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Delay-Constrained Application Feasibility of Bandwidth Variable Cognitive Radio Systems using Random Access

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Abstract. In this paper, delay-QoS-provisioning capability of the random access-operated secondary network is analyzed. The performance of the delay-QoS-provisioning capability is evaluated in terms of the probability that delay-QoS is violated while the minimum required throughput is satisfied. Through analyzing the delay-QoS-provisioning capability of the secondary network, we can evaluate the feasibility of secondary applications which the random access-operated secondary network can.

Keywords: Cognitive Radios, Random Access, QoS-Provisioning

1 Introduction

Recently, the scarcity of spectral resource has become the most important issue because the spectral efficiency almost reaches the Shannon's capacity limit [1]. In order to increase capacity of wireless communication systems, more spectral resources should be secured. In such situations, it can be cost-efficient way to increase the capacity of wireless communication system that we can use unutilized spectral resource. LTE-U [2] might be a good example to make use of under-utilized ISM band as well as IEEE 802.11af [3].

In this paper, we investigate the performance of cognitive radio system using random access [4][5]. Especially, we evaluate the feasibility of delay-constrained applications such as real-time applications including voice service [6]. In cognitive radios, radio system parameters can be adjusted via software-defined radio manners. Hence, according to the adjustment of radio parameters of cognitive radios, it will be shown that what real-time application can be feasible in random-access operated-cognitive radio environments. Further, we can know what number of users can be simultaneously supported in an amount of unused spectral resources.

We evaluate three delay-constrained applications: voice service, real-time collaboration and file transfer, which are, respectively, representatives of low data rate with moderate delay constraint, middle data rate with tight delay constraint and high data rate with loose delay constraint. Through these feasibility evaluations, we can take a view of potential role of cognitive radio in future wireless communication systems.

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2 Application Feasibility

Two representative secondary applications are considered with the minimum required throughput and delay constraint in Table 1 [6].
Voice telephony requires only a little throughput with a moderate delay constraint. Real time collaboration is the class including video conference, real-time gaming and real-time video services, which represents secondary applications requiring relatively high throughput with a very tight delay constraint. File exchange service just need large throughput with a loose delay requirement.

The bandwidth of an idle channel is assumed as 6Mhz according to one digital TV channel in North America [7]. For the CSMA protocol, the minimum contention window size is sixteen times of a contention slot, and the maximum number of backoff stages is six, which is one of mandatory modes in [8]. If the minimum contention window size and the maximum number of backoff stage is fixed, the transmission probability can be determined for a given value of the number of secondary users [9]. For examples, in this case, transmission probability p_t is set at 0.0526 for ten secondary users and $p_t = 0.0409$ for fifteen secondary users. If we additionally select the payload length, we can calculate the delay violation probability. Although the operating value of frame length L can be varied depending on what application should be mainly supported, we focus on voice telephony service in this design example.

Table 1. Throughput requirements and delay constraints of application classes

Service Class	Min. Throughput Requirement	Delay Constraint
Class 1: Voice telephony	U_0 = 64*kbps*	D_{th} = 50*ms*
Class 2: Real time collaboration	U_0 = 2*Mbps*	D_{th} = 20*ms*

2.1 Class 1: Voice Telephony

To support the voice telephony service, 3200 bits should be transmitted per every 50 ms. We assume the lowest operable SNR(signal-to-noise ratio) value $\gamma = 3$ dB, and data transmitted in a payload 3200 bits We set frame length at $336.5\mu s$. Generally, the quality of voice telephony service is very sensitive to delay violation performance. Hence, we assume that the voice telephony service can be provided while the delay violation probability is maintained below 0.01.

Using those values, we can evaluate the delay violation probability as the number of secondary user increases via computer simulations. Simulation results show that this secondary network can support twenty voice telephony links with less than one percentage of the delay violation.

Let us consider the situation that the idle bandwidth or the SNR value of secondary users increases. The result of this case is that there is no improvement in the delay violation probability because the frame length is the smallest value among what we can choose. Therefore, even if the idle bandwidth and SNR value of secondary users increases, there is no performance in the delay violation probability.

2.2 Class 2: Real time collaboration

The delay violation probability of the real time collaboration is plotted in Fig. 1. Using the same payload length, this secondary network can support three and four secondary users with an idle TV channel and doubled idle channels, respectively, while the condition that the delay violation probability below 0.01 is satisfied. In this example, there is a room to improve the delay violation probability. When the idle bandwidth is doubled, three frames with the same frame length with the voice service should be transmitted. However, although the frame length is reduced to $321.2\mu s$, the number of frame transmitted is still three. Therefore, we can slightly decrease the delay violation probability. If we further reduce the frame length to make the number of frame transmitted be four, this secondary network can finally support five users using this class of application with the delay violation probability below one percentage. However, on the contrary, too reduced payload length causes increased delay delay violation probability because time consumed for the contention process increases as the number of frame transmitted in random access.

Subsequently, we investigate the effect of frame length control in this example on the delay violation probability of voice telephony service. Although the payload length is reduced until the frame length reaches the half of the initial payload length $336.5\mu s$ when the idle bandwidth is doubled, the number of frame transmitted that secondary users experience is still one. Therefore, the delay violation probability to voice telephony service is maintained, or even can be improved. However, if the payload length is controlled below the half of or over $336.5\mu s$, the performance of voice telephony service should be degraded.

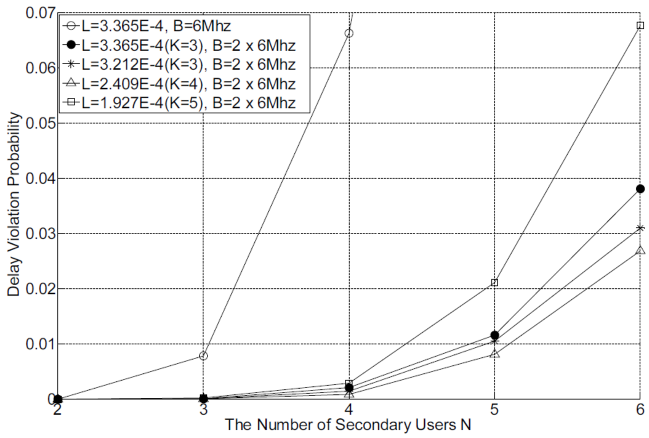

Fig. 1. Delay violation probabilities of real time collaboration

3 Conclusion

In this paper, we investigated the delay performance of cognitive radio network based on random access. Utilizing the frequency agility, it was shown that delay performance can be adjustable via frequency agility nature of cognitive radios. Service feasibility of two real-time applications was evaluated. Through this investigation, we can exactly make a decision about what application can be implemented in cognitive radios based on random access.

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