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A METHOD FOR CQI FEEDBACK BASED ON DISTRIBUTED COMPRESSED SENSING IN ADAPTIVE TWO-WAY RELAY SYSTEM

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ABSTRACT

In two-way relay wireless communication systems, adaptive modulation and scheduling are promising for increasing the system throughput. To achieve this goal, it is necessary to feedback the information of the channel quality indication (CQI). In this paper, we introduced a novel method for CQI feedback based on distributed compressed sensing (DCS) under orthogonal frequency division multiplexing (OFDM) system, and the feedback data are compressed and reconstructed using compressed sensing (CS) and DCS algorithm respectively. Simulation results shown that, compared with CS, DCS can significantly decrease the number of measurement under the same probability of recovery without increasing the complexity of terminals, and the throughput is increased, thus decreased the feedback expenses.

Keywords: *CQI, Two-way Relay, OFDM, Feedback Compression, Compressed Sensing (CS), Distributed Compress Sensing (DCS)*

1. INTRODUCTION

In recent years, wireless relay [1] communication has received extensive attention in wireless communication filed. As a core technology of modern communication systems, radio relay technology can effectively improve the transmission capacity and coverage of system. Adaptive modulation and scheduling are promising for increasing the system throughput in cooperative communication system. To apply suitable modulation and code scheme in two-way relay system under orthogonal frequency division multiplexing (OFDM) transmit technology, and considering apply adaptive scheme then the basestaion needs the channel information as signal-noise ratio (SNR) of all the sub-channels at every time. However, as to OFDM system, the amount of feedback data of channel quality indication (CQI) increases in proportional to the number of sub-carriers [2], which leads to large feedback expense, then it takes excessive key communication resources such as energy and bandwith. So it is necessary to compress the CQI, and researches on how to decrease the feedback expense have been a hot topic in recent years.

Data compressing plays effectively in decreasing feedback expenditure, three main compressive schemes for CQI are setting the optimal SNR threshold value of the scalar quantization method, scheduling with limited feedback based on the maximum signal to noise ratio and compressing based on lossy or lossless principle scheme [3]. Lossy compression of the CQI feedback schemes are mainly based on discrete cosine transform (DCT). In the OFDM system, the CQI feedback scheme Based on the DCT technology can reduce the amount of feedback data to the original by 2%~20% [4]-[5]. Using CS feedback method can significantly reduce the amount of feedback data [6]. Compressed sensing (CS) theory just about studying how to use the internal structure of single signal data to play compression coding and decoding, and only consider the signal correlation in time and frequency domain. Therefore, it is necessary to further use the spatial correlation of the multiple signals to study the distributed compress sensing (DCS) [7] algorithm. DCS theory fully using the sparse of multiple signal and spatial correlation between them. From Slepian-Wolf's information theory that the establishment of DCS in the observed rate theory, proved that the observed rate, lower bounds, and determine the DCS signal compression rate. Research has been made about environmental monitoring, MIMO communication and speech signal arrangement and so on, which

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constructed different joint sparse models [8]. By applying the DCS theory in wireless sensor network [9], the DCS theory presents advantage in safety, fault tolerance and adaptive channel capacity. Applying DCS scheme for feedback CQI in adaptive OFDM system obtain good performance [10].

In this paper, a new DCS method to feedback the CQI in adaptive two-way relay system is introduced. The proposed method utilizes the high degree of correlation of CQI between sub-carrier channels. The outline of the paper is as follows. In section 2 we present the property of wireless decaying channel. In section 3 we show the two-way relay system model. In section 4 the theory of compressive sensing is presented. In section 5 the proposed algorithm of OMP is characterized. DCS theory is shown in section 6, a sketch of sparse degree adaptive matching pursuit (SAMP) follows in section 7, corresponding simulation results are shown in section 8, and section 9 concludes the paper.

