인지무선 네트워크에서 통계적 특성을 이용한 채널선택기법

논 문
60-9-20

Channel Selection Scheme using Statistical Properties in the Cognitive Radio Networks

박 형 근*
(Hyung-Kun Park)

Abstract - In a CR (cognitive radio) network, channel selection is one of the important issues for the efficient channel utilization. When the CR user exploits the spectrum of primary network, the interference to the primary network should be minimized. In this paper, we propose a spectrum hole prediction based channel selection scheme to minimize the interference to the primary network. To predict spectrum hole, statistic properties of primary user's traffic is used. By using the predicted spectrum hole, channel is selected and it can reduce the possibility of interference to the primary user and increase the efficiency of spectrum utilization. The performance of proposed channel selection scheme is evaluated by the computer simulation.

Key Words : Cognitive radio MAC, Channel opportunities, Cognitive radio, Channel selection, Spectrum hole

1. Introduction

New wireless systems are introduced and wireless service and applications increases, the demands of spectral resource have been increased. However, almost all the spectrum bands already allocated to the conventional radio systems and the shortage of wireless spectrum becomes a serious issue in the wireless communications. In order to solve the problem of spectrum shortage and utilize the spectrum more efficiently, the FCC has recently suggested a new concept for dynamically allocating the spectrum resource[1], which is called cognitive radio technologies. Cognitive radio technology was proposed to increase the spectrum utilization in both licensed and unlicensed bands by using the spectrum hole for the secondary users in the way that coexist with primary users. In CR network, a licensed user has the right to use the allocated spectrum. However, the secondary user could use the spectral resource when it is not utilized and should vacate the spectrum when the primary user intends to use the spectrum. The secondary user should not introduce interference with primary networks.

MAC (medium access control) is one of the important parts of cognitive network. It plays an important role in the key functions of cognitive radio. Since the frequency bands allocated to a licensee have the exclusiveness of using this resource, a CR MAC protocol should not only utilize spectrum efficiently but also avoid interference and protect the primary users. One of the important issues is how to allocate channels to the CR users. The interference to the primary networks and efficiency of spectrum utilization seriously depend on the channel selection scheme.

Spectrum allocation should be designed to improve spectrum efficiency without interfering with the transmission of other licensed users. There have been several researches to design the opportunistic MAC protocol to reduce interference to the primary networks and increase the spectrum utilization. In opportunistic spectrum access MAC protocol[2], each CR user has a single transceiver and exchanges control information in a dedicated control channels, and all of the secondary users are synchronized by periodic beacon transmissions. The proposed MAC doesn't consider the characteristics of channel, such as utilization of primary, traffic pattern and transmission rate and so on, and chooses the available channels randomly. Statistical channel allocation (SCA) was proposed for the ad-hoc CR networks[3]. The SCA-MAC predicts the successful transmission rate for all the idle channels and their combinations based on the channel utilization. However, the complexity of SCA-MAC exponentially grows as the number of idle channels increases. Opportunistic cognitive MAC (OC-MAC) using spectrum hole prediction was proposed [4]. The OC-MAC protocol is to predict the remaining

* 정 회 원 : 한국기술교육대학교 정보기술공학부 부교수・공박
E-mail : hkpark@kut.ac.kr
접수일자 : 2011년 5월 12일
최종완료 : 2011년 8월 29일

idle time according the channel utilization and probability theory. OC-MAC considers the selection of single channel and does not support multi-channel transmission.

In this paper, we propose a spectrum hole prediction based opportunistic channel selection scheme which support multi channel transmission. By using the predicted spectrum hole, the interference to the primary user can be reduced and it can increase the spectrum efficiency.

