Cell Reselection Parameter Optimization in UMTS

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***Abstract*—With UMTS deployments well underway, one of the key performance metrics is standby time. In idle mode, standby time depends on the cell reselection mechanism. Operators can adjust stand-by time and camping cell quality performance by optimizing operator-configurable cell reselection parameters to, for instance, differentiate their service from others. In this paper, the impact of these parameters is investigated based on diverse field data from different characteristic RF environments (e.g. outdoor, indoor, low/high speed, pilot/not pilot polluted) collected in commercial networks. Performance metrics (camping cell quality, relative standby time) are computed for different parameter sets using a simulation platform that makes efficient use of over-sampled channel measurements to improve reliability and includes a standby-time model described below. Simulation results illustrate the tradeoffs for different parameter settings in different RF environments. Interestingly, camping cell quality and standby time do not always run in opposite directions.**

Keywords - UMTS; cell reselection; idle mode; parameter optimization; field measurements;

I. INTRODUCTION

In UMTS, the user equipment (UE) shall regularly search for a better cell to camp on according to the cell reselection criterion [1]. This mechanism is needed to insure an acceptable quality of the camping cell, and therefore to achieve the desired call setup performance. A very reactive cell reselection mechanism can guarantee an adequate quality of the camping cell at the expenses of stand-by time, which is decreased by frequent reselections. The reselection criterion is based on parameters provided by the network. In this paper, we provide recommendations for cell reselection parameter settings by processing an extensive set of field measurements with our simulation platform.

The paper is organized as follows. Section II provides an overview of the cell reselection mechanism and of the parameters involved. The field measurements are described in Section III, while the simulation platform is introduced in Section IV. The performance metrics used to compare different sets of parameters are described in Section V. In Section VI we present the simulation results. Conclusions are drawn in Section VII, including a recommended set of parameters for cell reselection.

II. CELL RESELECTION PARAMETERS

Idle mode operations are specified in [1]. In idle mode, the UE operates in discontinuous reception (DRX) to improve its stand-by time. At the beginning of each DRX cycle, the UE wakes up, reacquires the camping cell, and reads its paging indicator channel (PICH). Depending on the measured quality of the camping cell, the UE may trigger intra-frequency measurements and evaluate the cell reselection criterion. In particular, measurements are triggered if the common pilot (CPICH) signal to noise ratio (Ec/No) of the camping cell falls below Qqualmin + Sintrasearch. The cell reselection criterion is then evaluated by comparing the quality of the camping cell with the quality of the monitored cells. The measurement quantity can be either the CPICH Ec/No or the CPICH RSCP (received signal code power). In this study, we choose Ec/No as measurement quantity but there is no particular benefit in using one or another[1]. The reselection criterion [1] is such that the UE will reselect to a new cell if the quality of the new cell is at least $Qhyst_{2s}$ + $Qoffset_{2n}$ dB better for Treselection seconds than the camping cell quality.

III. FIELD MEASUREMENTS

A QUALCOMM test phone was used to collect field measurements from three different commercial UMTS networks in Europe, X, Y, and Z. In each market, we performed several runs of data collection along a metric route, which was selected in order to best characterize the specific deployment scenario. In Table I, the measurements are classified in terms of radio frequency (RF) environment and mobility. Market X and Z are examples of macro-deployment scenarios in suburban and urban areas. Market Y is an example of in-building micro-deployment scenario. The metric route leads through pilot polluted areas with several pilot signals of similar strength, areas with fragmented coverage with frequent change of best server, and areas where one pilot dominates.

TABLE I. CLASSIFICATION OF AVAILABLE DATA

Market (# runs)	*RF environment*	*Mobility*
X (4 runs)	outdoor; fragmented coverage; pilot pollution	vehicular; 40 min average time/run; 35 km/h average speed/run; strong speed variations from run to run
Y (3 runs)	indoor; some pilot pollution	pedestrian; 20 min average time/run; 4 km/h average speed/run
Z (1 run)	outdoor; some fragmented coverage	vehicular; 30 min average time/run;25 km/h average speed

[1] Due to the way the measurement quantities are defined in [2].

