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OPTIMIZATION OF A PROBABILISTIC INTERRUPTION MECHANISM FOR COGNITIVE RADIO NETWORKS WITH PRIORITIZED SECONDARY USERS*

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Abstract: In this paper, taking the various transmission needs of network users in cognitive radio networks into consideration, we analyze the system performance of cognitive radio networks by considering prioritized secondary users (SUs). The SUs are divided into SUs with higher priority (named SU1) and SUs with lower priority (named SU2). Unlike the preemptive and non-preemptive mechanisms proposed in conventional cognitive radio networks with prioritized SUs, in this paper, we propose a probabilistic interruption mechanism to balance the performance between the two types of SUs. We assume that if an SU1 packet arrives and finds the channel is being occupied by an SU2 packet, this SU1 packet will interrupt the SU2 packet's transmission with a probability (referred to as an interrupting index). In order to adapt to the digital nature of communication networks, based on the system actions of different types of packets, we build a discrete-time Markov chain model to derive the formulas for some important system performance measures. To assess the influence of the interrupting index on the system performance, we demonstrate the numerical results of different performance measures with respect to the interrupting index. Finally, from the perspective of the SU1 packets, we build an optimal function to obtain the optimal interrupting index under different parameter settings.

Key words: *cognitive radio networks, prioritized secondary users, probabilistic interruption mechanism, Markov chain, optimization*

Mathematics Subject Classification: *68M10, 68M20*

1 Introduction

Developing new strategies for enhancing spectrum utilization is currently a research focus in the field of communication networks [2]. Some researchers have put forward the idea that opportunistic spectrum occupancy can improve spectrum utilization, and thus cognitive radio networks are worthy of close attention [10]. In cognitive radio networks, secondary users (SUs) can use the spectrum opportunistically without disturbing the transmission of the primary uses (PUs) [3].

Conventional cognitive radio networks have only considered single class of SUs. However, SUs can generally have different priorities. For example, SUs with real time applications

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have a higher priority than SUs with non-real time applications [5]. This has necessitated the introduction of prioritized SUs into cognitive radio networks [11].

In recent years, some papers have begun to focus on the analysis for cognitive radio networks with prioritized SUs. Given the premise that PUs have the highest priority in cognitive radio networks, the interaction between SUs with different priorities has been classified as preemption and non-preemption [13].

In the preemptive mechanism, a higher priority SU can immediately interrupt a lower priority SU's ongoing transmission. In [9], the authors focused on analyzing the cumulative handoff delay of different prioritized SUs by using a preemptive priority M/M/2 queueing model. With numerical experiments, they compared the delays of different SUs. In [6], a channel reservation scheme was proposed for the SUs with higher priority. Some channels in the system were reserved and the SUs with lower priority could not occupy these channels. Numerical results showed that this kind of channel reservation scheme could effectively reduce the higher priority SUs' blocking rate.

While in practice, due to hardware or technical limitations in cognitive radio networks, an SU's ongoing transmission may not be immediately interrupted. For this reason, some non-preemptive mechanisms among the SUs were proposed and analyzed. In [8], a cognitive radio network with M classes of SUs was considered. The interaction between different SUs was non-preemptive. An M/G/1 model was built to analyze the system performance. In [4], a channel bonding scheme was introduced to improve the spectrum handoff utilization of the multiple SUs. A non-preemptive M/G/1 queueing model was built and the numerical results showed that the proposed channel bonding scheme could increase the SU's throughput significantly.

However, either the conventional preemptive or the non-preemptive mechanisms mentioned above may lead to a degradation of the quality of service (QoS) for a class of SUs. For example, in the preemptive mechanism, the transmission continuity for lower priority SUs will be degraded. While in the non-preemptive mechanism, the transmission quality for the higher priority SUs will be affected. To address this problem, in [7], a hybrid priority mechanism was proposed for multiple SUs by combining preemptive and non-preemptive disciplines. A predefined threshold was introduced to control the interruptions between the SUs, and a hybrid preemptive and non-preemptive queueing model was built and analyzed.

As mentioned above, we find that in most of available literature relating to prioritized SUs, such as [4], [7], most analysis considered a continuous-time queueing model. However, knowing the digital nature of modern communication, discrete-time queueing models are more suitable for analyzing cognitive radio networks [1]. In this paper, in order to balance the system performance between prioritized SUs, we propose a novel probabilistic interruption mechanism. An SU1 packet can interrupt an SU2 packet's transmission with a predefined probability (referred to as an interrupting index). Taking the network digital nature into consideration, we build a discrete-time Markov chain model. We analyze the system model and derive the formulas for some important performance measures. With numerical results, we show how the interrupting index influences the system performance. Finally, we optimize the interrupting index to balance the system performance of the two types of SU packets.