2. Channel selection Using spectrum hole prediction

When the CR users intend to utilize the primary network, they sense the channels and find the spectrum hole. To predict the spectrum hole, it is very important to develop a detail understanding of traffic characteristics of primary network. One of the most widely used traffic model is the Poisson Model [5]. The memory less Poisson distribution is the predominant model used for analyzing traffic in traditional telephony networks. In this paper, we modeled a primary user's traffic pattern in each channel as an Poisson distribution model.

$$s_i(t) = A_i e^{-\lambda_i t} \quad (1)$$

where λ_i is the primary user's packet arrival rate in the channel i ,and each channel may have different arrival rate. When CR user predicts spectrum hole, it senses the channels and selects the idle channels and we can write the initial value $A_i = 1$.

We define the spectrum hole t_h as the time duration that satisfy the minimum sucess probability α. The threshold α is the required minimum success probability of each subcarrier. The minimum success probability α does not means the success probability of multi channel transmission but the success probability of each single channel. The success probability is the probability that the CR user transmits packet without interference to primary user. Each channel is divided into several small time slots and spectrum hole t_h can be represented as the number of time slots, N_h.

When the CR user transmit packet using the spectrum hold N_h, the sucess probability should be greater than the threshold α.

$$\alpha \le s_i(N_{h,i} T_{slot}) = e^{-\lambda_i N_{h,i} T_{slot}} \quad (2)$$

where T_s is the time duration of a time slot. The spectrum hole is the maximum number of slots that satisfies Eq.(2) ,and we can get the number of time slots of spectrum hole as follows

$$N_{h,i} \approx \left\lfloor -\frac{\log\alpha}{\lambda_i T_{slot}} \right\rfloor \quad (3)$$

The spectrum hole N_h can be different according to the packet arrival rate λ and each channels may have different N_h value. N_h means the maximum number of time slots that can be used by CR users while it maintains the success probability α.

In the cognitive radio networks, to minimize the interference to the primary network is the most important factor. In the multi-channel transmission, CR users should select channels to minimize the interference to the primary user and it maximizes the success probability. If a CR user needs $N_{d,tot}$ time slots and uses the L channels to transmit the packets, the success probability of transmission is

$$S = \prod_{i=0}^{L-1} s_i(N_{d,i} T_{slot}) = e^{-T_{slot}\sum_i \lambda_i N_{d,i}} \quad (4)$$
$$N_{d,0} + N_{d,1} + \cdots + N_{d,L-1} = N_D$$

where $N_{d,tot}$ is the required total number of time slots to transmit CR user's packet and $N_{d,i}$ is the number of time slots allocated to the channel i. We then define the vector $\overline{N_d} = [N_{d,0}, N_{d,1}, \cdots N_{d,L-1}]$. CR users should find the $N_{d,i}$ values to maximize the success probability. Using the following equation, we can find vector $\overline{N_d^*} = [N_{d,0}^*, N_{d,1}^*, \cdots N_{d,L-1}^*]$ to maximize success probability.

$$\overline{N_d^*} = \underset{\overline{N_d}}{\operatorname{argmin}} \sum_{i=0}^{L-1} \lambda_i N_{d,i} \quad (5)$$
$$\text{subject to } \sum_{i=0}^{L-1} N_{d,i}^* = N_{d,tot}$$

To minimize $\sum \lambda_i N_{d,i}$ value in (5) , $N_{d,i}$ should be highest value for the channel with smallest λ_i. It requires complex calculation to find the channels having the minimum interference length because we should compare the all the cases of channel combinations. However, CR user simply allocate more time slots to the channel with smaller arrival rate λ_i to maximize success probability. As the number of channels used by CR user increases, the CR user can increase the transmission rate but sucess probability can decrease. If the channels has same λ_i value, CR users can uses all the channels to reduce the transmission time. In that case, the same amount of data is transmitted through the each channel. Fig. 1 shows the example of the channel selection and time slot allocation to transmit CR user's packet.

