Adaptive Symbol Request Sharing Scheme for Mobile Cooperative Receivers in OFDM Systems

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***Abstract*—In this paper we introduce an improvement of the symbol request sharing (SRS) cooperative scheme, namely the adaptive SRS (A-SRS). Both schemes are designed for systems assuming a source and several receivers with one target receiver among them which is denoted as destination. In addition, the source or the receivers are not restricted to be static. These schemes follow a request-answer strategy, in which the destination requests specific information from the remaining receivers. With this strategy the schemes achieve spatial diversity by performing maximum ratio combining (MRC) on selected subcarriers of a coded OFDM-based system. The A-SRS complements its predecessor by adding to it more sophisticated steps in the algorithm toward its implementation on real systems. With these enhancements, the A-SRS scheme preserves the same performance as SRS for hostile source-receiver channels; nevertheless, it provides a notably enhancement for better channels conditions. In terms of BER, for instance, the A-SRS outperforms the SRS scheme by some dB's of gain and it tends to converge more slowly as the number of receivers increases. Furthermore, the A-SRS scheme adapts the length of the cooperation overhead. Therefore, it reaches the highest throughput, which is not the case for the SRS scheme.**

I. Introduction

Cooperative communication is one of the promising topics to overcome challenges imposed by wireless communication networks that are currently being designed. For instance, the enormous increase in data traffic as well as the volume of communication devices connected to cellular networks are imposing the requirements for the next-generation cellular networks. It seems that these important factors are motivating an evolution toward 5G. 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 the technology that enables communication between two nearby devices directly without routing through the Evolved Packet Core (EPC). This technology is encouraging the cooperation between receivers.

For the purpose of our investigation, we assume a wireless communication system with a distant source and several receivers near to each other but physically separated. The system is not restricted to be static. Consider as an example a cellular network in a densely populated urban area, where a base station or a microcell communicates to a moving user equipment (UE). We can expect unfavorable conditions for a reliable communication, i.e., channel impairments as frequency and time selectivity besides a high signal-to-interference ratio (SIR). The idea of cooperation is that UE's nearby assist the target UE in order to enhance its information reception. Our focus is to exploit the space diversity inherently in the system by allowing some type of collaboration between receivers. Basically, the aim is to provide, among others, an overall higher throughput as well as an improvement in the spectrum and the energy efficiency.

Cooperation in wireless communication systems improves the system reliability. This has been investigated theoretically in, e.g., [1], [2], [3], [4]. However, these approaches are still difficult to implement in practical systems. Issues as e.g. extra time and complex synchronization methods for cooperation, are still in investigation. To this end, in [5], [6], [7], [8], [9] and [10], among others, a variety of practical solutions have been proposed. They focus on relaying schemes. For instance, [8] and [9] investigate partial maximum ratio combining (MRC) for static relays, while in [10] mobility is not limited.

In this paper, we continue our research on mobile cooperative receivers introduced in [10]. We present here, therefore, improvements to the symbol request sharing (SRS) scheme, namely, the adaptive SRS scheme (A-SRS). The main goal remains, which is to exploit the spatial diversity as much as possible but reducing further the cooperation overhead. This adaptive improvement introduces intelligent decisions on strategic stages of the cooperative algorithm. To make these decisions, the adaptive schemes employ error-detecting codes. Additionally, in A-SRS not only symbols with its channels gain may be shared, but also some extra bits to ensure a better decoding stage at the receiver node. Thus, the A-SRS scheme improves the reliability of the system and provides a higher throughput in comparison to SRS. The advantages of this adaptive scheme are demonstrated by further analysis and numerical simulations.

The paper is structured as follows. In Section II, the system is described. Sections III summarizes previous work relevant to our investigation, i.e., the SRS scheme. Afterwards, Section IV is dedicated to the proposed adaptive cooperation schemes. Numerical results and performance comparisons for illustration are presented in Section V, followed by a conclusion in Section VI.

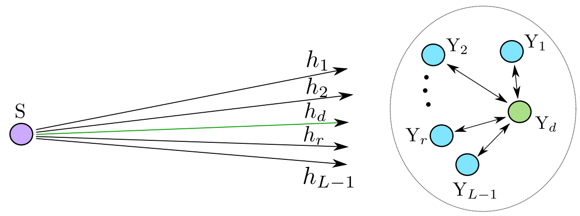

Fig. 1. System model, one source S and L receivers close to each other. S communicates a message to a destination node Y_d, all remaining receivers may serve as relays in order to assist Y_d in decoding the message. Independent channels $h_d, h_1, ..., h_{L-1}$ are assumed.

