Distributed Joint Source-Channel Coding for Relay Systems Exploiting Spatial and Temporal Correlations

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***Abstract*—In this paper, we propose a distributed joint source-channel coding (DJSCC) strategy to exploit spatial and temporal correlations simultaneously for transmitting binary Markov sources in a one-way relay system. The relay only extract and forward the source message to the destination, which implies imperfect decoding at the relay. The probability of errors occurring in the source-relay link can be regarded as spatial correlation between source and relay nodes. This spatial correlation can be estimated at the destination node and utilized in the iterative processing. In addition, the knowledge about the temporal correlation of the Markov source is also utilized at the destination. A modified version of the BCJR algorithm is derived to exploit the temporal correlation. Furthermore, extrinsic information transfer (EXIT) chart analysis is performed to investigate convergence property of the proposed technique with the aim of the suitable code design. Simulation results for bit error rate (BER) performance and EXIT chart analysis show that, by exploiting the spatial and temporal correlations simultaneously, our proposed technique achieves significant performance gain, compared with the case where the correlation knowledge is not fully used.**

I. Introduction

Cooperative communication techniques have drawn considerable attention recently, due to its excellent transmit diversity for fading mitigation [1]. One simple form of cooperative wireless communication is a single relay systems, which consists of one source, one relay and one destination. The role of the relay is to provide alternative communication routes for transmission, hence improving the probability of successful decoding of source information at the destination. In this relay system, the information sent from the source and relay are spatially correlated. Furthermore, the information collected at the source node are temporally correlated, according to the dynamics that governs the temporal behavior of the sensing object. These spatial and temporal correlations of the transmitted data can be regarded as redundant information which can be used for source compression and error correction in distributed joint source-channel coding (DJSCC).

In the presence of source-relay correlation due to the source-relay (referred to as intra-link) errors, there are many excellent coding schemes which can achieve efficient cooperative communications, such as [2], [3], where decode-and-forward (DF) relay strategy is adopted and the code is assumed to be strong enough to perfectly correct the intra-link errors. In practice, when the signal-to-noise ratio (SNR) of the intra-link falls under certain threshold, successful decoding at relay may become impossible. Hence, to completely correct the errors at the relay, strong codes such as turbo codes or low density parity check (LDPC) codes with iterative decoding is required, which will impose heavy computational burden at the relay. As a result, several coding strategies have been presented in [4]–[6], assuming that the relay can not always decode correctly the information from the source.

Joint source-channel coding (JSCC) has been widely used to exploit the temporal correlation of source, i.e., the memory structure inherent within the sequence output from the source. In the majority of the approaches to JSCC design, variable-length code (VLC) is employed as source encoder and the implicit residual redundancy after source encoding is additionally used for error correction in the decoding process, some related work can be found in [7]–[9]. Also, there are some literatures which focus on exploiting the memory structure of the source directly, e.g., some approaches of combining Hidden Markov Model (HMM) or Markov Chain (MC) with the turbo code design framework are presented in [10], [11].

In the schemes mentioned above, the exploitation of spatial and temporal correlations have been addressed separately. Not much attention has been paid to relay systems exploiting the spatial and temporal correlations simultaneously. A similar work can be found in [12], where the temporal correlations is represented by a very simple model, bit-flipping between current information sequence and its previous counterpart, which is usually unpractical. Extending the temporal correlations to more general case of source model, the problem of code design for relay systems exploiting the spatial and temporal correlations is still open.

In this paper, we propose a new DJSCC scheme for transmitting binary Markov source in single relay systems, based on [6], [11]. The proposed technique makes efficient utilization of the spatial and temporal correlations simultaneously to achieve

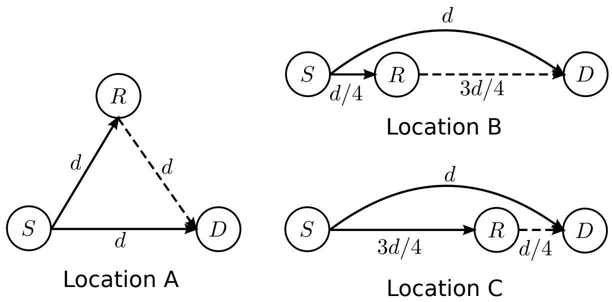


Fig. 1. A single relay system with different relay location scenarios. S, R and D denotes source node, relay node and destination node, respectively.

