3GPP TSG-RAN WG4 Meeting #53 **R4-094665**

Jeju, Korea, 9th – 13th November, 2009

Source: Nokia, Nokia Siemens Networks

Title: Out-of-Service indication with Quality Metric

Agenda Item: 6.1.1.7

Document for: Discussion

1. Introduction

During RAN4 meeting #52bis, there was discussion of way forward for Rel'9 idle mode reselection [1]. It was concluded that RAN4 should try decide on which enhancements should be considered in release 9 based on evaluation. This paper presents results for the performance of Out-of-Service indication (in idle mode) with both (Rel'8) RSRP-based and RSRQ-based Out-of-Service detection mechanism.

2. Out-of-Service (Oos) Simulations

Out-of-Service (OoS) is defined in 36.133, section 4.2.1.1 as follows:

> *If the UE has evaluated in N_{serv} consecutive DRX cycles that the serving cell does not fulfil the cell selection criterion S, the UE shall initiate the measurements of all neighbour cells indicated by the serving cell, regardless of the measurement rules currently limiting UE measurement activities.*
>
> *If the UE in RRC_IDLE has not found any new suitable cell based on searches and measurements using the intra-frequency, inter-frequency and inter-RAT information indicated in the system information for 10 s, the UE shall initiate cell selection procedures for the selected PLMN as defined in [1].*
>
> *After this 10 s period a UE in RRC_IDLE state is considered to be "out of service area" and shall perform actions according to [1].*

Thus, OoS evaluation is triggered when S-criterion for serving cell falls below zero for Nserv consecutive DRX cycles. If this persists for at least 10 seconds, the UE is "out-of-service".

For these simulations, we have used a only LTE network to study this effect: When a UE detects out-of-service, it reselects away and is removed from the simulation.

Since RSRP-based reselection is specified in Rel'8, as is the OoS indication, we evaluate the possible enhancements against that. Further, since one of the reasons for OoS based on a quality metric was the presence of CSG cells, evaluations were done in a scenario with and without CSG cells.

The following different OoS detection schemes were simulated:

1. OoS based on RSRP threshold (Rel'8-compatible mechanism, reference case)
2. OoS based on RSRP or RSRQ threshold (I.e. OoS is triggered when either metric becomes bad enough)
    - Since RSRQ is dependent on load on intra-frequency cells, two different loading options were considered: One where macro cells are fully loaded all the time, and one where there is partial load.
3. OoS based on RSRP threshold + frequency barring (I.e. Rel'8 but UE bars the frequency and reselects away from it when a non-allowed CSG cell is detected)

When UE detected an OoS in the simulations (i.e. after 10s in bad conditions), it would select to another frequency layer for the duration of the simulation. Frequency barring was modelled similarly: When UE detected a CSG cell that was 3 dB better than the current serving (macro) cell, the frequency became barred and UE reselected to another frequency layer. In effect, both OoS

and frequency barring resulted in UE being removed from the simulation. After this, a new UE would be eventually generated to the simulation.

The intent of the simulations was to compare case 1 against the rest, and to figure out answers to the following questions:

- Does adding RSRQ to OoS evaluation criterion help in detecting interference problems? How load-dependent does the measure become?
- How easily is OoS detected when there should be no coverage problems?
- How do the different OoS metrics behave in the presence or absence of CSG cells? Is there a difference as to how the metrics should be set depending on knowledge of CSG cells?
- How easy is it to set the OoS-threshold for RSRP/RSRQ? Can the same value be used regardless of (macro cell's knowledge of) the presence of the CSG cells?

3. Simulation scenario

The used scenarios were 3GPP macro Case 1 (57 cells with ISD 500 m, see Figure 1) and a scenario including both macro and indoor cells (see Figure 2 for the overall layout and Figure 3 for the single CSG hotspot building layout) where the CSG hotspots were approximately 83 meters apart and macro ISD 500 m was utilized. With 37 CSG hotspots in the scenario, there are roughly 12 CSG hotspots within the area of each of the studied eNBs. The penetration loss of 20 dB, used normally in 3GPP Case 1 propagation, was modified to 0 dB for the CSG scenario: The indoor cell propagation formula calculates penetration (=wall) loss already separately, so having the macro propagation include a penetration loss would have resulted in too good separation of interference for the indoor CSG cells. The exact pathloss calculation is detailed in Appendix B.

In CSG hotspot case, A CSG hotspot contains four buildings with CSG cells located inside, i.e. each hotspot as 4 CSG cells. Two different UE placements were simulated, by forming an 'hotspot' area within which the UEs were generated: First hotspot was placed close to a macro BS ('close-by CSG hotspot') and second on the macro cell-edge ('cell-edge CGS hotspot').

In the Case 1 scenario both 3 and 30 km/h UE velocities were simulated, but in macro-indoor scenario only 3 kmph was simulated. All UEs were operating in idle mode, with set background level of interference assumed in each case, but each UE was scheduled once every 10 seconds to obtain a distribution of the SINR for hypothetical paging message.

The measurement interval for RSRP and RSRQ was 1280 ms and the measurement filtering was over 2 measurement samples. No measurement error was used for RSRP or RSRQ measurements. Qhyst was set to 3 dB. $S_{intrasearch}$ was not used in any of the simulations, i.e. it was set high enough that users were not limiting their measurements at any point: Having $S_{intrasearch}$ would complicate the analysis further, and it is assumed that OoS should be detected at such levels that $S_{intrasearch}$ would not apply in any case.

To study how the presence of CSG cells affects the OoS detection and possible even threshold setting, we elected to study two different CSG hotspot cases: In the first case, the CSG hotspot area is placed close to the macro cell, and in the second case the CSG hotspot was placed roughly on the cell edge of the macro cell coverage. These cases were designed to spot simple differences that arise due to the different relative position within the macro cell, i.e. to show how much the macro cell DL signal strength affects the results.