The structure of following paper is given as follows. In Section 2, we demonstrate the system model based on the proposed probabilistic interruption mechanism. We also derive the steady-state distribution and some formulas for performance measures in Section 3. Then, we show numerical results to evaluate how the interrupting index influences the system performance in Section 4. In order to balance the system performance between the SU1 and SU2 packets, we optimize the interrupting index in Section 5. Finally, we conclude our paper in Section 6.

2 System Model

In this section, we provide an overview of the model assumption by considering the probabilistic interruption mechanism, and the model analysis using a Markov chain model is illustrated.

We focus on a single-channel cognitive radio network with one PU, one SU1 and one SU2. PU packets have absolute authority in the channel. PU packets can interrupt both the SU1 packets and the SU2 packets' transmissions. The SU2 is equipped with a finite buffer with capacity K to accommodate its packets, and no buffers are equipped to reduce the average system delay for the PU or the SU1.

An SU1 packet has a higher priority than an SU2 packet. In order to balance the system performance between the two types of SUs, we propose a probabilistic interruption mechanism in the network presented in this paper. For the case of an SU1 packet arriving during an SU2 packet's transmission (no PU packet arrival), the SU1 packet will interrupt the SU2 packet's transmission with a certain probability (referred to as an interrupting index, a parameter of the system we can give). We denote the interrupting index by α in this paper. We note that with this interrupting index α, the interruption actions of SU packets according to different network operating needs can be dynamically controlled. For a network with a higher need of transmission continuity of the SU2 packets, the interrupting index α will be set lower. While for a network with a higher need of transmission QoS of the SU1 packets, the interrupting index α will be set higher. Specially, for a network with hardware or technical limitations to interrupt the SU2 packets' transmission immediately, the interrupting index can be set to $\alpha = 0$. Therefore, the probabilistic interruption mechanism proposed in this paper will solve and adapt different interruption situations in cognitive radio networks. Moreover, we assume all the interrupted packets (including interrupted SU1 and SU2 packets) are forced to leave the system to reduce any possible interference.

As mentioned above, the probabilistic interruption mechanism mainly controls the interruption actions of the SU1 packets. In order to promote understanding of the system model, we depict Fig. 1 to show the system actions of SU1 packets in the proposed channel allocation scheme using the probabilistic interruption mechanism.

We assume the time interval is divided into equal slots. With the working principle of the probabilistic interruption mechanism, we can build a discrete-time Markov chain model under an early arriving assumption as follows.

We firstly abstract T_n, $S1_n$ and P_n, which denote the total packet number, the SU1 packet number and the PU packet number, respectively. We also assume the packet arrival intervals and transmission times follow geometric distributions. We denote λ_P, λ_{S1} and λ_{S2} as the arrival rates and μ_P, μ_{S1} and μ_{S2} as the service rates of the packets. We note that compared to some continuous-time arrival and departure processes assumptions, this assuming of geometric distributions is more suitable to following the digital features of modern communication networks. Based on the system actions of the three types of packets, $\{T_n, S1_n, P_n\}$ constitutes a Markov chain with state space as follows:

$$\Omega = (0,0,0) \cup \{(r,0,0) \cup (r,1,0) \cup (r,0,1) : 1 \leq r \leq K+1\}. \tag{2.1}$$

3 Performance Analysis

In this section, we develop the performance analysis with the system model built in Section 2. Taking the state transitions for the Markov chain $\{T_n, S1_n, P_n\}$ into consideration, we

