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Adaptive LDPC with DSTBC in Cooperative System

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Abstract

In the first part of the paper we proposed an adaptive LDPC iterative decoder depending on the prior knowledge of CSI after evaluating its performance under AWGN and Rayleigh flat fading channel. The proposed code leads to lower the delay caused by the iterative decoder beside acceptable performance, when reducing its iteration to a certain value that is satisfied the parity check operation instead of restricted it to uncertain value which may or may not grantees the converges. In the second part of the paper, LDPC was employed as an outer code with the DSTBC cooperative system. The collaborative system was simulated with two nodes, dual hope based on two relay protocol (DemAF and DAF). The concatenation of LDPC and DSTBC has been proved to be effective in achieving both diversity and coding gain. Adopting one of the introduced protocol is related to many factors, each one has its own advantage and disadvantage. To get the best strategy which equilibrates between the complexity and the performance, the proposed code in the first part was employed. The results demonstrate that the adaptive code successes in significant error floor reduction associated with the DemoAF protocol at the same time results in reducing the delay associated with the DAF protocol.

***Keywords**—DSTBC, LDPC, Dual hope, Cooperative system*

شفرة التفقد المتكافئ المنخفض الكثافة (LDPC) المكيفة مع شفرة مساحة الزمن الموزعة (DSTBC) في النظام المتعاون.

الخلاصة

في الجزء الأول من هذا البحث, اقترحنا مفك الشفرة التكراري المكيف ل شفرة التفقد المتكافئ المنخفض الكثافة بالأعتماد على المعرفة المسبقة لحالة القناة وبعد تقييم أداءه تحت قناتي ضوضاء كاوزين البيضاء المكيفة (AWGN) وقناة رايلي ذات الخبو المنبسط (Rayleigh flat fading). ان الشفرة المقترحة ادت الى تقليل التأخير الناتج من مفك الشفرة التكراري مع أداء مقبول عند تقليل عدد التكرار الى حد معين والذي يرضي عملية تفقد التكافؤ بدلا عن اعتماد قيمة غير محددة قد أو قد لا تؤدي الى التقارب. في الجزء الثاني من البحث شفرة التفقد المتكافئ المنخفض الكثافة وظفت مع شفرة مساحة الزمن الموزعة في النظام المتعاون كشفرة خارجية. تمت محاكاة النظام المتعاون مع عقدتين , ثنائي التحويل بالأعتماد على برتوكولي المرحل (DemAF and DAF). ان النظام المتتابع المكون من شفرة

التفقد المتكافئ المنخفض الكثافة و شفرة مساحة الزمن الموزعة برهن كفاءته في الحصول على كلا ربح التنوع و التشفير. أن تبني أحد البرتوكولين يعتمد على عدة عوامل لأن كل منهما له ايجابياته وسلبياته. للحصول على أفضل ستراتيجية التي توازن بين الأداء والتعقيد, وظفت الشفرة المقترحة في الجزء الأول. أكدت النتائج أن الشفرة المكيفة نجحت الى حد كبير في تقليل أرضية الخطأ المقرون ب (DemAF) في نفس الوقت أدت الى تقليل زمن التأخير المقرون ب (DAF).

Introduction

Although Multiple-Input Multiple-Output (MIMO) systems provide many advantages and achieve spatial diversity, they cannot be served to provide diversity when the wireless portable devices, cannot support multiple antennas due to size and power limitations. Instead cooperative communication has been an interesting topic for researchers in recent years. A cooperative communication system consists of source, relay, and destination nodes which have been accepted as a virtual MIMO system because it can provide transmit diversity instead of implementing multiple antennas at wireless nodes in wireless communication **[1].**

User cooperation in wireless networks was first investigated by Sendonaris *et al.* in **[2]** and **[3]** for cellular networks and for *ad hoc* networks by Laneman *et al.* **[4]** and **[5].** In **[6]**, the authors proposed a new cooperative strategy, called distributed space-time coding (DSTC). One of the main problem with the multi-node is the loss in the data rate as the number of relay nodes increases, so employing DSTCs reduces the data rate loss due to relay nodes transmissions without sacrificing the system diversity order **[7]**. Many researches efforts had been employed for DSTC system. In **[8]**, DSTC based on the Alamouti scheme and amplify-and-forward cooperation protocol was analyzed. An expression for the average symbol error rate (SER) was derived. In **[9]** the authors compared the performance of different DSTC designed for the MIMO channels under the assumption that the number of relays available is a Poisson random variable.

Motivated by the increasing importance of both MIMO system and cooperative communication in wireless networks, a large volume of valuable work has gone into the design of collaborative relay protocols, determining the higher coding and diversity gain in the past few years. All researches proved that by employing good codes e.g. turbo codes and low density parity check (LDPC) codes can always achieve better performance **[10]**.

LDPC codes possess two salient advantages: better error-correcting performance due to their good distance properties and lower decoding complexity for their parallel processing in decoding algorithm which fits the hardware implementation hardware nicely **[11]**. It has been naturally applied to many researches on MIMO systems to obtain higher coding gain against noise and interference, especially for burst interference which will seriously decrease the error-correcting ability of other codes **[12].**

Also some distributed low density parity check (D-LDPC) coding schemes have been developed recently to employ better performance of the cooperative systems, It has been shown that through proper code design, an D-LDPC scheme over wireless relay channels can perform very close to the theoretical limit **[13].**

Despite of many LDPC advantages there are some drawbacks e.g. their large frame lengths and substantial number of decoding iterations. The higher number of iterations causes input sequences to the LDPC decoder may have a slow convergence for some of the arbitrary error patterns obtained under the influence of random channel noise which reduces the effectiveness of the LDPC decoder [14]. Also due to the LDPC code inability to reach very low bit error rates at low signal-to-noise ratios (SNRs), a consequence the error rate floor phenomenon associated with iterative LDPC decoders is produced[15][16].