The load of both the CSG cells and macro cells were varying during the simulation: Both had, by default, a variable load that corresponds to roughly 50% PRB activity. This was modelled with a Markov chain so the on average, there was 100ms of activity followed by 100ms of inactivity and so on,

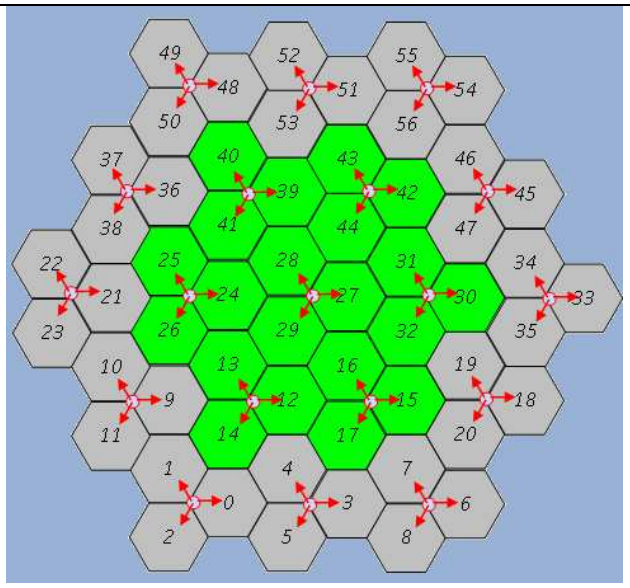

Figure 1. Case 1 scenario

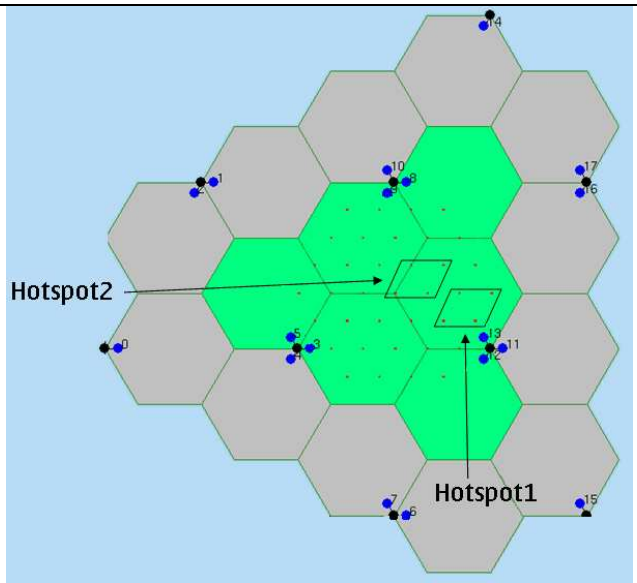

Figure 2. Macro scenario with CSG hotspot

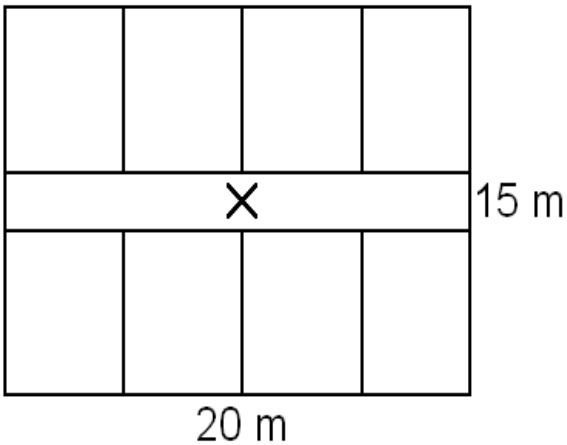

Figure 3. Building with indoor CSG cell within CSG hotspot

4. Simulation results for Case 1 scenario

Although in reality there should be no OoS detections if the network coverage has been well planned, it may be difficult to figure out how to assign the OoS detection threshold so that no unnecessary OoS detections happen. The Case 1 simulations were done to find out suitable range for the RSRP/RSRQ OoS detection threshold values. The values should be set so that in the typical Case 1 Macro scenario, where there should be good coverage everywhere, very few OoS detections happen. Figure 4, Figure 5 and show the proportion of calls with OoS detections with a range of threshold values for RSRP and RSRQ based OoS detection schemes, while Figure 6 shows the proportion of OoS detections calls with combined RSRP+RSRQ OoS detection scheme.

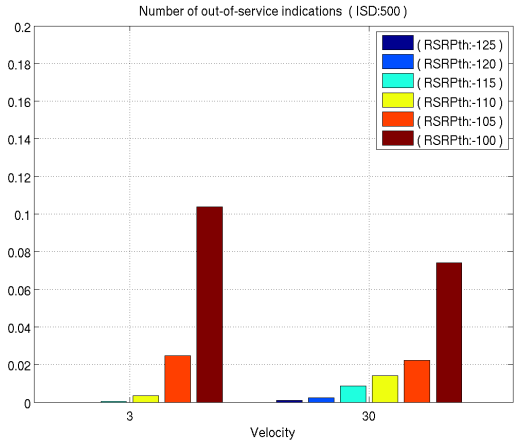

Figure 4. Macro case, Proportion of calls with OoS. OoS based on RSRP.

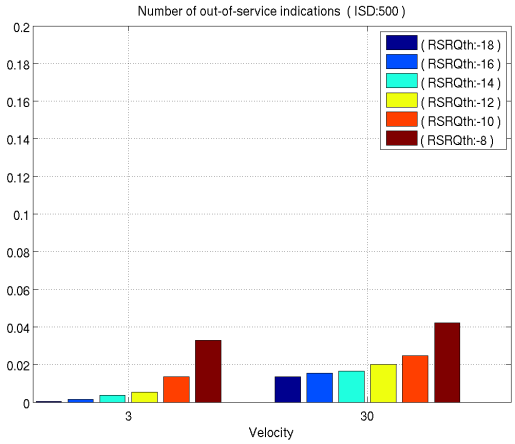

Figure 5. Macro case, Proportion of calls with OoS. OoS based on RSRQ.

