Study of Relay System Model in Wireless Cooperative Communication

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Abstract- **Single relay model is one of the simplest models of cooperative communication. Cooperative communication in a wireless network is more popular because of its flexibility and user-friendly nature. Here in this paper we compare the symbol error rate (SER) of single relay model in two cases, one when the relay decodes the information and only if it is able to decode correctly it forwards the information to the destination and secondly when the relay is unable to decode the information correctly but still forwards the information to the destination. The performance of the model which decodes correctly and then forwards the information is much better than the model which does not decode correctly but still forwards the information to the destination.**

Keywords**: decode and forward (DF), symbol error rate (SER), maximum ratio combiner (CRM).**

I. Introduction

Wireless communication technology is widely used in mobile access services. Invention of new techniques has bought a notable improvement in the field of wireless communication. These improvements in turn have revolutionized data rate, device size, communication reliability and network connectivity.

As wireless communication technology is very popular and user friendly, there is always traffic present in the network. As the traffic increases, the performance of the wireless network decreases. To maintain the network performance in this traffic, wireless communication networks should improve their capacity or efficiency to solve the traffic problem. To reduce the traffic problem in the wireless communication network, source can relay the information or message to another node so that it can forward the message or information to the desired destination. It promotes a new idea and techniques wherein there is a need of cooperation between user and nodes for designing an improved communication and networking system. Hence in summary, cooperation between the nodes will improve the performance of the communication system [1].

To understand how a cooperative communication network works, let us take an instant when the wireless channel is in a server fading state or you can say that the channel is quite bursty. Since the wireless channel is in a server fading state, the information sent by the source is not able to reach its destination and it is of not much use to keep trying via retransmitting protocols like ARQ. Then if we have a third party which is independent of the source-destination link as shown in figure 1, receiving the information sent by the source and forwarding it to its desired destination, then there will be a chance of successful transmission of information from the source to the destination without losing data in the medium. Thus it improves the overall performance of the wireless communication network.

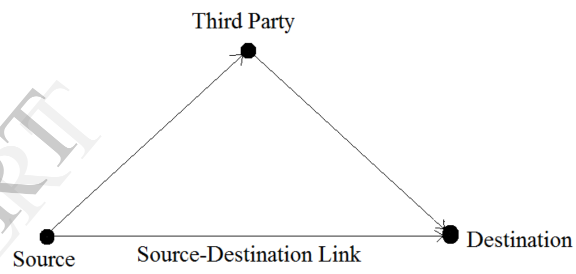

Figure 1: system model

II. System model

The system model of single relay cooperative communication system is shown in figure 2.

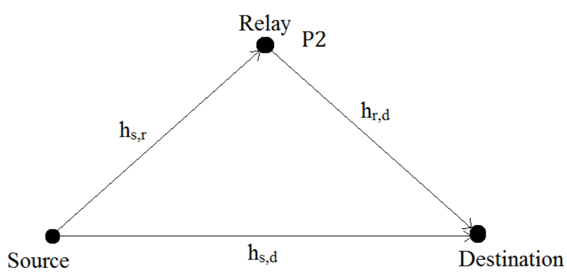

Figure2: Relay system model

Processing at the relay differs according to the employed protocols that are amplified-forward protocol (AF) and decode-forward protocol (DF). When the relay scales the received information and transmits that scaled information to its desired destination, then it is referred to as amplify and forward protocol. On the other hand, in decode and forward protocol, relay decodes the information and re-encodes it, and then retransmits that re-encoded information to its desired destination [1][3].

In this paper we consider the system model of communication networks in which decode and forward (DF) relaying protocol is used. As shown in figure 2; when source broadcasts the information then the information received at the source and destination are expressed [1] as

$$b_{s,d}=\sqrt{P1}\ h_{s,d}\, a + \eta_{s,d} \qquad \text{(i)}$$

$$b_{s,r}=\sqrt{P1}\ h_{s,r}\, a + \eta_{s,r} \qquad \text{(ii)}$$

Where $h_{s,d}$ and $h_{s,r}$ are the channel coefficient of the link between source-destination and source-relay respectively; $\eta_{s,d}$ and $\eta_{s,r}$ are their respective additive noise. 'a' is the information or message transmitted from the source. $b_{s,d}$ and $b_{s,r}$ are the information received at the destination and relay respectively.

