Survey of Adaptive Modulation Scheme in MIMO Transmission

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***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 in 3GPP Evolved Universal Terrestrial Radio Access (E-UTRA). This paper offers a general overview of the adaptive modulation scheme in wireless multiple-input multiple-output (MIMO) systems. Study a set of properties by which adaptive modulation systems are evaluated, and then apply this valuation method to survey a number of existing systems, also, discuss modulation schemes and channel modeling in detail since it is utilized in most current system or solutions, as well survey some MIMO models which are included in adaptive modulation activities in order to reproduce and corresponding MIMO system ratings. Comprehensive execution comparisons including, BER analysis, average spectral efficiency (ASE), modulation schemes, and channel model are presented.**

***Index Terms*—Adaptive modulation, MIMO, orthogonal frequency division multiplexing (OFDM), imperfect channel state information (CSI), bit error rate (BER), average spectral efficiency.**

I. INTRODUCTION

Multiple input multiple output (MIMO) technology is utilized in wireless communications in order to get the better link robustness or to increase the spectral efficiency (SE). The aimed from the Adaptive MIMO transmission will be chosen dynamically for the modulation scheme and the optimum MIMO mode for the purpose of optimizing the spectral efficiency when satisfying the quality of service (QoS) requirements Ref. [1]. Adaptive modulation (AM) systems working to an improved rate of transmission, and/or bit error rates (BERs), through using the channel information that is present at the transmitter. Adaptive modulation systems display great execution enhancements through fading channels compared to systems that do not use the knowledge of the channel at the transmitter. The basic idea of Adaptive Modulation (AM) is to adapt the modulation and coding scheme to the channel state conditions (CSCs) in order to accomplish the highest spectral efficiency at all times. The benefit from using the adaptive modulation (AM) in the wireless systems is to choice of higher order modulation, get the optimum throughput, covering for long distances, and by depending on the channel conditions, it is used to overcome fading and other interferences. Adaptive modulation (AM) may be used to provide many of the parameters which depend to the channel fading, these contain transmit power, channel code rate or scheme, data rate, instantaneous BER, and symbol rate Ref. [2], and Ref. [3].

Adaptive modulation represents promising technical interests to approach the maximum channel capacity in single input -single output (SISO) systems Ref. [4]-[6]. The benefits from Adaptive modulation is to optimize the average spectral efficiency (ASE) depending to the channel state information (CSI) that will be fed back (F.B) from the receiver to the transmitter through adapting transmit parameters, like modulation constellation, transmit power, coding parameters Ref. [7]. The adaptive modulation/ coding scheme provides different data rate to different users depending on their channel conditions. With the minimum total transmission power and targeted bit error rate (BER), adaptive modulation scheme assigns the sub-carriers and bits for multi-user in the system based on the time-variant channel information Ref. [8]. ACM is one of the adaptive techniques for facing fading and enhances the execution of wireless systems. It used to maximize bandwidth efficiency through chooses an optimal combination from the modulation and coding scheme (MCS), where the resolution is dependent on the channel state information (CSI), so, every MCS will be linked to a coding rate and constellation size Ref. [9]. Thus, Adaptive modulation and coding (AMC), is a term utilized in wireless communications to refer to the matching of the modulation, coding and protocol

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parameters to the average channel conditions for each user (e.g. The path loss, the interference with signals from other transmitters, the usable transmitter power , the sensitivity of the receiver, etc.). Adaptive modulation and coding (AMC) enables spectrally efficient transmission through time-varying channels. The basic idea is to estimate the channel at the receiver side and feedback this estimate to the transmitter side, thus, the transmission scheme may be adapted proportional to the channel characteristics Ref. [10]. In a system with AMC, when a user is close to the base station (BS) are typically assigned higher modulation order with higher code rates (e.g. 64QAM and R= 3/4 turbo codes), but the modulation order and / or code rate will decrease when a user is far from the BS. The transmitted signal is dependent to the variance of interfering base stations, fading, path loss, and noise which affect to the quality of the received signal in order to get the best value for the system capacity , coverage reliability, and data rate, so that, the transmitted signal is modified through a process called link adaptation Ref. [9], and Ref. [10]. Our main purpose of this paper is to provide a qualitative overview for the latest Adaptive Modulation Schemes or solutions and the considered algorithms from the literature, also showing a quantities' comparison of these systems or solutions. For example, Adaptive modulation MIMO system model shown in Fig.1, with n_T transmit antennas, n_R receiver antennas, and $n_R \times n_T$ MIMO channel matrix H. The input to the channel is explained through a $n_T \times 1$ column vector X, whereas the additive white Gaussian noise (AWGN) and the channel output are represented through $n_R \times 1$ column vectors *n* and Y. So, the input/output equation for the channel may be written such as

$$Y = Hx + n \tag{1}$$

Where H is the complex channel matrix with the $(i, j)th$ element being the random fading between the *i*th receive and *j*th transmit antennas. $n \in C^{n}R$ is the additive noise source and is modelled as a zero-mean, circularly symmetric, complex Gaussian random vector with statistically independent elements, this is, $n \sim C\mathrm{N}(0, \sigma_n^2 I_{nR})$. The *i*th element of $x \in C^{n_T}$ is the symbol transmitted at the *i*th transmit antenna, and that $y \in C^{n_R}$ of is the symbol received at *j*th received antenna. So, the H matrix may be express it in the singular value decomposition (SVD) form as

$$H = U \sum V^H \tag{2}$$

Where U is a $(n_R \times n_R)$ unitary matrix, V is a $(n_T \times n_T)$ unitary matrix $(U^H U = I_{n_R}$, and $V^H V = I_{n_T})$ and $\sum$ is a $(n_R \times n_T)$ matrix with only nonzero main diagonal entries of singular values of H. The received signal Y' can be achieved by multiplying it with U^H, so

$$Y' = U^H (Hx + n) \tag{3}$$

By substituting (2) into (1),

$$Y' = U^H (U \sum V^H x + n) \tag{4}$$

And by substituting $x = Vx'$ in (4),

$$\begin{aligned} Y' &= U^H (U \sum V^H V x' + n) \\ &= U^H U \sum V^H V x' + U^H n \\ &= \sum x' + n' \end{aligned} \tag{5}$$

