ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

Behavioral Study of Different Adaptive Modulation Techniques in MIMO Transmission: A Review Paper

Ms. Madhuri Gehlot, Mrs. Rashmi Pant

Abstract: Adaptive modulation (AM) technique may make more promote in the execution of wireless communication systems through adaptively conformity transmitter parameters to fading channels; therefore, it has been taken as one of the key physical techniques. Error performance and throughput in MIMO wireless systems can be improved through the use of Adaptive Modulation. Adaptive modulation selection plays an important role in wireless communication since the wireless channel conditions vary progressively. This paper offers a general overview of the adaptive modulation scheme in wireless multiple-input multiple-output (MIMO) systems.

Keywords: Adaptive modulation, multiple input multiple-output (MIMO), Orthogonal frequency division multiplexing (OFDM), Bit error rate (BER).

I. INTRODUCTION

Generally, the channel used in practical communication systems is either a multipath fading time-varying channel. It may depend on various factors of the channel such as the path-loss between the transmitter and receiver or channel fading due to multipath propagation. Therefore, using any one modulation technique to transmit signal in the channel would not fulfill the requirement of wireless environment. Consequently, different channel condition corresponds to different modulation type. Taking 802.11 standards [1] for example, there are four kinds of modulation type, i.e. BPSK, QPSK, 16- QAM and 64QAM [2]. Adaptive Modulation techniques have proven to be an effective way of transmitting data efficiently through time varying channels. Also in order to counter the adverse effects of Inter-Symbol Interference (ISI), Orthogonal Frequency Division Multiplexing (OFDM) [3]. All radio communications systems, regardless of whether mobile radio networks like 3GPP UMTS or wireless radio networks like WLAN, must continually provide higher data rates. In addition to conventional methods, such as introducing higher modulation types or providing larger bandwidths, this is also being achieved by using multiple antenna systems (Multiple Input, Multiple Output – MIMO). A MIMO [4] wireless system consists of N transmit antennas and M receive antennas. However, unlike phased array systems where a single information stream, say x(t), is transmitted on all transmitters and then received at the receiver antennas, MIMO systems transmit different information streams, say x(t), y(t), z(t), on each transmit antenna. These are independent information streams being sent simultaneously and in the same frequency band. Multiple-input multiple-output (MIMO) technology constitutes the basis for next generation wireless communication systems, for example in the standards IEEE802.11n or IEEE802.16 or LTE [5]. In particular, spatial multiplexing allows to achieve a spectral efficiency that grows linearly with the minimum of the number of transmit and receive antennas. Unfortunately, the considerable gains in spectral efficiency resulting from spatial multiplexing are bought dearly at the expense of additional signal processing complexity at the receiver, most prominently in the MIMO detection unit [6]. Spatial multiplexing is not intended to make the transmission more robust; rather it increases the data rate. To do this, data is divided into separate streams; the streams are transmitted independently via separate antennas [7]. We then obtain tight closed-form approximations for the BER of MIMO ZF receiver for M-QAM and M-PSK modulated signals.

II. ADAPTIVE MODULATION

Modulation [8] Modulation is the process by which a carrier wave is able to carry the message or digital signal (series of ones and zeroes). There are three basic methods to this: amplitude, frequency and phase shift keying. Higher orders of modulation allow us to encode more bits per symbol or period (time).

Amplitude Shift Keying (ASK) Amplitude shift keying (ASK) involves increasing the amplitude (power) of the wave in step with the digital signal (in other words, low = 0, high = 1) and is used in AM radio.

Frequency Shift Keying (FSK) Frequency shift keying (FSK) changes the frequency in step with the digital signal. Systems that use this modulation (broadcast FM radio) tend to be more resilient to noise since noise usually changes the amplitude of the signal. In Figure 1, different bits are represented by different frequencies which can then be detected by a receiver

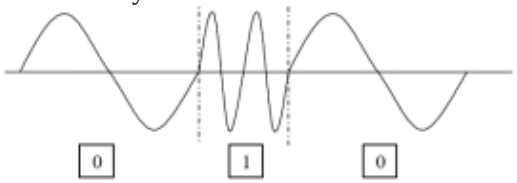

Figure 1: Frequency Shift Keying (FSK)

Phase Shift Keying (PSK) Phase shift keying (PSK) changes the phase of the carrier in step with the digital message. For binary phase shift keying (BPSK), each

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

symbol could indicate two different states or one bit per symbol (in other words, 0 = 0, 180 = 1).