In DF relaying protocol when the relay decodes the information correctly and forward the decoded information with power $\acute{P}2$ to the desired destination, then at the destination it can be expressed as

$$b_{r,d}=\sqrt{\acute{P}2}\ h_{r,d}\, a' + \eta_{r,d} \qquad \text{(iii)}$$

Where $h_{r,d}$ is the channel coefficient of the link between relay-destination. $\acute{P}2$ is the power of relay by which relay transmits the decoded information to destination. $\eta_{r,d}$ and a' are the additive noise of relay-destination link and decoded information at relay respectively. If the relay is unable to decode the information correctly then it does not forward the information to the destination and therefore relay power becomes '0' or remains idle [1] [8].

In this paper we consider that even if the relay unable to decodes the information correctly, then still it forwards the information to the destination. So here we have two conditions for comparison of performance analysis of the system, (i) when $\acute{P}2 = 0$, if relay unable to decode the information correctly then it remains idle and (ii) $\acute{P}2 = P2$, always; means even if the relay is unable to decode the information correctly still it forwards the information to the destination.

III. Theoretical Analysis

At destination signal or information from the relay and source are jointly combined with the help of maximum ratio combiner (MRC) introduced in [1]

$$b = b_{r,d}\ a1 + b_{s,d}\ a2 \qquad \text{(iv)}$$

Where $a1=\sqrt{P1}\ h_{r,d}$ /N0 and $a2=\sqrt{P2}\ h_{s,d}$ /N0 and N0 is the noise variance of the channel.

Assume that the average energy of the transmitted information in equation (i) and (ii) is 1, then the signal to noise ratio (SNR) of MRC at the destination is given by

$$\gamma = \frac{P1|h_{s,d}|^2+P2|h_{r,d}|^2}{N0} \qquad \text{(v)}$$

Here M-PSK modulation is used in system for transmitting the information. The SER formulation of an uncoded system with M-PSK modulation is given by

$$\Psi_{PSK}(\gamma) \cong \frac{1}{\pi}\int_0^{(M-1)\pi/M} \exp\left(\frac{-b_{psk}\ \gamma}{N0 \sin^2\theta}\right) d\,\theta \qquad \text{(vi)}$$

Where γ is the signal to noise ratio, $b_{PSK}=\sin^2\frac{\pi}{M}$ are introduce in[1] [8].

There are two cases, in case I if the transmitted information is decoded correctly by the relay then it can forwards the decoded information to the desired destination otherwise relay remains idle but in case II if the relay are unable to decode the information correctly then also it forwards the information to the destination.

When the information is sent by the MPSK modulation from the source, at the relay node the probability of incorrect decoding is $\Psi_{PSK}[P1|h_{s,r}|^2/N0]$ and the probability of correct decoding is $[1-\Psi_{PSK}[P1|h_{s,r}|^2/N0]$, explained in [1] . In the case of M-PSK modulation, the SER performance analysis can be obtained.

(a) In case I : System model for a case I is shown in figure 3, in which relay remains idle if it unable to decode the information correctly which is sent by the source.

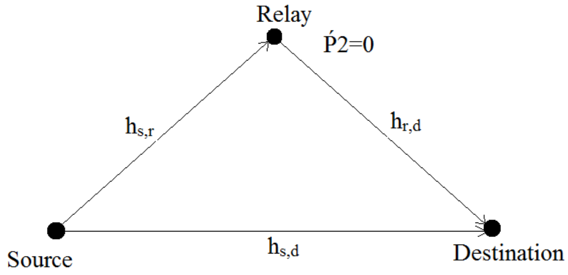

Figure 3: System model for a case I; here if relay unable to decodes the information then it does not forward information to the destination

$$P_{PSK} = \Psi_{PSK}(\gamma)\Big|_{\acute{P}2=0}\ \Psi_{PSK}(P1|\,h_{s,r}|^2/\,N0)$$

$$+\Psi_{PSK}(\gamma)\,\Big|_{\acute{P}2=P2}\,(1-\Psi_{PSK}(P1|\,h_{s,r}\,|^2/\,N0)\,) \qquad \text{(vii)}$$

By using equation (vi) and (vii) we can obtain the SER of the DF cooperative system with M-PSK modulation [5].

