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Improvement in Multihop Relaying Protocols using Monte Carlo and singular value decomposition technique in Cognitive Radio

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ABSTRACT

In this paper, we study performances of multi-hop transmission protocols in cognitive radio (CR) networks under impact software impairment. In the considered protocols, cooperative communication is used to enhance reliability of data transmission at each hop on an established route between a secondary source and a secondary destination. For performance evaluation, we derive exact and asymptotic closed-form expressions of outage probability and average number of time slots over Rayleigh fading channel. Then, computer simulations are performed to verify the derivations. Results present that the cooperative-based multi-hop transmission protocols can obtain better performance and diversity gain, as compared with multi-hop scheme using direct transmission (DT). However, with the same number of hops, these protocols use more time slots than the DT protocol. For these entire scenarios we used Monte Carlo simulation and singular value decomposition.

Keyword: cognitive radio network, AWGN, SVD, Monte Carlo simulation, AWGN etc.

I. INTRODUCTION

Cognitive radio networks (CRNs) have been introduced to enable efficient utilization of spectral resources [1]. Specifically in the underlay CRNs, the unlicensed or secondary users (SUs) coexist with the licensed or primary users (PUs) provided that the interference caused to PUs is below a threshold. This constraint limits the quality of service (QoS) of secondary communication. To enhance the QoS, multi-hop cooperative relaying has been introduced recently in CRNs. Spectrum sensing CRNs with multi-hop relaying is studied in [2]–[4]. The performance analysis of underlay multi-hop CRNs is presented in [5]–[8]. However, none of the aforementioned works consider cluster-based multi-hop relaying in underlay cognitive networks.

Channel fading owing to multipath propagation in a wireless communication system causes significant degradation in signal reception. Using various diversity techniques, we can mitigate signal degradation problem effectively. However, owing to the space limitations, it is difficult to install more than one antenna at the handsets. Thus, the cooperative relay technology provides us an excellent solution to support high data-rate wireless transmission as required in futuristic cellular and ad hoc wireless communications systems. In general, there are two forms of relaying protocols, namely cooperative relaying and multi-hop relaying, which will be briefly discussed in the sequel. First of all, as far as cooperative relay is concerned, depending on the functionality of relays, cooperative relaying uses two main protocols, namely amplify-and-forward (AF) [1] and decode-and-forward (DF) [2] protocols. For AF protocols, a relay simply amplifies received signals, and then forwards them to destination. Whereas for DF protocols, the relay receives signals, decodes them, and then forwards the estimated signals to the destination. However, from complexity point of view, the AF protocol is preferred. Furthermore, the AF protocols can use either fixed gain relays [3] or channel state information (CSI)-assisted relays [4,5]. A CSI-assisted relay exploits instantaneous CSI of source-to-relay link to adjust its gain. In contrast, a fixed gain relay simply amplifies its received signal by a fixed gain (here, the knowledge of received average power is required). Intuitively, system performance of the CSI assisted relays is superior to the performance of those with fixed gain relays. However, from practical implementation point of view, cooperative relay systems with fixed gain relays perform significantly better than the others.

II.DESIGN CHALLENGES IN MULTI-HOP CRN

Although multi-hop CRNs have the potential to achieve efficientspectrum usage, interference mitigation, higher throughputand extended coverage, there are several open researchissues in the design of multi-hop CRNs that need to be addressedfirst before they can be successfully deployed. Firstly,multi-hop CRNs face all the challenges that are inherent insingle hop CRNs. For example, CR devices are inherentlyheterogeneous in nature due to diversity in wireless accesstechnologies, user terminals, types of services and applicationsas well as the spectrum bands. Apart from these, multi-hopCRN design must deal with challenges that arise from themultiple hop nature of the communications. For example, itis not just sufficient to identify unused spectrum bands butto also regulate resource sharing (dynamic spectrum sharing/accessing) among all *flows* in the network and more importantlyaccomplish efficient *end-to-end* communication byestablishing routing amidst the dynamically changing sets ofcognitive relay nodes. Moreover, since PU transmissions mustbe protected, the biggest challenge for the CRNs is to enhanceand ensure quality of service (QoS) of secondary networksthemselves *without jeopardizing the PU's performance.* Inwhat follows, we will address some of the open researchchallenges arising in the design of MAC and Network layersof a multi-hop CRN and how they are interconnected (Fig. 2).

