Link Adaptation of OFDM Wireless System using Adaptive Carrier Spacing Method

Shuvabrata Bandopadhaya
Dept of ETC, Silicon Institute of Technology
Bhubaneswar, Odisha, India

Jibendu Sekhar Roy
School of Electronics Engineering, KIIT University
Bhubaneswar, Odisha, India

ABSTRACT

Link adaptation is an essential part of wireless communication in order to guarantee required QoS in dynamically varying channel by changing the transmitter parameter according to channel condition in order to utilize spectrum must efficiently. This work proposes a noble producer for link adaptation with adaptation of carrier spacing of OFDM based communication system according to the channel condition. This method of link adaptation may mitigate the need of perfect carrier frequency offset (CFO) estimation at the receiver side. The simulation result shows the switching levels for different types of channel described by stand ford University Interim (SUI) models for IEEE 802.16 based system using fixed threshold based algorithm.

General Terms

Link adaptation algorithm in OFDM

Keywords

Link adaptation, OFDM, CFO, Subcarrier spacing, SUI-model, IEEE 802.16.

1. INTRODUCTION

Long Term Evolution (LTE) is the principle candidate for next generation wireless communication has a special feature of link adaptation with time varying nature of wireless channel. It is the procedure of adaptation of some transmission parameters according to channel condition and type of application in order to guarantee the required minimum transmission performance such as data rate, but error rate and latency. The major task of link adaptation procedure is to optimally utilize adaptive transmission power control procedure accompanied with adaptive modulation (AM) and adaptive channel coding rate (ACR) according to channel condition in order to maximize throughput. The channel condition is the major criteria for the adaptation procedure which includes path loss, variation in multipath components and Doppler shift. The modem can accomplish link adaptation in a closed loop signaling scheme. It requires a duplex communication between two transceivers as the parameter adaptation is an action at transmitter in response to the channel estimation carried out of receiver.

Adaptation of transmission power with channel condition uses higher transmission power for poor SNR valued channel in order to guarantee required QOS but it may leads to co-channel interference in cellular wireless system. Adaptive modulation is a classical approach for link adaptation which adapts the spectral efficiency hence the data rate according to channel condition. This process maintains the transmission power constant throughout but varies number of modulation levels according to channel condition. The number of modulation levels is varied in such a way that the short-term BER is constant varying short term data rate but keeping average data rate is constant[1]. Orthogonal frequency division multiplexing (OFDM) is the key technology of LTE standard, which effectively converts frequency-selective channel in to number of flat fading channels by help of subcarriers and eliminates the inter symbol interference (ISI) by help of cyclic prefix. [2] OFDM is a technique of transmission which employees various subcarriers, where for each subcarrier the channel conditions are different in frequency selective channel. Hence it is proposed in [3] to choose the appropriate modulation mode for transmission in each subcarrier. Adaptive channel coding rate (ACR) is another alternative for link adaption where length of channel code is adapted according to channel condition [4]. There are several of hybrid adaptation schemes like variable rate variable power (VRVP) [5], had been proposed.

This paper proposes a noble procedure for link adaptation method which adapts the spacing between the subcarriers of the OFDM system according to the channel condition without altering the channel bandwidth. Spacing between subcarriers is an important issue for OFDM as the carriers has the tendency to drift due carrier frequency offset (CFO), and Doppler shift which limits the number of subcarriers and it requires extensive CFO estimation [6][7] which leads computational complexity at the receiver . In this adaptation process the need of CFO estimation reduces as it employees higher number of subcarriers hence lower carrier spacing for better conditioned channel and lower number of subcarriers hence higher carrier spacing for poor channel in order to maintain target BER. Hence the transmission data rate improves with improves of channel condition. The simulation result shows the switching levels for different types of channel described by stand ford University Interim (SUI) models [8] for IEEE 802.16 based system using fixed threshold based algorithm [9]. The organization of this paper is as follows: The OFDM system model and channel estimation are described in section 2, the proposed adaptive technique along with simulation result is provided in section 3 and section 4 concludes the paper.

