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PERFORMANCE EVALUATION OF 3-HOP RELAYING PROTOCOLS FOR COGNITIVE RADIO NETWORKS

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ABSTRACT

Cognitive radio network is an emerging field in communication and are giving benefits in various areas. It provides efficient utilization of frequency spectrum and spares bandwidth for other applications. There are various parameters in wireless communication that need improvement for reliable processing of system. The cooperative communication improves the network performance, energy efficiency, network throughput and many more. There are various protocols that are used for cooperative diversity such as amplify and forward, decode and forward, coded cooperation and so on. In this paper, amplify and forward relaying protocol for cognitive radio network is proposed. The data is communicated between transmitter and receiver by using 3-hop and cognitive relays are used accordingly. The encoding of information is done by space time block codes over two different channels such as Additive White Gaussian Noise channel and Rayleigh fading channel. The presence or absence of primary user is detected by using spectrum sensing technique. In this paper, energy detector sensing technique is used to detect the availability of the spectrum because of the less complexity of this system. The results are simulated by using MATLAB software.

KEYWORDS: Relaying protocols, Amplify and forward, Cognitive radio, energy detectors, Additive White Gaussian Noise channel, Rayleigh fading channel.

INTRODUCTION

The major challenges that are facing by wireless communication systems are efficient utilization of bandwidth, energy efficiency and improved link reliability. The channel over which data is transmitted suffers from fading and interference problems due to presence of

many other users.[1,2] The efficient use of bandwidth is achieved by using multiple antennas on transmitter as well as receiver side. It provides possibility of transmit different data streams simultaneously and improves the data-rate at available bandwidth. However, there are some issues like hardware complexity which makes difficult to install more antennas on mobile terminal.[3],[4] The above discussed problem is solved by using cooperative communication. This technique enables the single antenna mobiles in a multiple-user environment so that it can share and generate a virtual multiple antenna transmitter.[5]

There are various antenna diversity techniques such as Single Input Single Output, Single Input Multiple Output, Multiple Input Multiple Output and Multiple Input Single Output. The most widely used scheme is Multiple Input Multiple Output (MIMO) and shown in Figure 1.

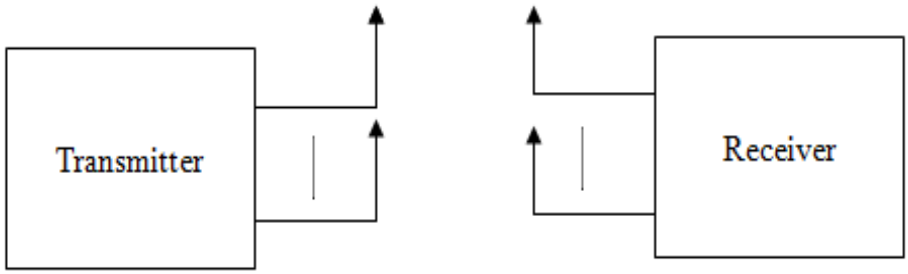

Figure 1: Multiple antennas as transmitter and receiver.

When source and relays are used to transmit data towards destination then the communication is called as cooperative communication or cooperative MIMO communication. The coding techniques which are employed at MIMO transmitting antennas are referred as Space Time Block Codes (STBC).[6],[7] Wireless relays are used at both sides when the distance between transmitter and receiver is long enough. The function of wireless relays is to receive the broadcast streams from transmitter, process that data and forwards to destination side. There are various protocols that are used at relays like Amplify and Forward, Decode and Forward, Compress and Forward, Decode-Amplify and Forward and so on. In Figure 2, MIMO cooperative relay communication system is shown and parameters R_1, R_2,……., R_n denotes cognitive relays and S, D denotes source and destination node respectively.

