International Journal of Applied Mathematics and Computing Science. Volume 4, Issue 1, (2015) 33-41
http://www.cayley-nielson.com/ijamcs

Interference Alignment Method in Pairing Virtual Systems for Virtual MIMO of LTE Uplink

Louise Jean[1,*], **Amy John**[2]
[1,2]Computer Science Department, Columbia University, 116th and Broadway, New York, NY 10027, USA
E-mail: [1]*LJean@columbia.edu*, [2]*AJohn@columbia.edu*

Abstract

In this paper, we consider that a virtual MIMO system for LTE uplink that uses the traditional 2×2 pattern, namely a two antennas' base station supports two single antenna's users simultaneously. This article proposed one kind of interference alignment algorithm for LTE MIMO based on the transmission time delay. This algorithm separates base station's receiving signal by odd time slot and even time slot, thus expected signal and unexpected signal are separated for UEs. A two antennas' base station may support 3 even 4 users simultaneously by using this algorithm to access the uplink LTE network.

Keywords: LTE; V-MIMO; Interference alignment.

1. Introduction

The fundamental targets for LTE concern increased data rates，improved system capacity and coverage range，reduced latency as well as reduced operator costs [1，2]. By adopting OFDM，MIMO and so on, new technology widely, the study of LTE technology is of great significance. The Multiple-inputs Multiple-output technology uses multiple transmission antennas and multiple receiving antennas to resist the influence of wireless fading channel [3-4] it provides a space diversity gain and enhances the system capacity and the frequency spectrum efficiency of the wireless communication system enormously. It is the key technology for next generation mobile communication.

LTE wireless communication system has used the MIMO technology most comprehensives by now. Compared with IEEE 802.16e, which only mainly used the space diversity technology, LTE has used every kind of MIMO transmission mode. The downlink MIMO mode of LTE include: transmission diversity, space multiplexing, beam forming and space division multiple access.

But in cellular mobile communication system, in order to use the space multiplexing or the space diversity gain of MIMO system effectively, spacing between antenna arrays must larger than coherent distance of channel. In practical application, we consider two antennas are non-correlated when the distance between them larger than half a wave. In the future mobile communication time, it will be universal that we demand the equipment smaller and lighter. Quantity of UE's antenna will be restricted, which causes MIMO technology's superiority difficult to be displayed completely in the uplink transmission [3-5]. LTE uplink MIMO mode limited by the quantity of terminal transmission antenna and transmission power amplifier has only supported the space division multiple access mode.

Virtual MIMO (V-MIMO) technology may solve the above technical bottleneck very well [5-6] V-MIMO is one kind of space division multiple access (SDMA) technology. V-MIMO permits two or more than two users to transmit data using the same time-frequency resources. This technology has already been adopted by WIMAX. It might match two UEs with single antenna into a pair dynamically, carry on the Virtual MIMO transmission. Such 2 UE whose MIMO channels have good orthogonal may

ISSN 2333-2425 /
March, 2015

be possible to share the same time/frequency resources to enhance the uplink system's capacity. In the LTE uplink transmission, we generally match 2 UE a pair to form 2×2 V-MIMO. Two UEs of a transmitting antenna each respectively, share the same time-frequency resources. These UEs use the mutual orthogonal reference signal atlas to simplify the base station processing. Looked from the UE angle, 2x2 V-MIMO is different from the single antenna transmission merely lying in the reference signal atlas must be pair with other UE. But looked from the base station angle, it is truly a 2×2 MIMO system. The receiver may examine these two UE transmission signal jointly.

Recently, interference alignment has been proposed to achieve the optimal degree of freedom in single-input single output (SISO) interference channel (IC) [6-20]. Some studies are to achieve the interference alignment in signal scale. For the interference alignment in signal scale, multi-user interferences at each receiver are aligned based on specific signal structures. The others are to achieve the interference alignment in signal space. For the interference alignment in signal space, transmit precoding technique is used to align the multi-user interferences, that is, to restrict all interference to the same signal space that is separate from the desired signal space at each receiver.