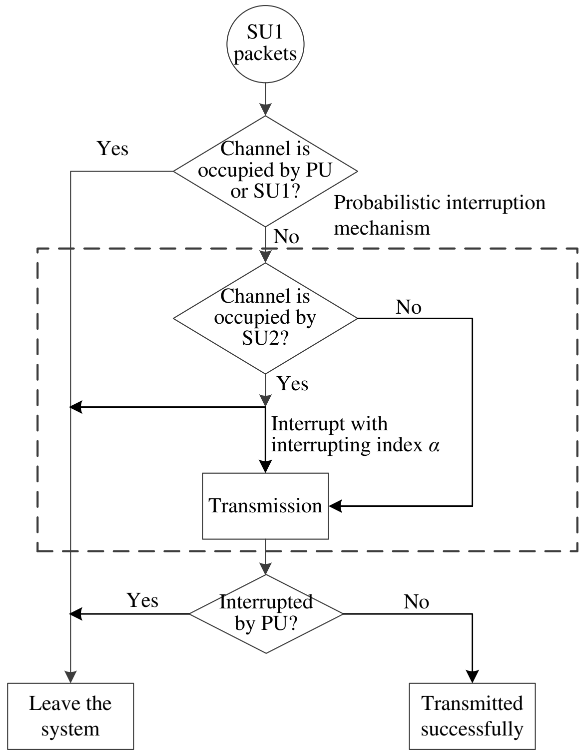

Figure 1: System actions of SU1 packets.

firstly give a detailed form of the transition probability matrix for the system state. Then we present the formula of the steady-state distribution $\pi_{r,s,t}$ and derive the result of the steady-state distribution. Finally, with the steady-state distribution $\pi_{r,s,t}$, we derive the formulas for some important performance measures for SU1 packets and SU2 packets, respectively.

3.1 Steady-State Distribution

From the state transitions for $\{T_n, S1_n, P_n\}$, we give a transition probability matrix $\boldsymbol{P}$ with $(K+2)\times(K+2)$ blocks as follows:

$$\boldsymbol{P} = \begin{pmatrix} \boldsymbol{S}_0 & \boldsymbol{T}_0 & \boldsymbol{W}_0 & & & \\ \boldsymbol{R}_0 & \boldsymbol{S} & \boldsymbol{T} & & & \\ & \boldsymbol{R} & \boldsymbol{S} & \boldsymbol{T} & & \\ & & \ddots & \ddots & \ddots & \\ & & & \boldsymbol{R} & \boldsymbol{S} & \boldsymbol{T} \\ & & & & \boldsymbol{R} & \boldsymbol{S}+\boldsymbol{T} \end{pmatrix}. \tag{3.1}$$

Each nonzero block in $\boldsymbol{P}$ can be given as follows:

$$\boldsymbol{S}_0 = \bar{\lambda}_P\bar{\lambda}_{S1}\bar{\lambda}_{S2}, \tag{3.2}$$

$$\boldsymbol{T}_0 = (\bar{\lambda}_P\bar{\lambda}_{S1}\lambda_{S2}, \bar{\lambda}_P\lambda_{S1}\bar{\lambda}_{S2}, \lambda_P\bar{\lambda}_{S2}), \tag{3.3}$$

$$\boldsymbol{W}_0 = (0, \bar{\lambda}_P\lambda_{S1}\lambda_{S2}, \lambda_P\lambda_{S2}), \tag{3.4}$$

$$\boldsymbol{R}_0 = (\bar{\lambda}_P \bar{\lambda}_{S1} \bar{\lambda}_{S2} \mu_{S2}, \bar{\lambda}_P \bar{\lambda}_{S1} \bar{\lambda}_{S2} \mu_{S1}, \bar{\lambda}_P \bar{\lambda}_{S1} \bar{\lambda}_{S2} \mu_P)^{\mathrm{T}}, \tag{3.5}$$

$$\boldsymbol{R} = \begin{pmatrix} \bar{\lambda}_P \bar{\lambda}_{S1} \bar{\lambda}_{S2} \mu_{S2} & 0 & 0 \\ \bar{\lambda}_P \bar{\lambda}_{S1} \bar{\lambda}_{S2} \mu_{S1} & 0 & 0 \\ \bar{\lambda}_P \bar{\lambda}_{S1} \bar{\lambda}_{S2} \mu_P & 0 & 0 \end{pmatrix}, \tag{3.6}$$

$$\boldsymbol{S} = \begin{pmatrix} \bar{\lambda}_P U & \bar{\lambda}_P \bar{\lambda}_{S2} (\mu_{S2} \lambda_{S1} + \bar{\mu}_{S2} \lambda_{S1} \alpha) & \lambda_P \bar{\lambda}_{S2} \\ \bar{\lambda}_P \bar{\lambda}_{S1} \lambda_{S2} \mu_{S1} & \bar{\lambda}_P \bar{\lambda}_{S2} (\bar{\mu}_{S1} + \mu_{S1} \lambda_{S1}) & \lambda_P \bar{\lambda}_{S2} \\ \bar{\lambda}_P \bar{\lambda}_{S1} \lambda_{S2} \mu_P & \bar{\lambda}_P \lambda_{S1} \bar{\lambda}_{S2} \mu_P & \bar{\lambda}_{S2} (\bar{\mu}_P + \mu_P \lambda_P) \end{pmatrix} \tag{3.7}$$

where $U = \mu_{S2} \bar{\lambda}_{S1} \lambda_{S2} + \bar{\mu}_{S2} \bar{\lambda}_{S1} \bar{\lambda}_{S2} + \bar{\mu}_{S2} \lambda_{S1} \bar{\lambda}_{S2} \bar{\alpha}$.

