Journal of Mobile Communication 6 (2): 28-37, 2012
ISSN: 1990-794X

Performance Analysis for WiMAX Networks with Employing LDPC Code and RS-CC

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Abstract: WiMAX is a wireless digital communication system based on the IEEE 802.16 standard which provides broadband wireless internet access at relatively a high rates-3 Mbps within a radius of 30 miles (data rate get down as distance increases). Various modulations and coding schemes support WiMAX network. Low Density Party Check (LDPC) code is a powerful error correcting codes which allows transmission at rates in close proximity to Shannon's limit for large block length. In this study, the low density party check codes is used with analyzing the system performance based on the IEEE 802.16 standard physical layer. The achieved results are studied and compared with the commonly used concatenated Reed-Solomon-Convolutional Codes (RS-CC) over the standard Additive White Gaussian Noise (AWGN) Channel model. It show that the system offer better performance with employing the LDPC codes.

Key words: WiMAX, LDPC, IEEE 802.16, RS-CC, internet, Iraq

INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) is poised to become a key technical underpinning of fixed, portable and mobile data networks. Service providers run out the WiMAX on both frequency bands: licensed and unlicensed. WiMAX can be used for a number of applications including last mile broadband connections, hotspot and cellular backhaul and high speed enterprise connectivity for businesses (Rabbani *et al*., 2011; Rengaraju *et al*., 2011). WiMAX is an implementation of the emerging IEEE 802.16 standard that uses Orthogonal Frequency Division Multiplexing (OFDM) for optimizing the wireless data services (Wang, 2011; Ehtisham *et al*., 2011). OFDM is a parallel transmission scheme where a high-rate serial data stream is split up into a set of low-rate sub-streams, each of which is modulated on a separate subcarrier. There by, the bandwidth of the subcarrier becomes small compared with the coherence bandwidth of the channel that is the individual subcarrier experience flat fading (Del Arroyo and Jackson, 2011).

For designing an intelligent and high speed communication WiMAX system, Adaptive Modulation and Coding (AMC) technique should be utilized. Based on the link quality this technique adapt and adjust the transmission parameters (modulation type and coding rate) and thus improving the spectrum efficiency. AMC is track the channel variations thus changing the modulation and coding scheme to yield a higher throughput by transmitting with high information rates under favorable channel conditions and reducing the information rate in response to channel degradation (Hasan, 2007; Pyun *et al*., 2011).

Thus, it is expected that as a station get close to the BS the SNR reaches a high valus so higher order modulation such as 64-QAM and less robust error correcting codes such as 3/4 rate convolutional code scheme may be used in this area to achieve a high level of the throughput. However in areas close to the cell boundary, the SNR is normally poor. So, the system steps down to a lower order modulation such as Binary Phase Shift Keying (BPSK) scheme and low-rate error-correcting codes such as rate 1/2 Low Density Parity Check (LDPC) codes to maintain the connection quality and link stability.

There are various modulation and coding schemes supported by WiMAX are analyze by numerous researchers over the last decade, Table 1 shows some of highlighted ones (El-Mahgoub and Nafie, 2011). In the downlink, QPSK, 16 QAM and 64 QAM are mandatory for both fixed and mobile WiMAX while the 64 QAM is

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Table 1: Modulation and coding supported in WiMAX

Modulation/coding	Downlink	Uplink
Modulation	Mandatory: BPSK, QPSK, 16 QAM, 64 QAM; BPSK optional for OFDMA-PHY	Mandatory: BPSK, QPSK,16 QAM; 64 Optional: QAM
Coding	Mandatory: Convolutional codes at rate 1/2, 2/3, 3/4, 5/6 Optional: Convolutional turbo codes at rate 1/2,2/3, 3/4, 5/6; repetition codes at rate 1/2, 1/3 1/6, LDPC, RS-Codes for OFDM-PHY	Mandatory: Convolutional codes at rate 1/2, 2/3, 3/4, 5/6 Optional: Convolutional turbo codes at rate 1/2, 2/3, 3/4, 5/6; repetition codes at rate 1/2, 2/3, 3/4, 5/6, LDPC

optional in the uplink. The FEC coding using convolutional codes is mandatory. Convolutional codes are combined with an outer Reed-Solomon code in the downlink for OFDM-PHY. The standard optionally supports turbo codes Low-density Parity Check (LDPC) codes at a variety of code rates (Andrews *et al*., 2007; Roca, 2007).