IV. Simulation Tool

Our simulation platform imports channel measurements taken by the test UE and emulates a standard compliant UE performing cell reselection. Further modeling within the boundaries of the standard is required to align simulator performance with UE performance.

The channel measurements are provided at much higher rate than one sample per DRX cycle. By shifting the starting point by a few milliseconds and sampling once per DRX cycle, we effectively gain several realizations of the multi-path channel, ultimately computing more accurate performance metrics. In other words, considering a run as a random process, the simulator can compute performance metrics by averaging over different realizations of the random process, thus increasing the reliability of its predictions. In addition, the reliability is increased by being able to base the performance metrics for different parameter sets on the same field data. Much more drive testing would be required to achieve the same reliability if we were to collect performance metrics directly from the UE.

V. Performance Metrics

The performance metrics considered are downlink camping cell quality (1%-tile of the CPICH Ec/No distribution), and UE stand-by time. The model described in [3] is used to compare each set of parameters with a reference case, in terms of ratio between the two stand-by times. The reference case is a stationary UE (i.e. reselection rate equal to zero) with a DRX cycle length of 2.56 s.

Let α be the ratio of the current drawn when the UE is awake and asleep, respectively. Let f_a be the fraction of time the UE is awake. Then the ratio between the stand-by times of two different parameter sets can be expressed as:

$$\gamma = \frac{ST_2}{ST_1} = \frac{1 + f_{a,1}(\alpha - 1)}{1 + f_{a,2}(\alpha - 1)} \tag{1}$$

In our simulations we assumed $\alpha = 100$. The fraction of time the UE is awake, f_a, is given by the average awake-time per cycle, T_{awake}, divided by the DRX cycle length:

$$f_a = \frac{T_{awake}}{T_{DRX}} \tag{2}$$

For T_{awake}, we used the following model:

$$T_{awake} = (30 + 250 R_{rslct}) ms / cycle \tag{3}$$

with R_{rslct} the reselection rate, defined as number of reselections per DRX cycle. The first term in (3) models the average awake-time per cycle needed by the UE to reacquire the camping cell, to monitor the PICH channel, and to evaluate the cell reselection criterion. The second term models the additional awake-time due to reselection. In fact, each time a reselection takes place, the UE must decode the system information broadcasted by the new cell, thus extending its awake-time.

VI. Simulation Results

A. DRX cycle length vs. Treselection

Initially, we study the interaction between DRX cycle length and Treselection. Nine sets of parameters are tested in the simulator: A0, A1, A2, B0, B1, B2, C0, C1, and C2. The letter indicates the DRX cycle duration: A, B, and C stand for 0.64 s, 1.28 s, and 2.56 s, respectively. The number indicates the Treselection value: 0, 1, and 2 denote 0 s, 1 s, and 2 s. The measurement triggering threshold is set to 10 dB (i.e. Qqualmin + Sintrasearch = 10 dB) and the hysteresis to 3 dB (i.e. $Qhyst_{2s}$ + $Qoffset_{2n}$= 3dB).

Figure 1 shows the performance of the different sets of parameters for Market X. A DRX cycle of 1.28 s (set B0, B1, and B2) improves the UE standby time by ~20-25% with respect to a DRX cycle of 0.64 s (set A0, A1, and A2) at, surprisingly, no significant expense in terms of camping cell quality. Of course, the UE wakes up more frequently with a DRX cycle of 0.64 s and can adapt more quickly to deteriorating channel conditions. However, more deteriorating CPICH Ec/No measurements are captured if the reselection process is delayed. As expected, a DRX cycle of 2.56 s (set C0, C1, and C2) instead of 1.28 s (set B0, B1, and B2) improves UE stand-by time by ~25% but decreases cell quality by 0.5-1 dB. Here, the DRX cycle duration is much larger than the reselection delay, leading to results in line with expectations. The performance of set C1 and set C2 coincide because in both cases the Treselection parameter is smaller than the DRX cycle period of 2.56 s. Simulations based on field data from Market Y and Z lead to similar results.

