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Subject : Potential downlink power control instabilities during soft handover

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1. Introduction

This contribution shed some light on the potential downlink power control instabilities caused by large uplink TPC error rates generated by uplink closed-loop power control.

2. Considerations

When a mobile station is in soft handover, a downlink transmission power level P_1 is updated by all cells in the active set, as a function of the TPC commands sent by this mobile station on the uplink [1]. This transmission power level P_1 is always used by all cells in the active set to transmit the DPCCH part of the DPCH, whatever the used downlink power control scheme (whether SSDT is used or not). However, in SSDT, this transmission power level could also be potentially used by any cell in the active set to transmit the DPDCH part of the DPCH, if this cell is chosen or think it is chosen as the primary cell.

We recall that in SSDT [1], the primary cell selection in the mobile station is based on the received levels of the <u>non-power controlled common pilots</u> of all active cells. This selection criterion is an optimum criterion since it is equivalent to the minimum path loss (large scale fading, including shadowing) or maximum carrier to noise plus interference ratio selection criterion.

If downlink transmission power levels, P_1, are common to all active cells, then the power-controlled dedicated pilot symbols of all active cells could be used in the mobile station to determine the relative path losses of all active cells. Unfortunately, the uplink TPC commands transmitted by the mobile station are not error free and cause discrepancies in active cells downlink transmission power levels, P_1. Hence, we could end up with extreme situations where the active station with the largest path loss produces the best received dedicated pilots power, because its downlink transmission power levels, P_1, is the largest one in the active set.

Nevertheless, from a downlink system capacity performance perspective, we still need to permanently guarantee comparable if not identical transmission power levels, P_1, in all active cells. This is guaranteed only and only if the TPC commands are received without errors (or with the same errors) in all active cells. If uplink connections with all active cells guarantee permanently reduced TPC error rates and soft handover duration is not too large, then little difference could be observed between all downlink transmission power levels. In this special case, the downlink power control could work correctly.

In uplink, error-free closed-loop power control is always carried with respect to the currently best receiving active cells. More precisely, the mobile station always reduces its uplink transmission power whenever any cell in the active set asks to do so. This power reduction is done independently of the uplink reception quality in other active cells. As a consequence, these cells could observe a very poor reception quality due especially to small scale fading (Rayleigh fading) on the uplink. This poor reception quality is not alleviated if downlink TPC commands are not error free as is the case in practice. As a consequence, if almost error-free TPC reception could be guaranteed for the best receiving active cell, it is far from being the case for all other remaining cells in the active set.

For the sake of illustration, let us assume that an uplink TPC error rate of 10^{-4} (which is a relatively stringent value) is guaranteed by the system for the currently best receiving active cell. Then, the instantaneous uplink TPC error rate seen by the other active cells could be as high as 10^{-2} and even 10^{-1}. Let us assume now that the soft handover duration is equal to 1 seconds (which is a relatively low value). During this period, as much as 1 s / 0.626 ms = 1600 timeslots are exchanged between the mobile station and the cells of the active set. If an instantaneous uplink TPC error rate of 10^{-2} and a downlink power control step Δ of 0.5 dB are assumed, then the observed downlink transmission power level P_1 difference could be greater than $2*(1600*10^{-2}*0.5)$ = 8 dB (this happens for an average $1600*10^{-2}$ errors occurring in uplink TPC commands requesting always a power increase by Δ dB). This difference is sufficiently large and could lead to a dramatic degradation in system capacity if not instabilities in UTRA FDD system operation, if one of the other active cells with this potential 8 dB power difference is selected as primary.

2. Conclusion

In soft handover, downlink power control errors could lead to a dramatic degradation in system capacity and even instabilities in system operation. A way out of this is to make periodically a downlink transmission power level P_1 alignment through the UTRAN.

3. References

[1] 3GPP RAN S1.14 V0.1.0 (1999-02), « UTRA FDD ; Physical Layer Procedures ».