Throughput Improvement of Optimal Turbo Coded V-BLAST Technique in MIMO-AM System

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Abstract: - In this paper, we propose and analyze an Adaptive Modulation System with optimal Turbo Coded V-BLAST (Vertical-Bell-lab Layered Space-Time) technique that adopts the extrinsic information from MAP (Maximum A Posteriori) Decoder with Iterative Decoding as a priori probability in two decoding procedures of V-BLAST scheme; the ordering and the slicing. Also, we consider and compare The Adaptive Modulation System using conventional Turbo Coded V-BLAST technique that is simply combined V-BLAST scheme with Turbo Coding scheme and that is decoded by the ML(Maximum Likelihood) decoding algorithm. In addition, we apply MIMO (Multiple Input Multiple Output) schemes to the systems for more performance improvement. The result indicates that the proposed systems achieve a better throughput performance than the conventional systems in the whole SNR range. And in terms of the throughput performance, the suggested system is close proximity to the conventional system using the ML decoding algorithm. In addition, the simulation result shows that the maximum throughput improvement in each MIMO scheme is respectively about 350 kbps, 460 kbps, and 740 kbps. It is suggested that the effect of the proposed decoding algorithm accordingly gets higher as the number of system antenna increases.

Key-Words: - AMC, Turbo Code, V-BLAST, MIMO, Iterative Decoding

1 Introduction

In the next generation mobile communication systems, the data throughput performance improvement will be among the hot issues. In order to fulfill the need for an ultra-high speed service, active researches on multiple-input-multiple-output (MIMO) systems that use multiple transmit and multiple receive antennas have been in progress. Generally, in MIMO systems, the main schemes considered are MIMO diversity scheme and MIMO multiplexing scheme [1][2]. Also, in order to improve the throughput performance, together with MIMO system, Adaptive Modulation and Coding (AMC) scheme has drawn much attention to the pioneer of the next generation mobile communication systems [3]. The AMC scheme adapts a coding rate and modulation scheme to the channel condition, resulting in an improved throughput performance. Consequently, the combination of MIMO system and AMC scheme could be the solution for improving the throughput performance.

Considering the complexity, in this paper, as the scheme of MIMO system combined with AMC scheme, we will select V-BLAST scheme [4] and Turbo Coding scheme [5]. Turbo Coding scheme with Iterative Decoding implies parallel concatenated recursive systematic convolutional codes, and is iteratively decoded using a posteriori probabilities (APP) algorithms for the constituent codes [6].

We will present the performance analysis of the Adaptive Modulation Systems with several Turbo

Coded V-BLAST techniques. As the method for more performance improvement, we will then consider a 2x2 MIMO scheme using 2 transmit and 2 receive antennas, a 4-2x2 MIMO scheme applying STD (Selection Transmit Diversity) scheme that selects 2 antennas from 4 transmit antennas [7], and a 4x4 MIMO scheme using 4 transmit and 4 receive antennas, a 8x8 MIMO scheme using 8 transmit antennas and 8 receive antennas.

The remainder of this paper is organized as follows. the structures of a transmitter and a receiver of the Adaptive Modulation Systems with optimal Turbo Coded V-BLAST techniques are proposed in Sect. 2. Also, the section will analyze the consideration factors for system implementation. In Sect. 3, the performance and the complexity of each system are verified by computer simulation, analyzed, and compared. Finally, the conclusions will be drawn in Sect. 4

2 The Adaptive Modulation System with optimal Turbo Coded V-BLAST Technique

In this chapter, the structure of the Adaptive Modulation System with optimal Turbo Coded V-BLAST technique is proposed.

Fig. 1 shows the transmitter-receiver structure of the proposed system. The difference with the Adaptive Modulation System using conventional Turbo Coded V-BLAST technique that is simply combined V-BLAST scheme with Turbo Coding scheme is that in the proposed system, the extrinsic information from MAP Decoder is used as a priori probability in two decoding procedures of V-BLAST scheme; the ordering and the slicing [8][9]. This scheme operates iteratively and is defined as the Main MAP Iteration. Also, whenever it operates, internally an iterative decoding of MAP Decoder is performed and this method is defined as the Sub MAP Iteration.