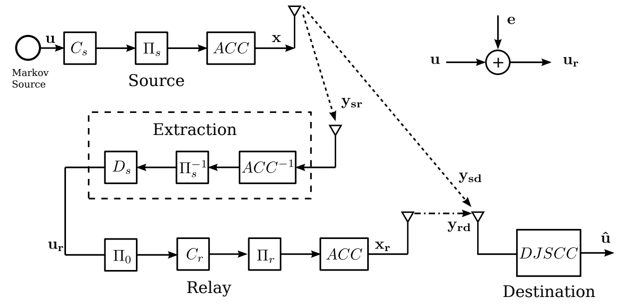


Fig. 2. Proposed relay strategy and its equivalent bit-flipping model

additional coding gain. The rest of this paper is organized as follow. Section II introduces the relay system model and defines the spatial and temporal correlations. The proposed decoding algorithm is described in Section III. In Section IV, EXIT chart analysis of the convergence property evaluation of the proposed decoder is performed in terms of the extrinsic information exchange. Section V shows the BER performance of the system based on EXIT chart analysis. Finally, conclusions are drawn in Section VI with some remarks.

II. System Model

A. Single Relay System

In this paper, a single-source single-relay one-way system is considered where all links are assumed to suffer from Additive White Gaussian Noise (AWGN). The relay system operates in a half-duplex mode. During the first time interval, the source node broadcasts the signal to both the relay and destination nodes. After receiving signals from the source, the relay extracts the data and then re-encodes and transmits them to the destination node in the second time interval.

The relay can be located closer to the source or to the destination, or the three nodes keep the same distance with each other. All of these three different relay location scenarios are considered in this paper, as shown in Fig. 1. The geometric-gain [3] G_{xy} of the link between the node x and y, with regard to the source-destination link, can be defined as

$$G_{xy} = (\frac{d_{sd}}{d_{xy}})^l, \tag{1}$$

where d_{xy} denotes the distance of the link between the node x and y. The pass loss exponent l is empirically set to 3.52 [3]. Note that the geometric-gain of the source-destination link G_{sd} is fixed to 1.

The received signals at the relay and at the destination nodes can be expressed as

$$\mathbf{y}_{sr} = \sqrt{G_{sr}} \cdot \mathbf{x} + \mathbf{n}_r, \tag{2}$$

$$\mathbf{y}_{sd} = \sqrt{G_{sd}} \cdot \mathbf{x} + \mathbf{n}_d, \tag{3}$$

$$\mathbf{y}_{rd} = \sqrt{G_{rd}} \cdot \mathbf{x}_r + \mathbf{n}_d, \tag{4}$$

where $\mathbf{x}$ and $\mathbf{x}_r$ represent the symbol vectors transmitted from the source and the relay, respectively. Notations $\mathbf{n}_r$ and $\mathbf{n}_d$ represent the zero-mean AWGN noise vectors at the relay and the destination with variances σ_r^2 and σ_d^2, respectively. The SNR of source-relay and relay-destination links for the three different relay location scenarios, as shown in Fig. 1, can be decided as: for location A, $SNR_{sr} = SNR_{rd} = SNR_{sd}$; for location B, $SNR_{sr} = SNR_{sd} + 21.19\ dB$ and $SNR_{rd} = SNR_{sd} + 4.4\ dB$; for location C, $SNR_{sr} = SNR_{sd} + 4.4\ dB$ and $SNR_{rd} = SNR_{sd} + 21.19\ dB$.

B. Spatial Correlation

The diagram of the proposed relay strategy is illustrated in Fig. 2. At the source node, the original information bits vector $\mathbf{u}$ is first encoded by a recursive systematic convolutional (RSC) code, interleaved by Π_s, encoded by an doped accumulator (ACC) with a doping rate K_s and then modulated using binary-phase shift keying (BPSK) to get the coded sequence $\mathbf{x}$. After obtaining the received signal $\mathbf{y_{sr}}$ from the source, the relay performs the decoding process only once to extract $\mathbf{u_r}$, which is an estimate of $\mathbf{u}$. $\mathbf{u_r}$ is first interleaved by Π_0 and then encoded following the same encoding process but with a doping rate K_r to generate the coded sequence $\mathbf{x_r}$.