In this paper an adaptive iterative LDPC decoder will be introduced in a manner to tradeoff between rate of converges and good performance, then will be employed with a DSTBC in a cooperative system with dual hope relay, also the performance is evaluated for both DemoAF and DAF relay protocol (the strategies of these protocols will be explained in section 3.1)

The rest of this paper is organized as follows: section 2 and 3, LDPC and DSTBC are explained. The system model is discussed in section 4. Simulation and results are illustrated in section 5. The last section 6 contains the conclusion.

LDPC

LDPC codes are a capacity approaching class of codes that were first described in a seminal work by Gallager [17]. Gallager work showed that random regular LDPC codes are asymptotically good and perform close to the Shannon capacity limit when the block length increases. Tanner in [18] rediscovered LDPC codes using a graphical interpretation [19].

Structure of LDPC Codes

LDPC codes can be described by a sparse parity-check matrix H containing a sparse number of non-zero entries. The term low-density means that the number of ones in each column and row of the parity-check matrix is small compared to the block size. Linear codes are defined in terms of generator and parity-check matrices. Generator matrix G maps information u to transmitted blocks x called codewords. For a generator matrix G, there is a parity-check matrix H which is related as $G.H^T=0$. All codewords must satisfy $x.H^T= 0$ in terms of the parity-check matrix H. If the parity-check matrix H has the same weight per row and the same weight per column, the resulting LDPC codes is called regular. Assume (dv, dc) are used to represent a regular LDPC code whose column weight is dv and row weight is dc. When the weight in every column is not the same in the parity-check matrix, the code is known as an irregular LDPC code [20].

As an example, LDPC code of codeword size n=8 and rate 1/2 can be specified by the following parity check matrix [21].

$$\mathbf{H} = \begin{bmatrix} 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The same code can be equivalently represented by the bipartite (Tanner) graph in Figure (1)

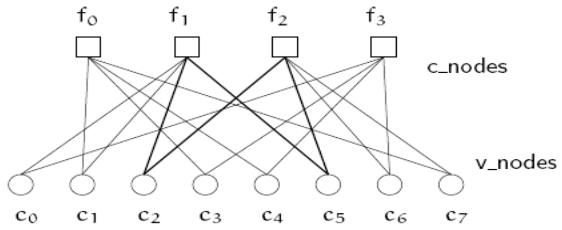


Figure (1) Bipartite (Tanner) graph of an LDPC code

Tanner graph are separated into two distinctive sets and edges are only connecting nodes of two different types. The two types of nodes in a Tanner graph are called variable nodes (v-nodes) and check nodes (c-nodes). The creation of such a graph is rather straight forward. It consists of m check nodes (the number of parity bits) and n variable nodes (the number of bits in a codeword). Check node f_i is connected to variable node c_j if the element h_{ij} of H is a 1 [21].

LDPC Encoding

The message bits are conventionally labeled by $u = [u_1, u_2, \cdot\cdot\cdot, u_k]$, where the vector u holds the k message bits. Thus the codeword c corresponding to the binary message can be found using the matrix equation

$$c = u.G \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

For a binary code with k message bits and length n codewords the generator matrix, G, is a $k \times n$ binary matrix. The ratio k/n is called the rate of the code. A code with k message bits contains 2^k codewords. These codewords are a subset of the total possible 2^n binary vectors of length n [22].

The generator matrix for a code with parity-check matrix H can be found by performing Gauss-Jordan elimination on H to obtain it in the form

$$H = [A, I_{n-k}] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where A is a $(n-k) \times k$ binary matrix and I_{n-k} is the size n-k identity matrix. The generator matrix is then

$$G = [I_k, A^T] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

LDPC Iterative Decoding

Consider an LDPC code of length *n* and design rate *R*=*k*/*n*. An iterative decoder for this code can be viewed as a graph that has *n* variable nodes (bit nodes), an edge interleaver, and *(n-k)* check nodes as in Figure (2). The *i*-th variable node represents the *i*-th bit of the codeword. This bit is involved in $dv^{(i)}$ parity checks, so that its node has $dv^{(i)}$ edges going into the edge interleaver. The edge interleaver connects the variable nodes to the check nodes, each of which represents a parity-check equation. The *i*-th check node checks $dc^{(i)}$ bits so that it has $dc^{(i)}$ edges. The sets of variable and check nodes are referred to as the variable-node decoder (VND) and check-node decoder (CND), respectively. Iterative decoding is performed by passing messages between the VND and CND [23].

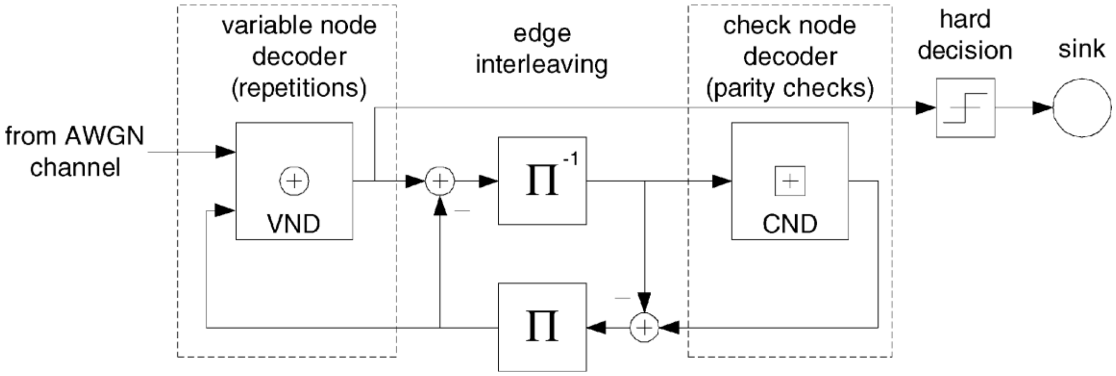


Figure (2) Iterative decoder for an LDPC code

The procedure of iterative decoder will be explained by the following equations, suppose the Tanner graph consists of *n* bit nodes and *m* (where *m*=*n*-*k*) check nodes. In the first step, bit nodes x_i, $i = 1, 2, \ldots\ldots, n$, are initialized with the prior log likelihood ratios (*LLR*) given in (5) below using the channel outputs y_i, $i = 1, 2, \ldots\ldots, n$ [24].

