Cooperative Request-answer Schemes for Mobile Receivers in OFDM Systems

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***Abstract*— In this paper we propose a practical solution to implement the symbol request sharing (SRS) cooperative scheme in real systems. The SRS scheme is designed for systems with a source and a destination among a group of receivers. The idea of cooperation is that nearby receivers assist the destination in order to enhance its information reception and avoid a retransmission from the source if possible. The SRS scheme follows a request-answer strategy. Specifically, we evaluate SRS when quantization is considered. For an ideal case without quantization, SRS achieves spatial diversity by performing maximum ratio combining (MRC) on selected subcarriers of a coded OFDM-based system. However, it turns out that SRS fails when the shared information is quantized prior to its retransmission to the destination. To overcome this drawback the SRS-EQ scheme is introduced, which is equivalent to SRS. It performs a phase correction at the relays before information is shared. It is shown that SRS-EQ is a viable option for cooperation in real systems.**

***Index Terms*— Cooperative Receivers, OFDM, symbol request sharing, maximum ratio combining**

I. Introduction

The growing demand in data transmission capacity is motivating the design of the next communication network technologies. For instance, according to [1], the global mobile data traffic grew by 74 % from 2014 to 2015, and the data traffic is expected to grow at a compound annual growth rate of 53 % from 2015 to 2020. This projection gives an insight into the possible evolution of the future wireless mobile networks. How to improve the reliability of the communication, throughput, spectrum and energy efficiency are some of the issues that future mobile communication networks have to deal with.

In order to meet the growing demand in data transmission rates without significantly compromising the quality of service (QoS) experienced by the end-user, for example in cellular networks, the number of base stations (BS) tends also to increase [2]. In addition, as indicated in [3], the radio access network consumes most of the energy in mobile communication networks, i.e., the BS in cellular networks. Therefore, energy efficiency is another important issue that has received significant attention from both academia and industry in the last years.

One of the causes of this trend has been the availability of personal mobile communications worldwide, the emerging machine to machine communications (M2M) and the Internet of things (IoT). With this perspective, it is expected that networks will be more dense. Hence, cooperation among end-users close to each other may help to meet the requirements of wireless networks. The 3rd Generation Partnership Project (3GPP) is aware of these challenges. Therefore, the case of Device-to-Device (D2D) communication has been specified by 3GPP in LTE Rel-12. D2D is considered as a technology that enables direct communication between two nearby devices without routing through the Evolved Packet Core (EPC).

The advantages that cooperation can bring to the wireless communications has been investigated theoretically in, e.g., [4], [5], [6], [7]. However, these approaches are still difficult to implement in practical systems. Issues such as huge cooperation overhead and complex synchronization methods for cooperation, are still under investigation. To this end a variety of practical solutions have been proposed. For instance, in [8] the symbol request sharing (SRS) cooperation scheme with a request-answer strategy is introduced. This scheme achieves spatial diversity by performing maximum ratio combining (MRC) on selected subcarriers of a coded OFDM-based system.

In this paper we present our research on cooperative communication in a more generic fashion but with the aim of a practical implementation. We assume a system with a distant source and several receivers, with one target receiver among them which is denoted as destination. The receivers are assumed to be close to each other but physically separated. Consider as an example a cellular network in a densely populated urban area, where a base station communicates to a moving user equipment (UE). We can expect unfavorable conditions for a reliable communication, i.e., channel impairments like frequency and time selectivity as well as a high signal-to-interference ratio (SIR). The idea of cooperation is that UEs nearby assist the target UE in order to enhance its information reception and avoid a retransmission from the BS if possible. We evaluate the SRS for real systems, i.e., we design and introduce suitable quantizers for the information sharing. The main goal remains, which is, the cooperation scheme should exploit the spatial diversity inherent in the system but reduce the cooperation overhead as much as possible. For this purpose, a modification of SRS is introduced which reduces the amount of cooperation overhead and improves the reliability of the cooperation scheme.

The remainder of this paper is organized as follows. In Section II, the system is described. Section III describes the cooperative schemes. Numerical results and performance comparisons for illustration are presented in Section IV, followed by a conclusion in Section V.