Errors may occur between $\mathbf{u}$ and $\mathbf{u_r}$, as shown in Fig. 3. Apparently, better BER performances can be achieved with more iterations. However, this advantage becomes negligible in low SNR_{sr} scenarios. In this case, the information bits are simply extracted instead of performing iterative channel decoding. Consequently, the relay complexity can be further reduced without degrading the system performances by the proposed algorithm, detailed in Section III.

In this paper, the spatial correlation represents the correlation between $\mathbf{u}$ and $\mathbf{u_r}$, which can be regarded as a bit-flipping model, as shown in Fig. 2. $\mathbf{u_r}$ can be defined as $\mathbf{u_r} = \mathbf{u} \oplus \mathbf{e}$, where $\mathbf{e}$ is an independent random variable and $\oplus$ indicates modulus-2 addition. The correlation property between $\mathbf{u}$ and $\mathbf{u_r}$ is characterized by p_e, where $p_e = \Pr(\mathbf{e} = 1) = \Pr(\mathbf{u} \neq \mathbf{u_r})$.

C. Temporal Correlation

The temporal correlation represents the memory structure of Markov source. In this paper, a stationary state emitting binary Markov source $\mathbf{u} = u_1 u_2 \cdots u_t \cdots$ is assumed, of which the transition matrix is:

$$A = [a_{i,j}] = \begin{bmatrix} a_{0,0} & a_{0,1} \\ a_{1,0} & a_{1,1} \end{bmatrix} = \begin{bmatrix} p_1 & 1-p_1 \\ 1-p_2 & p_2 \end{bmatrix}, \tag{5}$$

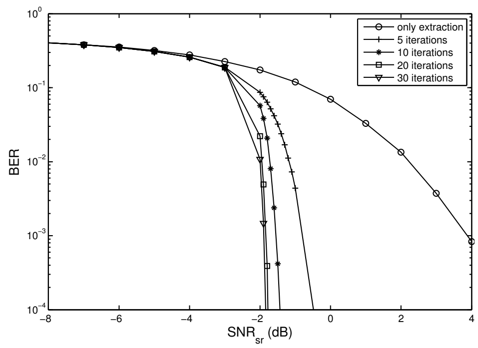


Fig. 3. BER of the intra-link over AWGN channel versus SNR_{sr}. The doping rate at the source node is $K_s = 1$.

where $a_{i,j}$ is the transition probability defined by

$$a_{i,j} = \Pr\{u_t = j | u_{t-1} = i\}, \quad i,j = 0,1. \tag{6}$$

The entropy rate [13] of stationary Markov source is given by

$$H(S) = -\sum_{i,j \in \{0,1\}} \mu_i a_{i,j} \log a_{i,j}, \tag{7}$$

where $\{\mu_i\}$ is the stationary state probability distribution.

III. PROPOSED DECODING SCHEME

The block diagram of the proposed DJSCC decoder for relay system exploiting the spatial and temporal correlations is illustrated in Fig. 4. The maximum a posteriori (MAP) algorithm proposed by Bahl, Cocke, Jelinek and Raviv (BCJR) is used for decoding convolutional codes and the ACC. In order to take into account the temporal correlation of the source, a modified version of the BCJR algorithm is derived to perform joint source and channel decoding at D_s. However, D_r can not exploit the source memory due to the presence of Π_0, as shown in Fig. 2.

At the destination node, the received signals from the source and the relay are first converted to *log-likelihood ratios* (*LLR*s) $L(\mathbf{y}_{sd})$ and $L(\mathbf{y}_{rd})$, and then decoded by the two independent horizontal iteration (*HI*) loops, respectively. Then the extrinsic *LLR*s generated from the two D_s and D_r in *HI*s are further exchanged via the vertical iteration (*VI*) loops through an *LLR* updating function f_c, of which role is detailed in the next chapter. This process is performed iteratively, until the convergence point is reached. Finally, hard decision is made based on the a posteriori *LLR*s obtained from D_s.

