$$CO: R_k(T_k, e_k) \geq R, k = 1, \dots K, \qquad (1)$$

$$\text{C1, C2, C3 and C4} \qquad (2)$$

Based on the convexity of problem (1), problem (2) is also a convex optimization problem and satisfies Slater's condition. Thus, the duality gap between the primal problem and its dual problem must be zero, which motivates us to solve the dual problem instead. The partial Lagrangian function of problem (2) with respect to C0 is expressed as

$$\mathrm{L}(\tau = e, \lambda) = \sum_{k=1}^{k} (R_k(T_k, e_k) - R)$$

Let D stand for the possible set of (τ , e) that C1 − C4specify. Then, issue (1's Lagrange dual function is written as

$$g(\lambda) = \min_{(T,e)\in D} L(\tau = e, \lambda)$$

With $\lambda_k$standing for the nonnegative dual variable connected to C0, where$\lambda = [\lambda_1, \dots, \lambda_k]$. Specified by C1, C2, C3 and C4 ,let D be the possible set of τ , e).

For the reasons listed below, this algorithm can reach its ideal state. The optimal for the given and can be reached first as and e fulfilling the KKT condition are successively optimised. We can then ensure that the solution converges to the optimum for the given R due to the convex character of problems (1) and (2), by using the ellipsoid approach to update and. As a result of the bisection search method's assured convergence and optimality, R will also converge to the optimum.

IV EXPERIMENTAL RESULTS

The numerical findings used to assess the effectiveness of the suggested energy harvesting CR techniques are shown below. 110 mW was used as the detecting power. The energy required for both sensing and transmission is included in the energy levels used to create overlay and underlay transmissions. As a result, if the sensing and transmission times are 0.002 milliseconds and 0.098 milliseconds, respectively, and the sensing, overlay, and underlay transmit powers are 110 mill watts, 50 mill watts, and 30 mill watts,

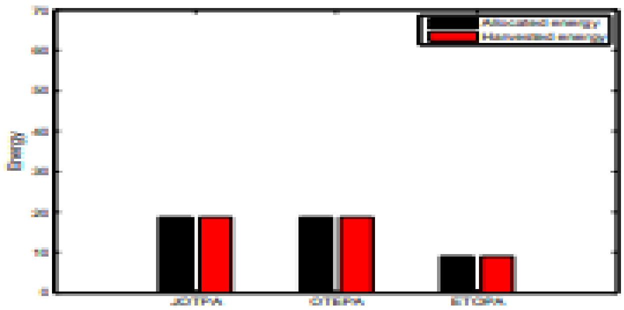

Fig. 2. R ∗ versus K for different scenarios: Pt = 40 dB, Ip = 10 dB

The fact that all of the SUs' gathered energies have been assigned is another noteworthy finding in Fig. 2. Because PR's interference power constraint is so lax, SUs can employ all of the gathered energies to increase throughput.

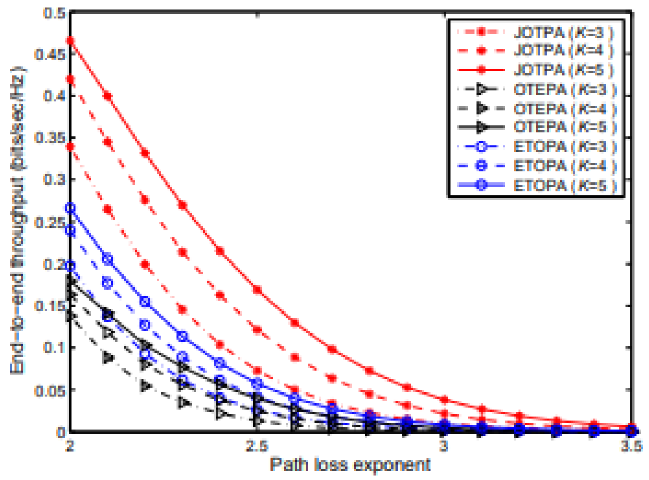

Fig. 3. SUs' energy statuses in Scenario 2 using various algorithms: Ip = 5 dB, K = 3, and Pt = 40 dB..

Multi-hop transmission is an effective way to overcome the impact of path loss, as is evident in Fig. 3, where R increases as K grows. However, as the throughput benefit does not always rise with K, K cannot be arbitrarily raised. When = 2, for instance, JOTPA gains throughput from K = 3 to K = 4 by 23.72%, but only by 10.86% from K = 4 to K = 5.

CONCLUSION

In a hybrid cognitive radio network with primary receiver SINR constraints, this study focused on performance maximisation of an m-channel distribution of secondary users with harvesting capabilities. In a hybrid cognitive radio network where STs can gather from RF signals, a unique technique has been presented to assign numerous channels. A metric that enables each ST's prioritisation during channel allocation was proposed in order to maximise allocation performance. Using this paradigm, we looked into the end-to-end throughput maximisation problem while taking into account the interference power constraint and the energy causality restriction. We then presented the JOTPA method to accomplish the best resource allocation. Additionally, we found that JOTPA achieves higher end-to-end throughput and higher green energy utilisation than ETOPA and OTEPA under all situations considered by comparing three alternative resource allocation algorithms.

REFERENCES

1. Hasan, Z.; Boostanimehr, H.; Bhargava, V.K. Green Cellular Networks: A Survey, Some Research Issues and Challenges. *IEEE Commun. Surv. Tutor.* 2011, *13*, 524–540. [Google Scholar] [CrossRef][Green Version]
2. Cai, L.X.; Poor, H.V.; Liu, Y.; Luan, T.H.; Shen, X.; Mark, J.W. Dimensioning network deployment and resource management in green mesh networks. *Wirel. Commun.* 2011, *18*, 58–65. [Google Scholar] [CrossRef]
3. Cuadras, A.; Gasulla, M.; Ferrari, V. Thermal Energy Harvesting Through Pyroelectricity. *Sens. Actuators A Phys.* 2010, *158*, 132–139. [Google Scholar] [CrossRef]
4. Kolodzy, P.; Avoidance, I. Spectrum policy task force report. *Fed. Commun. Comm.* 2002, *40*, 147–158. [Google Scholar]
5. Mitola, J.; Maguire, G.Q. Cognitive radio: Making software radios more personal. *IEEE Pers. Commun. Mag.* 1999, *6*, 13–18. [Google Scholar] [CrossRef][Green Version]
6. Zhang, L.; Liang, Y.-C.; Xin, Y. Joint beamforming and power allocation for multiple access channels in cognitive radio networks. *IEEE J. Sel. Areas Commun.* 2008, *26*, 38–51. [Google Scholar] [CrossRef]
7. R. Zhang and C. K. Ho, “MIMO broadcasting for simultaneous wireless information and power transfer,” IEEE Trans. Wireless Commun., vol. 12, no. 5, pp. 1989–2001, May 2013.

8. A. Goldsmith, S. A. Jafar, I. Maric, and S. Srinivasa, “Breaking spectrum gridlock with cognitive radios: an information theoretic perspective,” Proc. IEEE, vol. 97, no. 5, pp. 894–914, May 2009.
9. W. Chung, S. Park, S. Lim, and D. Hong, “Spectrum sensing optimization for energy-harvesting cognitive radio systems,” IEEE Trans. Wireless Commun., vol. 13, no. 5, pp. 2601–2613, May 2014.