**TSG-RAN Working Group1 meeting #10 TSGR1#10 R100-0070**
**Source: InterDigital Communications Corporation**

**Title: On the Performance Gain Due to Cell Parameters cycling**

# 1 Introduction

Cycling of cell parameters was proposed by TI [1] as a method that improves path estimation in the presence of intercell interference. This paper evaluates the performance gain due to improved path estimation. The performance gain is evaluated using simulation. The simulation assumptions were agreed by TI and InterDigital following a pre-meeting email discussion.

This paper shows that assuming perfect detection of true and false paths the performance gain is quite small even for the worst case of midamble pairs. Since in practice such perfect detection is not possible, the achievable performance gain will be lower. In addition the scenario of bad midamble pairs can be avoided by proper planning. Finally, cycling of cell parameters increases the complexity of the UE. The limited performance gain does not justify the added complexity. We therefore conclude that introducing cycling of cell parameters cannot be justified by improved path estimation.

# 2 Simulation Assumptions

- Downlink scenario (common spreading factor of 16)
- Fully loaded system. For own cell and interfering cell we assume 8 users with 8 distinct midamble shifts per cell. Note that it is not realistic to have 16 distinct midambles per time slot because each service in the DL requires at least 2 codes that share the same common midamble.
- When cycling is used we assume perfect detection of true and false paths.
- Static propagation model in both cells (interfering and own).
- UE at the cell edge; The interfering cell also has a UE on its cell edge, sharing the same midamble shift and power as the UE of interest (Note that this is another worst case assumption). The distances from the base station of all other UEs in the interfering cell are distributed uniformly in the range (Rmin,Rmax). In the examples of Section 5 we assume that (Rmin,Rmax)=(100 meter, 1000 meter). We consider both $R^4$ and $R^2$ propagation laws.
- The delays and complex amplitudes of the paths are obtained via the Steiner joint channel estimation method [2] with post processing of the channel estimates.
- Error free estimation of the true paths.
- The post processing of channel estimates rejects all coefficients with power less than X dB below the maximal coefficient. Values of X are discussed in Section 5.
- The data estimation is performed by a rake receiver (MRC combiner with weights obtained from channel estimation).
- Performance gain is expressed by the gain in Eb/No for the worst case of midamble pairs. Expressions for Eb/No are derived in section 3. The procedure to identify the worst pair of basic midamble codes is outlined in Section 4.
- The Eb/No values of interest are o to 6 dB.

# 3 Derivation of the gain Eb/No

First we will derive simple expressions, neglecting cross-terms. Then we will refine the derivation to include cross-terms. The simulation results in Section 5 indicate that neglecting the cross terms is justified as it provides a good approximation for the accurate expressions.

## *3.1 Simplified derivation with no cross terms.*

<u>Received signal</u>

$$y(n) = \sum_{i=1}^{N} a_i s(n - n_i) + \sum_{i=1}^{M} g_i r(n - m_i) + w(n) \qquad (1)$$

$a_i, n_i$ complex amplitudes and delays of own paths

$g_j, m_j$ complex amplitudes and delays of interfering paths

w(n) white noise

<u>Output of MRC combiner with no false paths</u>

$$z_0 = \sum_{j=1}^{N} a_j^* \sum_n y(n) s^*(n - n_j) \qquad (2)$$

$$\cong \sum_{i=1}^{N} |a_i|^2 Q + \sum_{i=1}^{N} a_i^* \sum_n w(n) s^*(n - n_i)$$

where Q is the spreading factor. The approximation in the second line of (2) was obtained by neglecting terms of the form

$$\sum_n s(n - n_i) s^*(n - n_j) \quad i \neq j \qquad (3)$$

$$\sum_n r(n - m_i) s^*(n - n_j) \qquad (4)$$

Note that the first term of Equation (2) represents the signal term while the second term represents the noise term.