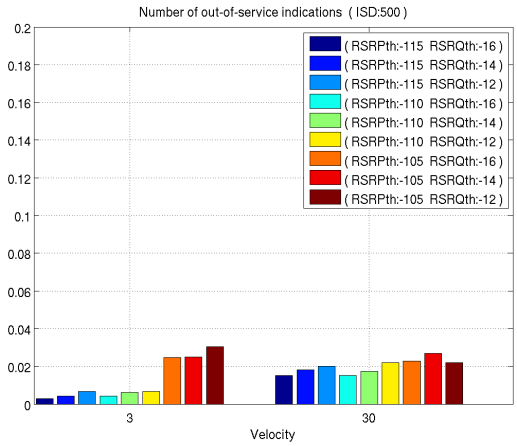

Figure 6. Macro case, Proportion of calls with OoS. OoS based on RSRP+RSRQ.

With RSRP, simulated threshold values larger than -105 dBm seem not very reasonable: High number of OoS detections happen despite the absence of coverage problems. Similary with RSRQ based detection, threshold values would need to be lower than -10dB, For he combined RSRP+RSRQ scheme shows that these values, chosen in isolation, work well together.

Note that in with some threshld values, there are more OoS indications with 3 kmph than 30 kmph UE velocity. With higher velocity UE do not stay in bad conditions long enough to trigger OoS..

From the results, it is seen that with RSRP based threshold lower than -110 dBm or RSRQ threshold lower than -15 dB, OoS indications happen in about 1% of calls on average. These threshold values were selected to be used in further simulations with CSG hotspot cases. Since the presence or absence of CSG cells should not affect the macro cell configuration, the same threshold values ought to apply in both cases.

SINR distributions are given for the aforementioned cases are given in **Figure 7** to **Figure 12**. These show no obvious differences between the schemes, even for unreasonable OoS threshold values. This is as expected since there are no coverage problems in the scenario, and a very robust MCS was used for sending the paging messages. Thus all UEs are in coverage.

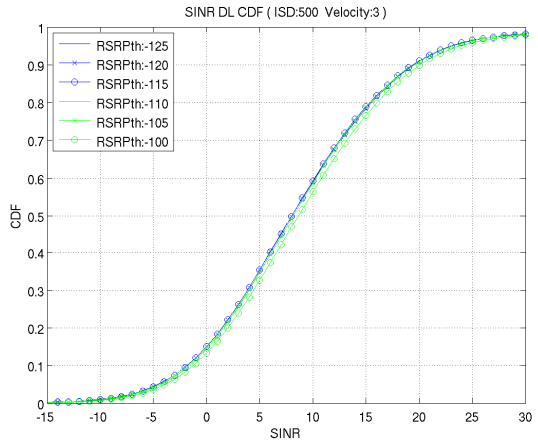

Figure 7. Macro case @ 3 km/h, paging SINR CDF. OoS based on RSRP.

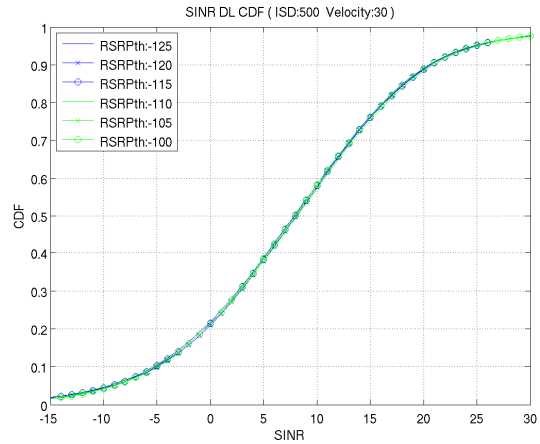

Figure 8. Macro case @ 30 km/h, paging SINR CDF. OoS based on RSRP.

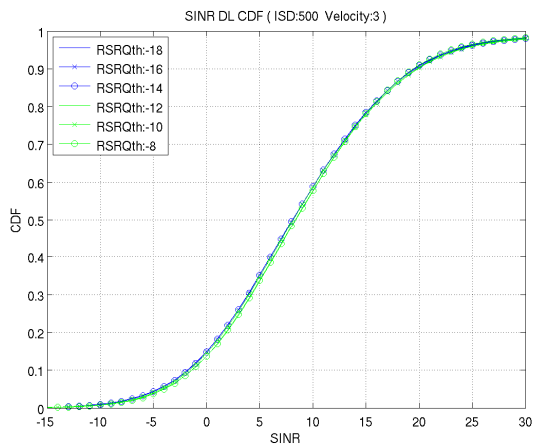

Figure 9. Macro case @ 3 km/h, paging SINR CDF. OoS based on RSRQ.

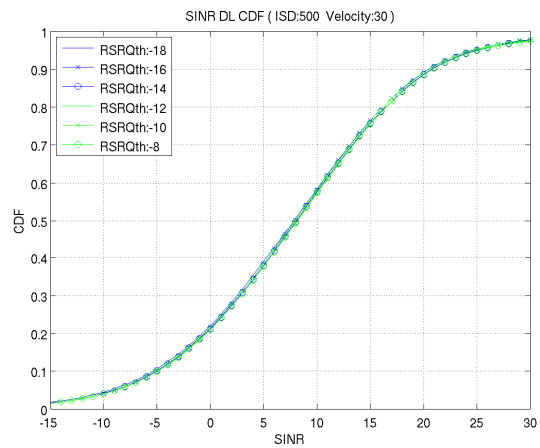

Figure 10. Macro case @ 30 km/h, paging SINR CDF. OoS based on RSRQ.