B. Effect of velocity and RF environment

Next, we focus on field data from Markets X, Y, and Z for a DRX cycle equal to 1.28 s (sets B0, B1, and B2) and different Treselection values, cf. Figure 2. A Treselection of 1 s (set B1) instead of 2 s (set B2) improves the camping cell quality by ~0.5-1dB at the expense of stand-by time which is reduced by less than 2%. A Treselection of 0 s (set B0) instead of 1 s (set B1) improves the camping cell quality by ~0.5-0.7 dB at the expense of a ~5% reduction in stand-by time. From Figure 2 we can also observe that the "tradeoff curve" (i.e. stand-by time performance as a function of camping cell quality for different values of Treselection) depends on RF environment and velocity characterizing the different markets.

To analyze the effect of velocity on cell reselection performance, we compare the fastest and the slowest run from Market X (average speeds of 45 Km/h and 25 Km/h, respectively) in Figure 3. Velocity degrades the reselection performance both in terms of stand-by time by 2% (higher speeds increase the number of reselections over time) and cell quality by 0.5 dB. Here, different velocities do not lead to different "tradeoff curves". The "tradeoff curve" depends mainly on the RF environment.

C. Treselection vs. hysteresis

Treselection and hysteresis ($Qhyst_{2s}$ + $Qoffset_{2n}$) are inter-dependent in controlling the tradeoff between cell quality and stand-by time. Here, we study the interaction between these two parameters. The focus is still on DRX cycle length of 1.28s. The Treselection values of 0 s, 1 s, and 2 s are tested in combination with different hysteresis values. In particular, the Treselection value of 0 s is tested in combination with hysteresis values from 1 dB to 13 dB in steps of 2 dB. The Treselection values of 1 s and 2 s are tested in combination with hysteresis values from 1 dB to 7 dB in steps of 2 dB. Figures 4 and 5 show the performance of the different parameter sets for Markets X and Y, respectively. In each figure, the three different curves relate to the three tested values of Treselection. The different data points on each curve represent different hysteresis settings. Each data point is labeled with a letter 'h' followed by a number indicating the hysteresis value (e.g. 'h7 stands for "7 dB hysteresis").

Increasing the hysteresis always reduces the reselection rate. While this always improves stand-by time, it does not necessarily degrade cell quality. On the contrary, for a given Treselection, there is an optimal amount of hysteresis that maximizes cell quality by preventing the UE from making wrong reselection decisions in case of large signal fluctuations (as expected higher hysteresis is required for smaller values of Treselection). Based on simulation results, the minimum recommended hysteresis settings are 7 dB and 3 dB for a Treselection of 0 s, and 1 s, respectively. Higher values of hysteresis can still be used to trade off camping cell quality vs. stand-by time. Our preferred setting would be a Treselection of 0 s in combination with a hysteresis of 7-9 dB, because it maximizes cell quality without significantly degrading the stand-by time performance. However, since Treselection is shared with the inter-RAT (Radio Access Technology) reselection functionality [1], which is more expensive [4], a Treselection larger than 0 s is suggested. Accordingly, our recommendation comprises a Treselection setting of 1 s in combination with a hysteresis of 3 dB. This alternative choice results in a loss of ~1 dB in terms of camping cell quality, which could be avoided if intra-frequency and inter-RAT reselection functionalities were to use different Treselection timers.

D. Sintrasearch and Qqualmin

The measurement triggering threshold (i.e. $Qhyst_{2s}$ + $Qoffset_{2n}$) should be set such that measurements are triggered when the camping cell quality starts to deteriorate and a cell reselection is desirable. On the other hand, unnecessary measurements should be avoided because, depending on the UE implementation, they may have a negative impact on stand-by time[2]. In the previous simulation, this threshold was set to -10 dB. Here we compare four different threshold levels: -8 dB, -10 dB, -12 dB, and -14 dB. Two different combinations of Treselection vs. hysteresis are used: Treselection of 0 s in combination with 7 dB hysteresis, and Treselection of 1 s in combination with 3 dB hysteresis. A DRX cycle length of 1.28 s is set as well.

Simulation results are shown in Figure 6. Cell quality performance is maximized with a threshold of -8 dB or -10 dB. Threshold levels lower than -10 dB can be used to reduce the reselection rate, and thus to trade off camping cell quality vs. stand-by time.

