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A Novel Spectrum Sensing Technique for Cognitive Radios under Shadow Fading Environment

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Abstract

Background/Objectives: Cognitive radios are future communication devices which will have the ability to bring revolution in communication systems. The major role of cognitive radios to sense its surrounding environment to use white spaces in spectrum for complete utilization of spectrum band. **Methods:** This paper presents a lightweight solution to mitigate the shadow fading using the one-bit padding factor by using data packets or acknowledgements exchanged between the two cognitive ends. **Findings:** The proposed model called Multiple Frequencies Sensing – One-Bit Parent Frequency Management (MFS-OBPFM) works on the principle of exchange of bit information which is processed and analyzed on the receiver side, and analyzed for the spectrum availability pattern. The shadow fading patterns are found and analyzed in time domain and data is scheduled according to these shadow fading patterns. The frequency domain is designed according to the spectrum availability factor. The proposed model is expected to give the performance parameters of throughput, time complexity, total energy consumed and number of reports by the primary and secondary user. The proposed model has been tested on the basis of various performance parameters of energy, time, etc. The proposed model has shown efficient results in the terms of performance parameters than the existing models. **Improvements:** The proposed model is consuming less energy in different data volume transmission as compared to the energy efficient model in same data volume.

Keywords: Cognitive Radios, Communication Systems, Shadow Fading, Spectrum Sensing

1. Introduction

A Cognitive Radio (CR) is an intelligent device - https://en.wikipedia.org/wiki/Radio that has an ability to change its behavior dynamically according to its programming. Cognitive radios transceivers are designed in such a way that they use the best wireless channel around them. Such a radio has the intelligence to detect spectrum holes or free channels in wireless spectrum, according to these channel specifications changes its communication parameters and allow more reliable wireless communications in a given spectrum band. Changing its parameters dynamically is a type of dynamic spectrum management. Due to the limited amount of network resources, so to use these limited sources efficiently cognitive radio devices change their transmission and reception parameters to provide more efficient use of these resources[1] .Cognitive radios are capable of configuring the radio system parameters such as operating frequency, waveform parameters; networking protocols etc. Cognitive radios analyze these parameters and exchange this information within the network. This exchange helps other cognitive devices to access this information and work accordingly. A cognitive radio also checks its performance parameters in a continuous manner, in addition to other radios output parameters and based on this information, change its communication parameters and decide its RF environment. Cognitive radios also change its setting to provide better communication. Cognitive radios are software defined radio with the ability to change its network environment to meet the user demands. Thus cognitive radios work on the principle of identifying other cognitive radios in its sur-

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rounding and to strategize its communication parameters in such a way so that it reduces the interference to and from other cognitive radios[2].

There are so many techniques of spectrum sensing such as 2 - stage wideband spectrum sensing technique. In the coarse spectrum sensing, the entire frequency range with the bandwidth is analyzed. A Multi-Resolution Spectrum Sensing (MRSS) scheme based on wavelet transform is used for coarse sensing. During detection, the occupied and candidate (unoccupied) channels are identified. During the fine sensing stage, detection takes place over the candidate channels to find unique features of modulated signals[3-5]. A reconfigurable processor is designed to classify any linearly modulated signal and according to simulation results it shows 95% accuracy in classification[6]. Another technique to reduce the energy consumption is to dynamically compress or decompress the data because due to these decompression and compression user can decrease the amount of data for communication and hence improve the energy saving ability of the system[7]. FHSS and DSSS are compared on the basis of this new technique. They conclude that FHSS is difficult to jam due to its random selection of channels as compared to DSSS; hence the FHSS signal has better overall performance. FHSS is better than DSSS and suitable to use for military communication purpose[8-9]. FHSS can also be used at a higher bandwidth to maintain the BER and to increase the data rate efficiently[10-11]. Joseph Mitola explained cognitive radio's working in his foremost paper in the form of a cyclic process known as 'The Cognition Cycle'. The proposed cycle works in different stages: the first stage is 'observe' in which the radio sensors analyze external features such as GPS coordinates to identify its location etc. The first stage of this communication process is an 'orient' stage. In this stage the input data is received by the system and orientation of system takes place. The next stage is a planning of different operations which can be possibly performed on user data and 'decide' one best solution out of the possible alternatives. The final stage is to 'act' on it by allocating required resources. This model was quite generic and complex to understand and observe-think-act cyclic approach has been discussed to provide a better understanding of cognitive communication. The cognition cycle is proposed which can be classified as an observer-orient-plan-decide-act process in which the radio learns about its surroundings at each stage[12]. There are some more studies have been done on cognitive radios such analyzing each spectrum sensing technique with MATLAB, considering probability of false alarm and missed detections as performance parameters[13-14]. Performance of cognitive radios can also be increased or quantified in low SNR by using hard detection for local sensing[15].