A. MAC Layer Challenges in Multi-hop CRN

In a wireless multi-hop network comprising of CR-enableddevices, nodes can tune to different spectrum bands at anypoint in time. This varying channel activity gives rise toseveral MAC layer issues.

Co-ordination challenges in neighbor discovery:

Neighbordiscovery period is defined as the time taken by a node todiscover its neighbor(s). Neighbor discovery is invoked whena node does not have any information about its "closest"neighbor(s) and needs to find a neighbor for transmission or information exchange. When a CR node switches on ormoves to a new frequency channel, it performs *listen beforetalk* to detect the presence of the PU as well as nearbyneighbor (relay) node(s) within its communication range inorder to establish a route to the intended destination. Since itis possible for each node in the network to choose its ownspectrum band, it is necessary for the given CR node to listenin the preferred channel(s) of *each* of the relay node(s). Hencethe number of channels to scan can be potentially large.

Moreover due to the dynamic nature of the configuration ofa multi-hop network, the relay node(s) can switch channelseven within the discovery period. A co-ordination policy thatkeeps the neighbor discovery period to a minimum is neededbetween the probing node and the respondents.

Heterogeneity in radio frequency ranges: The physical propagationcharacteristics of electromagnetic waves over differentspectrum bands can be another concern for multi-hop CRNs.

Radio frequency range is defined as the maximum distanceup to which a signal can be transmitted and *successfully*received. As mentioned earlier, given constant transmit power,a low frequency signal can travel farther, penetrate wallsand other obstacles but its information capacity is lower anddirectionality poorer, compared to a higher frequency signal.

Thus transmissions on different frequencies will have differentmulti-path effects and attenuation resulting in heterogeneousradio frequency range. Also FCC regulates the maximumtransmit power depending on the physical location of thefrequencies in the spectrum band. These factors together implythat the selection of an *optimal relay node at the MAC layernow involves the selection of optimal spectrum bands as well*and hence becomes a multi-variable optimization problem.
Moreover FCC regulates the maximum transmit powerdepending on the physical locations of the different frequencychannels in the spectrum band, which also contributes to theheterogeneity in radio frequency range. Thus the selection of*optimal* relay node(s), at the MAC layer also involves theselection of the best spectrum bands for control signaling anddata transmission.

Deafness problem: Consider a CR source S1, that wantsto transmit to a destination node, D1, using multiple hopsas shown in Fig. 1. Upon detecting the presence of the PU,any or all of the relay node(s) can trigger dynamic frequencyswitching and move to a new channel. Let us assume that therelay node A forwards S1's packets to relay node B usinga spectrum band color coded blue in the figure. Suppose aprimary TX now returns to the "blue" band near the relaynode B, but outside the sensing region of A or S1. B candetect the incumbent transmission in-band and will switch toa new channel. As A is outside the range of the primary TX,it can neither detect the primary, nor guess that a frequencyswitching has occurred resulting in the “deafness” problem.

Hence A would continue to re-transmit the same packetseveral times, assuming packet loss due to unreliable wirelessmedium. Hence, synchronization is required in the channelswitching protocols in the MAC layer to guard against thedeafness problem.

