Inter-System Cell Reselection Parameter Optimization in UMTS

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Abstract—**With WCDMA networks being deployed in Europe and throughout the world, one of the big challenges is to make cell reselection and handover between GSM and WCDMA work smoothly. Inter-system cell reselection between WCDMA and GSM enables the user equipment in idle mode to choose a new cell of another system to camp on, thus providing service availability when WCDMA coverage fades out. In this paper, we study inter-system cell reselection parameter settings by processing field measurement data collected in different networks. Performance metrics (relating to service availability and WCDMA idle mode coverage) are computed with our simulation platform to evaluate different sets of parameters in WCDMA-network-boundary, coverage-hole, and entering-a-building scenarios. Based on the simulation results, we discuss optimization trade-offs and recommend a set of parameters for each scenario.**

I. Introduction

In WCDMA, the user equipment (UE) shall regularly search for a better cell to camp on according to the cell reselection criteria [1]. This mechanism, based on parameters provided by the network, is needed to camp on a good quality cell, and therefore achieve the desired call setup performance.

In a recent study [6], intra-frequency cell reselection parameter settings have been optimized for standby time and camping cell quality. Following the same approach, we focus on inter-system cell reselection in idle mode, required at the border of WCDMA coverage to provide seamless service availability to the UE by reselecting to GSM. To provide recommendations for inter-system cell reselection parameter settings, extensive channel measurements from the field have been processed with our simulation platform. Three scenarios were selected, where inter-system reselections are expected and which differ in radio frequency (RF) environment and in user mobility: a network-boundary scenario, a coverage-hole inside the WCDMA network and an entering-a-building scenario. Since the parameters involved in the cell reselection procedures are broadcast by the network and could be set on a per cell basis to enable a finer optimization of different scenarios, we look at the scenarios separately.

The paper is organized as follows. Section II provides an overview of the cell reselection mechanism and parameters. Field measurements are described in Section III while the simulation platform is introduced in Section IV. Performance metrics are described in Section V. In Section VI, we present simulation results for different scenarios which motivate scenario specific parameter recommendations. Conclusions are drawn in Section VII.

II. Inter-System Cell Reselection

A. WCDMA to GSM (W2G) cell reselection

As specified in [1], during idle mode operations, the UE operates in discontinuous reception (DRX) mode to improve its stand-by time, i.e. reacquiring the serving cell each DRX cycle. Depending on the measured serving cell quality *Qqualmeas*, the UE may trigger intra-frequency, inter-frequency, or inter-system measurements and evaluate the respective cell reselection criteria. In particular, inter-system measurements are triggered if

$$Qqualmeas < Qqualmin + SsearchRAT \quad (1)$$

or if the serving cell does not fulfill the cell selection suitability criterion for consecutive *Nserv* DRX cycles [2]. According to the standard [1], a WCDMA cell is suitable if

$$Srxlev > 0 \text{ and } Squal > 0 \quad (2)$$

TABLE I. WCDMA to GSM Cell Reselection Parameters and Measurement Quantities

Quantity	Description	Source
SsearchRAT	System specific threshold [dB]	broadcast
Qqualmin	Minimum cell quality [dB]	broadcast
Qrxlevmin	Minimum cell RX level [dBm]	broadcast
Pcomp	Power compensation [dB]	broadcast
$Qhyst_{1s}$	Serving cell *RSCP* hysteresis [dB]	broadcast
$Qoffset_{1n}$	Neighbor cell *RSCP* offset [dB]	broadcast
Treselection	Cell reselection timer [s]	broadcast
Qqualmeas	Common pilot channel (CPICH) *Ec/No* [dB]	measured
Qrxlevmeas	Common pilot channel (CPICH) *RSCP* [dBm]	measured
RLA	Received signal Level Averaged [dBm]	measured
Squal	*Qqualmeas – Qqualmin* [dB]	calculated
Srxlev	*Qrxlevmeas - Qrxlevmin – Pcomp* [dB]	calculated

When GSM cells are measured, the cell reselection criterion compares the CPICH *RSCP* of the WCDMA serving cell and monitored cells with the *RLA* of the GSM cells [2]. If a GSM cell is ranked higher than any WCDMA cell

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$$RLA - Qoffset_{1GSM} > Qrxlevmeas(\text{serving cell}) + Qhyst_{1s} \quad (3a)$$

$$RLA - Qoffset_{1GSM} > Qrxlevmeas(\text{monitored cells}) - Qoffset_{1n} \quad (3b)$$

for *Treselection* seconds, the UE reselects to that GSM cell.

