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Improvements to Site Selection Diversity Transmission (SSDT)

1 Introduction

Site selection diversity transmission has been proposed and included in the 3GPP RAN S1.14 document on “UTRA FDD: Physical layer procedures”.It is a macro-diversity method, to be used in soft handover mode, activated by the network. Its main objective is to transmit on the downlink from the best cell, thus reducing the interference caused by multiple transmissions in a soft handover mode. A second objective is to achieve fast site selection without network intervention, thus maintaining the advantage of the soft handover.

A majorissue with the SSDT technology is the impact of uplink symbol errors on its performance. These errors can corrupt the primary ID code and and this may lead to wrong decoding in the base receivers. As a result, a wrong base station or even no base station at all can be assigned as primary. The SSDT procedure in fact recognises the importance of uplink performance when it suggests that if the uplink signal quality in one of the cells in the active set falls below a certain threshold, this base automatically appoints itself primary.

Uplink performance also has an impact on downlink power control, and thus downlink capacity. In this contribution, we propose some enhancements to SSDT, taking into account the impact of uplink performance in the design of an improved procedure.

2 Site selection diversity transmission

2.1 SSDT procedure

SSDT operation, as described in [1], can be summarised as follows.

- Each cell is assigned a temporary identification,
- The UE:
    - measures reception levels of common pilots transmitted by the active cells,
    - selects the cell from its active set, with the highest common pilot power (section 5.2.3.4.5 in [1]) to be ‘primary’, all other cells are classed as ‘non primary’.
    - periodically informs a primary cell identification to the connecting cells. The primary cell identity code is delivered via vacant uplink TPC bits prepared by puncturing.
- The cells:

- A cell declares itself as non-primary IF:
  - the received ID is not its own ID
  - AND the received UL quality is above a threshold Qth.
- The non-primary cells switch off their DPDCH transmission power.

Moreover, the current description of SSDT leaves some open questions:

- Can the UE know/detect that a cell has appointed itself as primary, so as to use its signal in the data detection?

It is assumed here that it is easy for the UE to detect which cells are transmitting. In particular, it has been stated that **any means used to signal/detect the DTX transmission on the downlink, can be used here for DTX on the non-primary cells**. For instance, TFCI or blind rate detection can be used. This feature enables to get benefits from MRC combining of received signals at the UE. This also implies that SSDT will amount to classical soft handover if all cells have poor uplinks.

- What are the signals on which the UE relies for generating TPC commands in the UL?

If the TPC commands sent by the UE are based on Maximum Ratio Combining of the pilot symbols of all active cells, the data part will not be power controlled efficiently. On the other hand, selecting only the primary cell data for generating a TPC command seems not to be compatible with the management of multiple transmission levels in a cell: why should a cell B update its power level P1 according to the SIR for primary cell A?

2.2 Potential problem

Consider an active set composed of three cells: A, B and C, having relative pilot strengths and relative uplink signal qualities ranked as shown in Fig. 1.

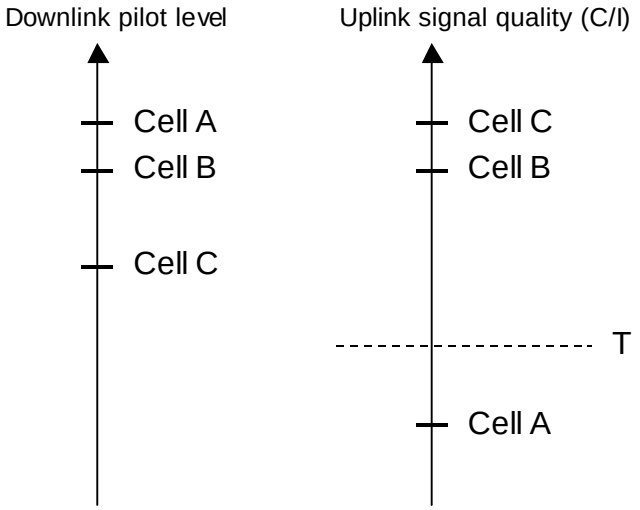

Fig. 1 Downlink pilot level and uplink signal quality for three cells in the active set

Possible reasons for the imbalance between the uplink and downlink in cell A, shown in Figure 1, may include a large amount of uplink only packet traffic over RACH and/or a presence of a strong interferer operating on the adjacent carrier in a neigbour uncoordinated network.

The SSDT procedure will operate as follows:

- Cell A has the strongest downlink pilot, and although it has a very low uplink quality, in accordance with the SSDT scheme, **the UE will select base station A as primary**.
- Because the uplink quality in cell A is below the threshold, **this cell** even if not selected by the mobile, **will declare itself primary**.
- In the other two cells the uplink signal quality is sufficiently good, and they decode the primary ID code correctly as the ID of cell A: **the other cells turn the Tx power off** (in the given dedicated channel).

Thus, the selected primary base station has the best downlink and the worst uplink among the base stations in the active set.

