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Cognitive Radio Spectrum Handoff Schemes Based On Spectrum Sensing

A Comprehensive Survey

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Abstract— ***Wireless communication techniques have gained popularity in the recent decade, wireless networks, at present, follow the technology of fixed spectrum allocation. This technique, in which spectrum bands are licensed by government agencies, follows the geographical division of regions and static access of the spectrum. Which limits the available spectrum causing in-efficiency; therefore we require a common method which can be applied to all network devices for optimal use of spectrum i.e. cognitive radios. Cognitive radio accesses the spectrum dynamically, which provides opportunistic spectrum access. There are many design issues and challenges in using CR network because of variable structure and quality of services. One such issue is spectrum handoff. Although there are many techniques by which a spectrum can be accessed by a user, in this paper spectrum handoff by spectrum sensing is discussed. There are three major methods to accomplish this handoff process which has been analyzed and compared, to provide a better scope for researchers physically implementing cognitive radios. This paper provides a comprehensive and brief survey on the cognitive radio spectrum handoff schemes based on spectrum sensing.***

Index Terms—Spectrum allocation, cognitive radio, dynamic access, handoff, sensing.

I. INTRODUCTION

Wireless networks, at present, are assigned and controlled by government agencies by providing licensed bands for communication, which follows static spectrum access technique generally based on geographical regions. This results in underutilization of spectrum. The division process was optimum in the past decade, but now massive increase in the number of potential users has caused the problem in the ease of access of spectrum, thus causing spectrum scarcity. This is a virtual scarcity as large portion of spectrum remains unutilized. Therefore, cognitive radio networks came into play. CR users are also known as secondary users (SU), they do not have a license to operate in preferred spectrum unlike primary users (PU) who have a pre-allocated spectrum band of operation. Therefore, to exploit this flexible feature the framework of CR network is designed in contrast to the existing, static access communication network.

CR has four main management frameworks [1], broadly classified as, spectrum sensing, this is the first and most important step of establishing a communication channel in CR network. In this step, the secondary user (the user who wishes to communicate via cognitive radio network) discovers and identifies the white spaces or the spectrum holes in a licensed or an unlicensed band [2]. It also identifies the occurrence of a PU in the band. Controls and decides the type of sensing to be performed for successful communication link establishment. The second work of a CR network is to select the best available channel according to the requirements and QoS this is known as, spectrum decision. Characterization and reconfiguration of a channel are done during this duration [3]. Spectrum access, allocation of resources and channel selection is performed in spectrum sharing framework. The intelligent decision of the management of the established link is taken in the last framework of spectrum mobility. Handoff is carried out during this duration; the cognitive radio user vacates the band when a primary user arrives [4].The CR user senses and allocates spectrum band based on the presence of spectrum hole and absence of PU, as shown in figure 1. This spectrum hole information is used to decide optimal channel out of many suggested bands. The CR user simultaneously keeps checking the presence of PU. If PU is detected handoff takes place immediately, and a link is established from another spectrum band. If PU does not appear, communication continues without any interruption. The process of transfer of communication link of two or more secondary users from the current busy channel to another vacant channel is known as spectrum handoff. This results in a delay in SU communication which degrades the network performance. In this paper, spectrum handoff by spectrum sensing technique is discussed due to its efficiency and ease of implementation. Part 2 below discusses the process and requirement of handoff in detail. Part 3 of the paper discusses three major forms of handoff technique which follow the process of spectrum access. Part 4 and Part 5 deals with the analysis and comparison of them.

