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Soft and Softer Handover in Communication Netwoks

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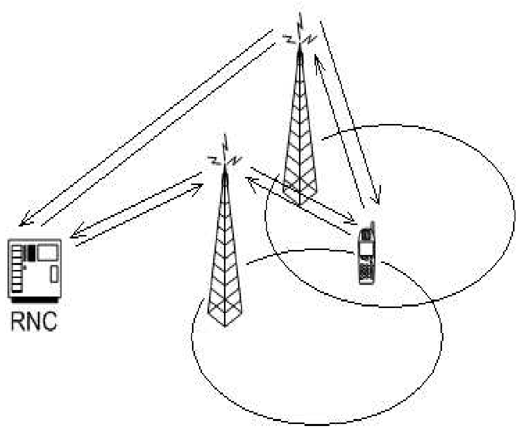
Soft and softer handover are the CDMA specific handover types implemented in the UMTS system and form one of the most characteristic features of the revolutionary WCDMA access method. In this paragraph the impact of

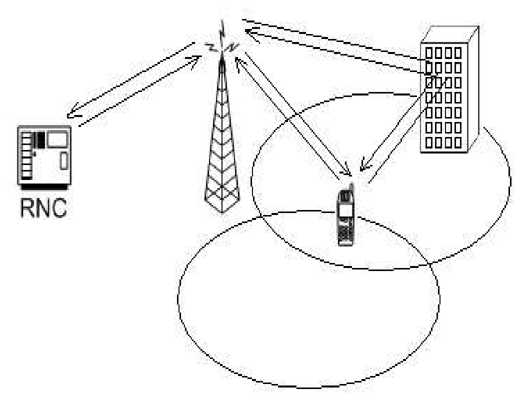


implementing this handover types on the system design is discussed in detail and also the algorithms behind these methods as described in 3GPP specification TR 25.922 are analyzed.

Figure: soft vs. softer handover

A soft or softer handover occurs when the mobile station is in the overlapping coverage area of two adjacent cells. The user has two simultaneous connections to the UTRAN part of the network using different air interface channels concurrently. In the case of soft handover the mobile station is in the overlapping cell coverage area of 33 two sectors belonging to different base stations; softer handover is the situation where one base station receives two user signals from two adjacent sectors it serves.

Although there is a high degree of similarity between the two handover types there are some significant differences. In the case of softer handover the base station receives 2 separated signals through multi-path propagation. Due to reflections on buildings or natural barriers the signal sent



from the mobile stations reaches the base station from two different sectors. The signals received during softer handover are treated similarly as multi-path signals. In the uplink direction the signals received at the base station are routed to the same rake receiver and then combined following the maximum ratio combining technique. In the downlink direction the situation is slightly different as the base station uses different scrambling codes to separate the different sectors it serves. So it is necessary for the different fingers of the rake receiver in the mobile terminal to apply the appropriate de-spreading code on the signals received from the different sectors before combining them together. Soft handover occurs in 5-10% of the connections.

Due to the nature of the softer handover there is only one power control loop active.

For soft handover the situation is very similar in the downlink direction. In the mobile station the signals received from the two different base stations are combined using

MRC Rake processing. In the uplink direction on the other hand there are significant differences. The received signals can no longer be combined in the base station but are routed to the RNC. The combining follows a different principle; in the RNC the two signals are compared on a frame-by-frame basis and the best candidate is selected after each interleaving period; i.e. every 10, 20, 40 or 80ms. As the outer loop power control algorithm measures the SNR of received uplink signals at a rate between 10 and 100Hz, this information is used to select the frame with the best quality during the soft handover.

Note that although the situation is described for two overlapping cells higher values are possible. As will be discussed later, the number of cells the mobile station can have simultaneous connections with is called the active set size.

