PERFORMANCE EVALUATION OF COOPERATIVE SPECTRUM SHARING IN MULTIHOP NETWORKS

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ABSTRACT
In spectrum-sharing cognitive radio systems, the transmit power of secondary users (SU) has to be very low due to the restrictions on the interference power dictated by primary users (PU). In order to extend the coverage area of secondary transmission and reduce the corresponding interference region, multi-hop amplify-and-forward (AF) relaying can be implemented for the communication between secondary transmitters and receivers. Monte Carlo simulation is a method used in this project for iteratively evaluating a deterministic model using sets of random numbers as inputs. The optimal power allocation is used to allocate the transmit power of secondary users (SU) to avoid the interference at the primary user (PU). The performance can be evaluated for different number of hops in terms of probability and interference power at the primary user with the signal to noise ratio using an amplify and forward (AF) relay protocol.

Keywords: Amplify and forward (AF), Cognitive radio (CR), Cooperative relaying, multi-hop relaying, power allocation, spectrum sharing.

1. INTRODUCTION
In recent years, the field of wireless communication systems has shown a tremendous amount of development with respect to research and practice. Applications range from the daily needs like mobiles, Wi-Fi, to commercial uses like satellite communications. With the aid of current technology, it is possible to communicate with any corner of the world. These technologies require a reliable and internet system for better performance. Currently users are being engaged by the services of a number of available wireless access systems. Especially, a number of new systems are capable of using not only the 800 MHZ to 6000 MHZ band which is suitable for broadband wireless access systems and for cellular communications but also the frequency bands such as the very high frequency (VHF) and ultra high frequency (UHF) bands. It seems that after around ten years, the majority of frequency bands, suitable for mobile communication systems, are entirely engaged and new solutions are compulsory. One of the possible solutions is to use the "Cognitive Radio" technology which is a radio or system, that is able to sense and that is fully aware of its functioning situation and can regulate its radio operating parameters autonomously according to collaborating wireless and wired networks. In order to more efficiently use the available spectrum on the frequency band, this technology is expected as a key technology.

Cognitive radio (CR) is a promising wireless technology to resolve the growing scarcity of the indispensable electromagnetic spectrum resources. By use of CR, secondary users (SUs) without explicitly assigned spectrum resources can co-exist with primary users (PUs) licensed with particular spectrum. In practice, some major communications regulators like the Federal Communications Committee (FCC) in U.S. and the Office of Communications (OFCOM) in U.K. have allowed secondary access for unlicensed devices to the terrestrial TV broadcast bands.

Among various forms of CR implementation, spectrum-sharing CR is especially appealing for practical deployment since it does not involve complex spectrum-sensing mechanisms. More specifically, spectrum sharing CR limits only the transmit power of SUs such that their harmful interference onto PUs remains below prescribed
tolerable levels. Because of the interference power constraint dictated by PUs, the transmit power of SUs in spectrum-sharing systems has to be very low, which limits the coverage area of secondary transmission. In order to extend the coverage area of secondary transmission and guarantee reliable communication, cooperative relaying techniques can be exploited. Using relaying techniques, a single or multiple idle users can be involved in forwarding messages between a secondary source and its destination.

2. SYSTEM MODEL

The last decade has witnessed the increasing popularity of wireless services. In fact, recent measurements by Federal Communications Commission (FCC) have shown that 70% of the allocated spectrum in US is not utilized. CR is a kind of intelligent wireless device, which is able to adjust its transmission parameters, such as transmit power and transmission frequency band, based on the environment. In a CR network, ordinary wireless devices are referred to as primary users (PUs), and CRs are referred to as secondary users (SUs). CR is defined as an intelligent wireless communication system that provides more efficient communication by allowing secondary users to utilize the unused spectrum segments.

A K-hop cooperative relaying system operating in a spectrum sharing cognitive radio (CR) environment is considered. The secondary users and primary users exchange data with some consecutive Amplify and Forward (AF) relay. All nodes are equipped with a single half duplex omni directional antenna. For the secondary multi-hop AF relaying link, all SUs work in a time division multiple access (TDMA) fashion. Only one SU transmits to its next node along the multiple path during each time slot. The received signal to noise ratio (SNR) at the Kth secondary node is defined as:

\[ \gamma_k = \frac{P_{k-1}}{\sigma_k^2} d_k^{-\eta_k} f_k^2 \]  

where \( \gamma_k \) is the received SNR, \( P_{k-1} \) is the transmit power of secondary users, \( \sigma_k^2 \) is the additive white Gaussian noise (AWGN) variance, \( d_k \) is the distance, \( f_k \) is the channel fast fading coefficient. The received SNR for the secondary users are calculated based on the different parameters. The interference coming from the primary transmitter is treated as noise.