2. Motivation

The existing spectrum sensing scheme is not found capable of their adaptability to the cognitive radio channels with the shadow fading and the performance is significantly reduced for the data transmissions. The problem of reduced data transmission ability causes the data drop across the given cognitive channel established between the two communication ends. The existing scheme has been found inefficient in tacking the shadow fading caused in the shorter intervals. The appearance of the micro-interval shadow fading is usually produced by the increase in the height of trees, wavy objects implanted on the high rise buildings, etc. The micro-interval fading causes the shorted data drops in the repetitive manner, which results in cyclic redundancy mismatch and hence forces the receiver's end to re-request for the bunch of data. This procedure directly adds the higher latency to the data transmissions and significantly affects the overall performance of the cognitive radio channel. The above problem is intended to cause the data overhead due to the TCP data re-request for the dropped or corrupted data. In this paper, we have proposed the innovative technique to mitigate the micro-noise from the cognitive channel caused by the micro-interval fading using the active bit method on each frequency. The proposed model is aimed at shortening the sensing interval and to utilize the request and reply mode instead of the automatic reply mode from the receiver's node end.

In this paper, the objective is to develop lightweight shadow fading mitigation method by using the spectrum sensing by offering one bit for each frequency. The proposed one-bit sensing mechanism will also utilize the energy detection mechanisms to identify the signal strength over each available frequency, which is further utilized by the sender's node to transmit the sensing request to the other end. Spectrum pattern availability is thoroughly studied by analyzing the replied bit-information from the receiver's nodes and then the individual frequency signal strength is utilized for the final decision of the spectrum allocation. The transmission scheduling is done according to the replied bit pattern and the signal strength analyzed by the non-cooperative energy detection method and this information is further utilized to sequence the egress data over the given cognitive radio channel.

3. Spectrum Sensing in Shadow Fading Environment

The pre-setup authentication methods are utilized to securely establish the connections between the communication ends. The sender's end always enquires the receiver's end, because the sender's end is giving up the data towards the receiver's end. The receiver's end responses with the pre-shared information, which is further utilized to establish the secure connection between both of the ends. This initial setup phase is associated with the initial authentication of the two ends to begin communication. Authentication is performed with a couple of viewpoints. The main reason for authentication is to ensure the security of the data transmission between two users. After the completion of the initial authentication setup phase, the spectrum sensing mechanism takes the place between the two ends of the communication. The sender and receiver nodes exchange the 1-bit data in order to recognize the availability of the spectrum. The spectrum availability is evaluated through the exchange of 1-bit query from sender's end and N-bit reply from the receiver's end. The 1-bit query is transmitted over the frequency channel with highest signal strength, and the replies follows on all of the frequencies. The frequencies with the lower signal strength are eliminated from the final frequency group for data propagation in order to minimize the chances of the data drop and the bit error rate.

3.1 Key Generation Algorithm

Key generation algorithm is required to build a trust between sender and receiver. This key generation is an initiation process for authentication between the primary and secondary user. Steps required for key generation algorithm are as follows.