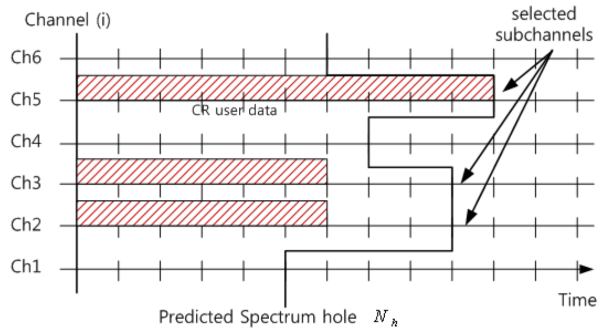

그림 1 CR데이터 전송을 위한 채널선택 슬롯할당의 예
Fig. 1 Example of channel selection and slot allocation for CR data transmission

3. Simulation and results

We evaluated the performance of proposed channel selection scheme via computer simulation. For the simulation environment, we considered one primary network and one cognitive radio network. The arrival process of primary service is modeled as an independent Poission process with mean arrival rate λ_i for channel i and service duration has the exponential distributed with mean service duration $1/\mu_i$. The parameter μ_i is the mean service rate for channel i and it was set to 1/60 (1/sec). We assumed that the number of channels is 16, the slot time is $20\mu\text{sec}$ and the packet size is 2048 bytes.

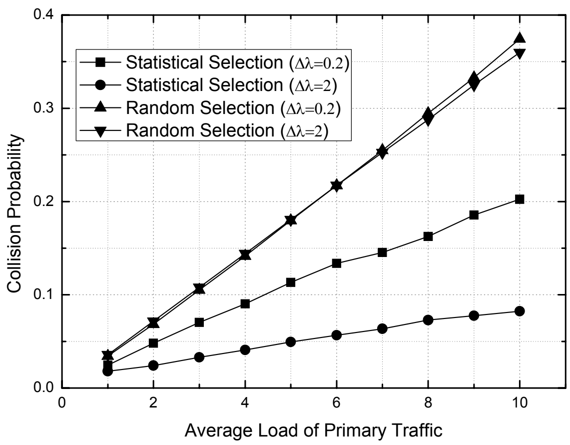

그림 2 평균부하와 정규화된 도착률 범위에 따른 충돌확률
Fig. 2 Collision probability according to average load and normalized range of arrival rate.

We compared the performance of proposed selection scheme with conventional simple method. The conventional method is random channel selection among the free channels without spectrum hole prediction. Fig. 2 shows the collision probability of the proposed channel selection scheme and the conventional scheme. As shown in Fig. 2, conventional channel selection has too high collision with primary user's data and the proposed channel selection has much lower collision probability. As the normalized range of primary traffic load ($\Delta\lambda$) increases, the proposed section scheme gets more opportunity to select better channel. Whereas random channel selection scheme does not depends on the difference of channel characteristics and has worse performance than the proposed one.

5. Conclusion

Channel selection is one of the most important fuction in the cognitive radio networks. Cognitive users should select channels not to interfere the primary network. In this paper, we proposed opportunistic channel selection scheme using the spectrum hole prediction. By using the statistical method, we predict the spectrum hole and reduce the interference to the primary user. Simulation results show that the proposed channel selection scheme can achieve lower collision with the primary network than conventional channel selection scheme such as random selection.

감사의 글

이 논문은 2010도 한국기술교육대학교 연구제 파견 연구비 지원에 의하여 연구되었음

REFERENCE

[1] M. Mchenry, "Spectrum white space measurements," New America Foundation Broadband Forum, June 2003
[2] Long Le and Ekram Hossain, “OSA-MAC: A MAC Protocol for Opportunistic Spectrum Access in Cognitive Radio Networks,” in WCNC, 2008.
[3] A. C.-C. Hsu, D. S. L. Wei, and C.-C. J. Kuo, “A cognitive MAC protocol using statistical channel allocation for wireless ad-hoc networks,” in IEEE WCNC, March, 2007.
[4] shao-yi hung, eric hsio-kuang wu and gen-huey chen, “an opportunistic cognitive MAC protocol for coexistence with WLAN” in IEEE Journal on Selected Areas in Communications, 6, 2008
[5] Marathe, M., and Hawe, W. “"Predicted Capacity of Ethernet in a University Environment,” Proceedings of Southcon 1982, March 1982, pp 1-10