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Performance Analysis of Half Duplex Single–Relay Protocol in Slow Fading Wireless Channel

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Abstract - In static relaying protocol, called Decode or Quantize and Forward (DoQF), is introduced for half duplex single-relay networks, and its performance is studied in the context of communications over slow fading wireless channels. The proposed protocol is inspired by the so-called Compress-and-Forward (CF) but only needs statistical Channel State Information at the Transmitter (CSIT). First, analyze the behavior of the outage probability Po of the proposed protocol as the SNR ρ tends to infinity. In this case, prove that ρ^2Po converges to a constant ξ. This constant as the outage probability gain and derive its closed-form expression for a general class of wireless channels that includes Rayleigh and Rice. Furthermore prove that the DoQF protocol has the best achievable outage gain in the wide class of half-duplex static relaying protocols and minimize ξ w.r.t the power allocation to the source and the relay and the durations of the slots. Next, focus on Rician channels to derive the Diversity-Multiplexing Tradeoff (DMT) of the DoQf. This Rician channel is a non line of sight component, it can achieve more gain compare to Rayleigh.

Keyword—DoQF, CF, CSIT, DMT.

I. INTRODUCTION

Relaying has become a widely accepted means of cooperation in wireless networks. In this focus on networks composed of one source, one destination and one relay that operate under the half-duplex constraint *i.e.*, the relay can either receive or transmit, but not both at the same time. The Fig 1 shows relay thus listens to the source signal during a certain amount of time (the first slot) and is allowed to transmit towards the destination during the rest of the time (the second slot). A wide range of relaying protocols have been proposed so far. Most of these protocols belong to one of the following families of relaying schemes: Amplify and Forward (AF), Decode and Forward (DF) and Compress and Forward (CF) [4]. The first classical family of relaying protocols is formed by Amplify and Forward (AF) protocols for which the relay retransmits a scaled version of its received signal. A second well known family of protocols is formed by the Decode and Forward (DF) approaches. In this case, the relay listens to the source during the first slot of transmission and tries to decode the source message. succeeds, the relay forwards the (re-coded) source message If it during the second slot. In this context, proposed a *dynamic* version of the DF (DDF, Dynamic Decode and Forward) in which the slots durations are supposed to be adaptive as a function of the (random) state of the source-relay channel. Although the DDF is attractive from a theoretical point of view, an implementation of the DDF requires the use of coders-decoders with adaptive length. To the best of our knowledge, the design of such codes for the DDF is still in its early stages.

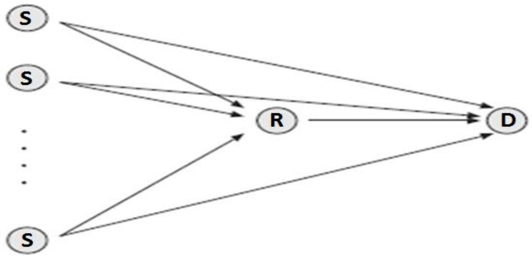

Fig 1.Transformation of signal to Destination

Now go back to the *static* protocols for which the relay listening time is constant and thus regardless of the channels realization. One of the most widespread *static* DF protocols is the so-called *non orthogonal* DF [4] (as opposed to the *orthogonal* DF [5]). By "non orthogonal" it is meant that the source and the relay are simultaneously transmitting during the second slot. The non orthogonal DF will be simply designated as DF in the rest of this paper. Finally, another classical family of relaying protocols is the Compress and Forward (CF) [4]. In the standard version of the CF [2], the relay uses a Wyner-Ziv encoder [3] to produce a source encoded version of its received signal and forwards it assuming that the destination disposes of a side information (the signal received on the source-destination link). Moreover, the relay is assumed to have perfect knowledge of the the relay-destination and source-destination channel gains. In order to overcome the Wyner-Ziv encoder and/or the perfect CSIT assumption, a few strategies inspired by the CF scheme have also been proposed in the literature. For example [4], where the strong assumption of perfect knowledge by the relay of the source destination and the relay-destination channels is replaced by a quantized feedback link from the destination to the relay. In the case of no CSIT at the relay is also treated and the performance degrades dramatically. In [2], vector quantization is performed by carefully choosing the relay data rate in order to have reliable link between relay and destination and then applies a *Successive Interference Canceller* (SIC) at the destination side.