Interference alignment schemes are presented in [16-18] in the form of transmit precoding matrices with closed-form expressions. However, these closed form solutions require global channel knowledge and are only available in certain cases. Distributed interference alignment algorithms are presented in this paper, which require only local channel knowledge at each node.

In this work we provide the new interference alignment scheme for the LTE MIMO interference channel through joint transceiver design. Simulation results show that the new interference alignment scheme has the better performance than the existing interference alignment schemes.

2. Pairing users in V-mimo

As a result of that signal from different user passes through different channel, thus the mutual interference degree between the users is different. Therefore, only then through the effective user pairing process, can obtain system's multi-user diversity gain well, and cause the mutual interference between the pairing users to be smallest. These will guarantee wireless link transmission reliability after cooperation. Different pairing way will bring the pairing users different pairing interference which will thus create varying degree packet rate by mistake, therefore, we will also need to consider how to reduce the pairing interference. V-MIMO technology may enhance the throughput of system very greatly, but actual pairing strategy as well as how to assignment resources effectively for the pairing users all can have very tremendous influence to the system’s throughput. Moreover only we obtain a good compromised between the performance and complexity, then V-MIMO technology's superiority can display fully.

We suppose that there are one base station with two antennas and N users each one has one antenna. Then channel vector between the base station and the nth user’s transmitting antenna is

$$v_n = \begin{pmatrix} v_{n,1} \\ v_{n,2} \end{pmatrix} \tag{1}$$

When users are paired, the pairing V-MIMO matrix is (suppose user i pairs with user j)

$$H_v = \begin{bmatrix} h_{11} & h_{21} \\ h_{12} & h_{22} \end{bmatrix} = \begin{bmatrix} v_{i,1} & v_{j,1} \\ v_{i,2} & v_{j,2} \end{bmatrix} \tag{2}$$

The receiving signal is

$$y = \frac{1}{\sqrt{N_t}} H_v P^{1/2} x + z = \frac{1}{\sqrt{N_t}} Hx + z \tag{3}$$

$$x = \begin{pmatrix} x^{[1]} \\ x^{[2]} \end{pmatrix}, \ y = \begin{pmatrix} y^{[1]} \\ y^{[2]} \end{pmatrix}, \ P = diag[C^{[1]}, C^{[2]}] \tag{4}$$

And x is the normalized transmitting signal vector; y is the corresponding receiving signal vector; N_t and N_r are the number of transmitting and reserving antenna separately, here $N_t = N_r = 2$. H_v is a MIMO channel quick fading matrix order N_t by N_r; $C^{[k]}$ is the SNR of k th reference signal; $H = H_v P^{1/2}$ is channel matrix order N_t by N_r; z is noise vector with zero average value.

At present two traditional user pairing strategy are random pairing strategy and orthogonal pairing strategy. Random pairing strategy: At present this kind of pairing method is used quite common. It's merits are that the way of pairing users is simply, producing pairing user is random, computation complexity is low and computation load is small. Regarding to the random pairing user, the shortcoming is that it is possible to have a quite large interference as a result of channel correlation. Because of the correlation between resources assignment and pairing user, so the resources cannot be used effectively and the performance of system throughput is unable to achieve superiority.

Orthogonal pairing strategy chooses two users to pair whose channel orthogonality are the best. It computes the orthogonal factor and chooses the biggest. We make

$$F = H^H H = \begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} \tag{5}$$

Then we define

$$D = \frac{(f_{11} + f_{22}) - (f_{12} + f_{21})}{tr(F)} \tag{6}$$

Here, $tr(.)$ indicates matrix trace. D is orthogonal factor of the orthogonal pairing strategy. This method may reduce the pairing interference between users. But because of the large computation load for searching orthogonal users, it is too complex.

Several other kinds of pairing strategy for example: Based on path loss and slow decline sorting pairing method, based on path loss threshold V-MIMO and receiving diversity technology, based on channel condition and service type V-MIMO and diversity transmission and so on. All those method above also has shortcoming like that there are high channel correlation and quite big interference between pairing users. In view of this question, we proposed one kind of algorithm which is called the interference alignment to apply in uplink V-MIMO transmission LTE system.