$$l_i = log\frac{p(x_i=0|y_i)}{p(x_i=1|y_i)} = \frac{2y_i}{\sigma^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where σ denotes the standard deviation of noise in Gaussian channel. Bit nodes first send the prior *LLR* messages to the neighboring check nodes along the edges of the Tanner graph, and the subsequent message exchange is governed by the bit-to-check message $Q_{i\to j}$ and the check-to-bit message $R_{j\to i}$ as represented in (6) and (7) below respectively, where $N(i)$ refers to the neighborhood of the node *i*,

$$Q_{i\to j} = l_i + \sum_{k\epsilon N(i)\backslash j} R_{k\to i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$R_{j\to i} = \prod_{l\in N(j)\backslash i} sgn\left(Q_{l\to j}\right)\Phi^{-1}\left(\sum_{l\in N(j)\backslash i} \Phi\left(\left|Q_{i\to j}\right|\right)\right) \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where $\Phi(x) := -\log [\tanh (x/2)]$ for $x \geq 0$. The posterior log-likelihood ratio at each bit node is then computed as:

$$LLR_i^{post} = l_i + \sum_{j \epsilon N(i)} R_{j \to i} \quad \text{..........(8)}$$

The message passing algorithm is typically allowed to run for a fixed number of iterations, both because convergence is not guaranteed when many cycles are present, and due to practical (delay) constraints. Based on the posterior *LLR*, a bit-wise hard decision is made: "0" if $LLR_i^{post} \geq 0$ and "1" otherwise.

The computations in the decoder are localized, e.g., computations at a check node are performed independent of the overall structure of the code. This implies that highly parallel implementations of a message passing decoder are feasible. Further, the computations are distributed, i.e., computations are performed by all nodes in the graph. Thus it is computationally feasible to decode long block length LDPC codes [25].

Distributed Space Time Coding

Cooperation is referred to as any architecture that deviates from the traditional approach that is where a user’s communication link is enhanced in a supportive way by other users [26]. In distributed system the source and relays cooperatively communicate with a common destination. This cooperative transmission among the source and relays forms a virtual antenna array. Figure (3) represents a wireless relay network [27].

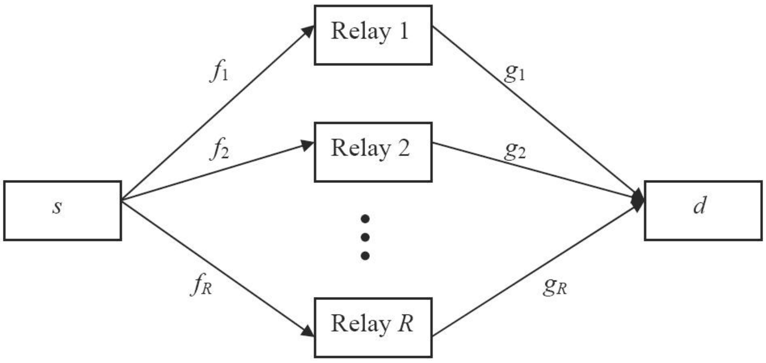


Figure (3) Wireless Relay Network

Conventional space-time coding schemes can be applied to relay networks for achieving the cooperative diversity and coding gain. It was shown that by cooperating distributively, the relays generate linear space-time codewords at the receiver. Most importantly, it achieves the maximal diversity order *R* in a network with *R* relays when the transmit power is infinitely large [28]. Several DSTBC schemes have been proposed. A simple DSTBC scheme was proposed by [5] Laneman based on orthogonal STBCs. In such a scheme different relays transmit different columns of the STBC code matrix, and at the destination a DSTBC codeword is formed STBC distributed cooperative system **[29].**

DSTBC strategy consists of two-phases protocol. In phase one, the transmitter sends the information signal to the relays and in phase two, relays send information to the receiver. The signal sent by every relay in the second phase is designed as a linear function of its received signal. It was shown that the relays can generate a linear space-time codeword at the receiver, as in a multiple antenna system, although they only cooperate distributively. .

The strategy of wireless relay network in Figure (3) is explained as follows **[27]:**

It is assumed that each node is equipped with a single antenna. It is considered symmetric channels and denote the source-to- *r*-th relay and *r*-th relay-to-destination links by f_r and g_r, respectively. Suppose each link has Rayleigh fading, independent of the others. Therefore, f_r and g_r are identically independent distributed (i.i.d) complex Gaussian random variables with zero-mean and variances $\sigma^2 f$ and $\sigma^2 g$ respectively. During the first phase, the source node, *s*, transmits a signal *s*= transpose ($[s_1, \dots, s_T]$), consisting of *T* symbols to all relays. Assuming the normalization, $E\{s^H.s\}=1$. Thus, from time 1 to *T*, signals $\sqrt{P_1 T}\; s_1$ ....$\sqrt{P_1 T}\; s_T$ are sent to all relays by the source. The average total transmitted energy in *T* intervals will be P_1T. Assuming f_r is not varying during *T* successive intervals, the received *T*×1 signal at the *r*-th relay can be written as:

$$r_r = \sqrt{P_1 T}\; f_r s + v_r \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

where v_r is a *T* ×1 complex zero-mean white Gaussian noise vector with the variance of N_1.

Before retransmitting the signal to the destination, relays manipulate the received signal r_r according to one of different provided protocols depending on the relative, location of the users, channel condition and transceiver complexity (types of protocol will be explained in 3.1)

Let denotes x_r be the transmitted signal from relays to the distention after manipulation. DSTC, assume linear dispersion space-time codes of multiple-antenna systems. In this system, the *T*×1 received signal at destination can be written as:

$$x = \sum_{r=1}^{R} g_r \; A_r \, x_r \; + w \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where *w* is a *T*×1 complex zero-mean white Gaussian noise vector with the variance of N_2, and A_r, $r = 1, \dots, R$, are unitary matrices. A_r.s, $r=1, \dots, R$, must describe columns of a proper *T*×1 space-time code.