II. System Description

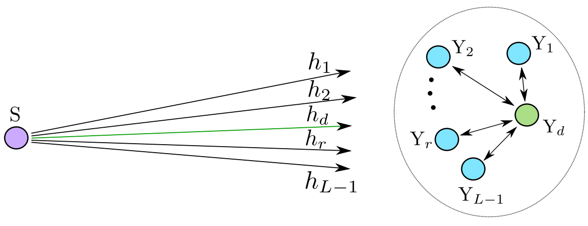

Fig. 1. System model, one source S and L receivers close to each other. S communicates a message to a destination node Y_d, all remaining receivers may serve as relays in order to assist Y_d in decoding the message. Independent channels $h_d, h_1, ..., h_{L-1}$ are assumed.

As shown in Figure 1, we consider a half-duplex wireless communication system in which the source node S desires to convey a message but only to a single receiver node denoted by Y_d, where d indicates one of the L possible nodes in the set of receivers $\mathbb{Y} = \{1, \ldots, L\}$. In order to increase the reliability of the data transmission, each remaining receiver is configured as a relay Y_r, with r in $\mathbb{Y}_d = \mathbb{Y} \backslash \{d\}$. Therefore, if Y_d is not able to correctly decode the received message, the remaining nodes in $\mathbb{Y}_d$ can serve Y_d in order to fix some transmission errors.

We assume that the receiver nodes are close to each other with a distance short enough to consider a perfect wireless channel between them, i.e., no fading effect and a very high signal to noise ratio (SNR). On the other hand, the receivers are considered far away from the source. The channels for the source-receiver links $\{h_i\}_{\forall i \in \mathbb{Y}}$ are assumed to be independent and identically distributed (i.i.d.), time-varying, frequency-selective multipath Rayleigh fading, with the same time and bandwidth coherence.

In order to avoid any intersymbol interference (ISI) and to mitigate the effects of frequency selective fading of the source-receiver channels, we assume a system based on a coded Orthogonal Frequency Division Multiplexing (OFDM) communication scheme. At the source, the information bit vector $\mathbf{b} \in \{0, 1\}^\kappa$ is first encoded, resulting in the codeword $\mathbf{c} \in \{0, 1\}^n$. We consider a rate-compatible punctured convolutional (RCPC) code, with a mother code rate $R_{\mathrm{c,m}} = \kappa/m$, the effective code rate $R_{\mathrm{c}} = \kappa/n$, and a total of n_{p} punctured bits $\{\mathbf{c}_{\mathrm{p}}\}$. Subsequently, $\mathbf{c}$ is mapped into $\mathbf{x} \in \mathbb{M}^N$, where $\mathbb{M} \subset \mathbb{C}$ is the constellation set of M-QAM symbols and N is the total number of data subcarriers. Both data symbols $\mathbf{x}$ and a total of N_{p} pilot symbols arbitrarily arranged are converted to the time domain by means of an IFFT with N_{c} points, i.e., $N_{\mathrm{c}} = N + N_{\mathrm{p}}$. To ensure an ISI free reception of the symbol, a cyclic prefix (CP) is added to $\mathbf{x}$ which is then removed at the receiver. The length of CP has to be equal to or longer than the overall channel impulse response. Finally a preamble is inserted at the beginning of the OFDM symbol prior to its transmission for the purpose of synchronization.

The vector $\mathbf{x}$ is conveyed by S to Y_d over the channel h_d. However, as depicted in Figure 1, all remaining relay nodes $\{\mathrm{Y}_r\}_{\forall r}$ will inevitably receive the same message but each one over independent channels h_r, with $r \in \mathbb{Y}_d$. Therefore, we can generalize the data transmission to all receiver nodes. Assuming an ideal symbol time offset (STO) and carrier frequency offset (CFO), the received signal $y_{i,k}$ at Y_i on the k-th subcarrier in the discrete frequency domain can be expressed as

$$y_{i,k} = h_{i,k} \cdot x_k + n_{i,k}, \text{ with } k \in \mathbb{K}, \tag{1}$$

