University of Wollongong

Research Online

Faculty of Informatics - Papers (Archive)

Faculty of Engineering and Information Sciences

An adaptive scalable multiuser-OFDM system for multimedia transmission over fading channels

Ahmed Muthana M. Nadhim
Huazhong University of Science and Technology

Jianhua He
Huazhong University of Science and Technology

Jiangtao Xi
University of Wollongong, jiangtao@uow.edu.au

Zongkai Yang
Huazhong University of Science and Technology

Recommended Citation

An adaptive scalable multiuser-OFDM system for multimedia transmission over fading channels

Abstract

In this paper, an adaptive scalable multiuser-OFDM system was proposed for multimedia transmission over fading channels. The proposed adaptive algorithm can adapt according to the channel status information of each user's channel status. This algorithm dynamically changes according to the user's channel changes; this can keep fixed QoS at the physical layer. Another predefined QoS for different sessions and services to be provided for different users. This QoS can be guaranteed by multimedia scalability. Scalability can adapt to the service requirements, in terms of transmission data rate and bandwidth. As a result, a robust multimedia transmission scheme is achieved by providing fix QoS for the end users in multiuser environment, by fixing QoS in the physical layer by the bit and power adaptation technique and also in service layer by scalability techniques. Furthermore, space diversity techniques are used to decrease the effect of frequency selective multipath effects in broadband wireless channels.

Keywords

Adaptive, Scalable, Multiuser, OFDM, System, for, Multimedia, Transmission, Over, Fading, Channels

Disciplines

Physical Sciences and Mathematics

Publication Details

An Adaptive Scalable Multiuser-OFDM System for Multimedia Transmission Over Fading Channels

Ahmed Muthana M. Nadhim*, Jianhua He*, Jiangtao Xi**, and Zongkai Yang*

*Electronics and Information EngineeringDpt.
Huazhong University of Science and Technology
Wuhan, China
ahmed_m_nadhim@hotmail.com
zkyang@public.wh.hb.cn

**School of Electrical, Computer and
Telecommunications Engineering
University of Wollongong,
*Wollongong, Australia*
jiangtao@uow.edu.au

Abstract

In this paper, an adaptive scalable multiuser –OFDM system was proposed for multimedia transmission over fading channels. The proposed adaptive algorithm can adapt according to the channel status information of each user's channel status. This algorithm is dynamically changes according to the user's channel changes; this can keep fixed QoS at the physical layer. Another predefined QoS for different sessions and services to be provided for different users. This QoS can be guaranteed by multimedia scalability. Scalability can adapt to the service requirements, in terms of transmission data rate and bandwidth. As a result, a robust multimedia transmission scheme is achieved by providing fix QoS for the end users in multiuser environment, by fixing QoS in the physical layer by the bit and power adaptation technique and also in service layer by scalability techniques. Furthermore, space diversity technique are used to decrease the effect of frequency selective multipath effects in broadband wireless channels.