Relays Protocols

To enable cooperation among users, different relay technologies can be employed as mentioned above in the previous section. In this paper two types of protocols are introduced as follows **[29]**:

Demodulation and Forward

To eliminate the effect of noise amplifications, several relay protocols have been proposed. Demodulation and Forward (DemAF) is one of the simple solutions among them. In DemAF the relay simply demodulates the received signals, with no decoding, and remodulates to reconstruct the symbols transmitted by the source. This process can simply remove the noise components residing in the received signals at relay. it is shown that the performance of DemAF depends on the position of the relay relative to the source and destination. When the relay is positioned midway between the source and destination, DemAF achieves its optimum performance and worsens as the relay moves closer or further to the source.

Decode and Forward

Decode and Forward (DF) is another commonly used protocol for eliminating the noise effect, especially for coded systems. The relay decodes the received signals and re-encodes them before forwarding to the destination. When the channel quality in the link between the source and relay is good, the process of decoding and re-encoding provides more powerful error correcting capabilities than DemAF. Thus, the method can considerably outperform DemAF. However, when the link from the source to the relay suffers from deep fading, decoding errors may occur at the relay. In this case, if the relay re-encodes these incorrect bits, error propagation will occur and lead to even worse performance.

System model

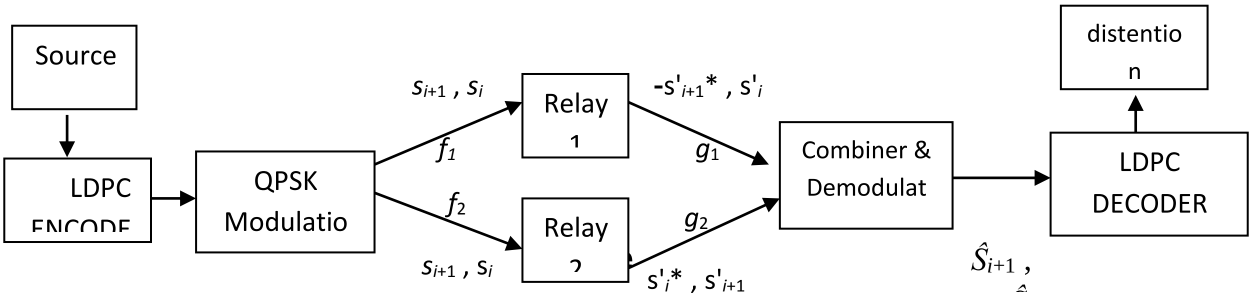


Figure (4) System Model

Figure (4) represents the system model. The data was generated randomly then coded by LDPC encoder which has the same parity check matrix of the Digital Video Broadcasting standard (DVB-S.2) [21]. The coded data is modulated using QPSK modulator then transmitted to both relays under Rayleigh slow fading channel, with the assumption that f_j and g_j attenuation amplitude kept constant for two symbols period.

At the first and second time slots (phase 1) the source sends its symbols (s_i, s_{i+1}) to both relays and the received signals will be:

$$rs_{i,j}=f_j\,.s_{i,j} + ns_{i,j} \quad \ldots\ldots\ldots (11)$$

where $i=1\ldots\ldots4$ and $j=1\ldots2$

$rs_{i,j}$ are the received signal at j-th relay at i-th time slots,

f_j is the channel link between the source and j-th relay,

$s_{i,j}$ is the symbol transmitted from the source to j-th relay at i-th time slot and $ns_{i,j}$ is the White Gaussian noise from the source to j-th relay at i-th time slot.

The relay nodes will recover the received signal and then retransmitted the recovered signal to the destination node in the form of Alamouti code using one of the introduced protocols in section (3.1). It is assumed that the relays have prior knowledge for channel state of information. Maximum Likelihood detector was adopted for detection in relays.

At the third and fourth time slots (phase two), the received signal at the destination will be (rd_i, rd_{i+1}) as follows:

$$rd_i = (s'_{i,j} \,.\, g_j + nd_{i,j}) + (s'_{i+1,j} \,.\, g_{j+1} + nd_{i,j+1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

$$rd_{i+1}=(-s'^{*}_{i+1,j} . g_j+nd_{i+1,j})+(s'^{*}_{i,j} .\, g_{j+1} + nd_{i+1,j+1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

where:

rd_i and rd_{i+1} are the received signals at the distention at the 3rd and 4th time slots,

$s'_{i,j}$ is the recovered signal by the j-th relay at i-th time slot,

g_j is the channels link between the relays and destination at i-th time slot and $nd_{i,j}$ is the received White Gaussian noise from the j-th relay to the distention at i-th time slot.

Finally these two signals are gathered together using simple combiner to produce $\hat{S}_i$ and $\hat{S}_{i+1}$, where:

$$\hat{S}_i = rd_i \,.\, g_j^{\,*} + rd_{i+1}^{\,*} .\, g_{j+1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

$$\hat{S}_{i+1} = rd_i \,.\, g_{j+1}^{\,*} - rd_{i+1}^{\,*} .\, g_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

$\hat{S}_i$ and $\hat{S}_{i+1}$ are demodulated and decoded using QPSK Demodulator and LDPC decoder.

