VOL. 12, NO. 7, APRIL 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ESTIMATING SUS ARRIVAL FOR CHANNEL SELECTION IN COGNITIVE RADIO

Danilo López Sarmiento[1], Edwin Rivas Trujillo[1] and Luis Fernando Pedraza[2]
[1]Department of Electronic Engineering, University Distrital Francisco José de Caldas, Bogotá, Colombia
[2]Faculty of Technology, University Distrital Francisco José de Caldas, Bogotá, Colombia
E-Mail: dalopezs@udistrital.edu.co

ABSTRACT

Generating optimal schemes for processing secondary user (SU) requests during the spectrum band selection stage is one of the current challenges of Cognitive Radio (CR), because it directly affects the time needed by a Base Station (BS) to select and assign a channel so SUs can send their data in an opportunistic fashion over the wireless network. Therefore, it's important to create strategies to reduce the processing time variable and thus improve system throughput. This research proposes the creation of a model for predicting the arrival at a BS of SUs with quality of service requirements, with the purpose of reserving the data transmission channel in advance depending on the required quality of service (real time (RT) or best effort (BE)). A model called SU Arrival Proactive Strategy was developed. It proves it's possible to optimize CR throughput because the time needed by the central station to assign a channel is less than when using a conventional spectrum band assignment strategy (in this paper, a reactive strategy).

Keywords: cognitive radio, spectral decision, prediction, secondary user, proactive strategy, spectrum decision.

1. INTRODUCTION

In the context of centralized cognitive radio (CR) wireless network spectrum selection as shown in Figure-1, most authors [1, 2, 3]have focused their models on the use of a reactive strategy, which is a major problem because of the time (a critical variable in telecommunications systems) it takes to search for and select an optimal free frequency for SU data transmission. Implementing a model (algorithm) where channel identification is decided milliseconds before the arrival of a cognitive user and based on the prediction of SU arrival helps to reduce assignment time, thus improving the spectrum decision stage [4]. In this regard, in order to describe and evaluate the model, an SU reactive arrival strategy is modeled, then a very succinct presentation of the proposed model (proactive strategy) is made, and finally the model is validated by showing that performance from the perspective of BS processing time is better when estimating SU future arrival.

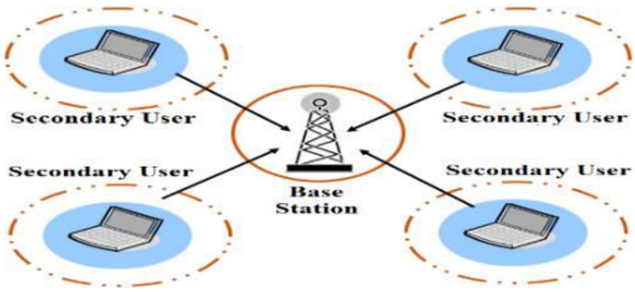

Figure-1. Infrastructure-based CRN.

2. SYSTEM MODEL FOR THE REACTIVE CASE

The block diagram for the model of the SU reactive strategy is shown in Figure-2.

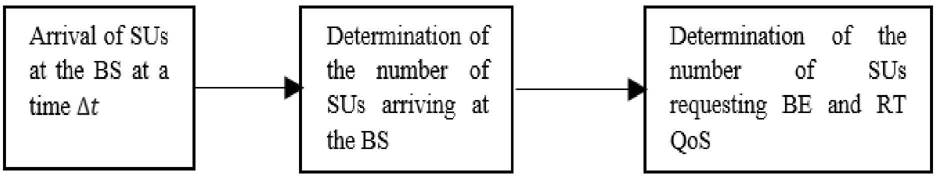

Figure-2. System of reactive arrival of SUs at the BS.

