Adaptive Modulation under Imperfect CSI in OFDM Based Systems

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Abstract— In this work adaptive modulation under imperfect channel state information CSI) has been analyzed in OFDM based systems. Key parameters considered are BER vs SNR and spectral efficiency due to link adaptation. In this work analytical approach has been adopted.

Keywords— OFDM; Frequency Synchronization; Fading; BER;

I. INTRODUCTION

In modern wireless cellular applications RRM(Radio resource management) and LA(Link Adaptation) are the two major aspects. Both of them are interdependent on each other. In the context of 4G networks the frequency reuse plan(reuse-1,fractional frequency reuse etc),packet scheduling even in other cells and placement of eNBs affect the link adaptation process. Networks are becoming unplanned, decentralized and heterogeneous. BS deployments increasingly driven by capacity needs rather than coverage needs.

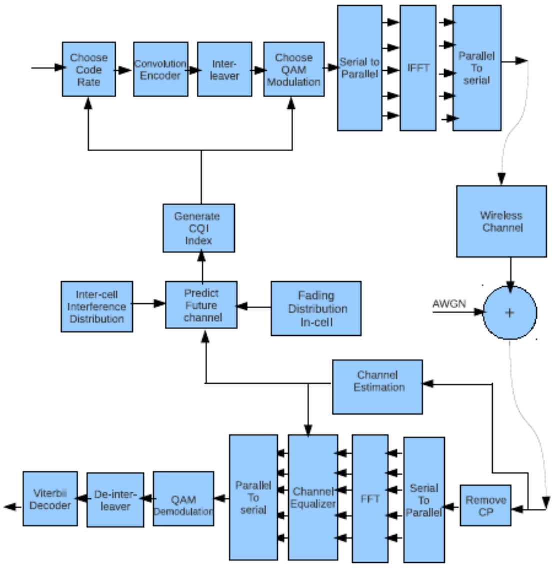
Paradigm is shifting from SNR to SINR. Link Adaptation process cannot be treated as isolated process dependent only on SNR,rather heavily depends on SINR. Under Link Adaptation the code rate and modulation levels needs to be adapted in order to maximize the spectral efficiency with the fluctuating link quality while simultaneously satisfying the target BER constraint and Power constraint. The cutoff-snr of each data rate is there. The highest supportable data rate is pumped based on the instantaneous link quality. Fundamental work have been done in [1] , [2] where the modulation levels and the transmit power is adapted while meeting the BER and power constraints.

Adaptive OFDM for wide band radio channels has been done in [3] where different modulation schemes are employed adaptively onto different sub carriers for frequency selective fading channel. In [4] bit and power is adapted for different sub carriers adaptively for multiuser OFDM case dynamically in time domain/frequency domain. Imperfect CSI in OFDM too leads to increase in BER from target BER, algorithm have been proposed in [5] to prevent this increase in BER due to imperfect CSI but this leads to under-loading of sub-carriers. Proportionate rate constraints has been included in Multiuser OFDM in [6]. The effect on OFDM due to imperfect CSIT has been done in [7].Based on CQI(channel quality index) feedback from UE, LTE-eNB select between QPSK,16-QAM and 64-QAM with different coding rates [8], [9]. Inner loop link adaptation has first hand in adaptive modulation. If there is any imperfection in CQI reporting it can be corrected by outer loop link adaptation and BLER can be maintained [10], actually margin is provided to ensure reliable communication so that even if there is deep BER/BLER don't goes beyond target BER/BLER.

As link adaptation is fundamental to achieve optimized spectral efficiency with BER/BLER constraints an attempt has been done through semi-analytical approach. From the research done by various authors/groups its clear that link level performance degrades dramatically due to imperfect CSI. 4G networks and beyond are becoming unplanned, decentralized and heterogeneous and hence interference should be given emphasis while doing Link Adaptation. An effort has been tried to compensate the effect due to imperfect CSI in OFDM based systems.

II. SYSTEM MODEL

In reality there is finite delay between the CSI/CQI estimated and sent for eNB and for reaching eNB. The impact of feedback delay can be compensated by using channel prediction but its effectiveness depends on the accuracy of the channel model. Certain work have been done as in based on prediction model. In most of the models they have considered the fading statistics(small scale fading) of UE in the cell of interest, but practically even the interference from the other cells play a significant role. SINR more important than SNR. The current 4G+femto/pico (heterogeneous) networks are different from conventional hexagonal cellular,hence SINR distribution too. A model is being proposed to effectively compensate the impact of feedback delay considering both incell and inter-cell fading statistics to be as near to practical scenario. Even the predicted CSI/CQI depends on the frequency reuse plan and and inter-cell interference associated. receiver.



III. Adaptive Modulation under Imperfect CSIT

In modern wireless cellular applications the link has to be adapted in order to maximize the spectral efficiency with the fluctuating wireless channel condition while simultaneously satisfying the target BER/BLER constraint. Fundamental work have been done where the modulation levels and the transmit power is adapted while meeting the BER and power constraints. The maximum number of bits that can be loaded onto each sub-carrier can be expressed as

$$b_L = 2\llcorner \frac{1}{2}\left(1 - \frac{1.6}{ln\left(\frac{TargetBER}{0.2}\right)}\gamma\right)\lrcorner$$

where γ is the SNR. Adaptive OFDM for wide-band radio channels has been done in [12] where different modulation schemes are employed adaptively onto different sub-carriers for frequency selective fading channel. In [13] bit and power is adapted for different sub-carriers adaptively for multiuser OFDM case dynamically in time domain/frequency domain. There is finite delay when channel is estimated at receiver and sent back to transmitter for adapting parameters. By that time channel conditions change and hence imperfect CSI is used for adapting link. BER bound for QAM with using outdated estimates for modulation and power adaptation can be expressed as

$$P_{b0}(\gamma[i-i_d]) = 0.2e^{\left[\frac{1.5\gamma[i-i_d]}{M-1}\frac{P(\gamma[i-i_d])}{\bar{P}}\right]}$$

by inverting above equation

$$M[\gamma[i-i_d]] = 1 + (-1.5)\frac{\gamma[i-i_d]}{ln(5P_{b0})}\frac{P(\gamma[i-i_d])}{\bar{P}}$$

where Pb0 is the BER constraint.

