3GPP TSG-RAN WG4 meeting #52 **R4-093169**
Shenzhen, P. R. China, 24 – 28 August, 2009

Agenda item: **8.2**

Source: **Nokia, Nokia Siemens networks**

Title: **Further evaluation of methods to handle non-allowed CSG cells in LTE**

Document for: **Discussion**

1. Introduction

In previous meetings the issue related to mixed carrier deployment of CS cells has been considered [1],[2]. This issue has been raised also in RAN2, which has sent an LS to RAN4 [3] asking WG4 view on the issue. This issue was discussed in RAN4 meeting #51bis and RAN4 send a response LS to RAN2, indentifying that RAN4 will still continue discussing certain open issues. A contribution [6] examining the performance of different options of handling the interference issues in mixed carrier CSG deployments and non-allowed cells was submitted to RAN4 meeting #51bis. In this contribution we continue to evaluate the performance of different options for handling the interference issues related to mixed carrier CSG deployments. We have evaluated additional re-selection algorithm proposed in [7] and also evaluated different load conditions.

2. System simulation assumptions

This study has been performed using a fully dynamic time driven system simulator which simulates UL and DL directions simultaneously with a symbol resolution. We have used RSRP measurements for evaluating the best cell and for making the actual cell selection and cell reselection decisions. In the simulations the UE makes RSRP measurements with predefined period ("measurement interval"). The collected measurement results are then non-coherently averaged over a predefined sliding window ("measurement period"). It is also assumed that cells are automatically detected by UE, thus no cell search procedure is modelled.

These studies have been done in a combined macro-CSG scenario with two frequency layers presented in Figure 1. Both frequency layers have co-located macro cells and there are CSG cells only on the higher priority layer. All users are located inside an active macro area, which is situated in the middle of three sites with total of 6 macro cells (area border indicated with dotted line in Figure 1). Users are able to connect only to the grey cells indicated in the figure. The surrounding white macro cells are interferers, i.e. they only create same kind of interference as middle 6 cells and a UE cannot do cell selection or reselection to them.

Inside the active macro area there are 37 buildings having uniform separation to their neighbouring buildings. UEs created to the surrounding macro area can enter to the buildings and exit from them. The layout of each building is depicted in Figure 2. The building walls do not restrict users' mobility but they do affect the signal propagation. A CSG cell with isotropic antenna is created in the middle of each building. The macro and CSG parameters are presented in Table 1 in annex.

In the simulations both CSG and macro network loads are varied to see the performance of each algorithm in different kind of conditions in the network. Although these simulations are used to evaluate idle mode performance, all UEs are sending one packet per 10 seconds to have an estimate for the Signal-to-Interference-and-Noise-Ratio (SINR) UE would have in downlink when starting a call.

Four different inter-frequency handover algorithms are simulated and compared to each others. The algorithms are presented in the next sub-sections. When compared to the previous contribution [6], only the algorithm 4 (based on proposal in [7]) is a new one and the others are the same ones used earlier.

2.1 Reselection algorithm 1 (RSRP)

RSRP based cell selections and reselections are done according to following criteria (the normal Rel'8 reselection criteria):

1. If UE is camped to a lower priority layer cell and there is another cell that is better than absolute threshold ($S_{nonServingCell,x} > Thresh_{x,high}$) on highest priority frequency layer, UE performs a cell reselection to that cell
2. If another cell is $Qhyst_s$ better than serving cell on the current frequency layer, perform reselection
3. If UE is camped to a higher priotity frequency layer cell and serving cell is worse than absolute threshold ($S_{ServingCell} < Thresh_{serving,low}$) and another cell is better than another absolute threshold ($S_{nonServingCell,x} > Thresh_{x,low}$) on a lower priority frequency layer cell, perform reselection to lower priority frequency layer cell

2.2 Reselection algorithm 2 ("Old" RSRP and RSRQ)

RSRP and RSRQ based cell selections and reselections are done according to following criteria (based on criteria proposed in [2]):

1. If UE is camped to a lower priority layer cell and there is another cell that is better than absolute threshold ($S_{nonServingCell,x} > Thresh_{x,high}$ AND $RSRQ_{nonServingCell,x} > Q_{qualmin}$) on highest priority frequency layer, UE performs a cell reselection to that cell
2. If another cell is $Qhyst_s$ better than serving cell on the current frequency layer, perform reselection
3. If UE is camped to a higher priority frequency layer cell and
    a. serving cell is worse than absolute threshold ($S_{ServingCell} < Q_{qualmin}$) and another cell is better than another absolute threshold ($S_{nonServingCell,x} > Thresh_{x,low}$) on a lower priority frequency layer cell OR
    b. serving cell is worse than absolute threshold ($RSRQ_{ServingCell} < Q_{qualmin}$) and another cell is better than another absolute threshold ($RSRQ_{nonServingCell,x} > Q_{qualmin}$) on a lower priority frequency layer cell perform reselection to lower frequency layer cell

2.3 Reselection algorithm 3 (RSRP and barring)

RSRP and barring based cell selections and reselections are done according to the following criteria (same as Rel'8 but added barring criterion):

1. If UE is camped to a lower priority layer cell and there is another cell that is better than absolute threshold ($S_{nonServingCell,x} > Thresh_{x,high}$) on highest priority frequency layer, UE performs a cell reselection to that cell
2. If another cell is $Qhyst_s$ better than serving cell on the current frequency layer, perform reselection
3. If UE is camped to a higher priority frequency layer cell and serving cell is worse than absolute threshold ($S_{ServingCell} < Thresh_{serving,low}$) and another cell is better than another absolute threshold ($S_{nonServingCell,x} > Thresh_{x,low}$) on a lower frequency layer cell, perform reselection to lower priority frequency layer cell
4. If the UE is camped on the highest priority frequency layer, and the cell with the strongest RSRP is a non-allowed CSG cell, then move to the lower priority layer and bar the highest priority frequency layer for T_{barred}=300 seconds.

2.3 Reselection algorithm 4 ("New" RSRP and RSRQ)

This algorithm is a combination of first (RSRP) and second ("Old" RSRP and RSRQ) (based on criteria proposed in [7]):

1. When the cell with strongest RSRP is a non-allowed CSG cell, reselection algorithm 2 is used.
2. When the cell with strongest RSRP is **not** a non-allowed CSG cell, reselection algorithm 1 is used.

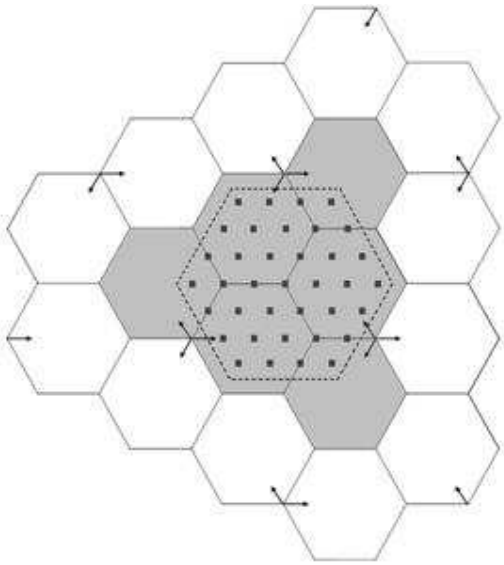


Figure 1. Simulation scenario

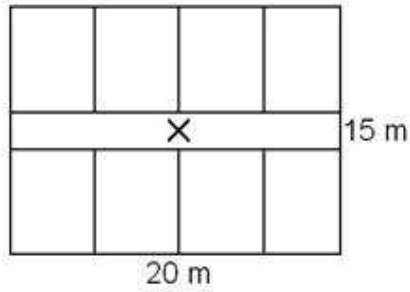


Figure 2 Building layout

3. Simulation results

In this section we present the simulation results for the scenario described in previous section.