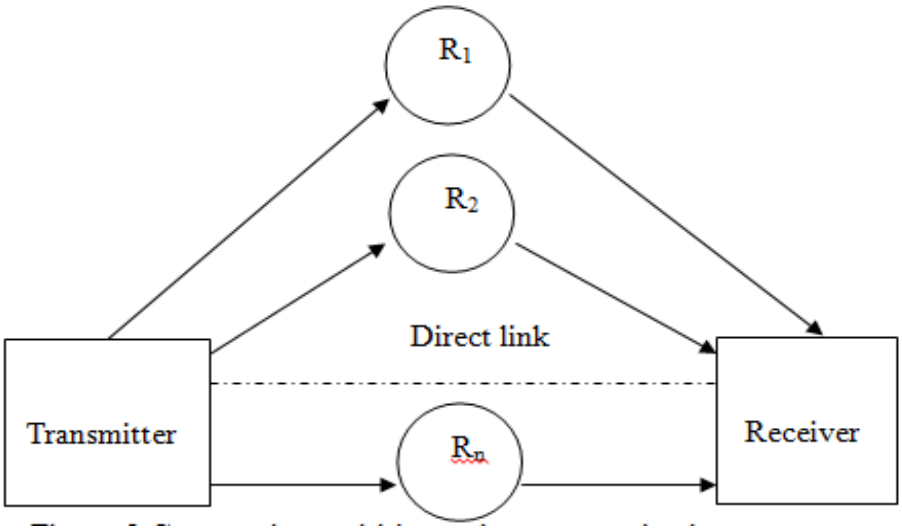

Figure 2: Cooperative multi-hop relay communication systems.

In this paper, cooperative cognitive radio network is employed using MIMO and Space Time Block Codes are used. Here, 3-hop network is analyzed using multiple relays. Moreover, the results are compared for two different channels such as additive white Gaussian noise channel and Rayleigh fading channel.

Literature review

A cognitive space-time frequency coding technique is proposed in paper.[8] Cooperative communications is new communication technology which allows distributed terminals to collaborate through some distributed transmission in wireless network. A cognitive space time frequency coding is used for seamless data transmission within the cognitive system. In this paper, cooperative communications for spectrum sharing is also considered. Moreover, author verified that in this paper,[8] Cognitive wireless relay network provides zero interference to primary systems.

Cognitive radio network plays an important role to increase the spectral efficiency in wireless communication systems. In paper,[9] decode and forward protocol is considered that is used to exploit the presence of spectrum holes. The strategy used is based on pure temporal sensing which means when transmitter is off then direct link is used for communication otherwise relay channel will be used for spatial sensing. In this technique, maximal ratio combining is used for combining the received signals. This paper proposed the relaying protocols for regenerative relays and analyzed that transmission capacity has increased of cognitive radio networks.

The author studied the performance of a primary user and a secondary user in a network which having cognitive radio capabilities.[10] The different parameters such as average packet transmission delays, secondary user's queue and average queues lengths are determined. In this paper, author considered TDMA mechanism where a secondary user and a primary user transmit packets on a shared spectrum band. Here probability generating function is considered, which is used to determine performance issues like optimum cooperation admission factor, power consumption, critical arrival rates for queuing stability.

The author[11] proposed new cooperative communication technology and it is based on physical-layer network coding. This paper also discussed the power allocation and relay selection scheme which maximize the system capacity. For the simplicity of system BPSK modulation is used for broadcasting of the code word. The analysis of signal noise ratio is carried out for each user and maximum ratio combination method is used for combines data received at different time slots. The results showed that primary user communicates efficiently with the cooperation of secondary user.

The issue of cooperative spectrum sensing is resolved in paper.[12] The author proposed two strategies for relay's location in cognitive radio and results are simulated based on parameters such as probability of detection and probability of false alarm. Here deteriorating effect of path loss is also studied. The path loss exponent 3 and Rayleigh fading channels are considered. Also various relays are installed with amplify and forward technique. The results showed that sensing has been improved by increasing number of relays and placing the relays nearer to primary user.

In paper,[13] different cooperative techniques for cognitive networks are considered. The reviews on various bandwidth efficient wireless communications under spectrum resource constraint are studied. In this paper, four different cognitive networks are designed for joint optimization of cooperative sensing techniques and other parameters. The key points are signaling overheads increased by using cooperative schemes and this can be overcome by designing distributed techniques. There are some issues related to reliability, for instance some attacking nodes destruct the cooperation. In heterogeneous networks, there is problem of spectrum scarcity and made cooperation between these networks difficult.

The author[14] considered 2-hop decode amplify and forward, 3-hop decode and forward and amplify and forward relaying protocols to achieve cooperative diversity. In this paper,

Alamouti space time block codes and Rayleigh fading channel is considered. The results are simulated for variable distance and number of relays. Energy detectors are used for spectrum sensing and if energy of primary user is less than a threshold then it shows absence of primary user. The parameters that are considered such as bit error rate and probability of detection. In the end, results verified that 3-hop decode and amplify, amplify and decode gives better values than other system.