Due to delay the channel SNR gets changed, but as outdated estimate is used at transmitter, hence

$$M[\gamma[i]] = 1 + (-1.5)\frac{\gamma[i]}{ln(5P_b)}\frac{P(\gamma[i-i_d])}{\bar{P}}$$

in the above equation the new BER is Pb .

Equations (2.2) and (2.3) can be equated as the modulation level remains the same and hence

$$1 + (-1.5)\frac{\gamma[i-i_d]}{ln(5P_{b0})}\frac{P(\gamma[i-i_d])}{\bar{P}} = 1 + (-1.5)\frac{\gamma[i]}{ln(5P_b)}\frac{P(\gamma[i-i_d])}{\bar{P}}$$

$$\frac{\gamma[i-i_d]}{ln(5P_{b0})} = \frac{\gamma[i]}{ln(5P_b)}$$

$$ln(5P_b) = ln(5P_{b0})\frac{\gamma[i]}{\gamma[i-i_d]}$$

$$5P_b = (5P_{b0})^{\frac{\gamma[i]}{\gamma[i-i_d]}}$$

$$P_b = 0.2(5P_{b0})^{\frac{\gamma[i]}{\gamma[i-i_d]}}$$

let us write

$$\frac{\gamma[i-i_d]}{\gamma[i]} = \varepsilon$$

$$P_b = 0.2(5P_{b0})^{\frac{1}{\varepsilon}}$$

Case I ε =1

Pb = P b0 implies that BER is same as target BER

Case II ε > 1

Pb > P b0 implies that BER is greater than target BER

Case III ε < 1

Pb < P b0 implies that BER is less than target BER

$$P_b\left(\frac{\gamma[t]}{\gamma[t-\delta t]}\right) = 0.2(5P_{b0})^{\frac{\gamma[t]}{\gamma[t-\delta t]}}$$

Let us write eq (2.4) in continuous time domain

BER dependence on feedback delay δt can be obtained by

$$P_b(\delta t) = \int_{\gamma_{th}}^{\infty}\left[\int_0^{\infty} P_b\left(\frac{\gamma[t]}{\gamma[t-\delta t]}\right)p(\gamma[t],\gamma[t-\delta t])dt\right]p(\gamma)d\gamma = \int_{\gamma_{th}}^{\infty}\left[\int_0^{\infty} 0.2(5P_{b0})^{\frac{\gamma[t]}{\gamma[t-\delta t]}}p(\gamma[t],\gamma[t-\delta t])dt\right]p(\gamma)d\gamma$$

$$p(\gamma[t], \gamma[t - \delta t])$$ the joint pdf

is given. The below shows the effect of increase in normalized delay on BER, here coherence time of the channel is taken to be

$$T_c = \sqrt{\frac{9}{16\pi f_m^2}} = \frac{0.423}{f_m}$$

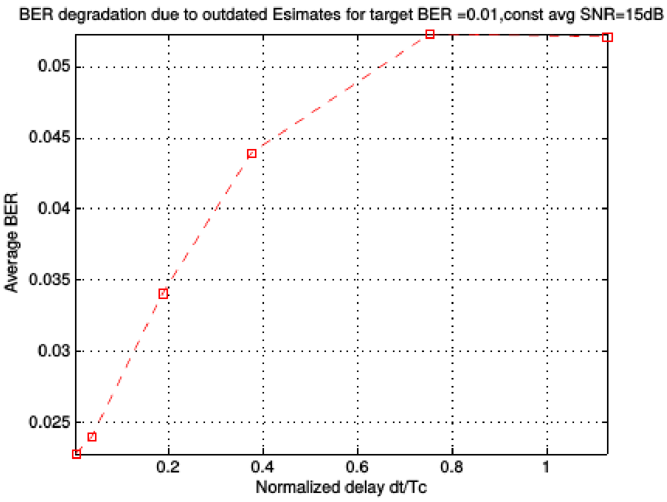


Figure 1. Average BER vs normalized delay

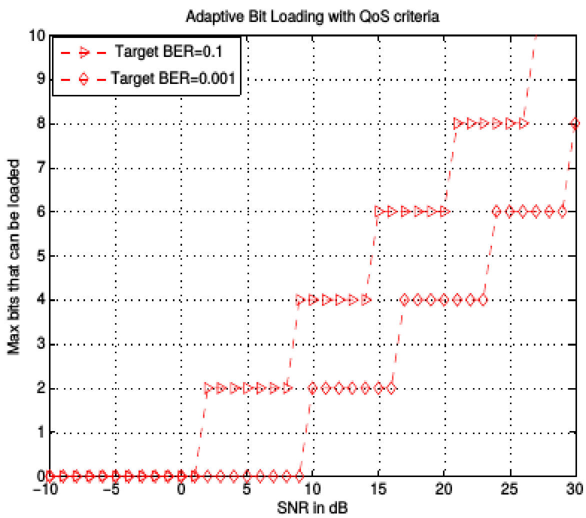


Figure 2: Adaptive modulation and coding under Rayleigh fading with target BER 0.1

VI. CONCLUSIONS

It is seen from the results that due to outdated CSI estimates there is in the average BER. Due to outdated estimates there is fall in spectral efficiency which hampers user performance ultimately.

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