1. Start-up the key generation module
2. Input variable ← {seed}
3. Assign input seed → {S}
4 .Apply the trigonometric sine function on S → S_{sin}

$$S_{sin} = \frac{opposite}{hypotenuse}$$

5. Apply the trigonometric cosine function over S_{sin} → S_{cos}

$$S_{cos} = \frac{adjacent}{hypotenuse}$$

6. Apply the trigonometric cosine function over S_{cos} → S_{log}

$$S_{log} = \frac{-lim}{e \to 0} \int_{e}^{\infty} \frac{dt}{t}(e^{-xt} - e^{-t})$$

7. Combine all of the above values using the following equation

$$K_B = S_{sin} \times S_{cos} \times S_{log}$$

8. If K_B is recorded as the negative value

$$K_B = -K_B$$

9. Convert the key to number format with left shift decimal function

$$Key = round(K_{\downarrow}B \leftarrow \mathbf{6})$$

3.2 Sender's Algorithm

1. Input parameters: variable status
2. In case the status 1 is entered (if status equals 1)
   a. Initialize the range for random function →{minVal, maxVal}
   b. Input the range variable to random function ← {minVal, maxVal}
   c. Run the random function
   d. Return the randomly produced seed value → {seed}
3. In case the status 2 is entered (if status equals 2)
   a. Prepare the socket for data transmission
   b. Wait for the ready state → {0, 1}
   c. If ready state equals 1
   d. Generate and return the acknowledgment flag initialized with value 1 to represent the request bit.
4. In case the status 3 is entered (if status equals 3)
   a. Obtain the input acknowledgement reply → {IAR}
   b. If IAR equals [1 1] <Two bit sequence reply>
      i. Initialize the connection setup procedure
      ii. Setup the connection when ready state is returned
5. Otherwise
   a. Quit the connection status
   b. Close the socket
   c. Reassign the ready state

d. Return the false value for connection status

3.3 Receiver's Algorithm

1. Input parameters: variable status
2. In case the status 1 is entered (if status equals 1)
   a. Mount the memory pointer
   b. Fetch the pre-shared information
   c. Return the pre-shared information
3. In case the status 2 is entered (if status equals 2)
   a. Prepare the socket for data transmission
   b. Wait for the ready state → {0, 1}
   c. If ready state equals 1
   d. Generate and return the acknowledgment flag initialized with value [1 1] to represent the request bit in two bit format

Note: two bit sequence depicts the connection status approval between the two edges.

3.4 Spectrum Sensing Flowchart

The spectrum sensing flowchart is shown in Figure 1.

4. Result Analysis

This paper presents the comparison of proposed model working with different spread spectrum techniques such as Direct Sequence Spread Spectrum (DSSS) and Frequency Hoping Spread Spectrum (FHSS). The simulation is carried out to evaluate different performance parameters such as throughput, data drop, and average energy consumed as well as number of sensing reports. The throughput can be defined as the amount of data transferred from transmitter to receiver or processed in a specified amount of time. It is usually measured in Kbps, Mbps, and Gbps. In simulation, the attacker nodes are programmed to flood the victim node with the various flooding formations or methods. The throughput has been obtained from the simulation to analyze the performance of the proposed model. The throughput is calculated at each transaction while sending the data.

