Efficient Hybrid ARQ schemes for Wireless Communication Systems

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Abstract: An efficient hybrid ARQ scheme based on the rate compatible block turbo codes has been proposed, and its performance has been analyzed. System efficiency is improved by means of adaptive rate code transmission using channel information, trading off bit rate for channel codes, with resulting energy saving. The rate adaptation scheme improves power efficiency while keeping packet delay minimized. On the other hand, power dependant strategies reduce power consumption. Simulation results show that the benefits obtained are very encouraging. The modified hybrid ARQ schemes with the channel information and efficient retransmission structures highly improve the throughput performance in the satellite communication system. Therefore, proposed schemes could be used in future communication systems.

Keywords: Hybrid ARQ, rata compatible codes, mobile communication systems, channel information, satellite channel.

1. INTRODUCTION

New standards in the framework of so-called forth-generation (4G) systems are investigated actively in the filed of wireless communications. These systems include networks with multimode, multiband, and multimedia high-capacity mobile terminal. Such future systems should be able to fulfill the stringent requirements for quality of service (QoS), mainly in terms of throughput, delay and error rate.

Satellite systems are unquestionably the most efficient means for reaching rural and remote areas of the world with a high-speed, ubiquitous link. Satellite communication has provided essential services in geographical areas that are underserved by terrestrial systems, as well as maritime and airborne communications. Furthermore, mobile communication and broadcasting systems converge to seam-less network as well as moving towards closer, mutually beneficial interworking with terrestrial mobile networks. Converged satellite-terrestrial deployments now promise to offer the full coverage services satisfying the low cost requirements of a broadband access services by using satellite link as a backbone link. Satellite communication system is focused on not as the exclusive system with terrestrial but as the high-level platform in the global seamless communication system.

This situation necessitated the hybrid ARQ schemes to guarantee quality of service (QoS) and manage resources through channels to user equipments which are varying with time and space. Rate compatible (RC) codes are widely used for adaptive coding and modulation (AMC) and hybrid automatic repeat request (ARQ) schemes in wireless communication systems, because they can produce various coding rates and coding gains with a single encoder and decoder.

Most of the previously proposed RC codes used convolutional codes or turbo codes based on convolutional codes [1][2]. They all used various puncturing patterns in a single code to produce several coding rates and coding gains. A few RC block codes have also been proposed [3]-[5]. However, they often produced very limited kinds of code rates and coding gains. This is mainly because puncturing block codes (or product codes) may substantially weaken the error correcting capability [3]. Our previous investigation proposed a RC block turbo code scheme to be used as an AMC [6] and adaptive hybrid ARQ schemes [7] that highly improves the system throughput, and compensates channel variations in mobile satellite systems.

In this paper, we investigate an efficient hybrid ARQ scheme using rate compatible block turbo codes. We show that the modified hybrid ARQ schemes with the channel information and efficient retransmission structures highly reduce the retransmission delay and improve the throughput performance in the satellite communication channel.

This paper is organized as follows. Section 2 describes the framework of the hybrid ARQ schemes with channel information and explains its operations. The simulation results are shown in section 3. In section 4, we conclude this paper.

2. MODIFIED HYBRID ARQ

To control power consumption in radio transmission, we adapt the radio transmission parameters (frame length, error control) with retransmission for varying channel condition. In addition, this mechanism can be a solution in the deep shadowing condition. However, the hybrid ARQ mechanisms have a trade off between energy saving and packet delay especially in satellite link.

2.1 Performance trade off in RC codes

The hybrid ARQ system use the RC code based on high dimensional turbo codes. The low rate code in RC code group will produce a good error correction performance but the maximum throughput will be limited. On the contrary, the hybrid ARQ systems using the high rate product codes will have larger maximum throughput. This trade off between code rate (throughput) and error correction capability (delay) will be a key to obtain an optimal performance in wireless communication systems. As code rate gets lower, error correction capability become better and thus requires smaller retransmissions at the cost of a limited maximum throughput.

