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Channel Selection for Spectrum Sharing using CR Nodes

[+] R.Kaniezhil[1*+], C.Chandrasekar[2] and S.Nithya Rekha[3*]

[*] Full–time Research Scholar, Dept. of Computer Science, Periyar University, Salem, TamilNadu, India
[2] Associate Professor Dept. of Computer Science, Periyar University, Salem, TamilNadu, India

Abstract. In the proposed work, if one service provider is found to be overloaded, it utilizes the spectrum of the other service provider which is found to be underutilized. Thus, CR nodes senses the best available channel for sharing and it provides the list of available channels to the overloaded service provider to utilize the under utilized spectrum efficiently. Spectrum sharing among service providers improve the spectral efficiency, probability efficiency of sensing and reduces the call blockage. If the number of service providers are increased to share the spectrum, this would reduces the high traffic patterns of the calls.

Keywords: CR, dynamic spectrum allocation, spectrum sharing, spectrum scarcity, spectrum access, utility performance.

1. Introduction

Traditional wireless networks have predominantly used direct point-to-point or point-to-multipoint (e.g., cellular) topologies. In contrast to conventional point-to-point communications, cooperative communications and networking allows different users or nodes in a wireless network to share resources and to create collaboration through distributed transmission/processing, in which each user's information is sent out not only by the user but also by the collaborating users [1].

Cooperative communications and networking is a new communication paradigm that promises significant capacity and multiplexing gain increase in wireless networks [2], [3]. To solve the problem of spectrum scarcity and spectrum underutilization, the use of Cognitive Radio(CR) technology is being considered because of its ability to rapidly and autonomously adapt operating parameters to changing requirements and conditions.

We can in fact dramatically improve the spectrum utilization if we allow a system to utilize dynamically not only a dedicated frequency band, but also the under–utilized frequencies that are allocated to other systems. This concept is referred to as *dynamic spectrum sharing.* Spectrum Sharing (SS) is seen as one possible approach to improving efficiency and considered by this programme covers both opportunistic sharing, as well as managed sharing of radio resources among multiple operators.

The paper structure follows: In Section 2 & 3, Cognitive Radio Technology and Spectrum sharing are briefly introduced. In section 4 , Channel Selection for Selective Sensing using CR Nodes is discussed as problem description. In section 5 and 6, performance measures of Spectrum sharing and simulation results are presented. Finally, we draw our conclusions in Section 7.

2. Cognitive Radio Technology

[+] Corresponding author. Tel.: +919994451525.
E-mail address: kaniezhil@yahoo.co.in

The key enabling technology of dynamic spectrum access techniques is cognitive radio (CR) technology, which provides the capability to share the wireless channel with licensed users in an opportunistic manner. The term, cognitive radio, can formally be defined as follows:

A ‘‘Cognitive Radio” is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. From this definition, two main characteristics of the cognitive radio can be defined as follows:

Cognitive capability: Cognitive capability refers to the ability of the radio technology to capture or sense the information from its radio environment. Consequently, the best spectrum and appropriate operating parameters can be selected.

- Reconfigurability: The cognitive capability provides spectrum awareness whereas reconfigurability enables the radio to be dynamically programmed according to the radio environment.

CR networks are envisioned to provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. This goal can be realized only through dynamic and efficient spectrum management techniques.