A. LLR Updating Function

First, the correlation property (error probability occurring in the intra-link) p_e can be estimated at the destination using the a posteriori *LLR*s of the uncoded bits, L^u_{p,D_s} and L^u_{p,D_r}, output from the decoders D_s and D_r, as

$$\hat{p_e} = \frac{1}{N}\sum_{n=1}^{N} \frac{exp(L^u_{p,D_s}) + exp(L^u_{p,D_r})}{[1+exp(L^u_{p,D_s})]\cdot[1+exp(L^u_{p,D_r})]}, \tag{8}$$

where N indicates the number of the a posteriori *LLR* pairs from the two decoders with sufficient reliability. Only the *LLR*s with absolute values larger than a given threshold can be used for calculating $\hat{p_e}$. The threshold is set at 1 in our simulations.

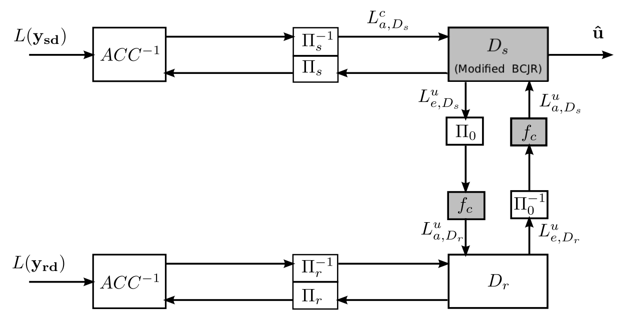


Fig. 4. The proposed DJSCC decoder for single relay system exploiting temporal and spatial correlations. ACC^{-1} denotes the de-accumulator.

Using the error probability estimates obtained by Eq. (8), the *LLR* updating function f_c shown in Fig. 4 can be defined as [5]

$$f_c(x) = \ln \frac{(1-\hat{p_e})\cdot exp(x) + \hat{p_e}}{(1-\hat{p_e}) + \hat{p_e}\cdot exp(x)}, \tag{9}$$

where x denotes the input *LLR*s. The output of f_c is the updated *LLR*s by exploiting $\hat{p_e}$ as the spatial correlation. The *VI* operations of the proposed decoder can be expressed as

$$L^u_{a,D_s} = f_c[\Pi_0^{-1}(L^u_{e,D_r})], \tag{10}$$

$$L^u_{a,D_r} = f_c[\Pi_0(L^u_{e,D_s})], \tag{11}$$

where $\Pi_0(\cdot)$ and $\Pi_0^{-1}(\cdot)$ denote interleaving and de-interleaving functions with Π_0, respectively.

B. Modified BCJR Algorithm

In this sub-section, we make modifications of the standard BCJR algorithm [14] for the joint decoding of Markov source and channel encoder C_s. Here, we ignore momentarily the serially concatenated structure, and only focus on the decoding process performed over the trellis diagram of C_s. For a convolutional code with memory length v, there are 2^v states in its trellis diagram, which is indexed by $m,\ m = 0, 1, \cdots, 2^v - 1$. The input sequence to the encoder $\mathbf{u} = u_1 u_2 \cdots u_t \cdots u_L$, which is also a series of the states of Markov source, is assumed to have length L. The output of the encoder is denoted as $\mathbf{x} = \{\mathbf{x}^{c1}, \mathbf{x}^{c2}\}$. The coded binary sequence is BPSK mapped and then transmitted over AWGN channels. The received signal is a noise-corrupted version of the BPSK mapped sequence, denoted as $\mathbf{y} = \{\mathbf{y}^{c1}, \mathbf{y}^{c2}\}$. The received sequence from the timing indexes t_1 to t_2 is denoted as $\mathbf{y}_{t_1}^{t_2} = \mathbf{y}_{t_1}, \mathbf{y}_{t_1+1}, \ldots, \mathbf{y}_{t_2}$.