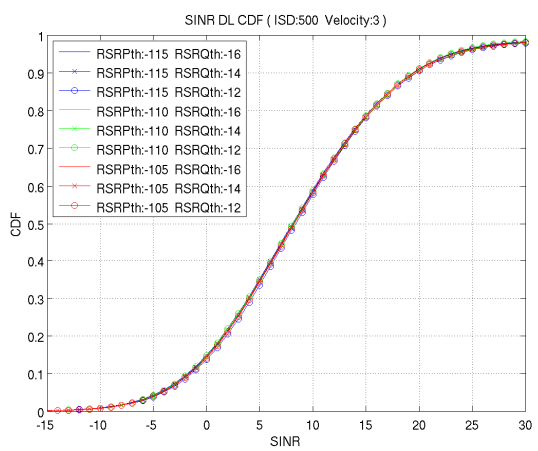

Figure 11. Macro case @ 3 km/h, paging SINR CDF. OoS based on RSRP+RSRQ.

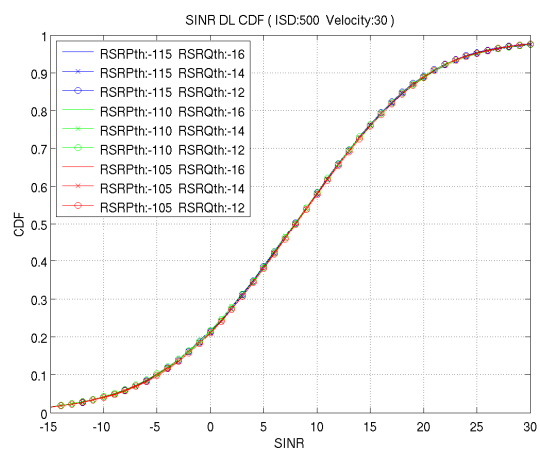

Figure 12. Macro case @ 30 km/h, paging SINR CDF. OoS based on RSRP+RSRQ.

5. Simulation results for Macro scenario with CSG cells

The layout of each hotspot is shown in Figure 3. Since the CSG cells within the hotspots were placed inside buildings, the simulations were also run so the buildings were included but the CSG cells were deactivated, i.e. the CSG cells were completely silent, not sending even reference symbols. This was done to find any bias in the OoS detection introduced by the buildings affecting the propagation conditions compared to the pure Macro case in section 2.2.

We first consider how many OoS detections happen in the close-by hotspot (hotspot 1 in the figures) with the chosen range of threshold values, both with and without activated CSG cells. These results are shown in Figure 13 to Figure 16.

For the close-by CSG hotspot,. the RSRP+RSRQ scheme is able to detect the presence of the CSG cells quite well, although the question remains whether the OoS indications are relevant or not. Neither the pure RSRP-based scheme or the RSRP+barring scheme results in no OoS detections in any of the simulated cases, but in the barring case, this is because barring it typically detected earlier than OoS.

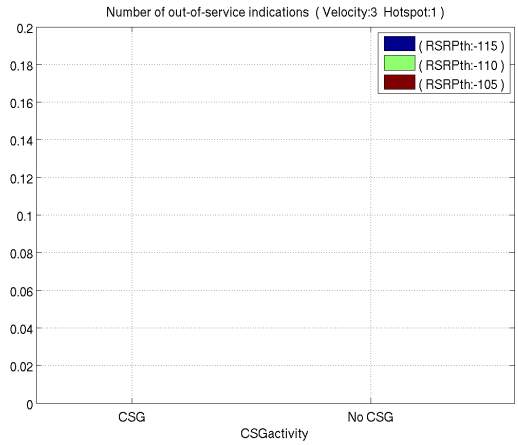

Figure 13. Close-by Hotspot. Proportion of calls with OoS. OoS based on RSRP.

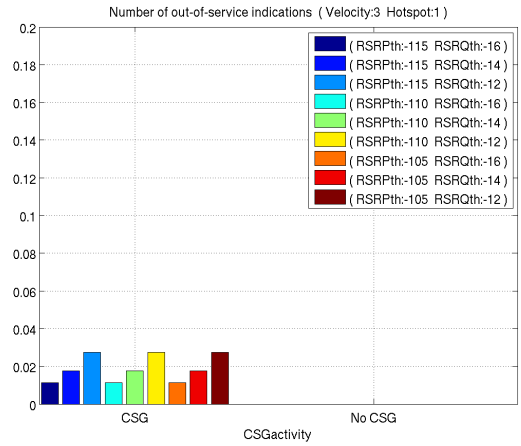

Figure 14. Close-by Hotspot, variable macro cell load. Proportion of calls with OoS. OoS based on RSRP+RSRQ

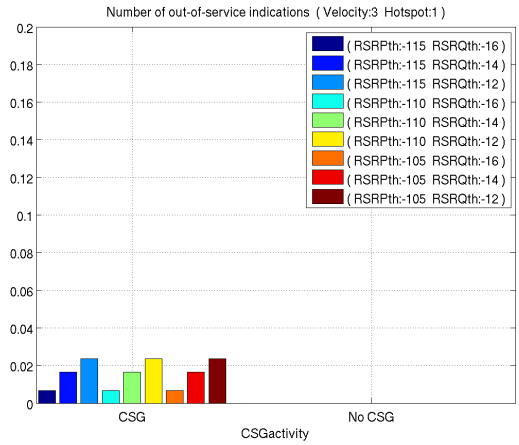

Figure 15. Close-by Hotspot, full macro cell load. Proportion of calls with OoS. OoS based on RSRP+RSRQ

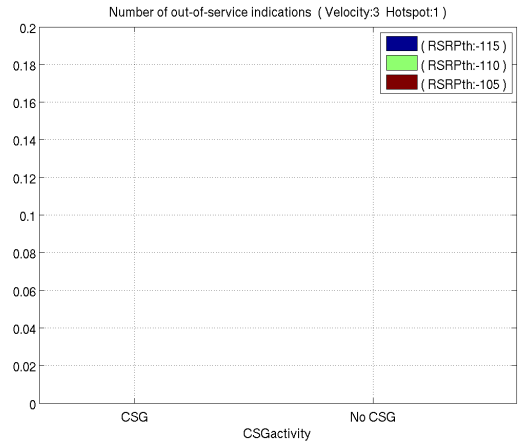

Figure 16. Close-by Hotspot. Proportion of calls with OoS. OoS based on RSRP. with barring.

