Performance Analysis of Space-frequence Block Coded WiMax Services

Chia-Sheng Tsai, Chao-Wei Chang
Computer Science and Engineering, Tatung University
40 ChungShan North Road, 3rd Section Taipei 104, R.O.C., cstsai@ttu.edu.tw

Abstract

The worldwide interoperability for microwave access (WiMAX) is a new candidate for next generation wireless access techniques. The characteristics of the high data-reception rates and wide radio coverage can offer good solution for "last mile" services. However, this OFDM-based system can be further improved by the MIMO architecture which was little discussed in the literature. Therefore, in this paper, we try to combine the WiMAX system with space-frequency block coding (SFBC) scheme. The simulation results reveal that the proposed system can achieve better performance than traditional architecture specified in the IEEE 802.16 standard.

Key words: WiMAX, MIMO-OFDM, SFBC

1. INTRODUCTION

The wireless communications bring more convenient life for people. The third generation (3G) service is a large coverage which is positioned at wireless wide area network (WWAN), but the transmission speed is not enough for the large data of exchange. The wireless fidelity (Wi-Fi) is a maturity technique, which provide the wireless local area network (WLAN) and also practice for several years. Even though the Wi-Fi can offer the high transmission speed, but the coverage range of Wi-Fi is small (about 30-100 meters) and Wi-Fi does not provide a good solution for hand over [12]. On the other reason, to build a network system at remote districts or lack of network areas is difficult and the cost of wiring is high. Hence, the existed systems are not enough to satisfy for people's requirement. Therefore, the WiMAX comes with the tide of demand. It positions at wireless metropolitans area network (WMAN) and provides a good solution for the "last miles" problem. Because of its high speed (about 70 Mbps) and wide coverage (about 50 kilometers), it can reduce the cost and complexity efficiently compared with deploy wired network. And the 802.16e, which focus the mobility of WiMAX, is also support about 70 km/hr and better solution for hand over problem.

However, the performance of OFDM-based systems can be enhanced by other diversity techniques, multiple-input multiple-output (MIMO) [5-11], especially. In this paper, we implement the WiMAX and combine which the SFBC. We analyze the performance of the systems and show the results.

The WiMAX system provides five air interfaces which are listed in Table 1. In this paper, we implement the downlink frame of WirelessMAN-OFDM with TDD mode in our simulation model.

TABLE.1. THE FIVE AIR INTERFACES IN WIMAX

Designation	Applicability	Duplexing mode
WirelessMAN-SC	10-66 GHz	TDD or FDD
WirelessMAN-SCa	Below 11 GHz Licensed band	TDD or FDD
WirelessMAN-OFDM	Below 11 GHz Licensed band	TDD or FDD
WirelessMAN-OFDMA	Below 11 GHz Licensed band	TDD or FDD
WirelessHUMAN	5-6 GHz License-exempt band	TDD

The different interfaces were focused on different application. For example, the 10-66 GHz band of WiMAX was the first drew up standard. It is suited for point-to-multipoint access, i.e. serving applications from small network area to the large network area. It is due to the bandwidths with single carrier modulation about 25 MHz or 28 MHz and the data rates in excess of 120 Mb/s. In high band channel, because of the wavelength is short, the line-of-sight (LOS) is required and multipath is negligible. In the other words, the wavelength in low band channel environment is longer and the bandwidth is smaller, so the LOS is not necessary and multipath may be significant. In this scheme, it support near-LOS and non-LOS (NLOS) but the additional functionality physical layer is required. The structure of this paper was layered as following. In section 2, we described the system model and the frame structure and the symbol allocation scheme in an OFDM symbol. In section 3, we described the decoding process of the SFBC-OFDM. In section 4, we show the parameter settings and simulation results in here. Finally, our conclusions were described in section 5.

2. THE SYSTEM MODEL

Figure 1 shows an original WiMAX system. At First, the data input into forward error control (FEC) that composes of a convolutional encoder and puncture. After punctured, the data stream transform into complex signals by modulation and serial-to-parallel out. Thereupon, modulated symbols transform into parallel form and then perform IFFT operations and then outputs data in serial form. Finally insert cyclic prefix and transmits the signals.