where $h_{i,k} \sim \mathcal{CN}(0, \nu)$ denotes the Rayleigh distributed fading coefficient, $\nu = \mathrm{E}\{|h_{i,k}|^2\} = 1$ is the variance, $\mathbb{K} = \{1, \ldots, N_{\mathrm{c}}\}$ the set of subcarrier indexes, and $n_{i,k}$ denotes the additive complex Gaussian noise term satisfying $n_{i,k} \sim \mathcal{CN}(0, \sigma_{\mathrm{n}}^2)$ with zero mean and variance σ_{n}^2. Moreover, we assume a perfect knowledge of the channel state information (CSI), $\mathbf{h}_i = [h_{i,k}]_{k=1}^{N_{\mathrm{c}}}$, of the source-receiver node link at receiver Y_i but not at S. In consequence, the total transmit power at the source is denoted by $\mathcal{P}_{\mathrm{S}} = N_{\mathrm{c}} \cdot \mathcal{P}_{\mathrm{S},k}$, where $\mathcal{P}_{\mathrm{S},k} = \mathrm{E}\{|x_k|^2\}$ is the average transmit power on the subcarrier k.

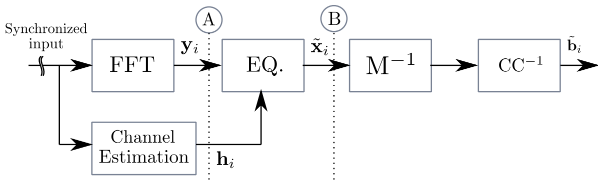

Fig. 2. Block diagram of a generic receiver Y_i $\forall i$, the input signal is assumed synchronized in t and f domain and with the cyclic prefix removed.

An oversimplified block diagram of a receiver is depicted in Figure 2. The signal $\mathbf{y}_i$ is defined in (1). Using CSI, each receiver can estimate its symbol vector $\tilde{\mathbf{x}}_i = [\tilde{x}_{i,k}]_{k=1}^{N_{\mathrm{c}}}$ on the k-th subcarrier by means of equalizing the vector $\mathbf{y}_i = [y_{i,k}]_{k=1}^{N_{\mathrm{c}}}$. The vector $\tilde{\mathbf{x}}_i$ is demapped and decoded resulting in the vector of estimated information bits $\tilde{\mathbf{b}}_i$. The A and B indicators in Figure 2 illustrate the stages in which the cooperation can be accomplished and will be described in the next section.

III. Cooperative Request-answer Schemes

In a cooperative request-answer scheme the destination Y_d requests from its neighbors specific information following some criteria. Therefore, we present here the symbol request sharing (SRS) scheme as previous work [8] and as a starting point in search for a more efficient manner to share the same information in real systems.

A. Symbol Request Sharing (SRS)

In SRS, cooperation is accomplished before the equalization stage, i.e., in the indicator A of the Figure 2. The SRS scheme selects the symbols to request as follows. The destination Y_d compares and identifies $0 \leq \alpha \leq N_\mathrm{c}$ coefficients in $\mathbf{h}_d = [h_{d,k}]_{k=1}^{N_\mathrm{c}}$ with the lowest power among the N_c coefficients and stores their indexes in $\mathbb{K}_d = \{v_{d,j}\}_{j=1}^{\alpha} \subseteq \mathbb{K}$. Y_d requests from all $L-1$ relays their respective symbols in the $(v_{d,j})$-th subcarrier, i.e., $y_{r,k}$ for all $k \in \mathbb{K}_d$ and for all $r \in \mathbb{Y}_d$. Hence, for each symbol request, there are $L-1$ replies. In the SRS, the receiver Y_d requests from the relays the symbol corresponding to the $(v_{d,j})$-th subcarrier under the assumption that for all d in $\mathbb{Y}$, for all r in $\mathbb{Y}_d$ and for small α, the probability that

$$|h_{r,k}|^2 > |h_{d,k}|^2 \qquad \forall k \in \mathbb{K}_d \tag{2}$$

is greater than the opposite case. Consequently, the symbol vector $\mathbf{y}_{\mathrm{SRS},d} = [y_{\mathrm{SRS},d,k}]_{k=1}^{N_\mathrm{c}}$ at the receiver Y_d after cooperation is

$$y_{\mathrm{SRS},d,k} = \begin{cases} h_{d,k}^* \cdot y_{d,k} + \sum\limits_{r=1}^{L-1} h_{r,k}^* \cdot y_{r,k} & \text{if } k \in \mathbb{K}_d \\ y_{d,k} & \text{else} \end{cases}, \tag{3}$$

where (*) indicates the complex conjugate. In (3) the modification of the noise power in the k-th subcarrier by the influence of the L channel coefficients can be noticed. Thus, the noise power must be compensated by

$$\sigma^2_{\mathrm{SRS},d,k} = \begin{cases} \sigma_n^2 \cdot \left(|h_{d,k}|^2 + \sum\limits_{r=1}^{L-1} |h_{r,k}|^2 \right) & \text{if } k \in \mathbb{K}_d \\ \sigma_n^2 & \text{else} \end{cases}. \tag{4}$$

It follows from (3) that all receivers can serve as relays for the $(v_{d,j})$-th selected subcarrier. Therefore, full maximum ratio combining (MRC) is accomplished on the subcarriers in $\mathbb{K}_d$.

