SOFT HANDOVER OPTIMIZATION IN UMTS FDD NETWORKS

Václav Valenta
Doctoral Degree Programme (1), FEEC BUT; Université Paris-Est, ESYCOM, ESIEE
E-mail: xvalen07@stud.feec.vutbr.cz

Supervised by: Roman Maršálek
E-mail: marsaler@feec.vutbr.cz

ABSTRACT

This paper presents UMTS FDD (Universal Mobile Telecommunications System - Frequency Division Duplex) SHO (Soft Handover) features and its impact on the network performance. Optimal values of SHO dynamic parameters were proposed and verified and measurements carried out proved that enlarging the SHO area in the indoor environment will lead to a significant improvement in the network. Measurements of the UMTS SHO performance have been performed in an experimental indoor UMTS picocell, where the effect of changing SHO dynamic parameters has been studied.

1. INTRODUCTION

SHO is one of the most important features in the UMTS FDD network that makes the data transition smoother and may improve the overall coverage and capacity performance of a network by means of macro diversity. To achieve the best QoS (Quality of Service) and provide flexibility in the network, dynamic parameters that characterise the SHO have to be chosen ingeniously, relative to the propagation characteristics and the available SHO gain. It is necessary to understand the behaviour of SHO especially in indoor environments, where the propagation is affected by multiple reflections, causing large fluctuations of the received signal and hence, more attention should be paid to various cases of the initial network planning.

2. UMTS HANDOVER

Handover is the essential way of providing mobility in a cellular architecture when moving from one cell to another [1]. Different types of handovers have been introduced in the UMTS system in order to cope with requirements such as load control, coverage and capacity, and to provide required quality of service [2]. For a user having an ongoing communication and crossing the cell edge, it is more convenient to use the radio resources in the new cell (so-called target cell) because the signal strength received from the “old” cell is getting worse as the user penetrates the target cell. The whole process of removing the existing connection in the current cell and establishing a new connection in the appropriate cell is called “handover”. The ability of a cellular network to perform efficient handovers is crucial in order to offer attractive services such as real-time applications and streaming media as planned in third generation networks [3].

UMTS handovers can be divided into different types such as intra-frequency, interfrequency, UMTS to GSM and other inter-system handovers. In this article, only SHO and softer handover performance will be considered.

2.1. SOFT HANDOVER

SHO is a handover in which the mobile station adds and removes radio links in such a manner that the UE (User Equipment) always keeps radio links to at least two Node B's [1]. During the softer handover, the UE has a connection to two or more sectors of a single Node B. The transmitting power of the UE is controlled by that Node B, to which the lowest propagation loss exists. The data transition is performed in the following matter: on the uplink, the signal from the UE is decoded in two or more Node B's and then routed to the RNC (Radio Network Controller) where the multiple signals are combined. On the downlink, the data stream is duplicated and sent through Node B's with specific scrambling codes. The UE receives and decodes all copies of the data and combines them [4].

SHO procedure is divided into three phases: measurement, decision and execution. In the measurement phase, E_c/N_0 of the CPICH (Common Pilot Channel) is evaluated based on measurement of the *RSCP* (Received Signal Code Power) and the *RSSI* (Received Signal Strength Indicator). *RSCP* is the power of the decoded pilot channel and *RSSI* is the total power in the channel bandwidth. E_c/N_0 is defined as *RSCP*/*RSSI*.

2.2. SOFT HANDOVER ALGORITHM

UE continuously measures the CPICH level of suitable cells and sends the results to the RNC. The cells to be measured are in the *Cell Info List* which is transmitted in the SIB 11/12 (System Information Block). According to this measurement RNC decides which SHO event will be activated. Three events are defined: addition of a cell to the Active Set, replacement of a cell and a cell removal or drop event. Execution depends on the CPICH power level and on the time-to-trigger value T (minimal time for which the CPICH signal level has to remain above or below a certain limit defined by the macro diversity threshold). Those cell that UE measures belong to Active, Monitored or Detected Set. Active Set is defined as the set of cells that are used simultaneously and these cells are included in the *Cell Info List*. Monitored Set includes cells that are not in the active set, but are included in the *Cell Info List*. Cells included in the Detected Set are neither in Monitored nor in Active Set. According to [2] soft handover occurs in 20-40 % of the connections.