Where

$$\begin{aligned} Y' &\equiv U^H Y \\ x' &\equiv V^H x \\ n' &\equiv U^H n \end{aligned} \tag{6}$$

It is important be noted that the powers of x and x', Y and Y', n and n' are the same, since U and V are unitary matrices. Since D is diagonal, so that, the channel matrix H in (5) has been decomposed into *m* parallel Eigen sub channels. So, x', Y', and W represented the equivalent channel input and output and the sub channel power gains respectively. The estimates for the channel matrix H and excerpts (U,V,W) can be make it in the channel estimation module by doing a singular value decomposition (SVD), or instead, the channel estimation module can estimate (U, V, w) directly without estimating H. So, V and U are utilized at the transmitter side and receiver side to decompose the MIMO channel into parallel sub channels. Whereas, W is utilized on both sides to adapt the transmit parameters to maximize the average spectral efficiency (ASE) under some restraints, such as, transmit power and BER limitation Ref. [7], and Ref. [11].

This review paper is organized as follows. Section II shows the measuring principles for adaptive modulation schemes, which include average spectral efficiency, modulation schemes and BER analysis, and channel model classification. While, Section III presents the considered current adaptive modulation schemes from the literature and their proposed solutions, and performance comparison. Also, Section IV shows adaptive modulation and coding. Finally, the conclusions will be drawn in Section V.

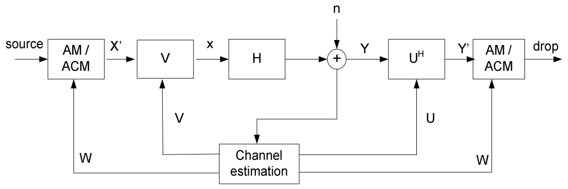

Figure1. Adaptive modulation MIMO system model.

II. MEASURING PRINCIPLES FOR ADAPTIVE MODULATION SCHEMES

It is not enough to measure the functioning of adaptive modulation schemes only by observing its accuracy. The performance benchmarking for adaptive modulation schemes has been defined as follows: average spectral efficiency (ASE)**,** modulation schemes and BER analysis**,** and channel model classification. After that, we make a comparison among different systems and solutions in Section (3).

A. Average Spectral Efficiency (ASE)

The ASE can be defined as the transmission rate that is split through the bandwidth (bps/Hz), and it may be computed as the average number of bits per channel symbol, where the ASE is a significant measurement of system execution only when the target BER restraint is fulfilled. The average spectral efficiency of the system is found as a weighted sum of the spectral efficiencies of each individual code, whereas the weight factor P_n for code *n* represent the probability that this code will be utilized:

$$ASE = \sum_{n=1}^{N} R_n . p_n$$
$$= \sum_{n=1}^{N} \left(\log_2(M_n) - \frac{1}{G} \right) . \left(\frac{L-1}{L} \right) . \left(Q\left(H, \frac{\gamma_n}{r\bar{\gamma}_h} \right) - Q\left(H, \frac{\gamma_{n+1}}{r\bar{\gamma}_h} \right) \right) \tag{7}$$

The probability P_n can be defined as the probability that the predicted SNRs falls in the interval $\langle \gamma_n, \gamma_{n+1} \rangle$ and it can be shown for Rayleigh fading with MRC as

$$P_n = Q\left(H, \frac{\gamma_n}{r\bar{\gamma}_h} \right) - Q\left(H, \frac{\gamma_{n+1}}{r\bar{\gamma}_h} \right) \tag{8}$$

Where $Q(x, y)$ represent the normalize incomplete gamma function [12, eq. 11.3]. The last component of (10) that is needed in order to compute BER is the information rate of each code $R_n \in \{1,2,.....,N\}$, so that, code *n*'s information rate for the case when 2G-dimensional ($G \in \mathbb{Z}^+$) Trellis codes are utilized can be expressed as [13], [14], and [15].

$$R_n = \left(\log_2(M_n) - \frac{1}{G} \right) . \left(\frac{L-1}{L} \right) \tag{9}$$

Where every *L*th channel symbol is a pilot symbol and, therefore, cannot transfer information; this is reflected in (9). So, if the *BER* becomes largest than BER_0, the system does not furnish the wanted transition reliability and the received data stream may be important to the end user Ref. [16], Ref. [13], Ref. [14] and Ref. [17]. MIMO diversity and MIMO multiplexing schemes are the main schemes considered in MIMO systems. As well, an Adaptive Modulation and Coding scheme have drawn much attention to the pioneer of the next generation mobile communication system in order to improve the throughput performance, together with MIMO system. The AMC scheme adapts a coding rate and a modulation scheme to the channel condition, resulting in improved throughput performance. Thus, the solution for improving the throughput performance is the combination of MIMO system and AMC scheme Ref. [18].