Even with the poor quality uplink in cell A, the uplink traffic connection will be maintained because RNC combines all data detected by the three base stations in the active set. However, the poor uplink quality in cell A will also affect the TPC symbols that convey the downlink power control commands. In the worst case, the TPC symbol error rate is 50% and if reliability indicators are used in interpretation of downlink power control commands, as described in S1.14 [1], the Tx power remains constant.

In any case, fast forward (downlink) power control in cell A clearly ceases to operate and that will thus **significantly degrade the downlink performance** as base station A is the only one transmitting to the mobile. Note that in a conventional soft handover performance degradation caused by this problem would have been less severe because of multiple active downlink connections.

3 Proposed improvements to Site Selection Diversity Transmission

3.1 Modification of the primary cell selection by the UE

In light of the abovementioned problem, our proposal is to modify the procedure for selecting the primary base station. The mobile has access to the information on the uplink interference floor, which is published on BCCH in each cell; a downlink path loss estimation can also be used for calculating the uplink signal quality criterion. Therefore the mobile is capable of comparing the uplink signal qualities of the cells in the active set.

It is proposed that after ranking the cells on the basis of downlink pilot level, the mobile, starting from the top of the ranking list, checks the uplink interference floor for the given cell and rejects the primary cell candidate that has the uplink quality criteria below a certain threshold. Note that

it is assumed here is that at least one of the cells in the active set has a sufficiently good uplink quality.

In terms of complexity, this requires the mobile to simultaneously receive DPCH and BCCH. The BCCHs of the cells in the active set may be monitored sequentially or in parallel, depending on the update rate of the SSDT scheme and on the position and frequency of the uplink interference information carried by the BCCH. (Note that for the SSTD scheme as proposed in [1], 5.2.3.4.5: "The UE Selects a primary cell periodically by measuring reception levels of common pilots transmitted by the active cells. The cell with the highest pilot power is detected as a primary cell." If the "common pilot" refers to the pilot of the BCCH, then this also assumes a mobile station is also able to simultaneously receive DPCH and BCCH, and the proposed enhancement implies very little extra complexity increase for the UE).

Returning to the example in Fig. 1, the proposed procedure will result in cell B (rather than A) selected as the primary. It is true that because of its low uplink quality, cell A will automatically appoint itself primary, and both cells B and A will be transmitting to the UE. Under the assumption that the UE knows which cells are transmitting, there is still an improvement of the system performance because the mobile receiver now does maximum ratio combining of the two detected signals, and on one of them (coming from cell B) power control is functional and therefore brings an extra benefit.

3.2 Additional improvements suggested

Two additional enhancements to SSDT can also be suggested:-

A mechanism for avoiding the situation (or recovering from the situation) when no base station becomes primary. With the current SSDT scheme, there exists a probability that all base stations including the one that was selected primary have uplink quality above the threshold, but the base selected primary wrongly decodes the ID code. As a result, no base station transmits data to the mobile (although according to [1], downlink TPC and TFCI portions are always transmitted). It is proposed that each base in the active set should periodically signal a binary indicator ("1" means that the base decided that it is primary, "0" otherwise) to the network, and in case of all zeros, the network commands all bases to become primary, i.e. SSDT mode is temporarily suspended. This may introduce an extra delay in operation of the scheme (remember that the SSDT proposal generally tries to avoid communicating with the network and employs fast uplink signalling instead) , but the extra delay may be small, especially in case of softer handover.

3.3 Modified SSDT procedure

The final sequel of operations is now performed:

- Each cell is assigned a temporary identification,
- The UE:

    - measures reception levels of common pilots transmitted by the active cells,
    - selects the cell from its active set, ***having the highest common pilot power while, at the same time, having an UL signal quality above a given threshold,*** to be 'primary', all other cells are classed as 'non primary'.
    - periodically informs a primary cell identification to the connecting cells. The primary cell identity code is delivered via vacant uplink TPC bits prepared by puncturing.
- The cells:
    - A cell declares itself as non-primary IF:
        - the received ID is not its own ID
        - AND the received UL quality is above a threshold Qth.
    - The non-primary cells selected by the UE switch off the transmission power.
- ***The network:***
    - ***Receives periodically from all cells in the active set a binary indicator ("1" means that the base decided that it is primary, "0" otherwise),***
    - ***In case of all zeros, the network commands all bases to become primary, i.e. SSDT mode is temporarily suspended.***

4 Conclusion

As a conclusion, the site selection diversity transmit power control method suffers from uplink transmission errors on both the transmission of TPC commands and of the primary cell ID and it can be improved if these effects are carefully taken into account. Three complementary features are proposed here:

(a) The mobile avoids selecting the base station with uplink signal-to-interference below a certain threshold as the primary base, thus improving downlink power control performance;

(b) The state of each base in the active set is signalled to the RNC and the RNC suspends the SSDT mode if all bases are non-primary, thus reducing the probability of a dropped call;

5 References

[1] 3GPP RAN S1.14, v0.1, "UTRA FDD: Physical Layer procedures"