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A Feature Analysis of MIMO Techniques for Next Generation Mobile WIMAX Communication Systems

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Abstract:

IEEE 802.16m (WIMAX) is a developing standard aiming next generation wireless systems (4G). In this standard, MIMO plays an important role in meeting the 4G requirements. Large number of MIMO techniques have been established for different links and with various amounts of available channel state information in IEEE 802.16e/m standard. This article offers review of the MIMO techniques in the IEEE 802.16e/m standard. This paper provides a comprehensive overview of critical developments in the field of multiple inputs multiple output (MIMO) wireless communication systems for next generation WIMAX networks. This paper throws light on transit diversity scheme for MIMO systems. Further, 2x2 Spatial multiplexing technique is elaborated and lastly various MIMO detection Techniques like V-blast, zero forcing and sphere decoding techniques are revisited.

Key words: MIMO, MIMO Diversity, Multiplexing, WiMAX

1. Introduction

MIMO systems for next generation wireless communication networks have been a major research interest for the last few years [1]. The use of several antennas at the receiver and the transmitter sides can considerably improve the channel capacity and data rate [2]. Many schemes have been suggested to explode the high spectral efficiency of MIMO channels, among which V-BLAST [3] is comparatively simple and easy to implement and can attain a large spectral efficiency. V-Blast is described quite in detail in this paper. Modern multiple antenna systems can be designed to take benefit of multipath as compared to traditional single antenna systems. When WIMAX is used in combination with multiple antenna systems, the throughput and rectification of error rate performance is improved by taking advantage of multipath effect.

Multiple-input multiple-output (MIMO) techniques are vital for achieving the minimum target cell spectral efficiency, peak spectral efficiency, and cell edge user spectral efficiency defined by the ITU.

Division of this paper is in two sections: the first section describes diversity and multiplexing schemes for WIMAX MIMO systems while the other section looks for different MIMO detection schemes.

2. Transit Diversity Scheme:

One of the WiMax arrangement profiles is the easy STC scheme counseled by Alamouti [4] for sending diversity on the downlink. In the IEEE 802.16e-2005 specifications, this scheme is devoted to as Matrix A. Originally, Alamouti's send diversity was counseled to circumvent the use of accord diversity and retain the subscriber stations simple. This method is requested subcarrier by subcarrier and can be described in Fig. 2.0
As follows:

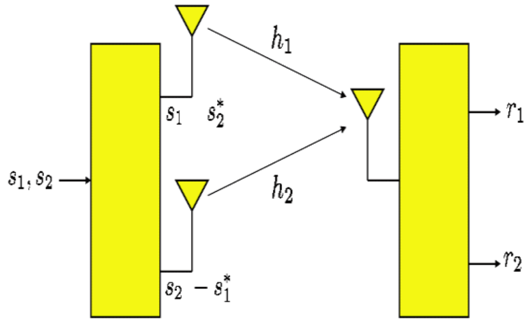

Fig. 2.0 Schematic block diagram of Alamouti's transmit diversity

Let's us assume that s_1 and s_2 are bit symbols of couple of consistent bit symbols of stream corresponds to input that will be transmitted at particular time period t_{21}transmission output at data at antenna element 1 transmits bit symbol s_1, the output of the antenna element2 it TX transmits bit symbol s_2, after the first interval when second interval starts, antenna element 1 transmits s_1* and antenna element transmits s_2*, channel responses are represented as h_1 and h_2. The receiver response can written as equation (1) and (2)

$$r_1 = h_1 s_1 + h_2 s_2 + n_1 \qquad (1)$$

$$r_2 = h_1 s_2^* - h_2 s_1^* + n_2 \qquad (2)$$

Here n_1 and n_2 corresponds to additive noises

$$x_1 = h_1^* r_1 - h_2 r_2^* = \left(|h_1|^2 + |h_2|^2\right) s_1 + h_1^* n_1 - h_2 n_2^* \qquad (3)$$

$$x_2 = h_2^* r_1 + h_1 r_2^* = \left(|h_1|^2 + |h_2|^2\right) s_2 + h_2^* n_1 + h_1 n_2^* \qquad (4)$$

The above equation express that the variable x_1 and x_2 provided to the threshold detector in order to determine the bit symbol s_1 and s_2 having no inference among them, further, here the signal coefficient is cumulative response of the secure modulus of couple of fading channels, this provides the optimum diversity of second order equals the receiver diversity having maximum ratio of combining.