Two different transmission power levels were used for CSG cells, 8 dBm and 20 dBm. Also two different CSG cell load conditions were considered; constant load with 100% utilisation and varying load with average 50% resource utilization. For macro network resource utilization, four different load conditions were used: constant 25%, 50% and 100% loads and variable load.

3.1 Initial threshold setting

To enable some level of comparability, an attempt was made to select the RSRP and RSRQ thresholds with reasonable values suited to the scenario under evaluation. For the results shown in this section the CSG cell power level of 8dBm or 20dBm was used with either constant 100% or varying load (with average 50% resource utilization).

In [6] we evaluated different RSRP and RSRQ thresholds were evaluated to identify suitable setting for the further analyses. In this contribution we evaluated further the RSRQ thresholds assuming RSRP threshold of -109dBm. In [6] the RSRP level of -109dBm was found to give worst SNIR results in mixed layer, but to minimize the number of reselections. As the difference in terms of observed SNIR was rather small between the different RSRP levels, and in case of two equal coverage layers it would seem most relevant to keep the number of re-selections low, it was chosen to use lowest RSRP threshold of -109 dBm.

Figure 3 and Figure 4 show the SNIR levels from whole simulated scenario for CSG cell power levels of 8dBm and 20dBm with constant CSG load assuming different RSRQ thresholds. Similar curves for varying load are shown in Figure 5 and Figure 6. Furthermore, Figure 7**Error! Reference source not found.** and Figure 8**Error! Reference source not found.** show the amount of inter-frequency reselections between the frequency layers when different RSRQ thresholds are also applied (i.e. using the reselection algorithm in section 2.2.). It can be seen that RSRQ threshold -7dB provides the best SNR distribution and that -9dB threshold comparable in most scenarios. Higher or lower thresholds result worse SNR distribution. As these two thresholds result the highest amount of re-selections, it was decided to use

also threshold of -11dBm in further evaluations. It gives somewhat worse SNR distribution, but results lower amount of inter-frequency reselections.

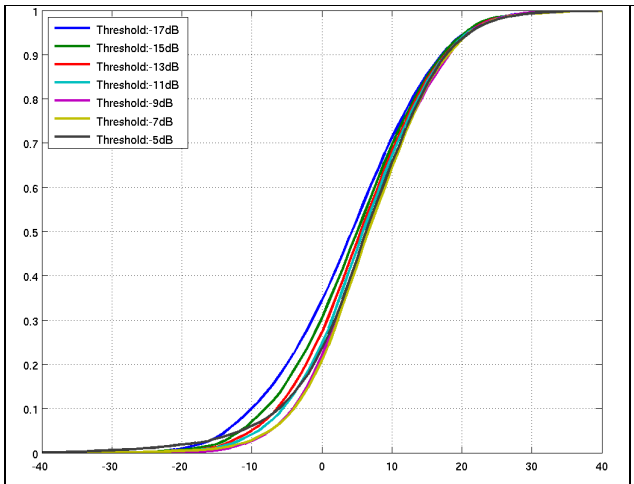


Figure 3. SNIR CDF on both layers with different RSRQ thresholds (Constant CSG Load and 8dBm TxP)

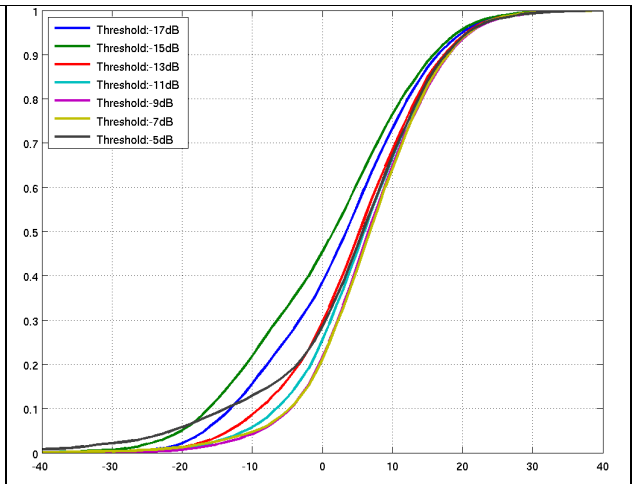


Figure 4. SNIR CDF on both layers with different RSRQ thresholds (Constant CSG Load and 20dBm TxP)

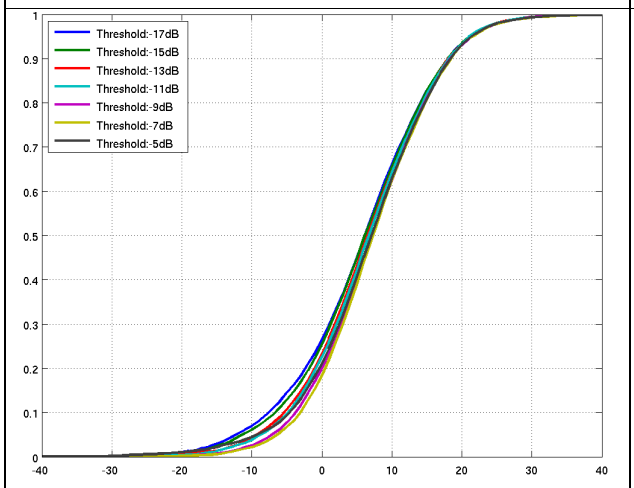


Figure 5. SNIR CDF on both layers with different RSRQ thresholds (Variable CSG Load and 8dBm TxP)

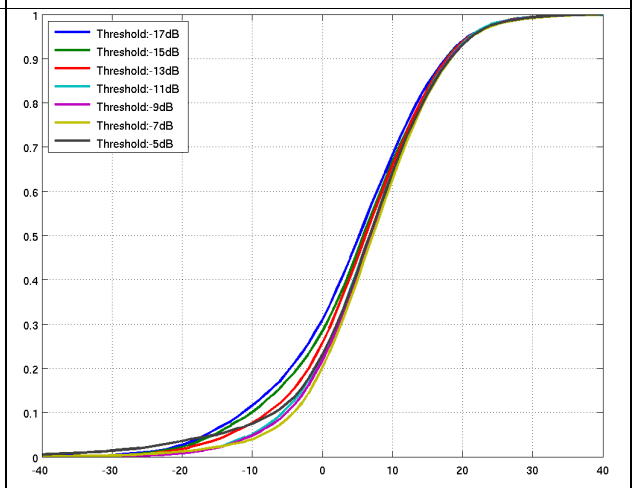


Figure 6. SNIR CDF on both layers with different RSRQ thresholds (Variable CSG Load and 20dBm TxP)