In this proposed system, let us consider a system equipped with M transmitter antennas and N receiver antennas. We further assume that each transmission channel is modeled as a flat Rayleigh fading channel. The received signal in the V-BLAST receiver is denoted by

$$X = Hs + n \tag{1}$$

where $X = [x_1, \cdots, x_N]^T$ is the received signal vector,

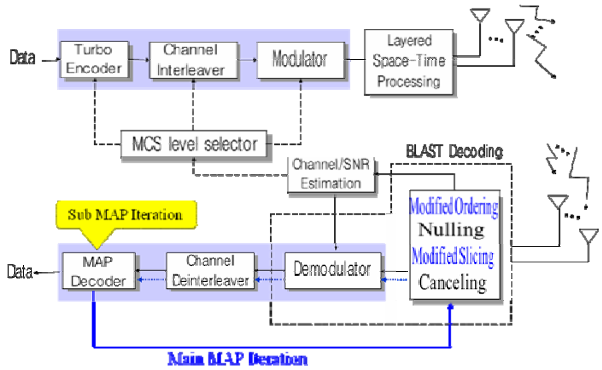

Fig. 1. Transmitter-receiver structure of the Adaptive Modulation System with conventional Turbo Coded V-BLAST technique

$s = [s_1, \cdots, s_M]^T$ is the transmitted symbol vector, H is the N×M channel matrix and $n = [n_1, \cdots, n_N]^T$ is the noise vector. The superscript T signifies the transpose matrix. The noise vector, n, is modeled as a complex Gaussian random process. s_m is the 2^Q -ary modulated symbol, that is $s_m = f\left(d_1^m, \cdots, d_Q^m\right) \in \Phi = \{\phi_1, \cdots, \phi_{2^Q}\}$, where Q denotes a bit number per symbol, $f(\cdot)$ denotes the symbol modulation function, $\{d_q^m\}_{q=1,\cdots,Q}$ represents the q-th information bits corresponding to s_m, and $\{\phi_i\}_{i=1,\cdots,2^Q}$ represents the i-th symbol.

The proposed slicing algorithm doesn't make Hard Decision with the received signal but it makes decision with the extrinsic information from MAP Decoder. This extrinsic information from MAP Decoder is the log-likelihood function, and it can be described as

$$L_{m,q} = \log \frac{p\left(d_q^m = 1\right)}{p\left(d_q^m = 0\right)} \tag{2}$$

where $L_{m,q}$ is the extrinsic information corresponding to d_q^m.

In the conventional V-BLAST ordering procedure, the decoding order is determined by the SNR of the corresponding layer. The conventional V-BLAST ordering is described as

$$l_k = \arg \min_m \| \left(H_k^+\right)_m \|^2 \tag{3}$$

where k stands for the decoding stage and the superscript + represents the pseudo-inverse matrix.

The SNR is a function of the channel power, and the layer with the largest channel power is the first one that is decoded. A high SNR means a low symbol error rate. From this fact, it follows that the maximum SNR criterion can be considered to be a specific version of the minimum symbol error criterion.

The proposed ordering algorithm is a function not only of the SNR but also of the extrinsic information, and it can be accordingly modified to

$$l_k = \arg\min_m P_m(e \mid X_k, H_k, L_m^{(i)}) \tag{4}$$

where $P_m = (e \mid X_k, H_k, L_m^{(i)})$ is the symbol error probability of the m-th layer and $L_m^{(i)} = \left[L_{m,1}^{(i)}, \cdots, L_{m,Q}^{(i)}\right]^T$ is the extrinsic information vector of the l_k-th layer at the i-th Main MAP Iteration. The symbol error probability, P_m, can be calculated from