B. GSM to WCDMA (G2W) cell reselection

During idle mode operations in GSM, WCDMA cells are measured when the *RLA* of the serving cell is lower (or higher, depending on the setting) than the parameter *Qsearch_I* [5]. If measurements are made, the reselection criterion is evaluated and the UE reselects to a suitable WCDMA cell if the following conditions hold for a period of 5 seconds [3-5]:

- the CPICH *RSCP* of the candidate WCDMA cell is at least *FDD_Qoffset* dB better than the *RLA* of the serving and of all suitable non-serving GSM cells
- the CPICH *Ec/No* of the candidate WCDMA cell is equal or greater than the parameter *FDD_Qmin*

TABLE II. GSM TWCDMA CELL RESELECTION PARAMETERS

Quantity	Description	Source
FDD_Qmin	Minimum CPICH *Ec/No* threshold [dB]	broadcast
Qsearch_I	WCDMA measurement threshold [dB]	broadcast
FDD_Qoffset	*RLA* offset for WCDMA ranking [dB]	broadcast

Although the above conditions may be fulfilled, the WCDMA cell might not meet the suitability criteria of equation (2) if the CPICH *RSCP* is too weak, thus causing the UE to return to GSM ("G2W-reject"). During a G2W-reject, a loss in service availability may occur (i.e. pages are not received nor is access possible during the time the UE attempts the reselection to WCDMA). If, on the other hand, the above conditions are fulfilled and a suitable WCDMA cell is found, the phone may return to GSM after a short time ("ping-pong"), also impacting service availability. In fact, each time an inter-system cell reselection takes place, the UE has to perform location area and routing area updates. These procedures can last several seconds and during this time the service will not be available.

The outlined cell reselection scheme is based on the 3GPP Release 99 standard. A fixed *RSCP* based threshold for G2W reselection has been added, as optional UE feature, to the standard [5] to mitigate some of the parameter setting constraints. Because most UEs in the market do not implement it, this feature is not considered in the sequel.

III. FIELD MEASUREMENTS

For the purpose of this study, field measurements have been collected in three different inter-system handover scenarios in commercial UMTS networks in Europe. The networks were lightly loaded and characterized by a low base station density. Both factors lead to higher *Ec/No* measurements for any given *RSCP* and vice versa. The network-boundary scenario is characterized by the loss of WCDMA coverage when leaving the WCDMA region. The coverage-hole scenario represents areas inside the WCDMA region that are subject to bad outdoor WCDMA coverage. The entering-a-building scenario implies bad indoor WCDMA coverage within a WCDMA area.

For each scenario, several runs along a metric route selected to best characterize the specific deployment scenario have been made to collect measurements. Table III classifies the scenarios in terms of RF environment and mobility.

TABLE III. CLASSIFICATION OF MEASURED DATA

Scenario	RF environment and mobility
Network-Boundary	• WCDMA coverage with high *Ec/No* for a given *RSCP* (fewer base stations at boundary to cause interference: less interference) • Gradual fading of WCDMA signal strength when moving into GSM only coverage • Sub-urban area, Vehicular channel, average speed of 20 km/h • Dominant pilot in WCDMA coverage • Measurements for the G2W direction are obtained by reversing the time axis (see Section IV)
Coverage-Hole	• WCDMA coverage with low *Ec/No* for a given *RSCP* (base stations all around: more interference) • Urban environment, Vehicular channel, average speed of 25 km/h with large speed variations between runs • Measurements are collected while crossing the hole area in both forward and reverse directions
Entering-a-building	• WCDMA coverage with medium *Ec/No* for a given *RSCP* (base stations all around but UE is closer to one: medium level of interference) • Entering and walking down a large indoor corridor of a large commercial building • Abrupt decrease in WCDMA signal strength when moving from WCDMA into GSM only coverage • Dominant pilot in WCDMA coverage, Pedestrian channel, average speed of 3 km/h • Measurements from indoor (GSM) to outdoor (WCDMA) are obtained by reversing the time axis (see Section IV)

IV. SIMULATION PLATFORM

Our simulation platform imports channel measurement data from a test phone. A standard compliant UE performing intra-frequency and inter-system cell reselection is emulated and the output is aligned with the real UE performance.