Samples of received signal can be represented as in equation (4) and (5).

$$r_{11} = h_{11}s_1 + h_{12}s_2 + n_{11} \quad (5)$$

$$r_{12} = h_{11}s_2^* - h_{12}s_1^* + n_{12} \quad (6)$$

For antenna element 1 at receiver side presented in equations (7) and (8)

$$r_{21} = h_{21}s_1 + h_{22}s_2 + n_{21} \quad (7)$$

$$r_{22} = h_{21}s_2^* - h_{22}s_1^* + n_{22} \quad (8)$$

In case of second receiving antenna. H_{ji} the responses of the channel originates from TX_i to Rx_j, having the values I_j, = 1, 2 n_{ji} shows the channel noises,

This proceeding don't provides the gain of spatial multiplexing gain but the diversity having the diversity level of 4, that is fully recoverable. Symbols s1 and s_2 are terminated by the receiver by using equations (9) and (10)

$$x_1 = h_{11}^* r_{11} - h_{12} r_{12}^* + h_{21}^* r_{21} - h_{22} r_{22}^* = \left(|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2\right)s_1 + h_{11}^* n_{11} - h_{12} n_{12}^* + h_{21}^* n_{21} - h_{22} n_{22}^* \quad (9)$$

$$x_2 = h_{12}^* r_{11} + h_{11} r_{12}^* + h_{22}^* r_{21} + h_{21} r_{22}^* = \left(|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2\right)s_1 + h_{12}^* n_{11} + h_{11} n_{12}^* + h_{22}^* n_{21} + h_{21} n_{22}^* \quad (10)$$

Above equations shows the at 2x2 mimo diversity system at fourth order signal is fully recoverable in this case MRC suffered from interference in this way tradeoff between interference and diversity gain should be addressed.

2.1. 2x2 spatial multiplexing scheme

Another efficient multi antenna system in WiMAx is 2x2 mechanism, which is based upon the matrix B=(s_1,s_2) , it does perform spatial multiplexing but does not provide the gain at Tx antenna element. It also provides the diversity gain a receiver side when maximal likelihood detection.

In order to define this scheme we have to use frequency and time domains except space domain. Scattering coefficients s1 and s_2 are transmitted Tx_1 and Tx_2 . hij corresponds to the channel response From the transmitter Tx_I to receiver Rx_j , thus two Rx antennas receives the signal

$$r_1 = h_{11} s_1 + h_{12} s_2 + n_1 \qquad (11)$$

$$r_2 = h_{21} s_1 + h_{22} s_2 + n_2 \qquad (12)$$

$$\begin{pmatrix} r_1 \\ r_2 \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix} \begin{pmatrix} s_1 \\ s_2 \end{pmatrix} + \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} \qquad (13)$$

The detector decides the appropriate symbol values for the scattering symbols and s_2 that provides the reduction in the Euclidean Distance

$$D(s_1, s_2) = \left\{ |r_1 - h_{11} s_1 - h_{12} s_2|^2 + |r_2 - h_{21} s_1 - h_{22} s_2|^2 \right\} \qquad (14)$$

The complexity of the detector depends upon the signal overlapping size and makes it use for implementable applications. [5-7]

3. MIMO Detection Schemes

Detection of the signal in the MIMO systems is an important in aspects to the receiver and transmitter sides of the system. MIMO systems converts a data stream into multiple data streams, hence each data stream is independently modulated and demodulated at the transmitter and receiver side of the system .The MIMO signals are transmitted through separate antennas which operate at the same frequency .When transmitted data streams reaches at the receiver they are separated using MIMO algorithms and principals that depend on estimates of all channels between the transmitter and each receiver.

