Analysis of Link Adaptation in OFDMA Based Cellular Systems

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Abstract— In cellular communication individual user quality of service depends on data rate that he receives and the data rate at which he can upload. The link between user and base station depends on the channel condition prevailing, path loss exponent, interference etc. Any arbitrary date rate can't be supported but depends on channel condition. In this paper I have analyzed mathematically and the results through power adaptation and hence rate adaptation.

Keywords—Adaptive Modulation; Link Adaptation; Fading; BER;

I. INTRODUCTION

In wireless communication the channel conditions between user and base station/ eNB is varies with carriers at a time instant. The channel condition also varies with. If channel condition is not good but the data rate pumped is higher, then there is chance of data loss. Similarly if conditions are good and less data rate is pumped then under utilization of the system would be there. Thus for better performance from user perspective as well as system perspective this link between user and base station should support optimal data rate.

In order to have the optimized performance of the link based on the channel condition the various parameters may be adapted. Some these are power, rate, Bit error rate (BER) limitation etc. Generally power and rate are adapted based on channel condition with BER limitation. In order to adapt power and rate channel condition should be known at the transmitter or receiver should feedback it to the transmitter. This feedback of channel condition from receiver to transmitter is known as channel quality information feedback and only index (CQI: channel quality index) is being sent from receiver to transmitter. Based on CQI power and rate are adapted at the transmitter.

Adaptive modulation done by some researchers are [1] – [8]. In [2] the modulation levels and the transmit power is adapted while meeting the BER and power constraints. As 4G is OFDMA based technology. Adaptive OFDM for wide-band radio channels has been done in [3] where different modulation schemes are employed adaptively onto different subcarriers for frequency selective fading channel.

Efficient link adaptation leads to enhancement in spectral efficiency and hence channel capacity. As 4G and beyond systems are based on dense heterogeneous deployments of eNBs targeting towards higher system capacity and hence better link adaptation ultimately contributes to enhancement in area spectral efficiency and overall system capacity.

As link adaptation is fundamental to achieve optimized spectral efficiency with BER/BLER constraints an attempt has been done through semi-analytical approach. OFDMA based cellular wireless systems and beyond systems have been considered in this work. The objective of this work is to optimize the spectral efficiency while satisfying BER constraint.

The rest of the paper is as follows: Section II deals with system model. In section II link adaptation/adaptive modulation has been discussed. Section III deal with results and their analysis. In section IV conclusions are there.

II. SYSTEM MODEL

$$y_i = \alpha_i h_i x_i + w \tag{1}$$

where α is the path loss component , h is the rayleigh channel coefficient and w is the AWGN, i being the subcarrier index. The order of modulation (no of bits in one symbol) that needs to be sent through the channel depends upon h (channel

$$M_i = f(h_i, \beta) \tag{2}$$

condition) and BER constraint

where h_i =instantaneous channel condition β = BER constraint

Power and rate are adapted based on channel condition with BER limitation. In order to adapt power and rate channel condition should be known at the transmitter or receiver should feedback it to the transmitter. The optimization criteria is to minimize power requirement and to maximize data rate that can be delivered.

A. Variable-Rate Variable-Power MQAM

Constellation size and power adapted to maximize average throughput given an instantaneous BER constraint.

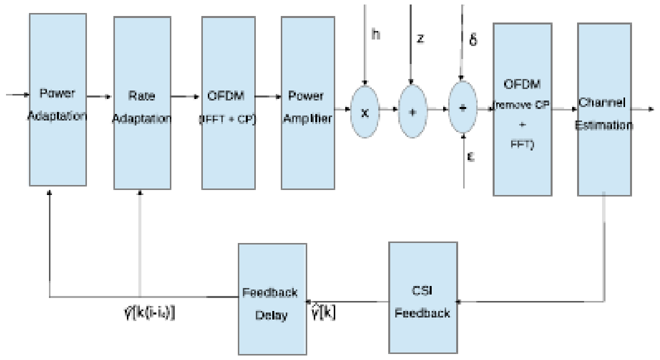


FIG. 1. SYSTEM MODEL FOR LINK ADAPTATION IN OFDMA BASED SYSTEMS.

The Fig1. is the system model used for this work which is link adaptation in OFDMA based systems. In this power and rate is adapted based on SINR estimate for each carrier γ[k]. In this h is channel impact (Rayleigh channel), z is AWGN, δ is timing offset and ε is frequency offset. In this work δ and ε are taken as 0 being ideal condition.