Only WCDMA channel measurements are imported, while we assume a constant good coverage with an *RLA* of -75 dBm for the GSM system. Moreover, we do not model different GSM cells. As a consequence, cell reselections within the GSM system, which may delay G2W reselection, are not modeled either. The impact on the results should be very limited due to the larger size of GSM cells in the 900 MHz band and due to the fact that only a limited portion of the metric route is recorded outside of WCDMA coverage.

Intra-system cell reselections and bad RF conditions can potentially delay the completion of the location area and routing area update procedures. For simplicity, we assume a constant delay obtained by averaging the values extracted from the field data.

The features listed below significantly reduce the amount of drive testing required for sufficient statistics (conventionally, performance metrics are collected once every DRX cycle directly from the UE):

- Channel measurements are logged at a much higher rate than one sample per DRX cycle. By shifting the starting point by a few milliseconds (i.e. longer than the channel coherence time) and sampling once per DRX cycle, we gain many realizations of the measured multi-path channel from one measurement run.
- Different parameter settings can be evaluated based on the same field data.
- The time axis of the field data can be reversed to emulate an identical measurement run in opposite direction. This facilitates a side-by-side comparison between the G2W and W2G cell reselection schemes.

V. Performance Metrics

The two primary metrics we want to consider are the WCDMA idle mode coverage and the service availability.

The WCDMA idle mode coverage corresponds to the percentage of the route the UE is camped on WCDMA cells. A large WCDMA coverage is desirable (consistently aligned in idle and connected mode) to e.g. make new UMTS services widely available.

Concerning the WCDMA service availability, we make use of the following indirect metrics:

- Lower 1%-tile of the WCDMA camping cell *Ec/No* and *RSCP* collected over the metric route. Low *Ec/No* and *RSCP* may lead to missed paging occasions and access failures, respectively.
- Inter-system cell reselections and G2W-rejects impact service availability since neither paging nor access work for the duration of both procedures (several seconds).

Finally, we count the W2G reselection trigger causes, i.e. unsuitability defined in (2) and measurement rules defined in (1). These indicate which parameters play a significant role in different loading conditions and RF environments.

VI. Simulation Results

Since the measurement data was collected in low site density networks under light load (cf. Section III), W2G reselections are more frequently triggered by unsuitability due to low *RSCP* rather than by the measurement rules. Accordingly, the parameter *Qrxlevmin* is the main driver for the W2G reselection while *Qqualmin* only plays a secondary role. Favoring WCDMA, the parameters *Qsearch_I* and *FDD_Qoffset* have been set such that WCDMA cells are always measured and reselected as soon as they meet the quality criteria. As a consequence, the G2W reselection is mainly driven by the parameter *FDD_Qmin*. As indicated in Table IV, *Qrxlevmin* settings of -115, -113, and -111 dBm are tested together with *FDD_Qmin* settings of -12, -10, and -8 dB.

TABLE IV. Parameter Set For Inter-System Cell Reselection

Parameter	Setting	Comments
Qrxlevmin	-115, -113, -111 [dBm]	In this RF, main driver for W2G reselection
SsearchRAT+ Qqualmin	-14 [dB]	To avoid ping pong: *FDD_Qmin* > *SsearchRAT+ Qqualmin*
Qqualmin	-18 [dB]	In this RF, secondary driver for W2G reselection
$Qoffset_{1n}+Qhyst_{1s}$	3 [dB]	Equation (3) is generally fulfilled
Treselection	1 [s]	Common to intra-frequency cell reselection
FDD_Qmin	-12, -10, -8 [dB]	Drives G2W cell reselection
Qsearch_I	Always measure W	To prioritize WCDMA
FDD_Qoffset	-infinite	To prioritize WCDMA