Proportion of calls with Oos for the cell-edge hotspot are show in Figure 17 to Figure 20. The cell-edge hotspot case is more challenging for the RSRP+RSRQ scheme. The OoS is detected sometimes even when the CSG cells are not activated, though this is dependent on the used threshold value and there are not extremely many detections. Decreasing the RSRQ threshold further down to -16dB reduces amount of these, but does not remove them completely. Similarly, the amount of barring increases with the cell-edge hotspot since the CSG cell may become stronger than the macro cell more often. The proportion of barred calls for each threshold value is shown in Figure 21.

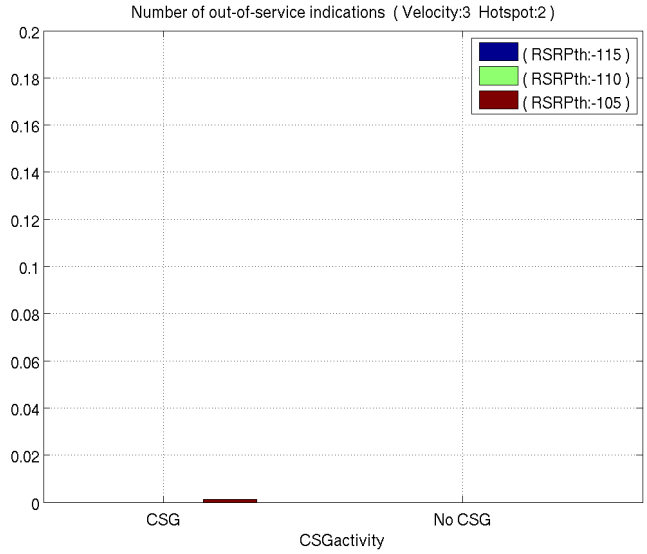

Figure 17. Cell-edge hotspot. Proportion of calls with OoS. OoS based on RSRP

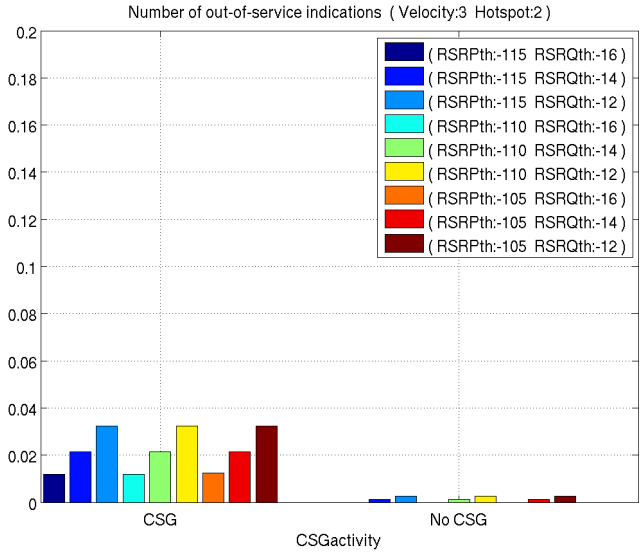

Figure 18. Cell-edge hotspot, variable macro cell load. Proportion of calls with OoS. OoS based on RSRP+RSRQ

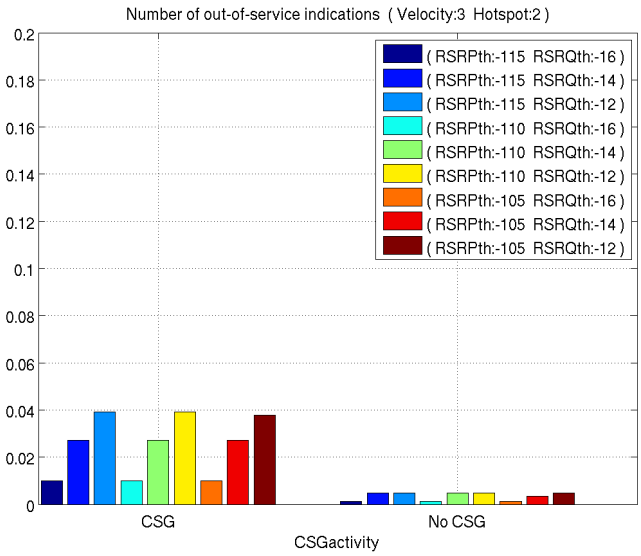

Figure 19. Cell-edge hotspot, full macro cell load. Proportion of calls with OoS. OoS based on RSRP+RSRQ

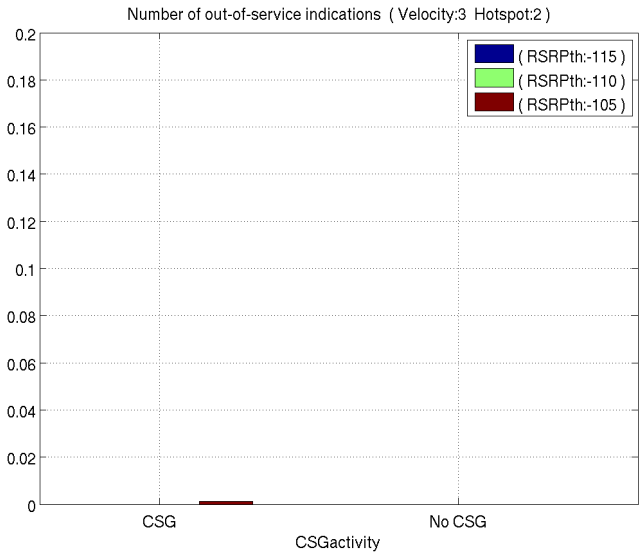

Figure 20. Cell-edge hotspot. Proportion of calls with OoS, RSRP OoS and RSRP reselection with barring