A. Variable-Rate Variable-Power MQAM

Constellation size and power adapted to maximize average throughput given an instantaneous BER constraint. BER bound

in verte d to

$$BER(\gamma) = 0.2e^{[\frac{-1.5\gamma P(\gamma)}{(M-1)\bar{P}}]} \quad (3)$$

get adaptive constellation size M[γ] below with K = 1.5/ln(5 BER) that meets the BER constraint for any adaptive power policy P[γ]

$$M[\gamma] = 1 + \frac{-1.5\gamma}{ln(5BER)}\frac{P(\gamma)}{\bar{P}} = 1 + K\gamma\frac{P(\gamma)}{\bar{P}}. \quad (4)$$

B. Optimization Formulation: Optimal rate and power adaptation for maximum throughput.

Optimize P(γ) and M(γ) to maximize

$R=E\log_2[M(\gamma)]$

Optimal power adaptation P(γ) can be found by maximizing average throughput

$$E[log_2(M[\gamma])] = E[log_2(1 + K\gamma\frac{P(\gamma)}{\bar{P}})] \quad (5)$$

relative to P(γ). i.e

$$\max_{P(\gamma)} E[log_2(M[\gamma])] = \max_{P(\gamma)} E[log_2(1 + K\gamma\frac{P(\gamma)}{\bar{P}})] \quad (6)$$

Let us assume an average transmit power constraint

$$\int_0^\infty P(\gamma)p(\gamma)d(\gamma) \leq \bar{P} \quad (7)$$

where p(γ) is the distribution of γ.

To find the optimal power allocation P(γ), we form Lagrangian

$$J(P(\gamma)) = \int_0^\infty log_2(1+K\gamma\frac{P(\gamma)}{\bar{P}})p(\gamma)d(\gamma) - \lambda\int_0^\infty P(\gamma)p(\gamma)d(\gamma) \quad (8)$$

Next we differentiate the Lagrangian and set the derivative equal to zero:

Solving for P(γ) with the constraint that P(γ) >

0 yields the optimal power adaptation that maximizes

$$\frac{P(\gamma)}{\bar{P}} = \frac{1}{\gamma_0} - \frac{1}{\gamma K} \qquad for \quad \gamma \geq \frac{\gamma_0}{K} = \gamma_K \quad (10)$$

$$\frac{P(\gamma)}{\bar{P}} = 0 \qquad else \quad (11)$$

(3) as

Optimal rate adaptation can be found by substituting optimal power adaptation into M(γ), yielding

$$R(\gamma) = log_2(\frac{\gamma}{\gamma_K}), \quad (12)$$

$\gamma > \gamma_K$,where γ_K is cutoff value for the water-filling

$$\frac{R}{B} = \int_{\gamma_K}^\infty log_2(\frac{\gamma}{\gamma_K})p(\gamma)d(\gamma) \quad (13)$$

power policy.

III. R ESULTS AND ANALYSIS

The figure 2 is plot of the probability of error vs SNR for QAM symbols under AWGN.

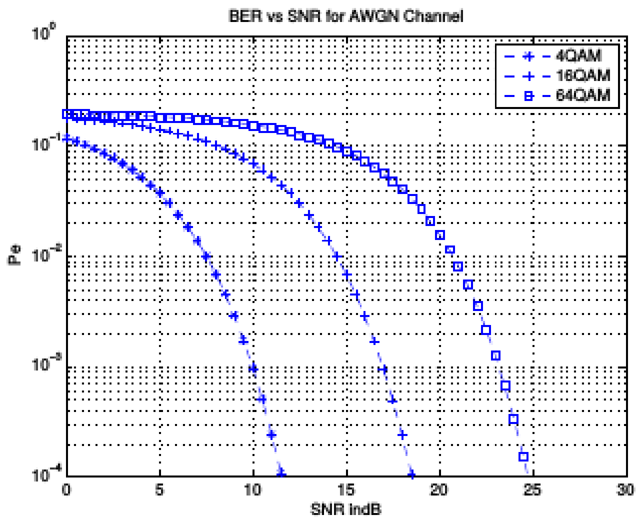


Fig. 2. Probability of error vs SNR in dB

From the figure it is seen that thresholds for BER constraint 0.1 are for 4QAM = 1.5dB, for 16QAM = 8dB and for 64QAM=14dB.

The figure 3 shows the plot of Rayleigh effect of the channel which is due reflection, scattering and diffraction.