A. Network-Boundary Scenario

In the network-boundary scenario, the route starts in good and ends in poor WCDMA coverage, while the GSM coverage remains strong all the way. Here, "WG→G" denotes the direction in which WCDMA coverage deteriorates and "G→WG" the reverse direction. As indicated in Figure 1, the WCDMA quality and strength are low in WG→G direction. In G→WG direction, the WCDMA quality is better because of the high *FDD_Qmin* settings, which have to be exceeded for 5s before reselecting to WCDMA. The downside is that the UE stays in GSM longer (cf. Figure 3). Figure 2 shows that a high *FDD_Qmin* is the most effective way to reduce inter-system reselections and G2W-rejects, thus improving service availability at the expense of a slight reduction in WCDMA idle mode coverage. A decrease in *Qrxlevmin* increases the number of inter-system cell reselections in G→WG direction because of fewer G2W-rejects, and decreases the serving cell strength. Therefore, we recommend *Qrxlevmin* = -111 dBm and *FDD_Qmin* = -8 dB. Figure 3 indicates that in WG→G direction most reselections are triggered by unsuitability due to low *RSCP*. In G→WG direction, W2G reselections (statistically insignificant) are neither caused by unsuitability nor by measurement rules but by missing channel measurements.

B. Coverage-Hole Scenario

In the coverage-hole scenario, the route starts and ends in points with good WCDMA coverage, denoted by A and B, while crossing an area with poor WCDMA coverage. Here, we use different channel measurements in A→B and B→A directions instead of reversing the time-axis, and results are provided for both directions. As indicated in Table III, due to the high interference, *Ec/No* is low for a given *RSCP*. Accordingly, W2G reselections triggered by the measurement rules are more significant (cf. Figure 6). Because of the relatively high *RSCP* levels corresponding to a certain *Ec/No* (cf. Figure 4), it is possible to use a low *Qrxlevmin* setting to effectively reduce inter-system reselections and G2W-rejects and to increase the WCDMA idle mode coverage. Therefore, a *Qrxlevmin* setting of -115 dBm is recommended. We also recommend a low setting of *FDD_Qmin* (-12 dB) to increase the WCDMA idle

mode coverage at the expense of a tolerable reduction in serving cell quality.

C. *Entering-A-Building Scenario*

In the entering-a-building scenario, the results are given for WG→G (i.e. entering the building) and G→WG directions (i.e. exiting the building) along the same route. The scenario is similar to the network-boundary case. In both cases, inter-system reselection is not avoidable. Due to RF, the WCDMA signal deteriorates more abruptly here but pedestrian user velocity compensates for the quick drop. As indicated in Figure 7, a medium interference level and *Ec/No* values can be observed, due to one dominant pilot and several nearby cells. The tail of the *RSCP* distribution is relatively low on the WG→G direction especially for low *Qrxlevmin* settings. Therefore, as in the network-boundary scenario, a *Qrxlevmin* of -111dBm is recommended. Figure 8 indicates that a high *FDD_Qmin* is most effective in reducing inter-system reselections and G2W-rejects while maximizing the service availability. In addition, a high *FDD_Qmin* = -8 dB improves the tail of the *RSCP* distribution at the expense of a slight reduction in WCDMA idle mode coverage, especially in indoor areas. As in the network-boundary scenario, most reselections in WG→G direction are triggered by unsuitability (cf. Figure 9). Note that a stationary indoor UE close to a site may experience high *Ec/Io* values for low *RSCP* and may require an even higher *FDD_Qmin* to avoid frequent G2W-rejects.

VII. CONCLUSIONS

We have introduced a concept to generate cell reselection parameter recommendations that significantly reduces the amount of driving test required otherwise. Then we applied this approach to different scenarios. Simulations show that the combination of *Qrxlevmin* = -115dBm and *FDD_Qmin* = -12dB works well in the coverage-hole scenario, while *Qrxlevmin*=-111dBm and *FDD_Qmin* = -8dB performs well in both network boundary and entering-a-building scenarios.

If parameters can not be set on a cell basis, the best compromise would be to apply the most convenient settings considering the entire RNC area (e.g. figuring out which scenarios and environments would be the most representative and strategic for that area).

When load increases, a further tuning of the above settings is necessary to optimize the performance with higher interference levels. Finally, connected mode parameters shall be considered for consistency with idle mode parameters.