1) Cooperation overhead: In SRS, symbols are selected to maximize the SNR on subcarriers with the lowest power. These advantages come at the cost of a cooperation overhead. Note also that for SRS in (3) not only the requested symbols but also the channel coefficients are relayed. The cooperation overhead is controlled by and is directly proportional to the parameter α. The cooperation overhead in SRS is the sum of the number of bits needed for the request from the destination and the amount of bits required for the reply from each relay.

The request consists in broadcasting all the indexes in $\mathbb{K}_d$. The method used to communicate the indexes can be selected depending on α. Two methods can be identified for this purpose. The first is to assign $\log_2(N_\mathrm{c})$ bits to address each index if the condition $(\alpha) \cdot \log_2(N_\mathrm{c}) < N_\mathrm{c}$ is fulfilled. If it is not the case, the second method consists in utilizing only one bit for each subcarrier for communicating the indexes in $\mathbb{K}_d$, e.g., with a “1” if the subcarrier is selected and with a “0” otherwise. We consider the second method. Therefore, only N_c bits are required for the index request.

Every receiver serving as a relay replays to the destination its $h_{r,k}$ and $y_{r,k}$ for $k \in \mathbb{K}_d$. Note that the CSI and the symbols are complex numbers and $|\mathbb{K}_d| = \alpha$. Moreover, we assume Q_h bits of resolution for the channel coefficients quantizer, and a Q_y bits resolution quantizer for every symbol. Finally, for every index requested, $(L-1)$ symbols and channel coefficients are relayed. Therefore, the maximum length of the overhead for SRS is

$$\Psi_{\mathrm{SRS}} = N_\mathrm{c} + \alpha \cdot (L-1) \cdot (Q_\mathrm{h} + Q_\mathrm{y}) \,. \tag{5}$$

The first term on the right hand side of (5) is fixed to the number of subcarriers N_c and the second term depends on the quantizers' resolutions. Hence, by designing appropriate quantizers, the cooperation overhead may be reduced.

2) Quantizer design: Two quantizers are required for the SRS scheme, $\mathrm{Q}_\mathrm{h}^{\mathrm{SRS}}$ and $\mathrm{Q}_\mathrm{y}^{\mathrm{SRS}}$, both with Q_h and Q_y bits resolution respectively. In order to minimize the mean-square quantization error, we propose the Lloyd-Max algorithm [9], [10]. The Lloyd-Max algorithm gives an optimum quantizer and only requires the probability density function (PDF) of the signals to quantize.

The first quantizer $\mathrm{Q}_\mathrm{h}^{\mathrm{SRS}}$ is for the channel coefficients. A wireless channel subject to fading environments can be modeled as a complex Gaussian random variable if the number of scatters is large enough. The channel is defined as $h = h_r + jh_i$, in which its real and imaginary components, h_r and h_i respectively, are independent and identically-distributed (i.i.d.) Gaussian variables with zero mean and variance σ_h^2. Therefore, $\mathrm{Q}_\mathrm{h}^{\mathrm{SRS}}$ can be designed as two 1D-quantizer, each one with a PDF $\sim \mathcal{N}(0, \sigma_\mathrm{h}^2)$. Hence, the real and the imaginary component of the CSI is quantized separately with $Q_\mathrm{h}/2$ bits.

The second quantizer $\mathrm{Q}_\mathrm{y}^{\mathrm{SRS}}$ is for the symbols given by (1). The real and imaginary components of the received symbol are i.i.d. and also the result of the sum of two random variables. For this reason a 1D-quantizer with $Q_\mathrm{y}/2$ bits resolution can be designed for each component. The resulting PDF required for the design of the quantizer is the convolution of two normal densities with final PDF $\sim \mathcal{N}(0, \sigma_\mathrm{h}^2 + \sigma_\mathrm{n}^2)$.