$$\boldsymbol{T} = \begin{pmatrix} \bar{\lambda}_P V & \bar{\lambda}_P \lambda_{S2} (\mu_{S2} \lambda_{S1} + \bar{\mu}_{S2} \lambda_{S1} \alpha) & \lambda_P \lambda_{S2} \\ 0 & \bar{\lambda}_P \lambda_{S2} (\bar{\mu}_{S1} + \mu_{S1} \lambda_{S1}) & \lambda_P \lambda_{S2} \\ 0 & \bar{\lambda}_P \lambda_{S1} \lambda_{S2} \mu_P & \lambda_{S2} (\bar{\mu}_P + \mu_P \lambda_P) \end{pmatrix} \tag{3.8}$$

where $V = \bar{\mu}_{S2} \lambda_{S1} \lambda_{S2} \bar{\alpha} + \bar{\mu}_{S2} \lambda_{S2} \bar{\lambda}_{S1}$.

From each block in $\boldsymbol{P}$ mentioned above, we know that the Markov chain $\{T_n, S1_n, P_n\}$ is non-periodic, irreducible and positive recurrent [1]. In order to further analyze the system model, we define the steady-state distribution $\pi_{r,s,t}$ as follows:

$$\pi_{r,s,t} = \lim_{n \to \infty} P\{T_n = r, S1_n = s, P_n = t\}. \tag{3.9}$$

Let $\boldsymbol{\Pi} = (\pi_{0,0,0}, \pi_{1,0,0}, \pi_{1,1,0}, \pi_{1,0,1}, \ldots, \pi_{K+1,1,0}, \pi_{K+1,0,1})$, and the results of $\pi_{r,s,t}$ can be obtained by calculating $\boldsymbol{\Pi P} = \boldsymbol{\Pi}, \boldsymbol{\Pi e} = 1$, where $\boldsymbol{e} = (1, 1, \ldots, 1)^{\mathrm{T}}$.

3.2 Performance Measures

In this subsection, we show some important performance measures of SU1 packets and SU2 packets, respectively.

3.2.1 SU1 Packet Performance Measures

As there is no buffer to accommodate SU1 packets, an arriving SU1 packet can be blocked if the channel is occupied by another SU1 packet or a PU packet. Therefore, we can obtain the expression for the blocking rate β_{SU1} of SU1 packets as follows:

$$\beta_{SU1} = \lambda_{S1} \left(\sum_{r=0}^{K+1} \pi_{r,0,0} \lambda_P + \sum_{r=1}^{K+1} \left(\pi_{r,1,0} (\bar{\mu}_{S1} + \mu_{S1} \lambda_P) + \pi_{r,0,1} (\bar{\mu}_P + \mu_P \lambda_P) \right) \right). \tag{3.10}$$

In the proposed probabilistic interruption mechanism, a special and important performance measure is the departure rate of SU1 packets. An arriving SU1 packet will interrupt an SU2 packet's transmission with an interrupting index α, and depart the system with probability $1 - \alpha$. Therefore, we can obtain the expression for the departure rate δ_{SU1} of SU1 packets as follows:

$$\delta_{SU1} = \sum_{r=1}^{K+1} \pi_{r,0,0} \bar{\mu}_{S2} \bar{\lambda}_P \lambda_{S1} \bar{\alpha}. \tag{3.11}$$

In the proposed probabilistic interruption mechanism, an SU1 packet's transmission can be interrupted by an arriving PU packet, and then this interrupted SU1 packet will be forced to leave. Therefore, we can obtain the expression for the interruption rate γ_{SU1} of SU1 packets as follows:

$$\gamma_{SU1} = \sum_{r=1}^{K+1} \pi_{r,1,0}\bar{\mu}_{S1}\lambda_P. \tag{3.12}$$