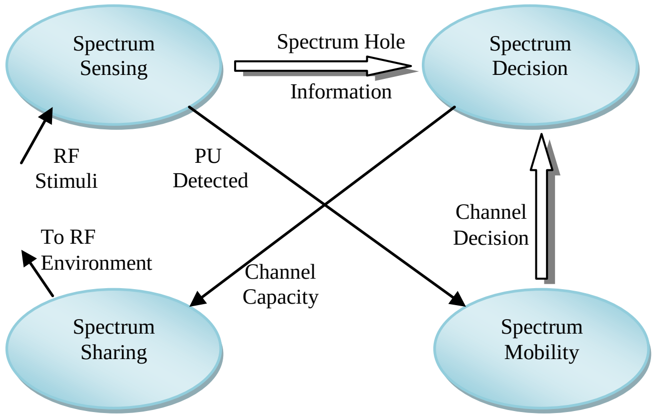

Fig 1: Cognitive Radio Management Framework

II. HANDOFF PROCESS

As discussed in Part 1, licensed and idle spectrum bands which are allocated by governments are also accessed by SU on the condition that SU vacates the band when a PU, which has the license, needs to access the spectrum. Therefore, to provide the primary users with vacant spectrum to avoid interference in their communication, the SU first pause its communication, vacates the band and again establish a link on another vacant spectrum band and resumes the communication, thus causing spectrum handoff [5]. As shown in figure 2, this process causes delay (t_d) and sluggish communication of SU, which in turn affects the performance and quality of service of SU. Spectrum handoff can occur due to several reasons, the first is which has been already discussed, i.e. when the PU arrives in the licensed spectrum which is being used by the secondary user at the time. This forces SU to vacate the channel and use another spectrum thus causing handoff. The second reason of spectrum handoff is the movement of SU in space. Due to this spatial movement, a possibility of channel interference with PU occurs, which again forces SU to vacate the spectrum. Thirdly, A CR user evacuates the spectrum band if it detects degradation in the link quality. The CR user periodically monitors the quality of channel being used for communication to analyze if it’s time for spectrum handoff. Spectrum handoff is a two-phase cyclic process [6]. As shown in figure 3, the first is the analysis phase and second is the maintenance phase. In the first phase, SU periodically keeps analyzing the environment for a trigger for handoff i.e. presence of PU or link quality degradation. On the detection of a trigger, CR user makes the decision to perform handoff.

For handoff, it goes into the second phase of maintenance. Here, the ongoing data transmission is first paused by Cognitive radio user. Next, it hands over its current channel to the primary user which claims it for setting up its communication link. The SU then decides another alternate spectrum band and jumps on its frequency to resume data transmission over the discovered free channel. This analysis and maintenance phase cycle continues uninterrupted. There are few parameters on which handoff quality and performance is decided, for example, number of spectrum handoff in a communication should be low, to reduce unnecessary delay in the data transmission, the handoff latency, i.e. time by which data transmission is delayed before resuming itself in new acquired channel after handoff, should be low. For proper handoff, the link maintenance probability, which is the probability of successful link establishment between PU and base station, should be high [7]. But, the increased number of handoff also reduces net data rate due to increase in latency. The latency increase increases the chances of interference of SU to the PU. Therefore, it is evident that a trade-off is required to perform the handoff specific to application. There are many schemes by which handoff can be performed. Some of them are handoff triggering- timing based, mobility based, initial and target channel probability based, game based, differential path loss based, grade based, operating mode, dedicated radio utilization, fuzzy logic based spectrum handoff technique. In this paper, spectrum handoff by spectrum sensing technique is analyzed and compared. In the following section, four popular spectrum handoff technique based on spectrum sensing scheme is discussed.

III. HANDOFF SCHEME BASED ON SPECTRUM SENSING

There are many spectrum handoff methods based on spectrum sensing schemes the most popular of them are discussed here,

A. *Recommended channel sensing sequence based spectrum handoff*

In this method handoff is performed in two possible situations, the first is that the handoff occurs in the present frame and the second, is when the secondary user performs handoff using multiple frames [8]. Various feedback algorithms are used to identify the situation. In this scheme, the handoff delay is less and is decided by performance metrics of the above stated two situations. Sensing accuracy and link maintenance probability are the parameters which are considered for analyzing performance metrics.

B. *Energy efficient spectrum sensing based handoff*

Energy efficient spectrum sensing based handoff spectrum scheme is popular due to its efficiency in terms of the spectrum as well as energy. At present, the vast wireless web is energy consuming and is affecting resources capabilities, the battery life of devices and environment adversely. This scheme is efficient in terms of energy and operational expenditure; it provides high utilization of the limited power and resources [9]. It requires less power for spectrum sensing. The method is based on the idea of periodic spectrum sensing. It also includes antenna selection mechanism which improves the performance by reducing the sensing time.