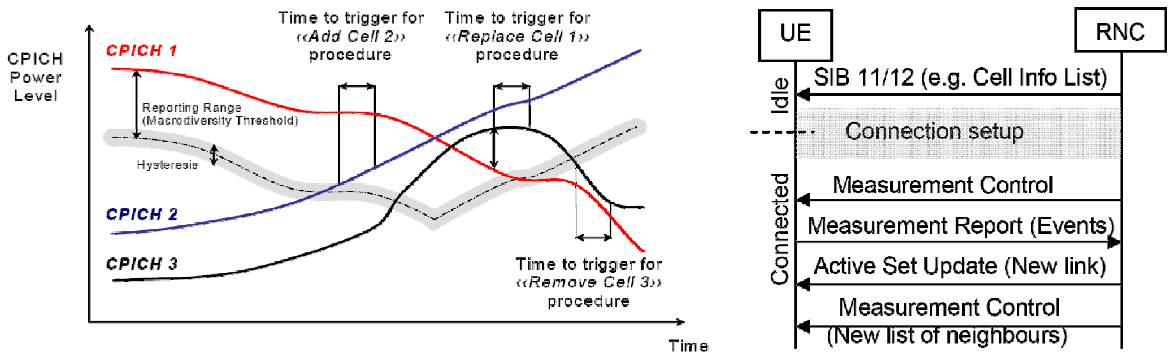


***Figure 1:** Example of the soft handover algorithm [5]*

2.3. Soft Handover Gain

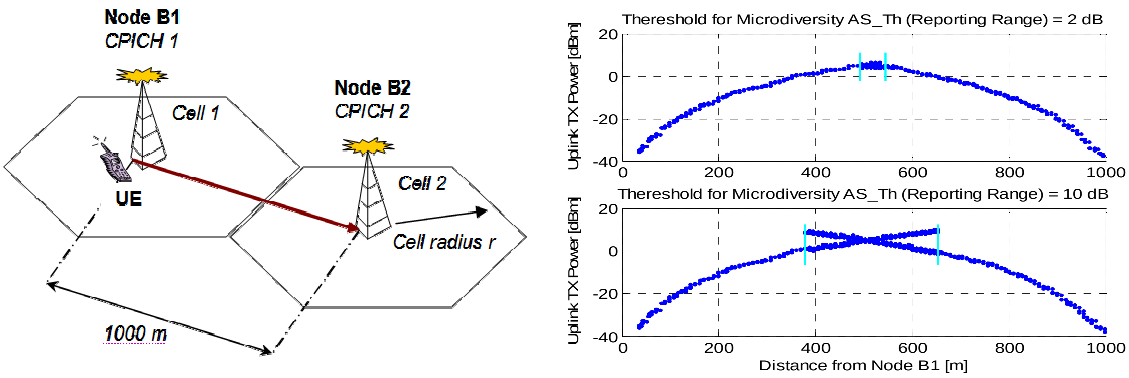
During the SHO, transmission is performed through more than one Node B and as it will be explained later on, this is the reason why the UE transmission power can be lowered. Since there is more than one Node B receiving the signal, the probability of correct reception increases, and thus the transmitting power can be decreased in order to keep the same BER. This can be explained by this example: it is possible to accomplish a given BER using only one link that fulfils this quality requirement or by employing two separate links with lower quality as long as the combining effect is sufficient to provide the requested quality of the radio connection [1]. For instance, let us assume a desired BER of 10^{-4}. This quality can be achieved when using only one radio link that fulfils the given BER or when using two radio links, each with a BER of only 10^{-2} (as $10^{-2} \cdot 10^{-2} = 10^{-4}$). Lowering the link quality enables the transmission power to be kept at lower levels resulting in less interference in the system. This phenomenon is called soft handover macro diversity gain.

3. UMTS HANDOVER MODELLING

UMTS network has been modelled with help of the OPNET Modeller simulation tool. The analysis demonstrates the SHO procedure and examines the influence of macrodiversity threshold values on the SHO probability and the SHO gain. SHO probability can be calculated either as a number of users in the SHO state over the total number of users or as a ratio of the time spent in the SHO state and the total time [1]. The time ratio method is valid only for a UE moving with a constant speed across two cells. In the following simulation, the second method has been used. This scenario is depicted in Fig. 2 *a)*.

$$\text{SHO Probability} = \Delta t_{SHO} / \Delta t_{total} \qquad (1)$$

The analytical model consists of two Node B's spaced 1000 meters apart. Power level of the CPICH is same for both Node B's (CPICH1 = CPICH2 = 30 dBm).



a) *b)*

Figure 2: *Analytical model used for SHO simulations (a). UE transmission power as a function of the distance from Node B1 for two different reporting ranges is depicted in figure b).*

SHO gain has been calculated as a difference between the average transmitted power during the SHO and the situation when only hard handover is enabled (equation 2). Fig. 3 shows SHO gain and SHO probability performance as a function of the reporting range.

$$\text{SHO Gain}\,[\text{dB}] = 10 \cdot \log\left(\text{MAX}\left[\frac{\text{time\_average}(\text{TX\_power}_{(HHO)})}{\text{time\_average}(\text{TX\_power}_{(SHO)})} \right] \right) \qquad (2)$$

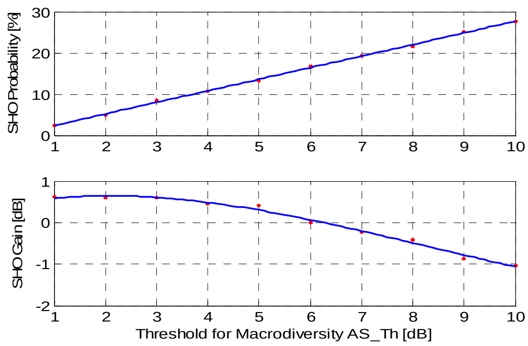


Figure 3: *SHO probability and SHO gain as a function of the reporting range (threshold for macrodiversity). Negative gain corresponds to such a situation when HHO outperforms SHO.*

It has been observed that the maximal achieved gain in this scenario is around 0.65 dB. This may seem negligible, but when considering a loaded cell with up to 20% of UE in the SHO state, the total uplink interference will decrease, and hence it will improve the overall coverage and capacity of a network.