In the proposed probabilistic interruption mechanism, an SU1 packet can be transmitted successfully if this SU1 packet is admitted access to the system (no blocking or departure) and at the same time is not interrupted by a PU packet during the transmission. Therefore, we can obtain the expression for the throughput θ_{SU1} of SU1 packets as follows:

$$\theta_{SU1} = \lambda_{S1} - \beta_{SU1} - \delta_{SU1} - \gamma_{SU1}. \tag{3.13}$$

3.2.2 SU2 Packet Performance Measures

If the SU2 buffer is full for an arriving SU2 packet, this packet will be blocked. Therefore, the expression for the blocking rate β_{SU2} of SU2 packets can be given by

$$\begin{aligned}\beta_{SU2} = \lambda_{S2}\left(\pi_{K+1,0,0}(1-\mu_{S2}\bar{\lambda}_{S1}\bar{\lambda}_P) + \pi_{K+1,1,0}(1-\mu_{S1}\bar{\lambda}_{S1}\bar{\lambda}_P)\right)\\ + \lambda_{S2}\pi_{K+1,0,1}(1-\mu_P\bar{\lambda}_{S1}\bar{\lambda}_P).\end{aligned} \tag{3.14}$$

In the proposed probabilistic interruption mechanism, an SU2 packet's transmission can be interrupted by a PU packet or an SU1 packet. Therefore, the formula for the interruption rate γ_{SU2} of SU2 packets can be given by

$$\gamma_{SU2} = \sum_{r=1}^{K+1} \pi_{r,0,0}\bar{\mu}_{S2}(\lambda_P + \bar{\lambda}_P\lambda_{S1}\alpha). \tag{3.15}$$

In the proposed probabilistic interruption mechanism, an SU2 packet can be transmitted successfully if this SU2 packet is not blocked and at the same time its transmission is not interrupted. Therefore, we can obtain the expression for the throughput θ_{SU2} of SU2 packets as follows:

$$\theta_{SU2} = \lambda_{S2} - \beta_{SU2} - \gamma_{SU2}. \tag{3.16}$$

4 Numerical Results

In this section, we explore the influence of the interrupting index in the proposed probabilistic interruption mechanism by using numerical results. We also show the effectiveness of the proposed probabilistic interruption mechanism compared to the conventional preemptive and non-preemptive mechanisms with numerical results. By referencing the parameter settings in [13], without loss of generality, we set the service rates as $\mu_P = \mu_{S1} = \mu_{S2} = 0.5$ in following numerical results.

Moreover, to validate the correctness of the mathematical analysis results, we present the simulation results by using MATLAB in Figs. 2-5. We find that the analysis results match well with the simulation results in Figs. 2-5.

Figures 2 and 3 show the departure rate δ_{SU1} and throughput θ_{SU1} of SU1 packets versus the interrupting index α with different arrival rates λ_P and λ_{S2} when $\lambda_{S1} = 0.5, K = 10$.

It is intuitive that the departure rate of SU1 packets decreases and the throughput of SU1 packets increases by increasing the interrupting index. As the interrupting index increases,

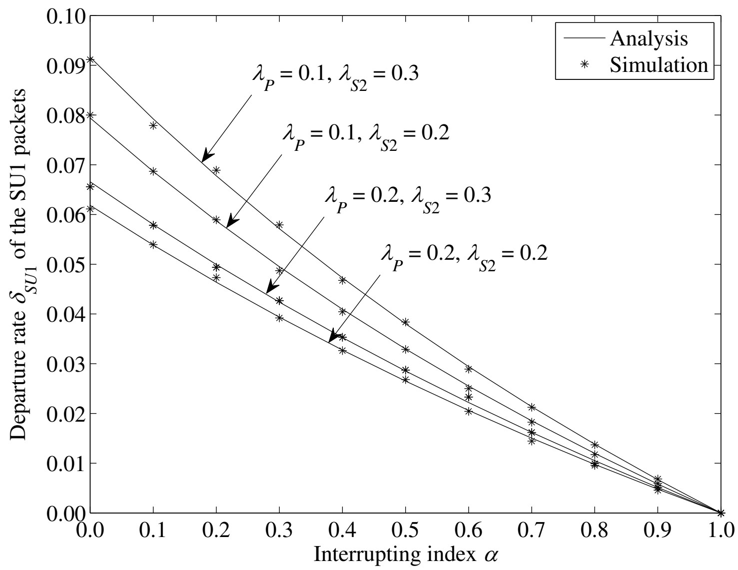

Figure 2: Departure rate δ_{SU1} of SU1 packets.