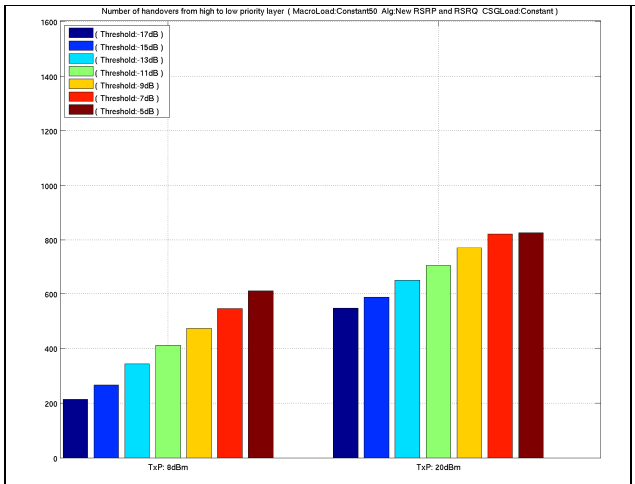


Figure 7. Number of reselections from high to lower priority layer based on RSRQ (Constant CSG Load)

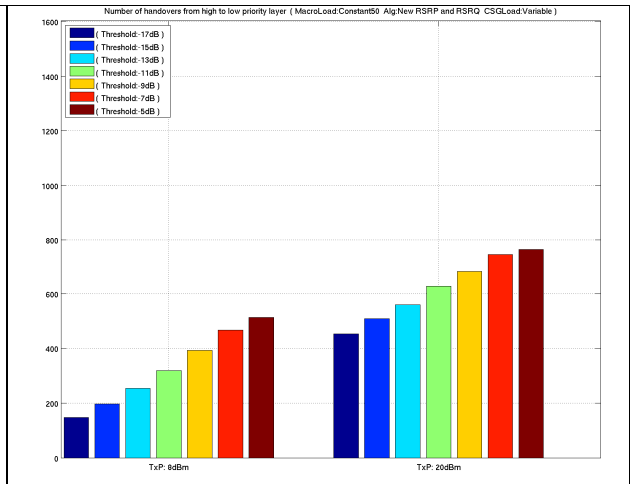


Figure 8. Number of reselections from high to lower priority layer based on RSRQ (Variable CSG Load)

3.2 Comparison of different schemes at constant CSG cell load

In this section we evaluate the performance of four different schemes in the scenario described in section 2. The RSRP threshold only case together with RSRP and RSRQ threshold case is compared to RSRP together with barring similarly as in [6]. Also the modified algorithm proposed in [7] has been evaluated. Different load conditions for macro cells has been assumed. This evaluation is done with several different RSRQ thresholds to account the feedback received in last meeting.

Figure 9 to Figure 14 show the SNIR distribution for all the evaluated algorithms and thresholds with different macro cell loads when CSG cell load is constant (100%) and transmission power either 8dBm or 20dBm. For non-barring based algorithms (e.g. algorithms 1, 2 and 4) lower threshold results lower SNR distribution. The SNIR distributions also become worse as macro cell load is increased, and the difference between different thresholds is reduced for RSRQ based algorithms. The SNIR distribution only for the higher layer is shown at Figure 15 to Figure 20. The amount of observed re-selections from higher priority to lower priority frequency layer are shown in Figure 21 to Figure 23[1]**Error! Reference source not found.Error! Reference source not found.**. It can be seen that lower threshold results fewer reselections for each of the re-selection algorithms as expected.

When comparing the RSRQ based algorithms, e.g. one using RSRQ always (Alg. 2) to one using it only when CSG cell is strongest (Alg. 4), some improvement can be seen in SNR distribution with Algorithm 4 when macro load is small (25%). However the performance is always worse than the RSRP with barring. Based on these curves it can be seen that the algorithm 4 e.g. RSRP with barring gives the best performance in terms of SNR with all loading configurations and CSG transmission powers.

[1] Please note that the bar for RSRP only algorithm with -109dBm is not visible as it is practically zero.

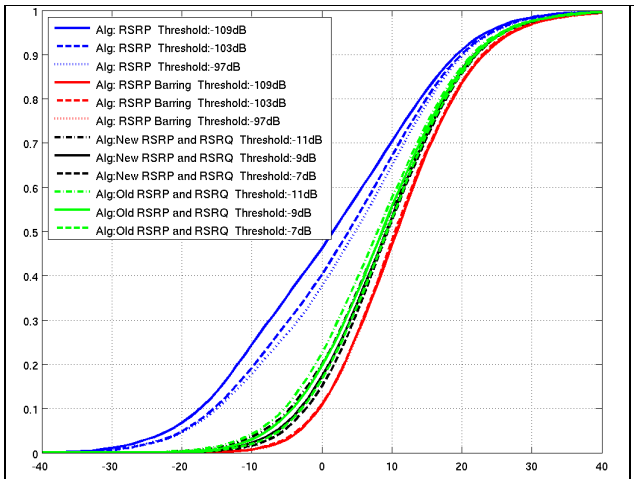


Figure 9. All SINRs (Macro load: constant 25%, CSG load: constant 100%, CSG TxP 8dBm)

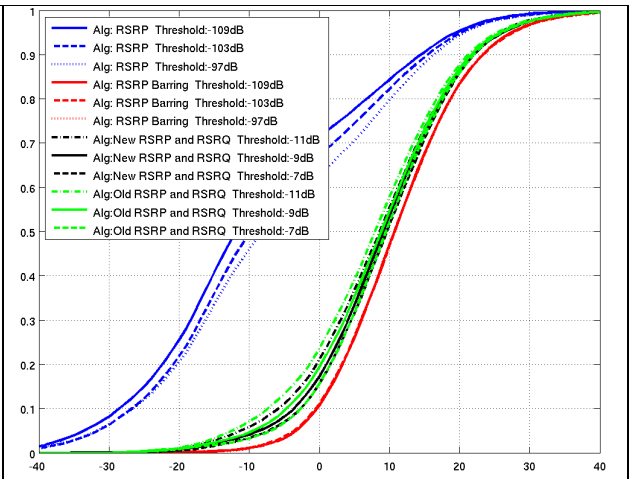


Figure 10. All SINRs (Macro load: constant 25%, CSG load: constant 100%, CSG TxP 20dBm)

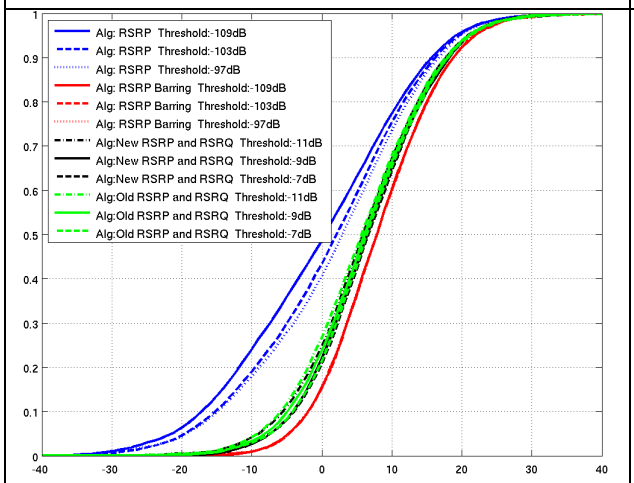


Figure 11. All SINRs (Macro load: constant 50%, CSG load: constant 100%, CSG TxP 8dBm)