2. OFDM SYSTEM MODEL AND CHANNEL ESTIMATION

If the complex symbol to be transmitted at nth OFDM transmission block is $\{S_{n,k}\}$ then the OFDM modulated signal can be represented by [10]

$$Sn(t) = \sum_{k=0}^{N-1} \{S_{n,k}\} \exp[\,j2\Pi(k\Delta f)t] \qquad (1)$$

Where Ts is the symbol duration, Δf is the sub-carrier spacing where N is the number sub-channel of OFDM symbol. The minimum condition that has to satisfy for the sub-carriers are orthogonal is

$$Ts = \frac{1}{\Delta f} \Rightarrow \Delta f = \frac{1}{T_S} \qquad (2)$$

With cyclic prefix (CP), the transmitted signal is extended to $T=Tg+Ts$, where Tg is the duration of guard interval. The transmitted signal with CP, can be expressed as

$$S_n(t) = \sum_{k=0}^{N-1} \{S_{n,k}\} \exp[\,j2\Pi(k\Delta f)t] \qquad (3)$$

The wireless channel impulse response can be expressed as [11]

$$h(t,\tau) = \sum_i \gamma_i(t)\delta(t-\tau_i) \qquad (4)$$

Where τ_i and $\gamma_i(t)$ are the delay and the complex amplitude of *i*th path respectively and they are wide-sense stationary (WSS) narrowband complex process and are independent for each path. Signal received at the receiver is summation of transmitted baseband symbol convolved with channel impulse response (CIR) and additive noise

$$r_n(t) = \sum_i \gamma_i(t) S_n(t-\tau_i) + n(t) \qquad (5)$$

Where $r_n(t)$ and $n(t)$ represents the signal received at receiver and adaptive white Gaussian noise (AWGN) in channel respectively. The base band version of received signal after demodulation

$$\{r_{n,k}\} = \frac{1}{Ts}\int_0^{Ts} r_n(t)\exp(-j2\Pi kn\Delta f)dt$$

$$= \frac{1}{Ts}\int_0^{Ts} \{\sum_i \gamma_i(t)\overline{Sn}(t-\tau_i) + n(t)\}\exp(-j2\Pi kn\Delta f)dt \qquad (6)$$

Using convolution theorem

$$\{r_{n,k}\} = H_k.\{S_{n,k}\} + n_k \qquad (7)$$

For $0<k<N-1$ and for all n. Where H_k is the frequency response of the wireless channel at *k*th sub-band and is defined as

$$H_k = \sum_i \gamma_i(t)\exp(-j2\Pi k\Delta f\tau_i) \qquad (8)$$

And n_k is the impact of Gaussian noise in frequency domain in *k*th sub- band. Hence the impact of channel is only multiplicative distortion at each sub-band of OFDM system. Channel estimation is the essential phase of OFDM based communication system in order to estimate the frequency domain channel transfer function as well as for adaptive modems to change transmission parameters for next packet to be transmitted. The channel state information (CSI) can be estimated using training symbols called pilot symbol which are known both at transmitter and receiver. Proper channel state information (CSI) is essential for design of a simple one-tap frequency domain equalizer in order to compensate the adverse effect of channel. The least-square (LS) estimator estimates the channel gain of *k*th sub-carrier as

$$\hat{H}_k = \frac{\{r_{n,k}\}}{\{S_{n,k}\}} \qquad (9)$$

3. PROPOSED ADAPTIVE MODEL AND SIMULATIONRESULTS

This model deals with adaptation of spacing between sub-carriers of the OFDM system according to the channel condition. But the distortion caused by channel may introduce offset in frequency which may degrade the QoS if there is not adequate channel spacing. The channel frequency offset (CFO) estimation includes complexity at the receiver and requires high degree of accuracy.