II. Related Works

Cooperative Diversity in Wireless Networks: Efficient Protocols and Outage Behavior

In this a variety of low-complexity, cooperative protocols that enable a pair of wireless terminals, each with a single antenna, to fully exploit spatial diversity in the channel. These protocols blend different fixed relaying modes, specifically amplify-and-forward and decode-and-forward, with strategies based upon adapting to CSI between cooperating source terminals (selection relaying) as well as exploiting limited feedback from the destination terminal (incremental relaying). For delay-limited and non ergodic environments, analyze the outage probability performance, in many cases exactly, and in all cases using accurate, high-SNR approximations.There are costs associated with our cooperative protocols. For one thing, cooperation with half-duplex operation requires twice the bandwidth of direct transmission for a given rate, and leads to larger effective SNR losses for increasing spectral efficiency. Furthermore, depending upon the application, additional receive hardware may be required in order for the sources to relay for one another. Although this may not be the case in emerging *ad hoc* or multi-hop cellular networks, it would be the case in the uplink of current cellular systems that employ frequency-division duplexing.

Hybrid Digital-Analog Relaying for Cooperative over Slow Fading Channels

Consider a three-node half-duplex orthogonal Gaussian relay network, It was assumed that CSI is available only in a forward flow in the network, so neither the source nor the relay has any CSIT. In this scenario, they used achievable expected rate as figure of merit. they proposed different HAD (hybrid digital-analog) relaying schemes, they also compared the performance of the new schemes to traditional relaying protocols, as well as to performance bounds obtained by providing perfect CSIT to compress-and-forward relaying.

Fading Relay Channels: Performance Limits and Space–Time Signal Design

Cooperative diversity is a transmission technique, where multiple terminals pool their resources to form a virtual antenna array that realizes spatial diversity gain in a distributed fashion. The first part of this paper is devoted to the information-theoretic performance limits of three different time-division multiple-access (TDMA)- based transmission protocols for the single relay channel. The second part of the paper deals with (distributed) space–time code design for the fading relay channel operating in the AF(amplify and forward) mode.

Outage Minimization With Limited Feedback for the Fading Relay Channel

This provides background regarding the protocols and models later they discuss about the general relay network and channel models. They describes the AF protocol which is the relay code used in this study. And investigates the outage performance of the relay protocol under the assumption that CSI is available to the transmitters. Considers power control with finite rate feedback. looks at the case of no transmitter CSI, and provides concluding remarks.

Relaying Protocols for Two Colocated Users

Consider a wireless network where a remote source sends information to one of two collocated users, and where the second user can serve as a relay. The source’s transmission is subjected to quasi-static flat Rayleigh fading, while the transmission of the relay experiences a fixed amplitude gain with a uniform random phase, capturing its close proximity to the destination. they propose relaying protocols which are based on Wyner–Ziv quantization at the relay, and demonstrate their high efficiency (in terms of expected throughput) with respect to previously reported relaying schemes based on amplify-and-forward and decode-and-forward.

Outage Probability-Based Power and Time Optimization for Relay Networks

The technique for outage probability minimization has been proposed for wireless relaying protocol with a statistical knowledge of the channels. The minimization problem is a convex problem with respect to powers given to the transmitting nodes and to the slot durations. The proposed method is fairly generic and works for a large number of relaying protocols. Some future research directions are the following: it would be interesting to search for outage minimization techniques suitable for other classes of relaying protocols such as the Dynamic Decode and Forward or Compress and Forward.