3. Basic Principle of the Algorithm

We start from the simple situation to discuss first. Presently, actual V-MIMO is generally 2×2 pattern, namely a two antenna's base station simultaneously supports two single antenna's users. These compose the traditional 2×2 MIMO as shown in Figure 1.

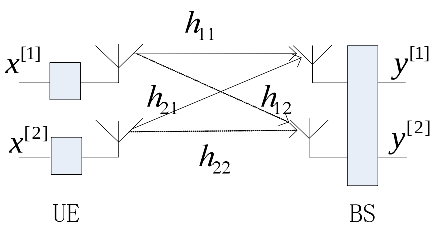

Figure 1. Traditional 2×2 V-MIMO

Two antennas $y^{[1]}$, $y^{[2]}$ of the base station receive two data packets $x^{[1]}$, $x^{[2]}$'s linear combination separately.

$$y^{[1]} = h_{11}x^{[1]} + h_{21}x^{[2]} \tag{7}$$

$$y^{[2]} = h_{12}x^{[1]} + h_{22}x^{[2]} \tag{8}$$

Base station may decode the receiving data packet $x^{[1]}$, $x^{[2]}$ simultaneously. In decoding process, we request the rank of channel matrix $H\begin{bmatrix} h_{11} & h_{21} \\ h_{12} & h_{22} \end{bmatrix}$ to be 2, namely we should select two single antenna users whose channel parameter must be non-correlated to compose a V-MIMO system. Well explaining as the front part, the existing user pairing strategy still has shortcoming like that there are high channel correlation and quite big interference between pairing users. In view of this shortcoming, we proposed one new transmission strategy based on interference alignment algorithm for uplink V-MIMO LTE system. This method does not have the request for UE's channel parameter. We can choose pairing users randomly. And a two antenna's base station can support three single antenna's user simultaneously to compose a V-MIMO system by applying this method. We said that this method is the interference alignment which achieves through the time delay.

Consider the 3×2 uplink V-MIMO LTE system shown in Fig 2, which are 3 users with single antenna and one base station with two antennas. In this wireless network there is a propagation delay associated with each channel. In particular, let us assume that the propagation delay is equal to one symbol duration for all desired signal paths and two symbol durations for all paths that carry interference signals. The channel output at receiving antenna $k \in \{1,2\}$ are defined separately as (9), (10).

$$\begin{aligned} y^{[1]}(n) = h_{11}x^{[1]}(n-1) + h_{21}x^{[2]}(n-2) + \\ h_{31}x^{[3]}(n-2) + z^{[1]}(n) \end{aligned} \tag{9}$$

$$\begin{aligned} y^{[2]}(n) = h_{12}x^{[1]}(n-2) + h_{22}x^{[2]}(n-2) + \\ h_{32}x^{[3]}(n-1) + z^{[3]}(n) \end{aligned} \tag{10}$$

where during the nth time slot (symbol duration) transmitter $j \in \{1,2,3\}$ sends symbol $x^{[j]}(n)$ and $z^{[j]}(n)$ is i.i.d. zero mean unit variance Gaussian noise (AWGN). All inputs and outputs are complex. Now, with all the interferers present, suppose each transmitter transmits only during odd time slots and is silent during the even time slots. Let us consider what happens at antenna 1of the base station. The symbols sent from its desired transmitter (transmitter 1) are received free from interference during the even time slots and all the undesired (interference) transmissions are received simultaneously during the odd time slots. Thus, we separate the receiving single to even time slots receiving single and odd time slots receiving single. For antenna 1 of the base station, we can define them as (11), (12)

$$y^{[1]}(n_e) = h_{11}x^{[1]}(n-1) \tag{11}$$

$$y^{[1]}(n_o) = h_{21}x^{[2]}(n-2) + h_{31}x^{[3]}(n-2) \tag{12}$$

As the same, even time slots and odd time slots receiving single at antenna 2 of the base station can also be defined as (13), (14)