Relaying protocols

Basically relay is an access point that act as intermediate between source and destination. It also works as repeater for wireless communication. When there is long distance between transmitter and receiver then relay is used between them and several relaying protocols are used to forward the data. In this paper, 3-hop relay network is used.

a) Amplify and Forward

In this scheme, relays used to amplify the received signal and then forwards to the receiver. The regeneration of the signal is not takes place. The noisy signal is amplified and then forwarded to destination without decoding and also known as non-regenerative relaying protocol.[15]

Mathematically,

$$x_r(n) = x_t(n) * \beta \quad (1)$$

The parameter β comprises of average transmitted signal power, relay power, noise variance and fading coefficient.

b) Decode and Forward

Data is decoded after receiving, re-encodes and then forwarded signal to destination. The decoded signal is basically the estimate of original signal and also called as regenerative relaying protocol.[16]

c) Decode, Amplify and Forward

This protocol is the combination of AF and DF relaying protocols. The signal is decoded and re-encoded and amplified before send it to the destination.

Mathematically,

$$x_{r,d}(n) = x_{r,s}(n) * \beta \quad (2)$$

$x_{r,d}(n)$ denotes signal transmitted from relay to the destination and β represents scaling factor.

System model

In this paper, Space Time Block Codes are used and it is based on the principle of transmitting and receiving multiple copies of original transmitted signal using multiple antennas at transmitter and receiver.[2] The data is transmitted using matrices in which row gives the information of time and column represents space. The elements shows in matrices are orthogonal to each other therefore STBC codes are known as OSTBC codes. Here, multiple-input multiple-output scheme is proposed for data transmission. This technique improves the performance of the system because in this it is possible to transmit two symbols in one time slot. The system model for coding is shown in Figure 3.

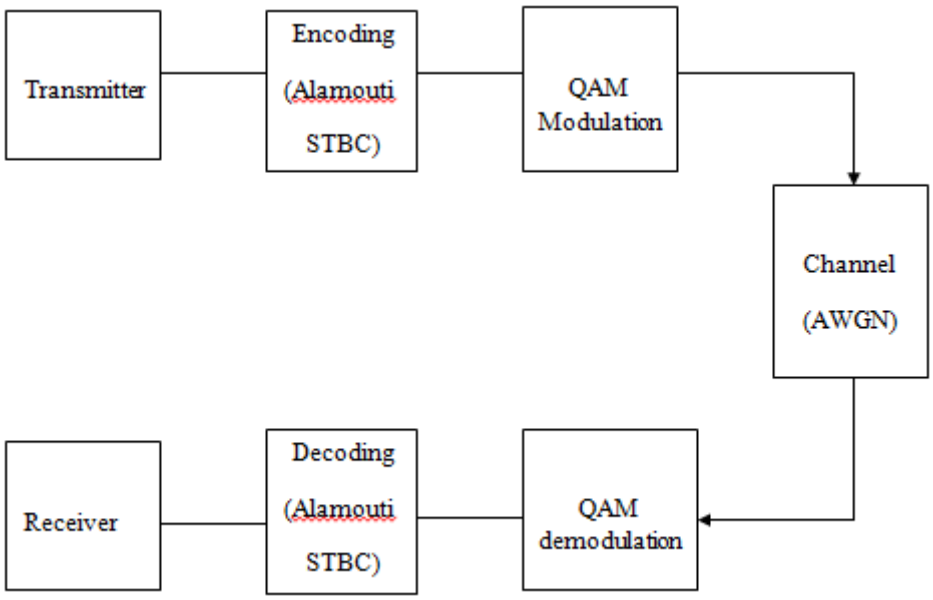

Figure 3: System Model.

The reliable data transmission is only possible if relays cooperate with transmitter as well as receiver in cognitive radio network. There are various relaying protocols used at relays such as amplify and forward, decode and forward, compress and forward and so on.

The system model for cognitive network is shown in Figure 4. It shows the primary user, cognitive network and cognitive relays. Here cognitive network is worked as decision maker and there are many signal detection techniques such as energy detection, wavelet detection, and cyclostationary sensing technique.[17] In this paper, AWGN and Rayleigh fading channel is considered. The parameters h_{pr} denotes channel mean power between primary user and relays and h_{rr}, h_{rd} represents channel mean power within relays and relays to receiver respectively. The coefficient α is the path loss exponent in wireless transmission.

