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To: Dr. Brian L. Evans, EE464H Supervising Professor

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Subject: Proposal for Quantifying Tradeoffs in Adaptive Modulation Methods for IEEE 802.16a Wireless Communication Systems.

OVERVIEW

The need for wireless services is growing extremely fast, but the radio spectrum has bounds imposed by practical limitations on the circuit designs and use regulations from federal governments. Spectral efficiency is therefore of primary concern in the design of future wireless data communications systems. Efficiency of a wireless cellular system may be achieved at several levels of the system design [1]:

- at the radio coverage planning level by minimizing cell area and the cochannel reuse distance.
- at the communication link level through bandwidth efficient coding and modulation techniques.
- at the network/system level by using sophisticated channel allocation schemes that maximize the overall carried traffic.

This project will be dealing with the physical and link sub-layers of the communications link layer.

IEEE 802.16a uses orthogonal frequency division multiplexing (OFDM) with 256 sub-carriers. In OFDM, the data stream is divided into many parallel bit streams, which are modulated on different sub-carriers. These carriers are narrow-band, and have the property of being mathematically orthogonal to each other. Orthogonality ensures that the carriers can be separated out at the receiver without interfering with each other. Each sub-carrier experiences attenuations due to the channel independent of the others. Adaptive modulation can then be performed on a subcarrier basis rather than on the entire channel.

Adaptive modulation tries to combat fading effects of the channel by employing a higher order modulation mode when the channel quality is good (high signal to noise ratio SNR), and a lower order one when the channel quality is bad (low SNR). By doing so, it tries to maximize the throughput, while keeping the bit error rate (BER) lower than the predefined threshold of 10^{-6} for IEEE802.16a wireless communication systems [2]. When quantifying tradeoffs in modulation techniques, we will look at the spectral efficiency, BER, and implementation complexity.

PROJECT DESCRIPTION

In this project, I propose to improve the existing IEEE 802.16a LabVIEW simulation, developed mainly by Mr. Ian Wong, one of Prof. Evans' PhD students. The project will consist of three parts as follows:

1) The first part will be to use the NI Modulation Toolkit [3] in order to design a more realistic wireless channel model.
2) The second part will be to implement forward error correction (FEC) in order to reduce errors in the transmission.
3) In the third part, I will look at the optimization of throughput, by implementing adaptive modulation.

DESIGN CONTENT

In this project, I am designing and implementing three parts of an 802.16a wireless communication system. I will then put them together with the existing LabVIEW simulation to get the complete system. Testing and evaluation will take place at different stages of the design process, after completing each component, and after putting the whole system together.

BACKGROUND

Channel Modeling:

A wireless communication system consists of a transmitter, a receiver, and a channel. The channel is the medium in which the signal that carries data travels. Its quality can be quantified by measuring the received signal strength and the BER for example. But the channel changes over time. It might change slowly or rapidly, depending on whether the receiver is moving or not, and depending on whether the environment between transmitter and receiver is changing or not. For the type of systems considered, the transmitter will be fixed, but the receiver could be static or moving. There are many different algorithms to model the channel that differ in complexity and accuracy. For this project, a very realistic channel model is needed.

I will use Wide Sense Stationary Uncorrelated Scattering (WSSUS) as the channel model. This is a widely used method for time varying fading wireless channels both in time and frequency domains [4]. I will also implement two popular channel estimations techniques, and compare their communication performance vs. implementation complexity.

Forward Error Correction:

After improving the channel model, I will implement forward error correction (FEC) in order to reduce the bit error rate. The simulator already implements randomization and interleaving, and FEC needs to be implemented in between these two functions. Adding forward error correction should make the communication system perform better in terms of BER. In wired and wireless communication systems, FEC is a system of error control for data transmission wherein the receiving device has the capability to detect and correct errors. It is accomplished by adding redundancy to the transmitted information using a predetermined algorithm. The two main categories are block coding and convolutional coding. Block codes work on fixed-size blocks of bits or symbols of predetermined size, while convolutional codes work on bit or symbol streams of arbitrary length. The Reed Solomon (RS) is a type of block coding while the Viterbi algorithm is a convolutional one. A recent (early 1990s) development in error correction is Turbo coding, which combines two or more relatively simple convolutional codes (CC) and an interleaver to produce a block code that can perform very well [5]. I will implement encoding following the IEEE encoding standards for the 802.16a (see Figure 1).