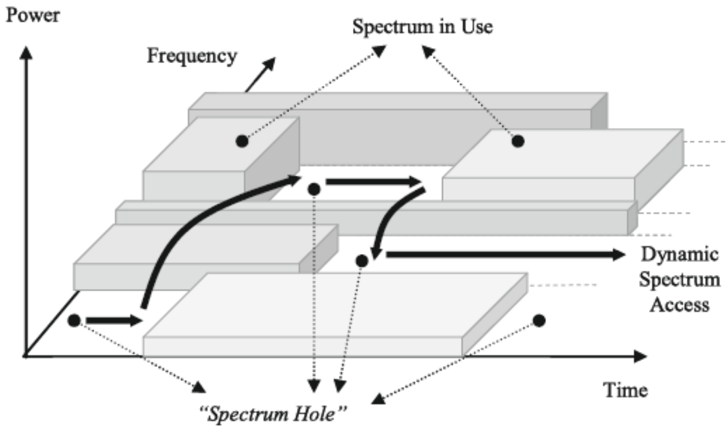

Fig. 1: Spectrum Hole Concept

The ultimate objective of the cognitive radio is to obtain the best available spectrum through cognitive capability and reconfigurability as described before. Since most of the spectrum is already assigned, the most important challenge is to share the licensed spectrum without interfering with the transmission of other licensed users as illustrated in Fig.1.

2.1. Proposed CR Nodes Sensing

With the capability of sensing the environment and finding the available spectrum dynamically, CR technique can help to implement spectrum sharing and improve the spectrum utilization efficiency. In the proposed work, CR engines such as learn and decision does the work of Spectrum Sensing. Here, CR nodes help to provide the list of available channels and it checks the availability of the channels. Mobile nodes get the information of availability of channels from BS through the CR nodes as shown in Fig. 2.

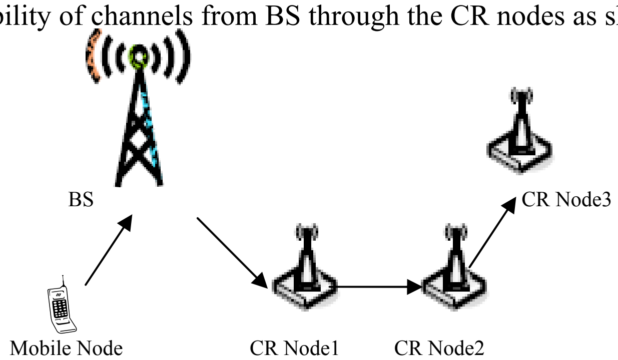

Fig. 2: CR Nodes sensing the available channels

3. Spectrum Sharing

3.1. Basic Functionalities

Spectrum sharing techniques are generally focused on two types of solutions, e.g., spectrum sharing inside a CR network (intra-network spectrum sharing), and between multiple coexisting CR networks (inter-network spectrum sharing) [4]. Inter-network spectrum sharing can be carried out either based on a spectrum broker that is connected to the base-station [5] or in a distributed approach without support of the central network entity [7]. Unlike spectrum decision, spectrum sharing mainly focuses on resource management within the same spectrum with the following functionalities:

- Resource Allocation: Based on the QoS monitoring results, CR users select the proper channels (channel allocation) and adjust their transmission power (power control) [9] [11] to achieve QoS requirements as well as resource fairness.
- Spectrum Access: It enables multiple CR users to share spectrum resources by determining who will access the channel or when an user may access the channel [12].

3.2. Proposed Architectural Concept

The infrastructure-based network can provides sophisticated spectrum sharing method with the support of the base-station. Thus, it can exploit time slot-based scheduling and dynamic channel allocation to maximize the total network capacity as well as achieve fair resource allocation over CR nodes. Furthermore, through the synchronization in sensing operation, the transmission of CR nodes and primary users can be detected separately, which decouples sensing operation with spectrum sharing. Generally, CR networks use a periodic sensing scheme where CR nodes are allowed to transmit only during the transmission period followed by sensing (observation) period. In this architecture, the transmission period is synchronized over all CR nodes.

