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Efficient spectrum sharing with avoiding spatial fragmentation of white space

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Abstract

This letter proposes an efficient spectrum sharing by using a smart channel selection with considering the spatial shape of white space (WS) for cognitive radio systems. Here, we consider the environment in which secondary users (SUs) share the same spectrum with multiple channels. In such situation, the assignment channel avoiding spatial fragmentation is important because other SUs can easily access to remaining WS. In this paper, we utilize a perimeter to area ratio of WS for channel assignment as a criterion for evaluating value of remaining WS. We confirm the effectiveness of the proposed spectrum sharing method by using computer simulations.

Keywords: Spectrum sharing; White space; Channel assignment

1. Introduction

Due to rapid growth of spectrum usage for mobile communications, how to find spectrum resource for future mobile communication is a key issue to growth sustainable connected community via wireless networks [1]. Spectrum sharing between primary users (PUs) and secondary users (SUs) by using cognitive radio technologies is a solution for effectively improving spectrum efficiency [2]. In such spectrum sharing system, there are lots of works discussing how to share the spectrum without giving harmful interference toward a PU from SUs. Spectrum sensing and spectrum database technologies can be considered for finding white space (WS), which is unused spectrum by PU. While almost all researches considering spectrum sharing attract attention to methods for finding WS and protecting PU, it is also required to consider methods for sharing WSs among multiple SUs without interfering each other and with improving spectrum efficiency [3]. Some papers propose a channel assignment method for SUs under existing multiple WS candidates. Refs. [4,5] propose auction based spectrum allocation methods for multiple SUs. However, these researches do not consider the spectrum efficiency for sharing the same channel in a space domain. In [6], a channel assignment method for maximizing the SU communication quality is proposed. In this research, the distance between SUs on the same channel is maximized to minimize the mutual interference among SUs. This method can maximize the quality of SUs when the number of SUs is small. However, the spectrum resources are fragmented in a space domain when the number of SUs becomes large and the reaming spectrum resources for new SUs are limited. In order to solve a spectrum fragmentation problem by sharing the same channel among multiple SUs, we have to consider a scheme to densely pack multiple SUs among available WSs for remaining valuable WS to new SUs.

In this letter, we propose a novel channel assignment scheme for SUs based on the perimeter to area ratio of WS, which is a new criterion for evaluating the value of reaming WS after channel assignment. The perimeter to area ratio of WS can be used for estimating the shape and the area of the remaining WS suitable for a new SU. This is because the larger perimeter to area ratio means complex shape of WS under the same area and also small area of WS under the same shape. The true circle with large area, which is suitable WS for a new SU, obtains the small perimeter to area ratio. Therefore, in this letter, a central control server for SUs uses the perimeter to area ratio

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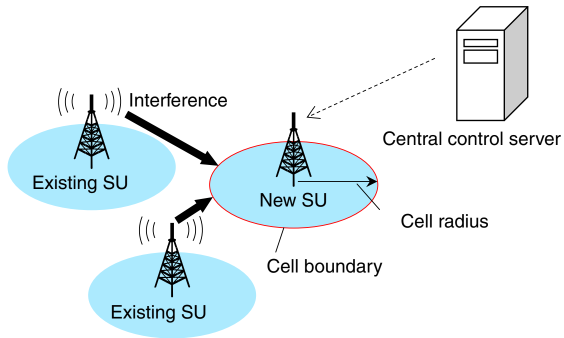

Fig. 1. System model of the proposed channel assignment.

of WS as a criterion of value of the remaining WS and assigns the channel to minimize the difference of the perimeter to area ratio of WS before and after joining a new SU. In order to evaluate the effectiveness of the proposed channel assignment, we perform computer simulations. We can confirm that the proposed channel assignment scheme increases the number of SUs and new SUs can effectively utilize WS.

The rest of this letter is organized as follows. Section 2 explains a system model assumed in this letter. In Section 3, the proposed channel assignment procedure is shown. Section 4 shows the effectiveness of the proposed method by using computer simulation. Finally, conclusion is given in Section 5.