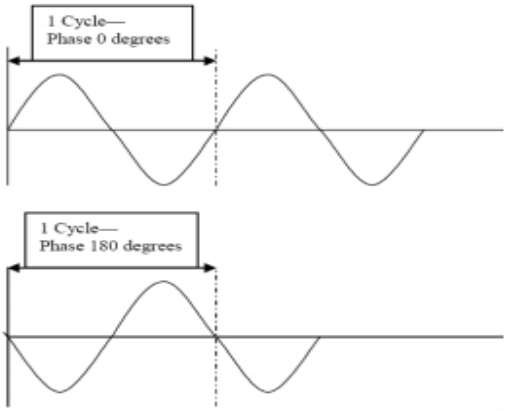

Figure 2: Phase Shift Keying (PSK)

Quadrature Phase Shifting Keying (QPSK) QPSK adds two more phases: 90 and 270 degrees. Now two symbols per bit can be transmitted. Each symbol's phase is compared relative to the previous symbol; so, if there is no phase shift (0 degrees), the bits "00" are represented. If there is a phase shift of 180 degrees, the bits "11" are represented.

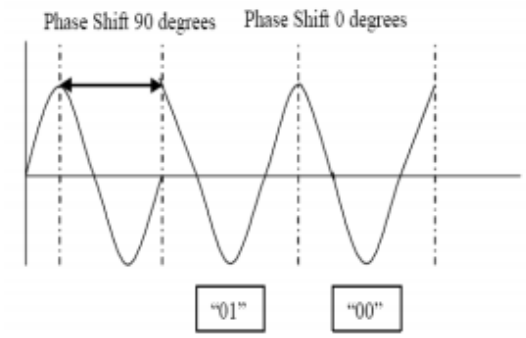

Figure 3: Quadrature Phase Shift Keying (QPSK)

Quadrature Amplitude Modulation (16- QAM) ASK and PSK can be combined to create QAM where both the phase and amplitude are changed. The receiver then receives this modulated signal, detects the shifts and demodulates the signal back into the original data stream.

Adaptive Modulation Different order modulations allow you to send more bits per symbol and thus achieve higher throughputs or better spectral efficiencies. However, it must also be noted that when using a modulation technique such as 64-QAM, better signal-to-noise ratios (SNRs) are needed to overcome any interference and maintain a certain bit error ratio (BER).

The use of adaptive modulation allows a wireless system to choose the highest order modulation depending on the channel conditions. In Figure 4, you can see a general estimate of the channel conditions needed for different modulation techniques. As you increase your range, you step down to lower modulations (in other words, BPSK), but as you are closer you can utilize higher order modulations like QAM for increased throughput. In addition, adaptive modulation allows the system to overcome fading and other interference.

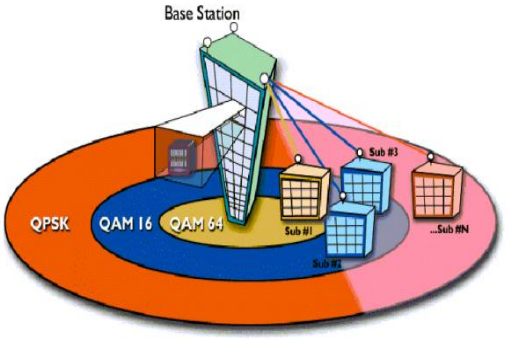

Figure 4: Adaptive Modulation and coding

III. ADAPTIVE CODING & MODULATION (ACM)

ACM [9], Adaptive Coding and Modulation, has the potential to improve the availability of your satellite links and also deliver significant bandwidth savings. Adaptive Coding and Modulation is a technology which can automatically change the modulation and forward error correction or FEC of a link (referred to as MODCOD) to compensate for changes in link conditions – commonly weather induced (e.g. rain fade) but also due to changes in the RF environment (e.g. level changes, interference). The use of ACM makes it unnecessary for service operators and system designers to trade off desired link availability and throughput. When compared with links designed using fixed coding, ACM can increase the throughput of a robust link by allowing it to dynamically adjust to a less robust modulation/coding (MODCOD) resulting in higher throughput under clear sky conditions. Conversely, when compared to a modestly robust fixed rate coded link, ACM can provide increased link availability by dynamically adjusting to lower order MODCOD under rain fade conditions. Standard duplex services assign fixed modulation and FEC for each leg of the link. ACM technology is able to alter the modulation and FEC by implementing a 'feed-back' circuit containing link performance information. This circuit can be combined with the service or provided on a separate link (e.g. PSTN). Normally the symbol rate of the link must be constant to ensure the allocated bandwidth remains the same on the satellite. Accordingly the data rate is altered to compensate for any ACM changes in modulation and FEC.

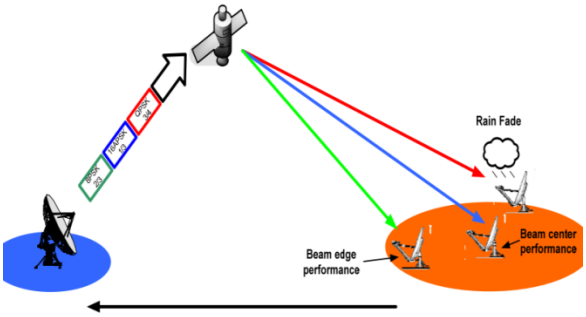

Figure 5: The effects of ACM technology under different atmospheric conditions.

