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A Survey on Spectral Handoff Mechanisms for the Cognitive Radio Network

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Abstract— In a cognitive radio network, the cognitive radio (CR) devices also called as secondary users (SU's) need to change their operating frequency due to the inclusion of primary user (PU) in that frequency band. Thus when a PU arrives in a frequency band and asks for a channel in that band, it gets that band and occupies the channel which may be occupied by a SU. In this situation, the SU needs to find another channel in a different frequency band which leads to the spectral handoff. Thus in addition to the location based handoff's for the SU, spectral handoff also occur. This spectral handoff may be done several times for the SU. Thus this situation leads to the study of handoff mechanism. This paper carries out a survey of the handoff types and their mechanisms which have been already conceptualized.

Keywords- *Cognitive Radio, handoff, spectral handoff, spectrum sensing, proactive, reactive.*

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I. INTRODUCTION

In a cognitive radio network, the cognitive radio (CR) devices are the non-registered users and hence also called as secondary users (SU's) where as the registered devices are the primary user (PU) in the underlying technology. The frequency resource used for com-munication has a sporadic usage. Meaning that the frequency resource is over utilized and underutilized at some point in time and region. The SU devices use this frequency resource for communication on the basis of two rules:-

1. SU do not create interference to the close by PU.
2. 2.SU should vacate the occupied frequency channel if it is demanded by the PU.

The above two rules are given by the FCC (Federal Communication Commission) [1] and the SU abide to them in order to coexist and operate in close vicinity of the PU. Hence the cognitive radio devices are called as secondary users (SU's) and hold a lower priority for resource consumption than the primary registered users.

Generally for a PU, handoff occurs when the device changes the cell i.e it changes its location, leading to the spectral handoff limited to only the cell shift.

Hence it is called as location based handoff than the spectral handoff. Whereas for the SU, two scenarios exists; first, wherein the SU changes location to have a spectral handoff and second wherein, even though the SU is stationary at some location, may undergo spectrum shift due to the inclusion of the PU in close vicinity with the SU.

These scenarios force the SU to change their operating frequency several times to keep operating. Hence the handoff for these devices are called as spectral handoff's than location handoff.

This paper, is further arranged as- first the spectrum handoff procedure is described, next different handoff categories are given, then the different handoff techniques are described, and finally the paper concludes with a conclusion.

II. COGNITIVE RADIO HANDOFF PROCEDURE

Cognitive radio has to undergo spectrum handoff when the primary users (PU) appear in the channel occupied by the secondary users (SU). In this situation, the secondary user has to immediately handoff (transit or switch) from the current channel to the target channel. This target channel is either chosen by the SU on its own or allocated by the base station. The target channel selection is based on the sensing technique and the received signal strength. Centralized sensing, distributed sensing are the sensing techniques to name some.

Now, as soon as the SU decides to go for a spectral handoff, there incurs a handoff delay. This delay is measured from the time the SU pauses its transmission till it switches the target channel and becomes ready to resume transmission.

Following example gives a scenario wherein two SU's are communicating and PU arises:-

1. Let us suppose that, two secondary users SU1 and SU2 communicate on the say channel Ch1.
2. Now, while this communication is going on, we have a primary user(PU) appearing on Ch1 . SU1

can detect this appearance event and prepare to perform spectrum handoff procedure.

3. Next, SU1 immediately pauses its current communication within a predefined duration. Now it has to notify SU2 of the interruption event before another predefined time interval. It also notifies the SU2 of the target channel.

4. Then, SU1 and SU2 can begin the resumption of its transmission on the selected target channel.

III. COGNITIVE RADIO HANDOFF TYPES

The handoff type defined here is used to find the target channel and select it for the handoff completion procedure. Thus, here general methods to select the target channel is given. Basically, there are two target channel selection methods- proactive and reactive selection. The handoff done on these basis are know as-

1. proactive spectrum sensing handoff and
2. reactive spectrum sensing handoff.

