Abstract—This paper investigates the problem of information transmission over the simultaneous relay channel with two users (or two possible channel outcomes) where for one of them the more suitable strategy is Decode-and-Forward (DF) while for the other one is Compress-and-Forward (CF). In this setting, it is assumed that the source wishes to send common and private informations to each of the users (or channel outcomes). This problem is relevant to: (i) the transmission of information over the broadcast relay channel (BRC) with different relaying strategies and (ii) the transmission of information over the conventional relay channel where the source is oblivious to the coding strategy of relay. A novel coding that integrates simultaneously DF and CF schemes is proposed and an inner bound on the capacity region is derived for the case of general memoryless BRCs. As special case, the Gaussian BRC is studied where it is shown that by means of the suggested broadcast coding the common rate can be improved compared to existing strategies. Applications of these results arise in broadcast scenarios with relays or in wireless scenarios where the source does not know whether the relay is collocated with the source or with the destination.

I. INTRODUCTION

Cooperation between nodes can serve for boosting the capacity and improving the reliability of the communication, especially in wireless networks. Mainly for this reason, extensive research has been done during the recent years on the topic. The relay channel consists of a sender-receiver pair whose communication is aided by a relay node which helps the communication between the source-destination pair. Substantial advance on this problem was made in [1], where upper and inner bounds on the capacity of the discrete memoryless relay channel (DMRC) were established and two cooperative strategies, commonly referred to as Decode-and-Forward (DF) and Compress-and-Forward (CF), were introduced. Based on these strategies, further work has been recently done on different aspects of cooperative networks including deterministic channels, and also other examples of cooperative networks like multiple access relay, broadcast relay, multiple relays and fading relay channels, etc. (see [2], [3] and references therein).

The specification of wireless networks undergoes extensive changes due to a variety of factors (e.g. interference, fading and user mobility). As a consequence, even when the channels are quasi-static, it is often difficult for the source to know the noise level of the relay link. Hence, the encoder is unable to decide on the suitable coding strategy that would better exploit the presence of the relay. This scenario is frequently seen in ad-hoc networks where the source is often assumed to be unaware of the presence of relay users. Nevertheless in most of the previous works the channel is assumed to be fixed and known to all the users. Indeed the problem of uninformed source cooperative networks has been studied in [4], [5], where achievable rates and coding strategies were developed for relay networks. It is of practical importance to allow the coding to adapt to the channel conditions. In fact, no matter how a set of possible channel outcomes (e.g. level noises, user positions, etc.) can be defined, such scenarios can be addressed as the simultaneous relay channel [5]. In this case, the encoder knows a set of the possible channels but it is unaware of the specific channel that controls the communication. Besides, an interesting connection between simultaneous and broadcast channels (BCs) was first suggested in [6] and then fully exploited for slowly fading MIMO channels [7]. This idea was used in the context of relay channels in [5], [8]–[10].

The performances of DF and CF strategies is directly related to the quality of the channel (e.g. noise conditions) between the relay and the destination. More precisely, DF scheme performs better than CF when the relay is near to the source, whereas CF scheme is more suitable when the relay is near to the destination. In this paper we investigate the simultaneous relay channel (SRC) with two users (or possible channel outcomes). Each of these channels are assumed to be such that in order to take full advantage of the relay, one of them would require to relay the information via DF scheme and the other via CF scheme. This problem can be seen as related to sending common and private informations over the broadcast relay channel (BRC) where one destination is aided by a relay, which uses DF scheme, and the other destination is aided by another relay which uses CF scheme. Based on this approach we derive an inner bound on the capacity region of this scenario. The central idea here is to broadcast information to both users and enabling the source to take simultaneously advantage of DF and CF schemes. It is shown that block Markov coding, commonly used with DF scheme, can be also adapted to CF scheme based on backward decoding idea. Hence when the source sends common information it becomes oblivious to the relaying strategy (similarly to the setting addressed in [4], [11]).