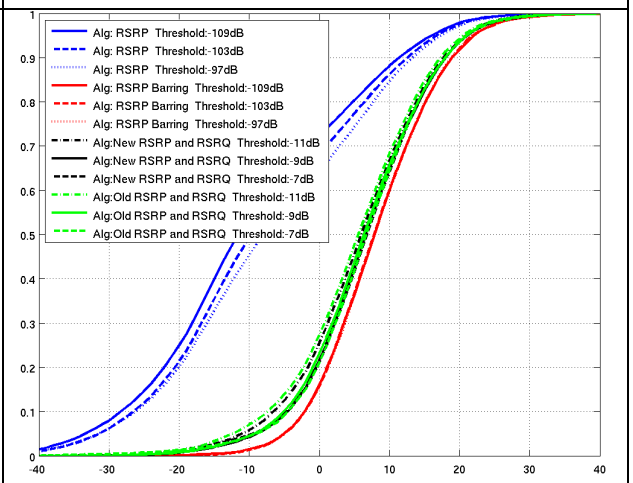


Figure 12. All SINRs (Macro load: constant 50%, CSG load: constant 100%, CSG TxP 20dBm)

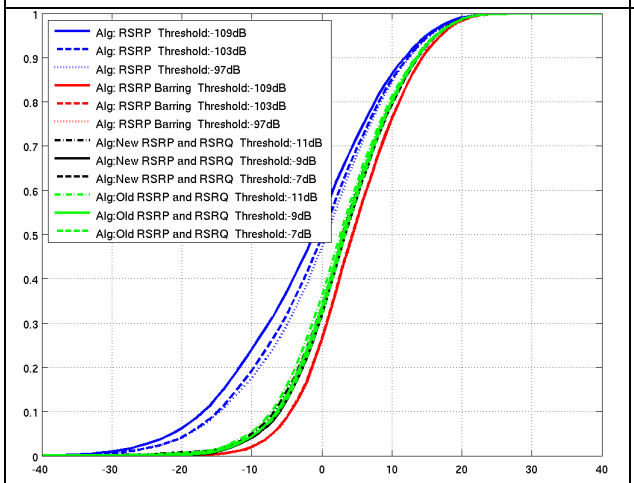


Figure 13. All SINRs (Macro load: constant 100%, CSG load: constant 100%, CSG TxP 8dBm)

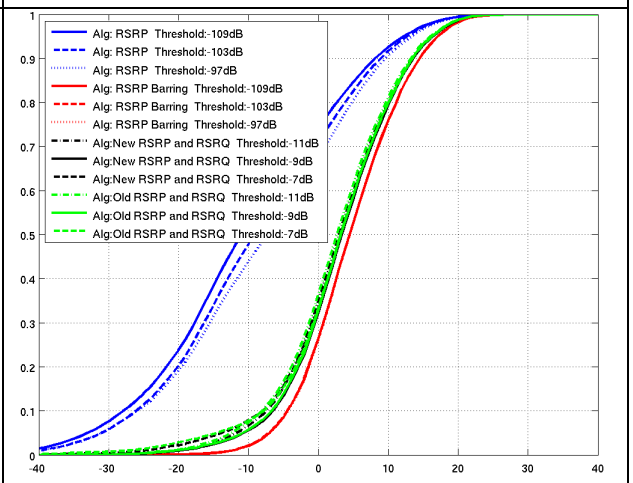


Figure 14. All SINRs (Macro load: constant 100%, CSG load: constant 100%, CSG TxP 20dBm)

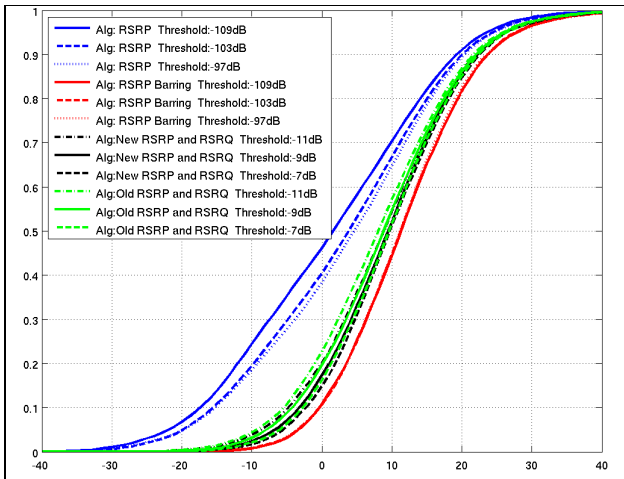


Figure 15. High prio. net. SINRs (Macro load: constant 25%, CSG load: constant 100%, CSG TxP 8dBm)

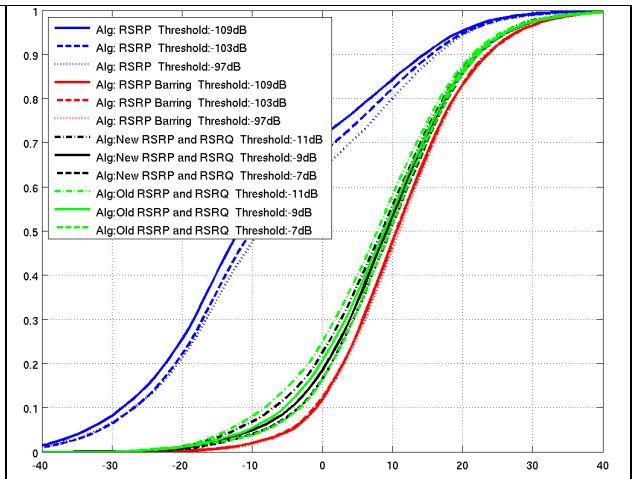


Figure 16. High prio. net. SINRs (Macro load: constant 25%, CSG load: constant 100%, CSG TxP 20dBm)

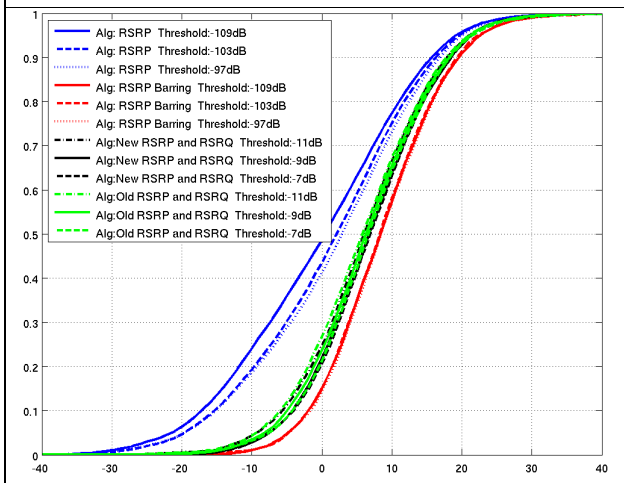


Figure 17. High prio. net. SINRs (Macro load: constant 50%, CSG load: constant 100%, CSG TxP 8dBm)

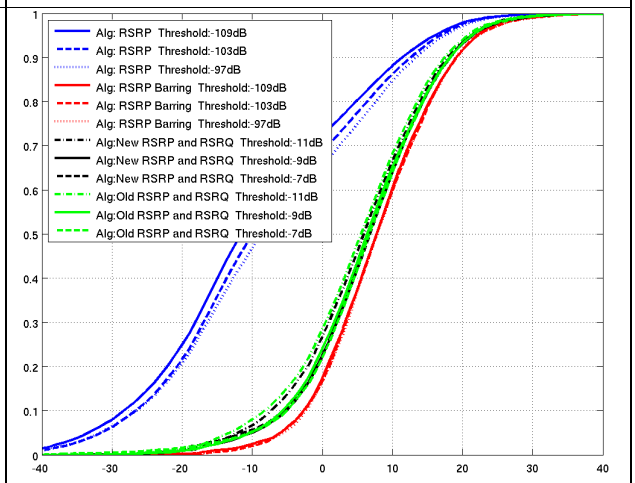


Figure 18. High prio. net. SINRs (Macro load: constant 50%, CSG load: constant 100%, CSG TxP 20dBm)