2. System model

2.1. Channel assignment among multiple SUs

In this letter, we consider a channel assignment strategy for multiple SUs sharing the same WS spectrum. Here, we assume the PU of this spectrum is located far away from these SUs and there is no interference between PU and SUs. Therefore, we just focus on the channel assignment among SUs without consideration of PU situation. The system model considered in this letter is shown in Fig. 1. We assume the system of SU consists of a fixed base station and forms coverage area of downlink within the cell boundary for avoiding interference between other SUs. The channel of each SU is assigned by a central control server from multiple candidate WS channels according to the assignment strategy discussed in Section 3. The central control server has the information of each SU system such as location, transmit power, cell radius and the minimum required signal power to interference plus noise power ratio (SINR). The channel is successively assigned to each SU.

2.2. Propagation and interference model

In this letter, the interference among SUs is calculated by the average SINR obtained from the propagation loss based on the exponential propagation loss model. The propagation loss of the exponential propagation loss model is shown by

$$L_{pathloss}(d) = -10\log_{10}\left(\frac{\lambda}{4\pi d_0}\right) + 10n\log_{10}\left(\frac{d}{d_0}\right), \quad (1)$$

where $L_{pathloss}(d)$ is the propagation loss in dB at a distance of d meters from the transmit antenna of SU, λ is the wavelength of the carrier frequency, n is the propagation factor, d_0 denotes a reference distance. The received power of the desired signal and the interference power from other SUs is calculated according to Eq. (1). In this letter, we do not consider the fading and shadowing effects for designing the channel assignment. The unstable received signal power is treated by the margin of transmit power at the channel assignment.

2.3. Perimeter to area ratio of WS

In the proposed channel assignment method, we utilize the perimeter to area ratio of WS η, which is calculated by

$$\eta = \frac{L}{S}, \quad (2)$$

where L denotes the perimeter of WS and S denotes the area of WS. If the area of WS is the same, the perimeter to area ratio becomes large when the shape of WS is complex. On the other hand, the perimeter to area ratio is minimum when the shape of WS is true circle. If the shape of the WS is the same, the perimeter to area ratio becomes large when the area of WS is small. Usually, the simple shape with large area WS is suitable for SUs because the large transmit power can be utilized. From this point of view, we consider the perimeter to area ratio of WS is used for criterion of choosing appropriate WS when the multiple candidate channels of WS can be selected.

3. Proposed channel assignment method

In this letter, we utilize the perimeter to area ratio of WS for evaluating the value of remaining WS when the central control server assigns the channel to a new SU. In the proposed channel assignment method, the perimeter to area ratio is minimized to remain the shape of WS to be valuable for other SUs. Therefore, if a new SU requests a channel in WS, the central control server assigns the channel with the minimum difference perimeter to area ratio of remaining WS before and after assignment of a new SU with keeping the minimum required SINR at all surrounding SUs. The detail assignment procedure is shown below.

(1) *Checking minimum required SINR*

When the new SU requests the channel on WS, the central control server checks the SINR at the new SU and surrounding SUs by calculating the received power of the desired signal and the aggregated interference from other SUs. The received signal power from ith SU at the arbitrary point (x, y) is calculated as,

$$P_i(x, y) = 10^{\left(\frac{P_{i,dBm}}{10}\right)},$$
$$P_{i,dBm} = W_i - L_{pathloss}\left(\sqrt{h_i^2 + D_i^2(x, y)}\right), \quad (3)$$

where the gain of each antenna is defined as 0 [dBi], i denotes ID of SU, $P_i(x, y)$ denotes the received power from, ith SU at the arbitrary point (x, y) in mW, W_i is the transmit power of ith SU in dBm, h_i is the antenna height of ith SU. Then, $D_i(x, y)$ denotes the distance between the point (x, y) and the coordinate point of ith SU given by,

$$D_i(x, y) = \left(\sqrt{(x_i - x)^2 + (y_i - y)^2}\right). \quad (4)$$