<u>Output of MRC combiner with false paths</u>

$$z = \sum_{j=1}^{N} a_j^* \sum_n y(n) s^*(n - n_j) + \sum_{j=1}^{M} b_j^* \sum_n y(n) s^*(n - m_j) \qquad (5)$$

$$\cong \sum_{i=1}^{N} |a_i|^2 Q + \sum_{i=1}^{N} a_i^* \sum_n w(n) s^*(n - n_i) + \sum_{i=1}^{M} b_i^* \sum_n w(n) s^*(n - m_i)$$

where the approximation in the second line of (5) was obtained by neglecting cross-terms similarly to the approximations (3)-(4). Note that the first term of (5) represents the signal term, while the second and third terms represent the noise term.

Now we can evaluate the SIR for the two cases above.

SIR for MRC with no false paths

Deriving the SIR from Equation (2) we get,

$$SIR_0 = \frac{\sum_{i=1}^{N} |a_i|^2 Q}{s_w^2} \qquad (4)$$

where $s_w^2$ is the variance of the white noise, i.e.,

$$s_w^2 = E[|w(n)|^2]$$

SIR for MRC with false paths

$$SIR = \frac{\left[\sum_{i=1}^{N} |a_i|^2\right]^2 Q}{s_w^2 \left[\sum_{i=1}^{N} |a_i|^2 + \sum_{i=1}^{M} |b_i|^2\right]} \qquad (5)$$

Max SIR gain assuming perfect detection of true and false paths

$$\boxed{G_{\max} = \frac{SIR}{SIR_0} = \frac{\left[\sum_{i=1}^{N} |a_i|^2 + \sum_{i=1}^{M} |b_i|^2\right]}{\left[\sum_{i=1}^{N} |a_i|^2\right]} \qquad (6)}$$

In other words the SNR gain is given by (energy in true paths + energy in false paths)/(energy in true paths).

### *3.2 Refined derivation with cross terms*

The following refinement was suggested by TI.

Consider the cross terms in Equations (3) and (4). Neglecting the cross terms in (4) is justified because data in different cells are scrambled by different scrambling codes. However, it may be desired to retain cross terms in the form of (3). Repeating the derivation of Section 3.1 with retaining the cross terms of (3) we obtained the following refined expressions for the SIR with no false paths, SIR with false paths and SIR gain.

SIR for MRC with no false paths

$$SIR_0 = \frac{\left[\sum_{i=1}^{N} |a_i|^2\right]^2 Q}{s_w^2 \left[\sum_{i=1}^{N} |a_i|^2\right] + \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} |a_i a_j|^2} \qquad (7)$$

<u>SIR for MRC with false paths</u>

$$SIR = \frac{\left[\sum_{i=1}^{N} |a_i|^2\right]^2 Q}{s_w^2 \left[\sum_{i=1}^{N} |a_i|^2 + \sum_{i=1}^{M} |b_i|^2\right] + \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} |a_i a_j|^2 + \sum_{i=1}^{M} \sum_{j=1}^{N} |b_i a_j|^2} \qquad (8)$$

<u>Max SIR gain assuming perfect detection of true and false paths</u>

$$\boxed{G_{\max} = \frac{SIR}{SIR_0} = \frac{s_w^2 \left[\sum_{i=1}^{N} |a_i|^2 + \sum_{i=1}^{M} |b_i|^2\right] + \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} |a_i a_j|^2 + \sum_{i=1}^{M} \sum_{j=1}^{N} |b_i a_j|^2}{s_w^2 \left[\sum_{i=1}^{N} |a_i|^2\right] + \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} |a_i a_j|^2} \qquad (9)}$$

Note the in the refined expression of equation (9) the SIR gain depends on Eb/No for the desired signal in the following way:

$$s_w^2 = \frac{Q\sum_{i=1}^{N} |a_i|^2}{(E_s / N_0)} = \frac{Q\sum_{i=1}^{N} |a_i|^2}{2(E_b / N_0)} \qquad (10)$$

where $E_s$ is the energy of the complex symbol. In the downlink scenario we can assume that the spreading factor Q=16.