B. SRS scheme after equalization (SRS-EQ)

By letting the relays perform the equalization before replying to the destination, half of the overhead produced by the quantized CSI in (5) can be saved without affecting the performance of the SRS scheme. Our goal is to share the equalized symbol and the magnitude of the channel instead of sharing it as a complex coefficient. Hereafter, the SRS scheme after equalization will be denoted as SRS-EQ to distinguish it form the SRS scheme.

The k-th estimated symbol at the i-th receiver is found by equalizing the signal received in (1), that is,

$$\tilde{x}_{i,k} = \frac{y_{i,k}}{h_{i,k}} = x_{i,k} + \frac{n_{i,k}}{h_{i,k}} = x_{i,k} + \tilde{n}_{i,k} \ , \tag{6}$$

where $\tilde{n}_{i,k} \sim \mathcal{N}(0, \sigma_{\tilde{n}}^2)$ and $\sigma_{\tilde{n}}^2 = \sigma_n^2/|h_{i,k}|^2$. In order to achieve the same result as in (1), the equalized symbols in (6) are sent to the destination where they are weighted with the corresponding channel powers as follows

$$y_{\text{EQ},d,k} = \begin{cases} |h_{d,k}|^2 \cdot \tilde{x}_{d,k} + \sum\limits_{r=1}^{L-1} |h_{r,k}|^2 \cdot \tilde{x}_{r,k} \\ y_{d,k} \end{cases} . \tag{7}$$

The subscript EQ is to distinguish the SRS scheme after equalization. Note that for (7), each relay must reply with its equalized symbol and the magnitude of its CSI. This method does not require a quantization of a complex channel coefficient but only its magnitude. Moreover, there is no need to compensate changes in power of the noise given by (4), i.e., $\sigma^2_{\text{EQ},d,k} = \sigma^2_{\text{SRS},d,k}$, due to the fact that these changes are already compensated with the power of the channel.

1) Cooperation overhead: From (7) it can be noticed that only the equalized symbols and the magnitude of the channel have to be shared. Thus, following the same deduction as for (5), the cooperation overhead turns to be

$$\Psi_{\text{EQ}} = N_\text{c} + \alpha \cdot (L-1) \cdot \left(Q_{|\text{h}|} + Q_\text{x}\right) \ , \tag{8}$$

where $Q_{|\text{h}|}$ and Q_x denote the quantizer resolution in bits of $|h_{r,k}|$ and $\tilde{x}_{r,k}$ in (7).

2) Quantizer design: For this scheme, two quantizers are necessary, $\text{Q}^{\text{EQ}}_{|\text{h}|}$ with $Q_{|\text{h}|}$ bits resolution and $\text{Q}^{\text{EQ}}_{\text{x}}$ with Q_x bits resolution. As in III-A.2, we search for the PDF for each of them in order to use the Lloyd-Max algorithm. The first quantizer is for the magnitude of the channel which is a Rayleigh random variable with PDF

$$p(|h|) = \frac{|h|}{\sigma_\text{h}^2} \, \text{e}^{-\frac{|h|^2}{2\sigma_\text{h}^2}} \ . \tag{9}$$

and $2\sigma_\text{h}^2 = \text{E}\{|h|^2\}$. Note that one 1D-quantizer for $\text{Q}^{\text{EQ}}_{|\text{h}|}$ is required. The second quantizer is for the equalized symbol $\tilde{x}_{r,k}$, which has a conditional PDF

$$p(\tilde{x}|x) = \frac{1}{\sqrt{2\pi\sigma_n^2}} \, \text{e}^{-\frac{|\tilde{x}-x|}{2\sigma_n^2}} \ , \tag{10}$$

that is, the probability that $\tilde{x} \in \mathbb{C}$ is received given that $x \in \mathbb{M}$ was transmitted. As for SRS, each component of $\tilde{x}$ is quantized separately with $Q_\text{x}/2$ bits.

IV. Simulation Results and Discussions

In this section, the performance of the cooperation scheme presented in Section III is evaluated and discussed. The performance of ideal SRS is used as a benchmark.

