3GPP TSG-RAN WG4 Meeting #52 **R4-093191**

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Title: Evaluation of mobility state detection schemes with variable UE velocity

Agenda Item: 9.13

Document for: Discussion

1. Introduction

UE based speed detection related aspects were discussed in previous RAN4 meetings. Results for cell reselection based mobility state detection were presented in [1], [2] and [3]. Initial results for dual filtering scheme were presented in [4] and further results with 1.28 seconds DRX cycle comparing both speed detection schemes in [5] . Study plan for mobility state detection-based cell reselection was presented in [6] and according to the plan initial results with varying UE velocity were presented in [7] . In this paper we present further system level results with both speed detection schemes in varying UE velocity conditions.

2. Simulations

In this section we present the simulations comparing the performance of single triggering, dual triggering and cell reselection based mobility state detection schemes in RRC_IDLE with variable UE velocity. The main simulation assumptions are summarised in section 2.1 and the results are given in section 2.2. Conclusions are given inside the text in Section 2.2 and summarised in Chapter 3.

2.1 Simulation scenario

Main characteristics of the simulation tool are given in earlier contributions [1], [2], [3] and [4]. The used scenario was 3GPP macro case 1 with 57 cells of ISD 500 m and additionally a case with ISD 3000 m. Variable UE velocity was utilized in all cases. All UEs started with random velocity selected from [3, 50, 120 kmph] in ISD 500 m case and [3, 50, 120, 250, 350 kmph] in ISD 3000 m case. In intervals of 100 seconds, UEs selected randomly a new velocity from the given values. Simulation time was same in the all cases (~ 700 seconds), each call lasting for the whole simulation duration, so each UE changed velocity six times during the simulation. Statistics were collected from 570 UEs that were continuously in idle mode.

The measurement quantity used for the reselection evaluation was RSRP. The RSRP measurement period was 1280 ms and the measurement filtering was over 2 measurement samples. The measurement error for the reselection criterion evaluation was 3 dB (i.e. according to [8]).

The two filters for the dual triggering scheme, called SHORT (intended to trigger for UEs moving at fast speed) and LONG (intended to trigger for UEs moving at slow speed) filter, both had their own Qhyst and Treselection. For cell reselection based mobility state detection, two mobility states (called NORMAL and HIGH) were utilized, with different values of Treselection and Qhyst for both states (i.e. the values are scaled in HIGH mobility state). Cell reselection based state detection evaluation window T_{CRmax} was 30 seconds for ISD 500 and 60 seconds for ISD 3000 to enable adaptation for velocity changes in 100 second intervals. The objective of the simulations was to compare how each scheme adjusts to variable UE velocity conditions. To compare the results, comparable (i.e. same, as much as possible) parameter values were utilised for Treselection and Qhyst. To obtain a fair comparison for the dual triggering case, single trigger settings were simulated to get baseline results without any kind of speed detection. The utilized Qhyst and Treselection simulation settings are presented in Table 1 for all schemes.

Cell reselection scheme	Setting	Value [Qhyst, Treselection]
Single trigger (Scheme:1)	Set:1	[3 dB, 0 ms]
	Set:2	[1 dB, 1280 ms]
	Set:3	[0 dB, 2560 ms]
Dual trigger (Scheme:2)	Set:4	{SHORT, LONG} = { [3 dB, 0 ms], [1 dB, 1280 ms] }
	Set:5	{SHORT, LONG} = { [3 dB, 0 ms], [0 dB, 2560 ms] }
Cell reselection based state detection (Scheme:3)	Set:6	{NORMAL, HIGH} = { [1 dB, 1280 ms], [3 dB, 0 ms] }
	Set:7	{NORMAL, HIGH} = { [0 dB, 2560 ms], [3 dB, 0 ms] }

Table 1. Qhyst and Treselection settings for cell reselection schemes.

Note that Set 4 parameters are a combination of Set 1 & Set 2 parameters, Set 5 parameters are a combination of Set 1 & Set 3 parameters, Set 6 parameters are a combination of Set 2 & Set 1 parameters and Set 7 parameters are a combination of Set 3 & Set 1 parameters. Thus, Set 4 & Set 6 should be comparable against each other, and similarly Set 5 & Set 7 should be comparable.

2.2 Simulation results

In this section the simulation results for the evaluated schemes are presented. First the results for the average number of cell reselections per call and proportion of ping-pong reselections (a “ping-pong reselection” is defined as a reselection that occurs after less than 5 seconds since the previous reselection) are presented. Then, the proportion of time being camped in a cell with best RSRP level is used for comparing the schemes. Additionally velocity distributions are presented.