1. Introduction

Multimedia has become one of the driving

components for the mobile communications market. OFDM is one of the candidates for mobile communications. When OFDM is used for a multiuser application to provide a highly flexible and efficient communication system, configuration of the multiuser OFDM system relies on required applications and a computation complexity [1]. For multimedia communications, the delay constraint limits the use of Automatic Repeat request (ARQ). Therefore, we focus on a variable rate allocation method combined with an adaptive modulation, which support a multirate multiuser-OFDM system for several services with a simple hardware complexity. For optimum reception of the transmitted image, an efficient scalable technique was used in this paper based on Multiplexed Wavelet Transform (MWT) [2]. MWT layering system has the advantages of high design flexibility and improved bandwidth efficiency through selective choosing the wavelet family to be used at each layer. In addition, to mitigate the effects of fading in wireless channels, we consider using space-time block codes (STBC) as a spatial diversity technique to decrease the fading effects in both time and frequency domain for OFDM signal. The system proposed in this paper incorporates both the advantages gained by using the wavelet functions for multimedia scalability, and using adaptive OFDM for multimedia transmission.
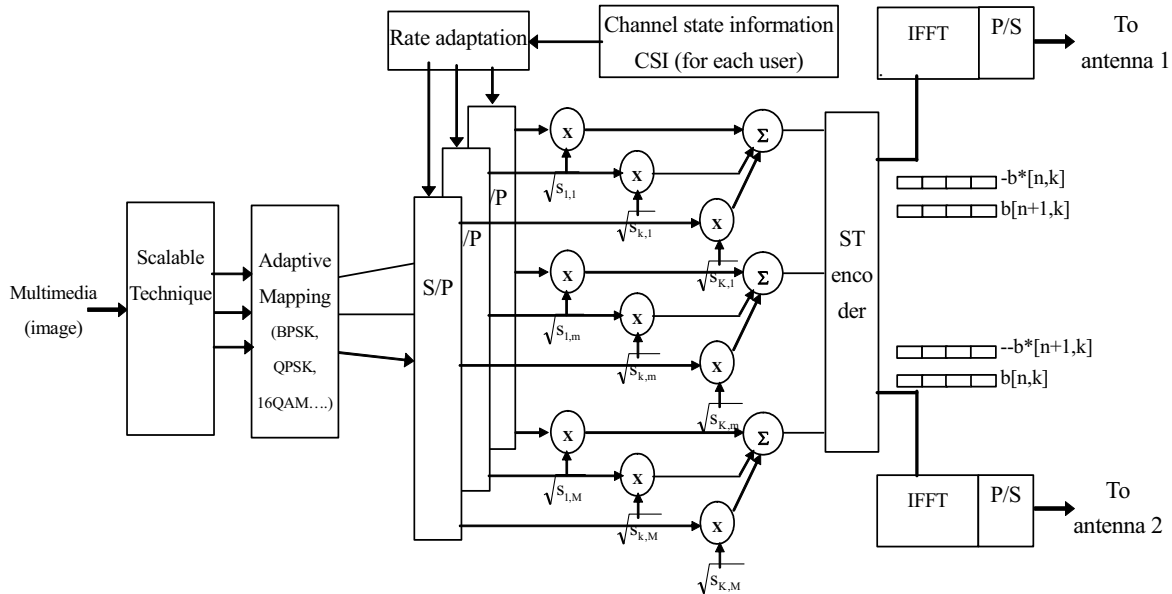
Figure 1 Block diagram of a downlink scalable multiuser-OFDM system with transmit power-adaptation

2. System Description

In this paper, we consider the problem of multiuser support in an adaptive OFDM system. We assume that we assign 2~8 carrier for low rate receivers, 16~64 carriers for high-rate receivers, and 128~512 carriers for indoor very high-rate data transmission [3]. When subcarriers are allocated to each user, we use a method of grouping adjacent subcarriers allocated to each user [1]. An algorithm for maximizes the total throughput was used by assigning different bit and rate for each user, as well as different power assignment [3]. Another goal is to minimize the average computational complexity.

The structure of the proposed adaptive scalable multiuser-OFDM system is shown in Figure 1. For comparison purposes, two image coding algorithm were used. One is the standard JPEG image coder, the other is MWT [2]. JPEG coder do not support scalability, while the output of the MWT encoder is scalable such that whatever the receiver was, the received data can be used to reconstruct the original image with corresponding quality. We assume that the channel state information (CSI) for all users at the base station is already known. The base station transmitter is controlled by adaptive bit allocation

and rate decision algorithm according to channel state information and the transmitter power. This system has a variable user number and each user has different data rate $\{b_k\}$ bits per OFDM symbol, $k=1,2,\ldots, K$, where K is the number of users. In the transmitter, each subcarrier is adaptively modulated by adaptive bit allocation alogrithm. After adaptively modulated, the different number of subcarriers is reallocated according to the required bit rate for each input image. The information from the different Kth users are fed into the adaptive modulator use a corresponding modulation scheme according to the assigned number of bits for each subcarrier. We define $b_{k,m}$ as the number of bits of the kth user assigned to the mth subcarrier. The adaptive modulator allows $b_{k,m}$ to assign value in the set $B=\{0, 1, 2 , 3, 4, 5, 6, 7, 8, 9, 10\}$. This set consists of : no bit, BPSK, QPSK, 8PSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM. When CSI is available at the transmitter, the transmitter can adapt its transmit power for each users subcarrier signal in a symbol-by-symbol manner to increase the data rate, assuming that the fading characteristics of the channel are constant over one OFDM symbol duration, but vary from symbol to symbol. Users per OFDM symbol are reallocated from allocated bit size and IFFT/FFT size for each service. IFFT/FFT size

consists of the set $R=\{0, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048\}$. We assume that we assign $R_1=\{1, 2, 4, 8\}$ for low rate service, $R_2=\{16, 32, 64\}$ for high rate service, and $R_3=\{128, 256, 512\}$ for very high rate. The system, theoretically, can even support video services (in this case, motion compensation and estimation should be considered). Inverse Fourier transform (IFFT) transforms the variable-bit-length modulated symbols into the time domain samples. And a guard interval, cyclic prefix of the time domain samples is added before transmission to eliminate inter-symbol interference (ISI). At that point, the guard interval is greater than the maximum delay time. In the receiver, all the above operations are reversed. Channel estimation is used at the receiver to mitigate the effect of ISI in the decoded symbol.

