Implementation of Adaptive Modulation and Coding Technique using

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Abstract—Different order modulations combined with different coding schemes, allow sending more bits per symbol, thus achieving higher throughputs and better spectral efficiencies. However, it must also be noted that when using a modulation technique such as 64-QAM with less overhead bits, better signal-to-noise ratios (SNRs) are needed to overcome any Intersymbol Interference (ISI) and maintain a certain bit error ratio (BER). The use of adaptive modulation allows wireless technologies to yielding higher throughputs while also covering long distances. The aim of this paper is to implement an Adaptive Modulation and Coding (AMC) features of the WiMAX and LTE access layer using SDR technologies in Matlab. This papper focusing on the physical layer design (i.e. Modulation), here the various used modulation type will be implemented in a single Matlab function that can be called with the appropriate coefficients. A comparison with the hardware approaches will be made in terms of SNR vs. BER relation.

Index Terms—. Adaptive Modulation and Coding (AMC), Cognitive Radio (CR), LTE, Software Defined Radio (SDR), WiMAX.

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1 INTRODUCTION

T he growth in the use of the information networks lead to the need for new communication networks with higher data rates. The telecommunication industry is also changing, with a demand for a greater range of services, such as video conferences, or applications with multimedia contents. The increased reliance on computer networking and the Internet has resulted in a wider demand for connectivity to be provided "any where, any time", leading to a rise in the requirements for higher capacity and high reliability broadband wireless access Broadband wireless Access (BWA) telecommunication systems.

BWA intensively focused in the last few years. Thus, various new technologies with high transmission abilities have been designed. The BWA has become the best way to meet escalating business demand for rapid Internet connection and integrated "triple play" services. That is the very base of the HSPA, WiMAX, and LTE concept: a wireless transmission infrastructure that allows a fast deployment as well as low maintenance costs.

The emergent demand of all types of services, not only voice and data but also multimedia services, aims for the design of increasingly more intelligent and agile communication systems, capable of providing spectrally efficient and flexible data rate access. These systems are able to adapt and adjust the transmission parameters based on the link quality, improving the spectrum efficiency of the system, and reaching, in this way, the capacity limits of the underlying wireless channel.

Link adaptation techniques, often referred to as adaptive modulation and coding (AMC), are a good way for reaching the cited requirements. They are designed to 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.

2 BWA DEVELOPMENT ROADMAP

2.1 Preface

The current WiMAX revision is based upon IEEE802.16e-2005, approved in December 2005. It is a supplement to the IEEE802.16-2004. [1] Thus, IEEE 802.16e-2005 improves by:

- Adding support for mobility
- Scaling of the Fast Fourier transform (FFT) to the channel bandwidth in order to keep the carrier spacing constant across different channel bandwidths (typically 1.25 MHz, 5 MHz, 10 MHz or 20 MHz
- Advanced antenna diversity schemes, and hybrid automatic repeat-request (HARQ)
- Adaptive Antenna Systems (AAS) and MIMO technology
- Denser sub-channelization, thereby improving indoor penetration
- Introducing Turbo Coding and Low-Density Parity Check (LDPC)
- Introducing downlink sub-channelization, allowing administrators to trade coverage for capacity or vice versa
- Adding an extra QoS class for real time applications

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In the other hand, Long Term Evolution (LTE) is the latest standard in the 3rd Generation Partnership Project (3GPP), mobile network technology tree that produced the GSM/EDGE and UMTS/HSPA network technologies.[1][2]

The LTE specification provides downlink peak rates of at least 100 Mbps, an uplink of at least 50 Mbps and RAN round-trip times of less than 10 ms. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time division duplexing (TDD).

The main advantages with LTE are high throughput, low latency, plug and play, FDD and TDD in the same platform, an improved end-user experience and a simple architecture resulting in low operating costs. LTE will also support seamless passing to cell towers with older network technology such as GSM, cdmaOne, UMTS, and CDMA2000. The next step for LTE evolution is LTE Advanced and is currently being standardized in 3GPP Release 10. [3]
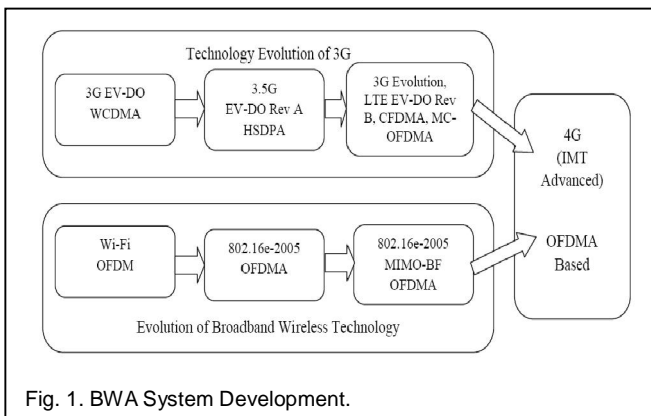

Fig. 1. BWA System Development.