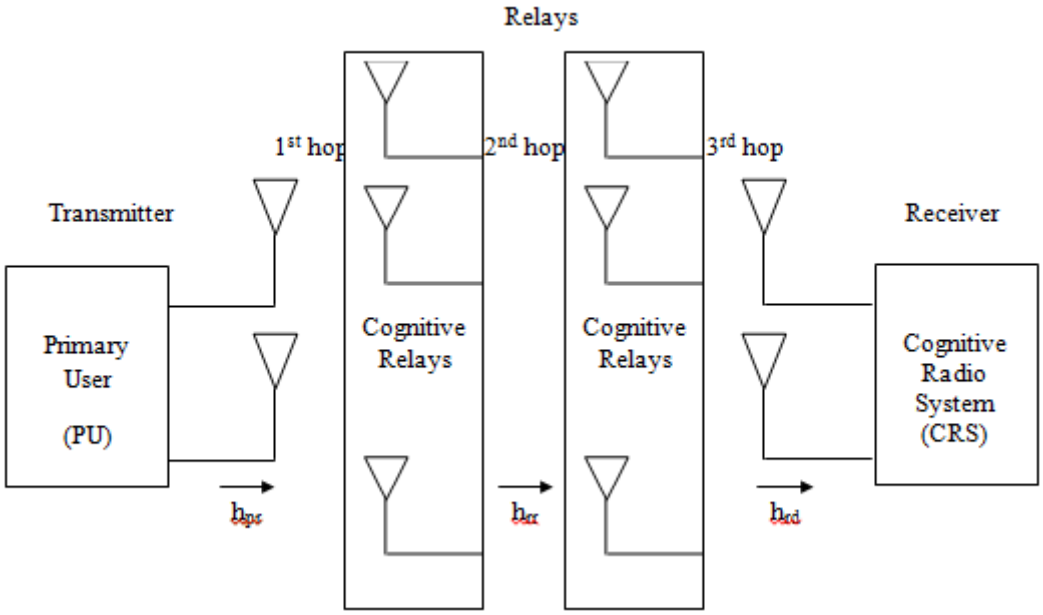

Figure 4: Proposed Cooperative radio network model.

Data is transmitted from transmitter to receiver in 3-hop. In 1st hop, STBC coding is used for encoding the data and broadcasted into the air. After that, this data is reached at receiver either by direct path or through relays. In 2nd hop, data is transmitted from one relay to other. In 3rd hop, decision is made by using cognitive radio networks, for instance primary user is present or absent. If cognitive radio made decision about absence of primary user within spectrum then it is possible to share spectrum between primary user and secondary user. In this proposed model, two antennas are installed at transmitter and receiver respectively however cognitive relays contain single antenna at transmitter and receiver respectively. The mathematically representation is as follows:

$$y_{pr} = h_{pr} * \alpha_n + \eta_{pr} \quad (3)$$

$$y_{pd} = h_{pd} * \alpha_n + \eta_{pd} \quad (4)$$

Where channel coefficients are denoted by $h_{pd,}$ h_{pr} and α_n, η represents Alamouti STBC encoded signal and AWGN respectively.

Simulation Results and Discussion

The results are simulated using MATLAB software. In Figure 5, graph is plotted between Symbol error rate and SNR. The range of SNR is considered from 0 to 20 in decibel scale. In this paper, 10^6 numbers of symbols are considered. The modulation is used for coding is 16-QAM. It gives better results than other modulation scheme.

