Investigation of soft-handover near street crossings in UMTS live Networks

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***Abstract*— In this paper we measured the soft-handover (SHO) probability at and near street crossings in UMTS. Literature quotes two main propagation paths in urban macro-cell scenarios: along street-canyons and over the rooftops. Due to the fact that propagation along street canyons is one of the main propagation paths we expected high SHO probability at street crossings. To evaluate this effect we measured the active-set-size along a route in the city center of Vienna in three different UMTS networks of three different operators. We analyzed the probability of being in SHO-state and the probability of various active-set-sizes for different distances from street crossings.The results show that probability of being in SHO does not depend on street crossings.**

I. Introduction

In this paper we investigate the SHO probability on or near street crossings in street canyons. We know from various papers [1], [2] that there are two dominant propagation paths in macro-cell scenarios: along the street canyon and deflection over the roof tops. Entering the crossing, the mobile would monitor a new strong cell propagating within the crossing street canyon. The decision if a new cell is added to the active-set is only based on a window function comparing different received CPICH (Common Pilot CHannel) energy, given by E_C/I_0. An unrequired increase of the active-set entering street crossings could be likely. After leaving the street crossing the mobile would drop the new cell. In an area with high traffic, this would introduce significant unrequired signaling traffic (see [3], [4]).

There are three so called sets in UTRAN (UMTS Terrestrial Radio Access Network). The active-set consists of the cells the mobile is actively connected to. A cell listed in the cell_info_list, being no member of the active-set, belongs to the monitored-set. The last set is the detected-set. It contains all cells from intra frequency measurements.

A handover is a mobility event of a mobile station, initiated by the change from cell A to cell B. There are two fundamental types of hand-over (HO). In hard-HO the mobile removes all connections to the old cell before entering the new one. This type of HO applies to all carrier frequency changes (i.e. cell A and B have different frequencies).

In the SHO mode the mobile equipment is logically and physically attached to several base-stations. In this mode it blocks logical and physical resources. Therefore a wrong decision to add a cell to the active-set will harm the UTRAN network performance. The core-network load will increase in SHO mode too. We assumed that the UTRAN is more restricted and therefore did not extract the intra-RNC and intra-SGSN separately. Figure 1 shows a principle scenario. A mobile terminal is moving in a street canyon, on Street1, which is the main propagation path of Cell1, approaching a street crossing with Street2, which is the main propagation path of Cell2. While the terminal is far away from the crossing only Cell1 is visible. When closing in to the crossing also Cell2 will get visible to the receiver and at some point in time the power of the CPICH may be close enough to add Cell2 to the active-set. After leaving the crossing on Street1, the power from Cell2 will again drop into the noise floor and Cell2 will be removed from the active-set again. In this case the radio-link addition of the UMTS terminal only generated additional signaling traffic without featuring any improvement.

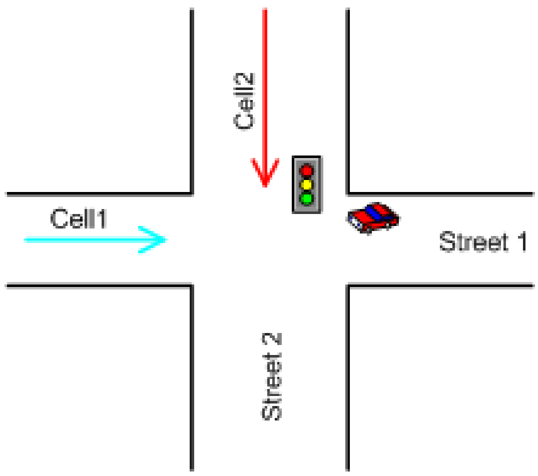


Fig. 1. Example for a street crossing scenario

This paper is organized as follows. In Section II the measurement setup is briefly described. Section III shows the extracted results and gives some interpretations. Section IV gives the summary and conclusions.

