Queuing Analysis of Opportunistic in Network Selection for Secondary Users in Cognitive Radio Systems

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Abstract

This paper analyzes network selection issues of secondary users (SUs) in Cooperative Cognitive Radio Networks (CRNs) by utilizing Queuing Model. Coordinating with Handover Cost-Based Network selection, this paper also addresses an opportunity for the secondary users (SUs) to enhance QoS as well as economics efficiency. In this paper, network selection of SUs is the optimal association between Overall System Time Minimization Problem evaluation of Secondary Connection (SC) and Handover Cost-Based Network selection. This will be illustrated by simulation results.

I. Introduction

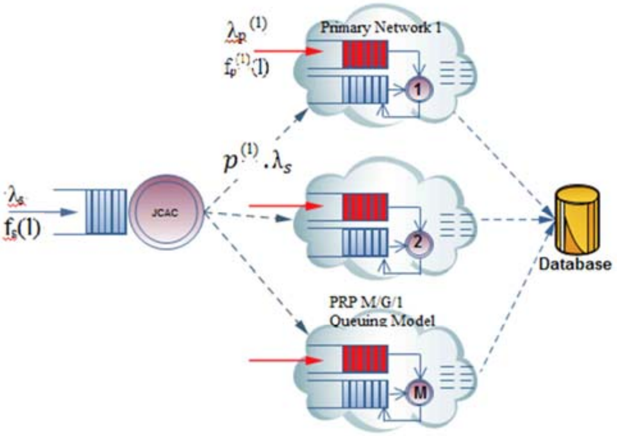
Cognitive radio (CR) is new technique allows Secondary User (SUs) (low-priority) access to licensed spectrum of Primary User (PU) (high-priority) thereby significantly improving overall spectrum efficiency [1]. Many researches of CR have mentioned network selection of SU such as [2],[3]. It is forecasted that in the future when deploying CRN, a number of CRNs with non-overlapping spectrum pools owned by different network operators may coexist in the same geographical area. Such scenario may lead to different network choices for SUs correspondent with different PU traffic intensities or different handover cost, bandwidth, latency, pricing, energy consumption, users' preference.

In this paper, we propose a system model for network selection of SUs and analyze it bases on M/G/l queuing method. And then, we can evaluate handover cost-combined latency of SUs in each network to optimize networks selection.

The remainder of this paper is organized as follows. The system is presented in section II. In Section III, we analyze the performance system model. Numerical results are shown in Section IV. Final section is conclusions.

II. System model

CRN's network selection model architecture is shown in Fig 1. In this paper, we consider uplink data transmission of SU via CRN. In this model SUs may utilize any free network in all the CRNs in the same geographical area. Each CRN can beowned by a different network operator. In which, JCAC(*Joint Connection Admission Control)* is introduced to makean admission decision upon a SU arrival. Besides, resource of each network is performed by non-overlapping spectrum pools owned by each network operator



.Fig.1 System model

An incoming SU will select a CRN as its destination according to the predefined selection policy in JCAC. After SC is connected to a CRN, if the selected CRN does not have any available spectrum to accommodate this SU, the connection will select other network. Otherwise, SC has to wait for available

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spectrum. The SC has to vacate the spectrum in use when a new PU requests to access this particular network. Assume that, each PU or SU uses one timeslot at a given time and the spectrum sensing procedure of each SU must be executed by the SU at the beginning of each time slot for protect PCs (PC).

In this paper we assume that all spectrum accesses of all channels of each network are modeled by PCs, and accesses of each SU are SCs. We also assume that the arrival processes of the PC and SC are Poisson. Parameters are denoted as below:

Symbol	Denotation
$\lambda_p^{(k)}$ (arrivals/slot)	average arrival rates of the PC at network *k*
λ_s(arrivals/slot)	average arrival rates of the SC of CR network
$L_p^{(k)}$ (bits/arrival)	sizes of the PCss of channel k
L_s(bits/arrival)	Size of the SC
$f_p^{(k)}(l)$	PMF of $L_p^{(k)}$
$f_s(l)$	PMF of L_s
$R_p^{(k)}$ (bits/slot)	data rate of the PC at channel *k*
R_s (bits/slot)	data rate of the SC

Note:$\lambda_p^{(k)}$, λ_s, $f_p^{(k)}(l)$ and $f_s(l)$ which can be estimated by the existing methods [4]

Table 2.1. Symbol denotations for arrival processes of PC and SC

The service time of the PC and SC at network k is $X_p^{(k)} = \frac{L_p^{(k)}}{R_p^{(k)}} \left(\frac{slots}{arrival}\right)$ and $X_s^{(k)} = \frac{L_s}{R_s^{(k)}} \left(\frac{slots}{arrival}\right)$, respectively.

As shown in Fig.1, each SC has M selections for its operating connection. According to our proposed analytical framework, in order to optimize SUs' selections in multiple networks, all SUs allow to select their operating connections with appropriate weight. The handover-cost of network *k* is denoted by c(*k*) and its weight is formulated as follows:

$$w^{(k)} \triangleq \frac{c(k)}{\sum_{k=1}^{M} c(k)} \quad (1)$$

Thus, the effective arrival rate of the SC at network *k*is

$$\lambda_s^k = w^{(k)}.\lambda_s . \quad (2)$$

III. Performance Analysis:

A. Performance Model

In the figure 1, each network *k* is modeled bypreemptive resume priority (PRP) M/G/1 queueing system with the aim of depicting the effects of multiple interruptions and network resources on the Overall System Time. Some key characteristics for the PRP M/G/1 queueing model are as below [6]:

- Connections of the PUs (connect to high-priority queue) and SUs (connect to low-priority queue) are 02 types of connections (users) to each server (network).