$$P_m(e \mid X_k, H_k, L_m^{(i)}) = \frac{1}{2^Q} \sum_{q=1}^{2^Q} \sum_{p=1, p\neq q}^{2^Q} P(\phi_q \mid L_m^{(i)}) P\{\phi_q \to \phi_p \mid X_k, H_k, L_m^{(i)}\} \tag{5}$$

where ϕ_q is the original transmitted symbol, ϕ_p is the possible symbol except for the original transmitted symbol (ϕ_q), $P\{\phi_q \to \phi_p \mid X_k, H_k, L_m^{(i)}\}$ is the pair-wise symbol error probability, and it can be obtained from

$$\begin{aligned} &P\{\phi_q \to \phi_p \mid X_k, H_k, L_m^{(i)}\} \\ &= P\{p(\phi_q \mid y_m) < p(\phi_p \mid y_m)\} \\ &= P\{\log p(\phi_q \mid y_m) < \log p(\phi_p \mid y_m)\} \end{aligned} \tag{6}$$

where y_m is the received symbol of the m-th layer. Let us assume that ϕ_j is the possible transmitted symbol and the variance of noise corresponding to the m-th layer is $\sigma_m^2 / 2$, in Eq. (6), the log posteriori function is described by

$$\begin{aligned} \log p(\phi_j \mid y_m) &= \log \frac{p(\phi_j \mid L_m^{(i)}) p(y_m \mid \phi_j)}{p(y_m)} \\ &= \log p(\phi_j \mid L_m^{(i)}) + \frac{\mathrm{Re}\{(\phi_j - \phi)(2y_m - (\phi_j + \phi))^*\}}{2\sigma_m^2} \end{aligned} \tag{7}$$

where ϕ is the original transmitted symbol and the superscript * signifies a complex conjugate.

3. Simulation Results

3.1 MCS level and simulation parameters

Tables 1 and 2 show the MCS level selection thresholds and simulation parameters, respectively. The detailed parameters in Table 1 are established based on the 1X EV-DO Standard[10].

There are many references in the selection of the MCS level selection threshold. As an example, the threshold can be selected to satisfy the required BER(Bit Error Rate) and the required FER(Frame Error Rate). Since we have put more emphasis on the data transmission rate, we select the threshold that maximizes the throughput performance in this paper. Namely, threshold of selected MCS level is gained from MCS level transmission rate performance intersection in each system.

In other words, one frame is set up with one transmission slot and frame length is 2048 symbols. If one bit error occurs in one frame, we take it as a frame error. When frame error does not occur, transmission

Table 1. MCS level

MCS level	Date Rate(kbps)	Number of bits per frame	Code rate	Modulation
1	614.4	1024	1/3	QPSK
2	1228.8	2048	2/3	QPSK
3	1843.2	3072	2/3	8PSK
4	2457.6	4096	2/3	16QAM

Table 2. Simulation parameters

Parameter	Value
Modulation	QPSK, 8PSK, 16QAM
Code rate	1/2, 2/3
Turbo Coding scheme	PCCC (Parallel Concatenated Convolutional Code)
MAP Iteration of the Adaptive Modulation System with Conventional Turbo Coded V-BLAST technique	4
Main MAP Iteration of the Adaptive Modulation System with Optimal Turbo Coded V-BLAST technique	4
Sub MAP Iteration of the Adaptive Modulation System with Optimal Turbo Coded V-BLAST technique	2
Number of Tx. antennas	2, 4, 8
Number of Rx. antennas	2, 4, 8
Channel	Flat Rayleigh fading

rate is calculated in accordance with V-BLAST technique by the order of "bit length * data rate * number of transmit antenna." The performance of transmission rate closely corresponds to the capacity of FER. So in accordance with transmission rate, performance analysis is obtained by error probability.

3.2. Complexity of each decoding algorithm in Adaptive Modulation Systems with several Turbo coded V-BLAST techniques

In section, we have considered the complexity of the proposed decoding algorithm, the conventional V-BLAST decoding algorithm, and the ML decoding algorithm in the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques.