First of all, three parameters indicating the probabilities defined as below are introduced:

$$\alpha_t(i,m) = p(u_t = i, S_t = m, \mathbf{y}_1^t), \tag{12}$$

$$\beta_t(i,m) = p(\mathbf{y}_{t+1}^L | u_t = i, S_t = m), \tag{13}$$

$$\gamma_t(\mathbf{y}_t, i', m', i, m) = p(u_t = i, S_t = m, \mathbf{y}_t | u_{t-1} = i', S_{t-1} = m'). \tag{14}$$

$\alpha_t(i,m)$, $\beta_t(i,m)$, $\gamma_t(\mathbf{y}_t,i',m',i,m)$ are found to be functions of both the output of Markov source and the states in the trellis diagram of C_s. More specifically, $\gamma_t(\mathbf{y}_t,i',m',i,m)$ represents information of input/output relationship corresponding to the state transition $S_t=m'\to S_t=m$, specified by the trellis diagram of C_s, as well as of the state transition probabilities depending on Markov source. Therefore, γ can be decomposed as

$$\gamma_t(\mathbf{y}_t,i',m',i,m)= \begin{cases} a_{i',i}\cdot\gamma_t^*(\mathbf{y}_t,m',m), & \text{if } (i',m')\in E_t(i,m);\\ 0, & \text{otherwise}, \end{cases} \tag{15}$$

where $a_{i',i}$ is defined in (6), and $\gamma_t^*(\mathbf{y}_t,m',m)$ is defined as

$$\gamma_t^*(\mathbf{y}_t,m',m)=p(\mathbf{y}_t,S_t=m|S_{t-1}=m'). \tag{16}$$

$E_t(i,m)$ is the set of states $\{(u_{t-1},S_{t-1})\}$ that can make the transitions to state $(u_t=i,S_t=m)$.

After γ is obtained, α and β can also be computed via the following recursive formulae

$$\alpha_t(i,m)=\sum_{i',m'}\alpha_{t-1}(i',m')\gamma_t(\mathbf{y}_t,i',m',i,m), \tag{17}$$

$$\beta_t(i,m)=\sum_{i',m'}\gamma_t(\mathbf{y}_t,i',m',i,m)\beta_{t+1}(i',m'). \tag{18}$$

Since the output encoder always starts from the state zero, while the probabilities for the Markov source starts from state "0" or state "1" is equal. Hence, setting α as $\alpha_0(0,0)=\alpha_0(1,0)=1/2$ and $\alpha_0(i,m)=0,\ i=0,1;m\neq 0$ is reasonable for initial values. Similarly, the initial conditions for β is $\beta_L(i,m)=1/2^{v+1},\ i=0,1;m=0,1,\cdots,2^v-1$.

Now the whole set of equations for the modified BCJR algorithm can be obtained. Combining all the results described above, we can obtain the conditional *LLR*s for x_t^{c1}, as

$$L(x_t^{c1})=L_{ap}(x_t^{c1})+L_{ch}(x_t^{c1})+L_{ex}(x_t^{c1}), \tag{19}$$

where

$$L_{ap}(x_t^{c1})=\log\frac{p(x_t^{c1}=1)}{p(x_t^{c1}=0)}, \tag{20}$$

$$L_{ch}(x_t^{c1})=\log\frac{p(y_t^{c1}|x_t^{c1}=1)}{p(y_t^{c1}|x_t^{c1}=0)}, \tag{21}$$

$$L_{ex}(x_t^{c1})= \log\frac{\sum\limits_{(i,m)\in B_t^1}\sum\limits_{i',m'}\alpha_{t-1}(i',m')\gamma_t(y_t^{c2},i',m',i,m)\beta_t(i,m)}{\sum\limits_{(i,m)\in B_t^0}\sum\limits_{i',m'}\alpha_{t-1}(i',m')\gamma_t(y_t^{c2},i',m',i,m)\beta_t(i,m)}, \tag{22}$$

which are the a priori *LLR*, the channel *LLR* and the extrinsic *LLR*, respectively, obtained as the result of the modified BCJR algorithm. The same representation should apply to x_t^{c2}.

