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Supporting Real-Time Data Transmissions in Cognitive Radio Networks Using Queue Shifting Mechanism

B. Seetha Ramanjaneyulu, VFSTR University, India
K. Annapurna, VFSTR University, India

ABSTRACT

As cognitive radio networks are conceptualized to make use of the opportunistic spectrum access, the users of these networks may face problems in satisfying their quality of service (QoS) requirements. Some services of users like real-time audio and video which cannot tolerate inter-packet delays will be affected more due to this. The problem occurs due to the non-availability of channels to these applications at some instants. This problem can be addressed if the available channels are judiciously distributed among the competing users. One such mechanism that dynamically allocates the competing users to multiple queues, and shifting the users to higher-level queues as the time elapses is introduced in this work. This is found to help the users of cognitive radio networks to communicate reasonably well even when fewer channels are available for opportunistic use. Results are indicated in terms of blocking probabilities of real-time data. Markov chain-based analysis and discrete event simulation studies are carried out.

KEYWORDS

Cognitive Radio, Markov Chains, Opportunistic Spectrum Access, Primary Users, QoE, QoS, Queue Shifting, Real-Time Transmission, Secondary Users

1. INTRODUCTION

Under-utilization of spectrum bandwidths allocated to various licensed services, has given rise to the concept of Cognitive Radio Networks (CRN). It is based on the proposal of using those under-unutilized bandwidths by non-licensed users, through opportunistic spectrum access (Mitola J., 2009). The main advantage of the cognitive radio networks is that they make better use of those bandwidths. If this mechanism is adopted in those frequency ranges in which many of the mobile and cellular communication systems are operating, it will be extremely helpful, because those bands are crowded heavily and hardly any bandwidth is available at government agencies to allot it to new services. In fact, there are some underutilized spectrum frequencies in these frequency ranges, which were originally licensed to terrestrial TV operations, and various applications of military and navigation (Young-June Choi, Shin K.G., 2011). So, cognitive radio networks are vying for better use of these

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frequencies. In the terminology of cognitive radio networks, the licensed users are called 'Primary Users' (PU) and the opportunistic cognitive radio users are called 'Secondary Users' (SU).

As sharing of available spectrum among Secondary Users is the most important aspect of cognitive radio networks, several proposals are made by researchers, for this sharing. Based on the way SUs avail the spectrum opportunity, three types of spectrum sharing paradigms are available (Goldsmith, A., Jafar, S.A., Maric, I. & Srinivasa, S., 2009). They are:

1. **Underlay Methods:** Here PUs and SUs coexist together such that SUs will use less power and hence do not disturb the PUs' communications.
2. **Overlay Methods:** Here SUs will make use of spectrum holes with the help of messages and code books shared by PUs. In return, SUs need to help in relaying the transmissions of PUs.
3. **Interweave Methods:** In this paradigm, SUs should continuously sense the spectrum for finding and exploiting the spectrum holes.

Of the above methods, overlay type of spectrum sharing is simple to implement, and hence the preferred one, in many contexts. While sharing the spectrum, allocation of channels to individual users can be made either through central administration or through distributed mechanisms. In the case of central decision making methods, one central system decides all the channel allocations in that region by collecting the data from all the cognitive radios of that region about their measurements and as well as the channel requirements. Measurements here refer to the sensing of spectrum activity by that cognitive radio. Energy detection is the commonly used method of spectrum sensing (Won-Yeol Lee; Akyildiz, I.F., 2008). In the case of distributed decision making methods, each cognitive radio takes the decision on its own by checking its measurements for all channels in its surroundings and then selecting a free channel for its communication. This kind of decision may be required in the cases where the cognitive radios operate in an environment where proper structure of the network doesn't exist. In the proposed work of this paper, centralized channel allocation is considered.

All the users of cognitive radio networks, especially the ones that use overlay methods of spectrum sharing, have to follow the basic principle of vacating the occupied channels whenever the licensed users of the spectrum want to use those frequencies. In such instants, the vacated SU needs to search for another vacant channel immediately to continue its communication (Elias Z. Tragos, Sherali Zeadally, Alexandros G. Fragkiadakis & Vasilios A. Siris, 2013). If it fails to find another vacant channel, then it needs to quit the system, which is called as dropping the transmission that will lead to degradation of quality of service (QoS) to SUs. This impact may not be same for all the users. For some users who are engaged in non time-sensitive communication like the e-mail transfer, it may not appear to be that severe. But for some users who are engaged in time-sensitive data transfers like the real-time audio, the impact is clearly evident. In such cases, if the cognitive radio transmission system is designed in such a way that it takes into consideration the time-sensitivities of user data, it may be able to fulfill the user requirements in a better way. One such proposal is introduced in this work. It is based on queuing systems. Multiple queues are considered, into which user data packets are queued in, based on their time-sensitive requirements. Of all these queues, the packets that travel in the first queue only are passed to the transmission system. That means, the packets that are put to different other queues need to shift from the lower-queues to the upper-queues, and finally to the first queue, as the time elapses. Time sensitiveness of the data packet and the time it already spent in the queues will decide its movement to the upper-level queues, and finally to the first queue from where it is transmitted. It can be considered as M/M/1 type of system, because single service of transmission system is considered. It can be extended to multiple number of services also, with ease. The proposed system is analyzed using Markov chain models and simulated with discrete event simulations. The proposed system is based on the concept of distributing the instant channel bandwidths to the needed users, as per their packet transmission urgencies.