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Title:	Performance Comparison of SIR-based and Level-based UL Power Control in case of Fading AWGN Interference
Document for:	Discussion

1 Introduction

This paper introduces some simulation results for uplink BER performance of low chip rate TDD system for both level-based and SIR-based power control (PC). The aim is to find out which kind of PC scheme should be used in the system.

2 The benefits of SIR-based power control

2.1 Fundamental

The purpose of power control is to minimize the receiver power fluctuations to within a value sufficient enough to obtain a required quality of service (QoS) from a given link. The fluctuations are mainly due to slow fading (i.e. shadowing) and fast fading (Rayleigh fading). If no intercell interference is considered or it is just regarded it as AWGN, the optimum situation of power control is that all users are received with the same constant power and thus, the interference among each user are the minimum (for non-JD receivers only). Another benefit from power control is that each user transmits only with the power that it really needs, as a result, the intercell interference in the network is reduced and the UE is able to save battery power. Finally, power control improves the fading statistics for the regarded UE, and thus, leads to a considerable performance improvement for environments with a low time variance. Consequently, a good power control algorithm is crucial to maximize the system capacity.

2.2 Why SIR-based PC?

Generally there are two kinds of power control schemes in use --- **level-based PC** and **SIR-based PC**.
Level-based PC is just controling the Rx power running towards a preset target level, that is, all users' signal will arrive at base station with nearly the same power. **SIR-based PC** is controling the SIR at the receiver end to be a nearly constant value. In the presence of AWGN intercell interference, the performance of both the two schemes are nearly the same.

From the practical point of view, SIR-based power control is preferable since it is the SIR not the Rx power alone that determines the quality of service (QoS).

Another reason for choosing SIR-based PC is that, in case of fading AWGN intercell interference (see 2.3 for more details) which is always the case when the target UE goes close to the edge of the cell coverage area, control only the Rx power to be stable will not reach a stable SIR and then QoS. In this case, the SIR should be stabilized and not the signal power itself.

A further issue is especially related to TDD systems. In TDD the users of every time slot will be interfered by interference which is independent both in power level and fading statistics. A SIR based power control algorithm is able to react on the individual situation of in the time slot in the best possible way.

2.3 Modelling of intercell interference

The characteristics of intercell interference for a power-controlled system is described in this section. The interference can be divided into three cases as follows.

(1) Fading AWGN interference: Here it is supposed that there is only one interfering user in the neighboring cell (see Fig. 1). For a power-controlled system, the Tx power of the interfering UE should have some reverse-fading peaks to withstand against the fast fading in the channel and then ensure less fluctuation in the Rx power of its host base station. I.e. in case the path loss of has maximum the TX power will also be maximum. When this signal arrives at the BS of target cell through another fading channel which is totally independent from the host fading channel, it should also have additional fading characteristic. Therefore, the interference has both fading and reverse-fading characteristics in this case.

(2) Quasi fading AWGN interference: If there are several interfering UEs in the neighboring cell, each of them would have fading AWGN characteristics and then the total interference to UEs in target cell would be the summation of several fading AWGN signal, this is what is called quasi fading AWGN interference.

(3) AWGN interference: Suppose there are infinite number of UEs in the interfering cell, the mixture of them should be like AWGN signal.

Consequently, the mobile radio scenarios occurring in the real environment are in-between the AWGN and the fading AWGN interference. In practice there are only few UEs determining the interference in the interference limited scenario. Therefore the first case is rather likely.