MATERIALS AND METHODS

Reed Solomon-Convolutional Code (RS-CC): Figure 1 shows using the reed-solomon convolutional code for the OFDM PHY. The RS-CC encoding is performed by first passing the data in block format through the RS encoder and then passing it through a convolutional encoder (Hasan, 2007; Roca, 2007). It is a flexible coding process due to the puncturing of the signal which allows different coding rates. The last part of the encoder is a process of the interleaving to avoid long error bursts. Supposing a t, error present in the received signal. The correcting RS code should have the following parameters: Block length, $n = 2^m - 1$ symbols, message size = k symbols, so the parity-check size = n-k = 2t symbols and the minimum distance = $d_{min} = 2t + 1$ symbols. Table 2 shows the parameters of RS-CC for different modulation used in WiMAX.

The native rate of convlutional encoder is 1/2 and a constraint length is 7. The puncturing vectors for these rates are shown in Table 3.

Low-density Parity Check Code (LDPC): Low-density Parity Check code (LDPC) is a linear block code so as other linear block codes it can be described via matrices. LDPC codes in WiMAX standards are Quasi Cyclic (QC) codes, the Parity Check Matrix H of (n-k-by-n) is mainly depend on the block length (n) message size (k), parity-check size, n-k and coding rate, R = k/n.

It is an expansion of a 24 (1-R)-by-24 base matrix which is expanded by z×z sub-matrices where z is also called an expansion factor. The size of each sub-matrix ranges from 24×24 to 96×96, furthermore the size must be divided by 4. So, there are 19 kinds of matrix H with different code length ranged from 576-2304 bits (Zhao *et al*., 2011; Wang *et al*., 2011; Xiang and Zeng, 2010).

Table 2: WiMAX block sizes and code rates used for the different modulation schemes (Telagarapu *et al*., 2011)

Modulation	RS code	CC code rate	Overall code rate
BPSK	(12,12,0)	1/2	1/2
4QAM	(32,24,4)	2/3	1/2
4QAM	(40,36,2)	5/6	3/4
16QAM	(64,48,4)	2/3	1/2
16QAM	(80,72,4)	5/6	3/4
64QAM	(108,96,6)	3/4	2/3
64QAM	(120,108,6)	5/6	3/4

Table 3: Puncturing vectors (Roca, 2007)

Rates	Puncturing vector
1/2	[1 1]
2/3	[1 1 1 0]
3/4	[1 1 0 1 1 0]
5/6	[1 1 0 1 1 0 0 1 1 0]

Table 4: The weight in WiMAX-LDPC matrix for different code rate

Code rate	Weight in column	Weight in row
1/2	[2,3,6] = {11/24,1/3,5/24}	[6,7] = {2/3,1/3}
2/3 A	[2,3,6] = {7/24,1/2,5/24}	[10] = {1}
2/3 B	[2,3,4] = {7/24,1/24,2/3}	[10,11] = {7/8,1/8}
3/4 A	[2,3,4] = {5/24,1/24,3/4}	[14,15] = {5/6,1/6}
3/4 B	[2,3,6] = {5/24,1/2,7/24}	[14,15] = {1/3,2/3}

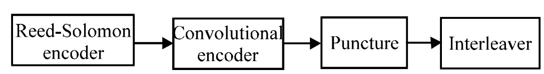

Fig. 1: RS-CC encoder of OFDM PHY

Then, each element $P_{i,j}$ of H_b is z×z sub-matrix and each element have a vector t. The t is chosen from the set {-1, 0, 1, 2,…, z-1} where 0 represents unit matrix, -1 means full-zero matrix and every integer means a circular right-shift matrix. LDPC has mainly two types of matrices:

Regular matrix: In this matrix, the number of one's in each column (weight in column) are equal for all matrix and also the number of one's in each row (weight in row) are equal.

Irregular matrix: In this matrix, the weight of column and row are variable vector. LDPC matrix of WiMAX is irregular matrix. Table 4 shows the weight in column and row in LDPC matrix of different code rate (Jun and Shu-Hui, 2009; Hehn *et al*., 2010; Gupta and Virmani, 2009):

$$H_b = \begin{bmatrix} P_{1,1} & P_{1,2} & \ldots & P_{1,24} \\ P_{2,1} & P_{2,2} & \ldots & P_{2,24} \\ \ldots & \ldots & \ldots & \ldots \\ P_{24(1-R)} & P_{24(1-R),2} & \ldots & P_{24(1-R),24} \end{bmatrix}$$

The overall system: Figure 2 shows the block diagram of the OFDM transmitter and receiver in WiMAX System. The OFDM is defined with three main blocks:

Channel coding: Channel coding whose main tasks are to prevent and to correct the transmission errors of wireless systems. This block may consist of LDPC or RS-CC.