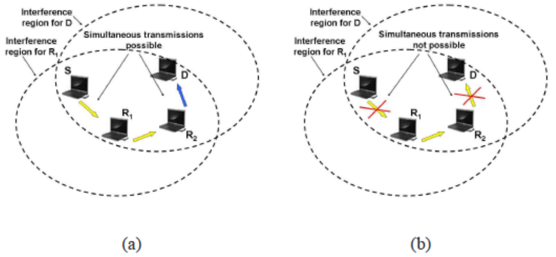

Figure 1: a) Relay nodes accessing different frequency channels makingsimultaneous transmissions possible; b) Relay nodes accessing same frequencychannels making simultaneous transmissions not possible

Distributed spectrum access at relay nodes: Fig. 1(a) showsa communication flow from source S to destination D throughthe relay nodes R1 and R2. For simplicity, let us assumeonly two frequency channels are available for this CRN.

Now, if S → R1 and R2 → D access different frequencychannels (colored yellow and blue respectively), simultaneous transmissions can take place. However, if the relay nodes areallowed autonomous and independent channel access, there isa finite probability that both the communication links (S → R1& R2 → D) will choose the same frequency channel leadingto interference and subsequent failure of communication asshown in Fig. 1(b). As the number of multi-hop communicationflows increases, there is likely to be an increase innumber of links attempting parallel transmissions in a certainregion and a simultaneous decrease in available frequencychannels. This will lead to an increase in the number of failedtransmission attempts. Thus it is clear that *distributed* MAClayer scheduling is necessary at the relay nodes in multi-hopCRNs.

B. Network Layer Challenges in Multi-hop CRNs

In conventional networks, whenever a new node switcheson, it announces its presence by broadcasting beacons andlistens to broadcast announcements (if any) from its peerson a single static frequency. In multi-hop CRN, generally,there is no pre-defined channel for the newly arriving nodes,which gives rise to several key routing issues that are uniqueto multi-hop CRN.

Suboptimal route selection: A major challenge for routing inmulti-hop CRNs is the current lack of coordination betweenneighbor/route selection and spectrum decision. Unlike intraditional ad-hoc networks, the *optimal* CR node in thesense of transmission range (or delay) may not be the closest*functional* neighbor (relay) in multi-hop CRN. Choosingthe closest node will result in suboptimal route for dataforwarding in the multi-hop CRNs as depicted in Fig. 2.

Thus, not only the distance between the source CR and therelay nodes, but also their operating frequency bands playa key role in deciding network connectivity. Depending onthe presence of PUs, relay nodes will dynamically accessand switch between frequency channels which will introducedynamic routing even within the same topology. So thetransmission/routing strategies will need to be coordinatedwith the spectrum decisions made at both the source CR andat the relay nodes in order to optimize routing decisions inmulti-hop CRNs.

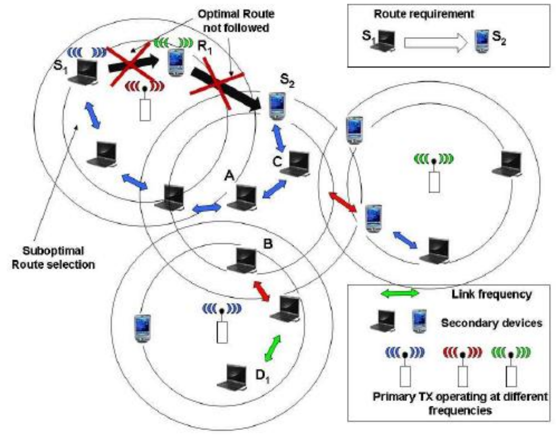

Figure 2: Suboptimal path selection

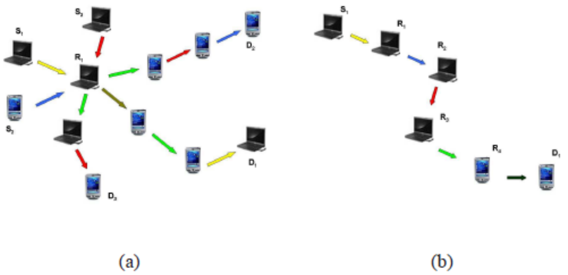

Figure 3: a) Switching delay at relay node R_1 due to multiple communicationflows (S1 → D1, S2 → D2, S3 → D3): R1 becoming bottleneck; b)Switching

delay along one single communication flow due to multiple relaynodes operating over different frequency channels