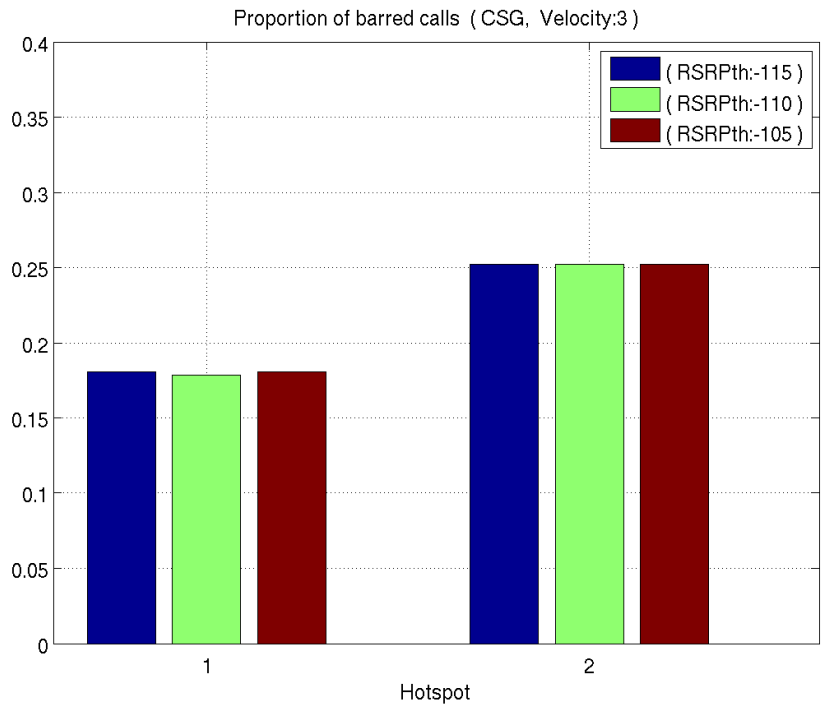

Figure 21. Proportion of barred calls in each CSG hotspot, RSRP OoS and RSRP reselection with barring

Next, a comparison of the success rate of paging (i.e. how often UE is able to receive sent paging message) is shown in Figure 22. Although all cases have success rate of >~95%, RSRP+barring has the best performance with both hotspot cases. These are taken from the cases with RSRP threshold = -110 dBm and RSRQ threshold = -14 dB.

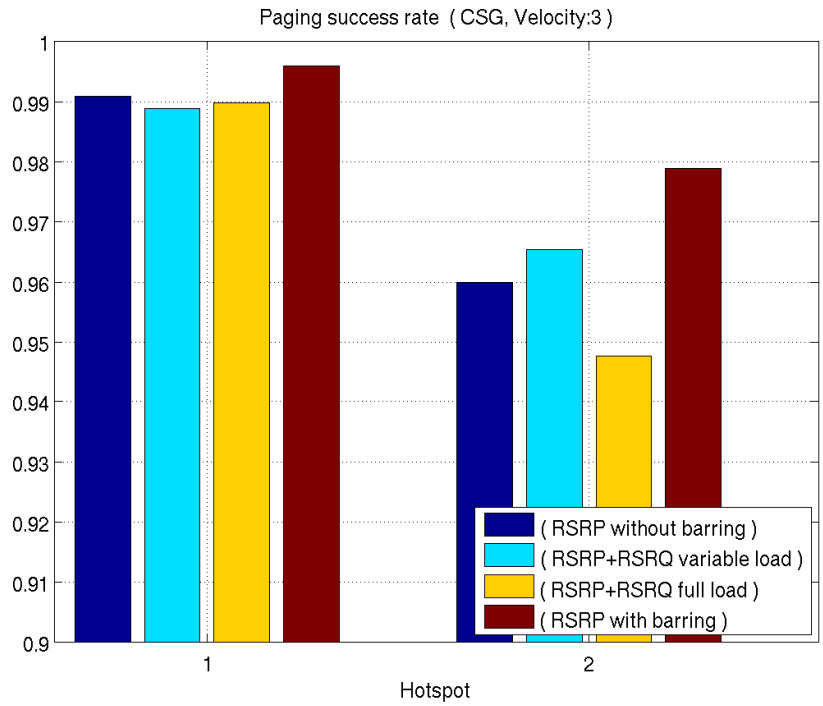

Figure 22. Paging success rate for RSRP, RSRP+RSRQ (2 different macro loads) and RSRP+barring

Finally, we look at the locations where OoS detections with RSRP+RSRQ and barring with RSRP+barring happen. These are shown in Figure 23 - Figure 32. These results show how close to the hotspot the baring/OoS detection is happening, and is there a detection also elsewhere in the scenario.

Figure 23 - Figure 26 show results for the cell-edge hotspot. With RSRP+RSRQ, the detections are rather well limited within the buildings or close to them. In case the CSG cells are deactivated, there are also some unnecessary OoS detections, as shown in Figure 19, happening at random positions.

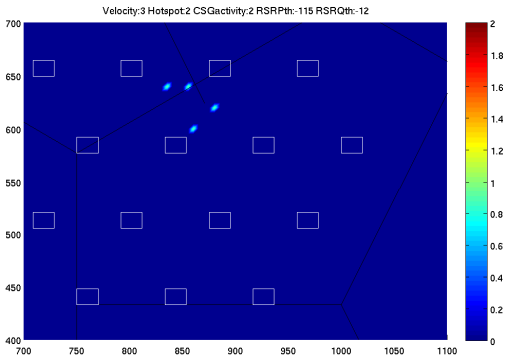

Figure 23. Cell-edge Hotspot, inactive CSG. OoS locations with RSRP+RSRQ OoS, variable macro cell load