V-BLAST (Vertical-Bell Laboratories Layered Space-Time) a detection algorithm for MIMO systems firstly identifies the signal with Highest SNR; afterwards it regenerates the received signal from some pre- available decision. Then, the signal rejuvenated and the received signal are subtracted and with this new sign; signal proceeds to the discovery of the second most dominant signal,. The process gives a smaller amount of interference to a received vector [8].

3.1 V-BLAST Technique

A data stream is demultiplexes into M sub-streams layers. The layers are settled parallel across time and space for V-BLAST and the cycling process is detached before transmission as depicted by the Fig below. At each receive antenna received signal is a superposition of additive white Gaussian noise (AWGN) plus M faded symbols.

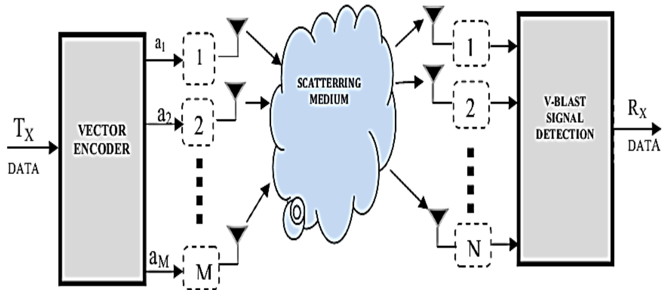

Fig. 3.0 Block Diagram of V-BLAST Architecture

Two main operations of detection process are:

1) Nulling (interference suppression): before normal detection of the first symbol, nulling operation suppresses interference by projecting the received vector onto the null subspace (perpendicular subspace) of the subspace spanned by the interfering signals.

2) Interference cancellation
(Subtraction): identified symbol contribution is deducted from the received vector. BLAST algorithm combines nonlinear (serial cancellation) and linear (interference suppression) algorithms. Propagation of decision errors is a drawback of V-BLAST algorithm. Additionally, initial identified symbols profit from lower receives diversity than advanced ones due to the interference suppression. Therefore, the procedure results in uneven diversity benefit for each symbol.

A small number of differences among D-BLAST (diagonal – Blast) and V-BLAST exists. D-BLAST is used with coded layers While V-BLAST layers can be encoded or coded. That is why cycling is used, providing added spatial diversity for each layer mainly over channels that are fading slowly. More, diagonal structure of D-BLAST makes each layer benefit from the same diversity advantage while unequal diversity advantages are attached with V-BLAST. However, D-BLAST for optimizing the performance of the code across time and space requires advanced inter-stream coding techniques. For D-BLAST some space-time is lost at start and the end of the burst. V-BLAST takes a single data stream and demultiplexes it into M sub-streams where M is no. of antennas (transmitter). Every sub-stream is fed to a separate transmitter after encoding into symbols. M Quadrature Amplitude Modulation (MQAM) is usually the method of modulation used in these systems. Phase modulation is combined with amplitude modulation in QAM, hence transmitting data over a limited bandwidth channel efficiently. BLAST's receivers function co-channel, all receiving the signals originating from all M of the transmitting antennas.

There are different models and algorithms which are used for the detection and estimation of the received signal. First model which is useful for the detection in MIMO is the Maximum Likelihood detection and estimation has been determined which gives optimum results in term of the low error in the probability of detain of combined signal. The Maximum Likelihood detection is applied with the help of brute force search over all of the possible transmitted vectors. The computational complexities of optimal models are generally exponential and impractical. For a constellation size of M and k users, Maximum Likelihood decoding will involve searching and evaluating over Mk possible vector for calculations. This disadvantage encouraged the interest in the implementation of suboptimal detection algorithms.

The linear receivers which can be implemented are the matched filter, the decor relator or zero forcing, the minimum mean squared error detectors, decision feedback equalization and the semi definite relaxation detector. Two of the estimation and detection schemes more efficiently used are namely Zero Forcing and Sphere Decoding. [9]

3.2 Zero Forcing

The most efficient and linear scheme used for the estimation and detection is zero forcing which gives optimal results in the MIMO systems .The receiver with the Zero forcing detector uses the estimated channel matrix to detect and estimate the transmitted signal.[10]

The following equation is helpful for the calculation of the matrix

S = (HHH) -1 HH **y** = H+ **y** (15)

Where;

HH is called Hermitian conjugate
H+ is called the Pseudo inverse

Each element of S estimated to the nearest point in the vector constellation diagram. The output of the filter is thus only a function of the symbol to be detected and the noise, this output is then fed into the decoder which estimates the transmitted symbol.