Using [5] as a reference, and considering Figure-2, we start by considering a two-state (ON-OFF) Markov system in order to determine the number of SUs that arrive at the CRN (Figure-1) and, based on queuing theory, a system of equations is created to establish the probability of states defined as:

$$P_{s,n}(t) = P(Z_s(t) = n \quad (1)$$

where$P$ is the probability function; $Z_s(t)$ is the state of the sth SU at time *t*; and the differential equation system is given by:

$$\frac{dP_{s,o}(t)}{dt} = \mu_s P_{s,1}(t) - N_s \lambda_s P_{s,0}(t) \quad (2)$$

$$\frac{dP_{s,n}(t)}{dt} = (N_s - n + 1)\, \lambda_s P_{s,n-1}(t) + (n+1)\mu_s P_{s,n+1}(t) - (n\mu_s + (N_s - n)\lambda_s) P_{s,n}(t) \quad (3)$$

$$\frac{dP_{s,N_s}(t)}{dt} = \lambda_s P_{s,N-1}(t) - N_s \mu_s P_{s,N}(t) \quad (4)$$

It's worth pointing out that μ_s is the SU service time distribution rate; λ_s defines the SU arrival process; N_s is the maximum number of nodes in interval $T = \Delta t$. Adapting Akter's idea in[5] to the reactive model, the expected number of cognitive nodes in a Δt will be determined first, then the number of RT and BE SUs arriving at the BS in a given time will be obtained. To that end, let $E[Z_s(t)]$ be the number of SUs at a time$t$, given by:

$$E[Z_s(t)] = \sum_{n=0}^{N_s} nP_{s,n}(t) \quad (5)$$

After calculating the derivative and by the operator's linearity,is obtained.

$$\frac{dE[Z_s(t)]}{dt} = \sum_{n=0}^{N_s} n\frac{dP_{s,n}(t)}{dt} = NM_sP_s$$

$$= N_s\lambda_s - (\lambda_s + \mu_s)\sum_{n=0}^{N_s} nP_{s,n}(t)$$

$$= N_s\lambda_s - (\lambda_s + \mu_s)E[Z_s(t)] \quad (6)$$

Assuming measurements are made at each instant in time T, the initial condition for the *mth* prediction $(t = mt)$ is considered to be:

$$E[Z_s((m-1)T)] = Z_s(m-1) \quad (7)$$

Solving the above equation yields:

$$Z_s(m) = Z_s(m-1)e^{-T(\lambda_s+\mu_s)} + \frac{N_s\lambda_s}{\lambda_s+\mu_s}\left[1 - e^{-T(\lambda_s+\mu_s)}\right] (8)$$

After determining the number of SUs that will arrive at the BS (Equation 8), the probability distribution given by:

$$P\{R(t) = m | R(t) = n\} \quad (9)$$

can be assigned to the $L+1$ groups of RT and BE requests, where $P(R(t) = n)$ is the general probability that in time t, m RT requests arrive, and specifically for the reactive case:

$$P(R(t) = n) = \frac{1}{2^{Z_s(t)}}\left\langle \begin{matrix} Z_s(t) \\ n \end{matrix} \right\rangle \quad (10)$$

because $Z_s(t)$ is the number of cognitive users who will reach the base station, of which n are requests with RT requirements; the rest will have BE requirements.

3. SYSTEM MODEL FOR THE PROACTIVE CASE

The methodology used to predict or calculate the probability of SU arrival with QoS requirements is shown in Figure-3. Assuming the existence of a database, consider (as in the reactive case) that L is the number of nodes that will arrive at the BS in a timeinterval Δt; in this regard, in order to predict or estimate the type of service the next SU will request, the number of possible combinations with L users will be determined first, where R of them will request QoS for RT, and the B rest $(B = L - R)$ will have BE service requirements. Note that $L = B + R$,and one and only one of the conditions $B > R$, $B = R$, or$B < R$will be met. Regardless of the sequence of Lrequests, it can always be associated with an element of the permutation group SL. Note that R can take on any value between 0 and L $(0 \leq R \leq L)$; thus, *L+1* possible groups will be obtained, where the process of alternating between two request types can be linked to imbrication. Therefore, given a number R of RT requests, how many possible combinations of RT and BE are there? To answer the question, it's necessary to realize that when imbrication occurs, the groups' relative order is maintained; therefore, it's enough to simply calculate how many manners there are for choosing R positions among the$L$ possible positions.