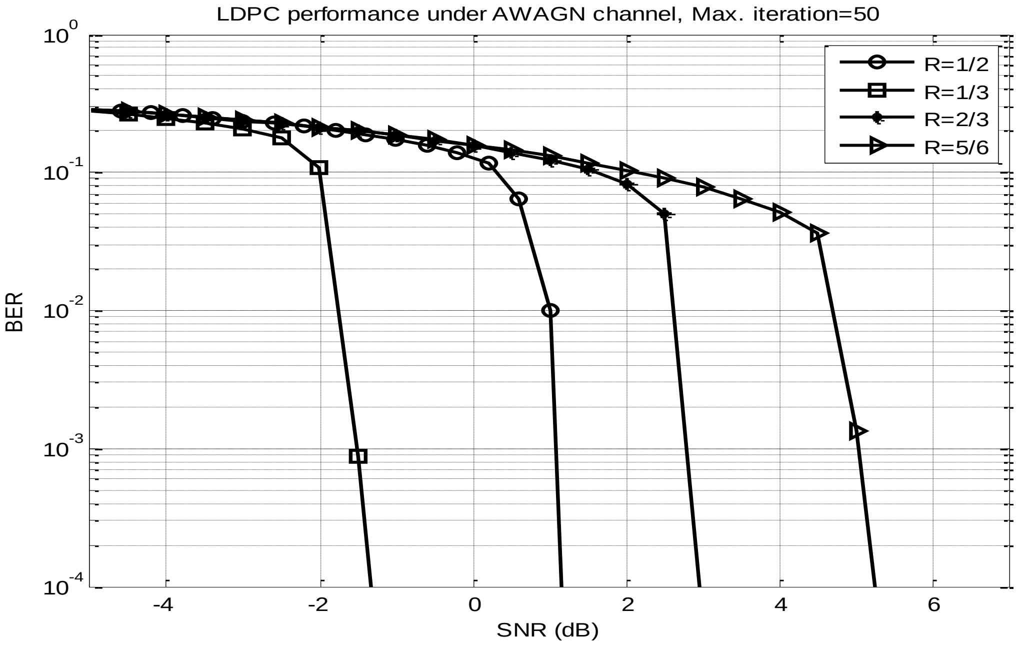
Simulation and Results

Our simulations are divided into two subsections.

Adaptive LDPC

This part deals with the performance of LDPC code under AWGN channel and Rayleigh flat fading channel with different code rate. The average of BER was calculated. The coded data are mapped to QPSK, at each SNR the number of the decoder iteration required for parity check to be satisfied was determined as shown in Figure (5),(6),(7) and (8).

Two things were noticed from the results abstracted from above. First the powerful capabilities of LDPC for error correction. Even with high rate, the code can achieves good performance at low SNRs .Also its decoding parallelism feature enable us to simulate the system with long input frame. Second restricted the decoder iteration to a certain number play an important role on the system performance. Choosing a small number for iteration leads to fast converges but with performance degradation, while choosing a large number will grantee the converges on the cost of time delay. This conclusion was explained in Figure (9) when the number of iteration is restricted by 4 and 20 iteration. In order to overcome this problem we adopt the idea of adaptive iterative decoder. Based on our pre- knowledge of the channel, we built a system with variable number of iteration depending on the value of SNR. The performance of the system with the adaptive iteration is shown in Figure (9), it is obviously noticed that the adaptive system verified the tradeoff between the speed of converges and good performance.