The Inverse Fast Fourier Transform (IFFT) and the Fast Fourier Transform (FFT): IFFT and FFT are used for, respectively modulating and demodulating the data constellations on the orthogonal subcarriers. There are 4 different types of subcarriers in an OFDM symbol. Data and pilot subcarriers (used for estimation and synchronization purposes). These two first types are considered active subcarriers. DC subcarriers together with guard subcarriers (used for guard bands) are commonly denominated as null subcarriers (Telagarapu *et al*., 2011; Yaghoobi, 2004; Bazzi *et al*., 2009).

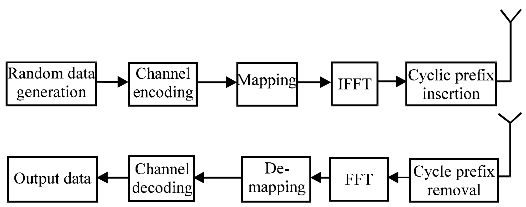

Fig. 2: The OFDM transmitter and receiver (Ehtisham *et al*., 2011)

Cyclic prefix: Cyclic prefix as a guard interval whose length should exceed the maximum excess delay of the multipath propagation channel.

RESULTS AND DISCUSSION

Figure 3-9 show the scatter plot for different modulation schemes when using RS-CC and Fig. 10-20 show the scatter plot for different modulation schemes by using LDPC both over an AWGN channel. The input frame is based on IEEE standard 802.16 d (Roca, 2007). The AMC depends on SNR. For example when the received SNR below 4 dB the transmitter send 1/2 BPSK (RS-CC or LDPC). The threshold SNR at BER given in the standard shows in Table 5. The results show that LDPC

Table 5: Threshold SNR for each coding-modulation scheme

Coding-modulation scheme	Threshold SNR
(1/2) BPSK	SNR<4
(1/2) QPSK	4<SNR<10
(3/4) QPSK	10<SNR<12
(1/2) 16-QAM	12<SNR<19
(3/4) 16 -QAM	19<SNR<22
(2/3) 64-QAM	22<SNR<28
(3/4) 64 QAM	SNR>28