Rate_ID	Modulation mode	RS-CC rate	Rate_ID	Modulation mode	RS-CC rate
0	4-QAM	½	3	16-QAM	¾
1	4-QAM	¾	4	64-QAM	⅔
2	16-QAM	½	5	64-QAM	¾

Figure 1: IEEE 802.16a Settings for Quadrature Amplitude Modulation (QAM) and Forward Error Correction (FEC).

Adaptive modulation:

Adaptive modulation takes advantage of the fluctuations in the response of the wireless channel. Depending on the response, the transmitter can adapt the constellation size or the code rate. In order for this to work, the transmitter needs to have knowledge of the channel, this can be done by estimating the channel response at the receiver (SNR and delay spread) and feeding it back to the transmitter (Figure 2), or by using blind estimation techniques, which predict the channel quality. Timing problems will arise whenever a feedback link is used, because by the time the transmitter adapts to the estimated channel conditions, the channel response could have changed.

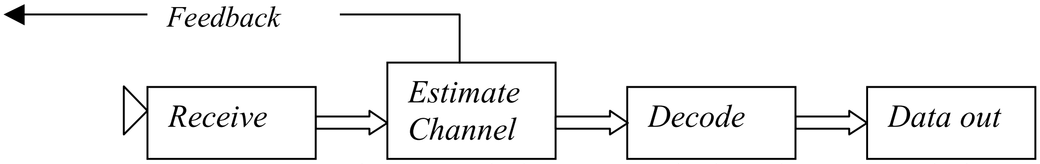

Figure 2: Typical Receiver Block Diagram with Channel Estimation Block

Adaptive modulation has been shown to have significant benefits when OFDM is used, but accurate and timely channel estimates are needed. This project will focus on trying to get accurate enough estimates of the channel and adapting the transmission of data given those estimates in order to improve performance.

DELIVERABLES

By the end of the project, I expect to have the working simulation with the three parts implemented. A new release (version 1.2) can then be made available to the public. I will also try to provide documentation for the simulator.

PROPOSED SCHEDULE

Jan. 23, 2004 – Research OFDM and the 802.16a standard, and learn the IEEE 802.16a simulator from UT Austin (1 week)
Feb. 13, 2004 – Complete part 1 of this project (3 weeks)
Mar. 13, 2004 – Complete part 2 of this project (4 weeks)
Apr. 24, 2004 – Complete part 3 of this project (6 weeks)
May 1, 2004 – Complete the documentation (1 week)

CONCLUSION

This project will produce version 1.2 of the IEEE 802.16a simulator. Three improvements will be made to the simulator. The channel model and forward error correction will be improved, and adaptive modulation schemes will be implemented. Students, researchers, and anybody interested will be able to simulate different scenarios of the communication process using adaptive OFDM modulation.

Sponsoring Professor's Signature	**Student Signature**
Professor Brian L. Evans	Abdelaziz Skiredj
Date: ________________	Date:________________

References:

[1] Mohamed-Slim Alouini and Andrea J. Goldsmith, “Capacity of Rayleigh Fading Channels Under Different Adaptive Transmission and Diversity-Combining Techniques”, *IEEE Transactions on Vehicular Technology,* Vol. 48, NO. 4, July 1999.

[2] IEEE802.16a Standard, part 16: “Air Interface for Fixed Broadband Wireless Access Systems” Accessed (12/27/04) http://grouper.ieee.org/groups/802/16/pubs/80216a-2003.html

[3] National Instruments Technical Staff, *Modulation Toolkit 2.0 for LabVIEW,* National Instruments, 2004.

[4] Hassan Yaghoobi. “Scalable OFDMA Physical Layer in IEEE 802.16 WirelessMAN”, Accessed (11/23/04) http://developer.intel.com/technology/itj/2004/volume08issue03/art03_scalableofdma/p01_abstract.htm

[5] Sergio Benedetto and Guido Montorsi, “Unveiling Turbo Codes: Some Results on Parallel Concatenated Coding Schemes”, Accessed (11/25/04) http://www.tlc.polito.it/~montorsi/papers/it96.pdf