Varying interference: Traditionally, multi-hop routingrequires finding the best signal-to-interference routes forcommunication before start of transmission. However, in amulti-hop CRN, the interference from the surrounding mayvary rapidly throughout the communications as the CR nodesin the interference range change their band of operationdynamically and potentially rapidly.

Switching delay at a *single* relay node: In multi-hop CRN,if a single relay node serves too many communication flows*operating at different frequency bands*, it must constantlyswitch between frequency bands in order to serve all flows.

Thus additional switching delay will be introduced at therelay node. This delay can become significant as the diversityof frequency bands across all communication flows increase,thereby making the relay node a *bottleneck* in the network.

As an example, node R1 in Fig. 3(a) accommodates threedifferent communication flows (S1 → D1, S2 → D2, and S3→ D3). R1 relays flow S1 → D1 by receiving packets on the yellow frequency and transmitting on the gray, flow S2 → D2by receiving packets on blue and transmitting on the greenband and flow S3 → D3 by receiving packets on the red andtransmitting on green band respectively. This implies that toserve all three communication flows, the relay node R1 has toswitch between the yellow, blue, red, green and gray bands.

Thus it is clear that delay at R1 is dominated by switchingdelay. This frequency switching and re-synchronization cause's data transmission to pause, thereby adversely affecting datathroughput. Although using multiple transceivers may potentiallyreduce the number of switching across communication flowsat a relay node, it could be energy consuming and inefficientin terms of processing at the operating systems level becausethe operating systems of CR nodes are interrupt-driven. Also,having multiple transceivers in one radio device does notautomatically imply concurrent transmissions over multiplechannels.

Frequency switching delay along multiple hops: While theprevious metric measured the delay at one single relay node,it is also essential to consider the cumulative delay incurredover all hops of a *single flow*. In Fig. 3(b) the complete endto-end communication from S1 → D1 employs five distinctfrequency channels. To serve this communication flow, eachof the intermediate relay nodes (R1, R2, R3 and R4) receivespackets on one frequency channel, switches its transceiver toanother channel and then transmits the packets out to nextrelay neighbor. The delay in this multi-hop communication isdependent on the cumulative channel switching delays at thetransceivers along the flow. Hence routing protocols must aimtoward minimizing cumulative delay along the entire path aswell.

III. SYSTEM MODEL

For multiple-antenna or MIMO relay networks in which every terminal in the network is deployed with multiple antennas, studies have mainly concentrated on spatial multiplexing systems in terms of capacity or throughput analysis. Capacity bounds for single relay MIMO channels are presented in [9]. While this work is primarily focused on the theoretical perspective, some more practical results considering specific signal processing algorithms and achievable rates have also been presented [10], [11].

A. MIMO relay channel

A simple MIMO relay channel is shown in Fig. 7, in which the source is equipped with Ns antennas, the relay is equipped with Nr antennas and the destination is equipped with Nd antennas. Unlike Section II we assume here that the direct link is ignored due to shorter distance between the source and the relays, relative to the destination. This simplifies the receiver processing. However, note that when the direct link is strong, direct transmission is usually the preferred choice especially for a MIMO link. We shall now discuss MIMO relay configurations using both AF and DF relays.