III. Proposed Method

Relay is a device which listens to the source signal during a certain amount of time (the first slot) and is allowed to transmit towards the destination during the rest of the time (the second slot). There are several protocols used for relay which are all adopted the some advantage as well as some problems. Problems may be in protocol performance like outage probability, multiplexing gain etc., the performance are improved by stage by stage development of relay protocols such as decode and forward (DF), compress and forward (CF) etc.

The DoQF relay protocol first tries to decode the source message based on the signal received during the first slot. If this step is successful, then similarly to the classical DF scheme, the relay retransmits a coded version of this message during the second slot based on an independent codebook. If the relay is not able to decode the message, it does not remain inactive, but it quantizes the received signal vector using a well chosen distortion value. These are performing in Rician channel.

3.1 THE PROPOSED DOQF PROTOCOL

In this section, fig 2 the source (node 0) needs to send information at a rate of R bits per channel use towards the destination (node 2). To this end, the source has as its disposal a frame of length T and a dictionary of $[e^{RT}]$ Gaussian independent vectors with independent $\mathcal{CN}(0,1)$ elements each. Vector of length equal to dictionary element which is transmitted by the source. The relay (node 1) listens to the source message for duration of t_0T channel uses where t_0 is a fixed parameter. At the end of this period of time that we refer to as slot 0, the relay attempts to decode the source message. In case of success, the relay searches in its own dictionary the word corresponding to the source's message and it transmits it during the remainder of the frame (slot 1) to the destination. The dictionaries of the source and the relay are independent and identically distributed. Let us partition the word X0 transmitted by the source as $[X_{00}^T, X_{01}^T]^T$ where the lengths of X_{00} and X_{01} are t_0T and t_1T, respectively, with. The signal of size t_0T received by the relay during slot 0 writes

$$Y_{1,0} = \sqrt{(\alpha_0 \rho)} H_{01} X_{00} + V_{10} \qquad (1)$$

The parameter ρ will represent the total power spent by the source and the relay to transmit the message as shall see in a moment. The gain $\sqrt{\alpha_0}$ is an amplitude gain applied by the source. Recall that the random vector $V_{1,0}$ represents the unit variance AWGN received by the relay. Assuming that the relay has a perfect knowledge of the channel H_{01}, it will be able to decode the source message if the event $\epsilon_{\{1\}} = \{\omega: t_0 \log\left(1 + \alpha_0 \rho G_{01}(\omega)\right) > R\}$ is realized. In case $\epsilon_{\{1\}}$ is realized, the relay will transmit during slot 1 the signal $\sqrt{\alpha_1 \rho X_{11}}$ of length t_1T where $\sqrt{\alpha_1}$ is the amplitude gain of the relay. In that case, the destination receives the signal $Y_2 = [Y_{20}^T, Y_{21}^T]^T$ given by the equation at the bottom of the page, where $V_2 = [V_{20}^T, V_{21}^T]^T$ is the unit variance AWGN received by the destination. Notice that the probability distribution of the vector $[X_{00}^T, X_{01}^T, X_{11}^T]^T$ is $(0, I_{(1+t_1)T})$.

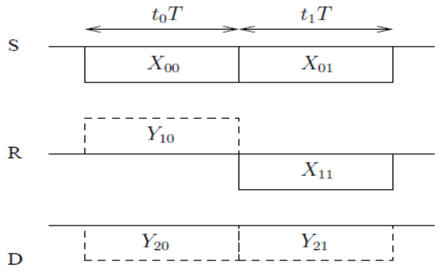

Fig. 2. Transmit/Receive signals for source (S),
elay (R) and destination(D).