B. Modulation Schemes and BER Analysis

The main objective from the modulation is to transmit a source data through a channel in a way will be more suitable for this channel. Therefore, the original data must be translated to the format that is compatible to the channel condition. Modulation may be divided into two types, depending on the data will be modulated, such as, band pass modulation and baseband modulation. Therefore, for the first type, the data will modulate the frequency of radio to the carrier wave at high frequency, while for the second type; it composed of transforming the data to the waveforms from the low frequency. There are some types of modulation that using in AM, such as Phase shift keying *(PSK)* that consists from the use of a carrier's phase with the transmitted bit stream, for some particular cases from phase shift keying (PSK) with various number from values M, to representation various cases from PSK, like, binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 8-PSK, 16-PSK, 64-PSK, and so on, where the:

$$M = 2^i, \qquad Where,\ i = 1, 2, 3, \ldots\ldots., n \tag{10}$$

Therefore, beneath the conditions of Additive white Gaussian noise (AWGN) channel, the probability of transmitting for the signals in the BPSK system (M = 2) equal to the half the symbol error probability, so:

$$P_e = Q\left(\sqrt{\frac{2E}{N_0}} \right) \tag{11}$$

Where:

$$Q(x) = \int_x^\infty \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{z^2}{2} \right) dz \tag{12}$$

And the *Q*-function $Q(x)$ is associated with the complementary error function, as that:

$$Q(x) = \frac{1}{2} ercf\left(\frac{x}{\sqrt{2}} \right) \tag{13}$$

Therefore, the bit error probability P_b in BPSK system is coincides to the P_e, because the symbol contains one bit, and so that, the energy per bit is the same the energy per symbol. QPSK represent extension for the BPSK, where M = 4, and the constellation points for the QPSK may be constituted by two orthogonal sets of BPSK constellation points. Since there are two bits per symbol in the QPSK system, the energy per symbol is twice the energy per bit. So, BER for the QPSK can be explained as:

$$P_b = \frac{P_e}{2} \approx Q\left(\sqrt{\frac{2E}{N_0}}\right) \tag{14}$$

That means QPSK provides the same BER as BPSK. That means BER for QPSK with twice the bit rate will be the same as for BPSK; therefore, this shows the inefficient way for uses the bandwidth in the BPSK. For M-PSK system, and beneath the AWGN channel conditions, the symbol error probability will be calculated by the same technique as was utilized for computation error probability in the QPSK. If the constellation points are labelled with the Gray code, therefore, the symbol error will cause the perversity of one bit out of log2 M bits containing the symbol. So, the BER for M-PSK will be as:

$$P_b \approx \frac{2}{\log_2 M} Q\left(\sqrt{\frac{2E_b \log_2 M}{N_0}} \sin\left(\frac{\pi}{M}\right)\right) \tag{15}$$

PSK is not utilized for high order when M > 8 because of BER becomes very high, so, quadrature amplitude modulation (QAM) will be used. QAM is a practicable modulation scheme technique for attaining the high data rate transport without increasing the bandwidth (B.W) for wireless communication systems. To beat for the injurious channel disability in wireless communication systems, QAM will combine with other schemes, such as adaptive modulation (AM) scheme in order to maximize the throughput. QAM represented as an extension for the QPSK, and BER for 4QAM equal to the BER for QPSK, while for M > 4, The BER for MQAM over the AWGN channel is given by Ref. [19], Ref. [20], and Ref. [21]:

$$P_b \approx \frac{4}{\log_2 M}\left(1 - \frac{1}{\sqrt{M}}\right) Q\left(\sqrt{\frac{2E_b \log_2 M}{(M-1)N_0}}\right) \tag{16}$$

Different types from QAM modulation will be used in various communication scenarios to meet the specified data rate performance. By utilizing various order modulations, more bits/symbol will be transported through the transmitter, therefore, the best spectral efficiencies or higher throughputs can be obtained. Thus, the better SNR is desired when using a modulation technique such as 64-QAM to beat to the any interference and maintain to the certain BER, Ref. [22].

C. Channel Model Classification

Different forms of MIMO channel models have been described through the last years, a lot of them based on measurements, where this proposed model can be classified in assorted ways. There are different classifications from the channel modelling depended on the type of channel that will be considered, such as Ref. [23]:

1) Wideband Models (flat-fading) vs. Narrowband Models (frequency-selective)

By looking at the bandwidth of the system, the MIMO channel models may be split into the wideband models and the narrowband models. The wideband models deal the propagation channel as frequency selective channel, this mean various frequency sub channels will have various channel responses. While the narrowband models deal with the channel that has frequency non-selective fading, and hence, the channel has the same frequency response more the entire system bandwidth Ref. [24].

2) Field Measurements vs. Scatter Models

To model the MIMO channel, one approach is to scale the MIMO channel responses during the field metrics. Through investigating the registered data, some significant characteristics of the MIMO channel may be got, and thus, the MIMO channel model may be modelled to have the same characteristics. A replacement approach is to assume a model that tries to watch the channel characteristics. This model may be utilized to explain the necessary characteristics for the MIMO channel while the built scattering environment is sensible Ref. [24].

3) Physical Models vs. Analytical (Non-physical) Models

The MIMO channel models may be split into two types are the physical and analytical models. Through characterization the double directional multipath propagation between locations transmit Tx and receiver Rx front end, the physical model characterizes an environment on the basic electromagnetic wave propagation. It is dependent on theoretical results and parameter setup, and it is independent of system bandwidth and antenna conformations such as: number of antennas, antenna pattern, polarization, array geometry, and mutual coupling. Physical MIMO channel models may be subdivided to the Ref. [25]:

- *Deterministic models*

Deterministic models description the physical propagation parameters in a totally determinism manner, examples for this are stored measurement data and ray tracing.

- *Geometry-based Stochastic models (GSCM)*

The impulse response for the geometry-based stochastic channel models (GSCM) is characterized through the laws of wave propagation that utilized in particular n_T, n_R , and scattered geometries, that are selected in a stochastic manner.