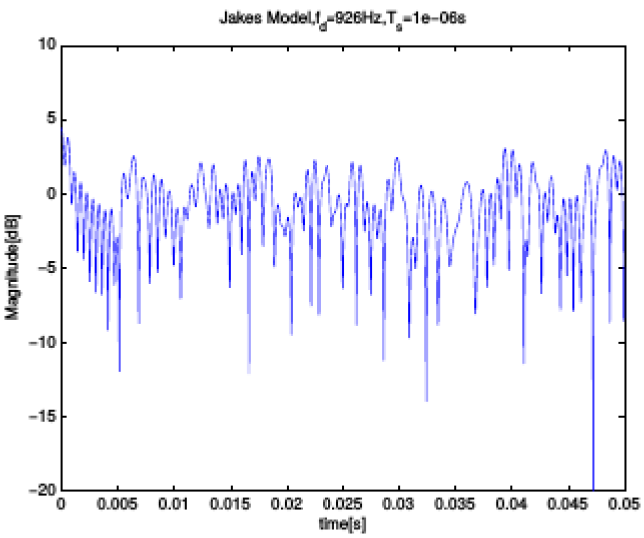


Fig. 3. Rayleigh Channel

The signal at a place and at a time is the combined effect of reflection,scattering and diffraction. Abscissa shows the time and ordinate shows the magnitude of h i.e channel in dB which is function of time.

Figure 4 is plot of spectral efficiency vs average SNR using link adaptation process.

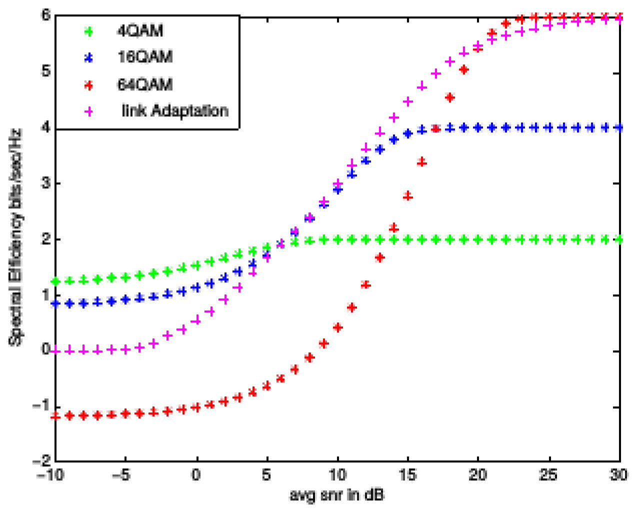


Fig. 4. Spectral efficiency after link adaptation

The figure shows that we are able to follow the tops of each of the modulation levels. We pump the max possible rate with the instantaneous channel condition simultaneously satisfying the BER constraint and this process is followed throughout the duration of sending data and hence maximization of spectral efficiency is achieved.

The figure 5 shows that effect of velocity on link adaptation spectral efficiency.

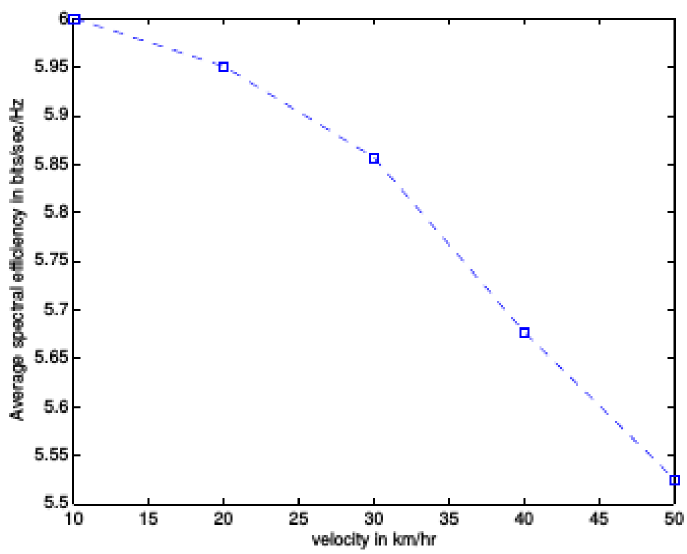


Fig. 5. Effect of velocity on link adaptation

From the figure it is seen that with increase in velocity there is fall in spectral efficiency. The reason behind is that with increase in velocity channel fluctuates rapidly and hence there is mismatch in exact instantaneous channel condition and the channel condition taken for selecting the rate thereby leading to increase in BER from target BER and hence fall in spectral efficiency takes place.