2. WIRELESS DECAYING CHANNEL

According to wireless communication theory, the impulse response of wireless time varying with multipath can be defined as follows

$$h(\tau, t) = \sum_{l=0}^{L-1} h_l(t)\delta(\tau - \tau_l(t)) \quad (1)$$

In (1) both $h_l(t)$ and $\tau_l(t)$ denote the complex gain of channel and the time decay of the l_{th} path relative to the first path delay at time t, and L is the number of paths arrived at the receiver. As the wireless channel is sparse and multipath, so we can play sample and compression simultaneously to obtain the CQI by CS process, which will largely reduce the expense of getting the channel information. Then we can simply apply DCS algorithm to recovery the information of channel state on the other terminal.

3. TWO-WAY RELAY SYSTEM MODEL

Consider a typical amplification forwarding Two-way relay transmission model of two subscribers, where relay is R, two users A and B send training sequence p_A and p_B to the relay R at the first slot respectively. The relay transmits the superimposed signal to terminals A and B at the second slot. The processing of exchanging information is show in Fig.1.

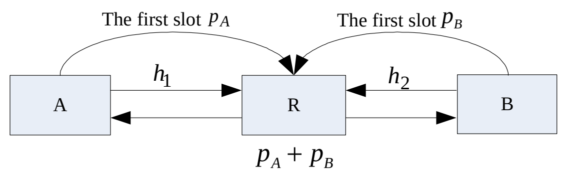

Fig.1 model of two-way relay system

We defined h_1 and h_2 as the sparse impulse response of the frequency-selective fading channels between terminals to relay. Without loss of generality, we only consider the feedback CQI of channel h_1, and we expect that the trend of h_2 will be the same, and The A, B all used OFDM multi-carrier transmission technology. Let P_1 P_2 and P_r be the average transmission power of terminals A, B and relay R respectively. The relay factor is α .We assume ideal synchronization among the three terminals. The received signal at A can be expressed as

$$y_A = \alpha h_1 y_R + n_R = \alpha\sqrt{P_B} h_1 * h_2 * p_B + \alpha\sqrt{P_1} h_1 * h_1 * p_A + \alpha h_1 * n_R + n_A \quad (2)$$

While n_R, n_A are the zero-mean complex valued AGWN vector of the relay and terminal A at the first slot and the second slot respectively. Let $H_1 = h_1 * h_1$ and $H_2 = h_2 * h_1$ are the convolution channel vector, and $n = \alpha n_R * h_1 + n_A$.

We assumed that $P_1 = P_2$, according to the random matrix theorem, system model can be simplified as liner matrix vector product form

$$y_1 = \alpha\sqrt{2P_1}(p_A * H_1 + p_B * H_2) + n \quad (3)$$
$$= \alpha\sqrt{2P_1}\, p * h + n$$

In (3) $p = [p_A, p_B], h = [H^T{}_1, H_2{}^T]$ then we can change the AF-TWRC feedback problem directly as P2P channel state feedback problem.

4. COMPRESSIVE SENSING THEORY

Aiming at sparse information, CS performs compression and sampling at the same time. The receiving terminal reconstructs the original information with high probability by optimal method.

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As to signal $x \in R^N$, it is sparse on the basis Ψ, S is its sparse representation, if S only has k non-zero components, and other $N-k$ are to be zero or its absolute value is very small, then signal X can be called as k - sparse signal. We can design a stable observation matrix $\Phi^{M \times N}$ $(M \prec N)$ not related to the transformation-basis to observe the vector S, define y as observation-values of S, and $y \in R^{M \times 1}$ is

$$y = \Phi x + e = \Phi \Psi s + e \qquad (4)$$

In (4) e is defined as noise. If $M \geq k \cdot \lg N$, and observation matrix under specified condition, then we can recover signal X by finding the optimal sparse solutions. For CS theory, the reconstruction algorithm is the core issue.

For observation-values under the ideal situation without noise, the idea of convex optimization algorithm to obtain the most sparse solution is by adding restrict, and the norm restrict is in common use. That is

$$\min \|x\|_p , s.t. y = \Phi x$$

(5)

However, this algorithm is very unstable, and it is NP problem, so in general, we convert to l_1 norm for solving this problem. The classical algorithms of CS theory for signal reconstruction are matching pursuit (MP) and orthogonal matching pursuit (OMP) and sparsity adaptive matching pursuit (SAMP) algorithm and so on.