$$y^{[2]}(n_e) = h_{32}x^{[3]}(n-1) \tag{13}$$

$$y^{[2]}(n_o) = h_{12}x^{[1]}(n-2) + h_{22}x^{[2]}(n-2) \tag{14}$$

We may see from the formula above that it is easy to decode the receiving signal when we separate the receiving signal time slot into odd time slot and even time slot. From the formula (11) and (13), we may decode the sending signal $x^{[1]}$ and $x^{[3]}$ directly, certainly, this can be worked out only in the situation that the channel parameters h_{11} and h_{32} are already estimated. Then, we substitute $x^{[3]}$ into formula (12) or substitute $x^{[1]}$ into formula (14). Choosing one formulas from (12) and (14) can decode the signal $x^{[2]}$. Therefore, decoding three user's data packets simultaneously also only need to estimate 4 channel parameters then, namely, h_{11}, h_{32}, h_{21}, h_{31} or h_{11}, h_{32}, h_{12}, h_{22}.

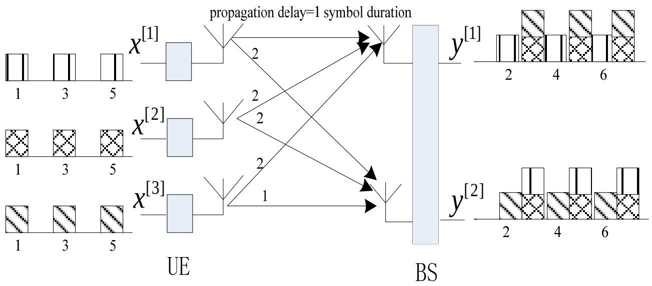

Figure 2. 3×2 V-MIMO using propagation delay

Compared with the traditional 2×2 V-MIMO, this kind of method which separates the time slot into odd time slot and even time slot by using time delay will be wonderful to separate the wanted signal and the interference signal. This method has these following merits. First, it can support more users to transmit data packets simultaneously, and also achieve 3×2 V-MIMO. Secondly, it is random to choose the single antenna pairing user. This avoids the complex pairing strategy and does not have the request for pairing user's channel parameter. Thirdly, supporting more users at the same time has not increased the quantity of channel parameter estimation. 3 users still only needed to estimate 4 channel parameters. It is possible to see form the analysis above, in fact 3 users have only used the odd time slot to transmit data packets, but the even time slot was idle, namely, average every two time slots altogether transmits 3 data packets. But the traditional 2×2 V-MIMO is every two time slots altogether transmits 4 data packets. Although this method has merits as stated above, it causes the throughput of the system in fact dropped. In order to solve this problem, we make a improvement to the algorithm as follows.

4. Improved Algorithm

We let the number of uplink users increasing to 4; namely, compose 4×2 V-MIMO system, as shown in

Figure 3.

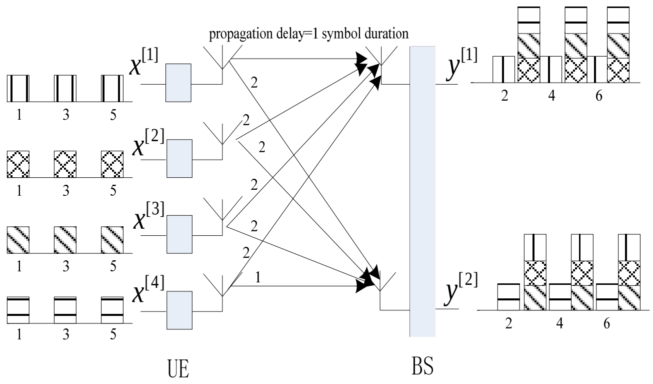

Figure 3. 4×2 V-MIMO using propagation delay

As the front analysis, we express the channel output at receiving antenna $k \in \{1,2\}$ separately as (4-1), (4-2)

$$y^{[1]}(n) = h_{11}x^{[1]}(n-1) + h_{21}x^{[2]}(n-2) + h_{31}x^{[3]}(n-2) + h_{41}x^{[4]}(n-2) + z^{[1]}(n) \tag{15}$$

$$y^{[2]}(n) = h_{12}x^{[1]}(n-2) + h_{22}x^{[2]}(n-2) + h_{32} x^{[3]}(n-2) + h_{42}x^{[4]}(n-1) + z^{[4]}(n) \tag{16}$$