3. OPTIMAL POWER ALLOCATION

The criterion for optimal power allocation at the secondary nodes is established. The average tolerable interference power at the primary user is \( W \) dB. The optimal power is constrained and this tolerable interference power is based on the interference power or average peak power. The power allocation parameter is determined based on the average interference power and it is expressed as

\[ E[\lambda_{k-1} - (\sigma_k^2/\eta_k)(h_k^2/f_k^2)] = 10^{W/10} \]  

Where \( \lambda_{k-1} \) is the optimal power, \( \sigma_k \) is the variance, \( \eta_k \) is the path loss ratio, \( h_k \) is the fading coefficient of the desired link, \( f_k \) is the fading coefficient of the interference link, \( W \) is the tolerable interference power at the primary user.

4. CHANNEL ESTIMATION

The channel estimation is based on sensing the primary and secondary users. The number of channels are allocated for the transmission of the data frames. The channel state information is provided to
each user. The sensing time is based on the detection probability.

The number of channels allocated in this project is 8. The noise and the power level can be estimated for each channel.

5. PERFORMANCE ANALYSIS

Consider the number of hops as an even integer with K=4. The multihop link is perpendicular by using an amplify and forward relay protocol. In this relaying scheme, the relay sends an amplified version of the received signal in the last time-slot. For cooperative communication, AF schemes provide spatial diversity to fight against fading; for capacity estimation of relay networks, such schemes provide achievable lower bounds that are known to be optimal in some communication scenarios and for analog network coding, given the broadcast nature of the wireless medium that allows the mixing of the signals in the air, these schemes provide a communication strategy that achieves high throughput with low computational complexity at internal nodes. The path loss ratio value is taken as 10 and it is used to calculate the distance parameters for the desired link and the interference link. The path loss ratio is given as

\[ \eta = \frac{d_k^{-\epsilon}}{l_k^{-\epsilon}} \]  
(3)

where, \(d_k\) and \(l_k\) are the distance parameters, \(\epsilon\) is the path loss exponent and the value is 4.

If the multihop link is perpendicular to the interference link then the value is normalized to unity. For K=4 hops the distance between the PU_1 and SU_2 is normalized to unity. The various distance parameters are calculated using the path loss ratio. The monte carlo simulation method is used in which the gain of the channel is subject to Rayleigh distribution with unit mean and the variance of AWGN at all nodes is set to unity.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>d_1</td>
<td>1.6</td>
</tr>
<tr>
<td>d_2</td>
<td>0.6</td>
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<tr>
<td>d_3</td>
<td>0.56</td>
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</tr>
<tr>
<td>l_4</td>
<td>1.14</td>
</tr>
</tbody>
</table>

The SNR of the received PU signal at the sensor depends on the PU transmitted power and the propagation environment. The two error probabilities are linked to each other through sensing time, SNR, and detection threshold. The detection performance improves with an increase in the SNR. After determining the SNR value as 15 dB then the optimal power is allocated to each secondary user under some constraints. The probability is determined based on probability density function.

The tolerable interference power is measured with respect to the optimal power and the distance parameters. The total transmit power at the secondary user is 10 and the interference power is found as W=30 dB. It indicates the increase in tolerable interference power leads to the better performance for different hops in multipath.

6. SIMULATION RESULTS

In this paper, the performance of cooperative spectrum sharing is evaluated for different number of hops using amplify and forward (AF) relaying protocol.
The Figure 2 indicates the performance of spectrum sharing for the different number of cognitive radio users. From the above graph, it is very clear that the alarm increases with the detection probability and it indicates that the channel can be reused when it is available. The probability of detection is the time during which the PU (licensed) is detected. If the sensing time is increased then PU can make better use of its spectrum and the limit is decided that SU can’t interfere during that much of time. More the spectrum sensing more PUs will be detected and lesser will be the interference because PU can make best use of their priority right.

To avoid the interference at the primary user the transmit power of secondary users has to be very low, so that the optimal power allocation algorithm is used to allocate the power optimally under maximum and minimum conditions. The optimal power is constrained and this tolerable interference power is based on the interference power or average peak power. The number of channels allocated is 8. The noise and the power level can be estimated for each channel. The below figure 4 represents the power allocation using the water filling for 8 channels and the various noise and power levels can be estimated.

After the power allocation is done, the performance can be determined with respect to the probability and the average interference power. The amplify and forward (AF) relay protocol is used for cooperative relaying in multihop networks. The SNR value is measured as 15 dB and it is used to estimate the interference power or average peak power which is termed as tolerable interference power at the primary user. The below figure 4 shows the probability degrades when there is an increase in tolerable interference power for different number of hops as k=2, 4. As the hops increases in the network, the coverage area for transmission can be extended.

6. CONCLUSION
In this project, the performance of cooperative spectrum sharing in cognitive radio is analyzed using multihop relay networks. The coverage area can be extended using the multihop cooperative relaying. The amplify and forward relaying protocol improves the performance of the multihop network and it is simple when compared with the other techniques. To avoid the interference at the primary user, the transmit power of secondary users has to be low, so optimal power allocation is done at the secondary user. The signal to noise ratio (SNR) value is 15dB, and the results are analyzed for different hops in terms of tolerable interference power and probability.

In future, the analysis of cooperative spectrum sharing in multihop networks can be done for different relaying protocols. The optimal power allocation can be used to limit the transmit power of secondary users for the tolerable interference at the primary user with the different number of hops.

REFERENCES