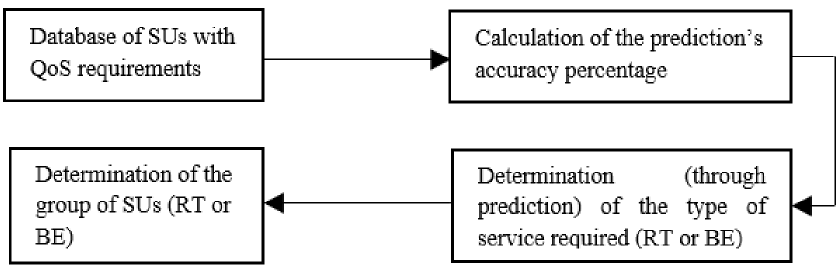

Figure-3. Model of the system of proactive arrival of SUs at the BS.

Thus, for a pre-established R, it's possible to find $\binom{L}{R}$ possible organizations, so the probable arrival of a requirement (estimation of the prediction) can be represented with an element $\{0,1\}^L = \{0,1\} * \{0,1\} * \ldots .* \{0,1\}$; the system is thus restricted to 2^L possible combinations of two groups of QoS requests instead of $L!$(number of elements in the set S_L). It's important to point out that for $L > 3$, the inequality $2^L < L!$is valid, and so this restriction implies a significant reduction in calculations. Associating probabilities, the groups made near the middle are more likely to occur; therefore, the probability is assigned to the division (R) that was made:

ARPN Journal of Engineering and Applied Sciences

$$\frac{1}{2^L}\binom{L}{R} \quad (11)$$

In order to assign probabilities to the combination $R=0$ and $R=L$, the answer is obvious (see Equation 11); but if $2 \leq R \leq L-1$is considered, a possible option is to assign a uniform distribution so that each combination of requests has a probability of $1/\binom{L}{R}$, and thus all possible rearrangements (except the identity) have a probability of $1/2^L$. In addition, it's clear that, due to imbrication, a permutation $P(\pi)$is obtained, and the probability associated to the permutation $\pi \in S_L$ is given by:

$$P(\pi) = \pi\, P(x_i);\; P(x_i) \in (0,1];\quad i = 1,2, \ldots, L \quad (12)$$

When $P(\pi)$ is compared to the uniform probability$u(\pi) = 1/_{L!}$, then for each $\pi \in S_L$ it's possible to determine the predictability of arrival of SUs requesting RT or BE (Equation 13).

$$\delta = \frac{1}{2}\sum_{\pi \in S_L}|P(\pi) - u(\pi)| \quad (13)$$

The $1/2$ factor in the previous equation allows the value of δ $(0 \leq \delta \leq 1)$ to be normalized. $\delta = 0$if and only if $P(\pi) = u(\pi)$ for every $\pi \in S_L$. If δ is very close to 1, the next SU's request is predictable to a high percentage (as observed in Figure-4 once the system is simulated); if the value of δ is very small, it means the prediction may be erroneous.