This work proposes adaptation of spacing between sub-carrier as per channel condition. If 2.56MHz spectrum is allocated for single OFDM symbol with various number of sub-carriers:32, 64, 128 and 256 with channel spacing of 80KHz, 40KHz, 20KHz and 10KHz respectively. In every channel estimation phase the pilot symbols are utilized to estimate the signal to noise ratio (SNR) using the method proposed in [12] for next transmission slot and change the subcarrier number accordingly in order to maintain the target BER for constant QoS. The complete algorithm for proposed link adaption is given in Table-1. The performance of OFDM system below through various type of channel model for IEEE 802.16 is evaluated via simulation. We have considered three types of channel described by Stanford University Interim. Fig-1, fig-2, fig-3 shows the performance of OFDM system with various sub-carrier spacing for through channels SUI-1 (Category-C) for flat terrain and light tree density, SUI-3 (Category-B) for moderate terrain and moderate and tree density, SUI-5 (Category-A) for hilly terrain and heavy tree density respectively. It is assumed that perfect channel state information (CSI) is available at receiver. For each type of channel two cases have been considered – single transmitting and single receiving antenna, and single transmitting antenna two receiving antenna for exploiting receiver diversity. Table-2 shows the SNR boundary range in dB for adaptation based on fig-1-3. All values are rounded up to nearest integer level.

Table-1: Proposed algorithm

Proposed Algorithm	
Signaling direction	Process
Forward Signaling	1. Transmit 1st block along the pilots inserted to estimate the channel state information (CSI) and SNR level.
Reverse Signaling	2. The information generated at the receiver about the channel SNR level during channel estimation process has to provide to transmitter through reverse signaling.
	3. Choice of appropriate parameter for next transmission slot as per table-1.
Forward Signaling	4. The exchange information about change of transmission parameters is transmitted to receiver through forward signaling.
	5. After receiving the information the receiver adjust its modem parameter according to that of transmitter.

Table-2(a): Channel type: SUI-1, Category-C

NO of Sub-carriers	32	64	128	256	32	64	128	256
Antenna configuration	1X1 (SISO) Configuration				1X2 ,With Receiver Diversity			
Target SER: 10^{-3}	23<sn<26	26<sn<29	29<sn<32	32<sn	21<sn<24	24<sn<27	27<sn<29	29<sn
Target SER: 10^{-4}	24<sn<28	28<sn<31	31<sn<34	34<sn	23<sn<25	25<sn<28	28<sn<31	31<sn

Table-2(b): Channel type: SUI-3, Category-B

NO of Sub-carriers	32	64	128	256	32	64	128	256
Antenna configuration	1X1 (SISO) Configuration				1X2 ,With Receiver Diversity			
Target SER: 10^{-3}	25<sn<28	28<sn<31	31<sn<34	34<sn	23<sn<26	26<sn<29	29<sn<32	32<sn
Target SER: 10^{-4}	27<sn<29	29<sn<32	32<sn<36	36<sn	24<sn<27	27<sn<30	30<sn<34	34<sn

Table-2(c): Channel type: SUI-5, Category-A

NO of Sub-carriers	32	64	128	256	32	64	128	256
Antenna configuration	1X1 (SISO) Configuration				1X2 ,With Receiver Diversity			
Target SER: 10^{-3}	28<sn<31	31<sn<34	34<sn<38	38<sn	26<sn<29	29<sn<32	32<sn<35	35<sn
Target SER: 10^{-4}	30<sn<33	33<sn<37	37<sn<40	40<sn	29<sn<33	33<sn<35	35<sn<38	38<sn

