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A Novel Approach to Real Time Spectrum Handoff

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Abstract*: Cognitive radio (CR) can significantly improve spectrum efficiency by allowing the secondary users to temporarily access the primary user's under-utilized licensed spectrum. Spectrum mobility issues arise when the primary user appears at the channels being occupied by the secondary users. The secondary users return to the occupied channel because the primary users have the preemptive priority to access channels. Spectrum handoff technique can help the interrupted secondary user to vacate the occupied licensed channel and find a suitable target channel to resume its unfinished data transmission. Preemptive resume priority (PRP) M/G/1 queuing network model characterizes the spectrum usage behaviors of the connection-based multiple channel spectrum handoffs. The proposed model derives the closed-form expression for the extended data delivery time of different proactive designed target channel sequences under various traffic arrival rates and service time distributions. The analytical method analyzes the latency performance of spectrum handoffs based on the target channel sequences specified in the IEEE 802.22 wireless regional area networks standards. We also suggest a traffic-adaptive target channel selection principle for spectrum handoffs under different traffic conditions.*
Keywords*- Cognitive radio, Spectrum handoff, PRP, M/G/1 queuing model, WRAN, Primary user, Secondary user.*

I. Introduction

Cognitive radio is a transceiver which automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters so more wireless communications may run concurrently in a given spectrum band at a place. This process is also known as dynamic spectrum management. Mobile computing involves mobile communication, mobile hardware, and mobile software. Communication issues include ad-hoc and infrastructure networks as well as communication properties, protocols, data formats and concrete technologies. Hardware includes mobile devices or device components. Mobile software deals with the characteristics and requirements of mobile applications [1].

Cognitive radio (CR) can significantly improve spectrum efficiency by allowing the secondary users to temporarily access the primary user's under-utilized licensed spectrum. Spectrum mobility issues arise when the primary user appears at the channels being occupied by the secondary users. The secondary users need to return the occupied channel because the primary users have the preemptive priority to access channels. Spectrum handoff techniques can help the interrupted secondary user vacate the occupied licensed channel and find a suitable target channel to resume its unfinished data transmission. One fundamental issue for spectrum handoff modeling in CR networks is the multiple interruptions from the primary users during each secondary user's connection [2], [3].

The issue of multiple interruptions results in the requirement of designing the target channel pool for a series of spectrum handoffs in a secondary connection. In this paper, we define the connection-based modeling techniques for spectrum handoff as the schemes that incorporate the effects of multiple interruptions from the primary users in an event-driven manner, and the slot-based modeling techniques mean that the interruptions to the secondary user are modeled in a time-driven manner. That is, the connection-based method characterizes the spectrum handoff only when the primary user appears, while for the slot based methods the spectrum handoff can be performed at each time slot[4], [5].

Spectrum handoff mechanisms can be generally categorized into two kinds according to the decision timing of selecting target channels. The first kind is called the proactive-decision spectrum handoff,1 which decides the target channels for future spectrum handoffs based on the long-term traffic statistics before data connection is established[6].

The second kind is called the reactive decision spectrum handoff scheme. For this scheme, the target channel is searched in an on-demand manner. After a spectrum handoff is requested, spectrum sensing is performed to help the secondary users find idle channels to resume their unfinished data transmission. Both spectrum handoff schemes have their own advantages and disadvantages. A quantitative comparison of the two spectrum handoff schemes was provided[7].

II. Problem Statement And Challenges

In the evolutions of the channel usage of the primary networks at each channel were modeled as Gilbert-Elliot channel, i.e., a discrete-time Markov chain which has two occupancy states: busy (ON) and idle (OFF) states. The idle state can be regarded as a potential spectrum opportunity for the secondary users. Note that the Markov chain model is suitable for the exponentially distributed service time, and how to extend it to the case with general service time distribution is not clear [1], [8]. In this model, the target channel selection problem in every time slot is modeled as a Markov decision process. According to the channel occupancy state at the current time slot, a decision maker can preselect the best action (target channel) to optimize its immediate reward at the next time slot.