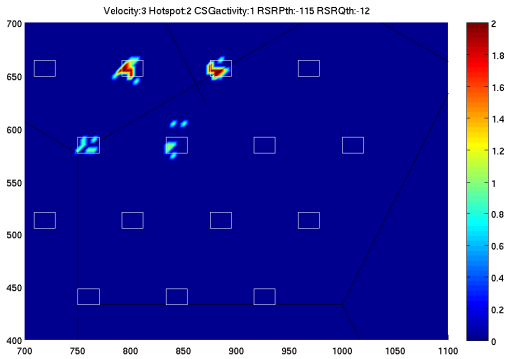

Figure 24. Cell-edge Hotspot, active CSG. OoS locations with RSRP+RSRQ OoS, variable macro cell load

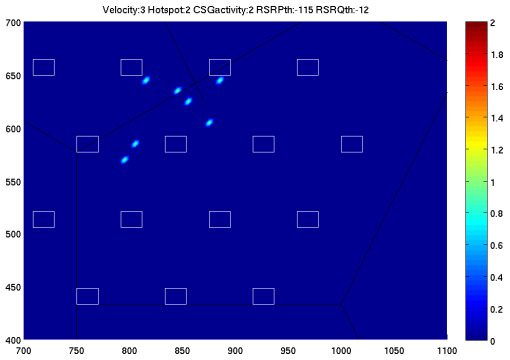

Figure 25. Cell-edge Hotspot, inactive CSG. OoS locations with RSRP+RSRQ OoS, full macro cell load

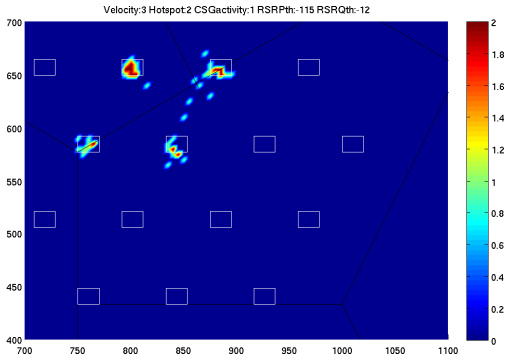

Figure 26. Cell-edge Hotspot, active CSG. OoS locations with RSRP+RSRQ OoS, full macro cell load

Results for the close-by hotspot are show in Figure 27 to Figure 30 for RSRP+RSRQ based OoS. The detections are better limited within the buildings than in the cell-edge case.

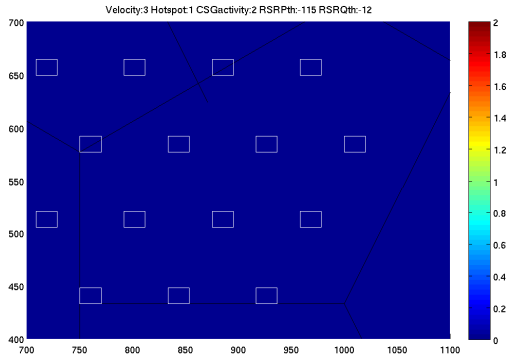

Figure 27. Close-by Hotspot, inactive CSG. OoS locations with RSRP+RSRQ OoS, variable macro cell load

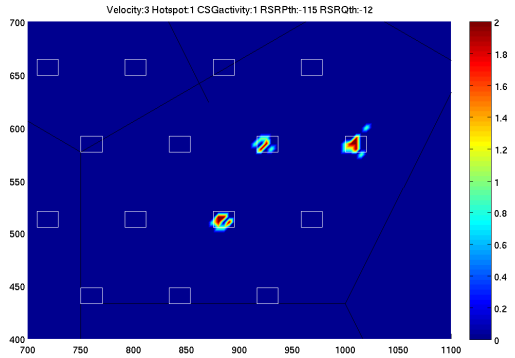

Figure 28. Close-by Hotspot, active CSG. OoS locations with RSRP+RSRQ OoS, variable macro cell load

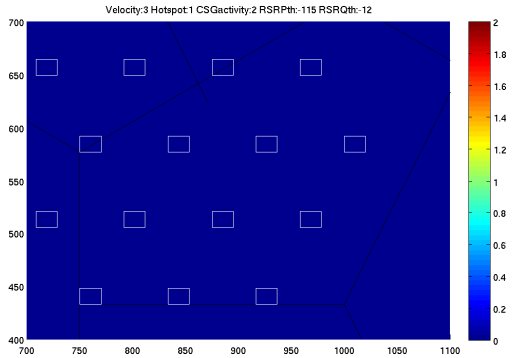

Figure 29. Close-by Hotspot, inactive CSG. OoS locations with RSRP+RSRQ OoS, full macro cell load

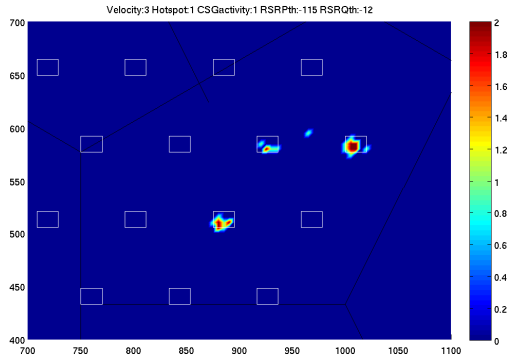

Figure 30. Close-by Hotspot, active CSG. OoS locations with RSRP+RSRQ OoS, full macro cell load

To compare the OoS detection locations against the barring locations, Figure 31 and Figure 32 show the frequency barring locations. It can be seen that the barrings are isolated quite well so that they happen only around the CSG cells.