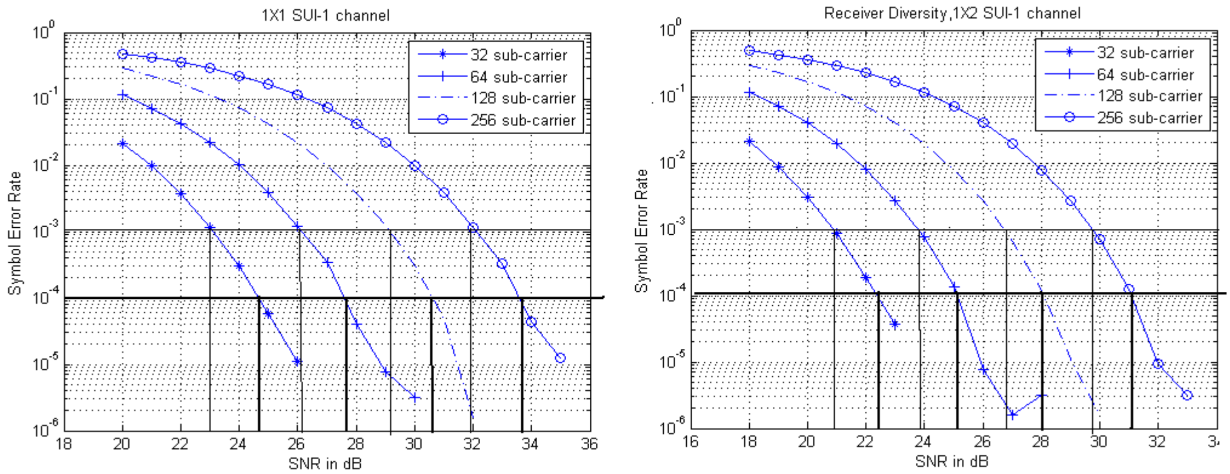

Fig-1: Channel type: SUI-1, Category-C

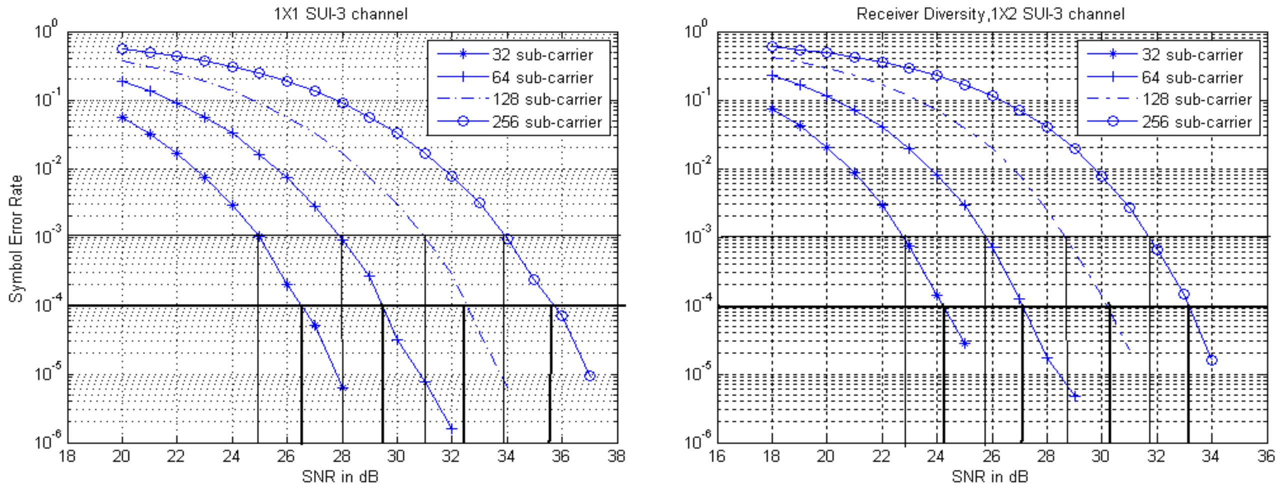

Fig-2 Channel type: SUI-3, Category-B

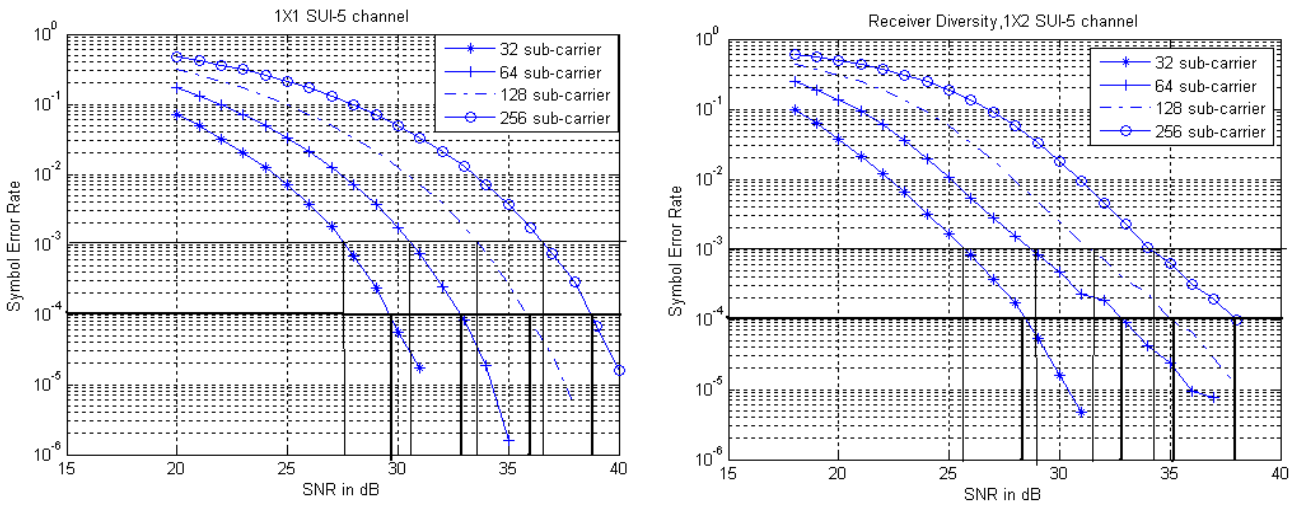

Fig-3 Channel type: SUI-5, Category-A

4. CONCLUSION

In this paper a novel link adaptation scheme with adaptation of carrier spacing between adjacent sub-carriers is proposed that includes the performance analysis of the scheme in various type of channel model for IEEE 82.16 and threshold of switching is provided for given target BER with SISO and 1X2 SIMO antenna configurations. This link adaptation scheme utilizes the spectrum with greater efficiency as same preamble is utilized for channel estimation as well as decision making in link adaptation process. Implementation of this link adaptation scheme with various combination of MIMO system may move future researchers forward.

5. REFERENCES

[1] W.T.Webb, R.Steele, "Variable rate QAM for mobile radio". *IEEE Trans . Commun*.Vol-43, no 7 ,pp-2223-2230 July 1995.

[2] Y.Li, H.Winters and N.R.Sollenberger, "MIMO-OFDM for Wireless communication:Signal detection with enhanced channel estimation", *IEEE Trans. Commun.*,Vol-50,no.9,pp-1471-77 sept-2002.

[3] T.Keller, L.Hanzo, "Adaptive modulation techniques for duplex OFDM transmission." *IEEE Trans, Vehicular Tech*. Vol-49,no-5,pp-1893-1906, sept-2000.