Figure(5) LDPC performance under AWAGN channel

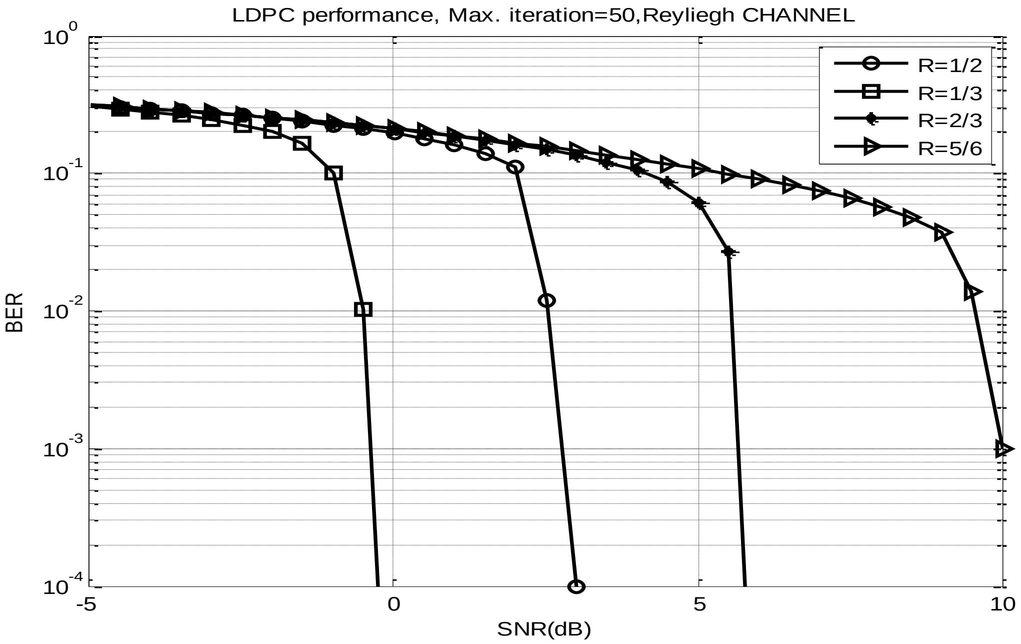


Figure (6) LDPC performance under Rayleigh flat fading channel

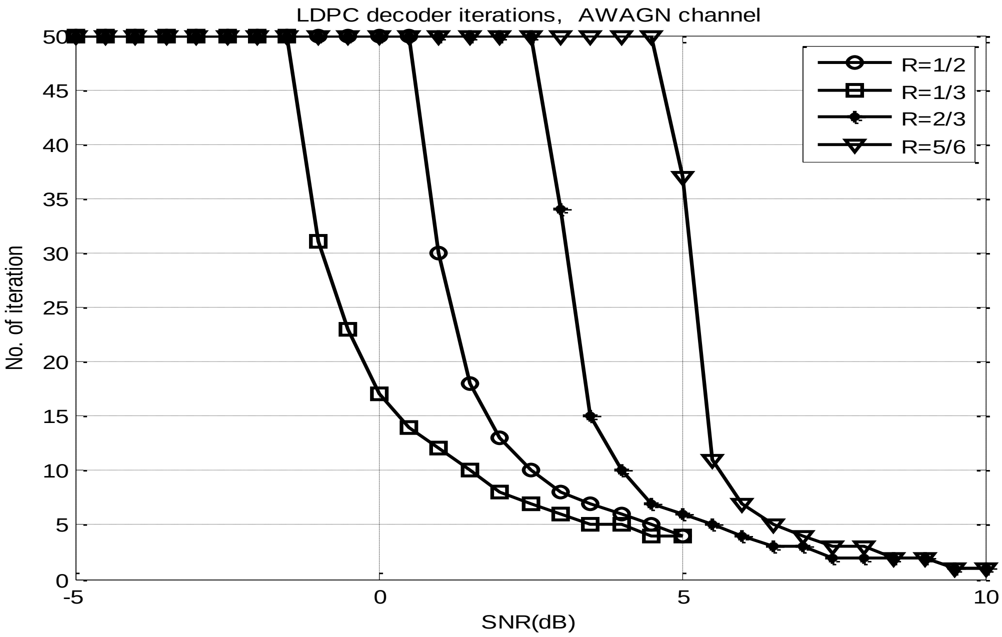


Figure (7) No. of LDPC decoder iterations(AWAGN channel)

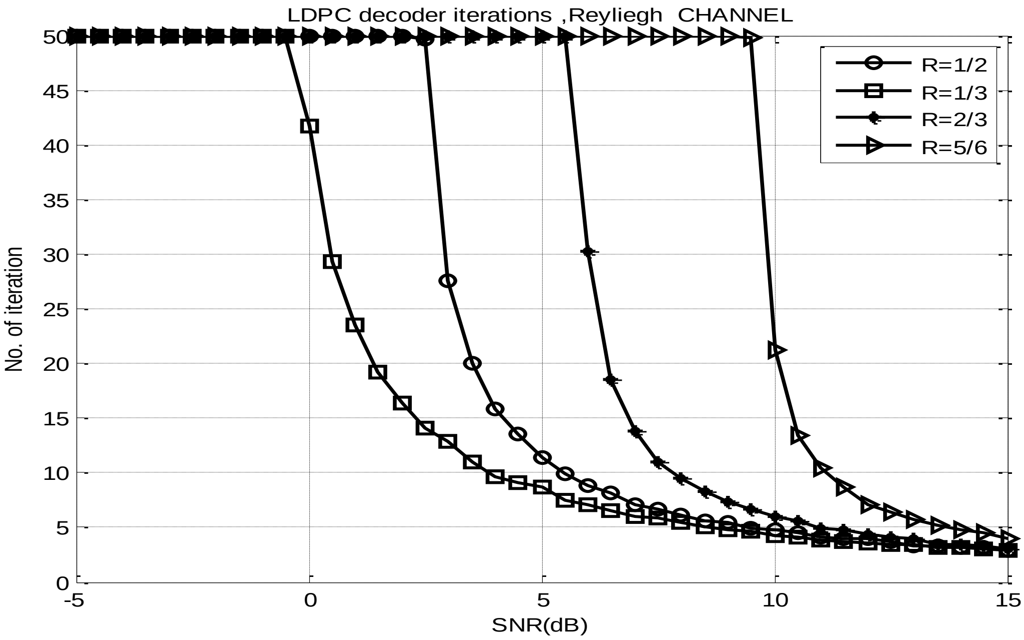


Figure (8) No. of LDPC decoder iterations(Rayleigh channel)

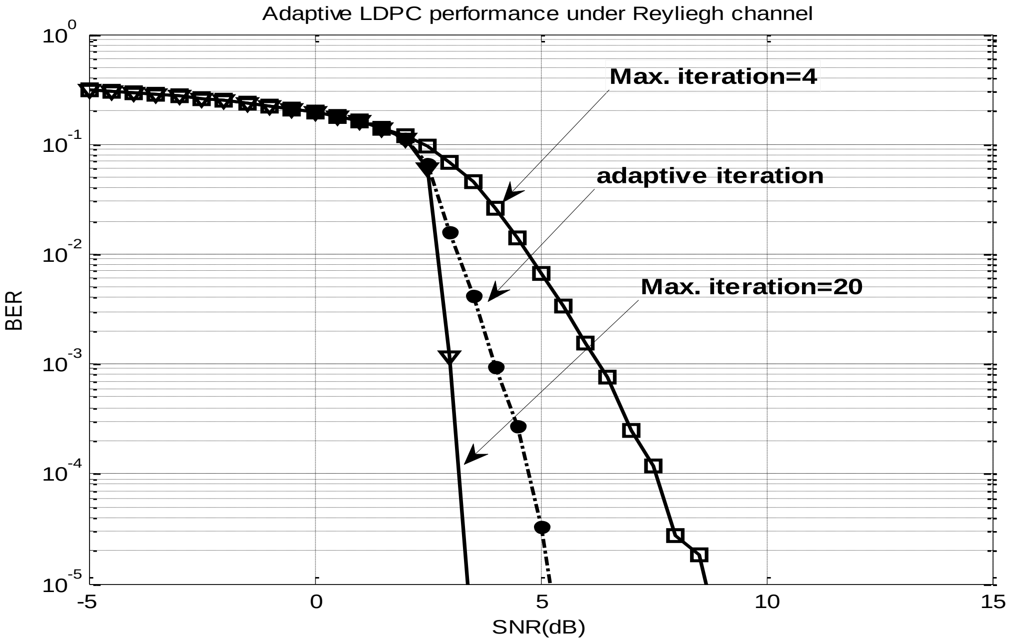
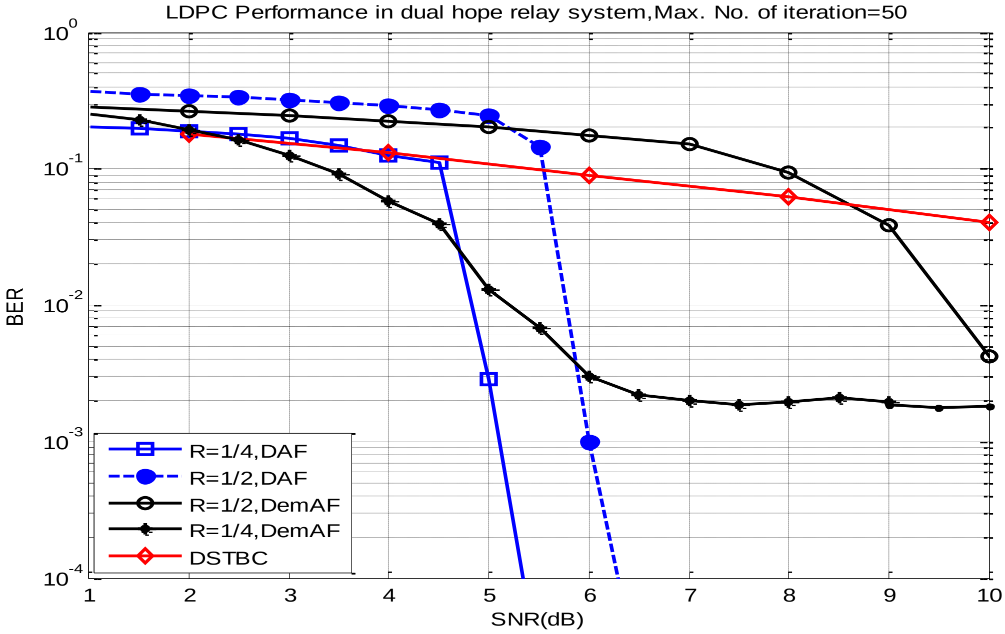