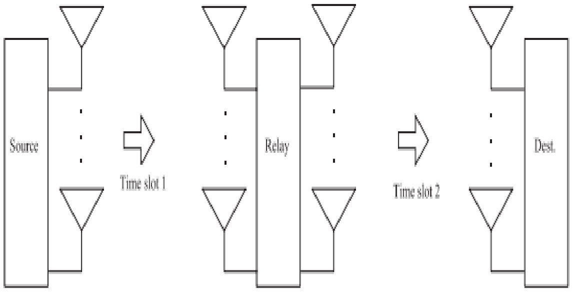

Figure 1: Basic system model of a MIMO two hop relay network

B. Conventional Relaying Modes

For DF relaying, the relay first uses all of its *Nr* antennas to jointly decode the signals; it then de-multiplexes the decoded message to form *Nr* data streams and uses all *Nr* antennas to recode and retransmit the data streams to the destination. The overall S-D capacity is typically constrained by the worse capacity of the S-R and R-D links. Since both of these links are likely to be strong compared with the direct link, the system capacity can be greatly improved. If the relay decodes the source transmission incorrectly, the relay obviously cannot send the correct information to the destination. However, if the transmission rate is below the end-to-end S-D capacity, the error rate can be made arbitrarily low by using powerful coding schemes such as low density parity check codes. One practical disadvantage for DF relaying is its high complexity due to the multi-antenna transceiver structure, as ML decoding might be required at both the relay and the destination to achieve the available link capacity. Suboptimal schemes, such as SIC, can be used instead to reduce the receiver complexity. Even still, the processing complexity of SIC increases at least linearly with the number of transmit and receive antennas. To overcome the relay processing complexity, AF relaying can be used instead. The process is much simpler as decoding or encoding is not required at the relay. However, one obvious defect for AF relaying is that the relay amplifies the receiver noise and thus causes a decrease in the SNR at the destination, which can be significant especially when the number of antennas at the relay is large (e.g., in the scenario where a fixed relay with large antenna array size is used).

C. Filter-and-Forward Relaying for MIMO Terminals

Unlike the situation for single antenna systems, in MIMO configurations the multiple propagation paths that exist between the transmit and receive antennas can be exploited to improve the relay's signal quality. We begin by discussing the AF relaying (AFR) protocol for MIMO systems. In order to improve the performance of AFR, the received signals at the relay antennas can be jointly filtered before AFR is used. Several recent papers have studied the optimal filter that should be used in the relay to maximize the end-to-end data capacity [10], [11], provided that R-D channel state information (CSI) is known to the relay. Overall, the strategy for selecting the optimal filter follows two steps:

(a) Decomposing the MIMO relay channel into several orthogonal, parallel spatial channels to avoid co-channel interference between different transmit antennas. This can be achieved by using the singular value decomposition to decompose the S-R and R-D channels into their constituent eigenvalues and eigenvectors.

(b) Allocating the transmit power optimally across the antennas at the relay (and the source, if the forward channel knowledge is available at the source).

While step (b) is usually complicated to perform with no apparent closed form solution, step (a) is simple to perform. It has been proved [10], [11], [12] that the optimal filter depends on the left singular vectors for the S-R channel and the right singular vectors for the R-D channel. These vectors are scaled by constants that determine the power allocation values across all the antennas at the relay. This design allows the end-to-end MIMO relay channel to be decomposed into several orthogonal, parallel relay channels. This further allows the signal to interferenceplus-noise ratio (SINR) for each sub-channel to be optimized. Thus filter-and-forward relaying (FFR) offers a significant performance advantage compared with the AFR method in terms of capacity, particularly when the number of relay antennas Nr is higher than for the source Ns or destination N_d. The FFR scheme also simplifies decoding at the destination, since the orthogonal relay channels can easily be recovered by filtering. This avoids using high complexity ML or SIC decoding at both the relay and the destination.

IV. PROPOSED METHOD

4.1 HETEROGENEOUS-MCS-SVD

We approach the connectivity problem outlined above by attempting to simultaneously converge towards both the correct observation data correspondences and the correct network parameters through the use of the MCS algorithm.
We iterate over the following two steps:

1) *The E-Step:* This calculates the expected log likelihood of the complete data given the current parameter guess:

$$Q(\theta, \theta^{(i-1)}) = E\left[\log p(O, Z|\theta)|O, \theta^{(i-1)}\right] \tag{1}$$

Where O is the vector of binary observations collected by each sensor and Z represents the hidden variable that determines the data correspondence between the observations and agents moving throughout the system.