$P_{PSK}=$

$$F1\left(1+\frac{b_{psk}\,P1\delta_{s,d}^2}{N0\sin^2\theta}\right)F1\left(1+\frac{b_{psk}\,P1\delta_{s,r}^2}{N0\sin^2\theta}\right)+$$

$$F1\left(\left(1+\frac{b_{psk}\,P1\delta_{s,d}^2}{N0\sin^2\theta}\right)\left(1+\frac{b_{psk}\,P2\delta_{r,d}^2}{N0\sin^2\theta}\right)\right)$$

$$\left[1-F1\left(1+\frac{b_{psk}\,P1\delta_{s,r}^2}{N0\sin^2\theta}\right)\right] \qquad \text{(viii)}$$

Where $F_1(x(\theta)) = \frac{1}{\pi}\int_0^{(M-1)\pi/M}\frac{1}{x(\theta)}\,d\theta$

(b) For case II : system model for case II is shown in figure 4, in which relay forwards the information to the destination even if it unable to decode the information correctly which is sent by the source.

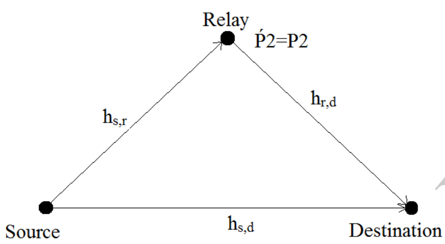

Figure 4: system model for case II; here even if the relay unable to decode the information correctly still it forwards the information to the destination

$$P_{PSK}=\ \Psi_{PSK}(\gamma)\,\Big|_{\acute{P}2=P2}\ \Psi_{PSK}[P1|\,h_{s,r}\,|^2/\,N0]$$

$$+\,\Psi_{PSK}(\gamma)\,\Big|_{\acute{P}2=P2}\,[1-\Psi_{PSK}[P1|\,h_{s,r}\,|^2/\,N0]$$

$$+\,\Psi_{PSK}[P1|\,h_{s,r}\,|^2/\,N0]\ \ [1-\Psi_{PSK}(\gamma)\,\Big|_{\acute{P}2=P2}\,] \qquad \text{(ix)}$$

By using equation (vi) and (ix) we obtain the SER of the DF cooperative system with M-PSK modulation for case II in which Ṕ2=P2 always.

$P_{PSK}=$

$$F1\left(\left(1+\frac{b_{psk}\,P1\delta_{s,d}^2}{N0\sin^2\theta}\right)\ F1\left(1+\frac{b_{psk}\,P1\delta_{r,d}^2}{N0\sin^2\theta}\right)\right)$$

$$F1\left(1+\frac{b_{psk}\,P1\delta_{s,r}^2}{N0\sin^2\theta}\right)+\left[1-F1\left(1+\frac{b_{psk}\,P1\delta_{s,r}^2}{N0\sin^2\theta}\right)\right]$$

$$F1\left(\left(1+\frac{b_{psk}\,P1\delta_{s,d}^2}{N0\sin^2\theta}\right)\left(1+\frac{b_{psk}\,P1\delta_{r,d}^2}{N0\sin^2\theta}\right)\right)\ +$$

$$\left[1-F1\left(\left(1+\frac{b_{psk}\,P1\delta_{s,d}^2}{N0\sin^2\theta}\right)\left(1+\frac{b_{psk}\,P1\delta_{r,d}^2}{N0\sin^2\theta}\right)\right)\right]$$

$$F1\left(1+\frac{b_{psk}\,P1\delta_{s,r}^2}{N0\sin^2\theta}\right) \qquad \text{(x)}$$

Where $F_1(x(\theta)) = \frac{1}{\pi}\int_0^{(M-1)\pi/M}\frac{1}{x(\theta)}\,d\theta$

IV. Result

SER of DF cooperation system model with M-PSK modulation for the two cases is shown below, which can be obtained by the equation (viii) and (x) and averaging it over the fading channel $h_{s,r}$, $h_{s,d}$, $h_{r,d}$ [1].

Exact SER formulation of the DF cooperation system with M-PSK modulation is calculated here by assuming $\delta_{s,r}=1$, $\delta_{s,d}=1$, $\delta_{r,d}=1$, N0=1, and P1= P2= P/2, for equation (viii). The graph of case I i.e. The exact SER formulation of the DF cooperative system is shown in figure 5. In this case if the relay unable to decode the information sent by the source then the relay does not forward information to the destination and relay remains idle. Hence at the destination only correct information reaches, therefore the performance of the system will improve as well as the reliability of the system increases.