3.3 Sphere Decoding (SD)

The sphere decoding is one of the excellent searching and estimating algorithms used along with Maximum Likelihood. The major disadvantage of the Maximum Likelihood is the complexity involved in calculation of the all possible vector candidates along with the many of them are not correctly placed at the desired position. This is attributable to the effect of the Gaussian distribution of noise, which makes code words that are far away from the received vector much less probable than code words close to the received vector.

The major idea which leads the sphere decoding is the searching the appropriate candidate location within the radius of sphere .the radius of sphere is given Z as shown in the below diagram. The sphere decoder proposes a very efficient method of identifying candidates in the sphere. [11]

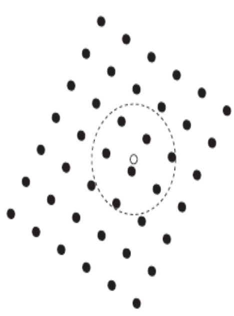

Fig.3.1. the sphere of radius Z for sphere decoding Algorithm

Conclusion:

In this article various MIMO techniques are reviewed, which are adopted or are under development in IEEE 802.16m standard. Different MIMO techniques were reviewed in depth. It is concluded that very good MIMO techniques are established and some promising technologies in stream line for next generation WIMAX Networks.

BIBLIOGRAPHY:

Alamouti, Siavash M. 1998. "A simple transmit diversity technique for wireless communications." *Selected Areas in Communications, IEEE Journal on* 16(8): 1451-1458. [4]

Damen, Oussama, Ammar Chkeif, and J-C. Belfiore. 2000. "Lattice code decoder for space-time codes." *Communications Letters, IEEE* 4(5): 161-163. [6]

Li, Xiaodong, et al. 2000. "Effects of iterative detection and decoding on the performance of BLAST." *Global Telecommunications Conference, 2000. GLOBECOM'00. IEEE*. Vol. 2. [1]

Telatar, Emre. 1999. "Capacity of Multi-antenna Gaussian Channels." *European transactions on telecommunications* 10(6): 585-595. [2]

Park, S., H. Zhang, W.H. Hager, and D.S Han. 2007. “Box constrained optimization for signal detection in MIMO channels.” In *Korean Society for Industrial and Applied Mathematics*, KSIAM 2007, Korea. [9]

Qinghua, L., L. Guangjie, L. Wookbong, L. Moon-il, D. Mazzarese, B. Clerckx, and L. Zexian. 2010. “MIMO techniques in WiMax and LTE: A feature overview.” in *IEEE Communications Magazine* 48: 86 –92. [11]

Studer, C., A. Burg and H. Bölcskei. 2008. “Soft-output sphere decoding: algorithms and VLSI implementation.” *IEEE Journal on Selected Areas in Communications* 26(2): 250 – 299. [10]

Tse, David. 2005. *Fundamentals of wireless communication*. Ed. Pramod Viswanath. Cambridge University Press. [7]

Viterbo, Emanuele, and Joseph Boutros. 1999. "A universal lattice code decoder for fading channels." *Information Theory, IEEE Transactions on* 45(5): 1639-1642. [5]

Wolniansky, P. W., G. J. Foschini, G. D. Golden, R. A. Valenzuela. 1998. "V-BLAST: An Architecture for Realizing Very High Data Rates Over the Rich-Scattering Wireless Channel". *Proc. URSI ISSSE*: 295–300[8]

Wolniansky, Peter W. et al. 1998. "V-BLAST: An architecture for realizing very high data rates over the rich-scattering wireless channel." *Signals, Systems, and Electronics, 1998. ISSSE 98. 1998 URSI International Symposium*. IEEE. [3]