3. Progressive Image Transmission

By using MWT, the reception of code bits can be stopped at any point and the image can be decompressed and reconstructed. MWT is a *nearly* lossless encoding technique, since it has noninteger tap weights and produce noninteger transform coefficients, which then truncated to finite precision. We assume that the original image is defined by a set of pixel values $p_{i,j}$, where (i, j) is the pixel coordinate. To simplify the notation we represent two-dimensional (2-D) arrays with bold letters. The coding is actually done to the array

$$\boldsymbol{c} = \Omega(\boldsymbol{p}) \tag{1}$$

where $\Omega(.)$ represents the hierarchical wavelet transformation (in [2]). The 2-D array $\boldsymbol{c}$ has the same dimensions of $\boldsymbol{p}$, and each element $c_{i,j}$ is called transform coefficient at coordinate (i, j). For the purpose of coding, we assume that each $c_{i,j}$ represented with a fixed-point binary format (in simulations we consider eight binary digits per each coefficient).

In a progressive transmission scheme, the decoder initially sets the reconstruction vector $\bar{\boldsymbol{c}}$ to zero and

updates its component according to the coded message. After receiving the value (approximate or exact) of some coefficients, the decoder can obtain a reconstructed image

$$\bar{\boldsymbol{p}} = \Omega^{-1}(\bar{\boldsymbol{c}}) \tag{2}$$

One of the advantages of progressive image transmission scheme is to select the most important information which yields the largest distortion reduction to be transmitted first [4].

4. Multimedia Scalability

As mentioned above, MWT can achieve both multirate and multiresolution scalability simultaneously during the bit stream extraction process. Suppose we encode a 30 fps CIF-format video sequence of size 352 pixels*288lines, and use $K=3$ and 8-frames video sequence. This means that we can have three possible spatial resolutions, four different temporal resolutions and arbitrary bit rates at the decoder. In the MWT encoders shown in Figure 2, motion compensation is applied in advance of MWT decomposition. Here, the first frame in a group of frames (GOF) is used as a reference frame, and succeeding frames in the GOF are then "mapped / registered" with respect to the reference frame by estimating a set of block motion vectors for each frame [2]. The output is then decomposed to produce the expansion coefficients. The expansion coefficients are quantized at different layers and encoded using variable length coder (VLC). The ordinary WT blocks, each implemented as an $N+1$ channel iterated filter bank, are represented as one input $N+1$ output devices. Outputs labled $n=1,\ldots,N$ correspond to wavelet coefficients at scale level n and output $N+1$ scaling coefficients. In order to compute the MWT, the input signal could be image or video signal demultiplexed over K channels that are in the wavelet transform blocks.
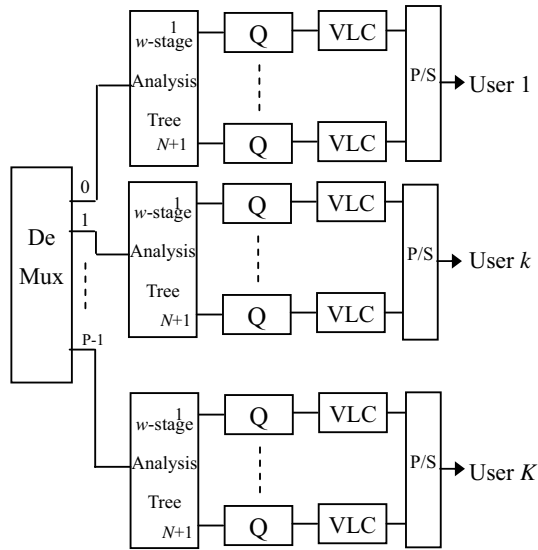
Figure 2 Block diagram of the MWT-based scalability technique