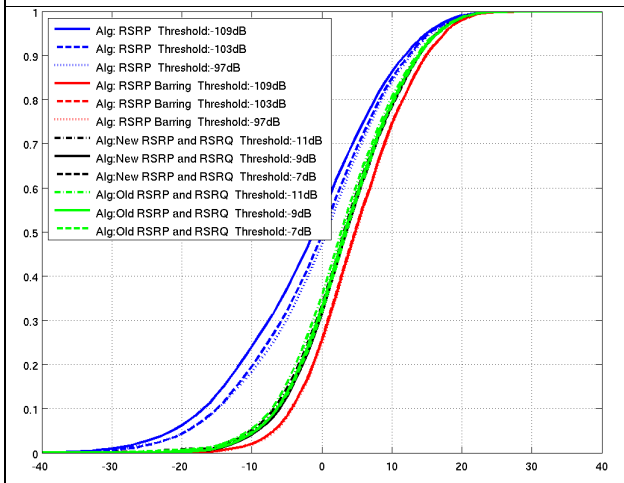


Figure 19. High prio. net. SINRs (Macro load: constant 100%, CSG load: constant 100%, CSG TxP 8dBm)

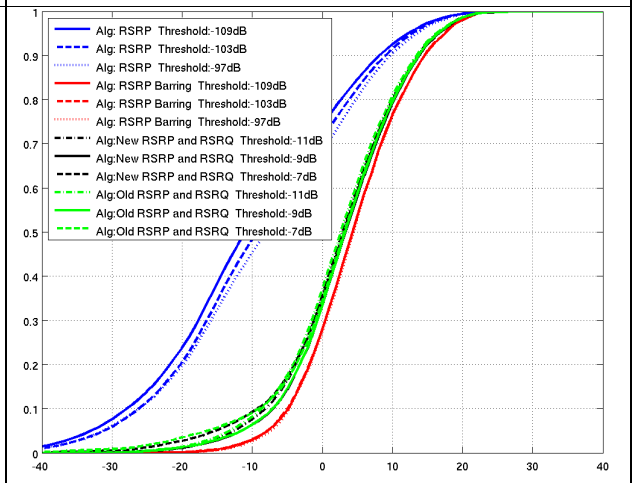


Figure 20. High prio. net. SINRs (Macro load: constant 100%, CSG load: constant 100%, CSG TxP 20dBm)

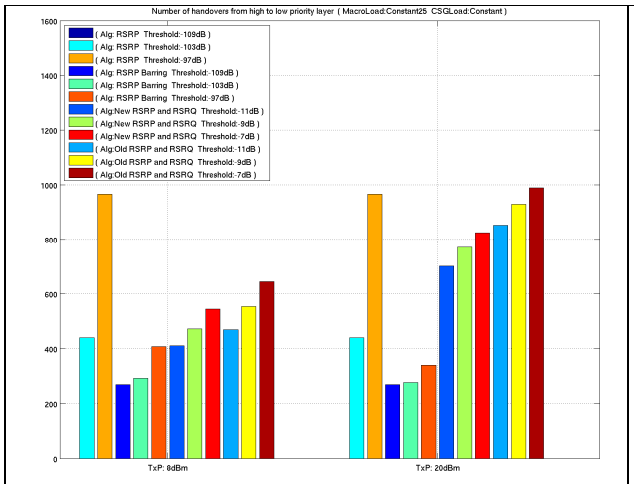


Figure 21 Number of reselections from high to low priority layer (Macro load: constant 25%, CSG load: constant 100%)

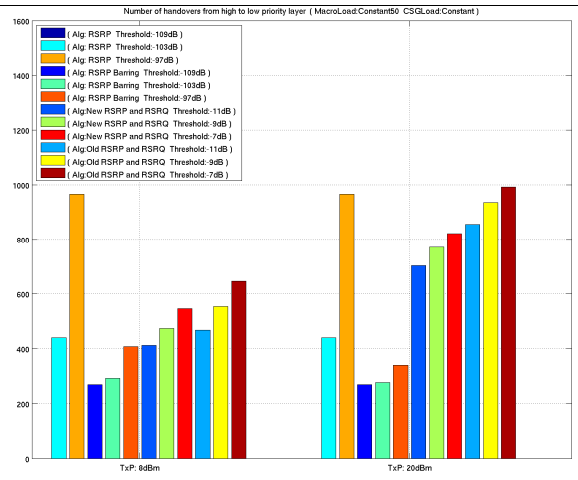


Figure 22 Number of reselections from high to low priority layer (Macro load: constant 50%, CSG load: constant 100%)

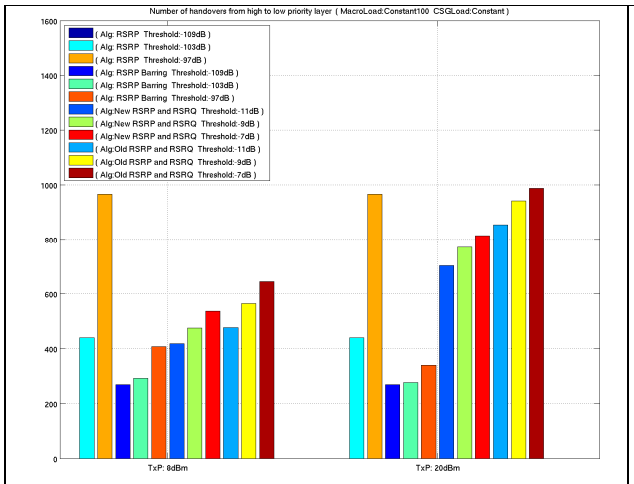


Figure 23 Number of reselections from high to low priority layer (Macro load: constant 100%, CSG load: constant 100%)

3.3 Comparison of different schemes at varying CSG cell load

In this section we evaluate the performance of the aforementioned re-selection algorithms in the scenario described in section 2 with varying CSG load. As in Section 3.2 different load conditions for macro cells have been assumed while also looking different thresholds for the RSRQ based algorithms.

Figure 24 to Figure 29 show the SNR distributions for the algorithms with different macro loads. Similar impact due to the macro cell load can be seen also for the variable CSG load cases as in constant load. Distributions for only the higher priority layer are shown in Figure 30 to Figure 35 Amount of the inter-frequency re-selections from higher priority layer to lower priority frequency layer are shown in Figure 36 to Figure 38[1].