So, for the $n_R \times n_T$ MIMO system, where the signal at the transmitter antenna array is denoted by the vector $s(t) = [s_1(t), s_2(t), ..., s_{nT}(t)]^T$, and the signal at the receiver antenna array are $y(t) = [y_1(t), y_2(t), ..., y_{nR}(t)]^T$.

In order to determine R_{MIMO}, assume the partial correlation function at the transmitter side is independent of receiving antennas *(j)*, and at the receiver will be independent of transmitting antenna *(k)*, so, the correlation coefficient at the transmitter between antenna k_1 and k_2 and at the receiver between j_1 and j_2 can be given by:

$$\rho^{T}_{k_1,k_2} = \left\langle \left|h^{(J)}_{j,k_1}\right|^2, \left|h^{(J)}_{j,k_2}\right|^2 \right\rangle \tag{17}$$

$$\rho^{R}_{j_1,j_2} = \left\langle \left|h^{(J)}_{j_1,k}\right|^2, \left|h^{(J)}_{j_2,k}\right|^2 \right\rangle \tag{18}$$

So, the symmetrical correlation matrix can be defined as:

$$R_T = \begin{bmatrix} \rho^T_{11} & \rho^T_{12} & \cdots & \rho^T_{1n_T} \\ \rho^T_{21} & \rho^T_{22} & \cdots & \rho^T_{2n_T} \\ \vdots & \vdots & \ddots & \vdots \\ \rho^T_{n_T1} & \rho^T_{n_T2} & \cdots & \rho^T_{n_Tn_T} \end{bmatrix}_{n_T \times n_T} \tag{19}$$

$$R_R = \begin{bmatrix} \rho^R_{11} & \rho^R_{12} & \cdots & \rho^R_{1n_R} \\ \rho^R_{21} & \rho^R_{22} & \cdots & \rho^R_{2n_R} \\ \vdots & \vdots & \ddots & \vdots \\ \rho^R_{n_R1} & \rho^R_{n_R2} & \cdots & \rho^R_{n_Rn_R} \end{bmatrix}_{n_R \times n_R} \tag{20}$$

And the correlation of two transmission coefficients that connect two different sets of antennas is determined by:

$$\rho^{j_1k_1}_{j_2k_2} = \rho^R_{j_1j_2}\rho^T_{k_1k_2} \tag{21}$$

So, the MIMO radio channel may be represented by the Kronecker product of the spatial correlation matrix at the receiver and transmitter as:

$$R_{MIMO} = R_R \otimes R_T \tag{22}$$

Where $\otimes$ represents the Kronecker product Ref. [26].

- *Nongeometric Stochastic models*

Physical parameters such as DoA, DoD, and delay for the non-geometric stochastic models will be depicted and determine in a completely random way through describe underlying probability distribution functions without presuming an underlying geometry. There are two classes of non-geometrical stochastic models, the first one called Saleh-Valenzuela model and the second one called as Zwick model. Analytical (non-physical) channel models represent the contrast to the physical models, thus, the impulse response or equivalently the transfer function for the channel between the individually transmit Tx and receive Tr antenna array will be described in a mathematical way, after that, the data in the channel matrix will be mixing such as analytical mathematical formulation without explicitly accounting for wave propagation. In a (MIMO) channel matrix, the individual impulse responses are subsumed, so, for synthesizing MIMO matrices to the algorithm development, the context of the system, and check the analytical models are very popular for this purpose. Analytical models may be more split to the:

- *Propagation-Motivated models*

It represented the first subclass models for the channel matrix through propagation parameters, and has some Examples, such as virtual channel representation (VCR) model [27], the finite scattered model Ref. [28], and the maximum entropy model Ref. [29].

- *Correlation-based models*

It describes the MIMO channel matrix statistically by using the correlations between the matrix entries. There are many known correlation models, such as:

- *The Kronecker model*

The MIMO channel model has been designed to incorporate channel correlation in order made it in a realistic way. Kronecker model is a very popular model, where it presumed the transmitter and receiver correlation properties to be independent and also is modelled individually. This model imposes all DoD will be associated to all DoA. The average DoA and the average DoD spectra are used to product of the the joint DoD-DoA spectrum of a synthesized Krocker channel by linking in the same pattern all DoD to the all DoA Ref. [30].

- *Independent and Identically Distribution (i.i.d) model*

This is the simple models for the MIMO channel. The random channel matrix for this model will be with i.i.d zero mean complex circularly symmetric Gaussian elements, and utilized in information theory for analytical appraisals. So, it needs one real valued parameter will be defined.

- *The Weishelberger model*

It is one of the analytical models and a continuation from the Kronecker model. To derivation of this model, it is importance for the Kronecker model to understand the coupling between the transmit Tx and receives Rx eigen modes. So, the parameters for the Weichselberger model represent the coupling matrix, and the eigen bases of the transmit and receive correlation matrices, UTx and URx Ref. [31], Ref. [32].

4) *Standardized Models*

In order to develop new radio systems, there are important tool used as Standardized models. They used to purpose of assessing the benefits from the various techniques such as multiple access, signal processing, etc. and in order to improve the performance and enhancing capacity. Thus, there are five standardized MIMO channel models that used in order to comparing various

MIMO systems and algorithms, such as, COST 259/273 Ref. [33], and Ref. [34], 3GPP SCM Ref. [35], IEEE 802.16a /SUI Ref. [36], IEEE 802.11n Ref. [37], and WINNER Ref. [38] channel models. An overview of this classification MIMO channel model is shown in Fig.2.