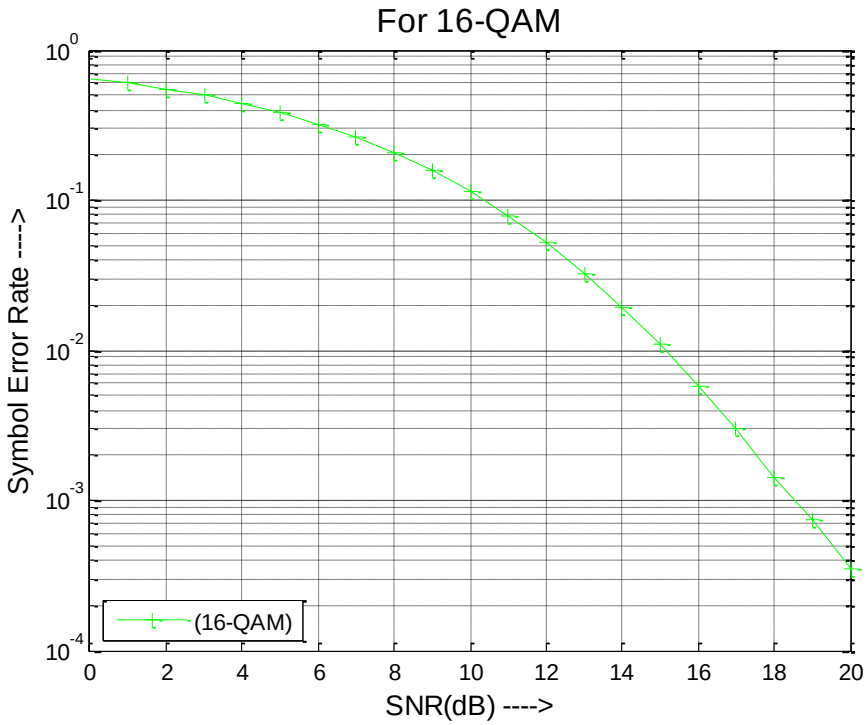

Figure 5: Alamouti STBC code using relaying protocol (QAM modulation).

In Figure 6, two transmitters and one receiver is considered. 16-PSK modulation is used for transmission of data. Here data and noise is generated randomly. The parameters used are symbol error probability and SNR. Figure 7 shows results for 8-PSK modulation.

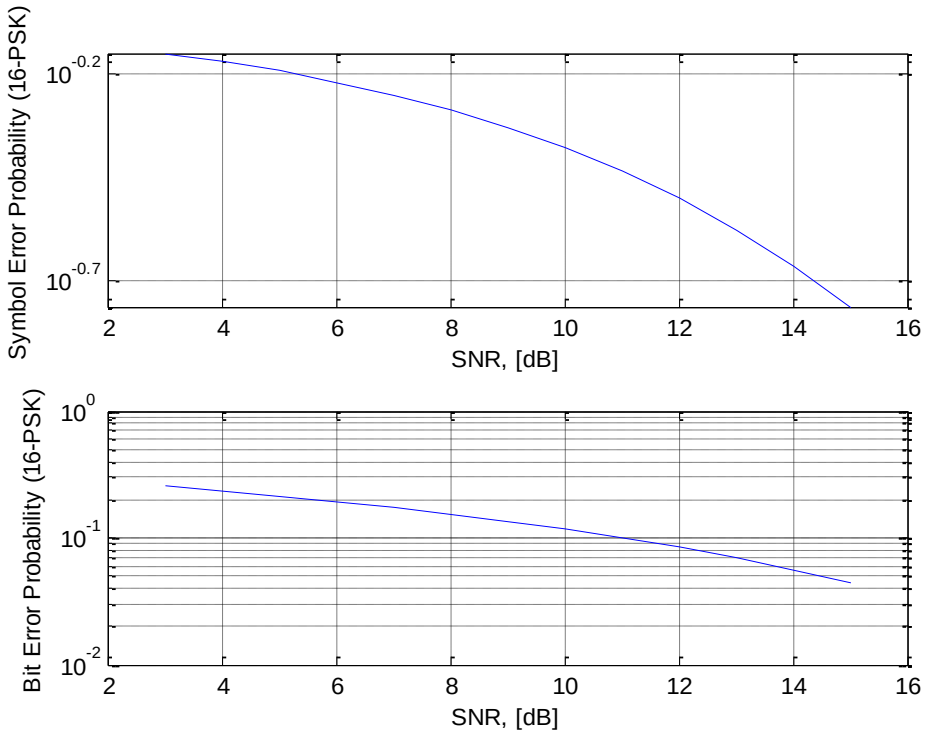

Figure 6: Alamouti STBC code using relaying protocol (16-PSK modulation).