The organization of this paper is as follows. Section II states definitions along with main results, while the main outlines of the proofs are given in Section III. Section IV provides Gaussian examples and numerical results.
II. PROBLEM DEFINITIONS AND MAIN RESULTS

A. Problem Definition

The simultaneous relay channel with discrete source and relay inputs $x, x' \in \mathcal{X}$, $y, y' \in \mathcal{Y}$, discrete channel and relay outputs $y_T, y_T' \in \mathcal{Y}_T$, is characterized by two conditional probability distributions (PDs) $\{P_T : \mathcal{X} \times \mathcal{Y} \rightarrow \mathcal{Y}_T\}_{T=1,2}$, where $T$ is the channel index. It is assumed here that the transmitter (the source) is unaware of the realization of $T$ that governs the communication, but $T$ should not change during the communication. However, $T$ is assumed to be known at the destination and the relay ends.

Definition 1 (Code): A code for the SRC consists of: (i) an encoder mapping $\psi : (W_1 \times W_2, W) \rightarrow \mathcal{X}^n$, (ii) two decoder mappings $\{\psi_T : \mathcal{Y}_T \rightarrow \mathcal{W}\}$, and (iii) a set of relay functions $\{f_{T,i} : \mathcal{X}^{n-1} \rightarrow \mathcal{X}_i^n\}_{i=1}^n$, for some finite sets of integers $W_T = \{1, \ldots, W\}$. The rates of such code are $n^{-1} \log W_T$ and its maximum error probability

$$
\epsilon_{\max}(n) \doteq \max_{(w_0, w_T) \in W_0 \times W_T} \Pr\{\psi(Y_T) \neq (w_0, w_T)\}.
$$

Definition 2 (Achievable rates and capacity): For every $0 < \epsilon, \gamma < 1$, a triple of non-negative numbers $(R_0, R_1, R_2)$ is achievable for the SRC if for every sufficiently large $n$ there exist $n$-length block code whose error probability satisfies $\max_{(w_0, w_T) \in W_0 \times W_T} \epsilon_{\max}(n) \leq \epsilon$ and the rates $n^{-1} \log W_T \geq R_T - \gamma$ for each $T = \{0, 1, 2\}$. The set of all achievable rates is called the capacity region for the SRC.

We emphasize that no prior distribution on the relay inputs $x, x'$ can be turned into that of the BRC [5]. This consists of a finite set of integers $\{1, 2\} \times \mathcal{Y}$, yielding the BRC setting. A block Markov coding is essentially oblivious to the relaying strategy and proves the same performance in both cases. An outline of the proof is given in Section III.

Corollary 1 (common-information): An inner bound on the capacity of the common-message BRC is given by

$$
R_0 \leq \max_{P_{X_1X_2} \in \mathcal{P}} \min \left\{ I(X; Z_1|X_1), I(X, X_1; Y_1), I(X; Z_2Y_2|X_2) \right\}.
$$

Corollary 2 (private information): An inner bound on the capacity region of the BRC with heterogeneous cooperative strategies is given by the set of rates $(R_1, R_2)$ satisfying

$$
R_1 \leq \min \left\{ I(U_1; Z_1|X_1), I(U_1X_1; Y_1) \right\}
$$

$$
R_2 \leq I(U_2; Z_2Y_2|X_2) - I(U_2; X_1)
$$

$$
R_1 + R_2 \leq \min \left\{ I(U_1; Z_1|X_1), I(U_1X_1; Y_1) \right\}
$$

$$
+ I(U_2; Z_2Y_2|X_2) - I(U_1X_1; U_2),
$$

for all joint PDs $P_{U_1U_2X_1X_2Y_1Y_2Z_1Z_2} \in \mathcal{P}$.

Remark 1: The region in theorem 2[1] includes Marton’s region [13] with $(X_1, X_2, V_0) = \emptyset$, $Z_1 = Y_1$, and $Z_2 = Y_2$.

Observe that the rate corresponding to the DF scheme that appears in theorem 2[1] coincides with the conventional DF rate. Here a common code for DF and CF users is employed hence it shows that a block Markov coding is essentially oblivious to the relaying strategy and proves the same performance in both cases. An outline of the proof is given in Section III.