The spectrum usage behaviors of the primary networks on each channel were characterized by a Bernoulli random process. Here, the connection maintenance probability is the probability that a secondary connection can finish its transmission within a predetermined number of handoff trials. Because both the busy and idle periods of the considered primary networks follow the geometrical distributions, it is more difficult to extend this modeling technique to the cases with other general service time distribution.

III. Related Work

In order to characterize the multiple handoff behaviors in CR networks, we should consider the three key design features, consisting of

1) general service time distribution;
2) various operating channels; and
3) queuing delay due to channel contention from multiple secondary connections.

In the literature, the modeling techniques for spectrum handoff behaviors can be categorized into the following five types:

1. the two-state Markov chain;
2. the arbitrary ON/OFF random process;
3. the Bernoulli random process;
4. the birth-death process with multidimensional
Markov chain; and
5. the PRP M/G/1 queuing model[1], [10].

Discrete-time two-state Markov chain: The evolutions of the channel usage of the primary networks at each channel were modeled as Gilbert-Elliot channel, i.e., a discrete-time Markov chain which has two occupancy states: busy (ON) and idle (OFF) states.

Arbitrary ON/OFF random process. It was assumed that the secondary user can estimate the distributions of the ON period and the OFF period based on long-term observations [11].

Bernoulli random process: The effects of multiple interruptions from the primary users on the connection maintenance probability in a connection-based environment, where the spectrum usage behaviors of the primary networks on each channel were characterized by a Bernoulli random process [12].

Multidimensional Markov chain: In the spectrum usage behaviors of both the primary and secondary networks were modeled by the multidimensional Markov chain. The actions of each primary and secondary user are indicated in the states of the Markov chain. Here, the action of each user can be “idleness”, “waiting at queue”, or “communication”[13].

M/G/1 queuing model: Some researchers used the preemptive resume priority M/G/1 queuing model to characterize the spectrum usage behaviors in a single-channel CR network [14], [15].

IV. Functional Design And Analysis

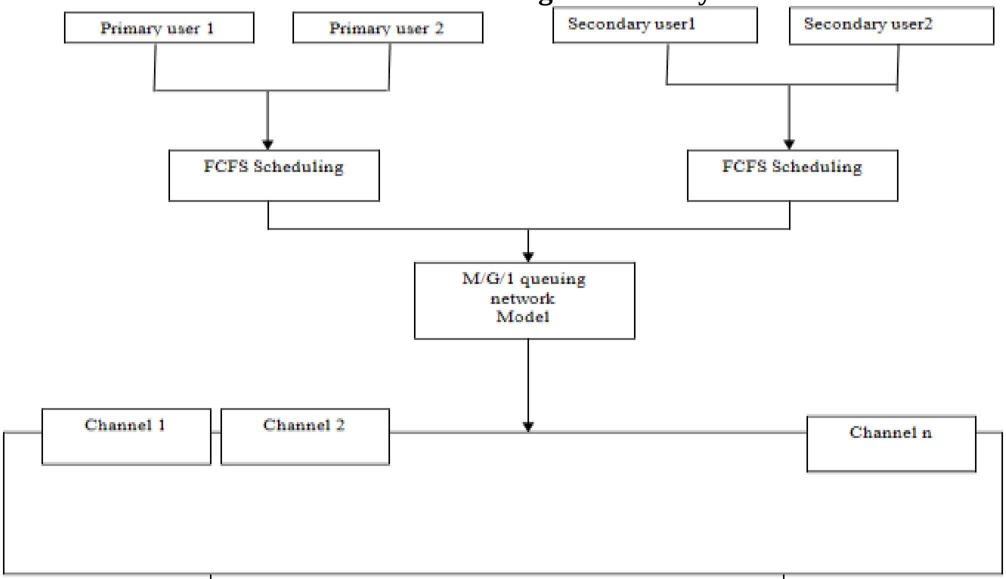


Fig 1: Overview architecture

Five set of functional steps needed as follows;
1. Modeling selection process.
2. Spectrum Decision Modeling.
3. Queuing network model.
4. Traffic pattern analysis
5. Evaluation criteria.