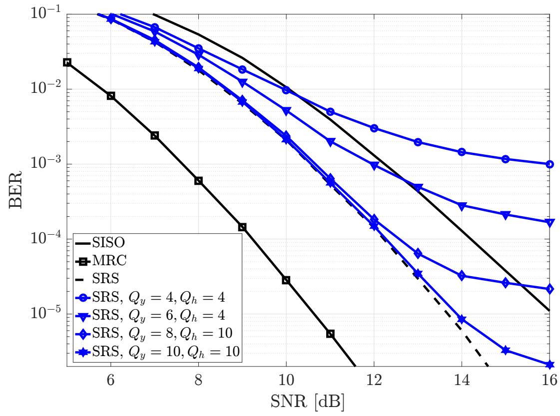

Fig. 3. The resulting BER comparison after SRS cooperation with $\alpha_\text{p} = 15$ %. SISO and MRC are benchmarked with $\alpha_\text{p} = 0$ % and $\alpha_\text{p} = 100$ % respectively. SRS is the ideal case of cooperation without quantizer, and for the non-ideal schemes, two quantizers are used, $\text{Q}^{\text{SRS}}_{\text{h}}$ with Q_h bits resolution and $\text{Q}^{\text{SRS}}_{\text{y}}$ with Q_y bits resolution.

A. Parameter Settings

The cooperation schemes are evaluated using the Monte-Carlo simulation method. For the source-receiver links, we assume an OFDM system with $N_\text{c} = 1024$ subcarriers, bandwidth β, inter-carrier spacing β/N_c and M-QAM modulation, where $M = 16$. Furthermore, a convolutional encoder with a non-systematic codeword and a constraint length set to 4 is used at the source. The mother codeword rate is set to $R_{\text{c,m}} = 1/3$, with punctured bits $n_\text{p} = m/3$, therefore the effective codeword is $R_\text{c} = 1/2$. At each receiver, a soft-input BJCR convolutional decoder with a generator polynomial $[13,15,11]_8$ is employed. We consider a system with $L = 2$ receivers. For the receiver-destination links, a perfect channel (error-free) is assumed, with a modulation scheme set to 256-QAM, i.e. $M_{\text{co}} = 256$. For clarity, we denote $\alpha_\text{p} = \alpha/N_\text{c} = 15$ %.

B. Simulation Results

The bit error rate (BER), measured at the destination node Y_d, is depicted in Figures 3 and 4 for both SRS and SRS-EQ cooperation schemes. The SISO plot shows a single-input single-output system, and it denotes the case where no cooperation is performed. MRC is the plot referring to full cooperation, which can be achieved by means of (3) or (7) with $\alpha = N_c$ and without quantizing. It can also be noticed that SRS and SRS-EQ are totally equivalent in terms of BER for any α_p when no quantization is performed. This is confirmed with the dashed line in both figures, SRS = SRS-EQ for quantizers with infinity bits resolution. Nevertheless, this does not hold if the relayed information is quantized.

Figure 3 shows the performance of SRS with respect to different quantizer resolutions. It is first noticed that the plots converge to a BER floor for any combination of quantizers. For instance, by setting $Q_\text{y} = 10$ bit and $Q_\text{h} = 10$ bit, it almost reaches the ideal SRS plot for lower SNR but it approaches a BER floor at SNR $= 15$ dB. This

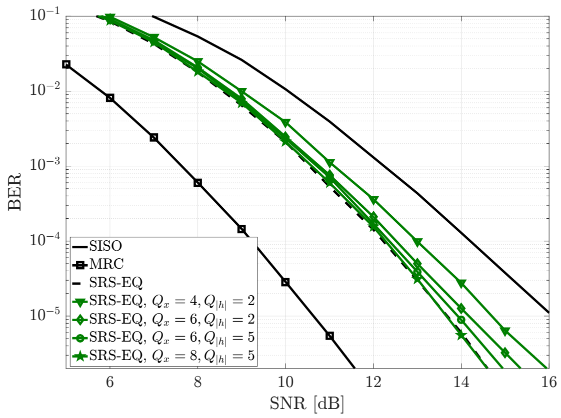

Fig. 4. The resulting BER comparison after SRS-EQ cooperation with $\alpha_\text{p} = 15$ %. SISO and MRC are benchmarked with $\alpha_\text{p} = 0$ % and $\alpha_\text{p} = 100$ % respectively. SRS-EQ is the ideal case of cooperation without quantizer, and for the non-ideal schemes, two quantizers are used, $\text{Q}_\text{x}^\text{EQ}$ with Q_x bits resolution and $\text{Q}_{|\text{h}|}^\text{EQ}$ with $Q_{|\text{h}|}$ bits resolution.