- The remaining transmission of the interrupted SU will be put into the head of the low-priority queue of the current operating network. And when the any current queue of PUisempty, the SUthat is interrupted by PU will not retransmit the whole data. Instead of that, it can resume the unfinished transmission

- A SC may experience multiple interruptions from the PCs during its transmission period.

Also assume that the first-come-first-served (FCFS) scheduling discipline is applied for connections that have the same priority access spectrum pools.

B. Analysis of Overall system time

The overall system time consists of waiting time and extended data delivery time in each network *k*. Let $E[T_w]$, and $E[W_w]$ be the average data delivery time and average waiting time for the cost-based spectrum decision methods. We have:

$$E[S^{(k)}] = E[W^{(k)}] + E[T^{(k)}] \quad (3)$$

Where E[.] is the expectation function

1. Extended Data Delivery Time.

Extended data delivery time determined from the moment when data in the first time slot is transmitted until data in the last time slot is completed. Considering transmission period of a SC, it is likely to have multiple spectrum handoffs due to the interruptions form the PUs. The spectrum handoff procedure helps the SU vacate the occupied channel becomes idle.

Following the PRP M/G/1 queueing model, according to [7], we have:

$$E[T^{(k)}] = E[X_s^{(k)}] + E\left[N^{(k)}\right].E[Y_p^{(k)}] \quad (4)$$

$$E[N^{(k)}] = \lambda_p^{(k)}.E[X_s^{(k)}]E[Y^{(k)}] = \frac{E[X_p^{(k)}]}{1-\lambda_p^{(k)}E[X_p^{(k)}]}$$

Where:
$N^{(k)}$: total number of interruptions for a SC at network k.

$Y_p^{(k)}$:busy period resulting from transmission of PCs at network k.

$T^{(k)}$: as the extended data delivery time of the SCs at channel k.

2. *Waiting Time*

Waiting time is defined as duration from the time instant that a SC arrives at the low-priority queue of the selected network toone that selected network becomes idle. Waiting time is the duration spent in the waiting queue by a SC.

Applying the PRP M/G/1 queueing theory [7], we have:

$$E[W_{pbc}^{(k)}] = \frac{E[R^{(k)}]}{(1-\rho_p^{(k)})(1-\rho_p^{(k)}-\rho_s^{(k)})} \quad (5)$$

$\rho_s^k = \lambda_s^{(k)} E[X_s^{(k)}]$; $\rho^{(k)} = \rho_p^k + \rho_s^k < 1$; $\rho_p^k = \lambda_p^{(k)} E[X_p^{(k)}]$ Where $\rho^{(k)}$ is the busy probability of network *k*. Furthermore, ρ_p^k, ρ_s^k are busy probabilities of primary and the SCs at network K, we ignore sensing errors

Where $E[R^{(k)}]$ is the average remaining time to complete the service of the connection being served at channel *k*. Referring to [6], we have:

$$E[R^{(k)}] = \frac{1}{2}\lambda_p^{(k)} E[(X_p^{(k)})^2] + \frac{1}{2} w^{(k)} \lambda_s E[(X_s^{(k)})^2] \quad (6)$$

Then, substituting (4) and (5) into (3), we get the expression for $E[S^{(k)}]$

Network selection of SC will be based on minimum time:

$E[S^{(k)}]$

IV. Numerical Results

Consider three network system with the following traffic parameters: $\lambda_p^{(k)}$ = 0.01, 0.02, 0.03, $E[X_p^{(k)}]$= 10, 20, 20, λ_s =0.01, $E[X_s^{(k)}]$ = 10, 10,10, handover cost = 1, 2, 3 (with k=1 to 3).

As shown in Fig.2, Secondary will select network with is the smallest overall time system. With $\lambda_p^{(1)}$=0.01, SU will select network 1 because cost-based time is the smallest. And when $\lambda_p^{(1)}$=0.04, SU will select network 2, because cost-based time is the smallest.

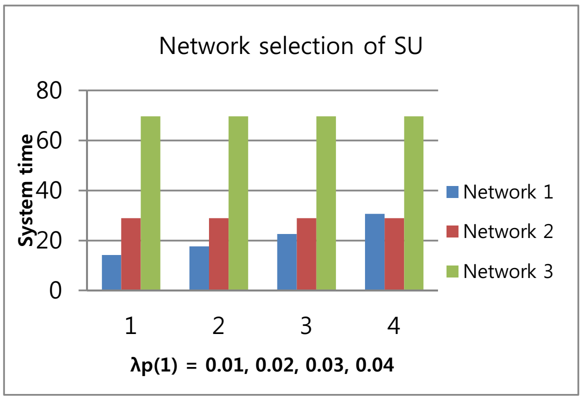

Fig.2. Network selection of SU when $\lambda_p^{(1)}$ = 0.01, 0.02, 0.03, 0.04 and $\lambda_p^{(2)}$ = 0.02, $\lambda_p^{(3)}$ = 0.03, $\lambda_p^{(4)}$ = 0.04

V. Conclusions

In this paper, an analytical framework has been proposed to design the system parameters for the handover based-cost network selection. The proposed model integrated with PRP M/G/1 queueing systems can evaluate the effects of multiple interruptions, overall system time (cost-based) of the SCs on each network *k* .

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