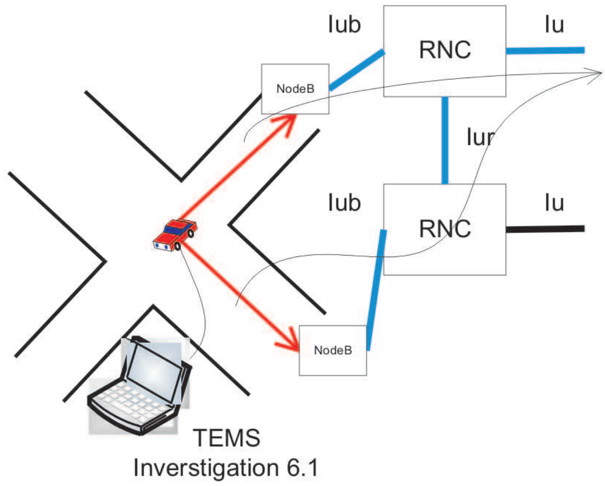
II. Measurement Setup

The measurements were performed in the live UMTS networks of three different operators in the city center of Vienna, Austria. We used a Sony Ericsson V800 (mobile1) and a Motorola A835 WCDMA (mobile2) both TEMS (Transmission Error Measurement System) edition[1] as mobile terminals. The radio link information was recorded using a notebook running the TEMS Investigation software coded by Ericsson [2]. The recorded file was parsed into an output file and analyzed with AWK scripting language. The setup is shown in Figure 2(a).

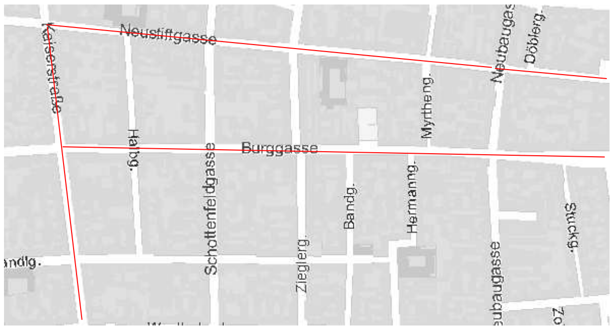
To observe the actual size of the active-set we established a voice call for the measurement period. The voice bearer has a bandwidth of 12.2 kbit/s and an error rate of 1%. The usage of a different bearer could derive different results.

The position information was recorded using a standard GPS feeding the data directly to the TEMS software. At each crossing a file-mark was created to enable post processing.

As we wanted to show a strong effect coming from street crossings we chose a route near the center of Vienna. There are narrow street-canyons which would serve as propagation paths and there is a strong coverage so that it is likely to obtain a large active-set. The actual route is shown in Figure 2(b), which is covered by macro-cells. We drove down the plotted route twice for each operator with an average speed of 32 km/h, not exceeding 45km/h. The TEMS software records active-set reports at a granularity of ≈ 0.1 sec.



(a) Measurement Setup



(b) Route

Fig. 2. Measurement Setup and Route

III. Results

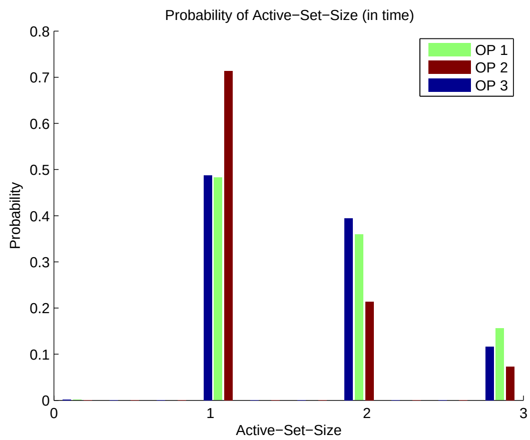
As a first step we computed the histogram of the active-set-size seen in the measurement. In this analysis we binned the data-set with respect to time. Thus, the histogram shows the time average of the active-set-size which can be seen in Figure 3(a). Here and in the following figures OP stands for operator. In [5] the standardisation group made several simulations to estimate the maximum size of an active-set. On page 103 there is a simulation result similar to our measurement setup. Comparing Figure 3(b) with our result (Fig. 3.(a)) we see that the histogram is nearly the same up to the size of three. We did not have a higher active-set-size than three, which could be due to advanced network optimization, an explicitly set limit in the RNC settings or a limit in the mobile handsets (see [4]). The simulation result from the ETSI used a mobile terminal, which was randomly positioned on a flat grid covered by macro-cells. As the figures show a qualitative similar result we can conclude that if there is an effect of narrow street canyons on the SHO state probability, it is small. We assume that the higher probability for an active-set-size of one in the network of OP2 indicates a low number of very big cells covering the measurement area.