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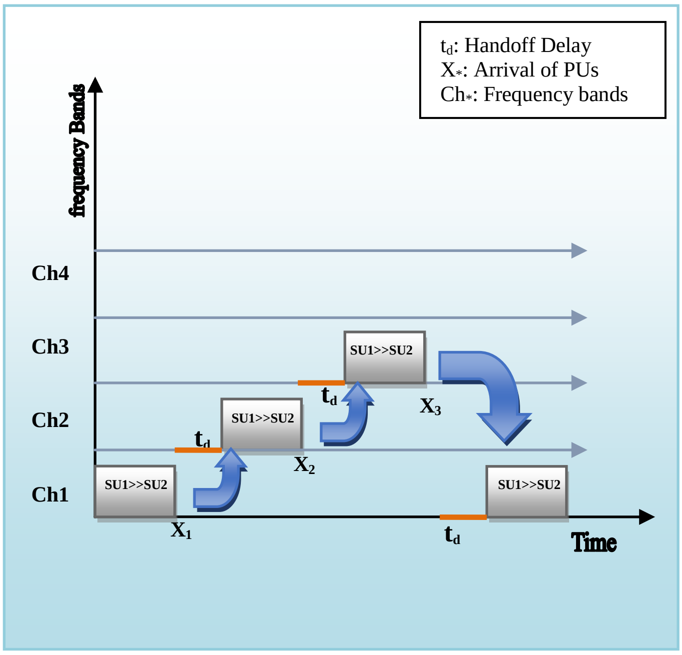


Fig 2: Communication of SU1 with SU2 (Handoff

Fig 3: Block Diagram of S

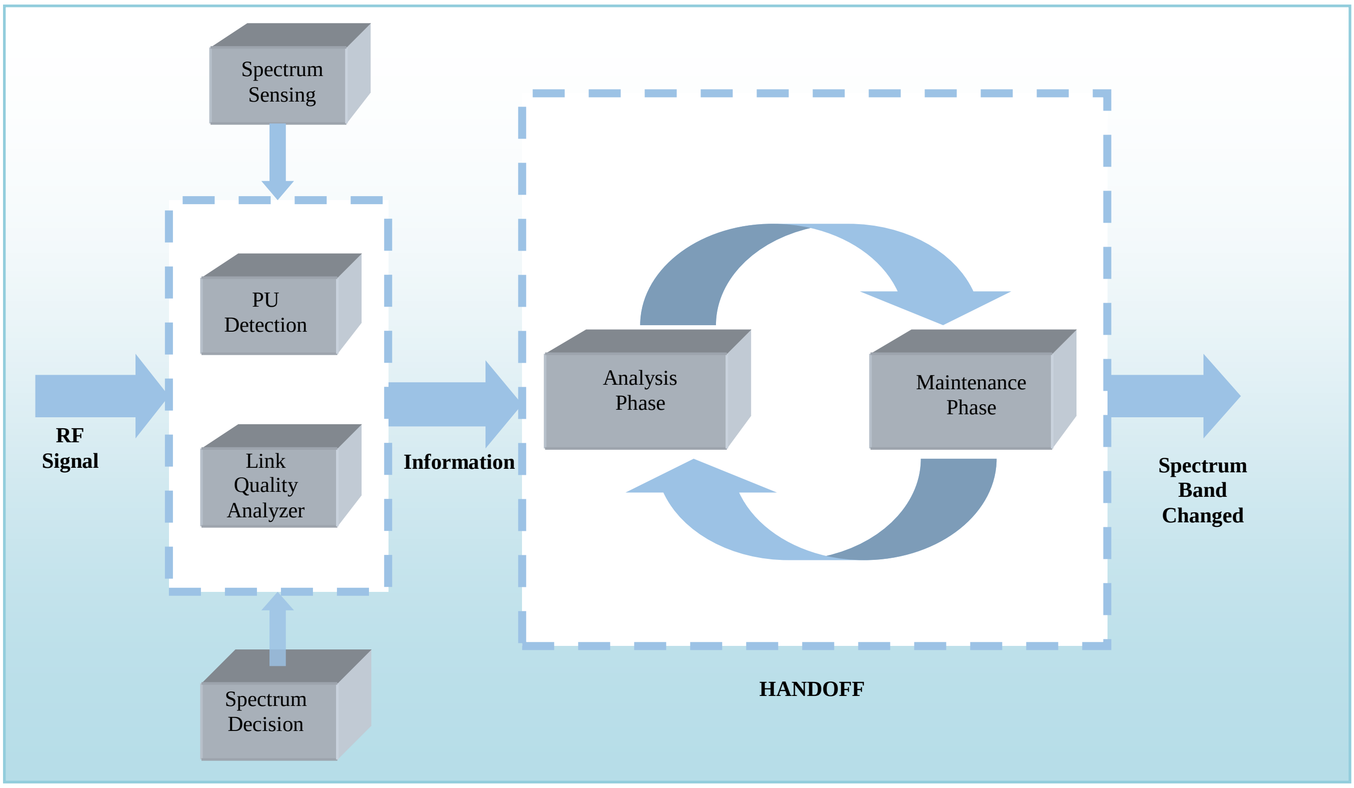
In this scheme, when CR user detects the presence of PU in the channel, which is being used by it for communication, it finds a suitable vacant band for its transmission and evacuates the current channel for PU.

