Comparative Study between Control Channel Establishment and Blind Rendezvous in Cognitive Radio Networks

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Abstract : The traditional static spectrum allocation policy will no longer cater the spectrum requirement of increasing demand of spectrum by new wireless devices. In static allocation policy, whenever licensed owners of the spectrum are silent or when they are not active that portion of the spectrum remains vacant which results in inefficient use of the spectrum. Cognitive Radio (CR) Technology has been recognized as a promising solution to support ever increasing wireless devices spectrum needs. The unlicensed users use the spectrum assigned to licensed users whenever they are not active or when they are not using it. In a CR environment, licensed users of the spectrum are Primary users (PUs) and unlicensed users of the spectrum are Secondary users (SUs). In a CR environment, SUs need to coordinate with each other for communication establishment. For this purpose, a dedicated common control channel (CCC) is a basic requirement but an always available CCC in a dynamic environment is difficult to maintain because of PUs random activity. To solve this issue, blind rendezvous is a technique for SUs to find each other without the need of a dedicated CCC. In this paper, a comparative study of various CCC establishment techniques and blind rendezvous has been done. It has been found that blind rendezvous is a promising solution for SUs for their communication needs in CR environment.

***IndexTerms* – Cognitive Radio, common control channel, rendezvous**

I. Introduction

The level at which the research has been done on Cognitive Radio (CR) technology in the last decade, CR networks (CRNs) has been established as a remedy for the problem of spectrum underutilization [1,2]. A recent survey shows that temporal and geographical variations in the utilization of the assigned spectrum ranges significantly with a high variance in time [3] as shown in Fig. 1 where the spectrum utilization is less than 6%. The method adopted in the CRNs is 'use when other is idle' which implies the unlicensed users of the spectrum which are referred to as secondary users (SUs) can use the spectrum assigned to licensed users or primary users (PUs) only when PUs are not using their assigned spectrum [1,2]. Apart from using the spectrum when PUs are idle, SUs need to vacate the spectrum they are using when PUs becomes active. SUs can get the service for their communication needs keeping in view priority to PUs. A basic Before communication establishment, SUs need to coordinate with each other for basic network functions. This coordination among SUs is provided by establishing a Common control channel (CCC) [4]. This CCC works as a backbone for secondary network infrastructure.

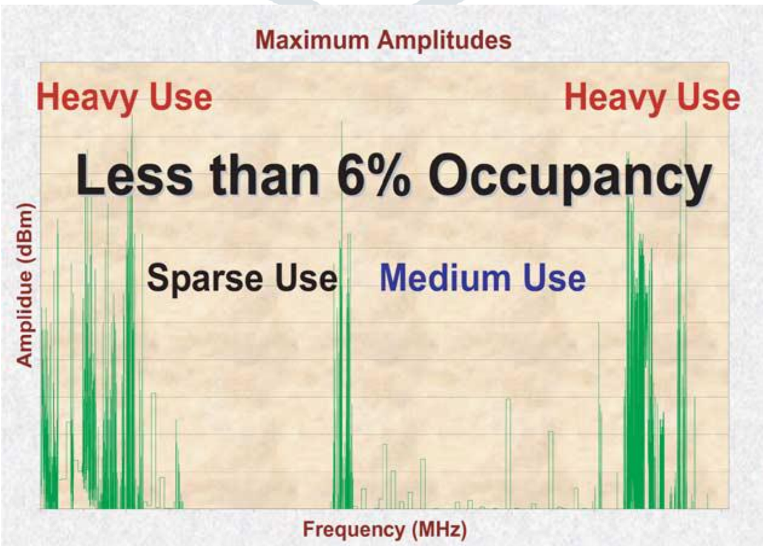

Fig. 1 Spectrum usage

II. Common Control Channel in CRNs

There are a variety of functions provided for the proper functioning of the CRN which includes the handshake between sender and receiver, compromise between SUs for channel use, the updates about the change in the network and updates about the availability of channels. The information about the availability of other vacant channel where the SU has to move is provided by the information available on CCC. The CCC thus acts as medium of communication between SUs for all their communication needs in a CR environment. With these basic functions provided by CCC, the techniques must be devised which can provide the reliable CCC. Although a control channel in legacy wireless networks provide the basic functions such as control message exchange, a single point of failure is always an issue. Apart from this, when network load is more than average the control channel saturation is one other issue which results in delay, loss of packets and overall degradation in the efficiency [5]. To mitigate these issues, many design schemes for CCC design schemes have been proposed [6] which provide the basis for control channel design in CR environment.