REFERENCES

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[5] 3GPP TS 05.08," Radio subsystem link control"

[6] D. Flore, C. Brunner, F. Grilli, V. Vanghi, "Cell Reselection Parameter Optimization in UMTS", submitted to ISWCS 2005

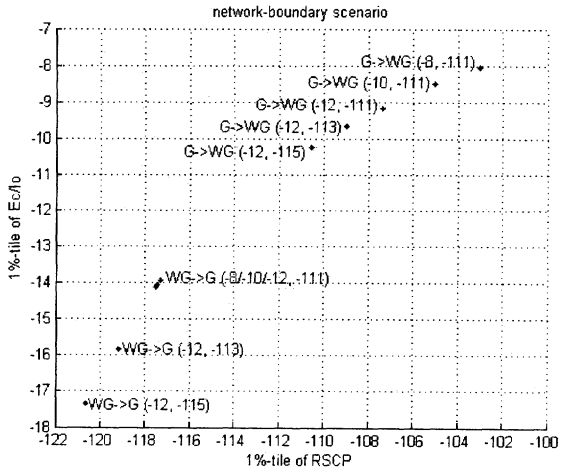

Figure 1: WCDMA serving cell quality in dB versus strength in dBm

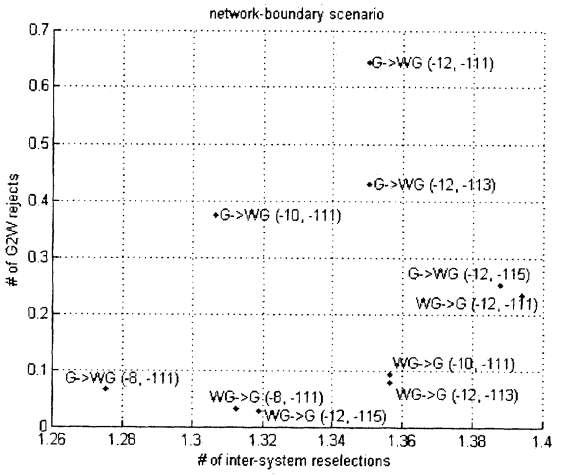

Figure 2: Number of G2W-rejects versus number of inter-system cell reselections

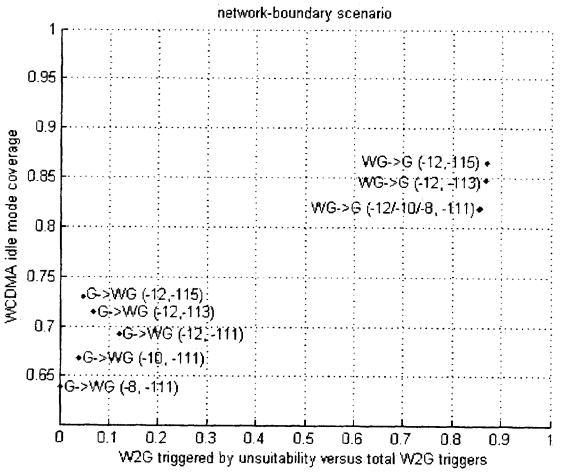

Figure 3: WCDMA idle mode coverage in percent versus W2G triggered by unsuitability relative to all W2G triggers