Multiplication operation contributes to the complexity of implementing the system in actuality. Each decoding algorithm is compared to the number of multiplication operation in table 3. In this table, C is a number of symbol, M is a number of transmit antenna, N is a number of receive antenna, B is a number of bit per symbol. The table shows that the proposed decoding algorithm is more complex than exiting V-BLAST decoding algorithm, but is less complex than ML decoding algorithm. Particularly, proposed decoding algorithm is relatively less complex than ML decoding algorithm when it is used with higher order modulation and many

Table 3. Complexity of each decoding algorithm

		ML Decoding	Conventional V-BLAST Decoding	Proposed Decoding
required multiplications		CM(M+1)N	(M+1)N3+(3/2)M2N+[(7/2)M-1]N-1	(M+1)N3+(1/2)M2N(N2+1)+(1/4)CMBN2+(5M-1)N-1
QPSK	M=N=2	96	47	93
	M=N=4	5120	467	2987
8PSK	M=N=2	384	47	253
	M=N=4	81920	467	50091
16QAM	M=N=2	1536	47	1085
	M=N=4	1310720	467	1049515

transmit-receive antenna.

3.3 Performance of the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques

Fig. 2 shows the throughputs of each decoding algorithm in the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques in a 2x2 MIMO scheme. We can see that the proposed systems achieve a better throughput performance than the conventional systems in the whole SNR range. And proposed system is close to existing ML decoding system in terms of the performance of transmission rate.

Fig. 3 shows the throughputs of the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques in a 2x2 MIMO scheme and a

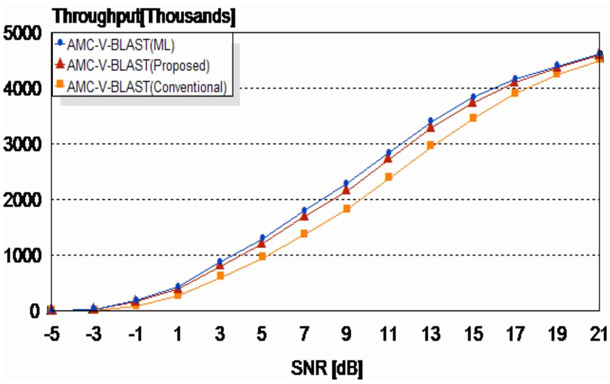

Fig. 2. Throughputs of each decoding algorithm in the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques in a 2x2 MIMO scheme

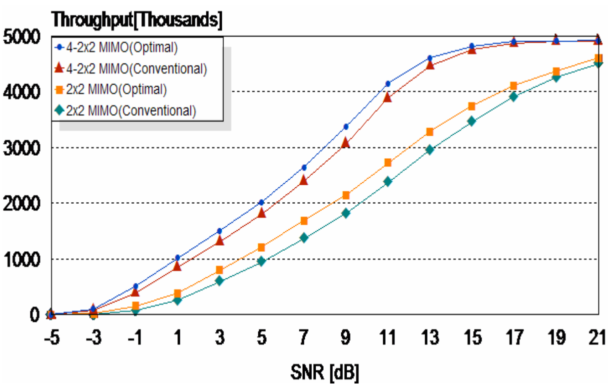

Fig. 3. Throughputs of the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques in a 2x2 MIMO scheme and a 4-2x2 MIMO scheme

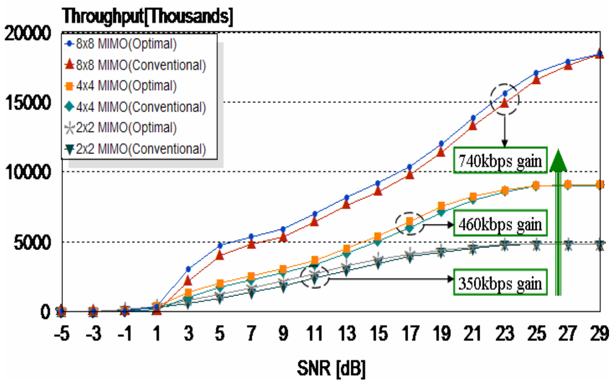

Fig. 4. Throughputs of the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques in a 2x2 MIMO scheme, a 4x4 MIMO scheme, and a 8x8 MIMO scheme