II. System Description

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 $\mathbb{Y}_d = \mathbb{Y} \setminus \{d\}$. Therefore, if Y_d is not able to correctly decode the received message, the remaining nodes in $\mathbb{Y}_d$ can serve to Y_d in order to fix some transmission errors. Note that $\mathbb{Y}_d$ is the collection of all receivers except the destination.

We assume that the source S and every receiver node are equipped with a single antenna. Besides, the receivers nodes are close to each other and faraway from the source, i.e., $d_{ab} \ll d_i,\ \forall i, a, b \in \{1, ..., L\}$, where d_{ab} denotes the distance from the receiver node Y_a to the receiver node Y_b, and d_i denotes the distance from S to any node Y_i, with $a \neq b$. Moreover, we assume that the receiver-receiver distance d_{ab} is short enough to consider a perfect wireless channel, i.e., no fading effect and a very high signal to noise ratio (SNR). On the other hand, the channels for the links between S and any receiver node $\mathrm{Y}_i, \forall i \in \mathbb{Y}$ 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) effects due to the frequency selectivity of the source-receiver channels, we assume a system based on a coded Orthogonal Frequency Division Multiplexing (OFDM) communication scheme. Hence, the length of the cyclic prefix have to be equal or longer than the overall channel impulse response. An ideal synchronization in both frequency and time is assumed by using special training symbols and a preamble. At S, the information bit vector $\mathbf{b} \in \{0,1\}^{1\times k}$ is encoded and interleaved by a random interleaver, resulting in the codeword $\mathbf{c} \in \{0,1\}^{1\times n}$. We consider a rate-compatible punctured convolutional (RCPC) code, with a mother code rate $R_{\mathrm{c,m}} = k/m$, the effective code rate $R_{\mathrm{c}} = k/n$, and a total of n_{p} punctured bits $\{\mathbf{c}_{\mathrm{p}}\}$. Finally, $\mathbf{c}$ is mapped into $\mathbf{x} \in \mathbb{M}^{1\times N_{\mathrm{c}}}$, where $\mathbb{M} \subset \mathbb{C}$ is the constellation set of M-QAM symbols and N_{c} is the total number of OFDM subcarriers. Subsequently, 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 likewise 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. 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 nodes 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 subcarirer k. Using CSI, each receiver estimates 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, decoded and de-interleaved resulting in the vector of estimated information bits $\tilde{\mathbf{b}}_i$.

III. Symbol Request Sharing

The goal of the SRS scheme is to share a "better" symbol $y_{r,k}$, which is requested by the receiver Y_d from the relay Y_r, where $d \in \mathbb{Y}$ and $r \in \mathbb{Y}_d$. We define "better" symbol in the sense that for all r the probability that $|h_{r,k}|^2 > |h_{d,k}|^2$ is greater than the opposite case. 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. Consequently, the symbol vector $\mathbf{y}_{\mathrm{SRC},d} = [y_{\mathrm{SRC},d,k}]_{k=1}^{N_{\mathrm{c}}}$ at the receiver Y_d after cooperation is

$$y_{\mathrm{SRS},d,k} = \begin{cases} h_{d,k}^* \cdot y_{d,k} + \sum\limits_{r=1}^{L-1} h_{r,k}^* \cdot y_{r,k} & \text{if } k \in \mathbb{K}_d \\ y_{d,k} & \text{else} \end{cases}, \tag{2}$$

where (*) indicates the complex conjugate. In (2) 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

$$\sigma_{\mathrm{SRS},d,k}^2 = \begin{cases} \sigma_n^2 \cdot \left(|h_{d,k}|^2 + \sum\limits_{r=1}^{L-1} |h_{r,k}|^2 \right) & \text{if } k \in \mathbb{K}_d \\ \sigma_n^2 & \text{else} \end{cases}. \tag{3}$$

It follows from (2) that all receivers can serve as relays for each of the α selected subcarriers. Therefore, full maximum ratio combining (MRC) is accomplished on the subcarriers in $\mathbb{K}_d$. 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 (2) not only the requested symbols but also the channel coefficients are relayed. It is important to note that the cooperation time is controlled and directly proportional to the parameter α.