Then we separate the receiving signal by odd time slot and even time slot. We write:

$$y^{[1]}(n_e) = h_{11}x^{[1]}(n-1) \tag{17}$$

$$y^{[1]}(n_o) = h_{21}x^{[2]}(n-2) + h_{31}x^{[3]}(n-2) + h_{41}x^{[4]}(n-2) \tag{18}$$

$$y^{[2]}(n_e) = h_{42}x^{[4]}(n-1) \tag{19}$$

$$y^{[2]}(n_o) = h_{12}x^{[1]}(n-2) + h_{22}x^{[2]}(n-2) + h_{32}x^{[3]}(n-2) \tag{20}$$

Obviously, we can decode $x^{[1]}$ and $x^{[4]}$ from formula (4-3) and (4-5) directly. Substitute the decoded data packets $x^{[1]}$ and $x^{[4]}$ into formula (4-4) and (4-6) to cancel directly, then we receive:

$$y^{[1']}(n_o) = h_{21}x^{[2]}(n-2) + h_{31}x^{[3]}(n-2) \tag{21}$$

$$y^{[2']}(n_o) = h_{22}x^{[2]}(n-2) + h_{32}x^{[3]}(n-2) \tag{22}$$

The above equation is similar with traditional 2×2MIMO, so long as rank of channel matrix $H\begin{bmatrix} h_{21} & h_{31} \\ h_{22} & h_{32} \end{bmatrix}$ is 2, namely, so long as founding two users whose channel parameters are non-correlated, we might decodes $x^{[2]}$ and $x^{[3]}$ simultaneously. Therefore, this kind of 4×2 V-MIMO system only needs to find two optimal pairing users according to the traditional LTE uplink user pairing strategy and moreover select other two users randomly. These four single antenna users and the base station will compose a V-MIMO system which can decode 4 data packets simultaneously. Compared with the traditional 2×2V-MIMO, this algorithm has supported more users and has not reduced system's throughput.

5. Simulation and Conclusion

Because this proposed algorithm does not have the request for pairing user’s channel matrix correlation. So we simulate the difference between the traditional V-MIMO and the proposed V-MIMO algorithm, when the pairing users are selected randomly, namely the channel matrix is random. In Figure 4, we simulate the real transmitting signal value; restorative transmitting signal value when selecting the pairing users randomly, namely the channel matrix is random; and the restorative transmitting signal value when the channel matrix is high correlated, namely orthogonal factor is small. Obviously channel matrix’s correlation has affected the signal restoration. When channel matrix has high correlation, the difference between real transmitting signal value and restorative transmitting signal value is also big.

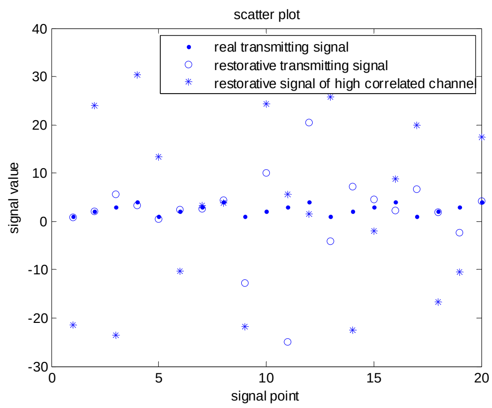

Figure 4. Influence of channel matrix correlation

In Figure 5 and Figure 6, we simulate the difference between real transmitting signal value and restorative transmitting signal value, when the pairing users are selected randomly, namely the channel matrix is random. Obviously in Figure 5, of the traditional V-MIMO system, the real transmitting signal value has certain difference to the restorative transmitting signal value. But in Figure 6, difference between the real transmitting signal value and the restorative transmitting signal value is small by applying our proposed algorithm.