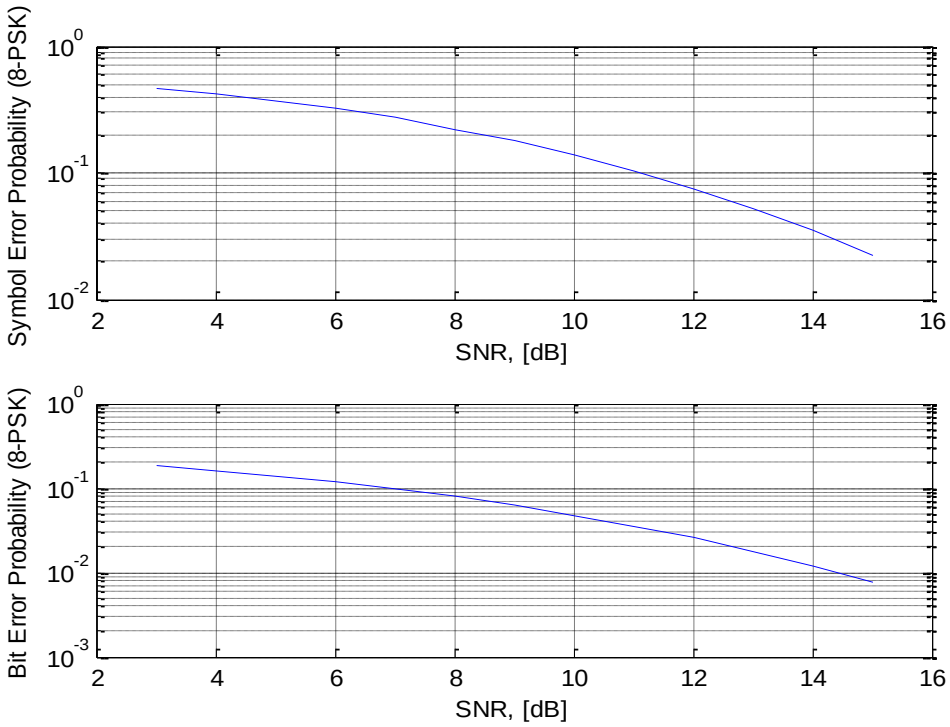

Figure 7: Alamouti STBC code using relaying protocol (8-PSK modulation).

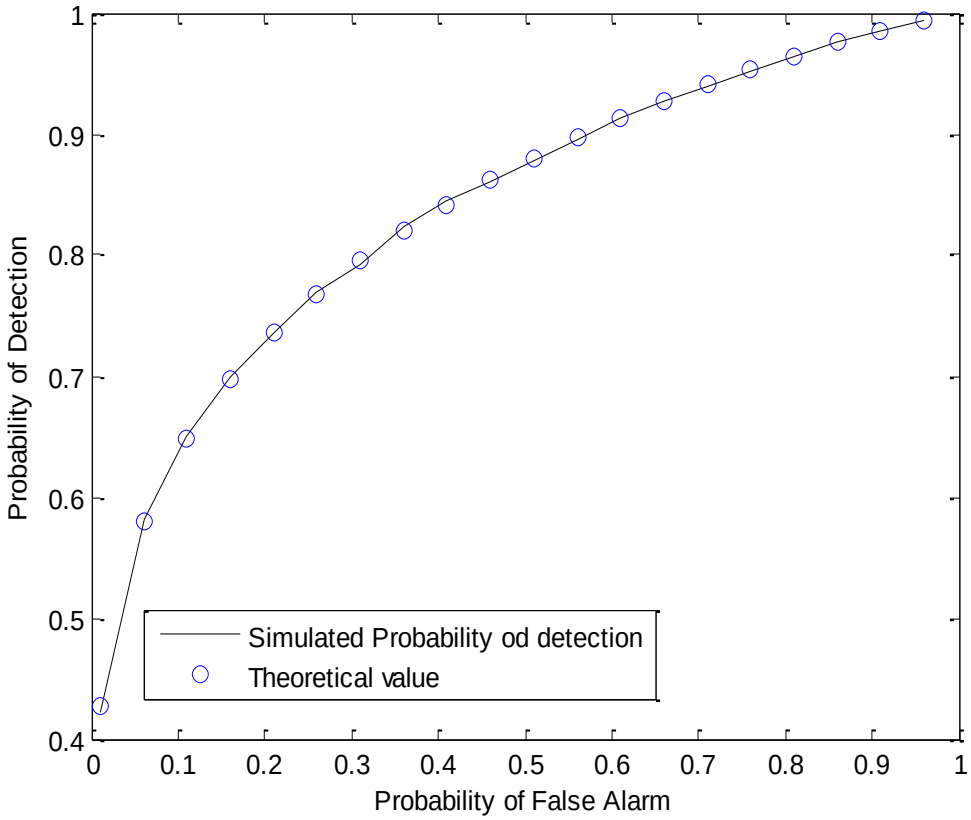

Figure 8: Probability of detection for Rayleigh fading channel.

Figure 8 gives the result for probability of detection for cognitive radio network using Rayleigh fading channel. It shows the value for both theoretical and simulated results.

CONCLUSION

In this paper, performance analysis of 3-hop relaying protocols has been done. The results are simulated for random generated noise and Rayleigh fading channel. Here two different simulations are considered that is QAM and PSK. The relaying protocols such as amplify and forward is used to transmit data from source to destination. The multiple hops are considered in this paper. The result for probability of detection for cognitive radio network is simulated. In this paper, different parameters such as symbol error probability, probability of detection, symbol error rate is considered.

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