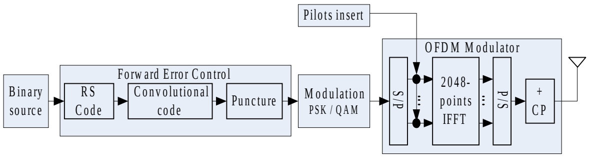

Fig. 1: The general WMAN-OFDM system

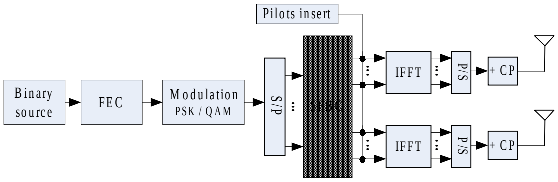

Fig. 2: The extended system

Furthermore, we extended the WiMAX to MIMO-WIMAX. In the standard of WiMAX, it is use the space-time coding (STC) for the MIMO architecture. In this paper, we deploy SFBC encoder (Alamouti code) between the modulation and IFFT as show in figure 2. This architecture is a kind of MIMO-OFDM that had been discussed in [4-11]. Alamouti proposed two schemes to allocate symbols for MIMO that are STC and SFC [3]. K.F. Lee and D.B. Williams proposed the STBC-OFDM and SFBC-OFDM [5]. In this paper, we also used SFBC to combine with the WiMAX rather than STBC. At the other scheme, SFBC, the scheme was depicted in figure 3.

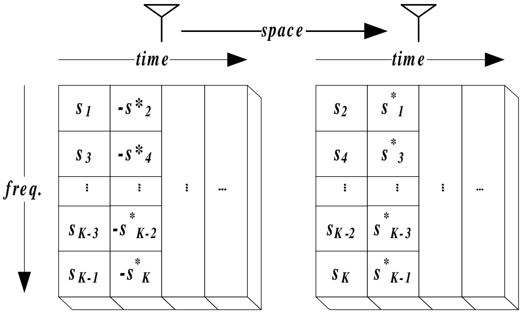

Fig. 3: The symbol allocation scheme of SFBC-OFDM

The bit stream as a vector per K data, which K denotes the number of data subcarriers (not include pilot subcarriers) was collected in an OFDM system. So the data vector before Alamouti encoder was represented as $[s_1, s_2\ldots s_K]^T$, the suffix of the s is i-th bit index and T denotes the transpose of the vector. After the SFBC encoder, the pilot subcarriers were inserted and we explain the rule later.

At the first step, we discuss the symbol allocation in SFBC encoder. We spread original symbol over different antennas as well as STBC. At the same symbol period, we spread diversity symbol on adjacent subcarriers in frequency domain. And then, we placed the new symbol-pair on the next adjacent subcarriers at the same symbol period. That is using two adjacent subcarriers to replace the two adjacent symbol periods. Note that the difference between the STBC and SFBC is that the diversity symbol is allocated on the adjacent symbol period at STBC scheme which was depicted in figure 4.

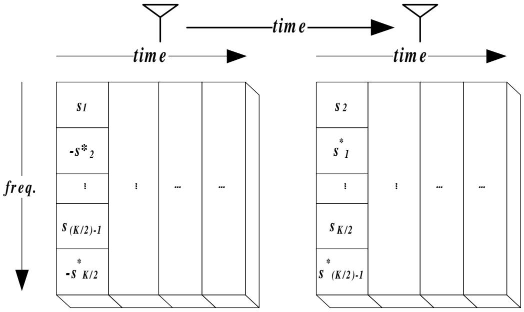

Fig. 4: The symbol allocation scheme of STBC-OFDM

In the SFBC-OFDM, the decoding process can be performed in each symbol period. In the STBC-OFDM, the decoding is performed per two symbol period. In the other words, the decoding latency of SFBC-OFDM is less than STBC-OFDM. It is because the STBC-OFDM needs two symbol periods to collect enough and perform the MIMO decoder. Furthermore, the memory cost of STBC-OFDM is less than SFBC-OFDM. In figure 3, SFBC-OFDM needs to keep 2×K data and then decode STBC. However, SFBC-OFDM just needs K data to decode the SFBC. On the throughput viewpoint, the SFBC-OFDM is equal to the STBC-OFDM. Both of them are produce K data over two symbol periods.

