Bit Error Rate of OFDM-IDMA System with ARQ

SHENG Shanfeng, CHEN Xiaoyu
Zhejiang Gongshang University, Hangzhou, China,
e-mail: *stlegar@163.com, xychen@mail.zjgsu.edu.cn*

Abstract: Orthogonal frequency division multiplexing (OFDM) is a simple mean to mitigate the inter-symbol interference and the narrow-band interference due to multi-path propagation. It enhances the capacity of the system effectively. The interleave-division multiple-access (IDMA) can be applied to multi-carrier systems to improve spectrum efficiency apparently. Auto repeat request (ARQ) is a usual method of reliable communication in noisy channel by controlling the transmission errors. Combining OFDM and IDMA technologies, the spectrum efficiency of the system can be greatly improved subjected to little increment of computational complexity. Bit error rate of multi-path systems can be effectively reduced by introducing iteration at the end of receiving. We propose an ARQ-OFDM-IDMA system, simulate the system in AWGN channel and Rayleigh channel environments. The bit error rates with respect to noise level are compared over these channels with different number of users. The simulation results show that: The transmission bit error rate of ARQ-OFDM-IDMA systems is less than that of OFDM-IDMA system under the same channel conditions.

Keywords: orthogonal frequency division multiplexing (OFDM); interleave-division multiple-access (IDMA); auto repeat request (ARQ); bit error rate (BER)

1 Introduction

As a high-speed transmission technology in wireless environment, OFDM converts high-speed serial data into relatively low-speed multi-channel parallel data, modulates different carriers and effectively utilizes the limited spectrum resources. It is a useful tool in combating frequency selective fading and inter-symbol interference (ISI)[3,5]. However, OFDM technology requires strict orthogonality among all the users. For example, in an OFDM-CDMA system, with the increasing number of users, the orthogonality among users would be damaged. The non-orthogonality causes serious multiple access interference, and thus practical usage of the system has been restricted. Recently, continuous effort has been put on the research of the iterative technique, the combination of iteration and CDMA results the new idea of IDMA, where users are separated with interleavers. OFDM-IDMA systems have been investigated in depth with multi-level and multi-angle perspective. The results show that OFDM-IDMA system can be more effective against multiple access interference and ISI[4,6,9], and attract much attention of the researchers. This paper will present an ARQ[1]-OFDM-IDMA system. The simulation results show that our system has a lower transmission bit error rate, is more effective against multiple access interference and transmission efficiency than OFDM-IDMA.

2 The ARQ-OFDM-IDMA System

2.1 The ARQ-OFDM-IDMA System Model

In the ARQ-OFDM-IDMA system model, most of the merits of OFDM –IDMA and ARQ are inherited. The key advantage of ARQ-OFDM-IDMA is that the MUD can be realized more efficiently and less complexity for each user independent of the channel length and the number of users. And the error rate of the system is less than that of OFDM-IDMA system.

As shown in Figure 1, the information-bit firstly enter the CRC encoder for error check coding. This part is to check whether there are error bits after the completion of error-correcting decoding (corresponding to forward error correction). The CRC encoding adds an additional period of parity check bits behind the original information packet, and constitutes a new packet. The new packet then enters the FEC encoder, FEC coding operation is applied in accordance with coding restriction. Then interweaver is applied to form a new sequence. Since interweaver is randomly generated, so that the correlation among the new chip sequences is greatly reduced[2]. Because of the independence of interweavers for different users, the correlation of different sequences is low. Then OFDM modulation turns the high-speed sequence into low-speed parallel data and inserts cyclic

978-1-935068-06-8 © 2009 SciRes.

prefix in order to combat multi-path inter-symbol interference. When all the above processes are completed, the signal is accessed to multiple-access channel for transmission, leaving a copy in the buffer at the same time for retransmission when it is needed.

And at the ending of the sender, the synthesis of the signal is

$$d_m = \frac{1}{NT}\int_0^{NT}[\sum_0^{N-1} d_n \exp(j2\pi f_n t)]\exp(-j2\pi f_m t)dt \quad (1)$$

where T is the period of the cycle, N is the carrier number, d_i is the original signal.

At the receiving end, the received signal is the summation of all user's signals and the noise. Firstly, the receiving signal enters into the OFDM demodulator. The