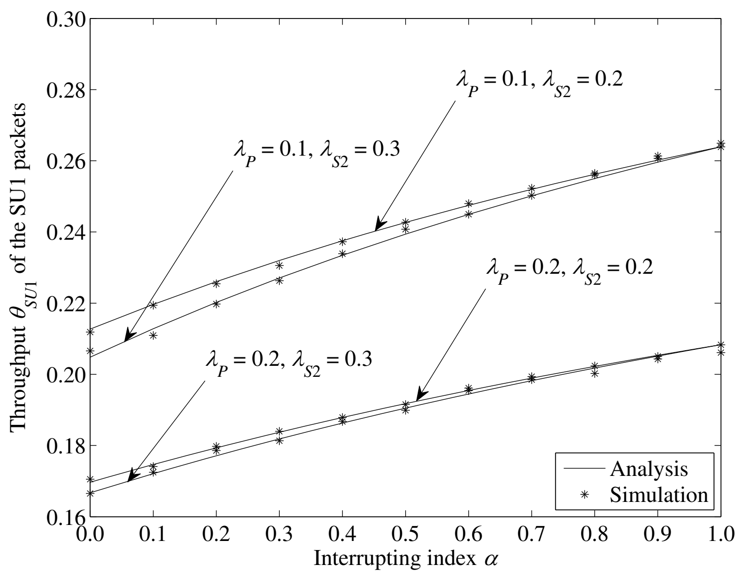

Figure 3: Throughput θ_{SU1} of SU1 packets.

more SU1 packets will preempt the channel, and the departure rate of SU1 packets will, of course, decrease. At the same time, the throughput of the SU1 packets will increase.

It is also found that increasing the PU packet arrival rate can decrease the SU1 packet departure rate. The explanation for this interesting change trend may be that a higher PU packet arrival rate means the possibility for the channel being occupied by a PU packet will be higher. Then the possibility of an SU2 packet occupying the channel is lower. That is to say, the possibility of an SU1 packet arriving during an SU2 packet's transmission will also be lower. Therefore, the SU1 packet departure rate will decrease. At the same time, as the PU packet arrival rate increases, the throughput of SU1 packets will decrease.

Moreover, the departure rate of SU1 packets can be increased and the throughput of SU1 packets can be decreased by setting a higher SU2 packet arrival rate. In the proposed probabilistic interruption mechanism, the system actions of SU2 packets can influence the system performance of SU1 packets. A higher SU2 packet arrival rate means the possibility for an SU1 packet encountering an SU2 packet's transmission is greater. Then more SU1 packets will depart the system. Therefore, the SU1 packet departure rate increases and the SU1 packet throughput decreases.

Figures 4 and 5 show how the interrupting index α influences the interruption rate γ_{SU2} and throughput θ_{SU2} of SU2 packets with different arrival rates λ_P and λ_{S1} when $\lambda_{S2} = 0.3, K = 10$.

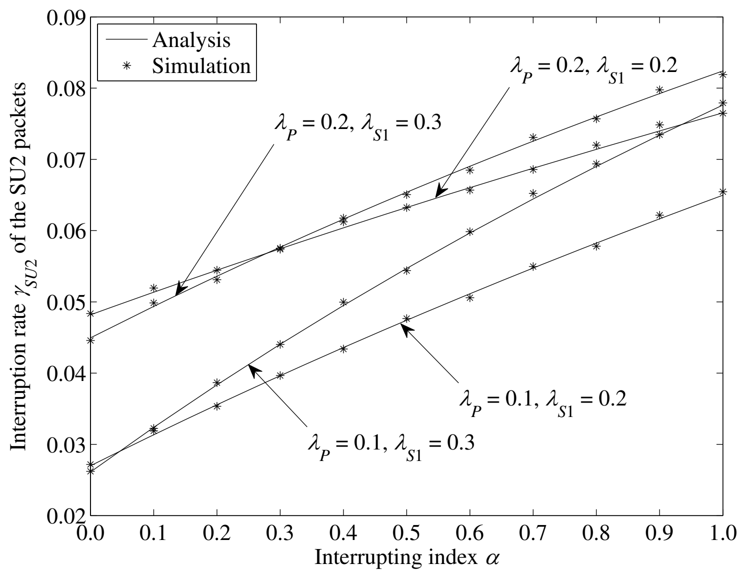

Figure 4: Interruption rate γ_{SU2} of SU2 packets.