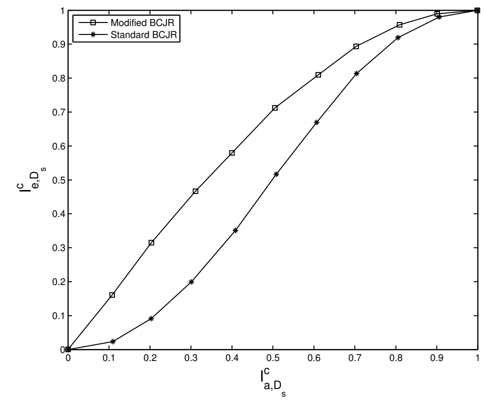


Fig. 5. Extrinsic information transfer characteristic of D_s, with standard BCJR and with modified BCJR, respectively. The spatial correlation is not considered. For Markov source, $p_1=p_2=0.8,\ H(S)=0.72$. Generator polynomials of C_s is $(G_r,G)=(3,2)_8$.

IV. EXIT Chart Analysis

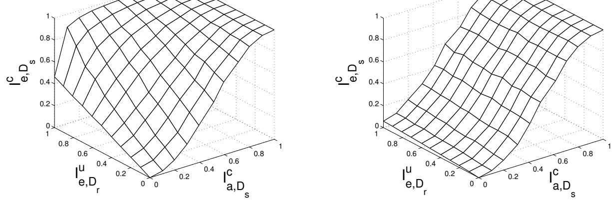
In this section, we present results of three-dimensional (3D) EXIT chart [15]–[17] analysis conducted to identify the impact of the temporal and spatial correlations on the joint decoder. The analysis focuses on the decoder D_s since the main aim is to successfully retrieve the information estimates $\hat{\mathbf{u}}$. As shown in Fig. 4, the decoder D_s exploits two a priori *LLR*s: L^c_{a,D_s} and the updated version of L^u_{e,D_r}, L^u_{a,D_s}. Therefore, the EXIT function of D_s can be characterized as

$$I^c_{e,D_s}=T^c_{D_s}(I^c_{a,D_s},I^u_{e,D_r},p_e), \tag{23}$$

where I^c_{e,D_s} denotes the mutual information between the extrinsic LLRs L^c_{e,D_s}, generated from D_s, and the coded bits by D_s. I^c_{e,D_s} can be obtained by the histogram measurement [16]. Similar definitions can be applied to I^c_{a,D_s} and I^u_{e,D_r}.

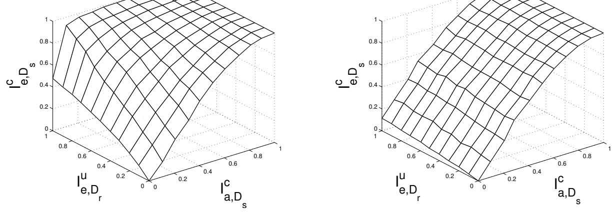
First, we assume that the spatial correlation is not exploited and only focus on the exploitation of temporal correlation. In this case, $I^u_{e,D_r}=0$ and the EXIT analysis of D_s can be simplified to two-dimensional. The EXIT curves with standard BCJR and with modified BCJR exploiting temporal correlation of Markov source are illustrated in Fig. 5. The code used in the simulation is a half rate memory-1 RSC with the generator polynomials $(G_r,G)=(3,2)_8$, and the Markov source with $p_1=p_2=0.8,\ H(S)=0.72$. Fig. 5 shows that for Markov source, the EXIT curve obtained by using the modified BCJR algorithm is lifted up over the entire a priori input value range, indicating that larger extrinsic information can be obtained.

Next we conduct 3D EXIT chart analysis for D_s to evaluate the impact of spatial correlation, considering the exploitation of spatial correlation only. The EXIT planes of D_s are illustrated in Fig. 6. Two different scenarios, a relative strong spatial correlation (corresponding to small p_e value) and a relative weak spatial correlation (corresponding to large p_e value) are considered. It can be seen from Fig. 6(a) that with a strong spatial correlation, the extrinsic information I^u_{e,D_r} provided by D_r, has a significant effect on $T^c_{D_s}(\cdot)$. On the contrary, when the spatial correlation is weak, I^u_{e,D_r} has a negligible influence on $T^c_{D_s}(\cdot)$, as shown in Fig. 6(b).