The various code rate codes [7] make by combining with sub blocks of 3 dimensional (3D) turbo product codes. For 3D product code example, 18 variations in the code rate are possible if we use a different component code in each axis. However, we select six codes that distinguished in code rate range. The various rate codes are shown in table 1. This table also shows the bit energy to noise spectral density ratio (E_b/N_0) to satisfy the required bit error rate (BER) performance, 10^{-6} and corresponding symbol energy to noise spectral density ratio (E_s/N_0) is calculated for choosing the first transmission code with channel condition.
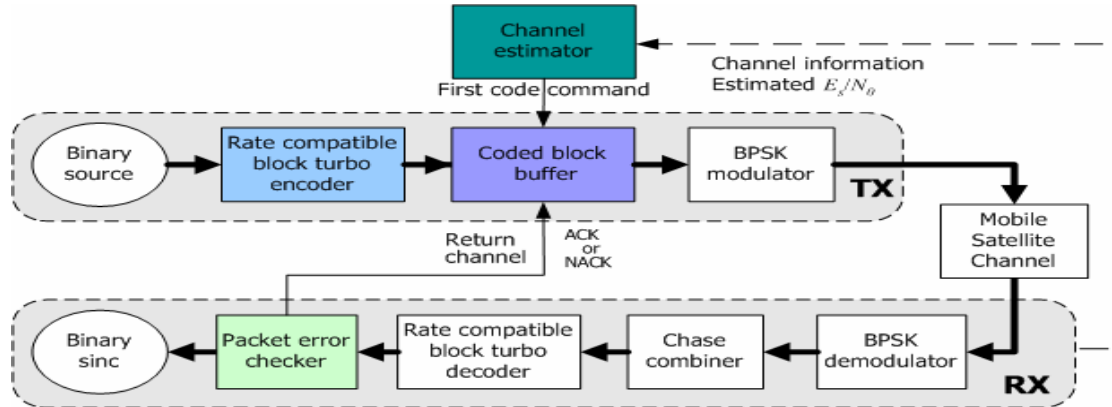
Fig. 1 System model using modified hybrid ARQ schemes with channel information.

Table 1 Various rate codes and performances

Code	Dimension	Code rate (in dB)	E_b/N_0	E_s/N_0
Code 1	2	0.52(-2.81)	5.0	2.19
Code 2	2	0.47(-3.25)	4.0	0.75
Code 3	3	0.39(-4.10)	3.0	-1.10
Code 4	3	0.36(-4.44)	2.7	-1.74
Code 5	3	0.34(-4.75)	2.2	-2.55
Code 6	3	0.32(-4.88)	1.5	-3.38

2.2 Communication system with hybrid ARQ

We proposed hybrid ARQ techniques with channel information. System model in Fig. 1 shows the hybrid ARQ systems using the RC product codes. The encoder generates a product code. Then, in the buffer, the encoded block is divided into an information block and parity blocks. We send a combination of these blocks corresponding to the given transmission method. We transmit firstly the code that was decided according to channel information. The receiver sends the result of the transmission as the positive acknowledgment (ACK) or negative acknowledgment (NACK). Depending on this acknowledgment, the transmitter decides the retransmission. The receiver combines the transmitted packets if necessary to offer more powerful error correction to recover the information. We assume that the return channel for sending ACK and NACK is error free.

2.3 Fixed hybrid ARQ

There is a classic type-I hybrid ARQ schemes using the RC product codes that we use a fixed code at every (re)transmission. In other words, whenever the transmission fails, we always transmit the same code. In type-II hybrid ARQ scheme, we transmit the lowest rate codes at the first transmission. If the first transmission fails, we send the additional parity block at the second transmission. If this fails again, we send more parity blocks at the successive retransmissions. In type-III hybrid ARQ scheme, we send full codes at every retransmission in order after sending the lowest rate code at the first transmission. In these fixed retransmission structure, the transmission process starts with the lowest rate code. If packet error occurs, retransmissions proceed with a lower rate code in order. The classical ARQ schemes have two fixed elements; the fixed starting code and retransmission steps. The fixed retransmission structure is not

adequate with varying channel condition because the early transmission using a low rate codes will fail with high probability in shadowing condition.