Corollary 2 follows by choosing $U_1 = U_2 = \emptyset$, $V_0 = X_1$ and $U_0 = X$. Whereas corollary 1 follows by setting $U_0 = V_0 = \emptyset$. The next theorem presents an upper bound on capacity of the common-message BRC.
Theorem 2.2 (upper bound): An upper bound on the capacity region of the common-message BRC is given by

\[ R_0 \leq \max \min \{ I(X; Z_1 Y_1 | X_1), I(X; X_1; Y_1), I(X; Z_2 Y_2 | X_2), I(X; X_2; Y_2) \}. \]

III. SKETCH OF THE PROOFS

A. Proof of Theorem 2.2

Reorganize first private messages, Fig. 2, \( w_i, i \in \{1, 2\} \) into \((s'_i, s_i, w_0)\) with non-negative rates \((S'_i, S_i)\) where \( R_i = S'_i + S_i \). Merge \((s'_1, s'_2, w_0)\) to one message \( s_0 \) with rate \( S_0 = R_0 + S'_1 + S'_2 \). Code Generation:

(i) Randomly and independently generate \( 2^nS_0 \) sequences \( \bar{v}_0 \) draw i.i.d. from \( P_{V_0}(v_0) = \prod_{j=1}^n P_{V_0}(v_{0j}) \). Index them as \( \bar{v}_0(r_0) \) with \( r_0 \in [1, 2^nS_0] \).

(ii) For each \( \bar{v}_0(r_0) \), randomly and independently generate \( 2^nS_0 \) sequences \( \bar{v}_0 \) draw i.i.d. from \( P_{U_0|V_0}(u_0|v_0) = \prod_{j=1}^n P_{U_0|V_0}(u_{0j}|v_{0j}) \). Index them as \( \bar{v}_0(r_0, s_0) \) with \( s_0 \in [1, 2^nS_0] \).

(iii) For each \( \bar{v}_0(r_0) \), randomly and independently generate \( 2^nT_1 \) sequences \( \bar{x}_1 \) draw i.i.d. from \( P_{X_1}(x_1) = \prod_{j=1}^n P_{X_1}(x_{1j}) \). Index them as \( \bar{x}_1(r_0, r_1) \) with \( r_1 \in [1, 2^nT_1] \).

(iv) Randomly and independently generate \( 2^nR_2 \) sequences \( \bar{x}_2 \) draw i.i.d. from \( P_{X_2}(x_2) = \prod_{j=1}^n P_{X_2}(x_{2j}) \). Index them as \( \bar{x}_2(r_2, s) \) with \( s \in [1, 2^nS_0] \).

(vi) Partition the set \( \{1, \ldots, 2^nR_2\} \) into \( 2^nR_1 \) cells and label them as \( S_2 \). In each cell there are \( 2^n(R_2 - R_1) \) elements.

(vii) For each pair \((\bar{u}_1(r_0, s_0), \bar{x}_1(r_0, r_1))\), randomly and independently generate \( 2^nT_1 \) sequences \( \bar{u}_1 \) draw i.i.d. from \( P_{U_1|U_0X_1}(u_1|u_0, x_1) = \prod_{j=1}^n P_{U_1|U_0X_1}(u_{1j}|u_{0j}, x_{1j}) \). Index them as \( \bar{u}_1(r_0, s_0, r_1, t_1) \) where \( t_1 \in [1, 2^nT_1] \).

(viii) For each \( \bar{u}_0(r_0, s_0) \), randomly and independently generate \( 2^nT_2 \) sequences \( \bar{u}_0 \) draw i.i.d. from \( P_{U_0|V_0}(u_0|v_0) = \prod_{j=1}^n P_{U_0|V_0}(u_{0j}|v_{0j}) \). Index them as \( \bar{u}_0(r_0, s_0, t_2) \) where \( t_2 \in [1, 2^nT_2] \).

ix) For \( b \in \{1, 2\} \), partition the set \( \{1, \ldots, 2^nT_1\} \) into \( 2^nS_b \) subsets and label them as \( S_{sb} \). In each subset there are \( 2^n(T_1 - S_b) \) elements.