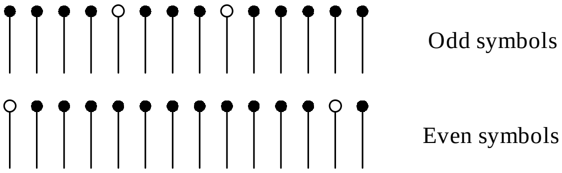

Fig. 5: The allocation of pilot subcarrier in PUSC symbol

Each OFDM symbol includes pilot subcarriers which is show in figure 5. The pilot insert into each OFDM symbol following the rule which is group of 14 subcarriers and each group include 2 pilot subcarriers. In figure 5, the black circle of pulse is the data subcarriers and the hollow circle of pulse is the pilot subcarriers.

3. THE DECODING OF SFBC-WIMAX

The transmitted signals after SFBC encoder can be presented in two coded vector as

$$X_1(n) = [s_1, -s_2^*, \ldots, s_{(K/2)-1}, s_{(K/2)}^*]^T$$
$$X_2(n) = [s_2, s_1^*, \ldots, s_{(K/2)}, s_{(K/2)-1}^*]^T \tag{1}$$

The length of collected vector is K/2. The $X_1(n)$ and $X_2(n)$ vectors are transmitted separately from the antenna 1 and 2. Let $X_o(n)$ be the odd elements of $X_1(n)$, and $X_e(n)$ be the odd elements of $X_2(n)$. And then the transmitted signals can be represented as

$$X_o(n) = [s_1, s_3, \ldots, s_{(K/2)-1}]^T$$
$$X_e(n) = [s_2, s_4, \ldots, s_{(K/2)}]^T \tag{2}$$

Moreover, $X_{1,o}(n)$, $X_{1,e}(n)$, $X_{2,o}(n)$ and $X_{2,e}(n)$ denote the odd and even elements of $X_1(n)$ and $X_2(n)$ respectively. Therefore, we let (1) represented in term of the even and odd elements to match the form of Alamouti code

$$\begin{bmatrix} X_{1,o} & X_{1,e} \\ X_{2,o} & X_{2,e} \end{bmatrix} = \begin{bmatrix} X_o & -X_e^* \\ X_e & X_o^* \end{bmatrix} \tag{3}$$

Hence, the receivers can follow the decoding process of Alamouti code and decode the received data.

Let Ë$_1$(n) and Ë$_2$(n) be the diagonal matrices which the entries are the channel impulse responses from antenna 1 and 2 respectively. Then the signals after OFDM demodulated at the receiver are given by

$$Y_o(n) = \Lambda_{1,o}(n)X_{1,o}(n) + \Lambda_{2,o}(n)X_{2,o}(n) + Z_o(n)$$
$$Y_e(n) = \Lambda_{1,e}(n)X_{1,e}(n) + \Lambda_{2,e}(n)X_{2,e}(n) + Z_e(n) \tag{4}$$

We assumed that the channel state information (CIR) was known, and the two vectors were produced from space-frequency decoder as

$$\hat{X}_o(n) = \Lambda_{1,o}^*(n)Y_o(n) + \Lambda_{2,e}(n)Y_e^*(n)$$
$$\hat{X}_e(n) = \Lambda_{2,o}^*(n)Y_o(n) - \Lambda_{1,e}(n)Y_e^*(n) \tag{5}$$

Assuming the complex CIRs the adjacent subcarriers (even and odd) are approximately equal. The equation (5) can be represent as

$$\hat{X}_o(n) = (|\Lambda_{1,o}|^2 + |\Lambda_{2,o}|^2)X_o + \Lambda_{1,o}^*Z_o + \Lambda_{2,e}Z_e$$
$$\hat{X}_e(n) = (|\Lambda_{1,e}|^2 + |\Lambda_{2,e}|^2)X_e + \Lambda_{1,o}^*Z_o + \Lambda_{2,e}Z_e \tag{6}$$

Finally, the X_e and X_o were decoded by (5) and (6). After X_e and X_o were decoded, we can retrieve the original transmitted vectors by (2) and (3).