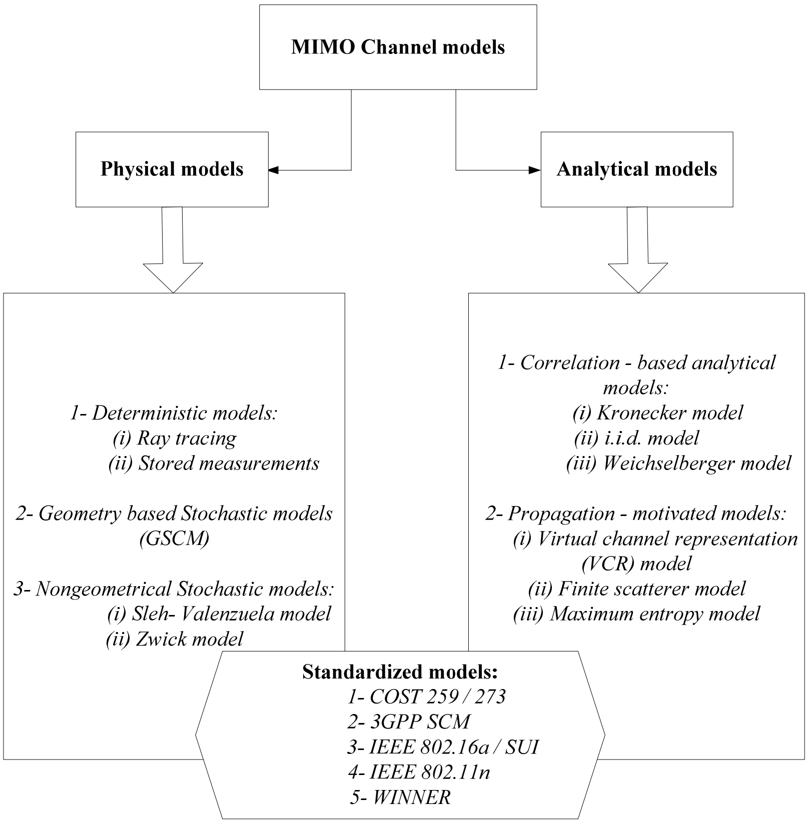

Figure2. Classification MIMO channel model

III. REVIEW OF SYSTEMS AND SOLUTIONS

Having described the common measuring principles, the adaptive modulation schemes and the important functioning metrics of MIMO systems, we are able to discuss specific systems. Adaptive modulation has been proposed for SISO systems in order to cope the ever increasing the request to the higher spectral efficiency Ref. [39], Ref. [2], and more expanded to MIMO systems to adjust the modulation order with respect to the fading channels Ref. [7], Ref. [40],and Ref. [41].

Zhou et al. in Ref. [7] deduced the optimal ASE if the adaptive modulation (AM) and power allocation will be utilized and inquired the deterioration of the overall system execution because of imperfect channel estimation. The execution of AM was measured in Ref. [39] over Nakagami fading channels, where closed-form expressions were rendered. In Ref. [2], Chung and Goldsmith studied several AM schemes subject to diverse bit error ratio (BER) and power restraints. The work in Ref. [42], the authors suggested adaptive modulation schemes in MIMO systems; so, a discrete rate AM-MIMO system can utilize a simple adaptation rule to maximize the average spectral efficiency (ASE).

The scope of this paper is to provide a complete overview of systems available till now. So, in this paper, we focus on the adaptive modulation scheme primarily on MIMO transmission. Thus, there has been some research efforts associated with this research topic, such as; Jimenez et al. in Ref. [1] offered a new joint AM and MIMO transmission algorithm for link adaptation in a MIMO-OFDMA cellular system under factual conditions (spatially correlated fading and imperfect CSI at the transmitter owing to user mobility). Modulation order and MIMO transmission mode are together chosen in order to optimize the ASE when conservation the BER under the specific target (BER_T).

An execution evaluation of the proposed algorithm is supplied under a long term evolution (LTE) downlink scenario and fundamental ASE gains are mentioned in disparity to standalone transmission modes. Therefore, when comparison made with the standalone modes, the proposed link adaptation scheme accomplishes the optimize ASE while the QoS requirement is satisfied.

Huang et al. Ref. [43] developed a systematic study of AM schemes in MIMO-OSTBC systems for the improve the spectral efficiency, Monte Carlo simulation is utilized to confirm the Closed-form expressions of system execution like ASE, BER, and outage probability (P_{outage}) that utilized to identify the optimal SNR thresholds for maximizing the ASE under the average bit error rate (A-BER) constraint. So that, for the reduced complexity of the optimal algorithm, a suboptimal solution based on the instantaneous bit error rate (I-BER) constraint is proposed which can attain approximately the same execution as the optimal method, and these methods are applied in a practical situation, so the channel estimation noise which affected to the overall system execution is investigation also. So, when the SNR increases, the achievable spectral efficiency degrades. Those effects of estimation noise on execution are measured through extension of the closed-form expressions in a more general form.

In Ref. [7], Zhou et al. developed two categories that apply to AM- MIMO systems with perfect or imperfect CSI in both the transmitter and receiver, which is the continuous rate and discrete rate. Where variable rate variable power (VRVP), variable rate (VR), and variable power (VP) systems in each category will be considered. So, the ASEs for continuous rate VPVR and VR systems at a high SNR range are almost same. While, at low SNRs, the VRVP system showing a large penalty compared with the VR system. Simulation and numerical results indicated that, all adaptive systems accomplish a full multiplexing gain with equal number of transmit and receive antennas, except the VP system. Closed form expressions for the ASE and BER were found. Also, for VR systems, the effect of CSI imperfection on the ASE and BER will be measured. So, closed form expressions for the ASE and BER were found. As well, for VR systems, the effect of CSI deficiency on the ASE and BER was measured.