(x) Then for each subset \( S_{sb} \), create the set \( \mathcal{L} \) consisting of those index \( t_2 \) such that \( t_2 \in S_{sb} \), and \( \bar{u}_0(r_0, s_0, t_2) \) is jointly typical with \( \bar{u}_1(r_0, r_1), \bar{u}_2(r_0, s_0, t_2) \).

(xi) Then for each subset \( S_{sb} \), create the set \( \mathcal{L} \) consisting of those index \( t_2 \) such that \( t_2 \in S_{sb} \), and \( \bar{u}_0(r_0, s_0, t_2) \) are jointly typical with \( \bar{u}_1(r_0, r_1), \bar{u}_2(r_0, s_0, t_2) \).
The pair \((s_{0i}, t_{2i})\) are decodes as the message such that \((w_{0i}, t_{2i})\) at destinations, the original messages \((w_{0i}, w_{1i}, w_{2i})\) can be extracted. One can see that the rate region of theorem 2.1 follows form equations (1)-(10), the equalities between the original rates and reorganized rates, the fact that all the rates are positive and by finally using Fourier-Motzkin elimination. Similar to [1], the necessary condition \((X_2; Y_2; Z_2) \geq I(Z_2; Y_2 | X_2, Y_2)\) follows from (7) and (8).

B. Proof of Theorem 2.2

It is easy to show that the upper bounds presented in theorem 2.2 are a combination of two cut-set bounds for the relay channel.

IV. Application example: The Gaussian BRC

In this section the Gaussian BRC is analyzed, where the relay is collocated with the source in the first channel and with the destination in the second one, as is shown in Fig. 1(b). No interference is allowed from the relay to the destination in the second one, as is shown in Fig. 1(b).

After decoding \((s_{0i}, s_{1i}, s_{2i})\) at destinations, the original messages \((w_{0i}, w_{1i}, w_{2i})\) can be extracted. One can see that the rate region of theorem 2.1 follows form equations (1)-(10), the equalities between the original rates and reorganized rates, the fact that all the rates are positive and by finally using Fourier-Motzkin elimination. Similar to [1], the necessary condition \((X_2; Y_2; Z_2) \geq I(Z_2; Y_2 | X_2, Y_2)\) follows from (7) and (8).

A. Achievable rates for private information

Based on Corollary 2 we derive achievable rates for the case of private information. As for the classical broadcast channel, by using superposition coding, we decompose X as a sum of two independent RVs such that \(\mathbb{E}\{X^2\} = \alpha P\) and \(\mathbb{E}\{X^2\} = \pi P\), where \(\pi = 1 - \alpha\). The codewords \((X_A, X_B)\) contain the information intended to receivers \(Y_1\) and \(Y_2\). We choose \(\hat{Z}_2 = Z_2 + \tilde{\alpha}_2\). First, we identify two different cases for which dirty-paper coding (DPC) schemes are derived.

Case 1: A DPC scheme is applied to \(X_B\) for canceling the interference \(X_A\), while for the relay branch of the channel is similar to [1]. Hence, the auxiliary RVs \((U_1, U_2)\) are set to

\[
U_1 = X_A + \lambda X_B, \quad U_2 = X_B + \gamma X_A.
\]

where \(\beta\) is the correlation coefficient between the relay and source, and \(X_A\) and \(X_1\) are independent. Notice that in this case, instead of only \(Y_2\), we have also \(\hat{Z}_2\) present in the rate. Thus DPC should be also able to cancel the interference in both, received and compressed signals which have different noise levels. Calculation should be done again with \((Y_2, \hat{Z}_2)\) which are the main message \(X_B\) and the interference \(X_A\).

We can show that the optimum \(\gamma\) has a similar form to the classical DPC with the noise term replaced by an equivalent noise which is like the harmonic mean of the noise in \((Y_2, \hat{Z}_2)\). The optimum \(\gamma^*\) is given by \(\frac{\pi P}{\sqrt{2}\gamma_N + \gamma_2}\) where \(N_1 = \left((d_{\gamma_2}N_2 + \hat{N}_2)\right)^{-1} + (d_{\gamma_2}N_2)^{-1}\). As we can see the equivalent noise is twice of the harmonic mean of the other noise terms.