The total time for the SRS cooperation scheme can be divided in the time required to send all the indexes in $\mathbb{K}_d$ (request) and the time for the symbol and CSI sharing (answer). T_s and M_co denote the time and the modulation order for the symbol transmission in any receiver-receiver node link respectively. The total time of the SRS cooperation overhead is then

$$t_\mathrm{SRS} = \frac{T_\mathrm{s} \cdot (N_\mathrm{c} + \alpha \cdot 2 \cdot (L-1) \cdot (Q + Q_\alpha))}{\log_2(M_\mathrm{co})}\ , \tag{4}$$

where Q bits of resolution are assumed for the channel coefficients, and a $Q_\alpha = \log_2(M_\mathrm{co}) \cdot Q$ bits resolution quantizer is assumed for every symbol where the factor $\log_2(M_\mathrm{co})$ is to compensate any modulation order. Moreover, 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 $(\alpha) \cdot \log_2(N_\mathrm{c}) < 1$ is fulfilled. If it is not the case, the second method consist 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. Therefore, only N_c bits are required for the index request. The second method is considered in (4). Further, for every index requested, $(L-1)$ symbols and channel coefficients are relayed and thus obtaining full MRC in Y_d for every subcarrier in $\mathbb{K}_d$.

IV. Adaptive SRS scheme

The SRS scheme presented in Section III ignores if the message at the destination Y_d is correct, i.e., if $\tilde{\mathbf{b}}_d = \mathbf{b}$. Including this process into the cooperation algorithm reduces the waste of resources which is the main goal of our paper. Thus, a further step to improve the SRS scheme leads us to introduce the adaptive SRS (A-SRS) cooperation scheme.

As stated before, for the A-SRS scheme, we need to employ the features of an error detection technique, e.g., cyclic redundancy check (CRC) code. Henceforth, for the sake of simplicity a perfect error detection technique is assumed. With the received signal stated in (1), a simple error bit denoted by $\epsilon_i \in \{0, 1\}$ is generated in the i-th receiver automatically. This error bits are sent to the destination Y_d. A "1" implies that $\tilde{\mathbf{b}}_i = \mathbf{b}$ and a "0" that the decoding stage was not successful. Hence, it is assumed that the destination Y_d is also aware of $\{\epsilon_r\}$, $r \in \mathbb{Y}_d$. With this information, Y_d can decide the strategy to follow.

The flowchart in Figure 2 summarizes the basic idea of the A-SRS algorithm, which begins as follows. Firstly, the destination node Y_d proofs if its estimated information bits have errors, i.e., if $\tilde{\mathbf{b}}_d = \mathbf{b}$. This result is stored in ϵ_d. If $\epsilon_d = 1$, then the algorithm ends without incurring in any further cooperation steps. In the case that $\epsilon_d = 0$, the destination checks the error bits $\{\epsilon_r\}$ of the remaining receivers. Thus, $\sum_{\forall r \in \mathbb{Y}_d} \epsilon_r > 0$ implies that at least one relay was capable of decoding without errors. In this case, the main goal is that any relay node Y_r with error-free information bits $\tilde{\mathbf{b}}_r$ assist the destination to decode correctly its message. One alternative is to send the correct information bits vector $\tilde{\mathbf{b}}_r$ to Y_d, but this solution is not suitable for real channels between receivers. An appropriated solution is that the r-th relay generates and shares the punctured bits vector $\tilde{\mathbf{c}}_{\mathrm{p},r}$ with Y_d. A relay node Y_r with $\tilde{\mathbf{b}}_r = \mathbf{b}$ can perfectly generate $\tilde{\mathbf{c}}_{\mathrm{p},r} = \mathbf{c}_\mathrm{p}$. This fact is demonstrated in [9], i.e., by having the correct punctured bits, the decoding success is ensured, which in this case will take place in Y_d. Therefore, after the $\tilde{\mathbf{c}}_{\mathrm{p},r}$ is shared, the A-SRS algorithm ends and no extra cooperation is necessary. The destination Y_d complements its code bits $\tilde{\mathbf{c}}_d$ with the received puncture bits $\tilde{\mathbf{c}}_{\mathrm{p},r}$ which will ensure an error free decoded message. Finally, in case $\sum_{\forall r \in \mathbb{Y}_d} \epsilon_r = 0$, namely, no receiver could decode correctly, the SRS scheme described in Section III is performed.