A. SHO probability near Street Crossings

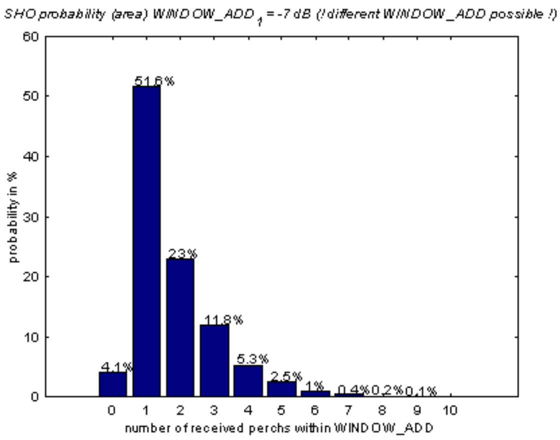
For further investigation of the effect of SHO-probability near street crossings we extracted the relationship between the probability of being in soft-hand-over and the distance to the actual crossing. In a first processing step we transformed the GPS positions to "distance from crossing" values. Due to the street canyons the accuracy of the GPS was not the best, we therefore binned the data to a 1m grid. The assignment of data-points to one street crossing was limited by halving distance from the actual to the next street crossing. The street crossings did not occur on a fixed grid, therefore some distance values accounted for more measurement results. We normalized the dataset of a single crossing by the number of measured crossings to avoid a bias. Finally, the data was accumulated to 1m bins and plotted in MATLAB. Figure 4 shows the result. We can see that there is no significant higher probability to be in soft-hand-over at or near a street crossing. We had at least expected an increase close to the street crossings. To compare the impact of the used end terminal we repeated the measurement for operator one with mobile2. Curve $OP1A835$ represents these data-points. Comparing $OP1$ and $OP1A835$ we see that the used end terminal has a high impact on the measurement results. We assume that the different results from mobile1 and mobile2

[1] Modified UMTS mobiles for TEMS data logging, engineered by Ericsson. Modifications in the firmware are done in order to provide internal measurements via the interface.

[2] TEMS Investigation 6.1



(a) Measured result



(b) Simulation, Source: ETSI [5]

Fig. 3. Active-set-size: Measurement Simulation

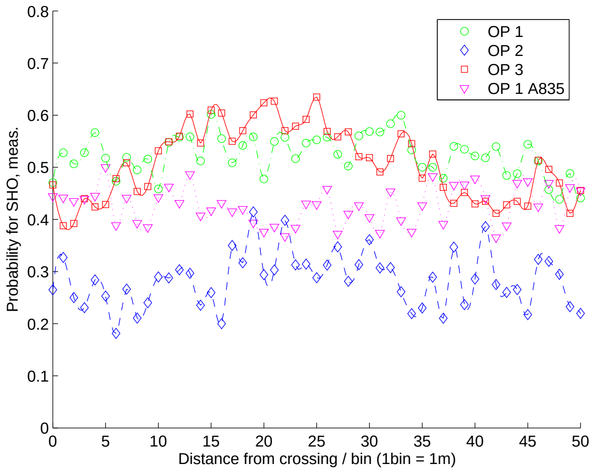


Fig. 4. Probability of SHO vs. distance from street crossing (data points with spline interpolations)

are due to different antenna patterns of the mobile terminals. Visual inspection showed, that the antenna pattern of mobile2 was less focused.

B. *Active-set-size near street crossings*

However, in our measurements there is no significant effect in SHO probability. So we can not say closing in on a street crossing would increase the active-set-size (AS-S). In a final step we therefore extracted the probability of the active-set-size with respect to the distance from the crossing. The data was extracted per each crossing and then normalized to the total number of street crossings. The results are shown in Figure 5. We can observe that the probability of the active-set-size does not show any clear effect in Figures 5 a and b, comparing distances $\leq 5m$ and $\geq 10m$. We do not have an explanation for the fact that the probability for $AS - S = 3$ drops at $OP1$ for values $\geq 25m$. From [6] we know that this distance is far too large to be caused by the street crossings.