The most important similarity between LTE and Wi-MAX is orthogonal frequency division multiplex (OFDM) signaling. Both technologies also employ Viterbi and turbo accelerators for forward error correction. From a chip designer's perspective, that makes the extensive reuse of gates highly likely if one had to support both schemes in the same chip or chip-set. From a software defined radio (SDR) perspective, the opportunity is even more enticing. Flexibility, gate reuse and programmability seem to be the answers to the WiMAX-LTE multimode challenge.

2.2 Hypothesis of AMC

In traditional communication systems, the transmission is designed for the "worst case" channel scenario thus, coping with the channel variations and still delivering an error rate below a specific limit. Adaptive transmission schemes, however, are designed to track the channel quality by adapting the channel throughput to the actual channel state. These techniques take advantage of the time-varying nature of the wireless channel to vary the transmitted power level, symbol rate, coding scheme, constellation size, or any combination of these parameters, with the purpose of improving the link average spectral efficiency (bits/s/Hz).

3 SYSTEM DESIGN

3.1 Preface

Most BWA support variety of modulation and coding schemes and allows for the scheme to change on a burst-by-burst basis per link, depending on channel conditions. Current systems contains separate hardware channel for each Modulation/Coding scheme. The more intelligent approach is to design single soft defined circuit for BPSK, QPSK, 16QAM, and 64QAM based on SDR then design a cognitive engine (CE) to determine which profile to load and operate. Following is a list of the various modulation and coding schemes supported by WiMAX and LTE.

Both WiMAX and LTE support a variety of modulation and coding schemes and allows for the scheme to change on a burst-by-burst basis per link, depending on channel conditions. Using the channel quality feedback indicator, the mobile can provide the base station with feedback on the downlink channel quality. For the uplink, the base station can estimate the channel quality, based on the received signal quality.

For example, when a user gets closer to a cell site, the number of channels will increase and the modulation can also change to increase bandwidth. At longer ranges, modulations like QPSK (which offer robust links but lower bandwidth) can give way at shorter ranges to 64 QAM (which are more sensitive links, but offer much higher bandwidth). Each subscriber is linked to a number of sub-channels that obviate multi-path interference. The upshot

TABLE 1

MODULATION/CODING SCHEMES SUPPORTED BY WiMAX [1]

Modulation	RS Code	Note
BPSK	(12, 12, 0)	12 data in, 12 data out
QPSK	(32, 24, 4)	4 erroneous bytes
QPSK	(40, 36, 2)	2 erroneous bytes
16QAM	(64, 48, 8)	8 erroneous bytes
16QAM	(80, 72, 4)	4 erroneous bytes
64QAM	(108, 96, 6)	6 erroneous bytes
64QAM	(120, 108, 6)	6 erroneous bytes

is that cells should be much less sensitive to overload and cell size shrinkage during the load than before. Ideally, customers at any range should receive solid QoS without drops that 3G technology may experience.
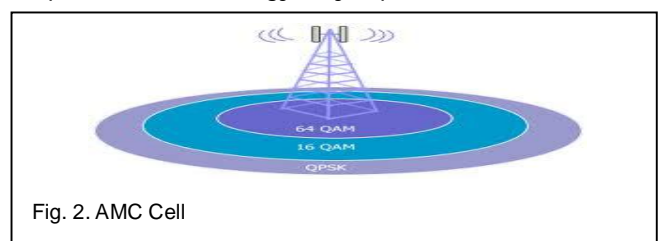