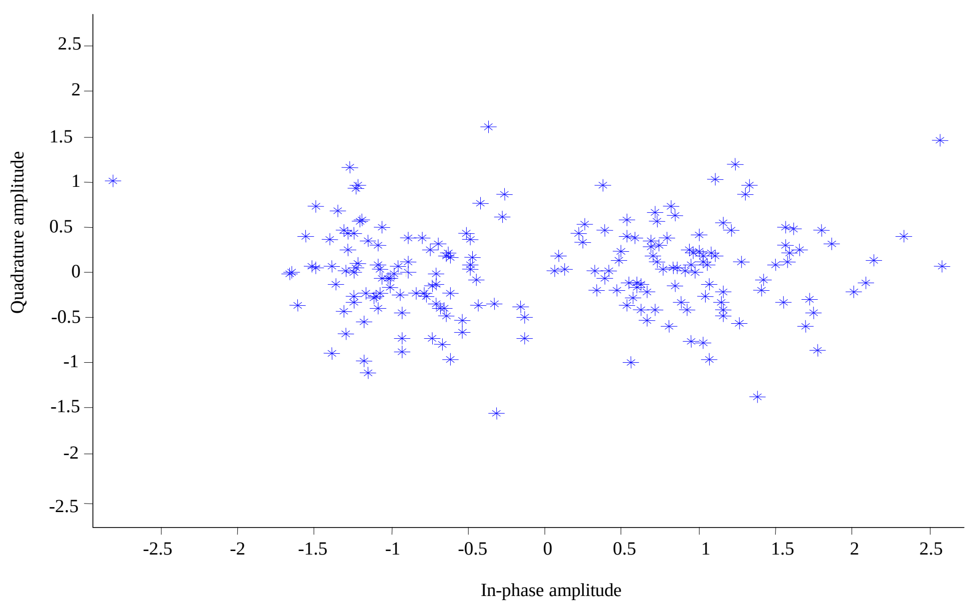

Fig. 3: Scatter plot for 1/2 RS-CC BPSK (SNR = 3 dB) in AWGN Channel Model

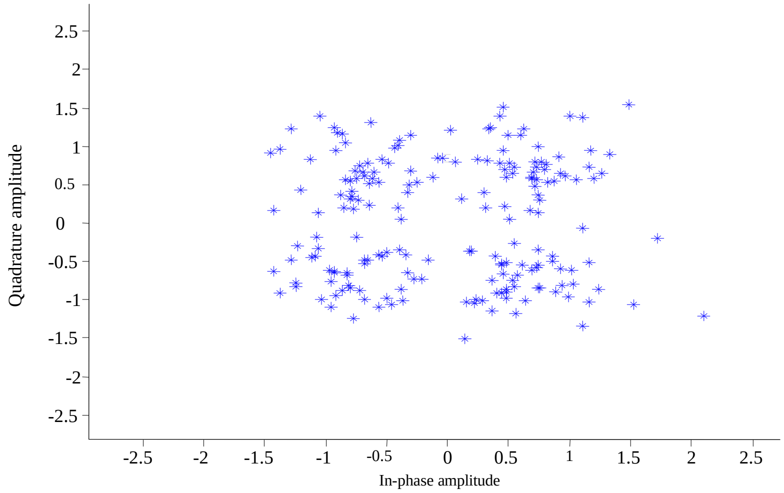

Fig. 4: Scatter plot for 1/2 RS-CC QPSK (SNR = 6 dB) in AWGN Channel Model

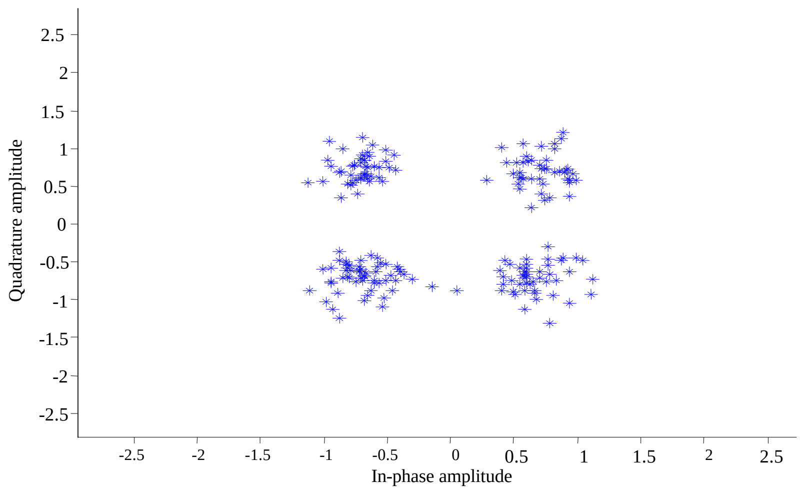

Fig. 5: Scatter plot for 3/4 RS-CC QPSK (SNR = 11 dB) in AWGN Channel Model

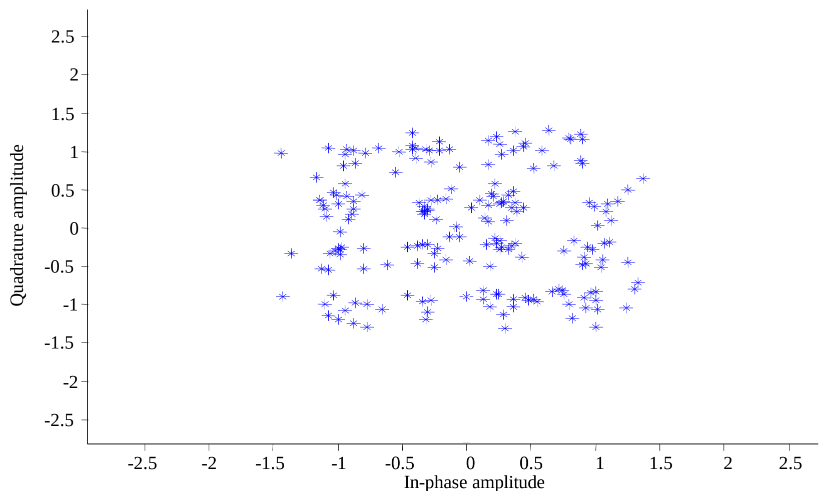

Fig. 6: Scatter plot for 1/2 RS-CC 16-QAM (SNR = 13 dB) in AWGN Channel Model