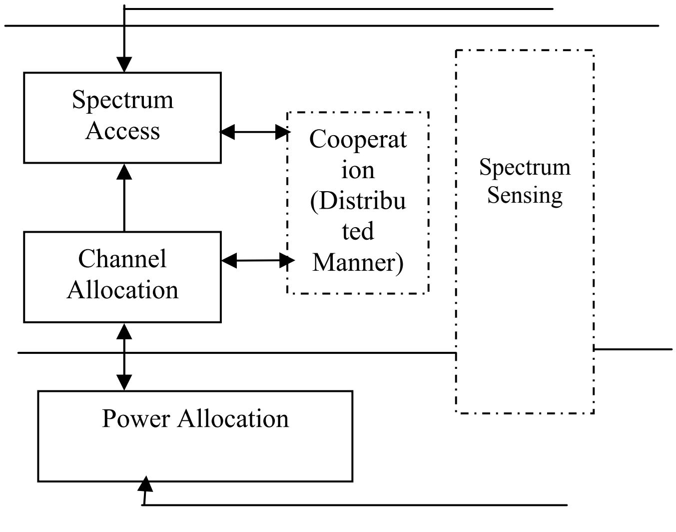

Fig. 3: Functional Block diagram for Spectrum sharing – Wireless Networks

Thus, spectrum sharing needs to focus on channel allocation or time-slot-based scheduling within this transmission period.

4. Channel Selection for Selective Sensing Using CR Nodes

In the proposed work, the channel assignment scheme accounts for the interference conditions and the power constraints at different bands. Channel availability can be determined by sending service request to the BS. BS receives service request from the mobile nodes and it will send the channel request to the CR node. CR node receives the channel request and sends the broadcast message to the adjacent CR node. A neighbor CR node receives the broadcast message and also sends the available channel list to the BS. CR node and its neighbors, updates the channel availability list and sends response to the BS. If BS receives the response from the CR node, it selects the available channel and sends service reply with the allocated channel to the mobile nodes. This shows the maximize utilization of a channel and it offers several services such as internet service, call service, multimedia service and so on to the mobile nodes. Our scheme, identifies 'available' channel list for each CR node. Such a list shows which channel is available to use depending on the distance among the CR node and High frequency band. Within a given neighborhood, multiple CR nodes may contend for access to one or more of the available channels.

In the proposed work, priority will be given to the primary user. It shows that if one service provider is found to be overloaded, it checks out the available channel using neighborhood CR nodes. If the service provider is found to be under-loaded, it accepts the other service providers to gain access the available channels in its region.

5. Performance Metrics

In this section, we look into the performance metrics which are used to evaluate the spectrum sharing among service providers. The metrics includes block counting, service unavailability and sensing efficiency.

1. Block count: The blocking probability for CR nodes is defined as the ratio of total blocked calls (or spectrum requests) over total calls processed by all service providers.
2. Service unavailability (Spectral Efficiency): Higher Spectrum efficiency is anticipated compared to service provider systems because the blocking count of user system is lower. Thus more calls can contribute to the maximize channel utilization.
3. Probability Efficiency (System Efficiency): Probability efficiency metric for service provider is determined by the processed traffic intensity and the total traffic loaded to service provider within the observation time.

6. Simulation Results

In the above sections, we have seen about the sensing scheme, spectrum selection method. In this section, we present simulation results on the performance of our proposed sensing framework. Channel assignment mechanisms in the traditional multi-channel wireless networks typically select the 'Best' channel for a given transmission. In the proposed work, we are choosing the available channel with the high probability and high frequency band.

To generate utility performance measures, we assume:

1) Maximal five service providers share their spectrum and 100 nodes are chosen.
2) Maximum limit of user/channel is 10 and Call arrival of each service provider is heterogeneous process.
3) Traffic rates are correlated jointly-Gaussian random variables;
4) The infrastructure of different service providers are located at the same position and the cell radii is also the same.
5) Each CR node has the ability of sensing its range within the coverage limits.
6) CR nodes have the capability of detecting all the available channels that are licensed to the other service providers.