Fig. 2. AMC Cell

3.2 System Architecture

3.2.1 Basic Wimax

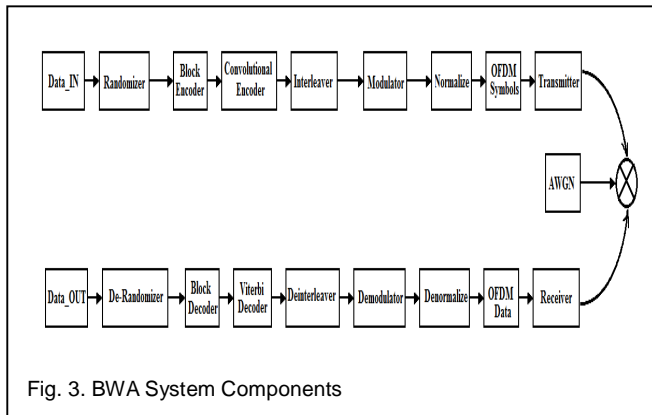The model for the WiMAX is build from the standard documents [1, 2] as follow;

Fig. 3. BWA System Components

3.2.2 Cognitive Engin

When the basic system successfully built and tested, a cognitive engine (CE) must develop to automatically direct the SDR to load and execute the appropriate profile. The CE refer to predefined polices, while continuously sensing the channel situation. Then, perform its logic to pick up the suitable configuration to execute it in the SDR system.
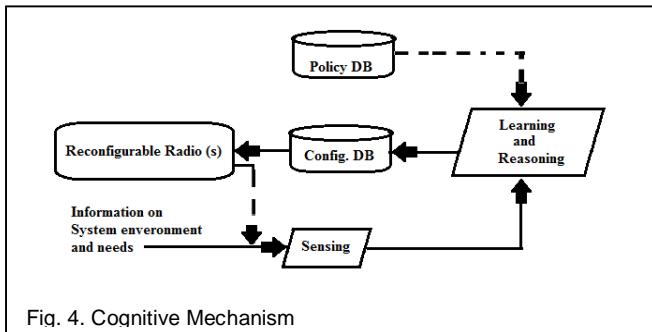

Fig. 4. Cognitive Mechanism

4 ADAPTIVE COMMUNICATION SYSTEM

4.1 AMC Architecture

The function of AMC is based on SDR-CR combination. The receiver evaluate received packets (i.e. SNR or BER) to estimate the Channel Quality Indictor (CQI) module, then feedback the transmitter to reconfigure itself for the next packet send.
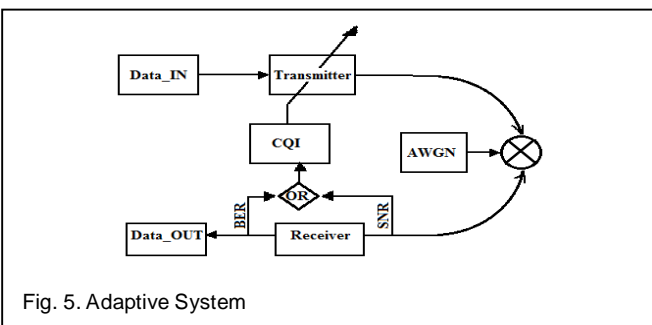

Fig. 5. Adaptive System

4.2 AMC System Performance

The performance of AMC highly depends on the accurate channel estimation at the receiver and the reliable feedback path between that estimator and the transmitter on which the receiver reports channel state information (CSI). In order to assure a high-quality implementation the next steps must be followed:

4.2.1 Channel Quality Estimation

The transmitter requires an estimate of the expected channel conditions for the next transmission interval. Since this knowledge can only be gained by prediction from past channel quality estimations, the adaptive system can only operate efficiently in an environment with relatively slowly-varying channel conditions. Therefore, the delay between the quality estimation and the actual transmission in relation to the maximal Doppler frequency of the channel is crucial for the system implementation since poor system performance will result if the channel estimate is obsolete at the time of transmission.

4.2.2 Parameter adaptation

The choice of the appropriate modulation and coding mode to be used in the next transmission is made by the transmitter, based on the prediction of the channel conditions for the next time interval. An SNR threshold such that it guarantees a BER below the target BER (BER0), is defined by the system for each scheme whenever the SNR is above the SNR threshold.

4.2.3 Feedback Mechanism

Once the receiver has estimated the channel SNR, converted it into BER information for each mode candidate, and, based on a target BER, selected the mode that yields the largest throughput while remaining within the BER target bounds, it has to feed back the selected mode to the transmitter in order that the adaptation can be performed.