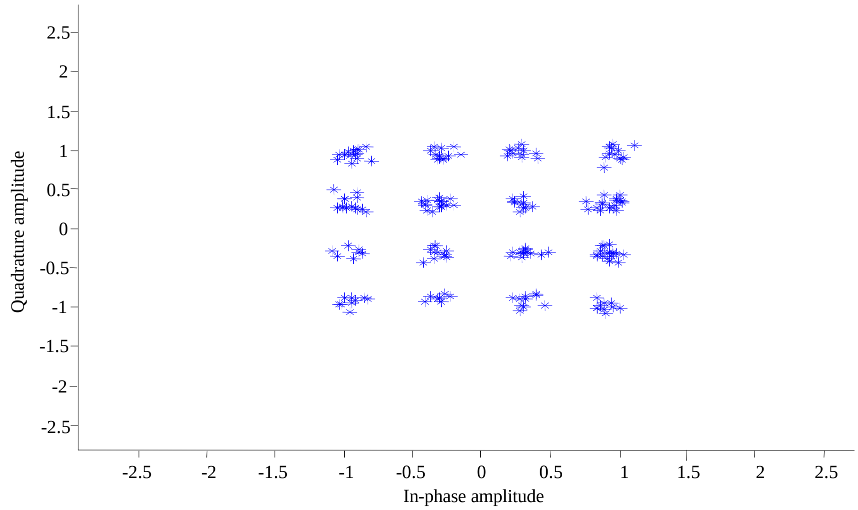

Fig. 7: Scatter plot for 3/4 RS-CC 16-QAM (SNR = 21 dB) in AWGN Channel Model

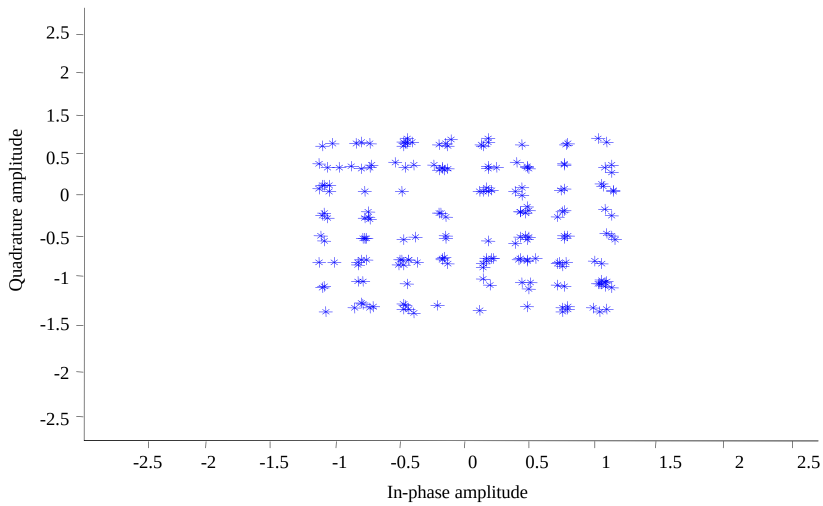

Fig. 8: Scatter plot for 2/3 RS-CC 64-QAM (SNR = 26 dB) in AWGN Channel Model

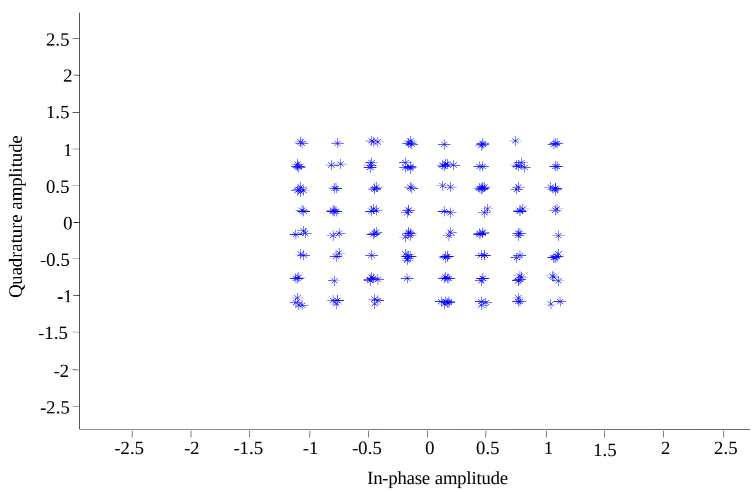

Fig. 9: Scatter plot for 3/4 RS-CC 64-QAM (SNR = 31 dB) in AWGN Channel Model

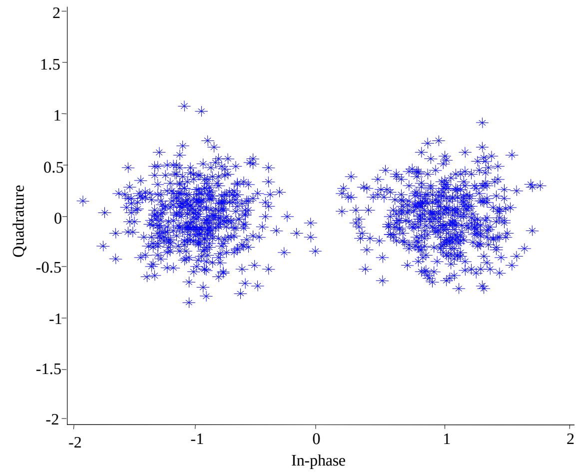