The tradeoff in the choice of Qqualmin is between avoiding premature out of service declarations [1], and maintaining the minimum cell quality and strength that guarantees the desired call setup performance. Evaluating call setup performance is beyond the scope of this paper. In our simulations, we used Qqualmin = -18 dB.

VII. CONCLUSIONS

Table II shows our recommended set of parameters for intra-frequency reselection. A DRX cycle length of 1.28 s is preferred over a DRX cycle length of 0.64 s because it improves the stand-by time by ~25% without loss in camping cell quality. A Treselection of 1 s in combination with a hysteresis of 3 dB is recommended (at least until intra-frequency and inter-RAT reselection functionalities will share the same Treselection timer). The chosen measurement triggering threshold is -10 dB.

This parameter set works well in all scenarios and achieves a good compromise between camping cell quality and UE stand-by time. Alternative settings can be used to trade off stand-by time and cell quality in a different way. Simulation results also show how the cell reselection metrics depends on the specific scenario. To achieve the best performance, the parameters can be fine-tuned for a specific deployment scenario or, even more aggressively, on a per cell basis.

TABLE II. RECOMMENDED PARAMETER SET FOR INTRA-FREQUENCY CELL RESELECTION

System Parameter	*Engineering Value*
DRX cycle	1.28 s
Qqualmin	-18 dB
Sintrasearch	8 dB
$Qhyst_{2s}$	2 dB
$Qoffset_{2n}$	1 dB
Treselection	1 s

REFERENCES

[1] 3GPP TS 25.304, "User Equipment (UE) procedures in idle mode and procedures for cells reselection in connected mode", http://www.3gpp.org/

[2] 3GPP TS 25.215, "Physical layer – Measurements (FDD)", http://www.3gpp.org/

[3] S. Sarkar and E. Tiedemann, "cdma2000: Battery Life Improvements Techniques" Conference Proceedings, PIMRC, Sept. 2000

[4] A. Garavaglia, C. Brunner, D. Flore, M. Yang, F. Pica, "Inter-System Cell Reselection Parameter Optimization in UMTS" Submitted to PIMRC, Sept. 2005

[2] The standby time model presented previously does not depend on the intra-frequency measurement rate.

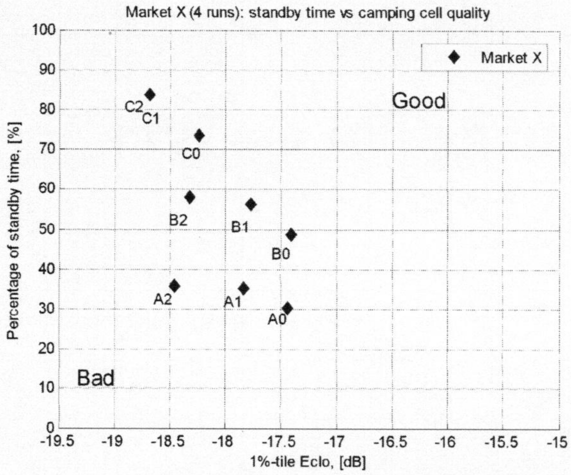

Figure 1. DRX cycles vs. Treselection for Market X.

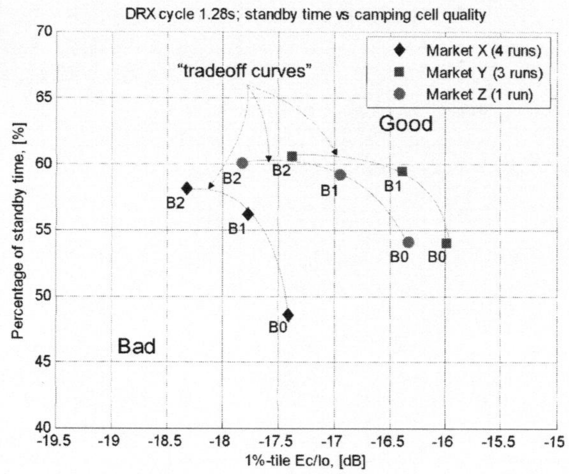

Figure 2. DRX cycle 1.28 s; all markets; different Treselection values.