4. SIMULATION RESULTS

The setting parameters as show in Tables 2 and 3:

Table.2. Parameter setting table of WiMAX

Parameters	Number
OFDM Symbol per frame	6
Symbol length	2112
FFT points	2048
Data subcarrier	1680
Guard subcarrier	268
Cyclic prefix	64
Modulation	QPSK, 16QAM, 64QAM
Convolutional code mother code	171, 133
RS-Code (n, k)	255, 239
Transmitter × Receiver Antenna	2 × 1

Table.3. Shortened RS-Code and Puncture configuration

Modulation	Profile #	Shortened RS (k, n)	Puncture mask
QPSK	1	24, 32	1101
	2	36, 40	11 0110 0110
16QAM	3	48, 64	1101
	4	72, 80	11 0110 0110
64QAM	5	72, 96	1101
	6	108, 120	11 0110 0110

Here, the FFT 2048 points mode and six partial usage of subchannels (PUSC) symbol was adopted to compose a downlink frame. The length of each OFDM symbol is 2112 which is composed of the 2048 points of IFFT symbol and 64 cyclic prefixes. The IFFT symbol includes 1680 data subcarriers (which contain 240 pilot subcarriers) and 367 guard subcarriers and 1 DC subcarrier. The modulations are QPSK, 16 QAM and 64 QAM. In each modulation, we use two profiles which are assigned different parameters of shortened RS code and different puncture configurations. We assigned numbers to the each profiles and shown it in later result of simulations.

In figure 6, we can obtain the QPSK has the lowest bit error rate (BER) and low signal-to-noise ratio (SNR). Then the next is 16QAM and the BER of 64QAM is poorer than the other three modulation method significantly. So the high modulation needs higher SNR to restrain the error. At the same modulation, the BER of bigger profile number is always poorer than the other one. It is because the protection ability of big profile number is less than the small profile number. Hence, the weak protection brings the higher error probability.

In figure 7, the SFBC was deployed and the performance enhanced marvellously. At the same BER, about 10-3, the performance improved about 3dB at each modulation. The results imply that we need fewer SNR to achieve the same quality as well as figure 6.

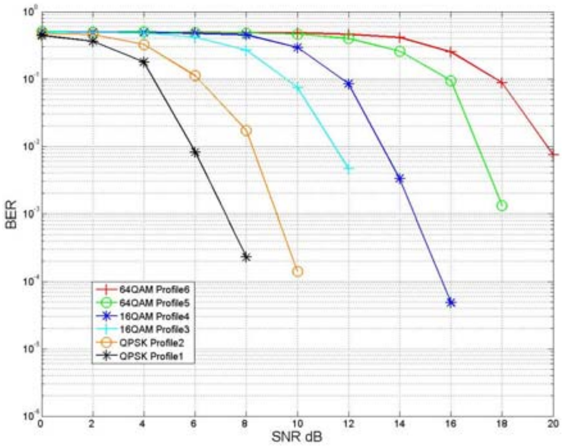

Fig. 6: WiMAX in AWGN condition

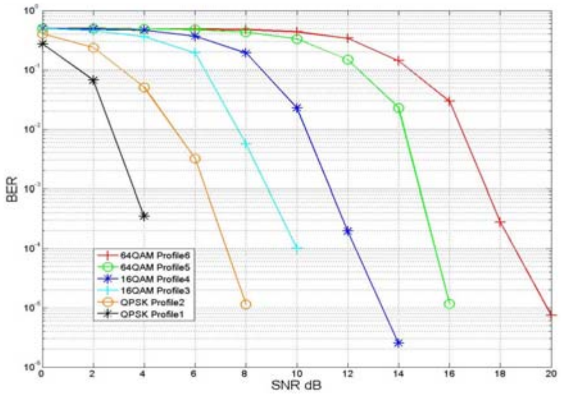

Fig. 7: SFBC-WiMAX in AWGN condition

Finally, a comparison was also made between the WIMAX and SFBC-WIMAX models in Rayleigh channel. However, after peer-reviewed process, the authors omit it because of the page limit.