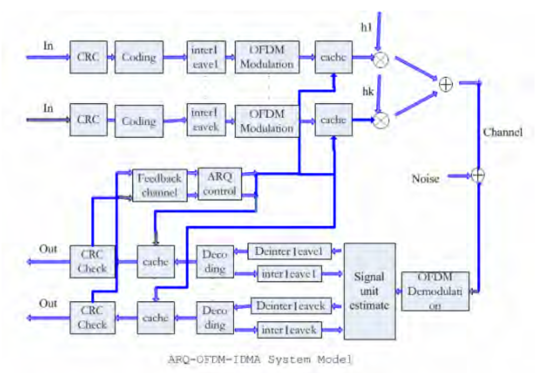

Figure 1. The ARQ-OFDM-IDMA system model

cyclic prefix is removed. Using the orthogonality of the carriers, the transmitted data on the parallel carriers is turned back into serial data streams by FFT. And the signal is

$$d_m^{'} = \frac{1}{NT}\sum_1^K h_k \sum_0^{N-1} d_k(i)\int_0^{NT} exp[j2\pi(\frac{i}{NT})t]\exp[-j2\pi(\frac{m}{NT})t]dt$$
$$+\frac{1}{NT}\int_0^{NT} n(t)exp[-j2\pi(\frac{m}{NT})t]dt \quad (2)$$

In this formula, the first term at the right hand side contains all the user information, the second one is for the noise term.

The next step is to reduce noise and interference from other users' chip sequences due to the low correlation among different user's chips[8]. This is done by iteration. The signal of the expected user comes out gradually after many rounds of iteration. The correlation between the two consecutive iteration outputs of the decoder becomes stronger and stronger. At the end of last iteration, hard decision is done on the data of the expected user. The copy is sent to the receive buffer for further use of possible retransmission. Finally, CRC check is applied on the packet. If the valid results show that all the information bits are decoded correctly, the packet will be sent to the user, then the cache is emptied, acknowledgment is sent to ARQ for sending new data. Otherwise acknowledgment should be sent to ARQ for sending the data again and retaining a copy in the buffer.

The middle part of the figure 1 is the structure of the system control logic part of ARQ[1] . Since ARQ control is added to the system, cyclic redundancy check coding is employed at the beginning of the sender, packets enter register prior to the channel, so the system can re-send when the transmission error happens, avoiding duplicate processing before the register. At the decoder of the receiving end, register is also employed for retransmission merger and taking full advantage of all the transmission of useful information to enhance the probability of a correct decision. At the very end of the receiver, CRC decoding is employed for sending the verification result to the ARQ control module through the feedback channel, corresponding to the CRC encoding at the sender. According to the checking results of CRC, ARQ control decides whether to send control massage of sending a new data blocks, or to send control massage of re-sending the original data blocks. The feedback channel connects the user's CRC checksum and the ARQ control module, receives the user's validation information and then sends it to the ARQ control[10] . There are two types of parity information: When no errors are found in the check bits, ACK is sent, then the ARQ control can instruct the transmit end to send the new data blocks, empty the transmit end register at the same time. Conversely, if one receives a Non-ACK, it indicates that the CRC checksum find the error bit, so the ARQ control will instruct the transmit end to resend the data block from the register.

Assuming that the signal to noise ratio is given as γ, bit error rate is $P_b(\gamma)$. Then the frame error rate:

$$P_p(\gamma) = 1-(1-P_b(\gamma))^{N_B} \quad (3)$$

where N_B is the number of bits in the packet. Suppose the largest number of retransmissions be $T_{\max}$, then the average number of transmissions is $T(\gamma)$:

$$T(\gamma) = 1+P_p(\gamma)+P_p(\gamma)^2+\ldots+P_p(\gamma)^{T_{\max}-1} = \frac{1-P_p(\gamma)^{T_{\max}}}{1-P_p(\gamma)} \quad (4)$$

The residual frame error rate $S_p(\gamma)$ is

$$S_p(\gamma) = P_p(\gamma)^{T_{\max}} \quad (5)$$

The throughput of ARQ-OFDM-IDMA system can be expressed as:

$$\eta_{ARQ} = (\frac{N_B-N_C}{T(\gamma)N_B})(1-S_p(\gamma)) = \frac{m\frac{N_B-N_C}{N_B}(1-S_p(\gamma))}{\frac{1-P_p(\gamma)^{T_{\max}}}{1-P_p(\gamma)}} \quad (6)$$

where m is modulation order.

2.2 Simulation Results and Analysis

The next Figures 2 and 3 display the performance comparison of the ARQ-OFDM-IDMA system which simulates different number of users under the AWGN channel and Rayleigh channel, respectively. Of which the OFDM modulation and demodulation use 128 sub-carrier, the length of FFT/IFFT is 128, the length of guard interval is 32. The CRC checksum is 24.The modulation is QPSK, the modulation order is 2 ,the bit rate per user is 256kbps, the symbol rates is 128 baud, the maximum transmission frequency of the spread-spectrum control part is set 5 in each data packet.

As it can be seen, when the number of user is 1 or 16，the BER curves have a rapid decline with the increase of signal to noise ratio. The performance of the system is good. When there are more users, the rate of decline slow down. However, comparing with the case of low signal to noise ratio, the increase of the signal to noise ratio still have some contribution in reducing the bit error rate.