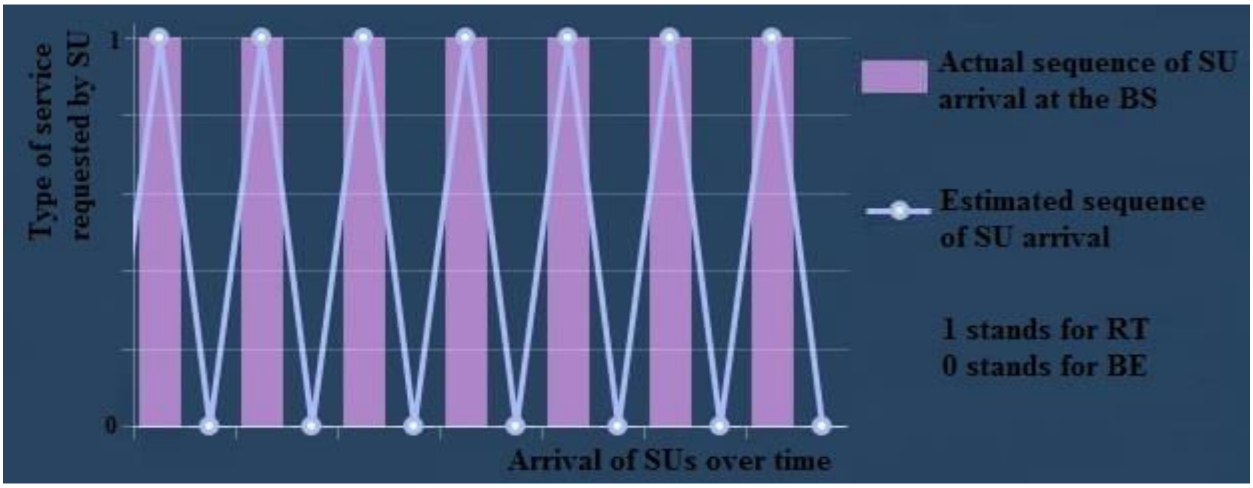

Figure-4. Evaluation of the estimation level of SU arrival at the BS under the proactive model.

In case R is constant, there'll be $\binom{L}{R}$ possible combinations, which indicates that the order of arrival of SUs and, therefore, of QoS requests, are independent from each other.

4. EVALUATION OF PERFORMANCE OF CHANNEL ACCESS REQUEST PROCESSING AT THE BS

The time to process a request can be defined as:

$$t_m = t_a + t_c + x(m)t_d \quad (14)$$

wheret_a is the arrival time of the nth SU; t_d, the processing time for the requested service; t_c, the channel assignment time; and x(m), the characteristic function defined by:

$$x(m) = \begin{cases} 1, & for\ the\ reactive\ model \\ & and \\ 0, & for\ the\ proactive\ model \end{cases} \quad (15)$$

In addition,

$$t_c = t_o.N_c \text{and} t_d = t_o.N_d \quad (16)$$

wheret_o is the time it takes the central node to perform an operation; N_c is the number of operations for channel assignment; N_d, the number of operations required to process the request.

The t_a can be calculated based on the distribution function given by:

$$t_a = \frac{1}{\lambda_{su}} ln\left(\frac{1}{P(x=n)}\right) \quad (17)$$

whereλ_{su} is the parameter of the distribution that was used. Therefore, t_m is determined by:

$$t_m = \frac{1}{\lambda_s} ln\left(\frac{1}{P(x=n)}\right) + t_o(N_c + x(m)N_d) \quad (18)$$

From the previous discussion, it's concluded that the only difference between the reactive and the proactive models is the term t_oN_d, which has a non-negative value, and makes it possible to state:

$$t(reactive) > t(proactive) \quad (19)$$

ARPN Journal of Engineering and Applied Sciences

5. CONCLUSIONS

The mathematical representation and evaluation of the models shows that the use of a proactive strategy is more efficient in terms of processing time than the reactive one because it precedes (through the use of prediction) the next SU's request, thus managing network resource access more rapidly.

REFERENCES

[1] Do C, Tran N, Hong C, *et al*. 2013. A lightweight algorithm for probability-based spectrum decision scheme in multiple channels cognitive radio networks. IEEE Communications Letters. 17(3): 509-512.

[2] Wang L-C, Wang C-W, Adachi F. 2011. Load-balancing spectrum decision for cognitive radio networks. IEEE Journal on Selected Areas in Communications. 29(4): 757-769.

[3] Kasbekar G, Sarkar S. 2010. Spectrum auction framework for access allocation in cognitive radio networks. IEEE/ACM Transaction on Networking. 18(6): 1841-1854.

[4] López D, Trujillo E, Gélvez G. 2015. Implementing a simulator of wireless cognitive radio network primary users. International Journal of Applied Engineering Research. 11(2): 967-975.

[5] Akter L, Natarajan B, Scoglio C. 2008.Modeling and forecasting secondary user activity in cognitive radio networks. Proceeding of 17th International Conference on Computer Communications and Networks ICCN, Virgin Island, USA. pp. 1-6, doi: 10.1109/ICCCN.2008.ECP.50.