5. CONCLUSION

The WiMAX system will offer higher speed and wider coverage for wireless communications. We can build a network system for remote suburban or lack of network service areas quickly without spending much cost for wiring. However, the performance of WiMAX can be improved by MIMO architecture due to the OFDM-based is one of the WiMAX schemes. In this paper, we implement the WMAN-OFDM combine with SFBC and analyze the performance of them. The results reveal the performance of SFBC-WiMAX is better than WiMAX exactly. We also show the performance for each profile where parameters were set as the standard of WiMAX. We know that the 64QAM gets the larger throughput in high-SNR environments. Even though the low bit modulation is the lowest throughput, but the SNR requirement is small and the QoS is more stable. Applying the SFBC to the WiMAX, we can see that the signal is better than without SFBC, i.e. we correct the complex data from wrong position to right positions. Besides, the proposed architecture makes the viterbi and RS decoder easily to improve the capability of error correction.

ACKNOWLEDGEMENT

This work was supported in part by National Science Council, Taiwan, R.O.C. under Grant NSC 95-2745-E-036-005-URD, and in part by Taiwan Telecommunication Industry CO. under Grant E95-02-I02-040.

REFERENCES

[1] The IEEE 802.16 Working Group on Broadband Wireless Access Standards, http://WirelessMAN.org/

[2] A. Ghosh, D.R. Wolter, J.G. Andrews and R. Chen, “Broadband wireless access with WiMax/802.16: current performance benchmarks and future potential,” IEEE Commun. Mag., vol. 43, no. 2, Feb. 2005, pp. 129 -136.

[3] S.M. Alamouti, “A simple transmit diversity technique for wireless communications,” IEEE Journal Selected Areas Commun., vol. 16, no.8, Oct. 1998, pp. 1451-58.

[4] Hongwei Yang, “A road to future broadband wireless access: MIMO-OFDM-Based air interface,”IEEE Commun. Mag., vol. 43, no. 1, Jan. 2005, pp. 53-60.

[5] K.F. Lee and D.B. Williams, “A space-frequency transmitter diversity technique for OFDM systems,” IEEE GLOBECOM., vol. 3, 27 Nov. - 1 Dec. 2000, pp. 1473-1477.

[6] S. Nanda, R. Walton, J. Ketchum, M. Wallace and S. Howard, “A high- performance MIMO OFDM wireless LAN,” IEEE Commun. Mag., vol. 43, no. 2, Feb 2005, pp. 101-109.

[7] A. van Zelst and T.C.W. Schenk, “Implementation of a MIMO OFDM-based wireless LAN system,” IEEE Trans. Signal Processing, vol. 52, no. 2, Feb. 2004, pp. 483-494.

[8] K. Suto and T. Ohtsuki, “Performance evaluation of space-time-frequency block codes over frequency selective fading channels,” Vehicular Technology Conference, vol. 3, 24-28 Sept. 2002, pp. 1466-1470.

[9] K. Suto and T. Ohtsuki, “Space-Time-Frequency Block Codes over Frequency Selective Fading Channels,” IEICE Trans. Commun., Vol. 3, Jul. 2004

[10] D.B. Lin, P.H. Chiang and H.J. Li, “Performance analysis of two- branch transmit diversity block-coded OFDM systems in time-varying multipath Rayleigh-fading channels,” IEEE Trans. Vehicular Technology, vol. 54, no. 1, Jan. 2005, pp. 136-148.

[11] C.B. Chae, M. Katz, C. Suh and H. Jeong, “Adaptive Spatial Modulation for MIMO-OFDM,” Wireless Communications and Networking Conference, vol. 1, 21-25 Mar. 2004, pp.87-92

[12] N. Fourty, T. Val, P. Fraisse and J-J. Mercier, “Comparative analysis of new high data rate wireless communication technologies "From Wi-Fi to WiMAX," Autonomic and Autonomous Systems and International

Conference on Networking and Services, 23-18 Oct. 2005, pp. 66-66.