2) *The M-Step:* This is updates our current parameter guess with a value that maximizes the expected log likelihood.

$$\theta^{(i)} = \underset{\theta}{\operatorname{argmax}}\, Q(\theta, \theta^{(i-1)}) \tag{2}$$

However, we employ the technique of MCS to calculate the E-Step because of the intractability of summing over the high dimensional data correspondences.
MCS differs from traditional by executing the Estep through a Monte-Carlo estimation process.

We approximate Q $(\theta,\theta(^{i-1}))$ by drawing M samples of an ownership vector $L^{(m)} = f_l^m$ which uniquely assigns the agent i to the observation oi in sample m. This is accomplished through a MCMC sampling technique which we will explain in the next section. We end up with

$$\theta^{(i)} = \underset{\theta}{\operatorname{argmax}} \left[\frac{1}{M}\sum_{m=1}^{M} \log p(L^{(m)}, O|\theta)\right] \tag{3}$$

Where $L^{(m)}$ is drawn using the previously estimated $\theta(^{i-1),}$

At every iteration we obtain M samples of the ownership vector L, which are then used to re-estimate the connectivity parameter θ (the M-Step). This process is continued until we obtain a final estimate of θ. The pseudo code for the algorithm is shown in Algorithm 1.
At every iteration of the algorithm the likelihood of the ownership vector increases and the process is terminated when subsequent iterations result in very small changes to θ.

By applying SVD method to the channel matrix H = $U\boldsymbol{\tau}V^{T}$, where U and V are Identity matrices and τ is Diagonal matrix. Diagonal matrix has non-zero entries only along its diagonal. Then diagonal elements are arranged in the descending order of their magnitude by decomposition which is the form of diag (τ1, τ2..........., τp) is the singular values of channel matrix commonly known as subchannel gain set. Hence channel at each data symbol is decomposed into parallel subchannels by the SVD method.
In this paper, the effective capacity of each subchannel is taken as the data rate with a certain QoS constraint. So the total effective capacity of N x L subchannels is taken as the system output and the total transmission power allocated to N x L subchannels is treated as the system input. As a consequence, the energy efficiency of MIMO systems is given by [4]:

$$\eta = \frac{C_{total}(\theta)}{E\{P_{total}\}} = \frac{\sum_{k=1}^{M}\sum_{l=1}^{N} C_{eff}(\theta)_{k,l}}{E\{P_{total}\}} \tag{4}$$

Where $C_{eff}(\theta)_{k,l}$ (k = 1, 2, . . . , M, l = 1, 2, . . . , N) is the effective capacity of the k th sub channel over the l th symbol, and E{ Ptotal } is expectation of the total transmission power allocated to all N x L sub channels.

A Cognitive Radio Network (CRN) is thus not just another network to interconnect cognitive radios. The CRNs are composed of various kinds of communication systems and networks, and can be viewed as s sort of heterogeneous networks. The heterogeneity exists in wireless access technologies, networks, user terminals, applications, and service providers. The design of cognitive radio network architecture is toward the objective of improving the entire network utilization, rather than just link spectral efficiency. From the users' perspective, the network utilization means that they can always fulfil their demands anytime and anywhere through accessing CRNs. From the operators' perspective, they can provide better services to mobile users, and allocate radio and network resources to deliver more packets per unit bandwidth in a more efficient way.

4.2 Algorithm for proposed method

1. The segments for lower energy node consumption formulation and second categories of important things to estimate the k-coverage probability in a network with log-normal investigation (however the shadowing distribution can be slightly random and without coverage sensing area of higher energy shifting nodes.