The major advantage of this scheme is that it can find most optimal target channel as spectrum sensing is accurate and reliable. The drawback is handoff latency due to reactive spectrum sensing. Spectrum sensing is performed after handoff trigger appears, which is usually a slow process, becomes the major factor for handoff delay in on-demand handoff process.

D. Proactive spectrum sensing based handoff

Here, proactive sensing and handoff mechanism is used. The CR user finds a backup target channel even before handoff trigger appears. This prediction is analyzed on the basis of primary user traffic model, for SU's evacuation before the arrival of PU.

The advantage of this scheme is that the backup is planned



before handoff so it reduces handoff latency. The chances of multiple handoffs are reduced as all the probable future target spectrums are analyzed beforehand [10]. The predicted channel could be outdated and would never be used, or there is a possibility that during handoff the predicted channel is

Fig 2:

already occupied. Due to imprecise primary user traffic model overall spectrum mobility is affected adversely.

IV. Research Issues and Challenges

There are many issues in spectrum handoff which needs to be addressed in near future. Some of them are discussed as follows:

A. Channel Contention

In most research works, communication is considered between two secondary users. But, practically, more than two SUs are involved and their simultaneous spectrum handoff can cause channel contention. Channel contention can cause handoff latency and decreases the number of successful handoffs. Distributed channel section algorithms are used to select available channel [11].

B. Reducing Number of Handoffs

In CR ad-hoc networks, due to the absence of a central base station, multiple handoffs can occur which increases handoff latency and negatively affects link maintenance quality. The scheme which should be employed should be such that it avoids unnecessary spectrum handoffs.

C. Spectrum Availability

For a secondary user to perform handoff operation a broad and dynamic range of the spectrum is required. In practice, a SU may experience high or low spectrum availability which makes handoff difficult due to limited choice of available spectrum.

Table 1: Comparison of Spectrum Sensing Based Handoff Scheme

D. Energy Efficiency

Spectrum sensing and continuous information update require a significant amount of energy. Spectrum sensing is a crucial step in management and mobility, thus, it increases power consumption which reduces efficiency and limits resources. Therefore, energy efficient spectrum handoff schemes should be used.

E. Standardization of Handoff Scheme

A standard handoff scheme is required throughout the world, for universal adaption of handoff for the end users and service providers. Current handoff schemes are designed for spectrum management of cognitive radios only. They can also be standardized for all types of ad-hoc devices for end users to easily grasp the concept. Till now, no spectrum handoff scheme is standardized.

F. Interference Avoidance

As discussed in Part I, secondary users are considered as low priority users as compared to primary users which have the license of a spectrum. As the primary user arrives, cognitive radio user has to pause its transmission and vacate the spectrum instantly, this may cause an unwanted interference in primary user's communication. It is important to use handoff mechanism which enables interference avoidance mechanism for exact and proper spectrum handoff.

G. Hardware Constraint - Limited Agility

For performing spectrum handoff the secondary user has to jump from one frequency band to another, sometimes the target band can be adjacent, i.e. can be reached by less hardware switching function, other times the target band can be far away

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delay in handoff [12]. Hence, hardware improvement is necessary to avoid this latency and inaccuracy in spectrum handoff.

Category of Spectrum Sensing based Handoff scheme	Description of Handoff Spectrum	Performance Parameter	Limitations
Recommended channel sensing sequence based spectrum handoff scheme	The main aim is to minimize handoff delay which is based sensing accuracy and link management probability.	Handoff delay	Inaccuracy in spectrum sensing.
Energy efficient spectrum based spectrum handoff	The main aim is to minimize energy requirement. Based on periodic spectrum sensing	Collision probability and energy efficiency	Inaccuracy in spectrum sensing.
Reactive spectrum sensing based	Target channel is wideband sensed after the spectrum handoff request is done to increase the accuracy of spectrum sensing.	Handoff delay	High handoff delay
Proactive spectrum sensing based	Target channel is wideband sensed before the spectrum handoff request is done.	Handoff delay	Incorrect PU traffic model can degrade handoff accuracy.

V. Conclusion

Spectrum underutilization problem has increased in the past decade due to licensed spectrum band allocation by government agencies. Cognitive radios are used to eradicate this problem as they access spectrum dynamically. As CR users use licensed and the unlicensed bands, in the same way, a handoff is required to avoid interference with primary users of the licensed band. There are many schemes by which spectrum handoff can be done. Optimal handoff scheme can be chosen by researchers based on CR management framework and network metrics. Handoff based on spectrum sensing is the most popular type of handoff scheme. The commonly used schemes are analyzed and compared. Challenges and research issues are discussed in this work. Unfortunately, there are many issues which remain unaddressed in recent research works on cognitive radio networks. The hardware limitations like power efficiency and handoff agility could be addressed for further improvement in spectrum handoff accuracy.