Different layers have different number of bits allocated to each quantizer. And at each layer, the number of stages "w" of the dyadic wavelet transform is adapted according to the receiver capability (pre-defined user's quality of service (QoS)). The multiplexed wavelets can also be designed for optimum solution for a given network. In case of RGB coloured images, the image is a three-dimensional signal, with R,G and B are two dimensional. One can apply a 2-dim wavelet transform at each stage individually to R,G and B. The output is also a 2-dim R,G and B signals but their sizes are halved after each stage. Such that the output RGB at each stage "w" is a 3-dim signal can be used to construct the original image at different resolution. This layering method provides many advantages; first, by using the MWT, optimization algorithms may used to optimize the value of "w" in response to the network requirements. Second, by choosing the suitable wavelet family, bandwidth efficiency enhancement can be achieved. By applying optimization algorithms the number of operations required will dramatically increase, and hence, more system latency.

## 5. User, Bit, and Power allocation for Multiuser Channel

The main concern of this paper is the study of the performance of an adaptive OFDM system which makes it possible to provide different services depending on instantaneous channel conditions and the transmit power, signal to noise ratio (SNR). The first parameter to consider is the transfer function of channel response. Since all subcarriers experience different channel gains in frequency selective fading channel, we first use the magnitude of the channel gain, $|H_{k,m}|^2$. The second thing to consider is the transmit power. If the transmit power goes high, receive power become also high, because the receive power is the transmit power times the magnitude of channel gains. In order to allocate an appropriate bit for each subcarrier, we first decide the required QoS, desired BER level accoding to different services. In case of image or video transmission, QoS required about 10^{-5} for coded OFDM system [5]. After deciding threshold for each service, we apply these thresholds considering given SNR and dynamic range value of several RMS delay spreads. To consider the dynamic range of fading channel is for adapting the required transmit power, which is varied by delay spread. If the delay spread is large, uncorrelateness and dynamic range become large. Therefore, BER by deep fade can be increase. The dynamic range can be obtained from difference of maximum and minimum value of channel frequency response. We must obtain the bit selection curve to choose the modulation parameters. The bit selection curve can be obtained by the performance of different modulation schemes accoding to SNRs in AWGN channel. Figure 3 shows an example of the performance of QAM modulation scheme with $M=4$, named QPSK. It also shows the desired BER region for the transmission of image and video with acceptable quality.

The adaptation selection curve
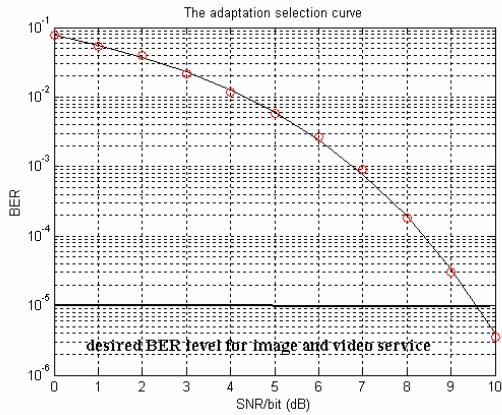
Figure 3 The adaptation selection curve (QPSK as an example)