(a) $p_e = 0.01$ (b) $p_e = 0.3$

Fig. 6. The EXIT plane of decoder D_s with different spatial correlations. Temporal correlation of the Markov source is not considered.



(a) $p_e = 0.01$ (b) $p_e = 0.3$

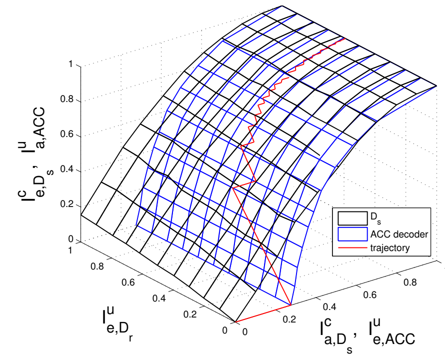
Fig. 7. The EXIT plane of decoder D_s, both the temporal and spatial correlations are exploited. For Markov source, $p_1 = p_2 = 0.8,\ H(S) = 0.72$.

For the proposed DJSCC decoding scheme, both the spatial and temporal correlations are exploited in the iterative decoding process. The impact of the spatial and temporal correlations on D_s, represented by the 3D EXIT chart, is shown in Fig. 7. Comparing it with Fig. 6, it can be observed that larger extrinsic information can be generated by exploiting the temporal and spatial correlations simultaneously, which will help decoder D_s to perfectly retrieve the information bits even at a low SNR_{sd} scenario.

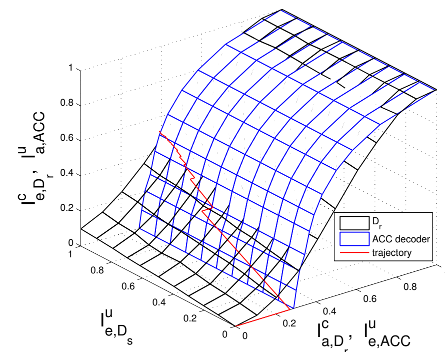
V. Convergence Analysis and BER Performance

A series of simulations were conducted to evaluate the convergence property, as well as BER performance of the proposed technique. The information bits are generated from a Markov source with $p_1 = p_2 = 0.8$ of which $H(S) = 0.72$. The block length is 10000 bits, and 1000 different blocks were transmitted for the sake of keeping reasonable accuracy. The encoder used at the source and relay nodes, D_s and D_r, are both memory-1 half rate RSC with generator polynomials $(G_r, G) = (3, 2)_8$. 5 *VI*s took place after every *HI*, with the aim of exchanging extrinsic information to exploit the spatial correlation. The whole process was repeated 50 times. In all the three relay location scenarios, performance was evaluated in terms of extrinsic information transfer trajectory and bit error rate (BER) versus SNR of the source-destination link. The doping rates were set at $K_s = K_r = 2$ for location A, while $K_s = 1,\ K_r = 16$ for both location B and C.

The convergence behavior of the proposed DJSCC decoder in relay location A with $SNR_{sd} = -3.5\ dB$ is illustrated in Fig. 8. As described in Section III, D_s and D_r are asymmetric, thus the upper and lower *HI*s are evaluated separately. It



(a) Upper *HI* with f_c function



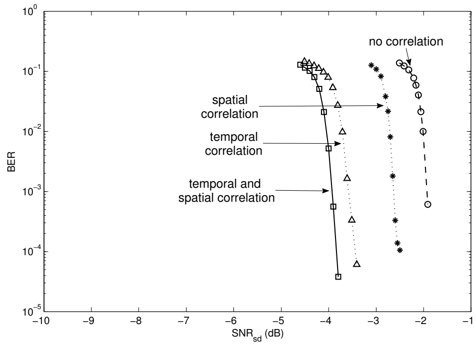
(b) Lower *HI* with f_c function

Fig. 8. The 3D EXIT chart analysis for the proposed DJSCC decoder in relay location A, $SNR_{sd} = -3.5\ dB$.

