TSG-RAN Working Group1 meeting #4 TSGR1#4(99)359

Source: InterDigital Communications Corporation

Title: Performance of Open Loop and Closed Loop Schemes for Uplink Power Control in TDD Mode.

1 Introduction

This paper compares the performance of closed loop and open loop schemes for uplink power control in TDD.

2 Open Loop and Closed Loop Power Control Schemes

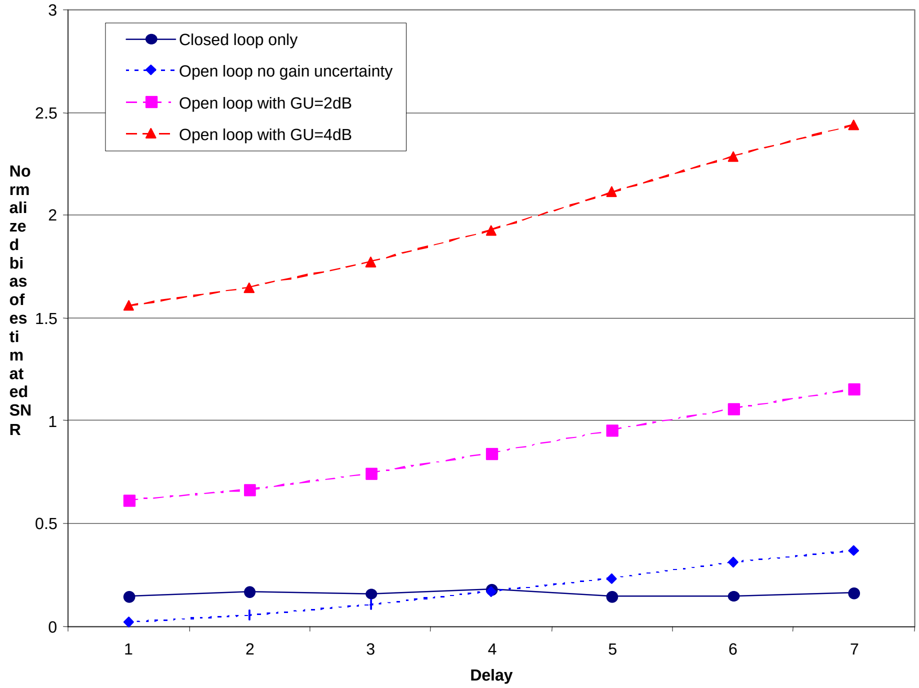
2.1 Closed Loop Power Control

Denote by T_{MS} the transmitted power of the mobile. Let b_{TPC} be the TPC bit (±1) and Δ_{TPC} be the closed loop step size. The TPC bit is determined as follows:

$$b_{TPC}(n) = \begin{Bmatrix} 1 & SIR(n-1) < SIR_0 \\ -1 & SIR(n-1) > SIR_0 \end{Bmatrix}$$

SIR_0 is the desired (target) SIR. The simulations of this paper assumes that one uplink slot per frame is assigned to the user. In this case n is the frame index, and SIR(n-1) is the SNR estimate for the previous uplink transmission of the user.

The closed loop power control can be described by the following equations:



G(n) is the closed loop gain at frame n. All powers and gains are expressed in dB.

2.2 Open-loop Power Control Scheme

Denote by P_{BTS} the desired received power at the base station and by T_{MS} the transmitted power of the mobile. Let R_{MS} be the received power of the down link common channel and T_{BTS} be the transmitted power of the down link common channel (broadcasted on the down link common channel). All powers are measured in dB. Note that T_{BTS}-R_{MS} provides an estimate of the pathloss L. The required transmitted power of the mobile can be expressed as,

$$\begin{aligned} T_{MS} &= P_{BTS} + \hat{L} + \Delta G \\ &= P_{BTS} + (T_{BTS} - R_{MS}) + \Delta G \end{aligned}$$

ΔG is a gain adjustment term representing the difference in dB between the down-link and uplink gains.

P_{BTS} can be estimated by,

$$\hat{P}_{BTS} = SIR_0 + \hat{I}$$

Where I is the estimated interference level at the base station (in dB).

