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Saturation Throughput of Myopic Policy for Opportunistic Spectrum Access Under Positively Correlated Channel Condition

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ABSTRACT *To solve inefficient spectrum usage problem, FCC promotes the opportunistic spectrum access for cognitive radio networks. Myopic policy, which maximizes immediate throughput, has been established as a simple and robust opportunistic spectrum access policy. We present a simple analytical model to compute the saturation throughput performance in the presence of multiple secondary users and multiple channels under positively correlated channel condition.*

KEYWORDS : saturation throughput, positively correlated channel, myopic policy

INTRODUCTION

The growth in wireless services has led to a shortage of bandwidth resources. This shortage problem is reported to be due to the inefficient nature of spectrum management policy [1]. As a solution, Federal Communications Commission promotes the opportunistic spectrum access (OSA). The OSA allows secondary users to opportunistically occupy an idle spectrum owned by primary user. To seize transmission opportunities, secondary users need to decide on which channel to sense and which channel to access. Myopic policy, which maximizes only immediate throughput, has been established as a simple opportunistic spectrum access policy [2, 3]. Zhao et al. [2] has discussed the lower and upper bounds on the saturation throughput for the case of only one secondary user.

It is also of interest to consider the myopic policy for multiple users competing for communication opportunities in multiple channels. This paper provides a simple analysis to compute the throughput of myopic policy in the presence of multiple secondary users and multiple channels. We focus on the saturation throughput, which is a fundamental performance figure defined as the limit reached by the total throughput of secondary users as the offered load increases.

MYOPIC SENSING POLICY

We consider a slotted primary network with N channels, each of which evolves as an independent, identically distributed, discrete-time Markov chain on probabilities p_{ij}. State 0 represents that the channel is occupied by state space $\{0,1\}$ with one-step state transition primary users while state 1 represents that the channel is idle. We consider secondary users seeking spectrum opportunities. Each secondary user having pending packets for transmission chooses one of the N channels to sense and access in each slot. Immediately before the beginning of slot t, its knowledge of the channels' state is given by its belief vector $(\beta_1(t),\dots,\beta_N(t))$, where $\beta_i(t)$ is the probability that channel i is in state 1 immediately before slot t, given all past decision and observations. Each user chooses an action to maximize expected immediate throughput [2], i.e., the index $a(t)$ of the channel the user selects at slot t is $a(t) = \arg\max_i \beta_i(t)$. Only if the selected channel is idle, the user transmits its packet. The belief vector is updated as follows:

$$\beta_i(t+1) = \begin{cases} p_{01}, & \text{if } a(t) = i \text{ and } \theta_{a(t)} = 0, \\ p_{11}, & \text{if } a(t) = i \text{ and } \theta_{a(t)} = 1, \\ \beta_i(t)p_{11} + (1-\beta_i(t))p_{01}, & \text{if } a(t) \neq i, \end{cases}$$

where $\theta_{a(t)}$ indicates the availability of channel $a(t)$.

THROUGHPUT ANALYSIS

Consider N independent and stochastically identical Gilbert-Elliot channels and M secondary users. In saturation conditions, each secondary user has immediately a packet available for transmission, after the completion of each successful transmission. Here we assume that sensing errors are negligible. Let $s(t)$ represent the state of the channel a tagged secondary user selects at slot t.

We consider the case of $p_{01} < p_{11}$. The myopic action is to stay in the same channel in the next slot if the channel in the current slot is sensed to be `idle'. Otherwise, the user switches to the channel visited the longest time ago. In this case, the key approximation in our model is that the probability that the switched channel is occupied by primary users is $p_B = p_{10}/(p_{01}+p_{10})$, which is the stationary probability that a channel is in state 0. Then, the stochastic process $s(t)$ is a discrete-time Markov chain with one-step state transition probability matrix

$$\begin{pmatrix} p_B & 1-p_B \\ (1-q)p_{10}+qp_B & (1-q)p_{11}+q(1-p_B) \end{pmatrix}$$

where q is the probability that a transmitted packet collides with packets from other secondary users. Let $\pi_k = \lim_{t\to\infty} \mathrm{P}\{s(t)=k\}$ be the stationary distribution of the chain. We obtain

$$\pi_0 = \frac{(1-q)p_{10}+qp_B}{1-(1-q)(p_B-p_{10})}$$

$$\pi_1 = \frac{1-p_B}{1-(1-q)(p_B-p_{10})}$$

The probability that a secondary user transmits in a generic time slot is π_1. The probability that a secondary user transmits on the same channel as the tagged secondary user during the same time slot is π_1/N. Note that q is the probability that, in a time slot, at least one of the other $M-1$ secondary users transmits on the same channel as the tagged user: $q = 1-(1-\pi_1/N)^{M-1}$. We obtain $1-q = [f(q)]^{M-1}$, where

$$f(q) = 1 - \frac{1-p_B}{N\{1-(1-q)(p_B-p_{10})\}}$$

Since $0 < f(0) < f(1) < 1$ and $f'(q) > 0$ for $0 < q < 1$, there exists a unique solution q of such that $0 \le q \le 1$. Numerically the value of q, and therefore, of π_0 and π_1, are found.

CONCLUSIONS

The exponential growth in wireless services has recently led to an increasing demand for more bandwidth resources and hence a shortage of them. To solve inefficient spectrum usage problem, FCC promotes the OSA. For the design of efficient OSA we need to optimize the sensing and access protocol. Myopic policy has been established as a simple and robust OSA policy. We presented a analytical model to compute the saturation throughput in the presence of multiple secondary users and multiple channels under positively correlated channel condition.

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