5. ORTHOGONAL MATCHING PURSUIT (OMP) BASED ON CS

We presented orthogonal matching pursuit (OMP) algorithm to reconstruct the feedback CQI in CS scheme. In OMP algorithm, we define K as the channel sparsity, r_k and F_k represent the residue and the estimated signal's support (called finalist) respectively. The process of OMP algorithm is shown in Fig.2

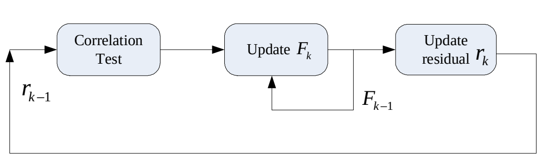


Fig.2 Conceptual Diagrams Of The OMP Algorithm

6. DISTRIBUTED COMPRESSIVE SENSING THEORY ALGORITHM

Distributed compressed sensing considering the correlation of multiple signals, Selection of different common components has different joint sparse effect. If we know each collective signal, then we can identify common components to make the sparse degree of joint sparse reach the minimum. The theory of DCS is built on joint sparse of signal set. Three patterns of joint sparse signal has been researched [7], and corresponding algorithms has been put forward to reconstitute the feedback CQI .Baron studied further about the autocorrelation and the cross correlation between multiple signal, and a model of distributed sparse signal compression perception.

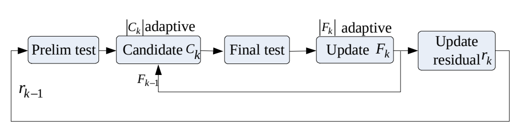
$$y_j = y\theta_j , j \in \{1,2,..., J\}, s.t\|\theta_j\|_0 = K$$

(6)

In (6) θ_j represents different signals at J common sparse position, and their zero norm values are equal to K, and J value got from the CS measurement matrix. DCS process reconstruction through jointly by the signal correlation. Study has been made that the reconstruction probability of DCS algorithms is higher than the individual reconstruction [8]. Applying DCS in wireless sensor network [9], and considering the spatial correlation between multiple signals, an algorithm based on DCS has been put forward to code D-value signal under no communication situation in different nodes. Compared with Separate reconstruction, DCS can jointly reconstruct signal group with less observed value, thus improve the efficiency of communication energy.

7. SPARSITY ADAPTIVE MATCHING PURSUIT (SAMP) BASED ON DCS

We introduced sparsity adaptive matching pursuit (SAMP) algorithm to reconstruct the feedback CQI. We define C_k represent the candidate set of the SAMP. Fig. 3 shows the process of SAMP.



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8. MODEL FOR SIMULATION AND CORRSPONDING RESULTS

In this paper, we considerate use OFDM transmit technology in two-way relay system, and study the channel CQI feedback of h_1 between terminal A and relay R. To verify our proposed feedback scheme, we make the following simulation of comparison between DCS and CS algorithm. In OFDM system, we set the frequency of sub-carrier at 5GHz, band is 20MHz, and the number of sub-carrier is 416 of each OFDM symbol, and 12 OFDM symbols included at each time slot. As for CS feedback scheme, the CQI is sparse on Fast IFFT transform, and applied Gauss stochastic matrix as measurement matrix. The CS applied OMP and DCS applied SAMP algorithm for reconstruction the CQI.

The feedback scheme based on CS can be expressed as follows: its coding and decoding process is shown in Fig.4.

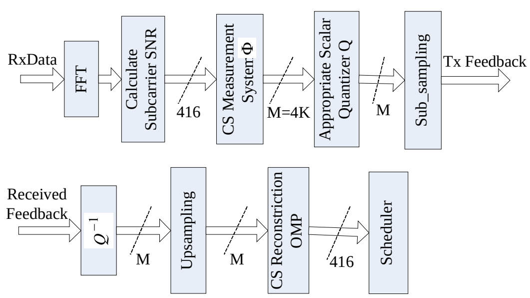

Fig.4 Process Of Coding And Decoding Of CS

In Fig.4 that M represent measurement values, and K is channel sparsity. We assured that the output of quantizer is5 bit, so the feedback is $5\times M$ bit. In this paper, we consider channel model of ITU Vehicular A, and the velocity of A is 75km/h. Power and delay are shown in table.1.