2. Sensors node uses quadrature technique or a modest analytic formula for coverage sense with advance node energy.

3. The new composite high-dimensional uses in quadrature approaches for low dimensions and quasi-random integration for higher (n>2) computes coverage probability for a network with AWGN channel (exponentially circulated with unit mean) and log-normal shadowing.

4. We present a modification of variables motivated by the dimensional spherical coordinates.

V. RESULT

This section describe the MATLAB-based simulation platform that provides interactive access to check the performance and comparative analysis of threshold value for energy detection method theoretically as well as practically.
In this segment, the after effects of models identified with Radio cognitive interchanges configuration are

exhibited. The objective is not simply the calculation or component. The objective is to watch that few new arrangements, joint effort plans or improvement instruments can be executed in this structure.

The lessening of vitality utilization is an undertaking that includes the general outline over all layers of the correspondence convention. Centering layer by layer, a few procedures for streamlining the utilization can be recorded for each level, yet because of subjective qualities, address the issue of utilization comprehensively has more promising circumstances.

The chances to upgrade vitality utilization can be partitioned in three delays: that get past the detecting of the range, those identified with the capacity to change transmission parameters and those that rely on upon the capacity to share learning of the system. Every situation utilizes a procedure of an alternate square. To begin with situation is identified with the capacity to change transmission parameters. The recreation comes about decide the productivity of the proposed MC-SVD calculation; we did far reaching execution utilizing MATLAB-construct iterative instruments based with respect to the diverse speed rates and assess energy use for every unit of private sort grid.

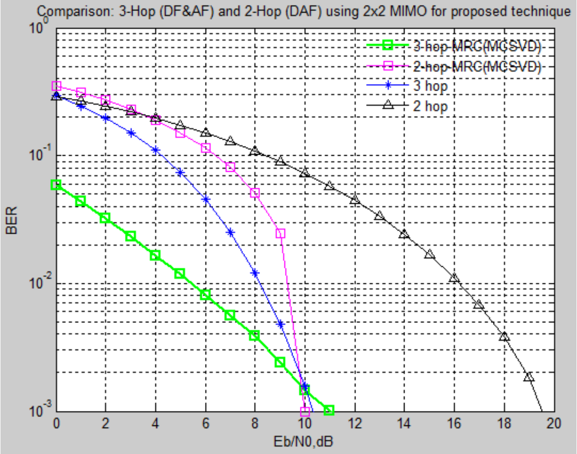

Figure 2: Comparison: 3-Hop (DF&AF) and 2-Hop (DAF) using 2x2 MIMO for proposed technique

In figure 2 , the SVD-based heterogeneous system is the best compared to the MC-SVD on the overall, it being observing that performances of MC-SVD - heterogeneous improving energy efficiency and minimizing BER(bit error rate) whenever but the existing method are lower as compare to proposed .The raising in SVD-based detection is consistent with previous results but the dropping of MC-SVD such type of signals frequency used where both raise cosine and root raised cosine are complex in signal energy efficiency.

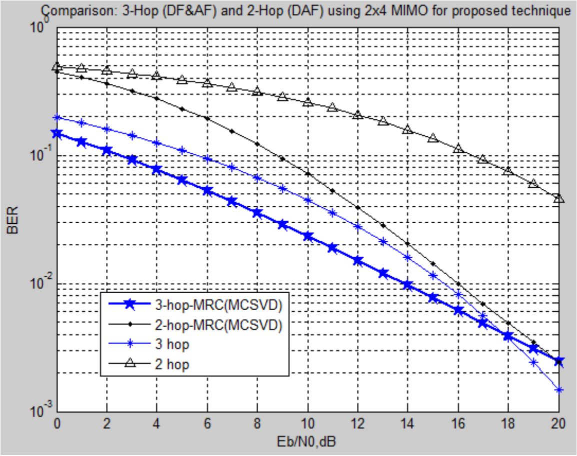

Figure 3: Comparison: 3-Hop (DF&AF) and 2-Hop (DAF) using 2x4 MIMO for proposed technique

Optimal relay forwards the source information using cooperating relaying protocols such as decode and forward(DF), Amplify and Forward(AF) , decode amplify forward (DAF) which combines the benefits of both DF and AF schemes. At the same time, jammer generates artificial noise using cooperative jamming scheme, to confuse the eavesdropper.