Where ρT represents the total energy spent by both the source and the relay. Note that $E_0 = \alpha_0\rho T$ is the source share of the total energy. Denote by E_1 the average energy spent by the relay. The energy E_1 should be selected such that the following (long-term) power constraint is respected

$$E_0 + E_1 \leq \rho T \qquad (2)$$

3.2 CASE WHEN THE RELAY DECODES THE SOURCE MESSAGE

The relay is able to decode the source message if
the event is realized.

$$\epsilon \quad = \{\omega : t_0 \log\big(1 + \alpha_0 \rho G_{01}(\omega)\big) > R\}$$

If this is the case, the relay transmits during the remainder of the frame (slot 1) the corresponding codeword of length $t_1 T$from its own codebook. The relay codebook is composed of $[e^{RT}]$Gaussian independent vectors with independent CN(0, 1) elements each. The relay selects the codeword$X_{11}$and transmits$\sqrt{\alpha_1 \rho} X_{11}$, which means that $\alpha_1 \rho T$ is the relay share of the total energy.

$$[Y_{20}^{\mathrm{T}}, Y_{21}^{\mathrm{T}}]^{\mathrm{T}} = \mathrm{H}_{\mathcal{E}} [X_{00}^{\mathrm{T}}, X_{01}^{\mathrm{T}}, X_{11}^{\mathrm{T}}]^{\mathrm{T}} + [V_{20}^{\mathrm{T}}, V_{21}^{\mathrm{T}}]^{\mathrm{T}} \tag{3}$$

Where,

$$H_\epsilon = \begin{bmatrix} \sqrt{\alpha_0 \rho} H_{02} I_{t0,T} & 0 & 0 \\ 0 & \sqrt{\alpha_0 \rho} H_{01} I_{t1,T} & \sqrt{\alpha_0 \rho} H_{01} I_{t1,T} \end{bmatrix}$$

3.3 CASE WHEN THE RELAY DOES NOT DECODE THE SOURCE MESSAGE (EVENT $\bar{\epsilon}$IS REALIZED)

The relay quantizes in this case the received signal during slot 0 and transmits a coded version of the quantized vector during slot 1 using the following steps.

a)**Quantization**: Denote by $\tilde{Y}_{10}$the quantized version of the received vector $\tilde{Y}_{10}$. Vector $\tilde{Y}_{10}$is constructed as follows. Clearly, all $t_0 T$components of vector $\tilde{Y}_{10}$are independent and CN(0, $\alpha_0 \rho G_{01}$+1) distributed. Denote by $\Delta^2(\rho)$ the desired squared-error distortion per vector component:

$$\mathbb{E}\big|\tilde{Y}_{10}(i) - Y_{10}(i)\big|^2 \leq \Delta^2\,(\rho). \tag{4}$$

The Rate Distortion theorem for Gaussian sources tells us that there exists a $\left(\lfloor e^{Q(\rho) t_0 T} \rfloor, t_0 T\right)$. Rate distortion code (for some Q(ρ)> 0) which is achievable for distortion $\Delta^2(\rho)$ provided that

$$Q(\rho) > log\left(\frac{\alpha_0 \rho G_{01} + 1}{\Delta^2(\rho)}\right). \tag{5}$$

Such a code can be constructed by properly selecting the quantized vector $\tilde{\mathrm{Y}}10$ among a quantizer-codebook formed by $\lfloor e^{Q(\rho) t_0 T} \rfloor$ independent random vectors with distribution $\mathcal{C}\mathrm{N}\big(0, (\alpha_0 \rho G_{01} + 1 - \Delta^2\,(\rho))\mathrm{I}_{\mathrm{t0T}}\big)$. Vector $\tilde{\mathrm{Y}}_{10}$ is selected from this codebook in such a