From corollary 2 we can see that the current definitions yield the rates: \(R_1 = \min \{I(U_1; Z_1 | X_1), I(U_1; Y_1; X_1)\}\) and \(R_2 = I(U_2; Y_2; \hat{Z}_2 | X_2) - I(U_1; X_1; U_2)\). The rate for optimal \(\gamma\) is as follows:

\[
R_1^* = \max_{0 \leq \beta \leq 1} \min \left\{ C \left( \frac{\alpha \beta P}{d_{\gamma_2}N_2} + \frac{\alpha \beta P}{d_{\gamma_2}N_2} + \frac{2 \sqrt{\alpha \beta P}}{d_{\gamma_2}N_2} \right) \right\},
\]

\[
R_2^* = \frac{C \left( \frac{\pi P}{d_{\gamma_2}N_2} + \frac{\pi P}{d_{\gamma_2}N_2} \right)}{\frac{1}{d_{\gamma_2}N_2}},
\]

where \(C(x) = \frac{1}{2} \log(1 + x)\). Note that since \((X_A, X_B)\) are chosen independent, destination 1 sees \(X_B\) as an additional channel noise. The compression noise is chosen as follows

\[
\hat{N}_2 = N_2 + \frac{P_2}{d_{\gamma_2}N_2}.
\]

Case 2: We use a DPC scheme for \(Y_2\) to cancel the interference \(X_1\), and next we use a DPC scheme for \(Y_1\) to cancel \(X_B\). For this case, the auxiliary RVs \((U_1, U_2)\) are

\[
\begin{align*}
U_1 &= X_A + \lambda X_B, \quad X_A = \hat{X}_A + \sqrt{\frac{\alpha \beta P}{\pi P}} X_1, \\
U_2 &= X_B + \gamma X_A.
\end{align*}
\]

From corollary 2 the rates with the current definitions are \(R_1 = \min \{I(U_1; Z_1 | X_1), I(U_1; Y_1; X_1)\} - I(U_1; U_2 | X_1)\) and \(R_2 = I(U_2; Y_2; \hat{Z}_2 | X_2) - I(X_1; U_2)\). The argument for the destination 2 is similar but it differs in its DPC, since only \(X_1\) can be canceled and \(X_A\) appears as additional noise. The optimum \(\gamma^*\) similar to [5] will be \(\gamma^* = \sqrt{\frac{\beta \alpha P}{\pi P}}\) where \(N_{12} = \left((d_{\beta}^\delta \hat{N}_2 + \hat{N}_2) + \beta \alpha P\right)^{-1} + (d_{\beta}^\delta \hat{N}_2 + \beta \alpha P)^{-1}\),

\[
R_2^* = C \left( \frac{\alpha \beta P}{d_{\beta}^\delta N_2} + \frac{\alpha \beta P}{d_{\beta}^\delta N_2} \right).
\]

For destination 1, the achievable rate is the maximum of two mutual informations, where the first term is given by \(R_{11} = I(U_1; Z_1 | X_1) - I(U_1; U_2 | X_1)\) that yields

\[
R_{11}^{(\beta, \lambda)} = \frac{1}{2} \log \left( \frac{\alpha \beta P(\alpha \beta P + \pi P + \delta_{\beta}^\delta S_{\beta})}{d_{\gamma_2}N_1(\alpha \beta P + \lambda^2 \pi P + (1-\lambda)^2 P) \alpha \beta P} \right).
\]
After adding the term rate follows as

Based on expressions (17) and (16), the maximum achievable two terms where the first mutual information can be decomposed into evaluate corollary 1. The goal is to send common-information 1 result in the classical rates [2]:

It should be noted that the constraints for 

Whereas the CF rate given by

represent the random state and the noise, respectively.

And the upper bound from theorem 2.2 is given as

Remark 2: Observe that the rate 21 is exactly the same as classical Gaussian CF [2]. This means that DF regular encoding can also be decoded in CF channel, as well for the case with collocated relay and receiver. The constraint for the compression noise remains unchanged. Notice that this observation parallels that made in recent results reported in [4] for a single relay channel, where the source is obviously to the presence of the relay. In our setting, the source is obviously to the relaying scheme of the relay.