V-BLAST techniques in a 2x2 MIMO scheme and a 4-2x2 MIMO scheme. We can see that the systems in a 4-2x2 MIMO scheme achieve better throughput performance than others. The systems in the 4-2x2 MIMO scheme applying STD improve the SNR through the selection diversity gain. This leads to a reduced error rate and increment in the probability to select the MCS level with a higher data rate. Accordingly, they achieve a greater throughput performance than others

Fig. 4 shows the throughputs of the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques in a 2x2 MIMO scheme, a 4x4 MIMO scheme, and a 8x8 MIMO scheme. We can see that the systems in a MIMO scheme using more transmit-receive antennas achieve a higher throughput performance. A MIMO scheme sends information out over multiple antennas and the information is received via multiple antennas as well. It uses additional pathways to transmit more information and then recombines the signal at the receiving end. The systems in a MIMO scheme provide a significant capacity gain over other systems, along with more reliable communication corresponding to the number of antennas. Consequently, the more transmit-receive antennas we use, the higher throughput performance the systems in a MIMO scheme can achieve.

In addition, the result shows that the maximum throughput improvement in each MIMO scheme is about 350 kbps, 460 kbps, and 740 kbps, respectively. That is, the proposed system in a 8x8 MIMO scheme has a higher throughput improvement than the proposed system in other MIMO schemes. It is suggested that the effect of the proposed decoding algorithm accordingly gets higher as the number of system antenna increases.

All things considered, we can say that the proposed system is less complex than existing ML decoding system while there is little difference in their throughput performance. And the complexity of the proposed system is higher than that of the conventional system; however, the performance improvement is also significant. The proposed system achieves a better throughput performance than the conventional system in the whole SNR range. And when each MIMO scheme is applied, we can enhance its performance significantly. Accordingly, the proposed system can become one solution for next-generation mobile communication system whose demand for high transmission performance gets higher.

5. Conclusion

In this paper, in order to improve throughput performance in downlink, we have implemented the Adaptive Modulation Systems with several Turbo Coded V-BLAST techniques. We have considered and compared its throughput performance. In addition, STD and MIMO schemes have further applied to the systems for more performance improvement. Through the improvement of SNR in the receiver of the systems applying STD scheme, the error probability is decreased at the range of relatively low SNR and, ultimately, the throughput performance is improved. In addition, the throughput performance can further be improved corresponding to the number of antenna as applying a MIMO scheme that uses multiple transmit and receive antennas.

We have proposed an Adaptive Modulation System with optimal Turbo Coded V-BLAST technique that adopts the extrinsic information from MAP Decoder with Iterative Decoding as a priori probability in two decoding procedures of V-BLAST; the ordering and the slicing. We have considered the system with conventional Turbo Coded V-BLAST technique that is simply combined V-BLAST scheme with Turbo Coding scheme and that is decoded by the ML decoding algorithm. With the result of performance comparison of the proposed decoding algorithm, the conventional V-BLAST decoding algorithm, and the ML decoding algorithm in Adaptive Modulation System with several Turbo Coded V-BLAST techniques, we can say that the proposed system is less complex than existing ML decoding system while there is little difference in their throughput performance. And the complexity of the proposed system is higher than that of the conventional system; however, the performance improvement is also significant. The proposed system achieves a better throughput performance than the conventional system in the whole SNR range. In addition, the simulation results show that the maximum throughput improvement in each MIMO scheme is respectively about 350 kbps, 460 kbps, and 740 kbps. It is suggested that the effect of the proposed decoding algorithm accordingly gets higher as the number of system antenna increases. Accordingly, if MIMO scheme can be applied in each case for higher performance of transmission rate, the proposed system will become one solution for next-generation mobile communication system.

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