A. *Proactive Spectrum Sensing Handoff*

In the proactive-sensing spectrum handoff, secondary users make the target channels for spectrum handoff ready before its transmission. In this case, secondary users periodically observe all available channels to obtain the channel usage statistics, and determine the candidate set of target channels for spectrum handoff according to the long-term observation outcomes. Next this observation is sent to the base station and the base station finally arises with the target channel selection for the secondary user.

B. *Reactive Spectrum Sensing Handoff*

In the reactive-sensing spectrum handoff, the target channels are searched by the on-demand manner. In this case, the instantaneous outcomes from wideband sensing will be used to determine the target channel selection for spectrum handoff . This selected channel is then acquired from the base station by the secondary user.

IV. DIFFERENT SPECTRUM HANDOFF TECHNIQUES

Li-Chun Wang and Chung-Wei Wang, [2] has proposed and analyzed a PRP M/G/1 queuing network model to decide in which condition the reactive- or proactive-sensing spectrum handoff should be carried out. Here every channel maintains a queue for the users based on their priority as- low and high priority queue. As the primary users has the high priority over the secondary users, it can grab the channel already occupied by the secondary user. Here two scenarios are given- the secondary users can stay on the current channel or change the current channel.

In first case, the unfinished data will be put into the tail of the low-priority queue of another channel. In the second case when the secondary user stays in the current channel, the unfinished data can be inserted into the head of the low-priority queue of the current channel. Thus in both cases the transmission is resumed when the channel becomes idle.

Further the paper considers the arrival rate of primary users (PU) ($\lambda 0$) and based on the mean value it calculates the transmission latency for reactive- and proactive-sensing spectrum handoff . Two transmission latencies are derived always- stay and the always-change cases. The first one is the always-stay case where the interrupted secondary user always stays on its default channel until its packet is transmitted completely. While the second one is the always-change case where the target channels alternately switches between two channels. With a lower value of arrival rate of primary users , the interrupted secondary user prefers to change the operating channel. By contrast, $\lambda 0$ is large, the interrupted customer prefers the always-stay strategy.

C.-W. Wang, L.-C. Wang, and F. Adachi, [3] has proposed a Markov transition model integrating with the PRP M/G/1 queuing network to characterize the multiple handoffs delay. During the whole transmission period a secondary user may undergo several spectral handoff's due to several interruption by the primary users. Hence a secondary user should have a series of target channels which can be utilized sequentially when required. Thus a reactive-decision spectrum handoff scheme is proposed which utilizes a Markov transition model that is further integrated with PRP M/G/1 queuing network to extract a target channel sequence.

The Markov chain consists of L stages, where L is the maximum number of interruptions for the secondary connections. M is the maximum number of states. State "Chk" represents the case that the channel k is selected for the target channel where $1 \leqslant k \leqslant M$. Also the Markov model has a start and a end state. Based on this model, the transition probability from state i to j denoted by $P_{i,j}$ and transition cost denoted by $C_{i,j}$ is calculated. Finally with the above two parameters a sequence of target channel is derived; also, the mean of cumulative handoff delay $E[D(k)]$ is calculated.

M. Kalil, H. Al-Mahdi, A. Mitschele, [4] has proposed a Opportunistic Spectrum Access with Backup (OSAB) channel. Generally, the spectrum handoff's are done in the licensed bands and not in the liscensed bands. Here in this paper the unlicensed bands are used as backup channels. The spectrum handoff is done in a proactive manner where each SU initiates a list of available channels in both bands to use it in case of the appearance of the PUs.

The only distinction between the licensed and unlicensed bands is that, the PU in licensed band have higher priority than the SU whereas in unlicensed band, both the PU's and SU's have the same priority. Further the link maintenance probability is calculated. The link maintenance probability refers to the probability that link is successfully maintained when the SU abandoned the channel. The performances of the link maintenance probability and the expected number of spectrum handoffs for the SUs is investigated using tow scenarios- first scenario having 6 licensed channels (LCs) and 0 unlicensed channels (UCs), and in second scenario 4 LCs and 2UCs. Also three traffic load conditions are evaluated namely-low, moderate and high traffic. Experimental results show that, the OSAB yields better results than just the OSA.