B. Lower and upper bounds on the common-rate

Based on Corollary [1] and Theorem [2.2] we derive lower and upper bounds on the common-rate. The definition of the channels remain the same. We define 

The goal is to send common-information at rate  

It should be noted that the constraints for \( \hat{N}_2 \) is still the same as [13].

C. Numerical Results and Discussion

In the previous sections we showed that by using the proposed coding it is possible to send common information at the minimum rate between CF and DF schemes  

We now assume a composite model where the relay is collocated with the source with probability \( p \) (refer to it as the first channel) and with the destination with probability \( 1-p \) (refer to it as the second channel). Therefore DF scheme is the suitable strategy for the first channel while CF scheme performs better on the second one. Then for any triple of achievable rates \( (R_0, R_1, R_2) \) we define the expected rate as

\[
R_{av} = R_0 + pR_1 + (1-p)R_2.
\]
The expected rates achieved with the proposed coding strategy and via conventional strategies are compared. Alternative coding schemes for this scenario are possible. The encoder can simply invest on one coding scheme DF or CF, which is useful when the probability of one channel is high so the source invests only on it. In fact, there are different ways to proceed: (i) Send information via DF scheme at the best possible rate between both channels. Then the worst channel cannot decode and thus the expected rate is \( R_{DF}^{max} \) where \( R_{DF}^{max} \) is the DF rate achieved on the best channel and \( P_{DF}^{max} \) is its probability; (ii) Send information via the DF scheme at the rate of the worst (second) channel and hence both users can decode the information at rate \( R_{DF}^{min} \). Finally the next expected rate is achievable by investing on only one coding scheme

\[
R_{av}^{DF} = \max \{ P_{DF}^{max} R_{DF}^{max}, P_{DF}^{min} R_{DF}^{min} \};
\]

(iii) By investing on CF scheme with the same arguments as before the next expected rate is also achievable

\[
R_{av}^{CF} = \max \{ P_{CF}^{max} R_{CF}^{max}, P_{CF}^{min} R_{CF}^{min} \},
\]

with definitions of \( (P_{CF}^{max}, R_{CF}^{max}, P_{CF}^{min}, R_{CF}^{min}) \) similar to before.

Fig. 3 shows numerical evaluation of the average rate. All channel noises are set to the unit variance and \( P = P_1 = P_2 = 10 \). The distance between \( X \) and \( (Y_1, Y_2) \) is \((3, 1)\), while \( d_{z1} = 1, d_{z2} = 2, d_{y1} = 0.9, d_{y2} = 0.1 \). As one can see in Fig. 3, the common rate strategy provides a fixed rate all time which is always better than the worst case. However in one corner the full investments on one rate performs better since the high probability of one channel reduces the effect of the other one. Based on the proposed coding scheme, i.e. using the private coding and common coding at the same time, one can cover the corner points and always doing better than both full investments strategies. It is worth to note that in this corner area, only private information of one channel is needed.

Fig. 4 shows numerical evaluation of \( R_0 \) for the common rate case without any probabilistic model. All channel noises are set to the unit variance and \( P = P_1 = P_2 = 10 \). The distances are set as \( d_{y1} = d_{y2} = 1 \) is 1, while \( d_{z1} = d_{z1} = 1 - d_{z1}, d_{y2} = 0.7, d_{y2} = 0.3 \). The position of the relay 2 is assumed to be fixed but the relay 1 moves with \( d_1 \in [−1, 1] \). This setting serves to compare the performances of our coding schemes regarding the position of the relay. It can be seen that one can achieve the minimum between the two possible CF and DF rates. These rates are also compared with a naive time-sharing strategy which consists in using DF scheme \( \tau \% \) of the time and CF scheme \((1 − \tau) \% \) of the time. This assumes that the sender uses time-sharing without knowing which channel is present which yields the achievable rate

\[
R_{TS} = \max_{0 \leq \tau \leq 1} \min \{ \tau R_{DF}, (1 − \tau) R_{CF} \}.
\]