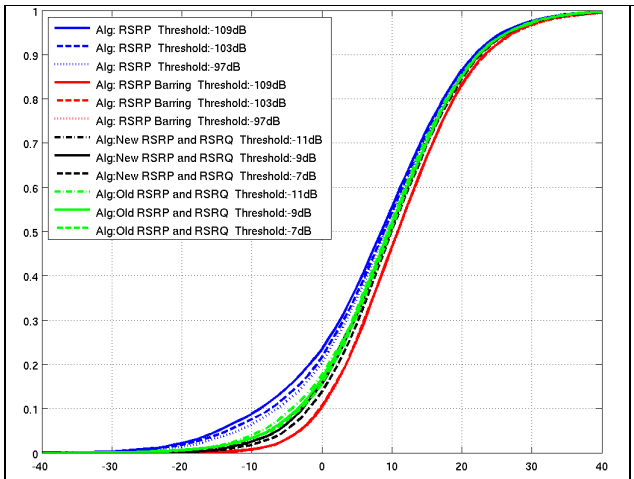


Figure 24. All SINRs (Macro load: constant 25%, CSG load: variable, CSG TxP 8dBm)

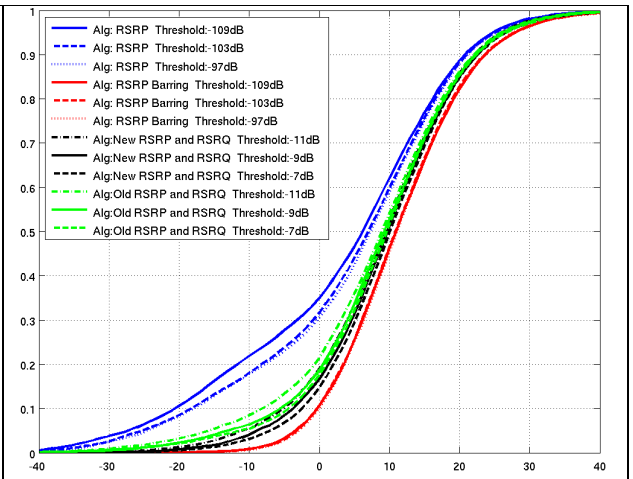


Figure 25. All SINRs (Macro load: constant 25%, CSG load: variable, CSG TxP 20dBm)

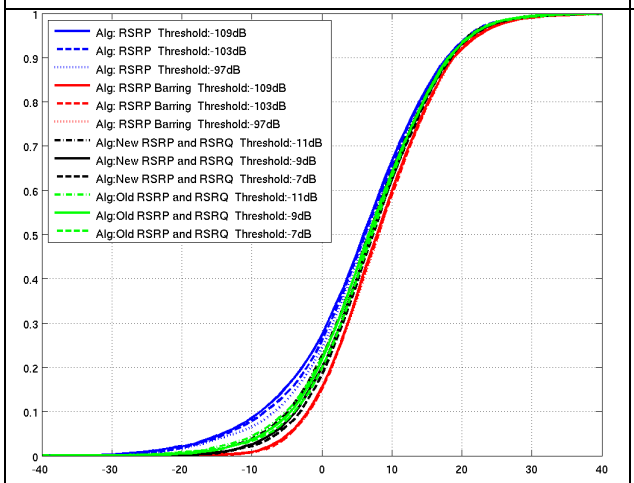


Figure 26. All SINRs (Macro load: constant 50%, CSG load: variable, CSG TxP 8dBm)

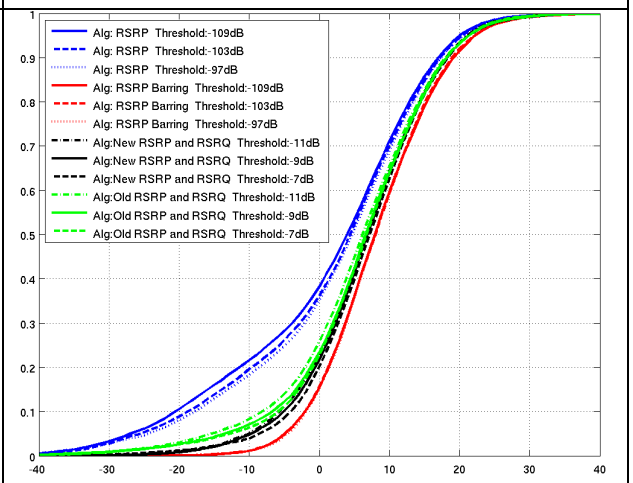


Figure 27. All SINRs (Macro load: constant 50%, CSG load: variable, CSG TxP 20dBm)

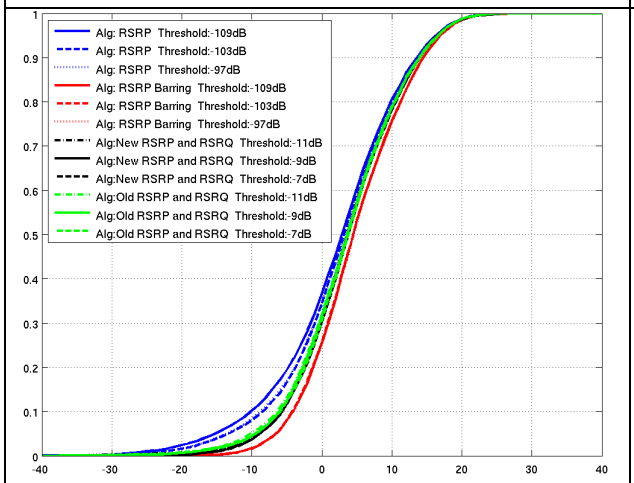


Figure 28. All SINRs (Macro load: constant 100%, CSG load: variable, CSG TxP 8dBm)

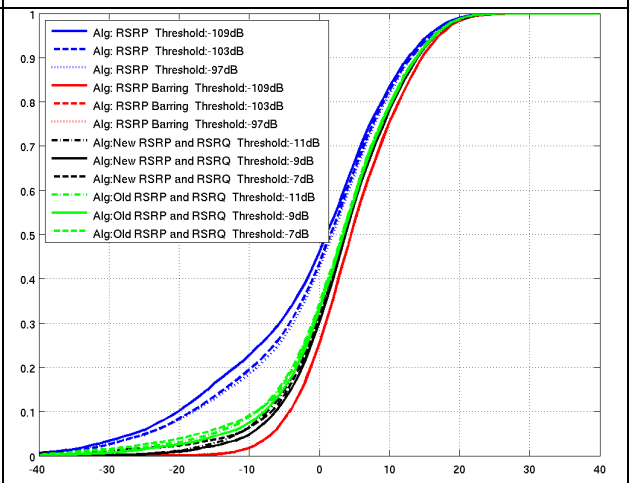


Figure 29. All SINRs (Macro load: constant 100%, CSG load: variable, CSG TxP 20dBm)

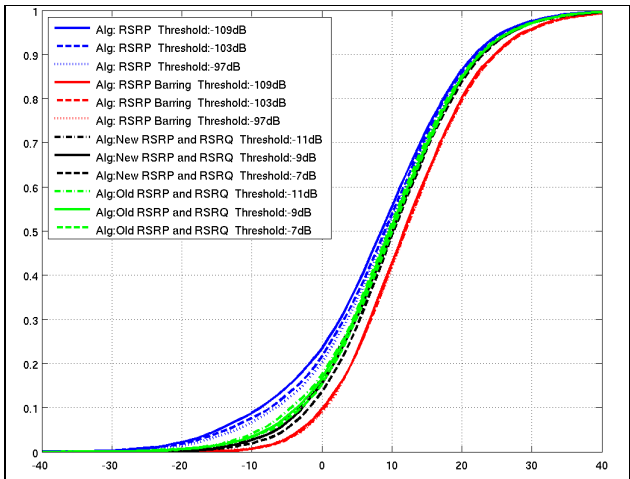


Figure 30. High prio. net. SINRs SINRs (Macro load: constant 25%, CSG load: variable, CSG TxP 8dBm)