[4] A.J.Goldsmith and S.Chua, "Adaptive coded modulation for fading channels". *IEEE Trans. Commun.*,Vol-46.no-5 pp-595-602 may 1998.

[5] Z.Zhou,B.Vucetic,"MIMO system with adaptive modulation" *IEEE Trans . Vehicular Tech.* Vol-54,no-5,pp- 1828-42,sept-2005.

[6] Y.Yingwei and G.B.Giannalis,"Blind carrier frequency offset estimation in SISO,MIMO and multiuser OFDM system." *IEEE Trans . Commun.*,Vol-53,no-1,pp-173-183,Jan 2005.

[7] J.M Lin, H.S.Ma,"A High performance base bound transceiver for SISO-/MIMO-OFDMA uplink communication" *IEEE Trans. Wireless Comm.* Vol-8,no-7 pp-3330-34,July-2009.

[8] IEEE 802.16 Broadband Wireless Access Working Group, "Channel models for fixed wireless applications", IEEE 802.16a-03/01, 2003-06-27.

[9] J.Torrance and L.Hanzo, "Optimization of switching levels for adaptive modulation in slow Rayleigh fading." *Electron . Lett,* Vol-32, pp-1167-69, June 1996.

[10] T.Hwang, C.Yang, G.Wel and S.Li, "OFDM and its wireless application: A Survey" *IEEE Trans , Vehicular Tech*. Vol-58 No-4 pp-1673-1694, May 2009.

[11] R.Steel, 'Mobile Radio Communication', New York: IEEE Press.1992.

[12] M. Zivkovic, R.Mathar,"An Improved Preamble-based SNR Estimation Algorithm for OFDM Systems", *21st Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications,*2010,pp-172-176.