$$y = \tilde{y} + \Delta \quad (\rho) Z \tag{6}$$

way that sequence Y10 and $\tilde{\mathrm{Y}}10$ are jointly typical w.r.t. the joint distribution $p_{(y,\tilde{y})}$ given by Where $\tilde{y}$and Z are independent random variables with respective distributions $\mathcal{C}\mathrm{N}\left(0, \big(\alpha_0 \rho G_{01} + 1 - \Delta^2\,(\rho)\big)\right)$ and $\mathcal{C}\mathrm{N}(0,1)$. Condition (10) ensures that such a vector $\tilde{\mathrm{Y}}10$ exists with high probability as T → ∞. Parameter $Q(\rho)$ can be interpreted as the number of bits used to quantize one component of the received vector Y_{10}. It must be chosen such that (10) is satisfied. As the rhs of (10) depends on the channel gain G_{01} it looks impossible at first glance to construct a fixed quantizer which is successful for any channel state. Nevertheless, recall that we are considering the case where event $\mathcal{E}$ is *not* realized *i.e.* ,$t_0 log(1 + \alpha_0 \rho G_{01}) < R$. It is thus sufficient to define $Q(\rho) = log\left(\frac{K}{\Delta^2(\rho)}\right)$ where K is any constant such that$K \geq e^{\frac{R}{t0}}$. We choose $K \ = e^{\frac{R}{t0}}$.

$$\mathcal{S} = \{w : \alpha_0 \rho G_{01}(w) + 1 > \Delta^2\,(\rho)\}. \tag{7}$$

Event $\mathcal{S}$ happens with negligible probability provided that $\Delta^2\,(\rho)$ is chosen properly.

b) **Forwarding the Relay Message**: During the second slot of length $\mathrm{t}_1\mathrm{T}$, the relay must forward the index of the quantized vector among the possible $\lfloor \mathrm{e}^{\mathrm{Q}(\rho)\mathrm{t}_0\mathrm{T}} \rfloor$ ones. To that end, it uses a Gaussian codebook with rate $\mathrm{Q}(\rho)\mathrm{t}_0/\mathrm{t}_1$. If we denote by X_{11} the corresponding codeword, the signal transmitted by the relay can be written as $\sqrt{\varphi(\rho)}\mathrm{X}_{11}$, where φ(ρ) is the power of the relay. Function φ(ρ) should be selected such that the power constraint given by (7) is respected.

c)**Processing at Destination**: In case the relay has quantized the source message (event $\mathcal{S}$ defined by (12) is realized), the destination proceeds as follows. It first tries to recover the relay message X_{11} received during slot 1 and uses it to help decode the source message. The signal of length t_1T received by the destination during the second slot can be written as

$$Y_{21} = \sqrt{\varphi(\rho)}H_{12}X_{11} + \sqrt{\alpha_0\rho}H_{02}X_{01} + V_{21} \tag{8}$$

Note that (13) can be seen as a Multiple Access Channel (MAC). In order to recover X_{11} (and consequently $\tilde{Y}_{10}$) from (13), the destination interprets the source contribution as noise. It succeeds in recovering $\tilde{Y}_{10}$ if the event

$$\mathcal{F} = \left\{w: t_1 log\left(1 + \frac{\varphi(\rho)G_{12}(w)}{\alpha_0\rho G_{02}(w)+1}\right) > Q(\rho)t_0\right\} \tag{9}$$

is realized. We distinguish between three possible cases.

IV.Simulation Results

In Fig. 3, plotted the DMT of the DoQF, orthogonal DF (non orthogonal) DF, non orthogonal AF (NAF), DDF, CF (with and without Wyner-Ziv coding [4]) and the MISO upper-bound. The DoQF outperforms the other static protocols that are *not* based on perfect CSIT. In contrast, the DDF protocol is still better than the DoQF but its dynamic approach leads to several implementation difficulties. The CF protocol with Wyner-Ziv coding (which needs perfect CSIT at the relay node) is DMT-optimal while its non Wyner-Ziv variant without CSIT [6] never achieves the MISO upper-bound and unfortunately offers poor performance.