The figure 6 shows power adaptation process for link adaptation.

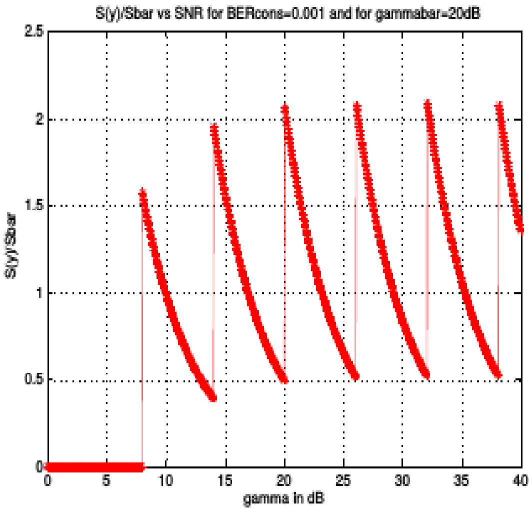
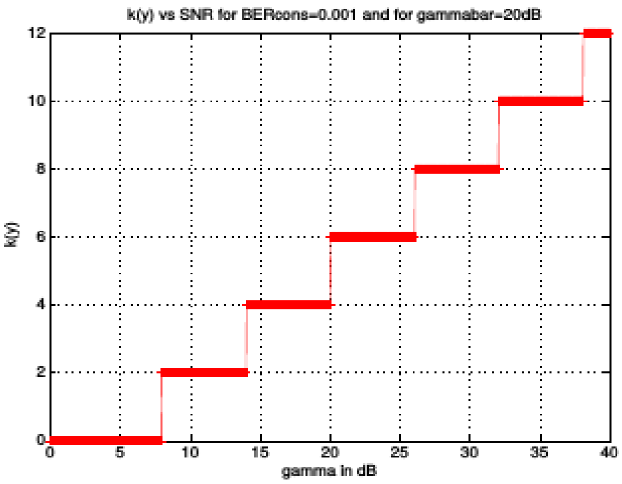


Fig. 6. Optimal Power Adaptation

From the figure it is seen that from the optimization perspective when the SNR is less then less power needs to be pumped whereas when Higher SNR is there, higher power needs to be pumped.

The figure 7 shows rate adaptation process for link



adaptation.

Fig. 7. Optimal Rate Adaptation

From the figure it is seen that from the optimization perspective when the SNR is less then less power and hence less rate needs to be pumped, whereas when Higher SNR is there, higher rate needs to be pumped.

Figure 8 shows plot of the loss in the rate due to quantization as compared to continuous adaptation.

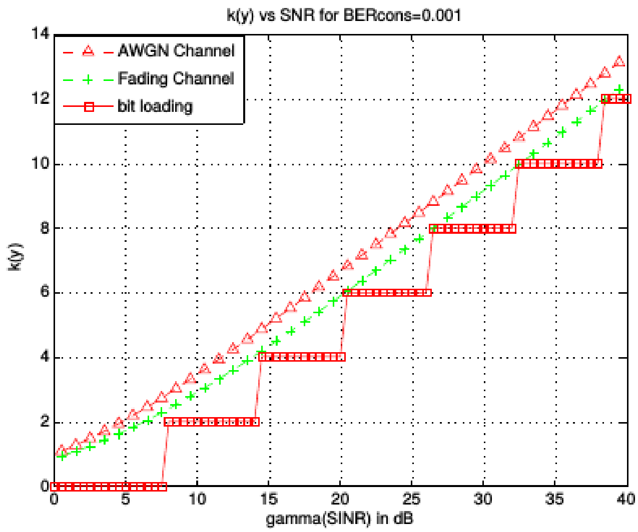


Fig. 8. Loss in rate due to quantization

It is seen from the figure that there is loss in SINR due to Quantization. In this work/figure a max loss of nearly 5dB is there.

IV. CONCLUSIONS

In this work link adaptation in OFDMA based system has been discussed. Link between eNB and user has been adapted by adapting power as well as rate. From the optimization perspective it is observed that for under weaker SNR less power and less rate needs to be loaded whereas under higher SNR high power and rate needs to be loaded. It is also seen that due to quantization there is loss in rate due to practical perspective.

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