1. Modeling selection process

Connection-based modeling techniques

For spectrum handoff as the schemes that incorporate the effects of multiple interruptions from the primary users in an event-driven manner.

Slot-based modeling

Techniques mean that the interruptions to the secondary user are modeled in a time-driven manner.
The above module is implemented to allocate the primary and secondary user in the channel for allocation process.

2. Spectrum Decision Modeling

Spectrum handoff mechanisms can be generally categorized into two kinds according to the decision timing of selecting target channels. The first kind is called the proactive-decision spectrum handoff,1 which decides the target channels for future spectrum handoffs based on the long-term traffic statistics before data connection is established.

3. Queuing Network Model

Queuing network model to take into account of all the effects of the general service time distributions of the primary and the secondary connections, various operating channels, and the queuing behaviors of multiple secondary connections. In this project the Queuing mechanism which has been implemented to analysis the neighboring channel to verify the target channel authentication and for collaboration.

4. Traffic pattern analysis

The arrival processes of the primary and the secondary connections on the queues of each channel are Poisson.

5. Evaluation criteria

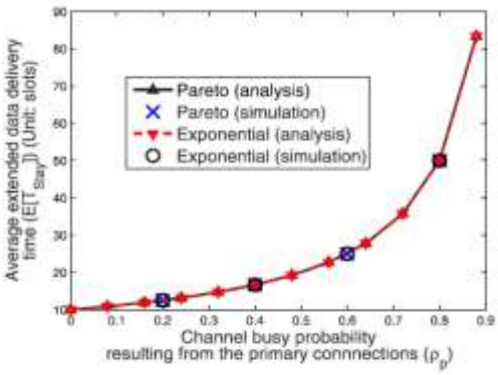
The traffic adaptive channel selection approach can appropriately change to better target channel sequence according to traffic conditions.

V. Experimental Result

We show numerical results to reveal the importance of the three key design features of modeling spectrum handoffs as discussed in Section, which consist of
1) general service time distribution;
2) various operating channels; and
3) queuing behaviors of multiple secondary connections. Here, we only show the effects of these key design features on E[T]. The effects on other performance metrics (such as E[T]/E[Xs]) can be derived based on similar manners.

Simulation Setup:

In order to validate the proposed analytical model, we perform simulations in the continuous-time cognitive radio systems, where the interarrival time and service time can be the duration of no integer time slots. We consider a three channel CR system with Poisson arrival processes of rates p and s for the high-priority primary connections and the low-priority secondary connections, respectively. The high priority connections can interrupt the transmissions of the low-priority connections, and the connections with the same priority follow the first-come-first-served (FCFS) scheduling discipline. Referring to the IEEE 802.22 standard, we adopt time slot duration of 10 mill sec in our simulations.



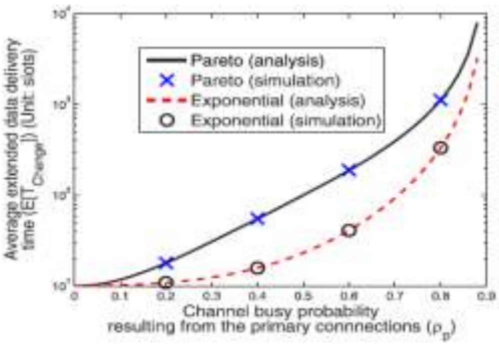


Fig (2) and (3) Effects of Pareto and exponential service time distributions for Primary connections on the extended data delivery time (E[T]change) and (E[T]stay).

VI. Conclusion

We have proposed a PRP M/G/1 queuing network model to characterize the spectrum usage behaviors with multiple handoffs. We studied the latency performance of the secondary connections by considering the effects of 1) general service time distribution; 2) various operating channels; and 3) queuing delay due to channel contention from multiple secondary connections. The proposed model can accurately estimate the extended data delivery time of different proactively designed target channel sequences. We assumed that the interrupted secondary user can resume its unfinished transmission on
The suitable channel. However, in other scenarios, the interrupted secondary user may need to retransmit the whole connection rather than resuming the unfinished transmission.

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