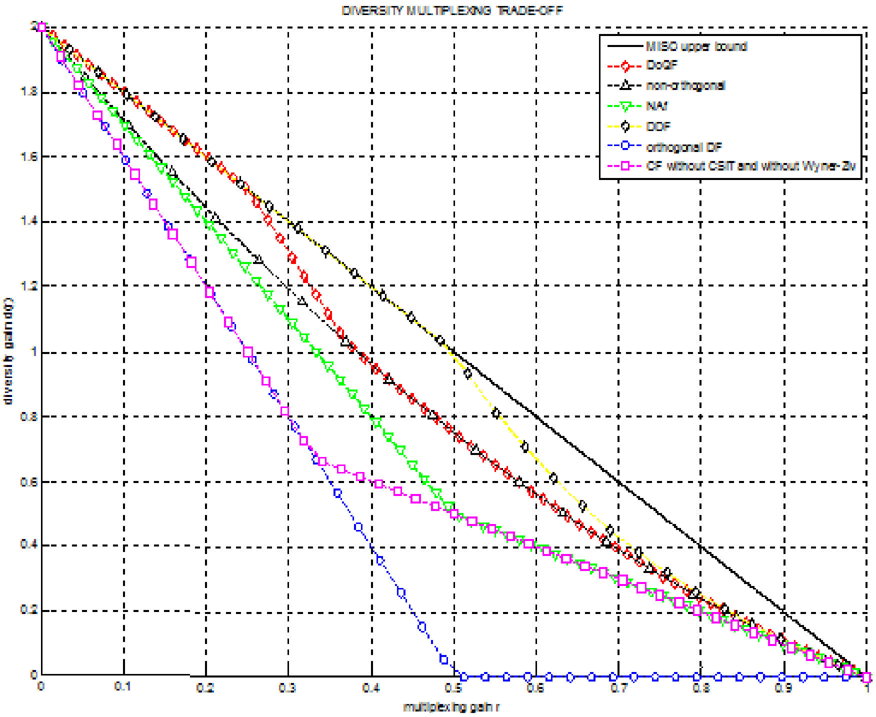

Fig 3. DMT of the DOQF and other protocols

In Fig. 3, outage probability performance with equal duration time slots and equal amplitudes for both the DF and the DoQF is compared to the performance after time and power optimization for different values of the SNR ρ. Both the simulated outage probability $Po(\rho)$ and the approximated outage probability $\xi DoQF\ \rho 2$ are plotted in this figure.

The relay is assumed to lie at two thirds of the source-destination distance on the source-destination line segment. Substantial gains are observed between the DF and the DoQF, and between optimized and non optimized protocols. Note that minimizing the outage gain continues to reduce the outage probability of the protocol even for moderate values of the SNR.