After the SRS scheme is accomplished, the error bit ϵ_i are once again generated and conveyed to the destination node. Y_d proofs if $\epsilon_d = 1$. If it is true, then the algorithm ends the cooperation process. If it is not the case, Y_d searches again for any relay with an error-free decoding, i.e., if $\sum_{\forall r \in \mathbb{Y}_d} \epsilon_r > 0$. In case that at least one relay node could decode correctly, the n_p generated punctured bits $\tilde{\mathbf{c}}_{\mathrm{p},r}$ will be sent to Y_d, which at the end leads also to finish the algorithm. Nevertheless, if neither the destination ($\epsilon_d = 0$) nor the relays ($\sum_{\forall r \in \mathbb{Y}_d} \epsilon_r = 0$) have error free decoded message after the SRS scheme, no further action takes place in terms of cooperation. The dummy variable κ in Figure 2 is introduced for this control.

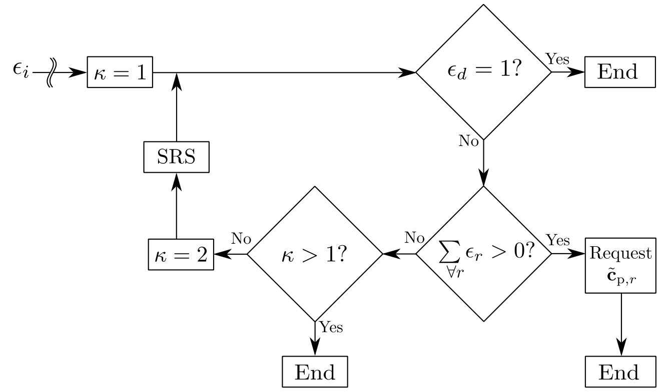

Fig. 2. A flowchart describing the adaptive symbol request sharing (A-SRS) scheme. This adaptive scheme begins after every receiver Y_i has decoded and generated its error bit $\{\epsilon_i\}$. Note that $i \in \mathbb{Y}$ and $r \in \mathbb{Y}_d$, and that κ is a dummy variable for control purpose.

The A-SRS is based on the SRS cooperation scheme, therefore, we expect that the performance of A-SRS will be at least as good as the SRS scheme. Besides the advantages

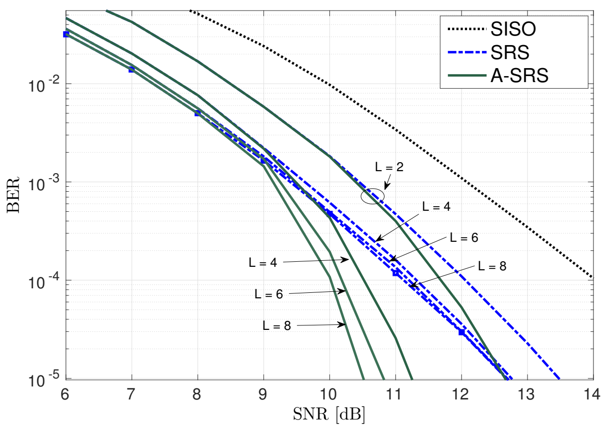

Fig. 3. The resulting BER comparison after cooperation. SRS and A-SRS are considered with $L = \{2, 4, 6, 8\}$ receivers, $\alpha_{\text{p}} = \alpha/N_{\text{c}} = 15$ %, an OFDM symbol with $N_{\text{c}} = 1024$ subcarriers and 16−QAM modulation.

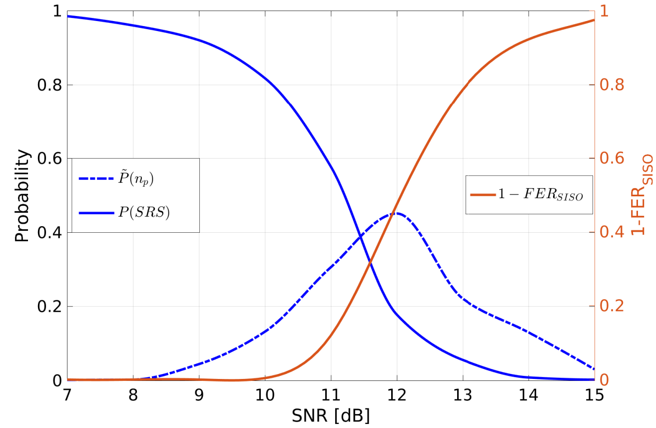

Fig. 4. Left y-axis: probabilities w.r.t. (5) regarding A-SRS. Right y-axis: the $1 - \text{FER}_{\text{SISO}}$ that corresponds to a SISO system. All plots corresponds to a system with $L = 4$.