In Ref. [44] the authors suggested MIMO systems for both perfect and imperfect CSI, with variable-power adaptive modulation (VP-AM) and antenna selection (AS) over Rayleigh fading channels. In order to achieve optimized SE to a target BER and an average power restraint; the optimum fading gain switching thresholds are derived. The presence conditions and singularity of the Lagrange multiplier for the restrained optimization of spectrum efficiency (SE) are analyzed. It is shown that the Lagrange multiplier does find and to be singular, if the existences conditions for MIMO systems with transmit antenna selection (AS) and receive MRC under perfect or imperfect CSI are satisfied. The theoretical expressions of the SE and average BER for the VP-AM and CP-AM systems are obtained, by using the switching thresholds for both perfect and imperfect CSI. Simulation for SE and BER shows that the theoretical analysis for both VP and CP systems are accurate and in good agreement with the simulation results. The results shown that, the evaluation of the SE of the VP-AM system will provide execution best than the CP counterpart and the VP-AM system with STBC. Also, it can achieve the target BER for different SNRs.

Xiangbin et al. in Ref. [45] presented the execution analysis of MIMO systems with MQAM and STBC over flat Rayleigh fading channels for imperfect CSI. Where the optimum fading gain switching thresholds for achieving maximum spectrum efficiency (SE) subject to a target BER and an average power restraint will be derived. It is shown that the Lagrange multiplier for the SE optimization will be exists. As well, it is singular for imperfect CSI and for SISO systems under perfect CSI. Numerical evaluation shows that the VP-AM scheme with STBC will provide better SE than its CP-AM scheme.

Z. Zhou and B. Vucetic in Ref. [46] proposed design for VPVR-AM-MIMO systems using imperfect CSI. Simulation and analysis results show that this design provides a good trade-off between the spectral efficiency (SE) and bit error rate (BER) execution in an adaptive way. So that, under a perfect CSI assumption, this proposed system makes the AM-MIMO system much more robust to CSI imperfections than a system designed.

The current adaptive modulation systems and solutions are shown in Table 1. In this table, the systems solutions are mainly the ones whose specifications have been reported by their developers. Also, the cases in which little or no information on them has been made available are excluded.

TABLE1:
ADAPTIVE MODULATION SCHEMES AND SOLUTION

System/ solution	Modulation Scheme	Adaptive Modulation Scheme	Performance (Significant)	Channel model	Average Spectral efficiency (bit/sec /Hz)	SNR gain at $BER_T = 10^{-3}$
Adaptive MIMO-OFDMA system [1]	QPSK, 16QAM, and 64QAM	Rank Adaptation mode	A substantial SE gain is noticeable in contrast to the standalone transmission schemes.	Spatially correlated Rayleigh-faded multi-antenna	Rank Adaptation mode achieves always the optimize ASE and a substantial gain is observed if compared with the standalone schemes (Tx BF and Precoded SM) .	SNR for (QPSK)=(10.35, 11.90, 14.50)dB, (16QAM)= (16.75, 18.50, 21.10) dB, and (64QAM)= (22.6, 24.35, 26.85) dB for $(\rho = 0.3,0.7$ and $0.9)$
Adaptive modulation schemes in MIMO-OSTBC systems [43].	BPSK, QPSK, 16QAM, and 64QAM	Adaptive M-QAM modulation schemes	The execution of the AM system may be evaluated through closed-form expressions, such as ASE, P_{outage} , A-BER and I-BER.	$H = R_r^{1/2} H_w R_t^{1/2}$ Where H_w refers the i.i.d Rayleigh fading channel. R_r and R_t represent the spatial correlations across the receiver and transmitter antennas.	Higher ASE performance for the A-BER restraint method than A-BER restraint method, it has better SE at medium or high SNRst but it lower than the upper bound in the low SNR regin, because , P_{outage} are high at low SNRs.	BPSK= 6.85, QPSK= 9.86, 16QAM= 16.61, and 64QAM= 22.59
AM-MIMO systems with perfect and /or imperfect CSI [7].	QAM with square constellation, such as: 4-QAM , 16-QAM ,etc.	Two categories of AM systems 1- Continuous rate category. 2-discrete rate category.	All adaptive systems attain a full multiplexing gain with equal number of transmit and receive antennas except the VP system, and BER execution of adaptive MIMO systems designed is very sensitive to the CSI deficiency.	Flat fading MIMO channel	Continuous rate VRVP and VR systems have almost the same ASE at a high SNR range, and VP system has an SNR penalty, while at low SNRs, the VRVP system displays a large penalty compared with the VR system.	$SNR = P/\sigma^2$ = 10dB, 15dB, 20dB
VP-AM-AS-MIMO system [44]	BPSK, 4QAM, 16QAM, 64QAM, and 256QAM	VP-AM and CP-AM schemes.	The evaluation of the SE of the VP-AM system will provide execution best than the CP counterpart and the VP-AM system with STBC, and can achieve the target BER for different SNRs.	Quasi-static flat Rayleigh fading channel	SE of the VP system is higher than that of the CP system, while SE for VP-AM–AS-MIMO system with $2R_e$ is larger than that with $1R_e$,and SE of adaptive scheme with $4T_r$ is higher than that with $2T_r$	At the high and low SNR, the VP1 scheme can satisfy the target with the BER below BER0, while at low SNR, the VP2 scheme fails to give the BER smaller than the target BER, whereas SNR= 9.5dB at target BER.
VP-AM-STBC-MIMO system [45]	BPSK, 4QAM, 16QAM, 64QAM, and 256QAM	VP-AM and CP-AM schemes.	The evaluation of SE shows that the better performs for VP-AM scheme compare with the CP -AM scheme and it is an effective means of increasing the SE.	Flat and quasi-static Rayleigh fading channel	The SE of the VP system is higher than that of the CP system. And for the VP system, the larger SE for the 2T1R system of using G2 compare with the 4T1R system using G4 or H4, and for the H4 compare with the G4 code.	2T2R-VP with G2= 9dB, 2T2R-VP with G2=8dB, 2T2R-VP with G2=7dB, and 3T2R-VP with G3=6dB
VPVR-AM-MIMO system with imperfect CSI [46]	4-QAM, 16-QAM, 64-QAM, 256-QAM and 1024-QAM	VPVR-AM scheme	The proposed system makes the AM-MIMO system much more robust to CSI imperfections than a system designed under a perfect CSI assumption, and makes a good trade-off between the ASE and BER in an adaptive way.	Flat uncorrelated Rayleigh fading channel	When increase SNR, the I-CSI system adapts the ASE to a lower level much earlier to forbid the BER worsening best than does the P-CSI system.	I-CSI system is much better than a P-CSI system for SNR= 10, 15, and 20 dB at BER_t