However, the challenge associated with adaptive modulation and coding is that the mobile channel is time-varying, and thus, the feedback of the channel information becomes a limiting factor. Therefore, the assumption of a slowly-varying as well as a reliable feedback channel is necessary in order to achieve an accurate performance of the AMC scheme. In this way, no delay or transmission error can occur in the feedback channel so that no discrepancy between the predicted and the actual SNR of the next frame appears. Moreover, the receiver must also be informed of which demodulator and decoding parameters to employ for the next received packet.

5 SIMULATION RESULTS

5.1 Functionality

A single function the can give different modulation order from BPSK to M-QAM (M= 2n, where n = 2,4,6,...) implemented in Matlab. The function called with the modulation order and the SNR in dB as input, then its plot the constella-
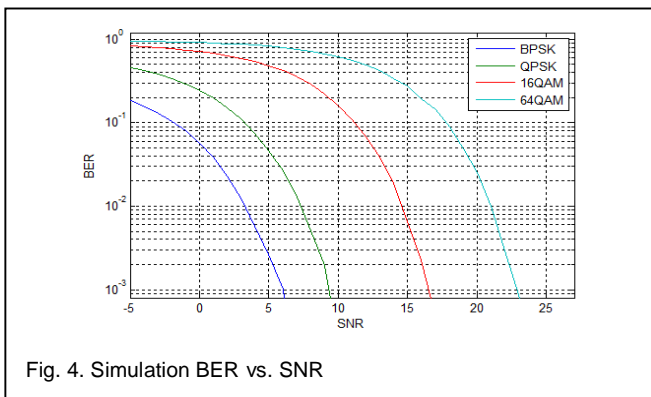
tion and calculates the BER.

Fig. 4. AMC Constalation Diagrams
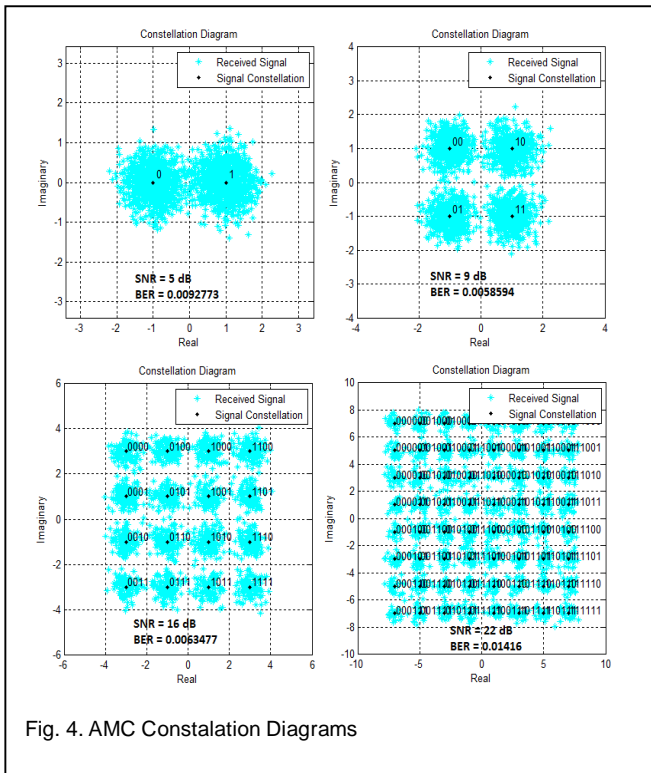
5.2 BER vs. SNR

BER is the number of error bits occurs within one second in transmitted signal. BER defined mathematically as follow;

$$BER = \frac{Number\ of\ Bits\ with\ Error}{Total\ Number\ of\ Bits\ Transmited} \qquad (1)$$

Fig. 4. Simulation BER vs. SNR

When the transmitter and receiver's medium are good in a particular time and Signal-to-Noise Ratio is high, and then Bit Error rate is very low. In our thesis simulation we generated random signal when noise occurs after that we got the value of Bit error rate.

$$SNR = \frac{Signal\ Power}{Noise\ Power} = \left(\frac{Signal\ Amplitude}{Noise\ Amplitude}\right)^2 \qquad (2)$$

6 CONCLUSION

The function implemented in this paper demonstrates the ability of converge AMC concepts in a single Matlab file. Tests show that all measured can be compared with the hardware model in terms of functionality and system performance. This component can be reused against a defined standard, IEEE 802.1 6e, LTE, or other BWA. The second part of the paper (Part II) will implement other system component related to coding both for source and channel. In the future this model can be expanded to include the components of the upper layers and a complete end to end BWA system could be built.

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