3G TR 25.922

This paragraph discusses the handover process as described in TR 25.922 of the 3GPP specifications. Basically the soft handover is composed of two main functions:

- Acquiring and processing measurements
- Executing the handover algorithm

Before starting the in-depth analysis of these functions some terms used for describing the handover process have to be defined:

- Set: list of cells or Node B's
- Active set: list of cells having a connection with the mobile station
- Monitored set: list of (neighboring) cells whose pilot channel Ec/I0 is continuously measured but not strong enough to be added to the active set.

__Measurements

Accurate measurements of the Ec/I0 of the pilot channel (CPICH) form the main input for obtaining the RRC measurement report, necessary for making handover decisions.

Mainly three parameters can be measured. Besides the Ec/I0 of the CPICH also the received signal code power (RSCP) and the received signal strength indicator (RSSI) are measured. RSCP is the power carried by the decoded pilot channel and RSSI is the total wideband received power within the channel bandwidth. Ec/I0 is defined as:

RSSI

RSCP

I

EC =

0

(2.1)

It is important to apply filtering on the handover measurements to average out the effect of fast fading. Measurement errors can lead to unnecessary handovers.

Appropriate filtering can increase the performance significantly. As long filtering periods can cause delays in the handovers13, the length of the filtering period has to be chosen as a trade-off between measurement accuracy and handover delay. Also the speed of the user matters, the slower the user equipment is moving the harder it is to average out the effects of fast fading. Often a filtering time of 200ms is chosen.

Other essential information needed during the so-called intra-mode handovers – soft and softer handover – is timing information. As the WCDMA network is of asynchronous nature there exist relative timing differences between the cells. To allow easy combining in the Rake receiver and avoid delays in the power control loops, the transmissions have to be adjusted in time. After the UE has measured the timing difference between the

CPICH channels of the serving cell and the target cell, the RNC sends DCH timing adjustment info to the target cell.

__The soft handover algorithm

The WCDMA soft handover algorithm as described in the 3GPP TR 25.922 specifications differs slightly from the IS 95A algorithm as used in cdmaOne, the standard for North American cellular systems also based on CDMA. Even though the significance of the latter cannot be ignored this discussion is restricted to the analysis of the WCDMA algorithm only.

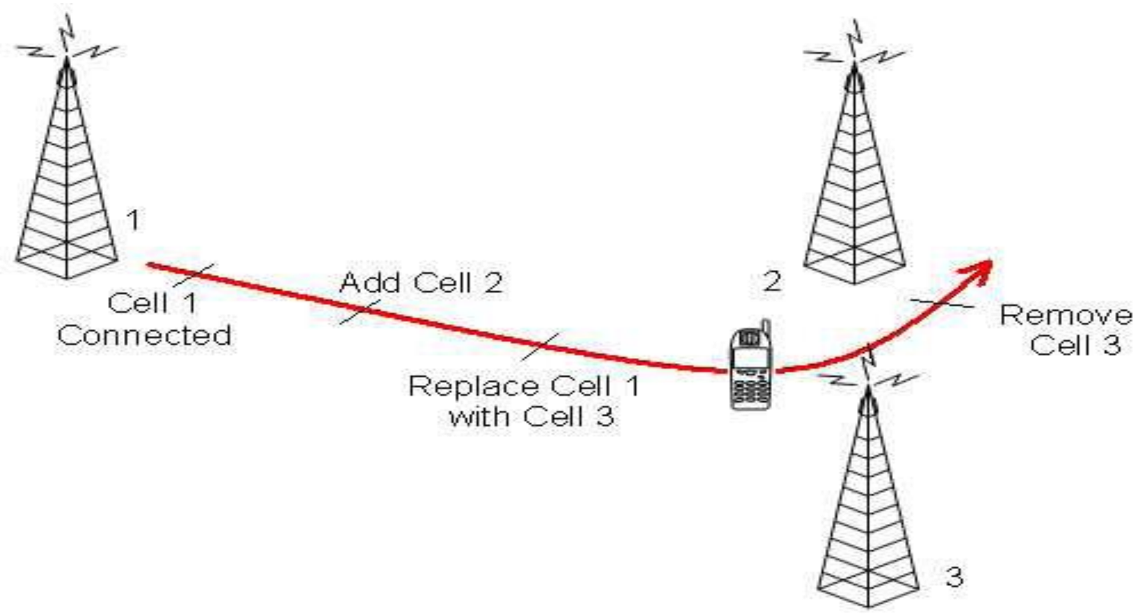
Based on the Ec/I0 measurements of the set of cells monitored, the mobile station decides which of three basic actions to perform; it is possible to add, remove or replace a node B in the active cell. These tasks are respectively called Radio Link Addition and Radio Link Removal, while the latter is Combined Radio Link Addition and Removal. The example below is directly taken from the original 3GPP specifications. Discussing this scenario gives a good insight into the algorithm itself and forms an introduction to the illustrating simulations included in the next paragraph. This scenario can be based on a user following a trajectory as shown below.