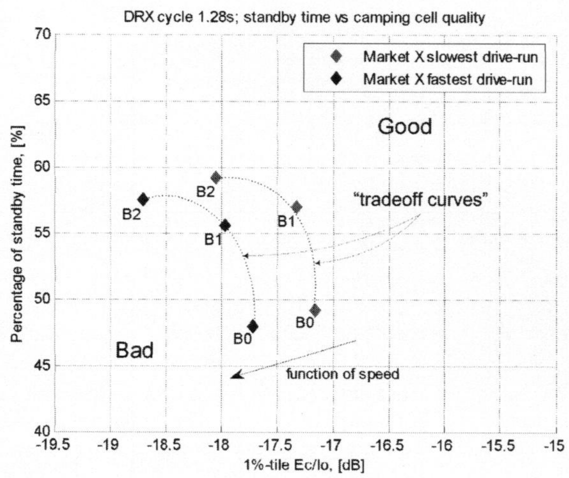

Figure 3. Highest speed run vs. lowest speed run for Market X.

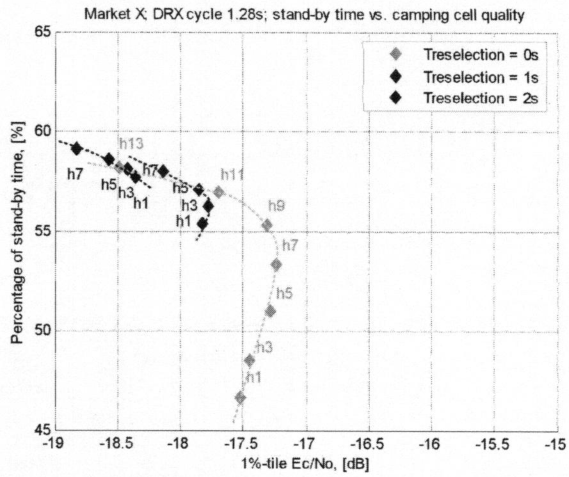

Figure 4. Treselection vs. hysteresis for Market X.

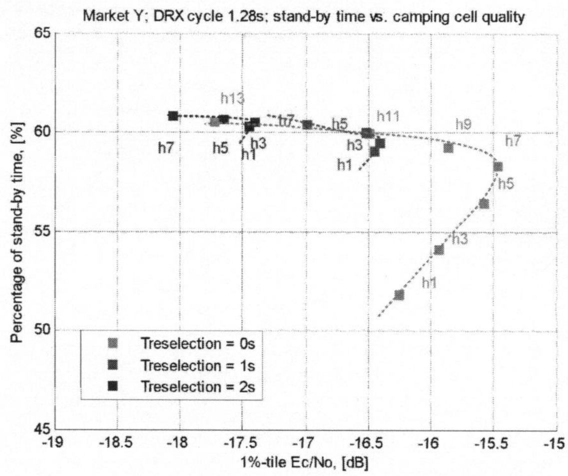

Figure 5. Treselection vs. hysteresis for Market Y.

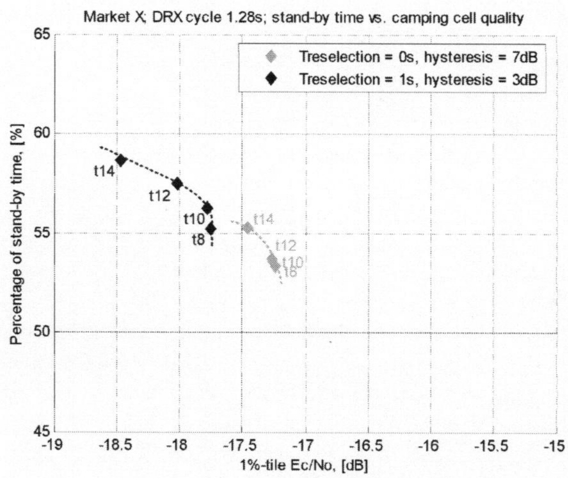

Figure 6. Measurement triggering threshold for Market X.