Thus we may know, our proposed algorithm is more optional to user’s selection and the signal restoration quality does not rely on pairing users’ channel matrix correlation, namely it does not need pairing strategy or only some partial users need to apply pairing strategy.

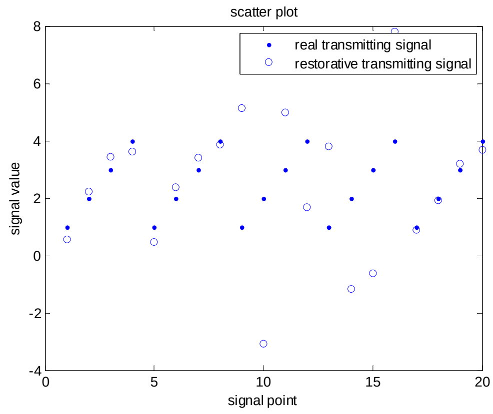

Figure 5. Traditional V-MIMO system

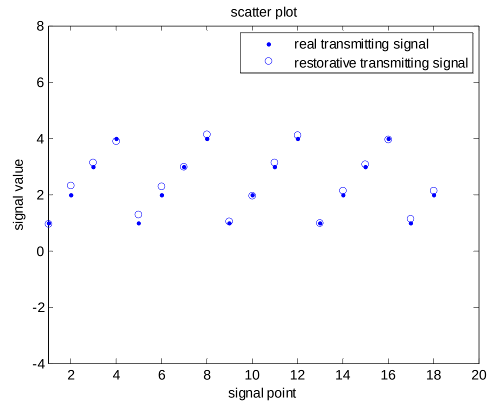

Figure 6. Applying proposed algorithm

References

[1] 3GPP TS 36．211version 10.0.0 Release 10, Evolved Universal Terrestrial Radio Access (E—UTRA):Physical channels and modulation.

[2] 3GPP TS 36．213 version 10.0.1 Release 10, Evolved Universal Terrestrial Radio Access(E—UTRA):Physical 1ayer procedures.

[3] Liu, J., Hu, S. H., Xiao, Y., Liu, X. L., Lee, M. H., Kim, K. S., “The Differential Transmitter and Receiver for Cognitive MIMO Systems”, IET 3nd International Conference on Wireless, Mobile and Multimedia Networks, (ICWMMN 2010), (2010): 122-125.

[4] Adhikary, Ansuman, and Giuseppe Caire. "On the coexistence of macrocell spatial multiplexing and cognitive femtocells." Communications (ICC), 2012 IEEE International Conference on. IEEE, 2012.

[5] Zhang, Ying-Kang, and Yang Xiao. "An Efficient SDMA Scheme Applied in Hot Spots Using Uniform Circular Array." 2010 IEEE Int ernational Symposium on Circuits and Systems (IEEE ISCAS 2010). 2010.

[6] Ngo, Hien Quoc, Thomas L. Marzetta, and Erik G. Larsson. "Analysis of the pilot contamination effect in very large multicell multiuser MIMO systems for physical channel models." Acoustics, Speech and Signal Processing (ICASSP), 2011 IEEE International Conference on. IEEE, 2011.

[7] Cadambe, Viveck, Syed Ali Jafar, and Shlomo Shamai. "Interference alignment on the deterministic channel and application to fully connected AWGN interference networks." Information Theory Workshop, 2008. ITW'08. IEEE. IEEE, 2008.

[8] Zarifi, Keyvan, Ali Ghrayeb, and Sofiène Affes. "Jointly optimal source power control and relay

matrix design in multipoint-to-multipoint cooperative communication networks." Signal Processing, IEEE Transactions on 59.9 (2011): 4313-4330.

[9] Pantisano, Francesco, et al. "Interference alignment for cooperative femtocell networks: A game-theoretic approach." Mobile Computing, IEEE Transactions on 12.11 (2013): 2233-2246.

[10] Jungnickel, V., et al. "Demonstration of virtual MIMO in the uplink." IET Smart Antennas and Cooperative Communications Seminar. 2007.