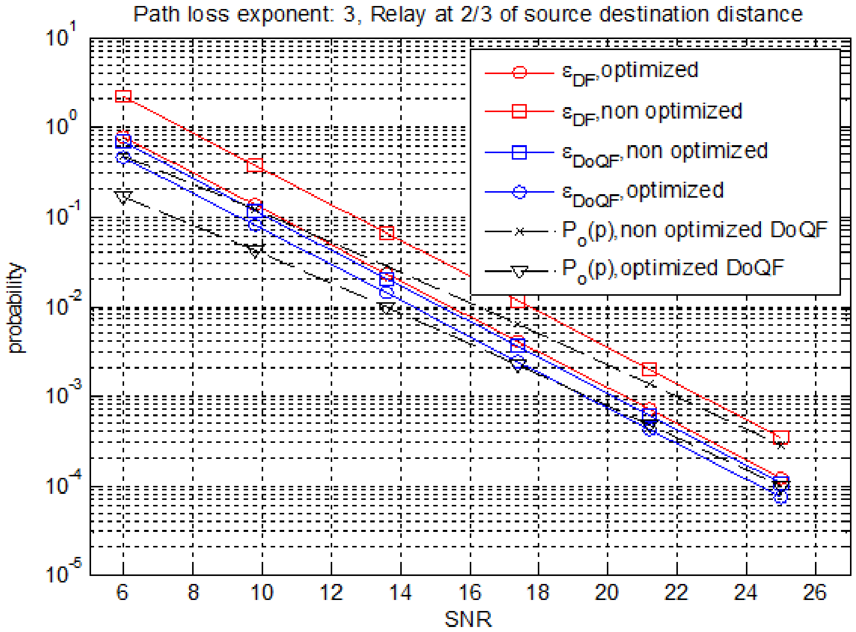

Fig 3. Outage performance of the DF and DOQF protocols

In Fig 4 shows the Outage performances of the DoQF protocols in Rayleigh and Rician fading channel. Compare to Rayleigh fading channel Rician achieves the more gain because of line of sight component and also power consuption is less through the channel.

The MISO upper-bound is thus reached by the DoQF for $r < 0.25$, but the DMT of the protocol deviates from the MISO bound for $r > 0.25$. Note that we allowed $t0$ and δ to depend on the multiplexing gain r. This additional degree of freedom will not change the fact that the DoQF protocol is static. Indeed, parameters $t0$ and δ do not depend on any channel coefficients.

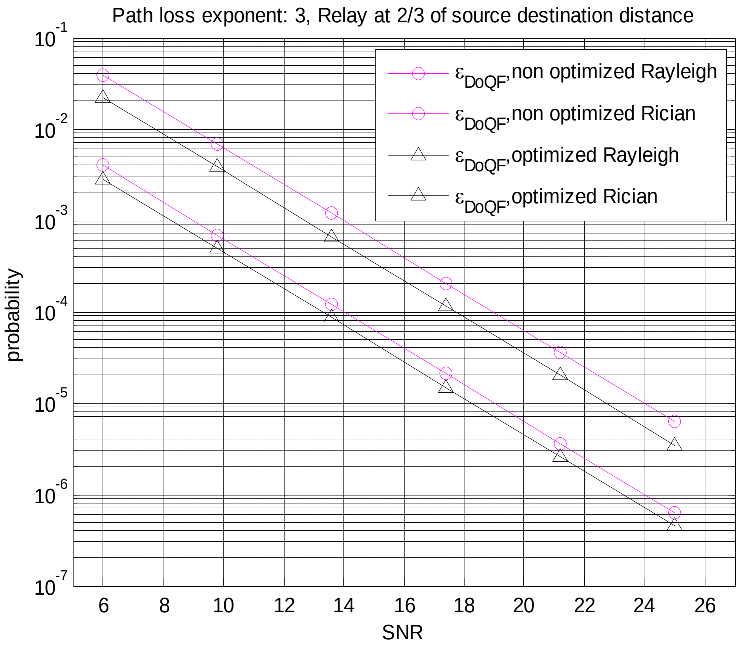

Fig 4. Outage performances of the DoQF protocols in Rayleigh and Rician fading channel

V. CONCLUSION

The wireless channels between the different nodes of the system were modeled as slow fading random processes. In this context, proposed a novel static relaying protocol based on a DoQF approach for networks composed of one source, one relay node and one destination. The DoQF can be considered as an enhanced Decode-and-Forward (DF) relaying scheme where the relay does not remain inactive in case of failure in decoding the source message; it rather quantizes the received signal using a well chosen distortion value and forwards this quantized signal towards the destination. Showed that unlike most of the existing relevant relaying schemes, the proposed protocol can be implemented with practical coding-decoding structures at both the relay and the destination. Furthermore, it does not require perfect CSI at the transmitter side. The proposed DoQF protocol was analytically evaluated using performance metrics which are suitable for communication over slow fading channels. This performance analysis proved the relevancy of the DoQF protocol in such fading scenarios. This noticeable result was sustained by our simulations. The proposed protocol has been finally shown to achieve the DMT of MISO for multiplexing gains lesser than or equal to 0.25. The proposed DoQF has better performance result in Rician fading channel as in terms of outage probability.

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