Figure 4 shows a comparison of error rate between ARQ-OFDM-IDMA system and the general system with 16 and 32 users under AWGN channel. The simulation shows that the performance of ARQ-OFDM-IDMA system is better that of OFDM-IDMA system with the performance under the same conditions. And the error rate has been significantly reduced. However, the difference between the two is not great when the number of users is

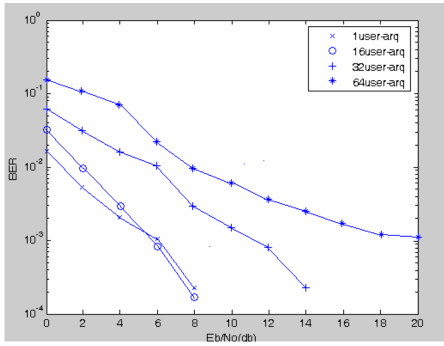

Figure 2. The BER of ARQ-OFDM-IDMA under AWGN channel

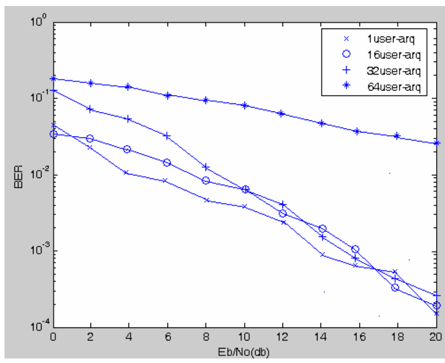

Figure 3. The BER of ARQ-OFDM-IDMA under Rayleigh channel

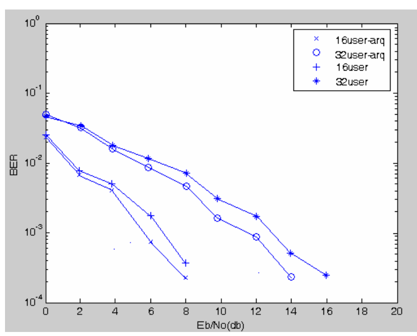

Figure 4. The BER of ARQ-OFDM-IDMA and OFDM-IDMA under AWGN channel

978-1-935068-06-8 © 2009 SciRes.

little. But when the number of users increases to 16 or 32, the advantages of ARQ-OFDM-IDMA system are significant.

The reason for the better performance of ARQ-OFDM-IDMA system comparing with OFDM-IDMA system is that ARQ system strengthens the strength of the expected user's signal through the retransmission merger while suppress the noise and the interference.

3 Conclusions

OFDM-IDMA system model is a hot topic of technology research in the fourth generation mobile communication. In this paper, we have established an ARQ-OFDM-IDMA system model, which is an improvement to the original OFDM-IDMA system. We give the simulation results for different users in different channels (AWGN, Rayleigh) based on the model, and then proceed to the analysis of the performance, and a brief summary of its characteristics. The simulation results show that our model has indeed a better performance than the original one for the parameters chosen.

4 Acknowledgements

This work was supported by Zhejiang Xinmiao Talents Project (3070KZ40621548).

References

[1] Qian Huang, Sammy Chan, Li Ping, and Moshe Zukerman, Improving wireless TCP throughput by a novel TCM-based hybrid ARQ[M], IEEE Trans. Wireless Commun., Vol. 6, No 7, pp. 2476-2485, July 2007.

[2] Hao Wu, Li Ping, and A. Perotti, User-specific chip-level interleaver design for IDMA systems[M],IEE Electron. Lett.,Vol. 42, No. 4, pp. 233-234, Feb. 2006.

[3] Lajos Hanzo, Thomas Keller, OFDM & MC-CDMA: A Primer[J], Wiley-IEEE Press,July 11, 2006.

[4] Li Ping, Qinghua Guo, and Jun Tong, The OFDM-IDMA approach to wireless communication systems[M],IEEE Wireless Commun. Mag., pp. 18-24, June 2007.

[5] Richard D.J. van Nee and Ramjee Prasad，OFDM for Wireless Multimedia Communications[J], Artech House, 2000.

[6] Li yunzhou, spectral efficiency of IDMA-OFDM systems [M],Journal of Tsinghua University 2005.03.
李云洲，IDMA-OFDM系统的频谱效率[M]，清华大学学报，2005.03.

[7] Liu qin,IDMA and interative MUD[M], Information Technology,2007.12.
刘琴，交织多址与迭代多用户检测[M]，通信技术，2007.12.

[8] Shen cui, Novel wireless communication scheme based on multi-carrier and chip interleave[M], Journal of Chongqing University of Posts and Telecommunications,2008.4.
沈翠，基于多载波和码片交织技术的无线通信新方案[M]，重庆邮电大学学报，2008.4.

[9] Jun Tong, Qinghua Guo, and Li Ping, Analysis and design of OFDM-IDMA systems[J], Eur. Trans. Telecomms., Vol, 19, pp. 561-569, June 2008.

[10] John G. Proakis，Communication system engineering[J], Publishing House of Electronics Industry, 2006.3.