Figures 1-2 show distributions for cell reselections per UE in ISD 500 and ISD 3000 case, and Figures 3-4 show more information about the triggered reselections:

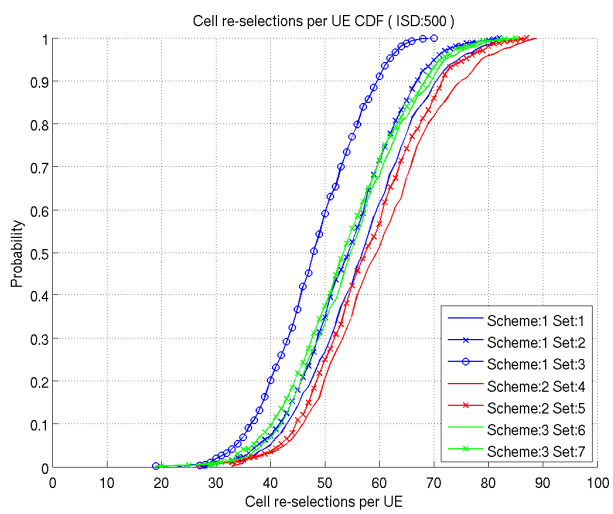

Figure 1. Number of cell reselections per UE distribution (ISD 500 m).

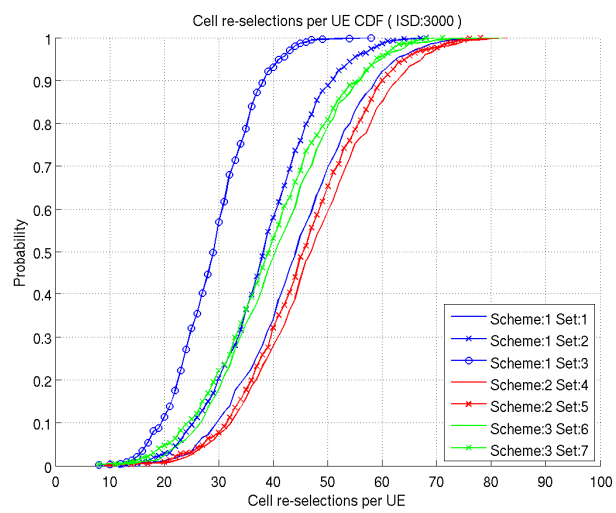

Figure 2. Number of cell reselections per UE distribution (ISD 3000 m).

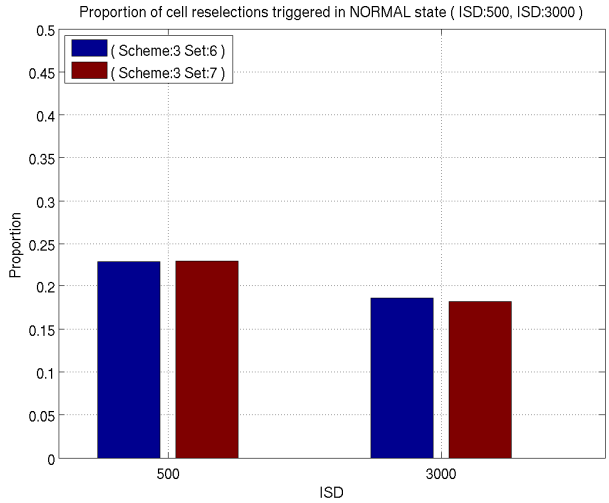

Figure 3. Proportion of cell reselection triggered in NORMAL state (ISD 500, ISD 3000 m).

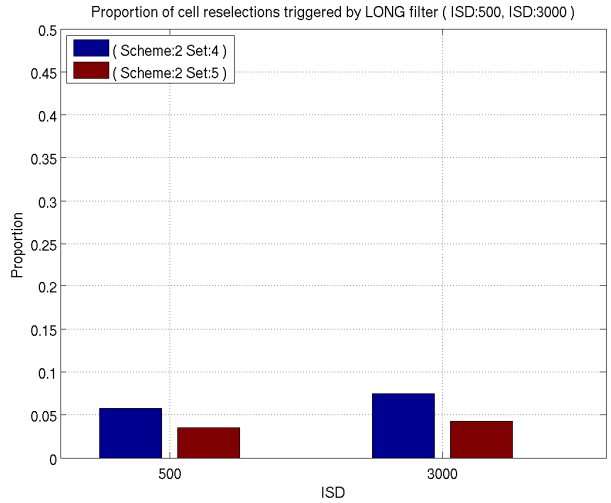

Figure 4. Proportion of cell reselection triggered by LONG trigger (ISD 500, ISD 3000 m).