Monte Carlo simulations are carried out and the obtained results are compared for different relay, jammer and eavesdropper locations. A study of comparison is made in terms of secrecy capacity and intercepts probability for the proposed relaying schemes in the presence of single eavesdropper. Finally from the simulated comparison study, it is observed that DAF scheme outperforms AF and DF schemes and we can also observe control jamming selection achieves more secrecy rate compared to without jamming and with optimal jamming.

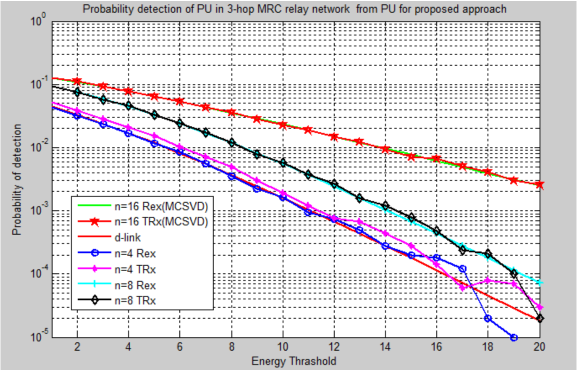

Figure 4: Probability detection of primary user in 3-hop relay network from PU for proposed method

We assign on-duration threshold and PU Interference probability of false alarm which are derived based on limiting distribution of Gaussian distribution based differential distances for each duration as we are finding results when PU interference for 0.8 is much higher for each on duration.

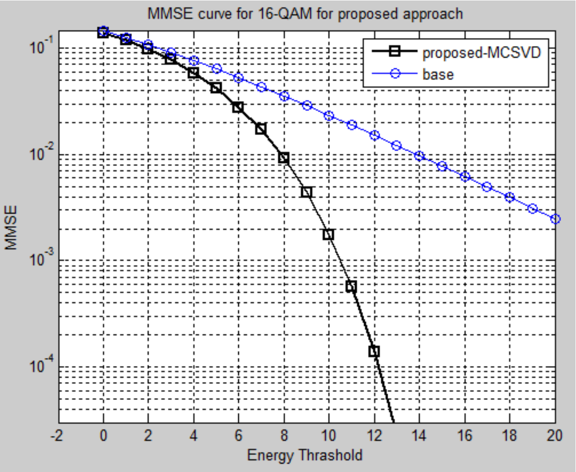

Figure 5: MMSE curve for 16-QAM for proposed approach

A receiver structure can be obtained if the linear trans-formation is sought which minimizes the mean square error between the transmitted bits and the outputs of the transformation. It takes the background noise into account and utilizes the knowledge of the received signal powers. It implements a linear mapping which minimizes E [|d -Ly|2], mean squared error between the actual data and the soft output of the conventional detector. Simulation Results for MMSE (Minimum Mean Square Error) Algorithm for various numbers of users in figure 4.

VI.CONCLUSION

In this paper, we evaluated outage performance of multi-hop protocols in cognitive radio networks under the impact of software noises. In particular, we derived the closedform expressions of outage probability and average number of time slots over Rayleigh fading channels. Monte-Carlo simulations were then performed to verify the derivations.Multihop wireless communication system with amplify and forward cooperative relays was introduced. At various modulation schemes, the performance of multihop relaying system was investigated. It can be obvious that using multihop technique improve the performance of the system and as we increase the number of relays between source and destination, the symbol error rate decreases but if this number increase over specified number, the interference will increase.

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