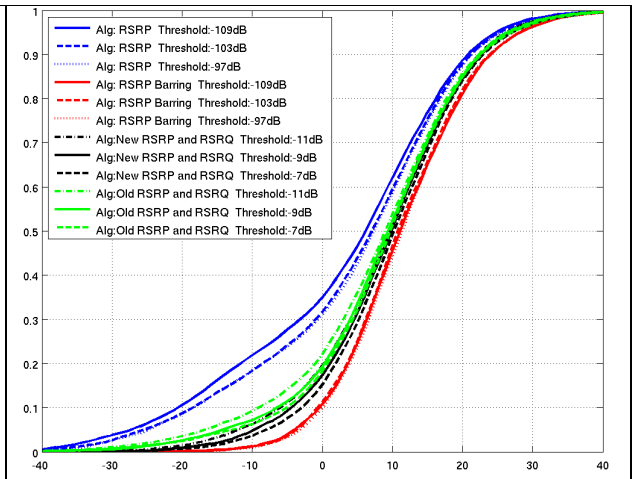


Figure 31. High prio. net. SINRs SINRs (Macro load: constant 25%, CSG load: variable, CSG TxP 20dBm)

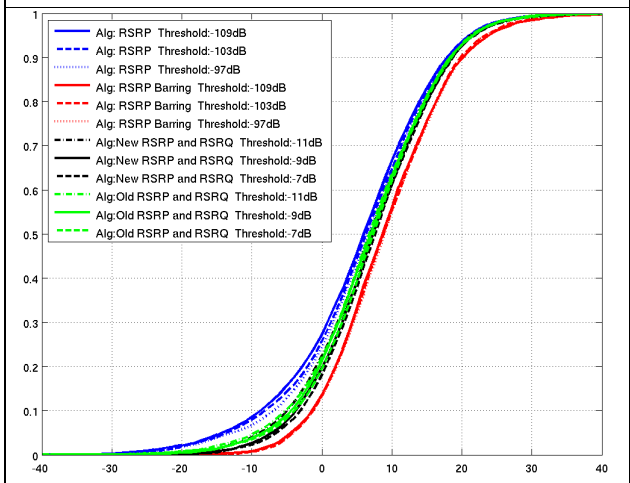


Figure 32. High prio. net. SINRs SINRs (Macro load: constant 50%, CSG load: variable, CSG TxP 8dBm)

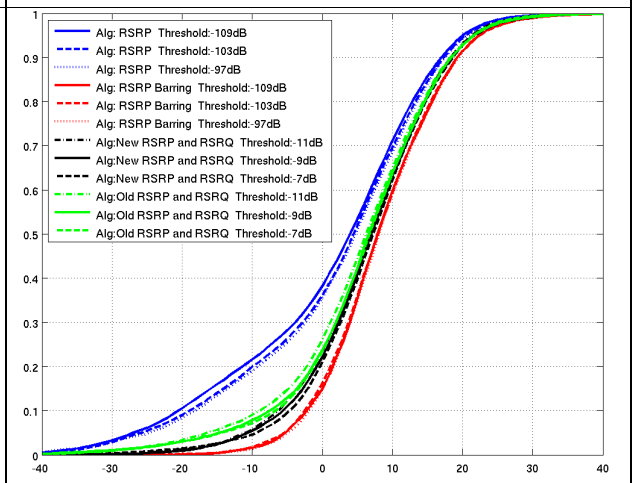


Figure 33. High prio. net. SINRs SINRs (Macro load: constant 50%, CSG load: variable, CSG TxP 20dBm)

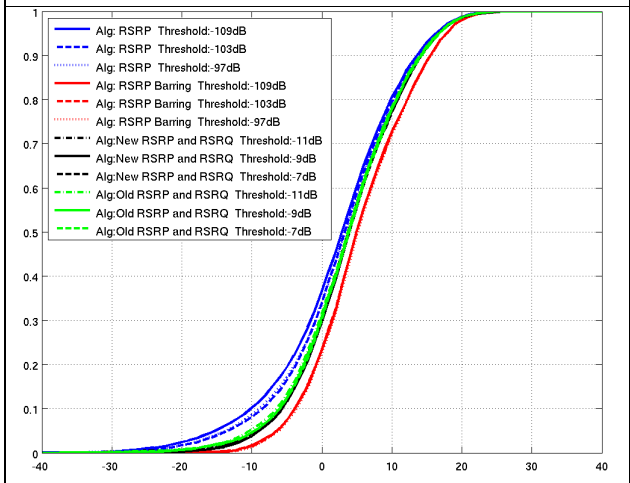


Figure 34. High prio. net. SINRs SINRs (Macro load: constant 100%, CSG load: variable, CSG TxP 8dBm)

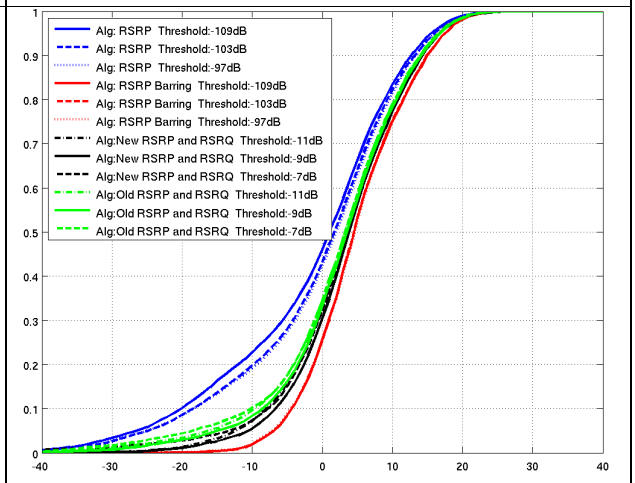


Figure 35. High prio. net. SINRs SINRs (Macro load: constant 100%, CSG load: variable, CSG TxP 20dBm)

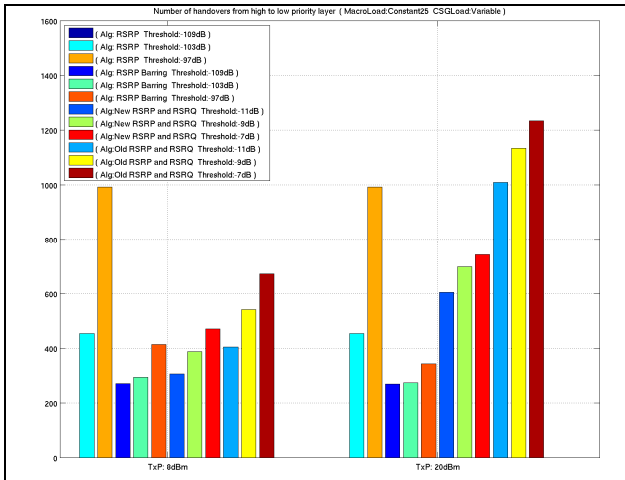


Figure 36 Number of reselections from high to low priority layer (Macro load: constant 25%, CSG load: variable)