Figures 4 and 5 show that we can increase the interruption rate and decrease the throughput of SU2 packets by setting a higher interrupting index. This is because most SU1 packets will choose to interrupt SU2 packets' transmissions with a higher interrupting index. Then the SU2 packet interruption rate increases and throughput decreases.

On the other hand, it is obvious that a higher PU packet arrival rate can increase the SU2 packet interruption rate and decrease the SU2 packet throughput. Moreover, when we set a higher SU1 packet arrival rate in Fig. 5, the throughput of SU2 packets will be lower. This is because the possibility of SU2 packets being transmitted will be lower, then the throughput of SU2 packets will be decreased.

Specifically, in Fig. 4, when the interrupting index is lower, a higher arrival rate of SU1 packets can cause a lower SU2 packet interruption rate. While as the interrupting index increases, the SU1 packet arrival rate rises, so the higher the SU2 packet interruption rate will be. We try to explain these special change trends in Fig. 4 as follows. When the interrupting index is very low, a higher SU1 packet arrival rate means more SU1 packets will occupy the channel and the possibility of SU2 packets occupying the channel will be lower,

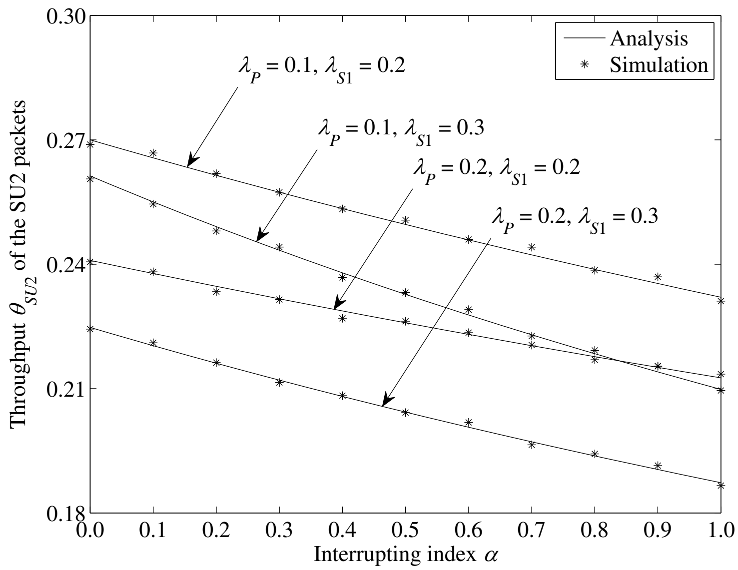

Figure 5: Throughput θ_{SU2} of SU2 packets.

and so the interruption rate will decrease. However, as the interrupting index increases, more SU1 packets will choose to interrupt SU2 packets' transmissions. Therefore, the SU2 packet interruption rate will increase due to the setting of a higher SU1 packet arrival rate when the interrupting index is higher.

Finally, in Figs. 2-5, we also compare the system performance of the proposed probabilistic interruption mechanism with the preemptive and non-preemptive mechanisms considered in some literature. In the figures, the fact that the interrupting index α is equal to 0 shows the system performance by using the non-preemptive mechanism considered in [13]. Comparing with the non-preemptive scheme shown in [13], by using the probabilistic interruption mechanism proposed in this paper, the departure rate of SU1 packets can be decreased and the throughput of SU1 packets can be increased. On the other hand, the fact that the interrupting index α is equal to 1 shows the system performance by using the preemptive mechanism considered in [6] and [9]. Comparing with the preemptive scheme shown in [6] and [9], by using the probabilistic interruption mechanism proposed in this paper, the interruption rate of SU2 packets can be decreased and the throughput of SU2 packets can be increased.

5 Optimization for Interrupting Index

From the numerical results in Section 4, we conclude that the higher the interrupting index is, the better the system performance of the SU1 packets will be. However, an increase in the interrupting index will degrade the system performance of SU2 packets. Therefore, in order to balance the system performance of SU1 and SU2 packets, it is necessary to optimize the interrupting index in the probabilistic interruption mechanism. In our paper, considering the relative priority of SU1 packets to SU2 packets, we try to optimize the interrupting index from the perspective of the SU1 packets. We assume that there is a reward $R_1(1-\alpha)$ which is related to the interrupting index α of the SU1 packets. In order to obtain this reward, an SU1 packet will agree to decrease the interrupting index to a certain degree. On the other hand, a benefit R_2 is conferred to the successfully transmitted SU1 packets. We can then express the benefit function $F(\alpha)$ in relation to the interrupting index α as follows:

$$F(\alpha) = R_1(1-\alpha) + R_2\theta_{SU1}. \tag{5.1}$$

We can obtain the expression for the optimal interrupting index α^* which realizes the maximal benefit as follows:

$$\alpha^* = \arg\max_{\alpha}\{F(\alpha)\} \tag{5.2}$$

where "arg max" stands for the argument of the maximum [12].