Figure (9) Adaptive LDPC performance under Rayleigh channel

LDPC in DSTBC Cooperative system

Our system model based on LDPC with DSTBC in a dual hope cooperative system was simulated. The performance of the system was evaluated when two protocols (DemAF and DAF) were adopted and with different LDPC code rate as explained in Figure (10). The system performance was compared with the performance of DSTBC, the results as illustrated in table(1) shown that the system with the DemAF protocol suffer from error floor phenomena with acceptable coding gain, while the system with DAF protocol verified a perfect performance at the cost of complexity. However it is not reasonable to adopt DAF protocol in multi hope relays network.

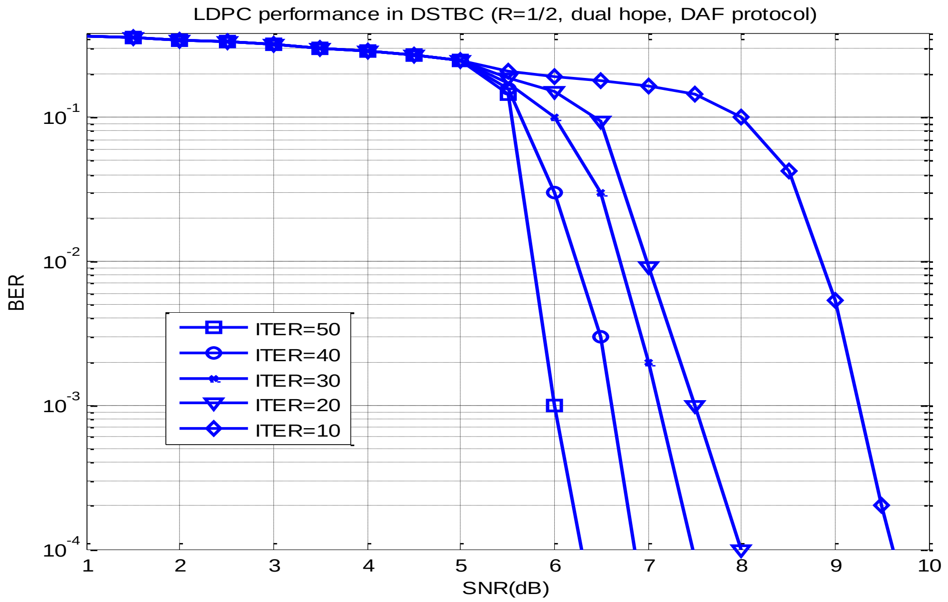


Figure(10) LDPC performance with DSTBC

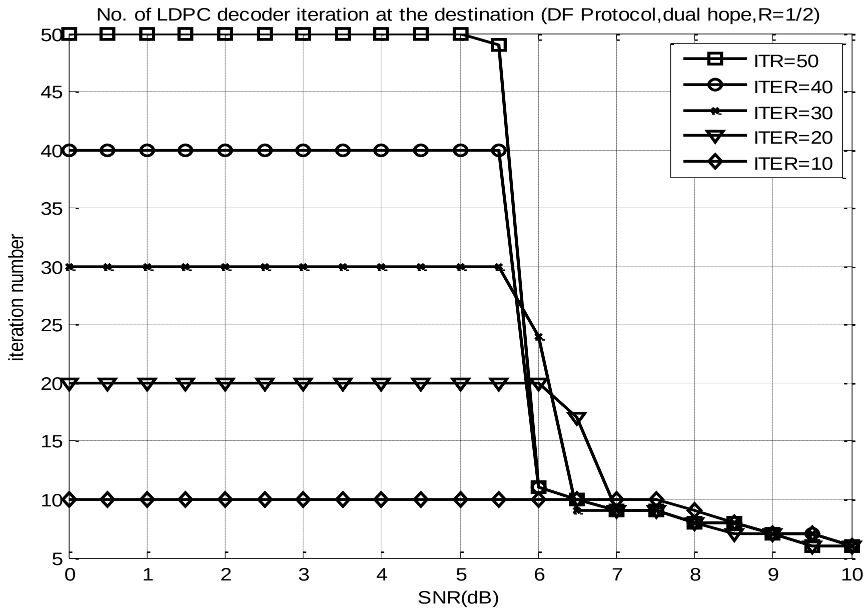
Table (1) coding gain for LDPC with DSTBC

LDPC Code rate	Coding gain at BER= 10^{-3}	
	DemAF	DAF
1/2	5 dB	20 Db
1/4	6 dB	21 dB

For the system which employing DAF protocol, the performance was evaluated when the maximum number of decoder iteration is restricted to 50, 40,……, 10. For each case the actual number of decoder iteration that is required for parity check to be satisfied was calculated (in both relays and distention decoder) for different values of SNR, as shown in Figure(11), (12) and (13).