Fig. 10: Scatter plot for 1/2 LDPC code-BPSK (SNR = 3 dB) in AWGN Channel Model

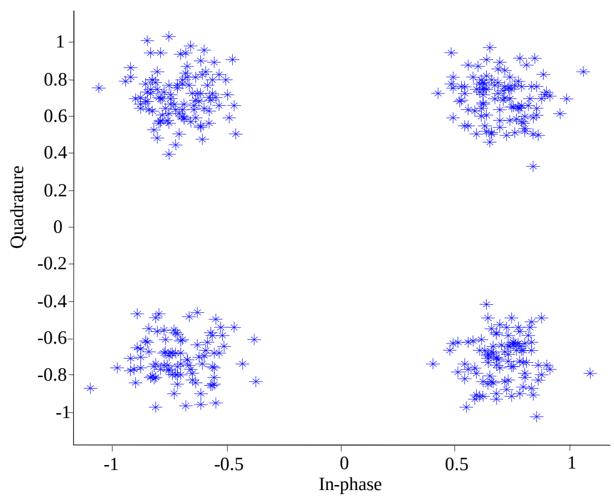

Fig. 11: Scatter plot for 1/2 LDPC code-QPSK (SNR = 6 dB) in AWGN Channel Model

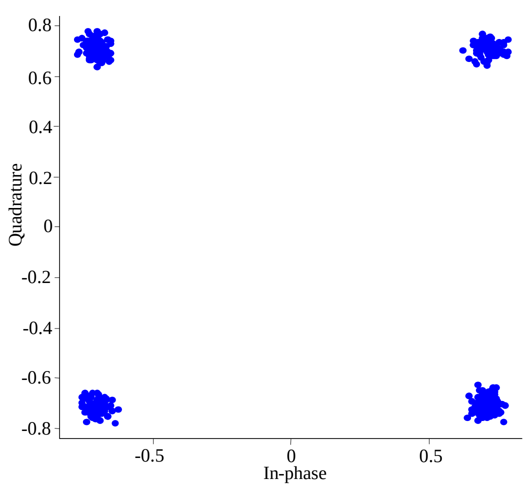

Fig. 12: Scatter plot for 3/4 A LDPC code-QPSK (SNR = 11 dB) in AWGN Channel Model

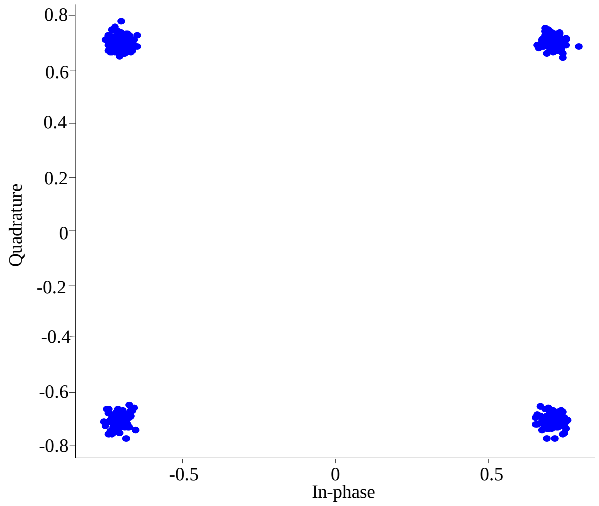

Fig. 13: Scatter plot for 3/4 B LDPC code-QSPK (SNR = 11 dB) in AWGN Channel Model