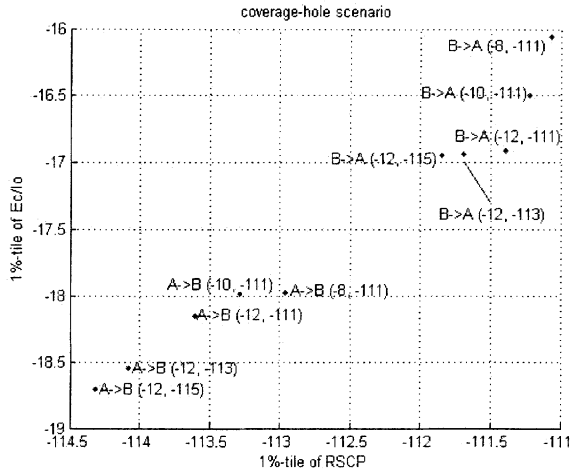

Figure 4: WCDMA serving cell quality in dB versus strength in dBm

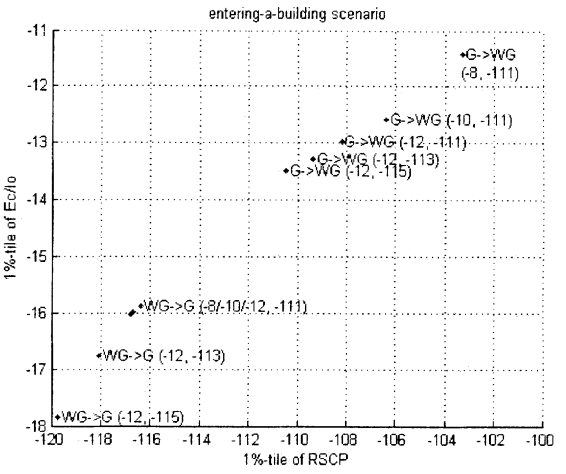

Figure 7: WCDMA serving cell quality in dB versus strength in dBm

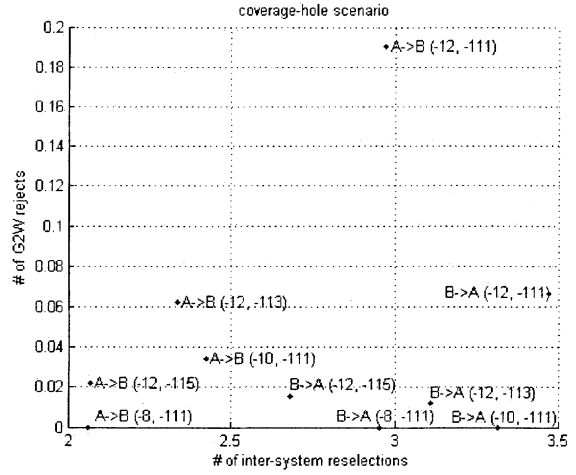

Figure 5: Number of G2W-rejects versus number of inter-system cell reselections

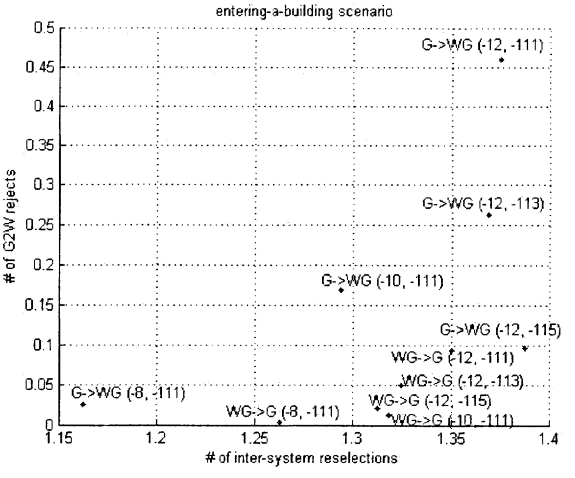

Figure 8: Number of G2W-rejects versus number of inter-system cell reselections

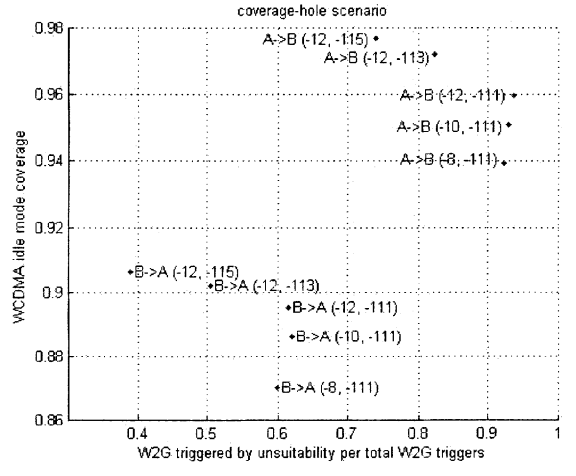

Figure 6: WCDMA idle mode coverage in percent versus W2G triggered by unsuitability relative to all W2G triggers

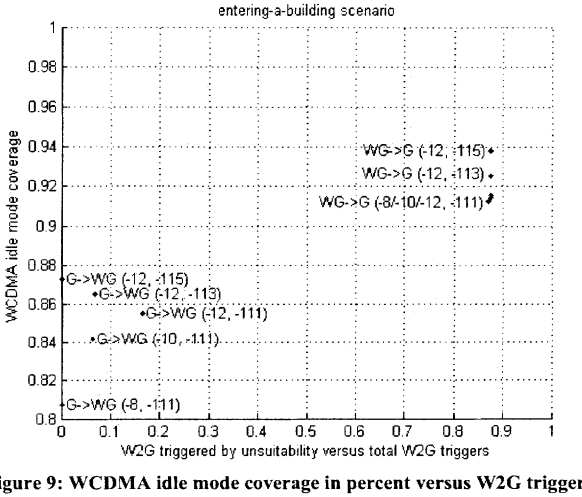

Figure 9: WCDMA idle mode coverage in percent versus W2G triggered by unsuitability relative to all W2G triggers