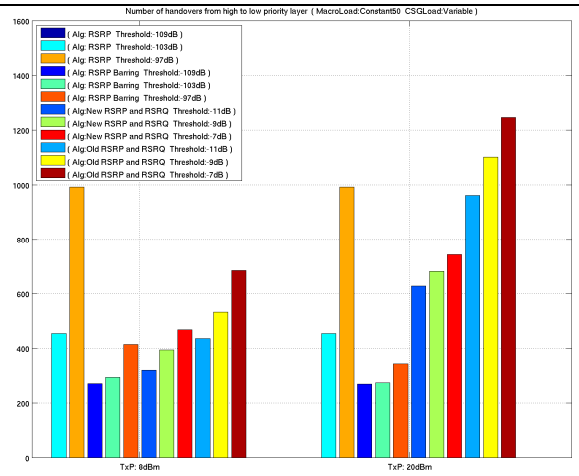


Figure 37 Number of reselections from high to low priority layer (Macro load: constant 50%, CSG load: variable)

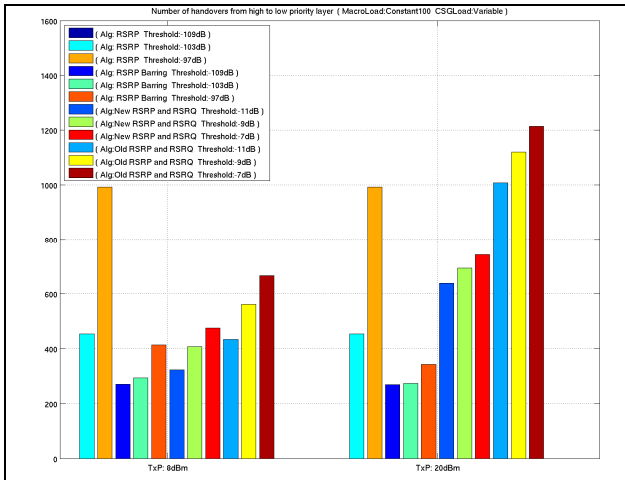


Figure 38 Number of reselections from high to low priority layer (Macro load: constant 100%, CSG load: variable)

4. Conclusions

In this contribution we have presented further evaluation the performance of different reselection schemes to avoid possible interference from (non-allowed) CSG cells. The evaluation was done in combined macro-CSG scenario with two frequency layers. On both frequency layers had co-located macro cells and a number of indoor cells were introduced to the higher priority layer modelling the CSG cells. The performance of different schemes was evaluated in terms of number of reselections and observed SNIR. Different CSG cell power levels together with variable or constant (full) loads were evaluated together with different loads in macro cells.

Based on the results presented it can be seen that best performance in terms of both, SNIR and number of reselections, can be obtained with barring based approach, where UE reselects to lower priority layer if the strongest cell at the given frequency layer is non-allowed CSG cell. RSRQ based approaches results increased number of reselections between priority layers due to measurement related uncertainties, and is affected by the bursty nature of the traffic load, but does not provide as good SNIR as the barring based approach. These results are in line with those presented in [6].

Thus accounting also the cell hearability evaluation presented in [6] in addition to the results presented on the performance of different re-selection algorithms, it would seem that when the UE determines that the strongest cell is a non allowed CSG cell, deterministic behaviour (such as barring) would best achieve the desired behaviour.

5. References

[1] R4-091896, Inter-Frequency Reselection Indicator (IFRI) Simulation Results, Qualcomm Europe

[2] R4-091895, RSRQ measurement requirement in idle mode, Qualcomm Europe

[3] R2-093592, “LS on handling of non-allowed CSG cells”, RAN WG2

[4] R4-092183, Handling of non-allowed CSG cells, Nokia & Nokia Siemens Networks

[5] R4-092601, Reply LS (IFRI, RSRQ measurement requirement in idle mode), Qualcomm Europe

[6] R4-092450, Evaluation of methods to handle non-allowed CSG cells, Nokia & Nokia Siemens Networks

[7] R4-092477, Reply LS (IFRI, RSRQ measurement requirement in idle mode), Qualcomm Europe

Annex

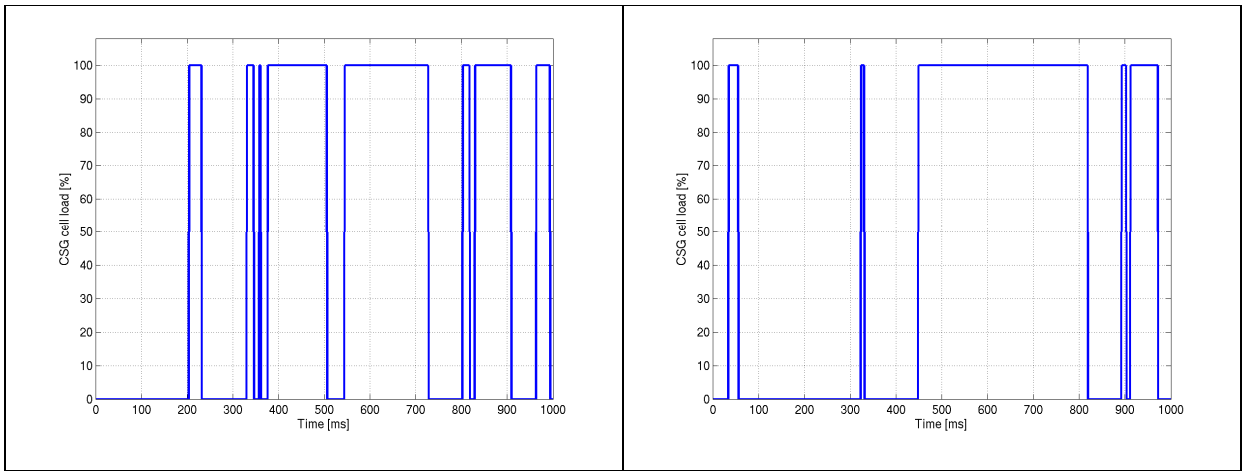
A.1 Parameters

Table 1. Key simulation parameters

Feature/Parameter		Value/Description
Operation Bandwidth		10 MHz
IFFT/FFT length		1024
Duplexing		FDD
Number of sub-carriers		600
NW synchronicity		Asynchronous NW
Sub-carrier spacing		15 kHz
Resource block bandwidth		180 kHz
Sub-frame length		1 ms

Reuse factor		1
Number of symbols per TTI		14
Number of data symbols per TTI		11
Number of control symbols per TTI		3
Simulations Scenario	Combined macro-CSG scenario with 2 frequency layers	High priority layer: 55 cells (18 macro cells and 37 CSG cells) Low priority layer: 18 macro cells
	Macro cell ISD	500 m
	Antenna pattern	Macro cells: 70-degree sectored beam CSG cells: Omni directional antennas
Distance-dependent path loss	Outdoor	$128.1 + 37.6\log_{10}(r)$
Distance-dependent path loss	Indoor	$37 + 30\log_{10}(r) + \sum k_w L_w$, k_w is number of penetrated wall and L_w is wall loss (5 dB)
Shadowing standard deviation		8 dB
Shadowing correlation distance		50m
Shadowing correlation between macro sites		1.0
Shadowing correlation between macro cells		0.5
Multipath delay profile		TU
UE Speed		3 kmh
Receiver		2RX MRC
RSRP Measurement Treselection $Qhyst_s$	Measurement Bandwidth Measurement Interval Measurement Period	6 PRBs 1.28 s in idle mode 2 measurement samples 0 3dB

A.2 Example of variable loading


CSG cell load [%]
Time [ms]
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
900
1000
CSG cell load [%]
Time [ms]