In order to show the change trend of the benefit function $F(\alpha)$ intuitively, with parameter settings used in Section 4, we plot Fig. 6 to show how the benefit function $F(\alpha)$ change versus the interrupting index α with different capacities K of the SU2 buffer when $\lambda_P = 0.2, \lambda_{S1} = 0.2, \lambda_{S2} = 0.3, R_1 = 3, R_2 = 100$.

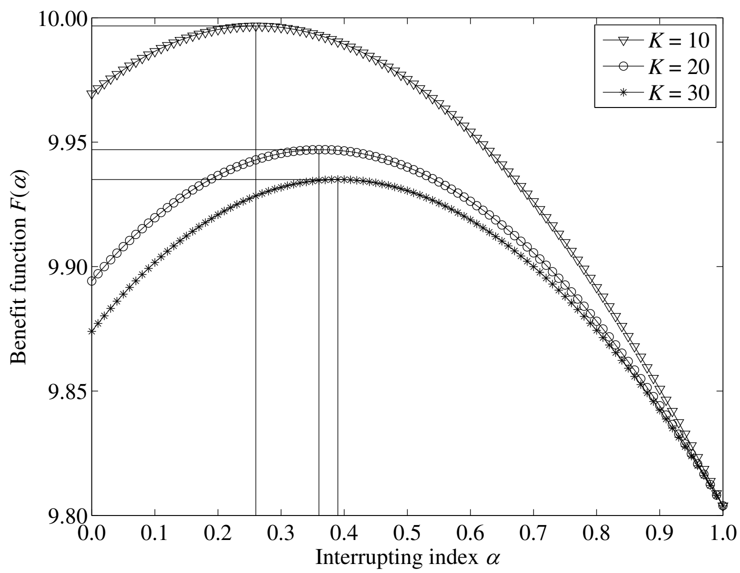

Figure 6: Benefit function $F(\alpha)$.

Figure 6 demonstrates that when the interrupting index is lower, the benefit function shows an increasing trend as the interrupting index increases. While as the interrupting index increases to a higher value, the benefit function shows a decreasing trend as the interrupting index increases. Therefore, there exists an optimal interrupting index for each buffer capacity in Fig. 6. We summarize the optimal interrupting index α^* and the corresponding maximal benefit $F(\alpha^*)$ in Table 1.

Table 1 shows that as the SU2 buffer capacity increases, the optimal interrupting index should be increased correspondingly. We try to explain this change trend as follows. As the SU2 buffer capacity increases, more SU2 packets will occupy the channel. However, this will decrease the SU1 packet throughput in the proposed probabilistic interruption mechanism. In order to increase the SU1 packet throughput, we should increase the interrupting index.

Table 1: Numerical results for the optimal interrupting index.

SU2 buffer capacity	Optimal interrupting index	Maximal benefit
K	α^*	$F(\alpha^*)$
10	0.26	9.9967
20	0.36	9.9470
30	0.39	9.9350

6 Conclusions

In this paper, as a mean of balancing the system performance of the SU1 packets and SU2 packets in cognitive radio networks with prioritized SUs, we proposed a probabilistic interruption mechanism. An interrupting index was introduced to control the interrupting actions of network users in the system. According to the working principle of the probabilistic interruption mechanism, we built and analyzed a discrete-time Markov chain to obtain some expressions for the performance measures of the two types of SU packets. Numerical results showed that compared to a conventional non-preemptive scheme, the departure rate of SU1 packets can be decreased and the throughput of SU1 packets can be increased in the proposed probabilistic interruption mechanism. Compared to a conventional preemptive scheme, the SU2 packet interruption rate can be decreased and the SU2 packet throughput can be increased in the proposed probabilistic interruption mechanism. Finally, from the perspective of SU1 packets, we optimized the interrupting index by building a benefit function and we also derived the optimal numerical results of the interrupting index to realize the maximal benefit.

The results of this paper provide the theoretical basis for the optimal design of the interrupting index in a probabilistic interruption mechanism in cognitive radio networks with prioritized SUs.

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