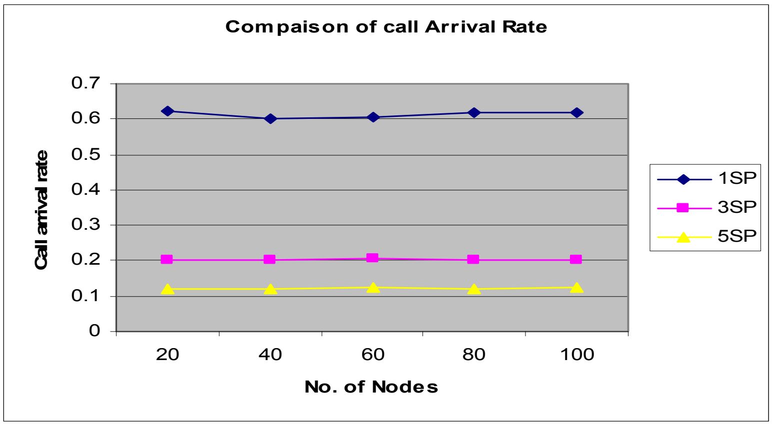

Fig. 4: Comparison of Call arrival rate

We conduct simulations to verify the potential of the call arrival rate for different service providers in terms of utility performance measures. We denote call arrival rate as the number of calls in a hour. Fig.4 shows the call arrival rate for different service providers and the traffic pattern of service provider is decreased with the increased number of service providers.

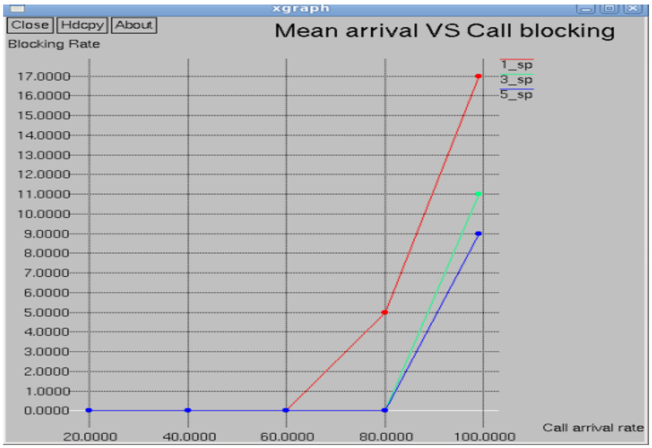

Fig. 5: Mean arrival Vs Call blocking

Fig.5 shows that, at higher traffic rates, the call blocking rate is higher when the traffic rates of different service providers are highly correlated. The outcome is the direct result of the fact that mobile using this system can select another service provider to gain access when one service provider is overloaded.

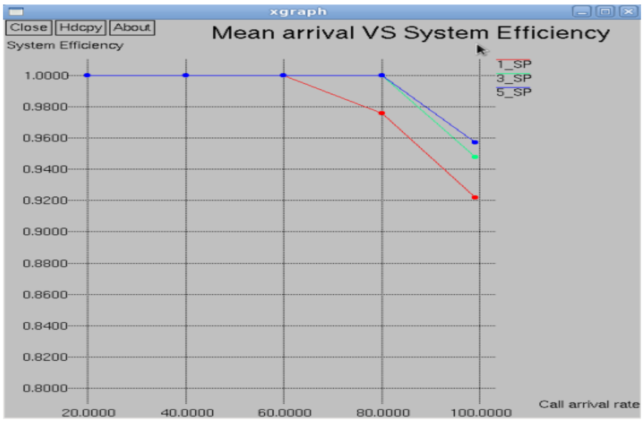

Fig. 6: Mean arrival vs System Efficiency

Fig.6 shows that, at high traffic rates, the system efficiency is lower when the traffic rates of different service providers are highly correlated. When the correlation is lower, based on Fig.6, the dropped calls decrease, thus, the total processed calls increase. The system efficiency decreases when the traffic rate is beyond the system capacity.

7. Conclusions

The proposed algorithm predicts the call arrival rate of primary users and it gives an approach to predicts the call holding time of the primary users. The proposed algorithm, which leads to the best transmission and observation time to maximize sensing efficiency satisfying the strict interference constraint of primary networks. At the higher traffic capacity, the call blocking rate is found to be high due to the higher traffic rates of different service providers are highly correlated. This prediction enhances the channel utilization of primary users and enhances the communication of primary users. CR nodes monitor the channel utilization of different service providers and avoids the scarce resource of the spectrum.

8. References

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