provided by the SRS scheme, the improvement reached with the A-SRS ensures that the destination can decode error-free the received message if at least one relay decodes correctly. This is inspected before and after SRS is accomplished. Nevertheless, the probability that a relay can decode error free after the execution of the SRS scheme is higher than without it. This is due to the fact that each relay receives automatically the information exchanged. Although a relay may not lack of information in the same subcarriers specified by Y_d, it does receive some extra information. Hence, each relay combines this information by means of (2) and enhance its own capability of decoding correctly the received message after the SRS cooperation scheme.

The exact duration that takes to perform the A-SRS cooperation scheme $t_{\text{A-SRS}}$ depends on the specific channel conditions at the moment that the message is being sent by the source. This may differ from message to message. Fortunately, for a big number of trials this duration converges to a expected value, i.e., $\bar{t}_{\text{A-SRS}} = \text{E}[t_{\text{A-SRS}}]$. This expected time can be summarized in two components. The first one is the time required for the SRS scheme t_{SRS} as indicated in (4). The second one is the time needed to send the n_{p} punctured bits $t_{\text{p}} = T_{\text{s}} \cdot n_{\text{p}} / \log_2(M_{\text{co}})$, which can be sent either before or after performing SRS. T_{s} and M_{co} are the same as indicated in (4). Hence, the expected time is

$$\bar{t}_{\text{A-SRS}} = t_{\text{SRS}} \cdot \text{P}(\text{SRS}) + t_{\text{p}} \cdot \tilde{\text{P}}(n_{\text{p}}) \,. \tag{5}$$

We denote with P(SRS) the probability that $\sum_{\forall i \in \mathbb{Y}} \epsilon_i = 0$, and with $\tilde{\text{P}}(n_{\text{p}})$ the probability that the punctured bits are shared. Note that the punctured bits are sent if $\sum_{\forall r \in \mathbb{Y}_d} \epsilon_r > 0$ and this could be the case with or without executing the SRS scheme.

V. Performance Analysys

In this section, the performance of the A-SRS cooperation scheme is evaluated. The performance of SRS is also analyzed and used as a benchmark.

A. Parameter Settings

The proposed cooperation scheme is evaluated using the Monte-Carlo simulation method. For the source-receivers link, we assume an OFDM system with $N_{\text{c}} = 1024$ subcarriers, bandwidth β, β/N_{c} inter-carrier spacing 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 BJCR convolutional decoder with a generator polynomial $[13,15,11]_8$ is employed. We consider a system with $L = \{2, 4, 6, 8\}$ 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 $\alpha_{\text{p}} = \alpha/N_{\text{c}}$ and set it to 15 %.

B. Throughput

The throughput provides a measurement of the performance of the scheme in terms of not only of the diversity gain but also the time required to convey the extra cooperation overhead. Therefore, it gives a fair comparison between schemes. It is basically the ratio between the of amount messages or packages correctly received and the time required for its communication. We considered a package as an OFDM symbol. Hence, the throughput is defined as

$$\xi = \frac{N_{\text{c}} \cdot \log M \cdot R_{\text{c}}}{t_{\text{SY}} + t_{\text{co}}} \cdot (1 - \text{FER}_d) \,, \tag{6}$$

where t_{SY} is the time incurred in the transmission of a OFDM symbol from S to Y_i, $t_{\text{co}} \in \{t_{\text{SRS}}, \bar{t}_{\text{A-SRS}}\}$ the cooperation time given in (4) and (5) respectively, and FER_d the frame error rate at Y_d. The probabilities given in (5) are linked with experimental probabilities by the Law of Large Numbers. These probabilities and the FER_d are estimated by simulation.