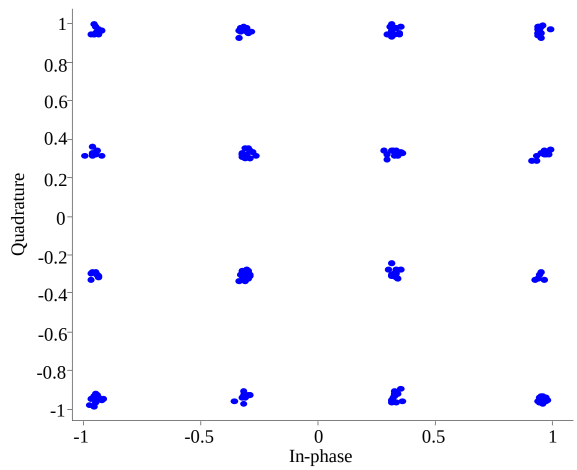

Fig. 14: Scatter plot for 1/2 LDPC code 16-QAM (SNR = 13 dB) in AWGN Channel Model

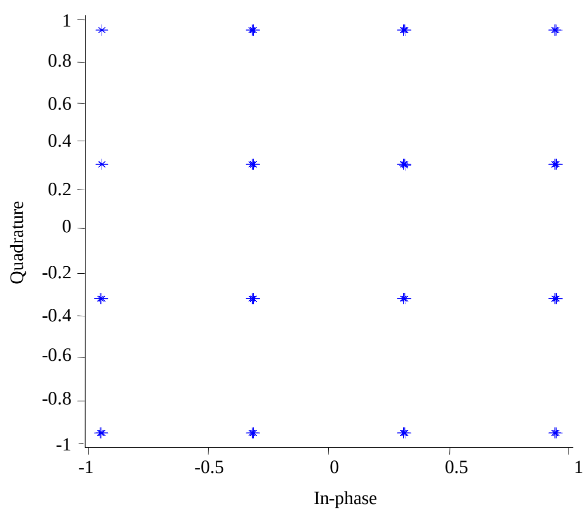

Fig. 15: Scatter plot for 3/4 A LDPC code 16-QAM (SNR = 21 dB) in AWGN Channel Model

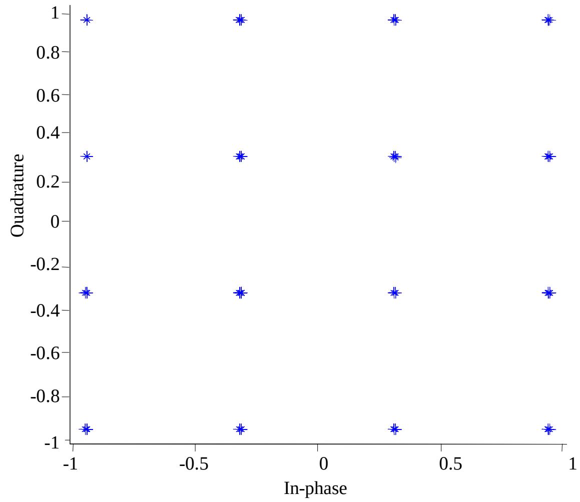

Fig. 16: Scatter plot for 3/4 B LDPC code 16-QAM (SNR = 21 dB) in AWGN Channel Model

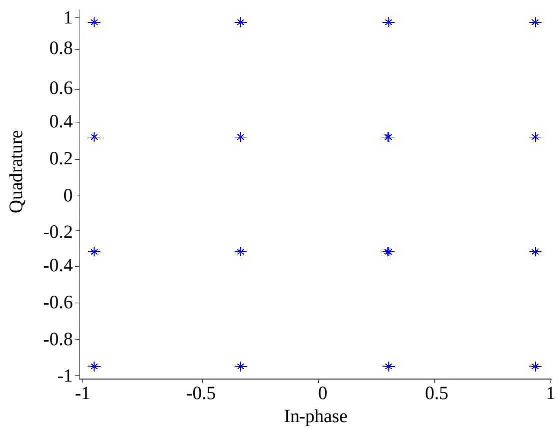

Fig. 17: Scatter plot for 2/3 A LDPC code 16-QAM (SNR = 26 dB) in AWGN Channel Model