2.4 Adaptive hybrid ARQ

The modified hybrid ARQ techniques provide a more powerful error correction scheme with the less delay using channel information. We improve the throughput performance by combining hybrid ARQ scheme with an adaptive coding scheme. In this method, we send the most appropriate code at the first transmission instead of the highest rate code.

As a first step, we estimate the channel condition as the parameter E_s/N_0 using pilot signal or average packet SNR of received bits. Secondly, we search the suitable code that has error correction capability in that channel condition in table 1.

By doing this, we can reduce failing rate at the first transmission, and thus reduce the number of retransmissions, especially in serious fading conditions. Furthermore, we select the code in retransmissions process based on the channel information instead of the code rate order. This scheme can achieve the improved throughput performance. Compared with the AMC scheme, the advantages of the modified step hybrid ARQ is on the combining process. The estimated channel information can be corrected through retransmission process. The selective repeat retransmission method [8] can be an efficient solution to such a system with long round trip delay.

3. SIMULATIONS

We simulated the performance of modified hybrid ARQ systems compared with conventional systems on a mobile satellite communication channel.

3.1 Channel condition

We consider a geostationary satellite system and use a mobile satellite channel model in [9]. Satellite channel also is generated a component of dynamic rain attenuation, so that the transmitted packet would experience dynamic behaviors of rain attenuation, shadowing and small-scale fading as table 2. We generate rain attenuation samples with interval of about a second, the shadowing process using Ka-band suburban model with the carrier frequency of 20.0 GHz, correlation distance of 5.0 m, and moving distance of 0.1 m. The small scale fading samples were generated using mobile speeds of 70 km/hour and modeled as Rician channel with 2 same power paths of zero and 30 nsec delay. We use the BPSK with a transmission symbol rate of 5 Mbit/s.

Table 2 Channel parameter values.

Rain Attenuation Shadowing	Rain attenuation interval	0.9375 (sec)
	Carrier frequency	20.0GHz
	Ka band	20~30GHz
	Correlation Distance	5.0m
	Moving Distance	0.1m
Small scale fading	Mobile speed	70km/hour
	2 path Rician channel (Same power)	Path 1: 0sec Path 2: 30nsec
AWGN	E_s/N_0	Noise STD
Etc	Data rate (BPSK)	5Mbit/sec

3.2 Simulation results

The proposed hybrid ARQ scheme using channel condition information has been tested by simulation. And the results obtained are shown as below.

At first, we define the throughput as the ratio of the number of the correctly decoded information bits to the number of bits transmitted in total. That is,

$$T = \left(\frac{\sum_{i=1}^{N} K_i}{\sum_{i=1}^{N} N_i} \right) (1 - PER), \qquad (1)$$

where K_i is the number of information bits for the ith transmitted packet and N_i is the total number of coded bits (re)transmitted to recover K_i information bits. N is the simulation times we investigated to estimate the packet error rate, PER. The number of information bit K_i will be the size of the information block, and is fixed regardless of any retransmission scheme. On the other hand, N_i will vary by the channel conditions and hybrid ARQ schemes. N_i is the sum of the transmitted bits at each retransmission as follows

$$N_i = \sum_{j=1}^{R_i} N_{ij}, \qquad (2)$$

where N_{ij} is the number of coded bits for the jth retransmission for the ith transmitted packet and R_i is the number of retransmissions for the ith packet.

Fig. 2 shows the throughput performance for hybrid ARQ schemes. Fig. 3 shows the transmission attempts that were limited the maximum number of transmissions to six times with which we can make a full 3D product code.

Based on our simulation result in Fig. 2, and Fig. 3, we cannot use the block turbo codes without hybrid ARQ techniques at low E_s/N_0 range. In other words, we have to compensate rain attenuation, shadowing and other fading elements using an efficient hybrid ARQ scheme in such a low power condition.