Analysis of the reselection amounts:

- The largest amount of cell reselections are triggered when the dual triggering scheme is in use.
- Utilizing Treselection of 2560 ms (Setting 3) causes the average amount of reselections to drop significantly compared to other settings.
- With cell reselection based mobility state detection (Scheme 3) the amount of reselection is clearly less than with dual triggering, because NORMAL state uses settings 2 and 3 and significant proportion of reselections are triggered in NORMAL state as shown in Figure 3.
- Figure 4 shows proportion of reselections triggered by LONG trigger in dual triggering settings 4 and 5. The results show that SHORT trigger is utilized the most (about 95% of the time). These variable UE velocity results are dominated by high velocities (120 kmph and more), because reselections are more frequent as velocity increases. The variable UE velocity results are well in line with the constant UE velocity results presented in [5].

From these, the conclusion is that the largest amount of reselections are triggered with the dual triggering scheme, because both triggers are evaluated constantly.

Figure 5 shows the proportion of ping-pong cell reselections (i.e. reselection occurring less than 5 seconds before the previous reselection) and Figure 6 shows the proportion of each velocity utilized in variable UE velocity conditions (Note that velocities 250 and 350 kmph are not utilized in ISD 500 case.):

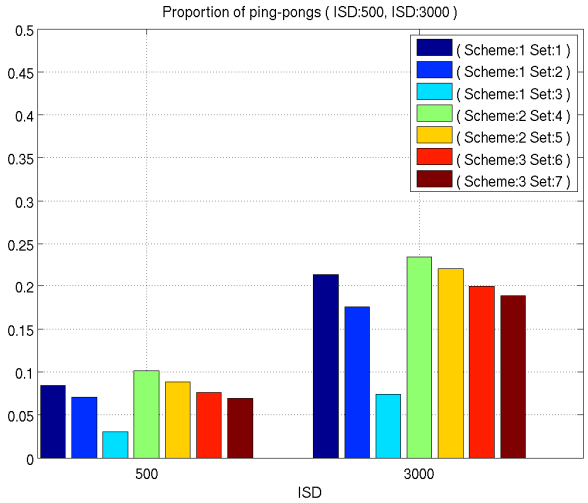

Figure 5. Proportion of ping-pong cell reselections (ISD 500, ISD 3000 m).

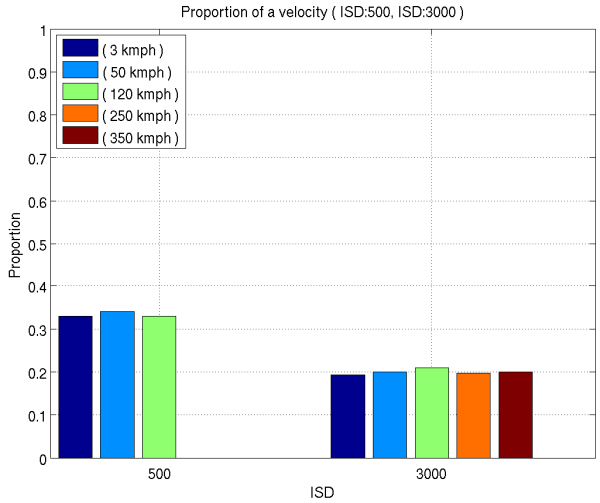

Figure 6. Proportion of a velocity during a call (ISD 500, ISD 3000 m).

Analysis of the ping-pong amounts:

- The biggest proportion of ping-pong reselection occurs with the dual triggering scheme.
- Single settings 2-3 with Treselection of 1.28 and 2.56 second provide the least amount of ping-pong reselections as they are least likely to trigger reselection on average.
- Single setting 1 and dual settings 4-5 cause more ping-pongs than cell reselection based state detection settings 6-7 as it takes at least T_{CRmax} for UE to switch to HIGH state (same as single setting 1), if UE velocity changes from 3 kmph to higher velocity.
- In ISD 3000 case, there are more ping-pong reselections than in ISD 500 case: Depending on the cell reselection scheme, 3-10% of reselection are ping-pongs in ISD 500 case and 7-23% in ISD 3000 case.

The conclusion from these is that the like with the amount of reselections, the largest amount of ping-pongs are triggered with the dual triggering scheme.

Figure 7 shows the proportion of call length in best cell distribution for all schemes in ISD 500 case. As a baseline, single trigger setting 3 shows clearly the worst performance as Treselection of 2560 ms is utilized and cell reselections are delayed the most. Other sets provide 5-10%-units more time camped in best cell at 50-percentile of distribution as mobility state detection or shorter Treselection for single trigger setting is utilized. Both dual trigger settings and cell reselection based state detection adapt well to variable UE velocity conditions, while dual trigger settings 4 and 5 provide 3-4%-units more time in best cell. Dual trigger settings evaluates both triggers constantly, thus it is somewhat faster to adapt current mobility conditions than cell reselection based state detection.