4. REAL TIME MEASUREMENTS ON UMTS

Real time measurements have been performed in the indoor environment with access to experimental and commercial UMTS networks. SHO performance has been examined for various reporting ranges and time-to-trigger values. It has been shown that the optimal indoor soft handover parameters differ from those for outdoor environment. Optimal values have been proposed for the macrodiversity threshold and time-to-trigger values in order to avoid some critical behaviour such as the ping-pong effect (continuous additions and removals of new links due to CPICH fluctuations) and the drop call.

4.1. Measurement Environment

The UMTS FDD indoor network consists of a RNC simulator, two Node B's and DAS (Distributed Antenna System) as shown in Fig. 4. The DAS is a combination of discrete antennas and radiating cables, covering one university building. Measurements have been analyzed with help of the Nemo Outdoor tool and a UMTS enabled mobile phone Nokia 7600. SHO measurements have been carried out along 80 meters long corridor with defined SHO areas. Results of the real-time measurements are presented in the conclusion.

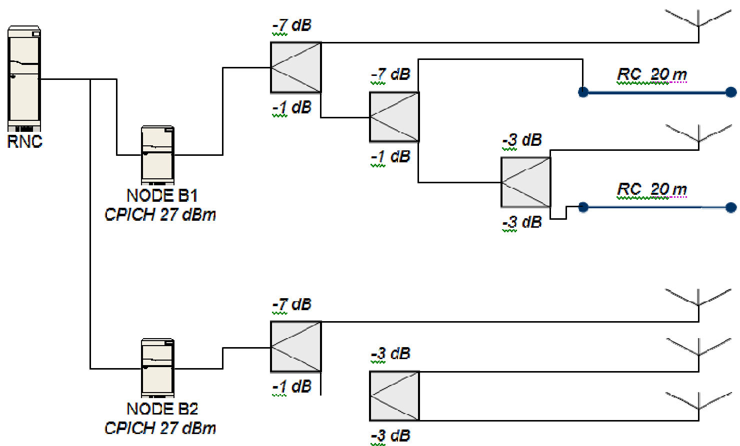


Figure 4: *Distributed antenna system used for measurements.*

5. CONCLUSION

Measurements of UMTS SHO performance have been performed in an indoor environment, where the effect of changing the SHO dynamic parameters has been studied. In order to mitigate the effect of fast signal fluctuations in the typical indoor environment and to eliminate the ping-pong effect, larger SHO areas should be considered. This has been achieved by prolonging time-to-trigger values and by increasing macrodiversity thresholds. Large ping-pong effects were observed in such cases, in which the dynamic parameters were set too low, e.g. «add cell» event 100ms/1dB and «remove cell» event 100ms/1.5dB – these values correspond to the typical outdoor dynamic parameters, where smaller SHO areas are desired. Optimal values for the time-to-trigger and the macrodiversity threshold were set in our specific indoor environment as follows: «add cell» event 640ms/6dB and «remove cell» event 640ms/8dB subsequently. This setting will guarantee a larger SHO area in the indoor environment, but on the other hand, as shown in our SHO simulation, an inadequate increase of the macrodiversity threshold (over 6.5 dB and more) may lead to higher energy consumption due to multiple connections. In such a case, SHO is no more favourable since the macrodiversity gain is nullified by additional interference. This is the reason why the dynamic parameters should be defined separately for outdoor and indoor environments. A longer time-to-trigger value and a higher macrodiversity threshold should be set in indoor environments in order to avoid call-drops, while in the outdoor environment, the dynamic SHO parameters should be set lower in order to profit from the available SHO gain and hence to decrease the uplink interference in a cell.

Another interesting direction for the future research should be focused on the SHO gain performance in the specific indoor environments. This topic is very challenging since the indoor environment exhibits a very low delay spread value and hence the UMTS behaves as a narrowband system with no sufficient multipath diversity gain. A solution for the specific indoor environment might be based on new MIMO methods. Another interesting idea could be based on a deliberate introduction of new propagation paths that exhibit independent fading and that are resolvable by the rake receiver.

ACKNOWLEDGEMENTS

This work was supported by the Czech Grant Agency under the grant No. 102/06/1569 and 102/08/H027 and by the research program MSM 021630513.

REFERENCES

[1] Valenta, V.: Soft Handover Optimization in UMTS Network. VUT Brno 2007.

[2] Holma, H., Toskala, A.: WCDMA for UMTS: Radio Access for Third Generation Mobile Communications. John Wiley and Sons, 2004.

[3] Cauwenberge, V.: Study of soft handover in UMTS. Centre for Communications, Optics and Materials, 2003.

[4] Walke, B.: UMTS: The Fundamentals. J. Wiley and Sons, 2003.

[5] 3GPP TR 25.922: Radio resource management strategies