Notice that with the proposed coding scheme significant gains can be achieved when the relay is close to the source (i.e. DF scheme is more suitable), comparing to the worst case.

\[\footnote{One should not confuse time-sharing in compound settings with conventional time-sharing which yields convex combination of rates.}\]

V. SUMMARY AND DISCUSSIONS

The simultaneous relay channel with two possible channel outcomes was investigated. The focus was on scenarios where each of the channel outcomes requires a different cooperative strategy. This problem is identified as equivalent to the broadcast relay channel (BRC) where an encoder broadcasts information to two destinations (or channel outcomes) aided by the help of two relays. The coding scheme introduced here enables the source to be oblivious to the relaying strategy. Furthermore it is shown that block Markov coding can be used to simultaneous relaying with DF and CF schemes. Achievable rates were derived and an upper bound on the common rate (or compound case) was also obtained. An application example to the composite Gaussian BRC where the source is unaware of the position of relay, i.e., if relay is collocated to the source or to the destination, was considered. It was shown that significant improvements can be made by using the proposed coding approach comparing to conventional coding strategies.

As future work, it would be of interest to extend the results in the present work to the setting investigated in [11] where the source would be oblivious not only to the relaying strategy but also to the presence of the relay.

ACKNOWLEDGMENT

This research is supported by the Institut Carnot C3S.

REFERENCES

[1] T. Cover and A. El Gamal, “Capacity theorems for the relay channel,” Information Theory, IEEE Trans. on, vol. IT-25, pp. 572–584, 1979.
[2] G. Kramer, M. Gastpar, and P. Gupta, “Cooperative strategies and capacity theorems for relay networks,” Information Theory, IEEE Transactions on, vol. 51, no. 9, pp. 3037–3063, Sept. 2005.
[3] Y. Liang and V. V. Veeravalli, “Cooperative relay broadcast channels,” Information Theory, IEEE Transactions on, vol. 53, no. 3, pp. 900–928, March 2007.
[4] M. Katz and S. Shamai, “Transmitting to colocated users in wireless ad hoc and sensor networks,” Information Theory, IEEE Transactions on, vol. 51, no. 10, pp. 3540–3563, Oct. 2005.
[5] A. Behboodi and P. Piantanida, “On the simultaneous relay channel with two possible channel outcomes,” in International Symposium on Information Theory, 2009, pp. 1179–1183.
[6] T. Cover, “Broadcast channels,” IEEE Trans. Information Theory, vol. IT-18, pp. 2–14, 1972.
[7] S. Shamai and A. Steiner, “A broadcast approach for a single-user slowly fading MIMO channel,” Information Theory, IEEE Transactions on, vol. 49, no. 10, pp. 2617–2635, Oct. 2003.
[8] I. Maric, A. Goldsmith, and M. Medard, “Information-theoretic relaying for multicast in wireless networks,” in Communications Conference, 2007. MILCOM 2007. IEEE, Oct. 2007, pp. 1–7.
[9] M. Yuksel and E. Erkip, “Broadcast strategies for the fading relay channel,” Military Communications Conference, 2004. MILCOM 2004. IEEE, vol. 2, pp. 1060–1065 Vol. 2, Oct.-3 Nov. 2004.
[10] A. Behboodi and P. Piantanida, “Capacity of a class of broadcast relay channels,” in IEEE International Symposium on Information Theory (ISIT 2010), 13-18 June 2010, pp. 590–594.
[11] M. Katz and S. Shamai, “Oblivious cooperation in colocated wireless networks,” Information Theory, 2006 IEEE Int. Symp. on, pp. 2062–2066, July 2006.
[12] Y. Liang and G. Kramer, “Rate regions for relay broadcast channels,” Information Theory, IEEE Transactions on, vol. 53, no. 10, pp. 3517–3535, Oct. 2007.
[13] K. Marton, “A coding theorem for the discrete memoryless broadcast channel,” Information Theory, IEEE Transactions on, vol. 25, no. 3, pp. 306–311, May 1979.