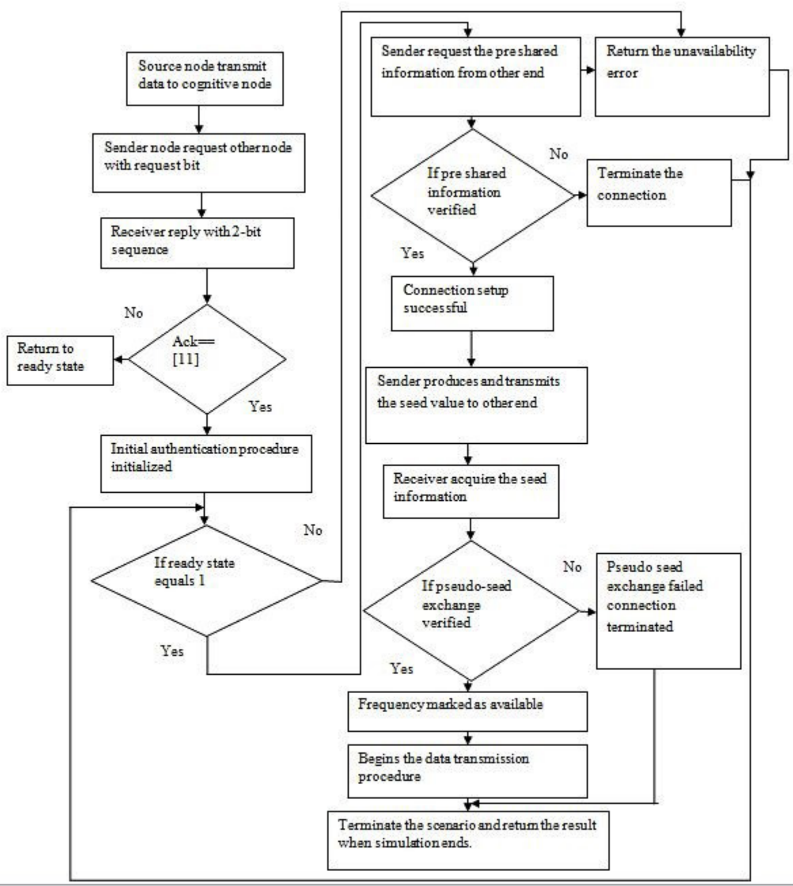

Figure 1. Spectrum Sensing Flowchart

4.1 Throughput

The amount of data or information which can be processed by a system with respect to time is known as throughput, or throughput can also be defined as a capacity of system to transmit the data within the network.

$$\text{Throughput} = \sum_{t=1}^{n} \frac{\text{total data processed}}{\text{capacity to process}} \times 100 \qquad (4.1)$$

Where, t = Time interval

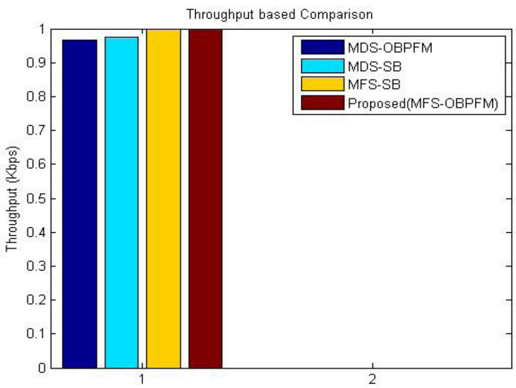

Figure 2. Throughput graph obtained from the simulation

In simulation sender's node send data to receiver's node on the other end and throughput is checked at an interval of 1.5 s. The throughput in the simulation is the number of megabytes (Mb) exchanged between the sender's node and the receiver's node on the cognitive radio channel as shown in Figure 2.

4.2 Time Complexity

The time complexity for the sensing mechanism is a sum of time which is required in generation of sensing packet by the source and time which is required to reach the packet at the receiver side. It is usually measured in sec.

$$\text{Delay} = \sum_{t=1}^{n} \frac{\text{time length}}{\text{total sensing packets}} \qquad (4.2)$$

Where, t = Time Interval

The Figure 3 shows the time complexity for sensing operations of each of the previously discussed model for a range of SNR values. DSSS shows the highest latent model at each SNR value and there is almost the linear decrease in time complexity with the increasing SNR. In case of FHSS, time based performance is better at each SNR than the conventional DSSS system. But its performance improved by the use of the proposed model with one-bit cognitive sensing process for each available frequency. DSSS (MDS-OBPFM) shows comparatively higher time complexity than FHSS (MFS-OBPFM) based proposed model for low Signal to Noise Ratio (SNR) but as we increase the SNR value the time complexity comparatively increases. It is quite evident from the above graph that FHSS (MFS-OBPFM) when combined with cognitive radio returns least time complexion (sensing latency) cost than the other systems. There is a significant decrease in time complexion at lower SNRs.