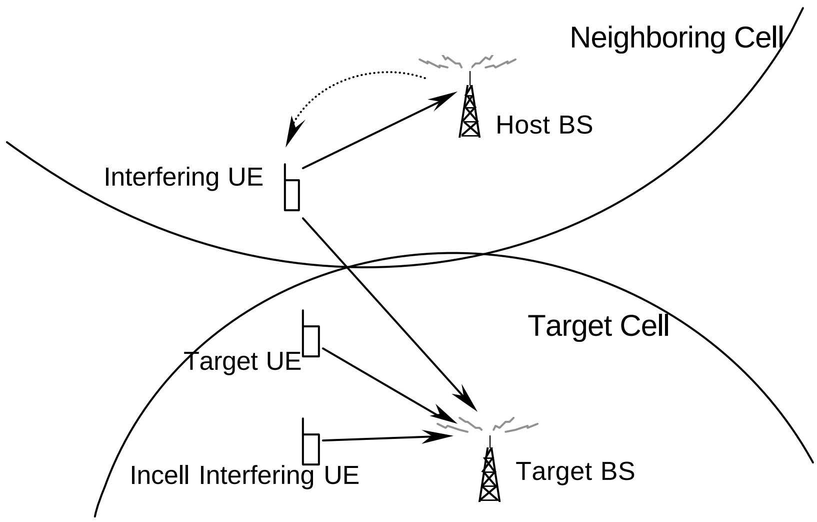

Figure 1. Layout of in-cell and inter-cell interfering sources

To evaluate the performance of power control schemes in the worst intercell interfering environment, here we consider only the extreme case of intercell interference, that is, only one interfering UE at the edge of neighboring cell. Obviously SIR-based PC can also perform well at AWGN interference.

3 Simulation assumptions

The following environment is used for the simulation:
Channel used: OTI A. (see Table 1 for the parameters of the channel)
Speed: 3 km/h.
Smart Antennas: No, only 1 RX antenna is used.
Power control step: 3 dB closed loop.
Totally 4 active users with 1 orthogonal code each.
No channel coding.
It is assumed that 1 UE being power controlled to its Node B is interfering the reception of the regarded UL.
Mobile radio channel for the interfering UE:

a) Power controlled OTIA for the TX power of UE
b) OTIA for the path to the target base station

Table 1 Outdoor to Indoor and Pedestrian Test Environment Tapped-Delay-Line Parameters

Tap	Channel A		Doppler Spectrum
	Rel. Delay (nsec)	Avg. Power (dB)	
1	0	0	CLASSIC
2	110	-9.7	CLASSIC
3	190	-19.2	CLASSIC
4	410	-22.8	CLASSIC
5	-	-	CLASSIC
6	-	-	CLASSIC

4 Simulations results

To evaluate the performance of SIR-based power control scheme and for comparison, totally three cases are tested, that is, no PC, level-based PC and SIR-based PC, with each of them being simulated both for erroneous channel estimation and ideal channel estimation.

Firstly, the three cases are simulation in case of erroneous channel estimation. Fig. 2 gives the BER performance for the three cases. Table 2 gives the corresponding Eb/N0 value of these schemes at certain bit error ratios. From the figure and table, we can easily find out the considerable performance gains for SIR-based PC than level-based PC and of cause no PC case.