In [7], a detailed analysis of control channel design has been given which pave the way for new design schemes of CC design in CRNs. In [7], the control channel design schemes have been classified broadly in two categories, Overlay and underlay as shown in Fig. 2. Other than control channel classification, this first level of categorization describes the way SUs operate in CRNs. In the overlay mode, the control channel has to be established exclusively of the frequency bands which are left vacant by PUs and on return of PUs, the control channel has to be broken and re-establish in some other vacant channel [7]. In Underlay approach, the control channel is established in the bands used by PUs not exclusively buy inclusively. Here, the control channel is established with a view to remain always available in the bands used by PUs by using the techniques such as spread spectrum. Using these techniques, the control information is to be sent over the control channel as low power short pulses which are then spread over large bandwidth and this transmission will appear as noise to the PUs. This way an always available control channel is maintained and is not affected by PU activity. As shown in Fig. 2, the overlay approach has further been divided into in-band and out-of-band schemes. This further division is based on whether the control channel has been established in the data channels (in-band) or has been established in a dedicated spectrum (out-of-band) either licensed or unlicensed. There are issues with each approach. Although the out-of-band technique provides a dedicated control channel but as it is established mostly in unlicensed band, it may suffer severe interference and then may not be of any use at all. If it is to be established in licensed band then it ultimately consumes the bandwidth available for actual use which results in degradation in spectrum utilization efficiency. On the other hand, the in band techniques are vulnerable to PU activity. In band techniques have further been divided in sequence based and group based techniques depending on the control channel establishment methods. The underlay approach uses ultra wide band transmissions.