Table.1 Channel Parameters

path	1	2	3	4	5	6
delay/ μ_s	0	0.5	1	1.5	2	2.5
power/dB	0	-2	-4	-6	-8	-10

8.1 Recovery Probability Versus Measurement Value

We set J=30, then take reconstruction of CQI by CS, DCS scheme respectively, From Fig.5, Fig.6we can see that the performance of h_1 and h_2 channel feedback is nearly the same. we can see that reconstruction CQI through by CS method, each signal need about 80 measurement value to recovery, compared with CS, DCS just 30 then can reach the same result. So we can conclude that to feedback the same CQI value, the speed of feedback of DCS is just 37.5% to CS scheme. So to obtain the same recovery probability, Feedback CQI scheme by DCS algorithm has more practical meaning.

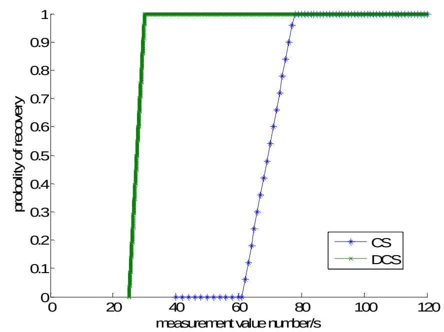

Fig.5 Recovery Probability Of Channel h_1

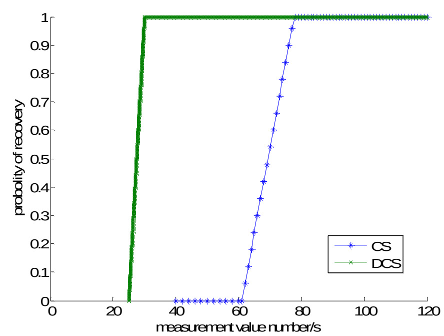

Fig .6 Recovery Probability Of Channel h_2

8.2 Throughput Versus Measurement Value

We consider the reconstruction throughput by CS, DCS feedback scheme, From Fig7, Fig.8 we can see that the performance of h_1 and h_2 channel feedback still nearly the same, when the measurement value is litter, the throughput of feedback method by DCS is increasing quickly with the number of measurement value, until reach the ideal value, in construct to DCS, the CS scheme still get lower throughput. Thus we apply DCS algorithm to reconstruct the feedback channel state information can contribute more throughput for two-way relay system under the same measurement value, which will largely reduce the CQI feedback expense.

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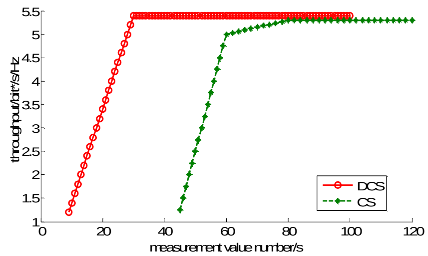

Fig .7 Throughput Of Channel h_1

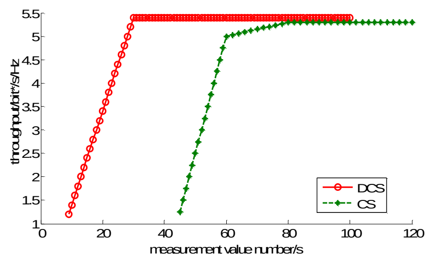

Fig .8 Throughput Of Channel h_2

9. CONCLUSIONS

In this paper, we presented a new method called SAMP algorithm based on DCS to feedback CQI of two-way relay system. Simulation results show that, compared with CS method, DCS can significantly decrease the number of measurement under the same probability of recovery without increasing the complexity of terminals, and the throughput is increased under the same measurement value, thus decrease the feedback expenses. Because of the time-vary characteristic of the wireless channel, the simulation results are not perfect. One important point of future work that is to seek more effective reconstruction algorithms for DCS scheme in feedback CQI filed. And to explore the usage of DCS scheme in other research filed.

10. ACKNOWLEDGEMENTS

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