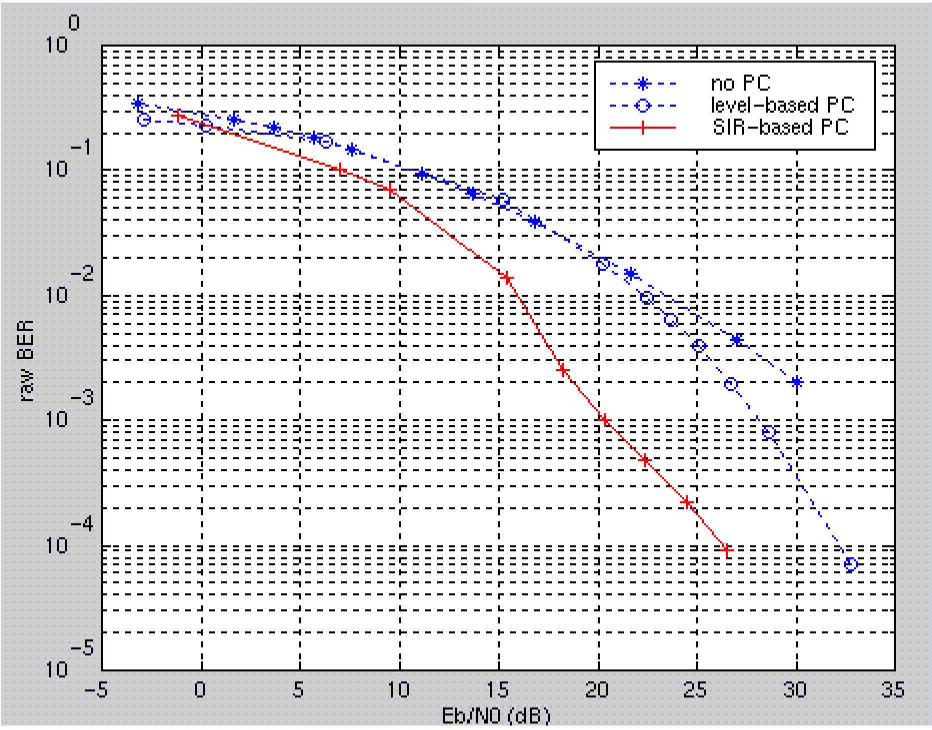

Figure 2. Uplink raw BER performance in case of fading AWGN interference and erroneous channel estimation

Table 2 Raw BER performance improvement of PC in case of fading AWGN interference and erroneous channel estimation

	Performance improvement [in dB]		
Raw BER	No PC	Level-based PC	SIR-based PC
0.1	0	0	3.5
0.05	0	-0.5	4.5
0.01	0	1.5	7.5

For comparison reason, the three cases using ideal channel estimation were simulated as well. Here ideal channel estimation means that the real measured Rx power and interference power used directly to make decision in power control algorithm. Fig. 3 gives the BER performance and Table 3 gives the relative Eb/N0 gain among these schemes at certain BERs.

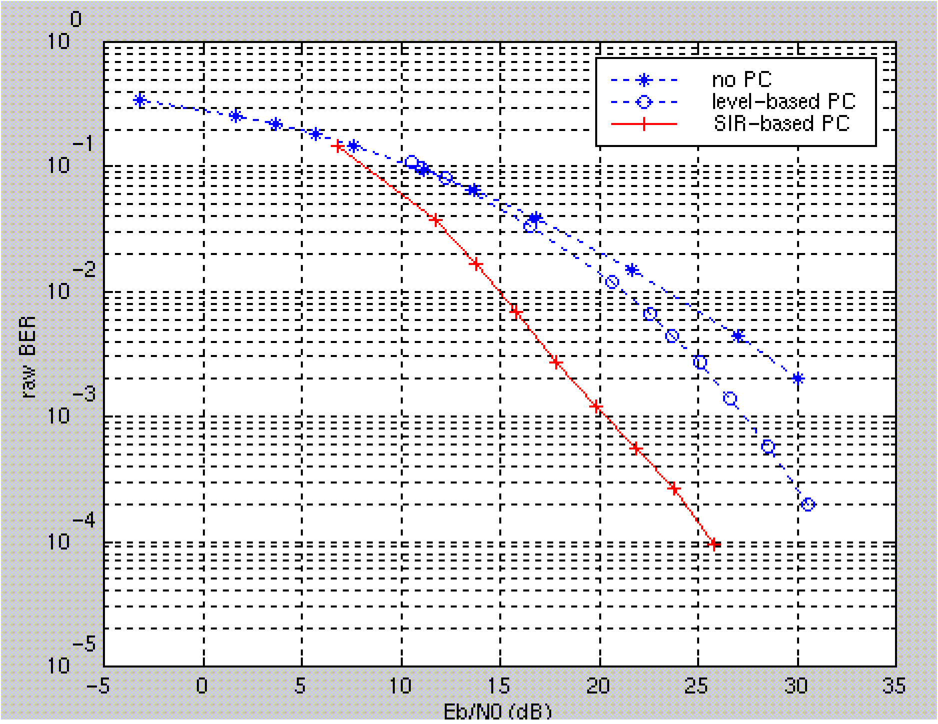

Figure 3. Uplink raw BER performance in case of fading AWGN interference and ideal channel estimation

Table 3 Raw BER performance improvement of PC in case of fading AWGN interference and ideal channel estimation

	Performance improvement [in dB]		
Raw BER	No PC	Level-based PC	SIR-based PC
0.1	0	0	2.5
0.05	0	0.7	4.6
0.01	0	2.7	8.5

Finally we combine all the simulation results into one figure (Fig. 4). From it we can see that the BER performance for erroneous channel estimation are quite near to that for ideal channel estimation.