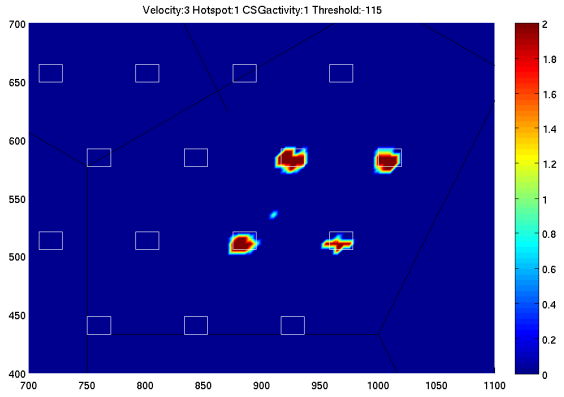

Figure 31. Close-by Hotspot, active CSG. RSRP+barring, Barring locations

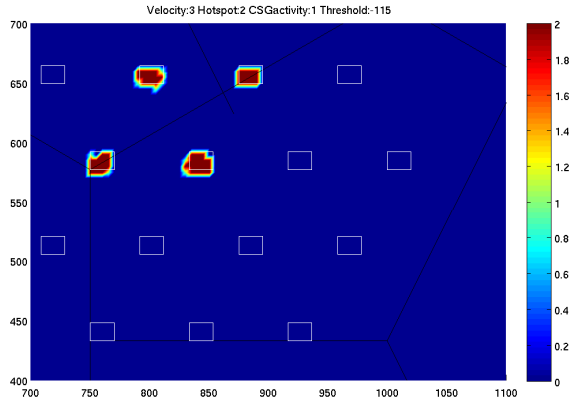

Figure 32. Cell-edge Hotspot, active CSG. RSRP+barring, Barring locations

6. Conclusion

We have shown results comparing the OoS detection with different options: Pure Rel'8-based scheme, RSRQ-enhanced scheme (i.e. OoS detection based on both RSRP and RSRQ) with two different macro cell loading options and finally Rel'8-scheme with frequency barring.

Any proposed addition of RSRQ to the suitability criteria needs to be signalled in a consistent way across all radio access technologies, including UTRAN and GERAN. If this is not done then ping pongs may occur eg if an E-UTRAN cell is considered suitable in GERAN or UTRAN mode based on RSRP, but after the reselection is initiated it turns out to be unsuitable based on RSRQ. Hence the needed signalling changes for introducing RSRQ suitability thresholds are thought to be significant, and not limited to RAN activities. Therefore the benefits provided by introducing the RSRQ should be carefully weighted.

The results show that while RSRQ-enhanced scheme is able to detect the presence/absence of the CSG cells, there are some unnecessary OoS detections when the CSG cell is not present. The macro cell load affects this somewhat, since fluctuations in the RSRQ may cause OoS to happen unnecessarily. However, RSRP+barring is also able to detect the CSG cell presence equally well or better, without being load-dependent.

The results indicate that RSRP+RSRQ is able to detect OoS in most cases, however no significant benefits were observed compared with RSRP+barring. Furthermore in terms of paging performance RSRP-+barring was providing best performance. In view of the significant additional specification effort and system information payload overhead to signal RSRQ suitability thresholds in E-UTRA, UTRA and GSM system information, our view is that compelling benefits would need to be identified to consider specifying such a scheme. By contrast, the specification of RSRP + barring requires no change to GERAN or UTRAN system information.

References

[1] R4-094066, Open Issues and Way Forward on REL9 Reselection Enhancements, NTT Docomo, Nokia, Qualcomm, Motorola, Ericsson

[2] R4-092832, Issues on RSRP-based cell reselection, NTT DOCOMO

[3] R4-093690, Idle mobility enhancements for E-UTRA release 9, Nokia & Nokia Siemens Networks

Appendix A: Simulation parameters

Feature/Parameter		Value/Description
Bandwidth		10 MHz
IFFT/FFT length		1024
Duplexing		FDD
Number of sub-carriers		600
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
3GPP Macro Cell Scenario	Cell layout	57 sectors/19 BSs
	Inter site distance (ISD)	500 m
	Minimum distance between UE and cell site	35 m
	Antenna pattern	70-degree sectored beam
Modified Macro-indoor scenario	Cell layout	6 macro cells + 37 indoor cells
	Macro ISD	500 m
Distance-dependent path loss	Macro cell model (TS 25.848)	$128.1 + 37.6\log_{10}(r)$
	Indoor model (Cost 231 multi wall; n_w is the number of walls crossed)	$38.4 + 20 \log_{10}(r) + n_w L_w$
	L_w	15 dB
Shadowing standard deviation		8 dB
Shadowing correlation between cells/sectors		0.5 / 1.0
Multipath delay profile		Typical Urban
UE Velocity		3, 30 kmph (30 kmph was only used in pure macro cases)
RSRP and RSRQ Measurement	Measurement period	1280 ms
	Measurement bandwidth	6 RBs
	Measurement error	0 dB
	Sliding window size	2 samples
	Qhyst	3 dB
Receiver diversity		2RX MRC
Number of UEs/active cell	Macro scenario	20 (420 UEs in the whole network)
Number of UEs	Macro-indoor scenario	300 UEs
Interference load		Variable load, 50% on average (also a case with RSRP+RSRQ OoS with 100% load)

Appendix B: Pathloss calculations in macro-indoor scenario

The pathloss calculation used in simulations depends on the eNB location. The macro eNBs are assumed to have 15m antenna height and located outdoors, while the indoor cells use 2m antenna height and are located indoors. The propagation models are as follow:

- Macro cell model is separated to outdoor and indoor models:
    - 128.1 + 37.6 log10(R) for 15 m antenna height (Outdoor macro cell)
    - 143.9 + 39.7 log10(R) for 2 m antenna height (Indoor cell)
    - No penetration loss (see below)
- Indoor model (Cost231 multi wall)
    - 38.4 + 20 log10(R) + nwLw
    - Nw is the number of crossed walls, and Lw is the wall loss for one wall

The pathloss calculations depend on both the UE and eNB locations:

- BTS and UE outdoors: (Outdoor) Macro cell model
- BTS and UE indoors in same house: Indoor model
- BTS outdoors and UE indoors: (Outdoor) Macro cell model + external wall loss
- BTS indoors and UE outdoor: max (Indoor model + external wall loss, Indoor macro cell model + external wall loss)
- BTS indoors and UE indoors, but in different houses: Indoor macro cell model + 2 * external wall loss