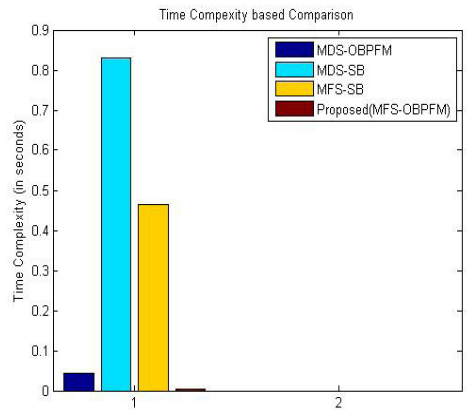

Figure 3. The time complexity based evaluation b/w existing and proposed model

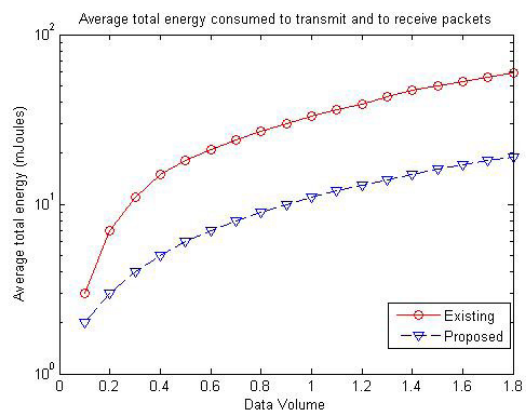

Figure 4. Average total energy required in transmission and reception of data.

4.3 Average Total Energy Consumed

In Figure 4 shows signal, yn(t), n = 1, ...,N, received by SUn at time t, under the idle and busy channel hypotheses, denoted by H0 and H1, respectively, are:

$$H0: yn(t) = wn(t),$$

$$H1: yn(t) = hns(t) + wn(t), (1) \tag{4.3}$$

where, s(t), hn, and wn(t) denote the transmitted signal from Primary User Base Station (PUBS), the channel gain from the PUBS to SUn, and additive white Gaussian noise (AWGN) with mean zero and variance σ2n, i.e. wn(t) ~ CN(0, σ2n), respectively.

4.4 Number of Reports

The number of reports (sensing reports) is evaluated in this simulation for the purpose of the resource load evaluation over the sender's and receiver's node produced due to the sensing operations. The parameter of the number of reports includes the total number of queries and replies exchanged between both ends and. The individual data size is also evaluated in order to measure the total data received or sent from both ends of the cognitive radio transmission is shown in Figure 5.

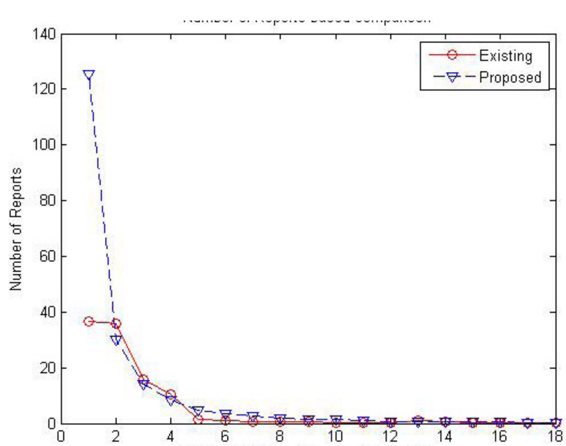

Figure 5. Number of sensing Reports based comparison.

5. Conclusion

Shadow fading is one of the major issues in deploying cognitive radio networks. This research studies the effects on BER when a cognitive process is embedded with signal modulation techniques, such as DSSS and FHSS. Further research introduces an improved bit-exchange mechanism for spectrum sensing. It can be concluded from this research that the combination of FHSS mechanism with cognitive radio communication results in lower number of error bits generated, specifically at lower SNR. The proposed model based upon the one-bit sensing sequence for spectrum sensing is the key model for the greater performance of the proposed model in comparison with the existing models. The proposed model is working on FHSS technique because FHSS has many advantages over other spread spectrum techniques. Simulation results clearly show that the proposed model has clearly an upper hand in terms of different parameters such as throughput, time complexity, and average energy consumed as well as the number of sensing reports. The proposed model has been found better in the terms of spectrum sensing latency and total energy consumption for the data transmissions over the given cognitive channel. There is no such method of spectrum sensing which gives the perfect results in every scenario. Hence it gives the hope for the future enhancement in cognitive radios. In this section, some areas of spectrum sensing which require modification are enlisted.

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