# 4 Procedure for identifying the worst case midamble pair

The received midamble can be modeled as:

$$\vec{r}_m = G_1 \vec{h}_1 + G_2 \vec{h}_2 + \vec{n} \qquad (11)$$

where $G_1 \vec{h}_1$ represents the received midamble from own cell and $G_2 \vec{h}_2$ represents the received midamble from the interfering cell. $G_n \;\; n = 1,2$ is constructed from the basic midamble codes of each cell according to Equations (6) and (7) in [2].

Assuming that $G_1$ is a square matrix, the Steiner based channel estimates for own cell are given by,

$$\hat{\vec{h}}_1 = G_1^{-1} G_2 \vec{r}_m = \vec{h}_1 + G_1^{-1} G_2 \vec{h}_2 + G_1^{-1} \vec{n} \qquad (12)$$

The second term of Equation (12) represents the false paths. Under the assumptions of this paper it can be shown that the worst case pair of basic midamble codes is the one that maximizes the matrix norm $\left\| G_i^{-1} G_j \right\|$ for all possible pairs of i and j. The matrix norm $\|A\|$ is defined as,

$$\|A\| = \sum_n \sum_m \left| A_{m,n} \right|^2$$

Performing exhaustive search over all pairs of basic midamble codes we found out that the worst case occurs when own cell= 60 and interfering cell=107.

# 5 Simulation results

The energy of the false paths depends on the post processing (thresholding) applied to the channel estimates. Figures 1 and 4 show the power of the false paths before thresholding for the worst pair of basic midamble codes. The power of the true path is set to 0 dB.

For the simulation in this paper we assume the following post processing: Reject all paths whose energy is X dB below the maximal path. Our experiments indicate that the optimal value of X for cases 1,2,3 defined by working group 4 ranges between 10 to 12 dB. Similar values apply for ITU channel models.

Figures 1-3 are for $R^4$ propagation law, while Figures 4-6 are for $R^2$ propagation law.

Figure 1 shows that using X in the range of 10 to 12 dB, all false paths will be rejected by the thresholding operation. In other words, there will be no performance gain due to cycling. Performance gains will be observed only if the threshold is lowered 13 dB or more below the maximal path. In the following we therefore consider X=15 dB.

Figures 2 and 5 show the power of retained paths while Figures 3 and 6 show the performance gain as a function of Eb/No.

We observe that for $0\text{dB} \le E_b / N_0 \le 6\text{dB}$ the performance gain does not exceed 1.15 dB. Recall however that the optimal value of X is smaller than 15 dB. Thus for properly selected threshold cycling will yield a smaller performance gain, even for the worst case of midamble pairs and perfect detection of false and true paths.

Figure 1: Power of False paths at the output of the channel estimator before thresholding. $R^4$ propagation law.

Figure 2: Power of false paths with X=15 dB (paths whose power is 15 dB below the maximal paths are rejected) $R^4$ propagation law.

Figure 3: Performance gain as a function of Eb/No with X=15 dB (paths whose power is 15 dB below the maximal paths are rejected) $R^4$ propagation law.

Figure 4: Power of False paths at the output of the channel estimator before thresholding. $R^2$ propagation law.

Figure 5: Power of false paths with X=15 dB (paths whose power is 15 dB below the maximal paths are rejected) $R^2$ propagation law.

Figure 6: Performance gain as a function of Eb/No with X=15 dB (paths whose power is 18 dB below the maximal paths are rejected) $R^2$ propagation law.

# 6 Conclusions

This paper shows that assuming perfect detection of true and false paths the potential performance gain due to cycling of cell parameters is quite small even for the worst case of midamble pairs. Since in practice such perfect detection is not possible, the achievable performance gain will be lower. In addition the scenario of bad midamble pairs can be avoided by proper planning. Finally, cycling of cell parameters increases the complexity of the UE. The limited performance gain does not justify the added complexity. Therefore we cannot recommend cycling of cell parameters based on improved path estimation.

# 7 References

[1] Texas Instruments , “Cycling of cell parameters to improve path estimation”, TSGR1#7(99)c53, August 30, 1999.
[2] B. Steiner, P Jung, “Uplink channel estimation is synchronous CDMA mobile radio systems with joint detection”, The fourth international symposium on Personal, Indoor and Mobile Radio Communications