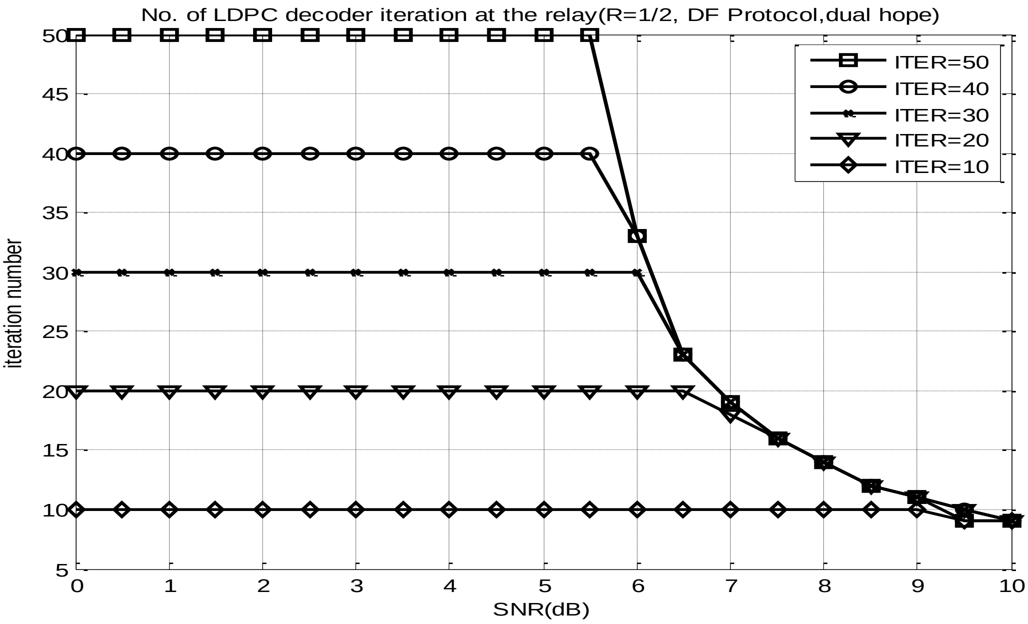


Figure(11) LDPC performance at DSBC (DAF)

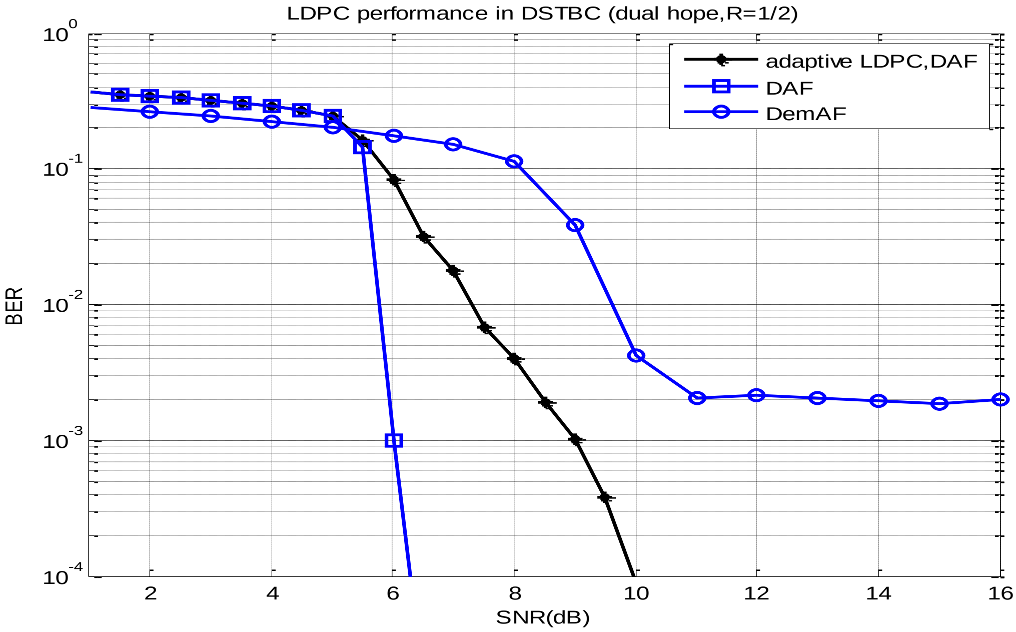


Figure(12) No. of LDPC decoder iterations at the distention

The results obtained from Figure (11), (12) and (13) show that for low SNRs (0 →6 dB), the Bit Error Rate (BER) is constant for any number of iteration mentioned before. At higher SNRs the number of iteration will be reduced with the increasing of SNR. According to this conclusion we built an adaptive LDPC decoder (at both the relay and distention), which vary its number of iteration depending on the prior knowledge of the channel state information. In this system we verified a tradeoff between complexity and good performance as shown in Figure (14). Also the proposed system is overcome the phenomena of the error floor associated with DemAF protocol.



Figure(13) No. of LDPC decoder iterations at the relay



Figure(14) Adaptive LDPC in DSTBC cooperative system

Conclusions

An adaptive LDPC was proposed and the performance in term of BER was calculated under both AWAGN and Rayleigh flat fading channel. The proposed code provides satisfying performance while reducing the delay related to the iterative decoder. LDPC was embedded in DSTBC dual hope cooperative system as an outer code. We evaluate the system performance when employing two relay protocol (DemAF, DAF), the results shown that the system which adopt the DemAF protocol can gain 6dB at SNR=10^{-3} with simple implementation, however its drawback is the error floor. Adopting the DAF protocol leads to a significant coding gain = 20 dB at SNR=10^{-3} and eliminating the error floor at the cost of increasing of complexity and time delay. To overcome this problem the adaptive LDPC was employed, the results shown that it can reduce the error floor, reducing the time delay and achieves an acceptable performance.

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