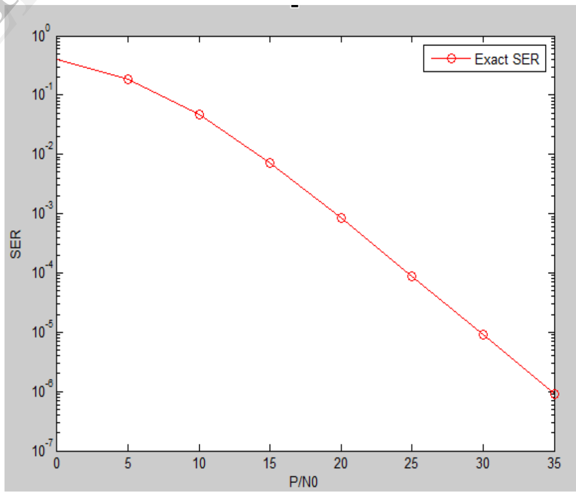

Figure 5: Graph obtain for exact SER; case I

In case II SER formulation of the DF cooperation system model with M-PSK signal is calculated here by assuming $\delta_{s,r}=1$, $\delta_{s,d}=1$, $\delta_{r,d}=1$, N0=1, and P1= P2= P/2, for equation (viii). The graph of case II i.e. The SER formulation of the DF cooperative system is shown in figure 6. In this case even if the relay unable to decode the information sent by source, still it forwards the information to the destination, therefore sometime incorrect information reaches at the destination. Hence the performance of the system reduces.

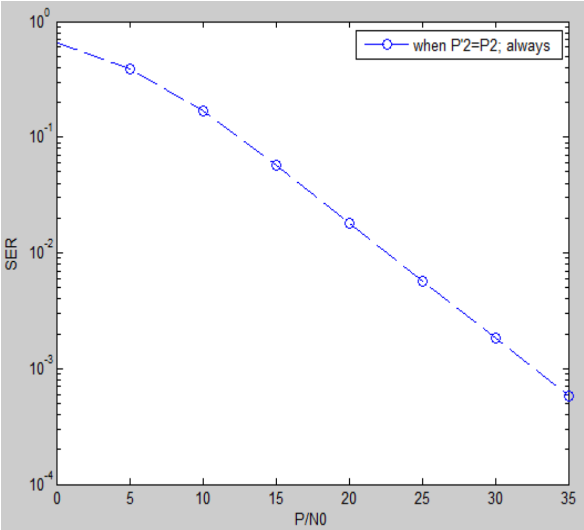

Figure 6: Graph obtains for when Ṕ2=P2 always in system model; case II

On the basis of above two evaluation of case I and case II, we compare their results shown in figure 7. This result shows that the performance of case I is better than the case II. This is because in case II if we forward the information to the destination, which is not correctly decoded by the relay, and that uncorrected data or information is transferred to the destination. The information received at the destination is not the complete information as the information is sent by the source. Hence the SER performance of this system is poor. But in case I if relay unable to decode the information correctly then it will not forward the information to the destination and relay become idle. Therefore, information received at the destination is always correct and SER performance of the system will improve. The comparison of case I and case II is shown below.

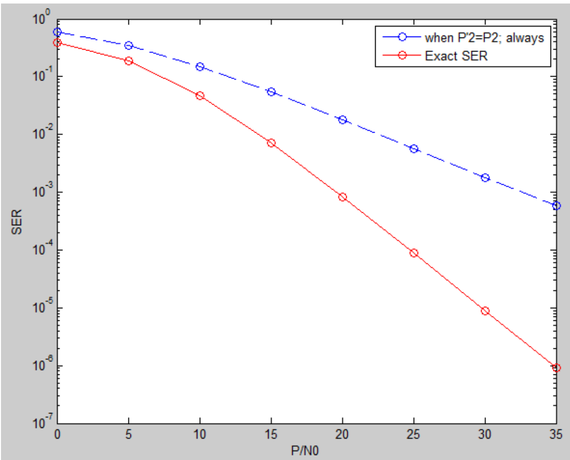

Figure 7: Comparison of case I and case II

V. Conclusion

In this paper, under the condition of case II we get a poor SER performance of the system as compared to case I. This research shows that if the relay is unable to decode the information correctly, then it should not transfer the information to the destination otherwise SER performance of the entire system will decrease and the information reached at the destination is lost in the channel. Symbol error rate (SER) of the system model in case I much better than symbol error rate (SER) of the system model in case II.

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