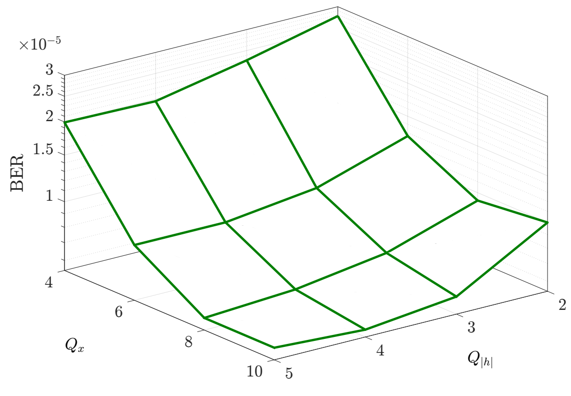

Fig. 5. BER for SRS-EQ depending on Q_x and $Q_{|\text{h}|}$ for a fixed SNR = 14 dB. Q_x and $Q_{|\text{h}|}$ give the resolution of $\text{Q}_\text{x}^\text{EQ}$ and $\text{Q}_{|\text{h}|}^\text{EQ}$ respectively.

behavior is explained by (3). Without quantization, Y_d is able to correct the phase of the relayed symbol, i.e., if we ignore the noise term for simplicity

$$h_{r,k}^* \cdot y_{r,k} = |h_{r,k}|^2 \cdot x_k \ . \tag{11}$$

However, for a quantized CSI and quantized symbol, the phase derotation in (11) does not hold anymore and a phase error will remain. The magnitude of this phase error is inversely proportional to the combination of Q_y and Q_h. Thus, the BER floor comes into sight when the power of the phase error is greater than the power of the channel noise.

In Figure 4, the performance of SRS-EQ scheme given by (7) is illustrated for different combinations of Q_x and $Q_{|\text{h}|}$. There is no BER floor in this scheme due to the fact that the phase of the received symbol is completely corrected at the relay before sending it to the destination by means of (6). In (7) the combination of the received signal is just a weighting with the channel power. Therefore, the loss of gain in SRS-EQ is due only to the quantization error. It can be noticed that (7) and (11) are equivalent. Moreover, there are different combinations for the quantizer resolutions, which may give different performance. To give an idea about how the BER for SRS-EQ depends on Q_x and $Q_{|\text{h}|}$, i.e., $\text{BER}_{Q_\text{x},Q_{|\text{h}|}}$, in Figure 3 the performance for a fixed SNR $= 14$ dB is presented. This performance is not symmetric. BER seems to be more sensitive to the resolution of $\text{Q}_\text{x}^\text{EQ}$ than the resolution of $\text{Q}_{|\text{h}|}^\text{EQ}$. For instance, $\text{BER}_{4,4} > \text{BER}_{6,2}$, although both need 8 bits to reply to the destination for each requested index in $\mathbb{K}_d$, their performance are slightly different.

V. Conclusion

In this paper, we evaluate the symbol request sharing (SRS) scheme for mobile cooperative receivers in OFDM systems. Specifically, we evaluate the scheme when the relayed information is quantized, as it must be done in real systems. Suitable quantizers have been designed in the spirit of Lloyd-Max algorithm for channel coefficients and for shared symbols. It is found that the SRS scheme is not suitable for a practical implementation. Due to the quantized signals, the destination is not able to correct the phase of the relayed symbol, thereby introducing a bit error rate floor and jeopardizing the performance of the scheme in terms of BER which is even worse than a SISO system for higher SNR's. To overcome this drawback, a modification of the SRS scheme is introduced, i.e., SRS-EQ. In this scheme, the phase correction is accomplished at the relays prior the transmission to the destination. No BER floor appears with SRS-EQ, therefore, it is suitable for practical systems. In our example system, with a total of 6 bits resolution between the quantizers, SRS-EQ provides a gain loss smaller than 1.5 dB w.r.t. the ideal SRS without quantization, and with 13 bits it reaches the ideal SRS performance at a BER $= 10^{-5}$, which makes SRS-EQ a viable option for a cooperation scheme in real systems.

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