IV. ADAPTIVE MODULATION AND CODING

The technique which is widely utilized in wireless communication systems is called adaptive modulation and coding (AMC). Which are the efficient resource allocation technique, and utilized to optimize the system resources through switching the system among various modulation coding schemes (MCSs). Thus, by depending on the channel quality which is estimated through the receiver, AMC allows the transmitter switches it's adaptive MCS.

And after that makes fed back to the transmitter by the channel state information (CSI) signal. So that, for the next transmission, this information will be utilized by AMC to choose the most appropriate MCS that have better match with the instantaneous channel conditions. So, for the get an optimal execution in both data rate and BER, the different modulation coding schemes will be utilized for different channel conditions, as depicted by Ref. [47], Ref. [48], and Ref. [49], where modulation scheme efficiency represents the amount of bits that will be carried through each transferred symbol.

For instance, QPSK modulation can carry two bits per symbol, while 64QAM modulation can carry six bits per symbol. Fig.3 and Fig.4 show the BER performances. While, Fig.5 and Fig.6 show the data rate performances for digital BPSK, QPSK, 8-PSK, 16-PSK, 64-PSK, 8-QAM, 16-QAM, and 64-QAM modulation schemes in both cases through the AWGN channel. Where BER will be chosen depending to the type of services desired to the various types for the applications. So, changing the modulation and/or coding will change the quantity of bits that will be transported per signal.

And therefore, modifying highest throughputs and improve spectral efficiencies. For instance, a 64 QAM modulation scheme can transfer roughly three times the throughput for 4 QAM modulation. These schemes may be utilized in various channel conditions to get better execution in terms of BER and data rate. In Fig.3 and In Fig.4**,** the BER_{target} value will be determined depending on the wanted QoS of the system and has the value equal to 10^{-3}. So, when the QoS requirement of a specific application will be necessary.

These figures used to switch among the different modulation coding schemes, in order that obtain a BER from the system below the BER_{target} value. Table 2, explained the modulation code scheme (MCS) selection procedure. Therefore, as explained in this table, the BER under the BER_{target} of 10^{-3}. Also, the modulation technique for the system must be switched from 64-PSK to 8PSK whereas the SNR declines less than 21.8 dB, and from 64-QAM to 8-QAM when the SNR will be less than 12.4 dB. The data rate for the schemes in Fig.4 and Fig.5 is compared with the channel limit capacity (Maximal rate of data transmitted through the channel), which is given by Ref. [50], and Ref. [51]:

$$C = \log_2(1 + SNR) \quad \text{bits/s} \qquad (23)$$

The comparison for PSK schemes execution is represented in Fig.3.

TABLE2.
VARIOUS MODULATION SCHEMES EXECUTED IN AWGN ENVIRONMENT

Modulation Schemes	E_b/N_o (dB) required for $BER_{target} = 10^{\wedge -3}$	Data Rate
BPSK	4.32	1
QPSK	4.32	2
8-PSK	7.57	3
8-QAM	6.2	3
16-PSK	12	4
16-QAM	8.12	4
64-PSK	21.8	6
64-QAM	12.4	6

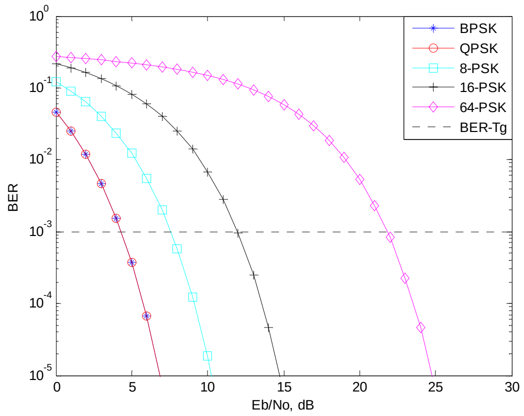

Figure3. Comparison of the performance of BER of MPSK modulation schemes in AWGN environment.

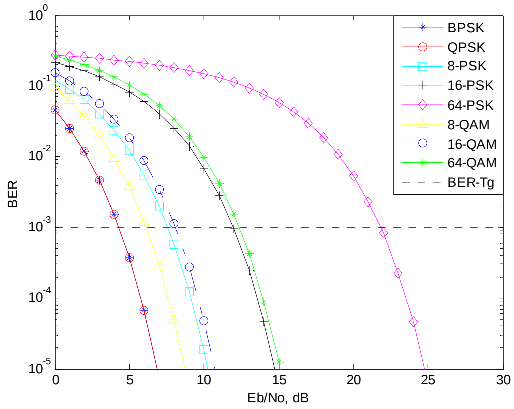

Figure4. Comparison of the performance of BER among different modulation schemes in AWGN environment.