In the simulations the open-loop scheme is implemented in the following way,

$$T_{MS}(n) = SIR_0 + \hat{I}(n) + \hat{L}(n) + \Delta G$$

Where L(n) is the most recent available path loss estimate and I(n) is the estimated interference level.

3 Simulation model and Assumptions

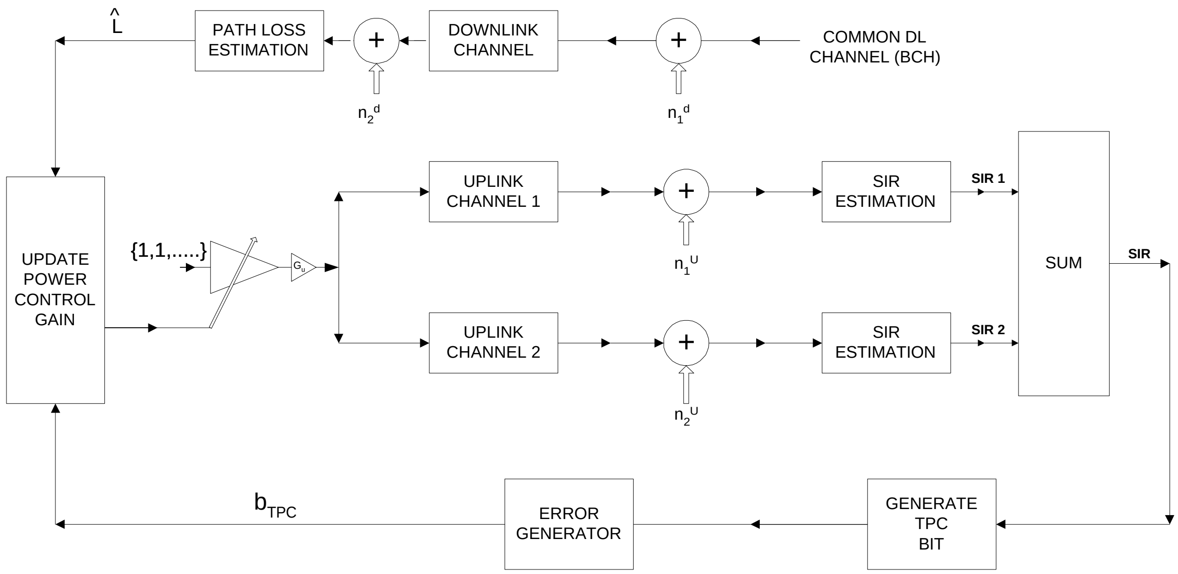


Figure 1: Simulation Block Diagram

A generic block diagram for the simulation is given in Figure 1. The simulation is performed at the symbol rate. It implicitly assumes a spreading factor of 16 for both the downlink common channel and the uplink power controlled channel. The simulation makes the following assumptions:

1. Additive noises n_1^u, n_2^u, n_1^d, n_2^d are independent white Gausssian noises with unity variance. For simplicity n_1^d is ignored in the initial stages of this study. Note that n_1^d represents interference from other users. This is a reasonable simplifying assumption since channelization codes provide orthogonality between downlink channels.
2. The uplink and downlink channels are simulated according to the ITU channel model [ITU-R M.1225, type B]. We used the channel coefficients which were created and distributed by Nokia as part of the Turbo-codes effort. The same set of channel coefficients is used for all three channels.
3. The path-loss is estimated at the mobile station following the reception of the downlink BCH channel. The path-loss is therefore estimated at a rate of 200 cycles per second (twice per frame). The path loss estimate is given by the following equation where T_{BTS} is the (known) transmitted power of BCH. We assume RAKE combining for both the mobile and the base station, and receive antenna diversity at the base station. Accordingly, the received power at the mobile station is estimated as the sum of the received signal powers of each of the multipaths. R^k_{MS} denotes the received power of the k-th multipath at the mobile station, and $P(n_2^d)$ denoted the power of the down-link noise n_2^d.