For a shared platform with widely distributed remotes, the benefits of ACM can be very significant. Shared platforms with ACM have the ability to alter the MODCOD for

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

traffic assigned to a specific remote on a frame-by-frame basis as shown in above figure 5.
The ACM capable system is not restricted to use of the MODCOD appropriate for the worst case site under fade conditions. As a result, higher throughputs relative to fixed code point systems can be achieved under both clear sky and rain fade conditions [10].
Additionally, ACM systems allow sites that are not affected by fade conditions to run at the highest MODCOD possible whilst fade affected sites have a reduced MODCOD configured to maintain link connectivity.

IV. SYSTEM MODEL

A. *MIMO System Model*

We assume a flat fading MIMO channel [11] with n_T transmit and n_R receive antennas represented by a $n_R \times n_T$ matrix H. The entries of H are independent to each other and $H_{j,i} \sim$ CN (0, 1).
The input to the channel is denoted by an $n_T \times 1$ column vector x, while the additive white Gaussian noise (AWGN) and the channel output are represented by $n_R \times 1$ column vectors n and y, respectively.
The entries of n are also assumed to be independent and $n_j \times 1 \sim$ CN $(0, \sigma^2)$. For convenience, we define

$$m \triangleq \min(n_T, n_R), \quad n \triangleq \max(n_T, n_R), \quad d \triangleq n - m$$

The channel input/output equation can be written as

$$y = \boldsymbol{H_x} + n. \qquad (1)$$

Applying a singular value decomposition (SVD) to **H**, we can express it as

$$\boldsymbol{H} = \boldsymbol{UDV^H} \qquad (2)$$

Where D is an $n_R \times n_T$ nonnegative and diagonal matrix with the singular values of **H**, $\{\sqrt{\lambda_i}\}_{i=1}^{m}$, as its main diagonal elements. Note that $\{\sqrt{\lambda_i}\}_{i=1}^{m}$ are eigenvalues of $\boldsymbol{HH^H}$. For convenience, we define the eigenvalue vector λ as

$$\lambda \triangleq [\lambda_1, \ldots\ldots, \lambda_m]^T \qquad (3)$$

U = $[u_1, \ldots\ldots, u_{nR}]$ and V = $[v_1, \ldots\ldots, v_{nT}]$ are $n_R \times n_R$ and $n_T \times n_T$ unitary matrices with left and right singular vectors of **H** as their columns, respectively. Substituting (2) into (1), we obtain

$$y' = D_x' + n' \qquad (4)$$

Where; $y' \triangleq U^H y, x' \triangleq V^H x, n' \triangleq U^H n.$

It is important to note that the powers of x and x' are the same, as well as y and y', n and n', since U and V are unitary matrices.
From (3) we can see that the channel matrix H has been decomposed into m parallel eigen subchannels since D is diagonal. The equivalent channel input and output are x' and y', respectively. The subchannel power gains are represented by λ, which constitute a random process due to the randomness of the channel entries of **H**.

According to (4), when the channel matrix **H** or the vectors (**U, V,** λ) are perfectly available at both the transmitter and receiver, the equivalent system model is shown in Figure 6.

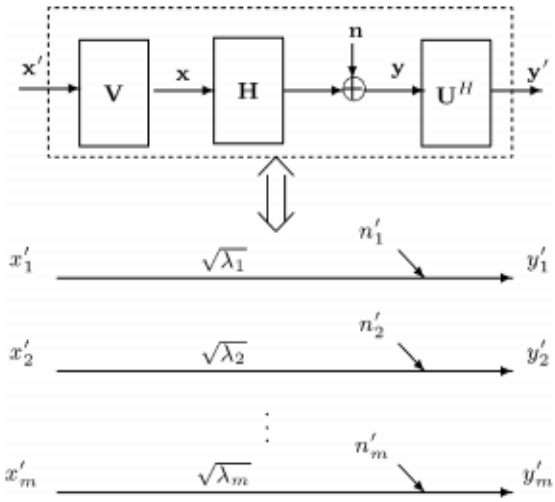

Figure 6. MIMO system and eigen subchannel equivalent model.