Thus, an intelligent and organized spectrum handoff scheme is required for efficient and accurate CR communication. Therefore, spectrum handoff in the cognitive radio network is a demanding field which requires special consideration of researchers.

Acknowledgment

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References

[1] I. F. Akyildiz, W. y. Lee, M. C. Vuran and S. Mohanty, "A survey on spectrum management in cognitive radio networks," in *IEEE Communications Magazine*, vol. 46, no. 4, pp. 40-48, April 2008. doi: 10.1109/MCOM.2008.4481339.

[2] Krishan Kumar, Arun Prakash, Rajeev Tripathi, Spectrum handoff in cognitive radio networks: A classification and comprehensive survey, In Journal of Network and Computer Applications, Volume 61, 2016, Pages 161-188, ISSN 1084-8045.

[3] M. T. Masonta, M. Mzyece and N. Ntlatlapa, "Spectrum Decision in Cognitive Radio Networks: A Survey," in *IEEE Communications Surveys & Tutorials*, vol. 15, no. 3, pp. 1088-1107, Third Quarter 2013. doi: 10.1109/SURV.2012.111412.00160.

[4] L. Giupponi and A. I. Perez-Neira, "Fuzzy-based Spectrum Handoff in Cognitive Radio Networks," *2008 3rd International Conference on Cognitive Radio Oriented Wireless Networks and Communications (CrownCom 2008)*, Singapore, 2008, pp. 1-6. doi: 10.1109/CROWNCOM.2008.4562535

[5] Krishan Kumar, Arun Prakash, Rajeev Tripathi, Spectrum handoff scheme with multiple attributes decision making for optimal network selection in cognitive radio networks, In Digital Communications and Networks, Volume 3, Issue 3, 2017, Pages 164-175, ISSN 2352-8648.

[6] C. W. Wang and L. C. Wang, "Analysis of Reactive Spectrum Handoff in Cognitive Radio Networks," in *IEEE Journal on Selected Areas in Communications*, vol. 30, no. 10, pp. 2016-2028, November 2012. doi: 10.1109/JSAC.2012.121116.

[7] I. Christian, S. Moh, I. Chung and J. Lee, "Spectrum mobility in cognitive radio networks," in *IEEE Communications Magazine*, vol. 50, no. 6, pp. 114-121, June 2012. doi: 10.1109/MCOM.2012.6211495.

[8] Wu, Chengyu & He, Chen & Jiang, Lingge & Chen, Yunfei & Shi, Qingjiang. (2015). Optimal Channel Sensing Sequence Design for Spectrum Handoff. IEEE Wireless Communications Letters. 4. 1-1. 10.1109/LWC.2015.2417556.

[9] Wang, Shaowei & Granelli, Fabrizio & Li, Ying & Chen, Shanzhi. (2014). Energy-efficient cognitive radio networks [Guest Editorial]. Communications Magazine, IEEE. 52. 12-13. 10.1109/MCOM.2014.6852077.

[10] L. C. Wang and C. W. Wang, "Spectrum Handoff for Cognitive Radio Networks: Reactive-Sensing or Proactive-Sensins?," *2008 IEEE International Performance, Computing and Communications Conference*, Austin, Texas, 2008, pp. 343-348. doi: 10.1109/PCCC.2008.4745128.

[11] Y.Song J. Xie "Common Hopping Based Proactive Spectrum Handoff in Cognitive Radio Ad Hoc Networks" Proc. IEEE GlobeCom pp. 1-5 2010.

[12] M. NoroozOliaee, B. Hamdaoui, X. Cheng, T. Znati and M. Guizani, "Analyzing Cognitive Network Access Efficiency Under Limited Spectrum Handoff Agility," in *IEEE Transactions on Vehicular Technology*, vol. 63, no. 3, pp. 1402-1407, March 2014. doi: 10.1109/TVT.2013.2283856.

[13] D. Lu, X. Huang, C. Liu and J. Fan, "Adaptive Power Control Based Spectrum Handover for Cognitive Radio Networks," *2010 IEEE Wireless Communication and Networking Conference*, Sydney, NSW, 2010, pp. 1-5. doi: 10.1109/WCNC.2010.5506.