4. SIR is estimated at the base station following the reception of the uplink channel. The SIR is estimated by the following equation where SIR_m, m=1,2, is the estimated SIR of the m-th antenna. R^k_m denotes the received power at the k-th multipath of the m-th antenna. $P(n^u_m)$ denotes the power of the noise at the m-th antenna.

$$S\hat{I}R = 10\log_{10}\left(S\hat{I}R_1 + S\hat{I}R_2\right)$$

$$S\hat{I}R_m = \frac{[\sum_{k=1}^{K}\hat{R}_m^k] - P(n_m^u)}{P(n_m^u)}$$

5. The TPC bits are received with an error rate of 10%.
6. The gain adjustment term ΔG has uncertainty of G_U dB.

4 Simulation Results

The simulation described in this sections assumes the following parameters:

- Closed loop power control step size: 1 dB.
- Target uplink SNR: 7 dB.
- Mobile speed: 30 km/h.
- ΔG=0 dB; G_U = 0 dB,2 dB,4 dB.

The simulation results are summarized in Figures 2-6. Figures 2-4 are for mobile speed of 30 Km/h, while Figures 5-6 are for 60 Km/h. Figure 2 shows the normalized standard deviation of the received SNR as a function of the delay between the uplink slot and the most recent down-link slot, where the delay is expressed in number of slots. The normalization is performed with respect to the mean value of the received SNR. Figures 3 shows the normalized bias of the received SNR as a function of delay. The normalization is performed with respect to the desired SNR. Each point in the graphs represents the average of 3000 Monte-Carlo runs. In Figures 2-3 the gain uncertainty G_U is assumed to be 0 dB. In this case the open loop schemes outperforms the closed loop scheme for small delays ($D\leq3$), while closed loop scheme is better than the open loop scheme for large delays ($D\geq5$). Both schemes have comparable performance for D=4. Figures 5-6 repeat Figures 2-3 for mobile speed of 60 Km/h. As may be expected, for higher mobile speeds the breakpoint occurs at lower delays. For example, for mobile speed of 60 Km/h the breakpoint occurs at D=2.

Figures 2-3 represent the unrealistic ideal case where there is no uncertainty in the gain adjustment term (G_U= 0 dB). Figure 4 shows normalized bias of the received SNR as a function of delay for several values of uncertainty. The results of Figure 4 indicate that uncertainty in the gain adjustment term causes considerable degradation in the performance of the open loop scheme. As may be expected the performance of the closed loop scheme is not affected by the gain uncertainty. Note also that the performance degradation of the open-loop scheme is represented by the bias of the SNR estimated, while the standard deviation results are independent of the gain uncertainty.

5 Conclusions

- When gain uncertainty is ignored, the relative performance of the two schemes is determined by the uplink/down-link delay. For large delays, the closed loop scheme outperforms the open loop scheme. For small delays the performance of the open loop scheme is superior to that of the closed loop scheme. The critical (breakpoint) delay decreases with increasing mobile speed.
- The performance of the open loop scheme is degraded when gain uncertainty is considered, while the performance of the closed loop scheme is not affected by gain uncertainties.

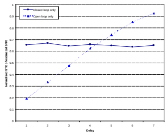


Figure 2: Normalized Standard Deviation of Received SNR as a function of Delay. No Gain Uncertainty (G_U=0 dB), v=30 km/h.

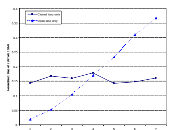
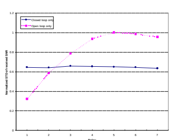


Figure 3: Normalized bias of Received SNR as a function of Delay. No Gain Uncertainty (G_U=0 dB), v=30 km/h.



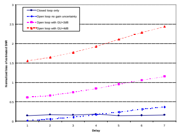


Figure 4: Normalized Bias of Received SNR as a function of Delay. Gain Uncertainty G_U=0, 2,4 dB, v=30 km/h.

Figure 5: Normalized Standard Deviation of Received SNR as a function of Delay. No Gain Uncertainty (G_U=0 dB), v=60 km/h.

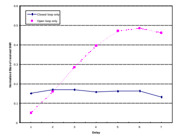


Figure 6: Normalized bias of Received SNR as a function of Delay. No Gain Uncertainty (G_U=0 dB), v=60 km/h.