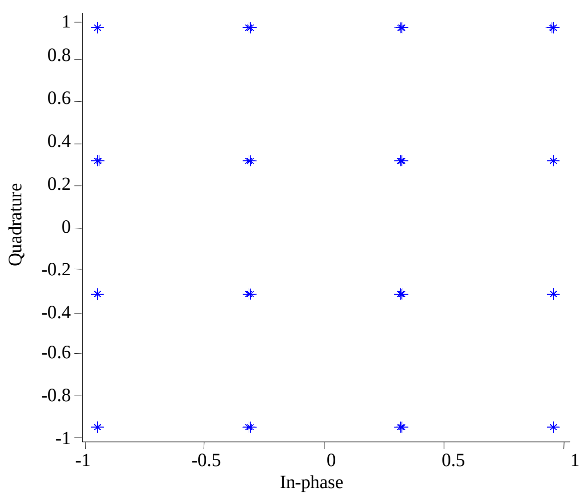

Fig. 18: Scatter plot for 2/3 B LDPC code 16-QAM (SNR = 26 dB) in AWGN Channel Model

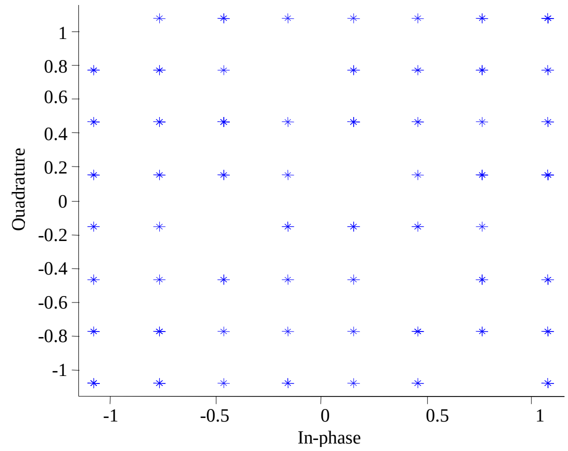

Fig. 19: Scatter Plot for 3/4 A LDPC code 64-QAM (SNR = 31 dB) in AWGN Channel Model

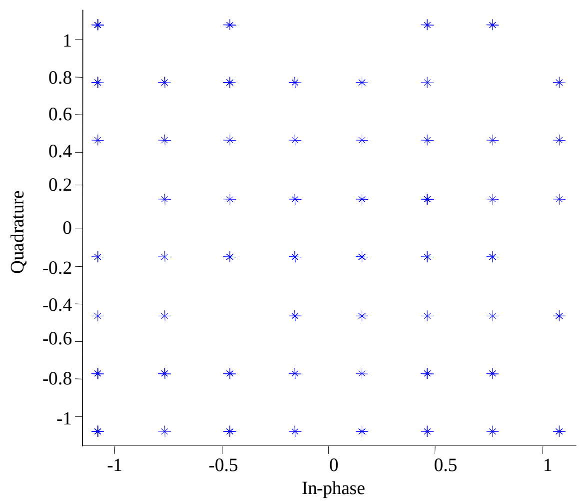

Fig. 20: Scatter plot for 3/4 B LDPC code 64-QAM (SNR = 31 dB) in AWGN Channel Model

give good performance compared with RS-CC. When researchers compare Fig. 3 (Scatter plot for BPSK with RS-CC 1/2) and Fig. 10 (Scatter plot for BPSK with LDPC 1/2), researchers notice that RS-CC have more noise compare with LDPC code. Also due to the matrix structure of (3/4A and 3/4B) LDPC code researchers notice that Fig. 12 (Scatter plot for QPSK LDPC 3/4 A at SNR = 11 dB) have more noise comparsse with Fig. 13 (Scatter plot for QPSK LDPC 3/4B at SNR = 11 dB).

CONCLUSION

The key contribution of this study is implementation of the IEEE 802.16 OFDM-PHY layer using Matlab in order to evaluate the PHY layer performance under AWGN channel model. The implemented PHY layer support all the modulation in WiMAX by using RS-CC and LDPC code with different code rate. Depending on received SNR the transmitter change the PHY later parameters such as modulation and coding for design intelligent and high speed communication WiMAX this technique called adaptive modulation and coding. For example when the received SNR is high (i.e., the subscriber station near the base station) the base station send higher order modulation and less robust error correcting code with high rate such as (3/4 SR-CC-64-QAM). From the scatter plot, researchers find that LDPC code have better performance than RS-CC.

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