6. Simulation Results

We assume a two-ray channel model with delay spread from 10 μs and Doppler frequency (f_d) from 10 Hz to 200 Hz. Two transmit antennas, as shown in Figure 2, and (2, 4) receive antennas are used for space-time block code. Reference [6] shows that image quality using STBC (2, 4) is always better than STBC (2, 2). The entire channel bandwidth, 800 kHz, is divided into 256 subchannels. The symbol duration is 320 μs. An additional 40 μs guard interval is used to provide protection from ISI due to channel multipath delay spread. To simulate QAM with different numbers of M, a simulation program was used that generates Gray coded M-level QAM symbols for any value of M [7]. Lena image of size 256 x 256 grayscale has been used for simulations. Figure 4 shows a comparison between JPEG coded images over OFDM system, and the MWT coded images over adaptive OFDM system. It is shown in the figure that MWT+OFDM has high PSNR values than that of JPEG+OFDM. And the difference is going to increase dramatically with the increasing signal to noise ratio. By comparing Figure 4 (a) and (b), one can notice that the effect of Doppler frequency (f_d) is noticeable but do not effect seriously the image quality for both systems.
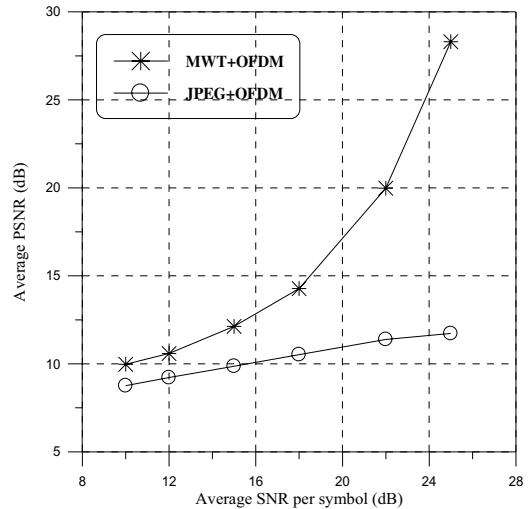
(a) f_d=200 Hz
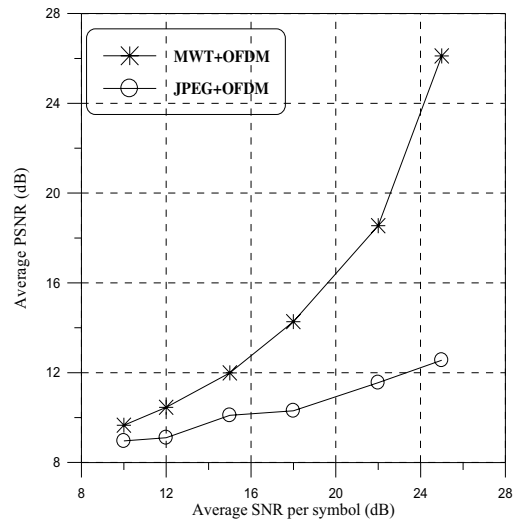
(a) f_d=20 Hz

Figure 4 PSNR comparisons between JPEG+OFDM and MWT+OFDM

The received image of Lena is shown in Figure 5, at two different SNR values equal to 15 dB and 25 dB, when f_d is 200 Hz. It is shown the image quality when transmitted using adaptive MWT OFDM system is much improved by increasing the average SNR value, this improvement would be gained by using the standard JPEG coded image.

(a) PSNR=12.1209 dB, SNR=15 dB

(b) PSNR=28.3069 dB, SNR=25 dB

Figure 5 Received images of Lena using
MWT+OFDM and Doppler frequency f_d=200 Hz

7. Conclusion

We have proposed an adaptive scalable multiuser-OFDM system efficient for image transmission over fading channels. Our algorithm is independent of the image size, number of components in the image, and image aspect ratio. This technique may also be useful to video transmission as *motion image compression*, this to need further investigations as future work. So it's very attractive as a new efficient adaptive image transmission standardization technique for MHP applications, as an example.

8. References

[1] E. Lawrey, "Multiuser OFDM", *Proc. Of the Fifth International Sym. On Signal Processing and Its Applications*, Vol. 2, 1999.

[2] Ahmed Muthana M. Nadhim, Jiangtao Xi, Zongkai Yang, and Jianhua He, "Image and Video Layering Using Multiplexed Wavelet Transform", *Global Mobile Congress, GMC' 2004*, Shanghai, China, 2004.

[3] J. Moon, S-Y. Park, and S. Hong, "Adaptive OFDM system for multi-rate multi-user services in wireless communications", *The 5th International Symposium on Wireless Personal Multimedia Communications*, Vol. 3, 27-30 October 2002, pp. 1039-1043.

[4] A. Said, and W. A. Pearlman, "A new, fast, and efficient image codec based on set partitioning in hierarchical trees", *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 6, Issue: 3, June 1996, pp. 243–250.

[5] L. M. C. Hoo, J. Tellado, J. M. Cioffi, "Dual QoS loading algorithms for DMT systems offering CBR and VBR services", *Global Telecommunications Conference, GLOBECOM 98*, Vol. 1, 8-12 November 1998, pp. 25-30.

[6] J. Song, and K.J.R. Liu, "Robust progressive image transmission over OFDM systems using space-time block code", *IEEE Transactions on Multimedia*, Vol. 4, Issue 3, September 2002, pp. 394 – 406.

[7] Ahmed Muthana M. Nadhim, Abdul-Karim A-R. Kadhim and Zongkai Yang, "Complex WPM-based Multicarrier System for Digital Subscriber Line", *IEEE International Conference of Information Technology and Applications*, ICITA'04, January 2004.