In [6] there is a simulation of the power level at a street crossing propagating from the crossing street. The goal was to find more sophisticated hand-over algorithms. There is a simulation of the signal level entering from the crossing street compared to the distance from the crossing. The result shows, that the signal level will drop sharply ($\geq 20dB/m$) for distances $\geq 5m$ from the crossing boarder.

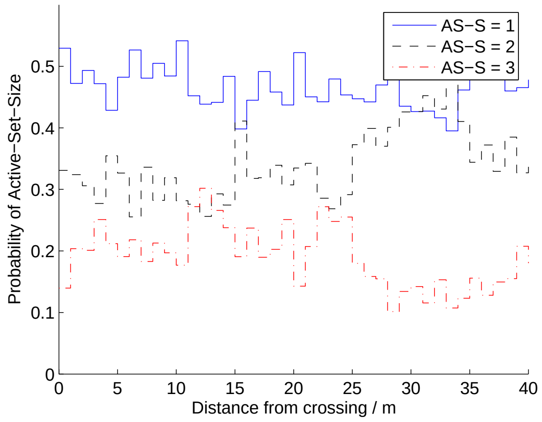
In Figure 5c we can see a slight decrease of the $AS - S = 1$ probability, according to the expected behavior. From above (Fig. 3a) we concluded that this provider uses large cells for UMTS coverage. It could be that the high number (density) of cells of provider one and two hides the effect we want to measure. Additionally our approach to measure the active-set-size does not cover events related to the change of active-set members (i.e. all members of the active-set could have changed, but the size did stay the same).

IV. Summary and Conclusions

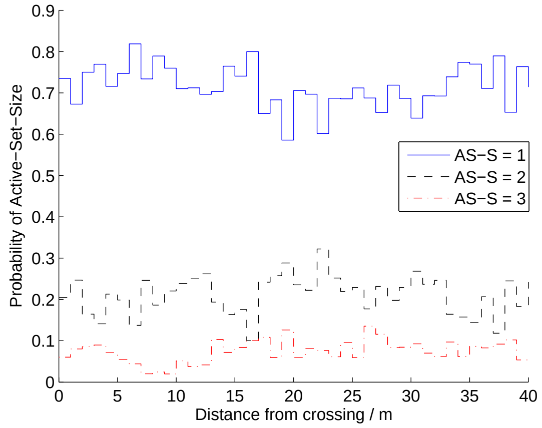
In this paper we analyzed the impact of street crossings on the probability of SHO-state in UMTS live networks. There are several papers that investigated propagation paths in macro-cell scenarios, where the propagation effects in street-canyons dominate. From these results we expected that street crossings are places with a high SHO probability. Nevertheless our measurements showed that there is no significant effect at street crossings.

Our explanation is that the UMTS radio subsystem is already highly optimized and therefore the antenna directions and tilts were chosen not to interfere at street crossings.

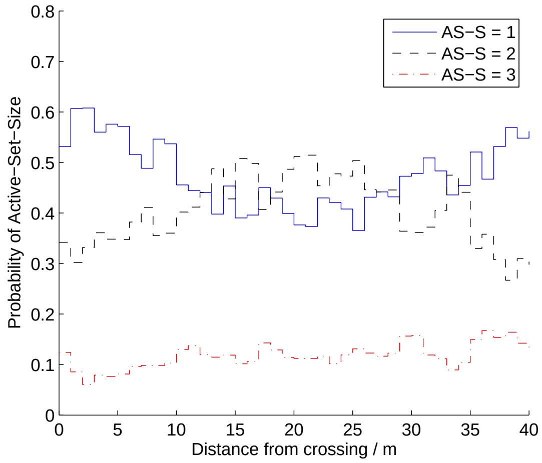
A next step could be to measure a single street crossing more precisely, analyzing the power of the control channels, coming from different cells. Additionally it would be interesting to analyze if there is a difference in the SHO size when entering or leaving the crossing. This could be due to delays in the HO algorithms on the terminal side. Finally we think it could be interesting to analyze different parameters, like the time a cell is member of the active-set.



(a) Operator 1



(b) Operator 2



(c) Operator 3

Fig. 5. Active-set-size vs. distance from street crossings

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