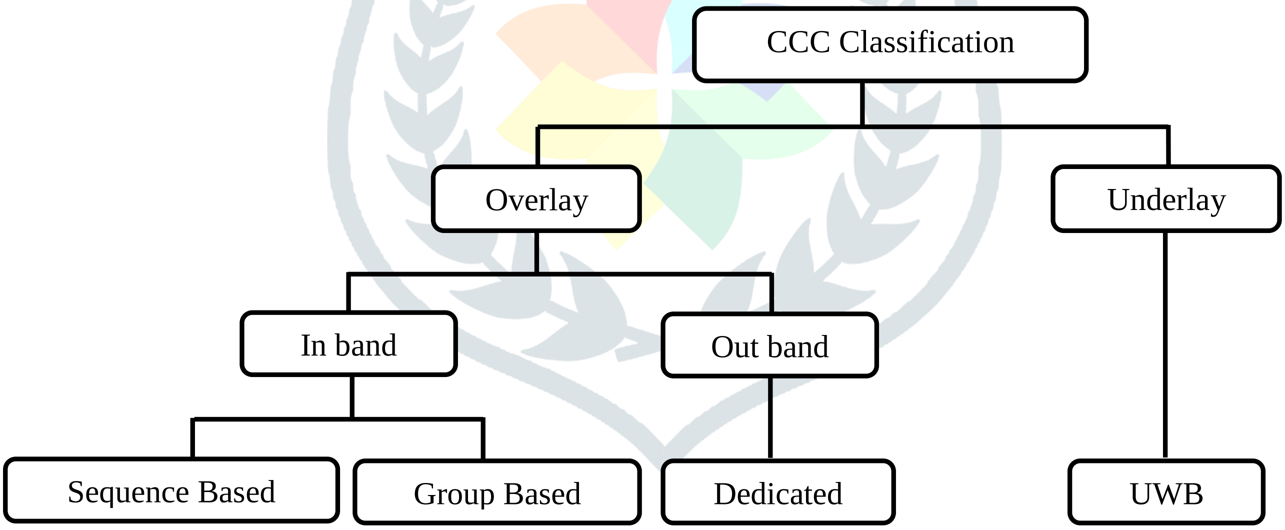

Fig. 2 Control channel design classification

III. Rendezvous in CRN

All the control channel design techniques discussed in the preceding section has issues associated with them. To mitigate these issues, one other approach of coordination between SUs rendezvous process. In this approach, SUs should detect the presence of each other without the aid of CCC to establish communication links so that the necessary information exchange can be carried out. Rendezvous is a process in which two or more radios meet each other on a common channel [8]. When not employing CCC, rendezvous is a basic necessity in a CR environment. But, SUs in a CRN are not aware of the presence of each other before meeting and also the available channels within the reach of each SU is different. Due to this, rendezvous establishment in a CRN is a challenging task keeping in view the time it takes for rendezvous. There are two approaches for establishing rendezvous in a Dynamic Spectrum Access (DSA) environment. One is with using a centralized controller [9,10] and the other is without any centralized controller which is called as blind rendezvous systems which are actually more favorable than the former one. For blind rendezvous, Channel-hopping (CH) is one of the most representative techniques [8]. Although in DSA environment, each SU may have its own set of available channels and it can differ with the available channel set of other users but it needs at-least one commonly available channel. In CH technique, each SU hops among its set of available channels and when the sender and receiver hops on the same channel at same time instant, rendezvous will be established. Based on the available channel set of SUs, the rendezvous establishment can be modeled as either symmetric or asymmetric. In Symmetric model, all the SUs in a CRN have the same set of available channels while in asymmetric model, SUs may have different number of available channels but have at-least one commonly available channel. A number of CH algorithms have been proposed in the literature [10-17]. The metric for performance evaluation has been taken as Maximum Time to Rendezvous (MTTR) and Expected Time to Rendezvous (ETTR). MTTR is the time taken for the two radios to establish a communication link by achieving rendezvous. It is desirable to design CH algorithms that can achieve a lower bound on MTTR and ETTR. Taxonomy of rendezvous techniques has been given in [16] which is shown in Fig. 3.

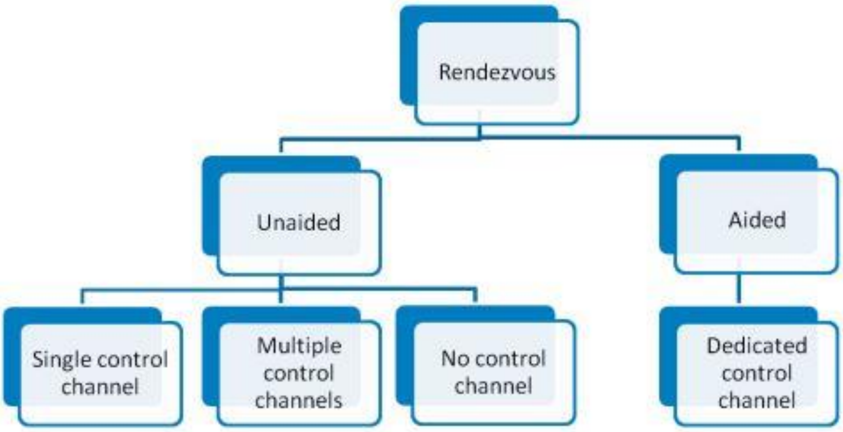

Fig. 3. Taxonomy of rendezvous techniques

In Fig. 3, systems that provide rendezvous have been classified as aided and unaided systems. As the name suggests, in aided systems, a centralized controller handles all the tasks of rendezvous establishment which includes directing the sender and receiver to achieve rendezvous. The centralized controller has been first establishment at the network formation stage and then works for overall management of the system. While it seems simple to establish such a system, this system is not robust to the changes in the network and thus it is not flexible and scalable. If the centralized controller fails, all the network functions disrupt and thus becomes a bottleneck. On the other hand, in the unaided rendezvous technique, there is no support of any centralized controller and the have to find each other for rendezvous on their own. The unaided rendezvous technique has further been classified in three categories; single control channel, multiple control channel and no control channel. In single control channel technique, SUs who want to communicate exploits a single control channel for rendezvous establishment. This method still is not favorable because every action of rendezvous depends on this single channel and its failure leads to total communication failure. In the second type of unaided rendezvous technique which is multiple control channel technique, SUs must find one another on one of the available channels for rendezvous establishment. Although having multiple control channels reduces the problem of single point of failure, the increased overhead in maintaining multiple control channels is still a daunting task. The third category of unaided rendezvous technique is no control channel and in this there is no control channel available and the SUs must find each other blindly on their own through CH.

CONCLUSION

CRNs promises to enhance spectrum utilization efficiency by providing access to unlicensed users when licensed users are not using it. The last decade has seen significant amount of research in CRNs. There are a variety of operations at each layer and one of the basic function in CRNs is to facilitate coordination among CR users. This coordination is generally provided by CCC. But there are some design challenges associated with designing an efficient CCC. One other approach for coordination among SUs without using CCC is through rendezvous process. For rendezvous establishment, Common Hopping is one the most sought after technique. In CH, each user hops among its set of available channels for rendezvous establishment. The metric to quantify the rendezvous technique is MTTR. There are issues associated with both of the techniques but rendezvous technique is found to be a better approach because of it does not depend a single channel and does not create a single point failure. However, algorithms must be devised to keep a minimum possible lower bound on MTTTR.

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