Average waiting time analysis in Cognitive Radio With and Without Relaying Capability

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Abstract

This paper presents average waiting time analysis in Cognitive Radio with and without relaying capability. We perform theoretical analysis by applying M/D/1 queuing scheme in order to find the waiting time in queue. Result indicates that the benefits of relaying for primary link depends on the data traffic characteristics of the primary user.

I. INTRODUCTION

In order to enhance network performance, the idea that combines cognitive and cooperative in a capacity view is presented by [2] which adds relaying capability to the secondary transmitter and relies on stability (i.e., finiteness of all the queues in the system at all times) as the criterion of performance. And the queuing analysis of priority queuing base on M/D/1 priority queuing scheme with perfect sensing conditions was presented in [1]. In this paper, we perform waiting time analysis in system model base on [2]. Poisson processes are assumed for packet arrivals and we use modified M/D/1 system to analyze the network performance. We use results from queuing to study time slotted cognitive radio system with one primary and one secondary link in case of sensing is not perfect and there are two kinds of errors: false alarm and missed detections.

II. SYSTEM MODEL

We adopted similar model as used in [2] where the authors considered a cognitive network with one primary and one secondary links as follow.

We consider time-slotted transmission where all packets have the same size and one time slot is required for transmission of a single packet. In addition, we assume that the size of all buffers is of infinite length. The packet arrival processes of self traffic at each node are independent and with constant arrival rates λ_P and λ_S for the primary and secondary users respectively. Note that transmission of packets can only start at the beginning of the slot, so that even if a packet arrives at the middle of

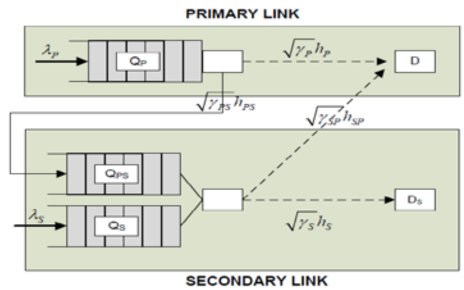

Fig.1. MAC and PHY layer view with one primary and one secondary single link with cognitive relaying capability

the slot, it has to wait half of the slot duration, even if the channel is free.

The radio propagation between any pair of nodes is assumed to be affected by *independent stationary Rayleigh flat-fading* channels $h_i(t)$ with $E[|h_i(t)|^2] = 1$ (t denotes time and runs over time slots). The average channel power gain (due to shadowing and path loss) is denoted by γ_i , where i reads "P" for the primary connection, "S" for the secondary, "SP" for the channel between secondary transmitter and primary receiver, and "PS" for the channel between primary transmitter and secondary transmitter. The cognitive node is able to correctly detect the transmission of the primary user if the instantaneous SNR $\gamma_{PS}|h_{PS}|^2$ is larger than a threshold α. Moreover, it is assumed that whenever the primary user is not transmitting, the secondary transmitter is able to detect an idle slot with probability P_{FA} of error (false alarm).

III. ANALYSIS BASED ON QUEUING

The waiting time analysis of primary user is analyzed in this part. The waiting time of a packet consists of three parts: time until the beginning/start of the next slot, time spent in a queue waiting time for the service to begin, and the average service time (transmission time). The packets of both users are served according to a first come first served discipline (FCFS).

Starting from the analysis result of M/G/1, known as Pollaczek-Khinchin and the fact that the M/D/1(where service times are assumed to be deterministic) is a special case of M/G/1 [3] and following similar steps as in [1] we have the average waiting time in queue W_P^Q for primary user:

$$W_P^Q = T_D + N_P^Q / \mu_P \quad (1)$$

Where T_D is the waiting time until the beginning of a slot, μ_P is service rate of primary user without relaying and N_P^Q is average number of packets in queue. Using Little's theorem [3], we have $N_P^Q = \lambda_P W_P^Q$ therefore we obtain:

$$W_P^Q = T_D + N_P^Q/\mu_P = T_D + \lambda_P W_P^Q/\mu_P \quad (2)$$

Then we obtain:

$$W_P^Q = \frac{T_D}{1-\lambda_P/\mu_P} \quad (3)$$

Total waiting time in system is given by summation of the waiting time in queue and the average service time of the packet. So we have the expressions for the waiting time for primary user W_P without relaying:

$$W_P = \overline{X} + \frac{T_D}{1-\lambda_P/\mu_P} \quad (4)$$

where $\overline{X} = 1/\mu_P$ = average service time. We assume that on average a newly arrived packet has to wait for 1/2 slot before the beginning of slot. In [2] the paper shows that the primary user selects its own arrival rate λ_P, ignoring the presence of a secondary node. It is then the task of the cognitive user to select its transmission node (here the power P_S) in order to exploit , as much as possible the idle slots left available by the primary activity while not affecting the stability of the system. So we assume that with arrival rate λ_P, primary user can choose the service rate to maximize the stable throughput of the system. With this assumption, we obtain:

$$W_P = \frac{1}{\mu_P} + \frac{1/2}{1-\lambda_P/\mu_P} \quad (5)$$

where μ_P is defined in [2] by (17). Similarly, we obtain the average waiting time W_P^{rel} for primary user with relaying:

$$W_P^{rel} = \frac{1}{\mu_P^{rel}} + \frac{1/2}{1-\lambda_P/\mu_P^{rel}} \quad (6)$$

where μ_P^{rel} is service rate of primary user with relaying and defined by (15) in [2].

IV. NUMERICAL RESULTS

The parameters are $\beta_P/\gamma_P = \beta_S/\gamma_S = -5$ dB, $\gamma_{SP} = 10$, and $\alpha/\gamma_{PS} = -5$ dB. With these parameters the probability of error detection is Per = 0.27 and the maximum service rate is $\mu_P^{max} = 0.73$, we also choose probability of false alarm $P_{FA} = 0.3$.

Fig.2 presents the delay for the primary user, as can be seen that without relaying, the average waiting time of primary user increases when the arrival rate go to μ_P^{max}. However, in case of relaying, the average waiting time of primary user are small and stable when λ_P goes to μ_P^{max}.

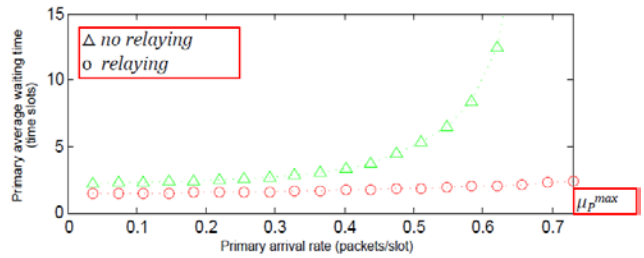

Fig.2. Average waiting time for the primary user.

V. CONCLUSION

In this paper we analysis the waiting time in Cognitive Radio with and without relaying capability in case of imperfect sensing by using M/D/1 model. The analysis showed the great effect of relaying capability on the waiting time of primary user. The results can also be used to evaluate the performance of the cognitive radio. In future work the analysis could be extended to secondary user and also to model with multi-user system.

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