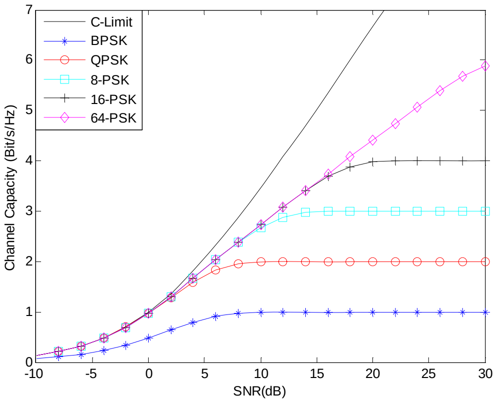

Figure5. Comparison of the performance of channel capacity of MPSK modulation schemes over AWGN environment.

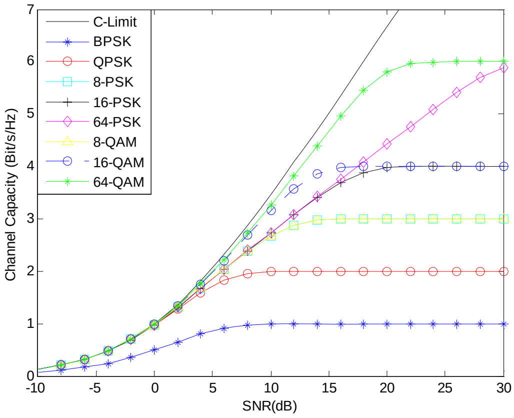

Figure6. Comparison of the performance of channel capacity among different modulation schemes over AWGN environment.

Adaptive modulation is utilized as a strong technical to improve the tradeoff between BER and spectral efficiency (SE). In AM, The receiver will make to estimates the received SNR, and using the feedback channel to send the feedback information to the transmitter, that decides the suited modulation constellation will be utilized through the channel. So, an appropriate choice for the modulation switching levels will be important for the execution of the adaptive modulation (AM) system. There are various modulations types will be engaged in this investigation like QPSK, 8-PSK, 16-PSK, 64-PSK, 8-QAM, 16-QAM, and 64-QAM, where the QPSK may be considered as 4-QAM Ref. [52]. From Rayleigh channel with the fluctuations in the instantaneous received the average signal power r, the probability density function (PDF) will be given by:

$$R(x,r) = \frac{2\sqrt{x}}{r}\exp(-x/r) \qquad (24)$$

For any modulation scheme, the upper bound to the BER execution in a Rayleigh channel will be given by:

$$P_r = \int_0^{\infty} P_G.R(x,r)dx \qquad (25)$$

Where P_G is the Gaussian BER execution as shown from (11) and (14) into (16), thus, for adaptive modulation signal, the upper bound BER execution will be calculated from:

$$P_A = \frac{1}{Th}\left\{2\int_{t_1}^{t_2} P_{QPSK}.R(x,r)dx + 3\int_{t_2}^{t_3} P_{8PSK}.R(x,r)dx + 4\int_{t_3}^{t_4} P_{16PSK}.R(x,r)dx + 6\int_{t_4}^{t_5} P_{64PSK}.R(x,r)dx + 3\int_{t_5}^{t_6} P_{8QAM}.R(x,r)dx + 4\int_{t_6}^{t_7} P_{16QAM}.R(x,r)dx + 6\int_{t_7}^{\infty} P_{64QAM}.R(x,r)dx\right\} \qquad (26)$$

Where $t_1, t_2, t_3, t_4, t_5, t_6$, and t_7 are the thresholds between transmission of QPSK, 8-PSK, 16-PSK, 64-PSK, 8-QAM, 16-QAM, and 64-QAM. While Th representing the throughput for the adaptive modulation (AM) system and may be explained by:

$$Th = 2P_{rQPSK} + 3P_{r8PSK} + 4P_{r16PSK} + 6P_{r64PSK} + 3P_{r8QAM} + 4P_{r16QAM} + 6P_{r64QAM} \qquad (27)$$

So, Fig.7 explained theoretical adaptive for the BER execution through Rayleigh channel depending to the (26) Ref. [53], and Ref. [54].

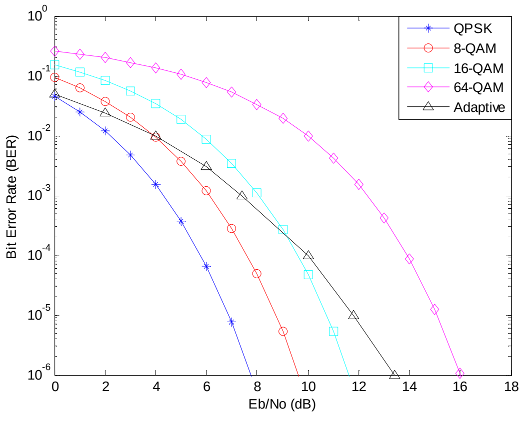

Figure7. Theoretical adaptive BER execution.

V. CONCLUSIONS

This paper provided a survey the current adaptive modulation techniques and systems for wireless MIMO systems. Different execution measurement criteria are discussed and several tradeoffs among them are remarked. In terms of modulation schemes and channel modelling, these adaptive modulation techniques and systems have important characteristics when applied in real conditions. Moreover, the most important characteristics of a number of channel models which proposed in the recent wireless standards will be summarized, after that discussed some proposed AMC for MIMO systems that relating to channel characteristics. Finally, discussion of the existing adaptive modulation and coding, then make comparison of the channel capacity performance among various modulation schemes over AWGN environment, also, performance of Gaussian BER execution and extended this to the adaptive modulation signal.

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