B. *Channel Capacity*

Assuming that the transmit power is subject to an instantaneous constraint

$$\sum_{i=1}^{m} p_i = p \qquad (5)$$

where p_i is the transmit power at subchannel i and P is the total transmit power, the instantaneous normalized capacity of this MIMO channel with full knowledge of **H**, denoted by C_{WF}, is given by [16]

$$C_{WF} = \sum_{i=1}^{m} log_2 (1 + p_1 \lambda_i / \sigma^2) \qquad (6)$$

The transmit power for each sub channel, allocated according to the water filling rule, is given by

$$p_i (\mu = \sigma^2 / \lambda_i)^+, \qquad (7)$$

Where $(x)^+ \triangleq \max(x, 0)$ and the Lagrangian multiplier μ is determined by (5). Aim is to approach the capacity in (6) using AM.

V. PERFORMANCE COMPARISON OF DIGITAL MODULATION TECHNIQUES

Let's take up some bandwidth-efficient linear digital modulation techniques (BPSK, QPSK and QAM) [2] and compare its performance based on their theoretical BER over AWGN [12].
Table 1 summarizes the theoretical BER (given SNR per bit ration – Eb/N0) for various linear modulations. Note that the Eb/N0 values used in that table are in linear scale [to convert Eb/N0 in dB to linear scale - use Eb/N0(linear) = 10^(Eb/N0(dB)/10)].
A small script written in Matlab (given below) gives the following output.

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

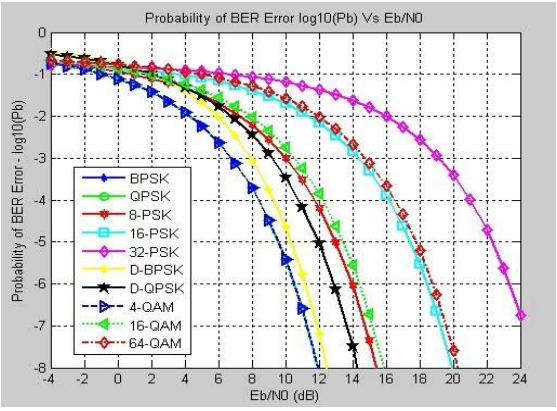

Table 1: Theoretical BER over AWGN for various bandwidth-efficient linear digital modulation techniques

VI. CONCLUSION

Modulation techniques used in IEEE 802.11 (Wi-Fi*), IEEE 802.16 (WiMAX*) and 3G (WCDMA/HSDPA) wireless technologies. The modulated signals are then demodulated at the receiver where the original digital message can be recovered. The use of adaptive modulation allows wireless technologies to optimize throughput, yielding higher throughputs while also covering long distances. Adaptive modulation selection plays an important role in wireless communication since the wireless channel conditions vary progressively. Therefore, it has been taken as one of the key physical techniques.

REFERENCES

[1] J. Kim, S. Kim, S. Choi, and D. Qiao, "CARA: Collision-aware rate adaptation for IEEE 802.11 WLANs," in *Proc. IEEE INFOCOM'06*, 2006, pp. 1–11.
[2] G. J. Foschini and Michael. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas". Wireless Personal Communications. January 1998.
[3] Y. Li, "Simplified channel estimation for OFDM systems with multiple transmit antennas," *Wireless Communications, IEEE Transactions on*, vol. 1, no. 1, pp. 67–75, Jan 2002.
[4] Heath R. W., Paulraj J.r. and Paulraj A. J. 2005. Switching Between Diversity and Multiplexing in MIMO Systems, IEEE Trans. Commun., vol. 53, no. 6, pp. 962 – 968.
[5] IEEE 802.11 TGn, Channel Model Special Committee, "TGn Channel Models for IEEE 802.11 WLANs," *802.11-03/940r4*, May 2004.
[6] Y.-S. Choi and S. Alamouti, "A pragmatic PHY abstraction technique for link adaptation and MIMO switching," *IEEE JSAC*, vol. 26, no. 6, pp. 960–971, August 2008.
[7] Tomoaki Ohtsuki, "Rate Adaptive Indoor Infrared Wireless Communication Systems Using Repeated and Punctured Convolutional Codes", *IEEE, 1999.*
[8] Analog Transmission of Digital Data eecs.yorku.ca/course_archive/201011/F/3213/CSE3213_07_ShiftKeying_F2010.
[9] S. Simoens, S. Rouquette-Léveil, P. Sartori, Y. Blankenship, and B. Classon, "Error prediction for adaptive modulation and coding in multipleantenna OFDM systems," *Elsevier Signal Process.*, vol. 86, no. 8, pp. 1911–1919, 2006.
[10] Muhammad Nadeem Khan, Sabir Ghauri, "The WiMAX 802.16e Physical Layer Model",University of West England.
[11] S. Haykin, "Fundamental issues in cognitive radio," in Cognitive Wireless Communication Networks, E. Hossain and V. K. Bhargava, Eds. New York: Springer, 2007, pp. 1–43.
[12] G. J. Foschini and Michael. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas". Wireless Personal Communications. January 1998.