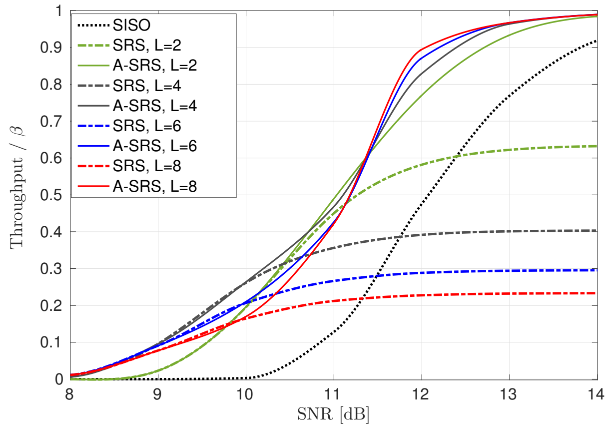

Fig. 5. Normalized throughput comparison between SRS and A-SRS, with $L = \{2, 4, 6, 8\}$ receivers, $\alpha_{\mathrm{p}} = \alpha/N_{\mathrm{c}} = 15$ %, an OFDM symbol with $N_{\mathrm{c}} = 1024$ subcarriers, 16−QAM modulation, and bandwidth β.

C. Simulation Results

At the destination node Y_d, the bit error rate (BER) is measured and depicted in Figure 3. The SISO plot shows a single-input single-output system, and it provides a benchmark for a system with no cooperation. The SRS and A-SRS schemes are compared. It can be noticed that the two schemes have a very similar performance at lower SNR's, nevertheless, A-SRS performs considerably better than SRS for higher SNR's. By just requesting 15% of N_{c} symbols at a BER $= 10^{-5}$ and with $L = 2$, it is shown that A-SRS gives close to 1 dB of gain with respect to the SRS plot and it still performs slightly better than a SRS scheme for $L = 8$. It can be also noticed that, the A-SRS scheme with $L = 4$ provides 1.5 dB of gain with respect to the SRS scheme with $L = 8$ receivers. Moreover, the convergence of the BER plots are more remarkable for SRS than for A-SRS as the number of receivers increases. For $L \geqslant 4$, plots of SRS perform very similar while plots of A-SRS show clearly improvements even for $L > 8$. Furthermore, the improvement of the A-SRS scheme in terms of BER is due to the fact that in the adaptive fashion the advantages of the decoding stages in every receiver are also considered after the SRS is executed. This can be confirmed in Figure 4, where plots of $\mathrm{P(SRS)}$, $\tilde{\mathrm{P}}(n_{\mathrm{p}})$ and $1 - \mathrm{FER}_{\mathrm{SISO}}$ for a system with $L = 4$ are presented. The probability of sharing the punctured bits are boosted by performing SRS. On the other hand, for higher SNR's the probability of any cooperation approaches 0, which is explained by $1 - \mathrm{FER}_{\mathrm{SISO}}$ approaching 1. For very high SNR's the destination Y_d is more likely to decode any message correctly without the need of cooperation. Therefore, A-SRS produces cooperation overhead when needed.

In Figure 5, the throughput given by (6) is illustrated for each cooperation strategy. As expected the A-SRS scheme outperforms SRS and SISO, which demonstrates the advantage of including an error-detecting code together with the SRS in a cooperation scheme. As in the BER plots, at regions with low SNR, A-SRS and SRS perform very similar. However, for higher SNR's the A-SRS scheme approaches the maximum throughput, which is not achieved by SRS. On the other hand, by inspecting the plots in Figure 5 of the A-SRS scheme, two regions can be identified, low SNR (< 11.4 dB) and high SNR (> 11.4 dB). We can notice that for low SNR the A-SRS scheme gives the best performance when $L = 4$ and for high SNR the throughput is directly proportional to L. Although this fact depends on the system configuration, it give us an important insight for choosing adequately L.

VI. Conclusion

In this paper, we presented the adaptive symbol request sharing (A-SRS) scheme for mobile cooperative receivers in OFDM systems. This adaptive fashion is an improvement which takes as a starting point the symbol request sharing (SRS) cooperation scheme. The performance of A-SRS has been measured and compared with SRS in terms of BER and throughput. It is shown that A-SRS outperforms SRS in both cases. For instance, by sharing symbols for just 15% of the subcarriers in an OFDM symbol at the destination node with 2 receivers, the A-SRS scheme reaches a slightly better diversity gain at a BER of 10^{-5} than the SRS scheme with 8 receivers. Furthermore, the throughput of A-SRS for higher SNR's reaches the maximum throughput and it results to be directly proportional to the number of receivers considered in the system. Towards a practical application, A-SRS realizes an appropriate trade-off between spatial diversity gain and extra cooperation overhead, which makes it a viable option for a cooperation scheme.

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