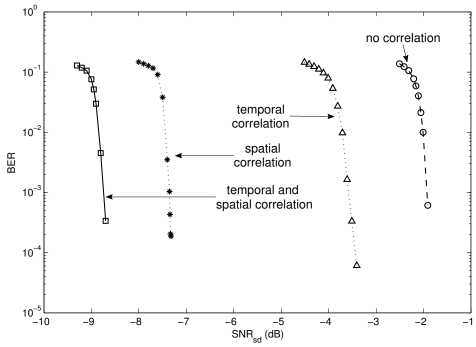
can be observed from Fig. 8(b) that the EXIT plane of D_r and ACC decoder finally intersects with each other at about $I^c_{e,D_r} = 0.52$. It can be obtained through simulations that $I^u_{e,D_r} = 0.59$ at this point, which means D_r can provide D_s with at most 0.59 extrinsic mutual information during the *VI*. Fig. 8(a) shows that when $I^u_{e,D_r} = 0$, the convergence tunnel is closed, but the convergence tunnel is slightly open when $I^u_{e,D_r} = 0.59$. Therefore, the exchanging of extrinsic mutual information between D_s and D_r helps the trajectory of the upper *HI* sneak through the convergence tunnel and finally reach the convergence point while the trajectory of the lower *HI* gets stuck. It should be noted here that since $\hat{p_e}$ is estimated and updated during every iteration, the trajectory of the upper *HI* does not match exactly with the EXIT planes of D_s and the ACC decoder. Similar situation happens to the trajectory of the lower *HI*.

The BER performance for the three relay location scenarios are shown in Fig. 9. To demonstrate the performance gains obtained by the exploitation of the temporal and spatial correlations, the BER curves that do not exploit any correlation and that exploit the temporal and the spatial correlation separately are also provided. It can be observed that the performance gain of 1.5 dB can be obtained by exploiting the temporal correlation of the Markov source only.

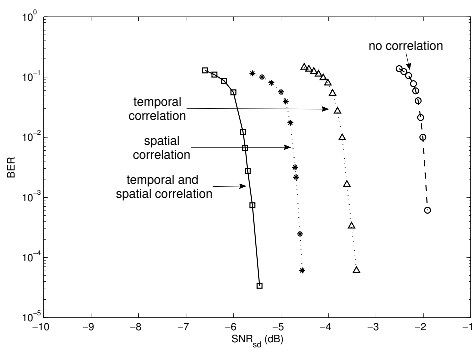
The performance gains obtained by exploiting only the



(a) Location A



(b) Location B



(c) Location C

Fig. 9. The BER performance of the proposed DJSCC decoder for relay systems with different relay location scenarios, with respect to the SNR of the source-destination link.

spatial correlations rely largely on the quality of the intra-link (which can be characterized by p_e), as described in the previous section. It can be seen from Fig. 9(a), 9(b) and 9(c) that, the performance gains obtained by exploiting spatial correlation only for location A, B and C are $0.6\ dB$, $5.4\ dB$ and $2.6\ dB$, respectively. Among these three different relay location scenarios, the quality of the source-relay link of location A is the worst and that of location B is the best, if the SNR_{sd} is the same. This is consistent with the simulation results.

The proposed DJSCC technique exploits the temporal and spatial correlations simultaneously during the iterative decoding process, thus larger performance gains can be expected. In fact, the performance gains of the proposed technique is larger, as shown in Fig 9 for location A, B and C, than the techniques that exploit the temporal or spatial correlation only, and the performance gains are $1.9\ dB$, $6.8\ dB$ and $3.5\ dB$, respectively.

VI. Conclusion

In this paper, we presented a DJSCC scheme for transmitting binary Markov source in a one-way relay system. In our proposed technique, a modified version of BCJR algorithm was derived to take into account the temporal correlation of the Markov source, while the LLR updating function is adopted to exploit the spatial correlation between the source and relay nodes. By exploiting the temporal and spatial correlations simultaneously, the proposed technique can achieve significant gains over the techniques that exploit only one-dimensional correlation. The performance superiority of the proposed technique has been verified through simulations.

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