L.Ch .Wang, W. Chung, [5] has used PRP M/G/1 queuing model to derive the performance from the quality of service (QoS) for the cognitive radio network. Spectrum sensing, spectrum sharing, spectrum decision, and spectrum handoff are evaluated to design better spectrum management policies to satisfy the QoS requirement of the secondary users in CR networks. The proactive spectrum handoff results are compared against the reactive spectrum handoff. Results clearly show that proactive spectrum handoff takes less time than the reactive spectrum handoff.

Soumaya Dahi, Sami Tabbane, [6] have used sigmoid a S-shaped curve to represent the life cycles of the cognitive radios. It has three distinct phases: an incipient or starting phase, a maturing phase, and a declining or aging phase. Here the SU selects a channel having the highest holding time (HT). Holding time means, the channel idle time which the SU learns from long observations. Using QoS and HT parameters, the SU selects a channel for handoff. Suppose that a SU selects a channel having highest HT but bad quality, the transmission may be interrupted because of non acceptable quality parameter even there is no interruption because of PU activity. In such a case, the SU should choose a channel having smaller HT but better quality parameter and then he resumes his transmission during the whole provided holding time. This handoff is also a proactive type of spectral handoff.

Lu Li, Yanming Shen, Keqiu Li, Kai Lin, [7] has proposed a novel proactive spectrum handoff approach based on time estimation (TPSH). In this approach, two probabilities namely- busy-to-idle, and idle-to-busy are calculated. These calculations are done in every time slot and the idle period vectors are calculated update the remaining idle time is for the SU. Only those channels are considered whose idle probability is larger than 50% instead of considering the average case. Suppose that the SU's remaining task duration is shorter than current channel's remaining idle period and if a PU is detected , SUs select a target channel using proposed algorithm and trigger reactive handoff.

J. Guo, H. Ji, Y. Li, X. Li, [8] have proposed a support vector machine (SVM) model to predict the handoff point, so that the SU can prepare to handoff before the channel is occupied by the PU. This mechanism is based on the proactive spectrum handoff method. After learning from the neighbours' broadcast information, SVM model predicts the handoff point and idle

spectrum channels for SUs. The spectrum handoff scheme consists of three parts. First a cooperative spectrum sensing mechanism is proposed. Then SVM model is used to predict the handoff point and choose one of the idle spectrum channels to handoff lastly. The input to the system is the node's information such node position, speed, currently using spectrum and so on, and the output is preparing for handoff (-1) or not (+1). Here the SVM model consider sonly two spectrum bands with frequencies as f1 and f2. The output of the SVM is unified to calculate Gc which gives a point where a handoff is needed.

Yuh-Shyan Chena,Ching-Hsiung Choa,Ilsun Youb, Han-Chieh Chaoc, [9] have proposed a Cross-layer protocol of spectrum mobility and handover. The protocol is split into three phases: (1) environment observation phase, (2) computation and analysis phase and (3) evaluation and transmission phase. In environment observation phase, each SU senses all the spectrum bands, in the transmission coverage of the current serving base station periodically. If the SU detects a frequency channel resource, reclaimed by PU, then it performs handoff on another frequency channel which it has already found out as unused while environment observation. Here two areas are considered namely non-overlapped and overlapped area for the computation and analysis phase. In the third and final phase, the actual handoff is done based on the earlier phase. Proposed protocol proves that the total handoff delay is decreased and also the number of handoffs are lessen thereby giving the SU's move time to stay on the current spectrum hole. This protocol is also of type proactive.

V. CONCLUSIONS

As per the survey carried out regarding the handoff's in cognitive radio networks, the handoff mechanism is categorized into two major categories namely-proactive and reactive spectrum handoff's. The survey further shows that, the proactive spectrum handoff yields better results in terms of the handoff delay and communication reliability than the reactive spectrum handoff's. Further it is worth to note that even though the study in this domain considers traffic loads, they lack considering a ping-pong effect which is very likely to arise in heavy traffic load scenarios. As a future study an algorithmic based approach can be developed to consider this effect and to minimize it.

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