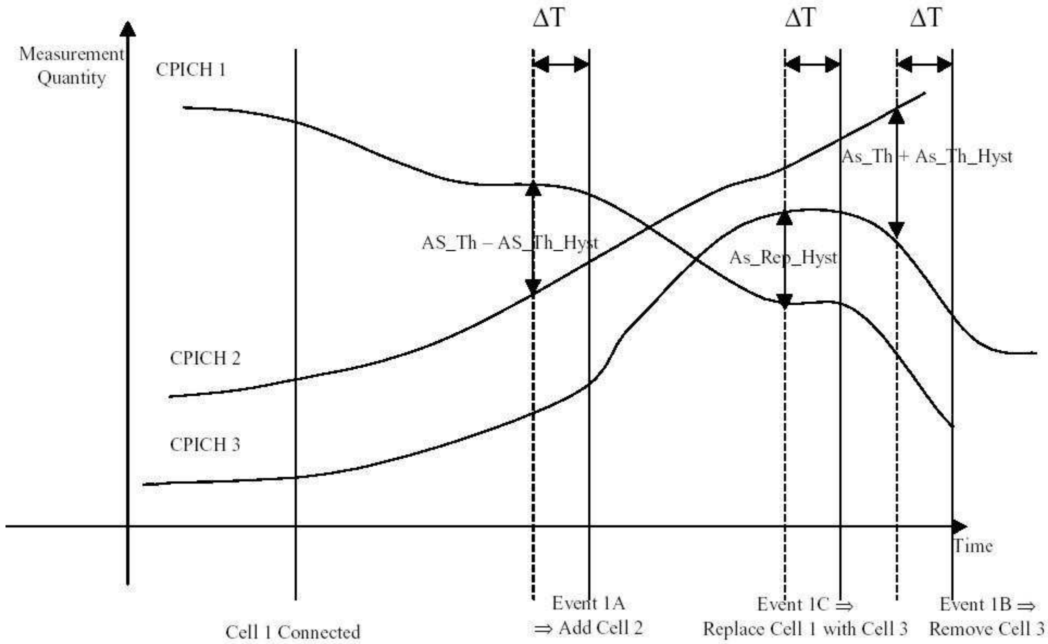
Figure: soft handover scenario

Delays in handovers can cause a user to penetrate deeply in an adjacent cell and generate harmful interference before the cell is added to the active cell.

Figure shows how the pilot signal strengths of the different cells evolve in time.

Figure: WCDMA handover algorithm (picture taken from)





At the start of the scenario the user is connected to cell number 1 which has the strongest pilot signal. Due to the user moving or to slow fading the perception of the signal strengths to the mobile user can change and following actions are taken:

- Event A: cell 2 is added
- Event B: cell 1 is replaced with cell 3
- Event C: Cell 3 is removed from the active set

This example could be based on a mobile user following a path similar to the picture below.

The main parameter in the soft handover algorithm is the threshold for soft handover as will be shown in the following chapters the value of this figure is a crucial design parameter, it determines the amount of users being in soft handover mode and hence influences the system capacity and coverage. Roughly stated it is the maximum difference in SIR two pilot signals can have so their cells can coexist in the active set.

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