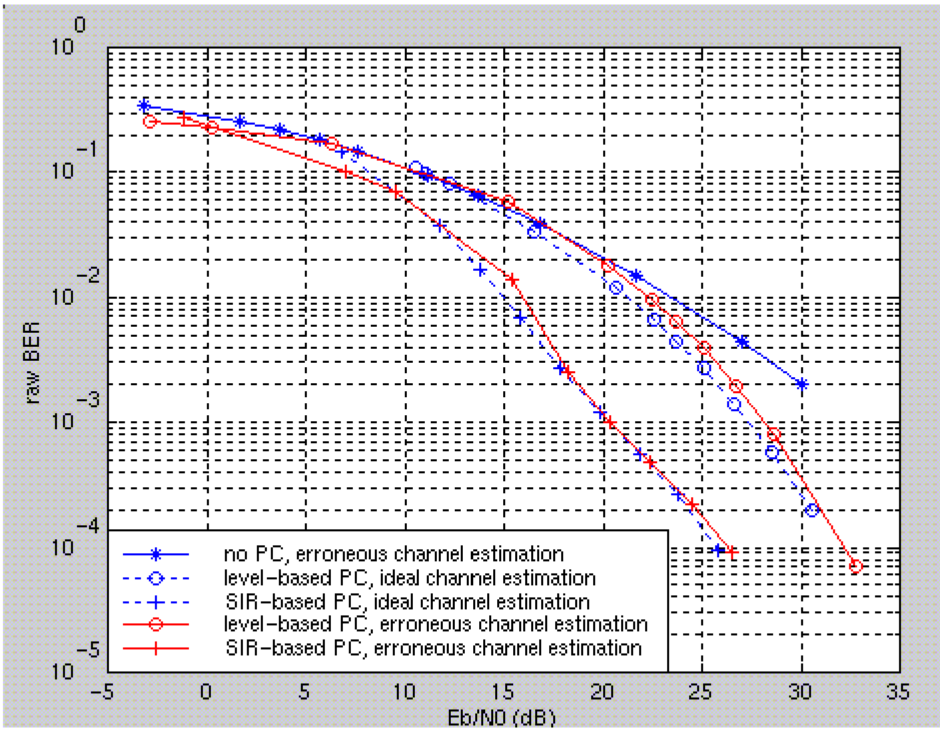

Figure 4. BER performance comparison

SIR-based Power control provides a visible improvement compared with level-based PC and no PC in case of fading AWGN intercell interference. As SIR-based power control is able to react more precisely to the deep fluctuation of interference from neighboring cell, it can get considerable improvement compared with that of level-based one. For uncoded transmission with BER at the level of 10^{-2}, it introduces about 6 dB improvement in Eb/N0 compared with level-based PC. What is very striking to be pointed out that in this worst case interference scenario, there is hardly any difference between level bases power control and no power control at all. Consequently, SNR based power control is a prerequisite of a successful power control at low speed for a wide range of interference scenarios.

5 Conclusion

The benefit of SIR-based power control shown in the link level simulation of this paper is considerable compared with level-based power control and no power control. Therefore, the SIR-based power control is likely to be used in the low chip rate TDD system in order to have a benefit of power controlling the Rayleigh in the general case.

For the transmission of power control symbols this means: Since the average interference power differs in each UL(DL at UE) time slot and the interference in the time slots is in general statistically independent it is highly beneficial that the TX power is controlled individually for each time slot.

This especially applies for UE having more than 1 UL (DL) time slot. Consequently multiple different TPC commands have to be transmitted for/from UEs using multiple time slots.