The type-I hybrid ARQ using the Code 1 or Code 6 produces better throughput than the same block turbo codes without retransmissions, before the throughput is saturated. Over the saturation range, the hybrid ARQ schemes cost for the additional retransmissions. For the fixed error protection codes without incremental redundancy, low rate code, Code 6 has better throughput performance than Code 1 in low E_s/N_0 range, while its throughput is limited at higher E_s/N_0 range. This is due to its better error correction capability at the expense of code rate (transmit power). Type-II and type-III hybrid ARQ schemes using the proposed RC product codes

can take advantages of each individual component code. In classical hybrid ARQ schemes, We send the highest rate code at the first transmission. If this fails, the lower rate code is retransmitted. Because the retransmission packet of the type-II hybrid ARQ contains only incremental redundancy blocks, the type-II hybrid ARQ scheme produces better throughput efficiency than other hybrid ARQ schemes in relatively high E_s/N_0 range.
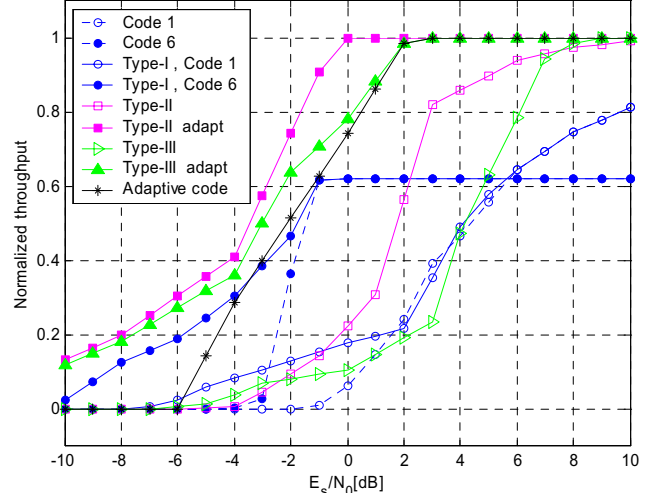

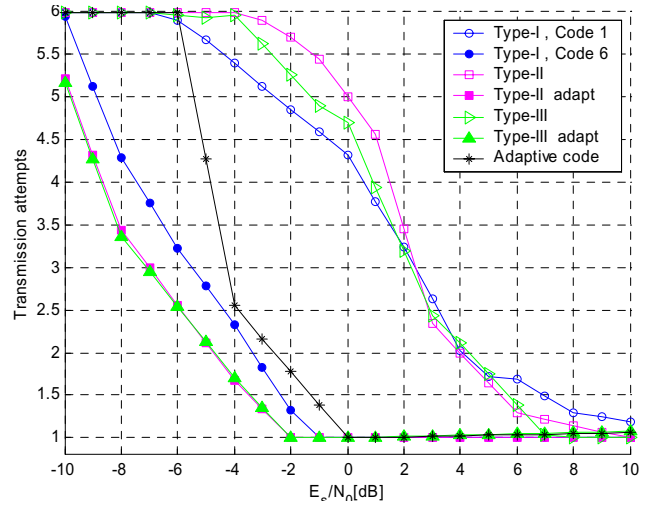Fig. 2 Throughput performance over satellite channel

Fig. 3 Transmission attempts over satellite channel

The type-II hybrid ARQ scheme showed the best throughput performance at a given transmissions attempts. However, type-III may be more advantageous in shadowing condition.

The modified hybrid ARQ that starts to transmission with the appropriate rate code according to channel condition highly reduces the number of transmission attempts about 14% ~ 75% than the fixed hybrid ARQ schemes in the E_s/N_0 range of -10dB ~ 5dB. It also shows the 15% ~ 50% delay reduction by adjusting the first transmission code with channel conditions in -10dB ~ 0dB compared with AMC scheme which are retransmitted but not combined for the fair comparison with ARQ schemes. These delay reduction lead to the throughput performance improvement. If we variegate the code selection in retransmission, we can obtain the larger performance gain.

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4. CONCLUSIONS

This paper introduced an efficient hybrid ARQ schemes using RC block turbo code. We estimated the throughput performance of the proposed RC block turbo codes combined with the hybrid ARQ schemes over mobile satellite channel condition. From the simulation results investigated in this paper, the proposed techniques are effective solutions to compensate rain attenuation and multipath fading in mobile satellite systems by allowing the adaptive error protection according to channel condition. It is also known that the performance can be further improved by combining with an adaptive retransmission code steps. The proposed hybrid ARQ will be an effective solution to adequate resource management for varying channel condition.

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