Figure 8 shows best cell distributions for ISD 3000 case. In comparison to ISD 500, the differences between cell reselection schemes are smaller in proportion of time in best cell. Setting 3 shows the worst performance with 5%-units less time camped in best cell than single trigger setting 1 and dual trigger setting 4-5. Also in ISD 3000m case both dual trigger and cell reselection based state detection settings adapt well to variable UE velocity conditions and dual trigger setting provide 1-2%-units more time in best cell at 50-percentile of the distribution.

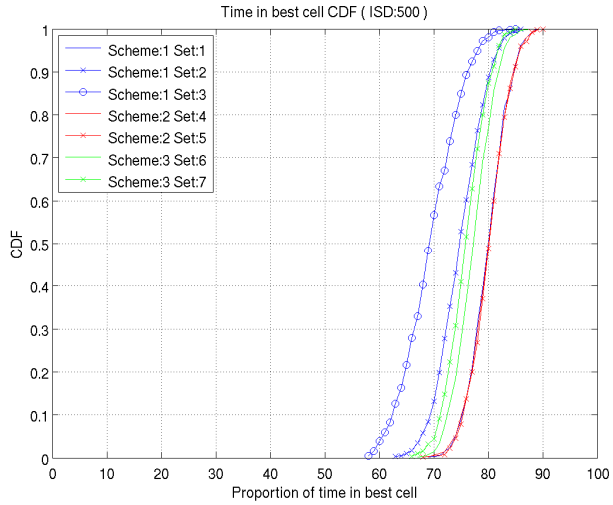

Figure 7. Proportion of time in best cell (ISD 500 m).

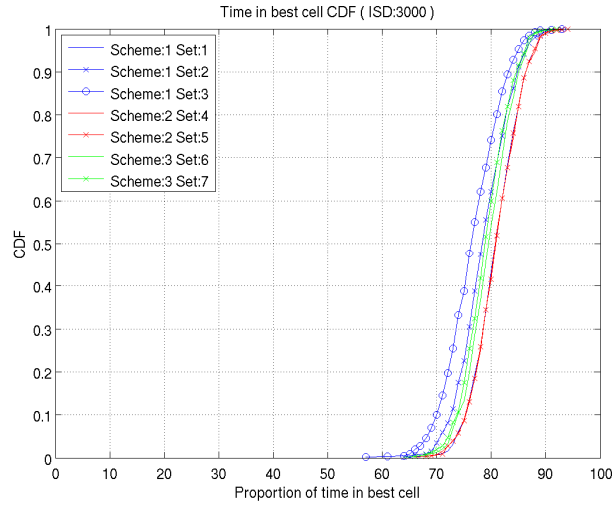

Figure 8. Proportion of time in best cell (ISD 3000 m).

3. Summary on the results presented in this contribution

In the previous section contribution we have new presented results comparing the dual trigger and cell reselection based mobility state detection schemes in variable UE velocity conditions. Additionally results without mobility state detection have been provided as baseline comparison. The results show that both the dual triggering and cell reselection-based mobility state detection scheme perform rather similarly. The dual triggering scheme triggers more reselections but also helps the UEs spend more time in the best cell, whereas the cell reselection-based mobility state detection scheme causes less reselections but UEs also spend slightly less time in the best cell. Overall, the performance of the two schemes was very similar and no major differences are detected.

4. Overview of the results

In addition to the results presented in this contribution, there has been rather extensive evaluation of the different the discussed schemes. According to simulation results (given [1], [2], [3], [4], [5], [7] and this contribution), it seems that both of the discussed schemes achieve more or less equal performance. In this section we try to create a simple summary of the observations made so far. Table 2 below summarises the findings, with + indicating better performance and – indicating weaker performance. Please note that this is not a strict criterion and in most cases the performance is more or less equal.

Metric	Mobility state detection	Dual triggering
Amount of reselections	+	-
Amount of ping-pongs (i.e. repeated reselections)	+	-
Time spent in best cell	-	+
Configuration effort (i.e. amount of parameters)	-	+
Convergence to correct state	- (difficult with three states)	+ (no states)

Table 1. High level summary of evaluations.

Thus as noted along the discussions had the reselection performance achieved is more or less equal. Dual triggering based approach gives slightly higher portion of time at the best cell, with the cost of increased number of reselections and ping-pongs compared to mobility state detection. However it could be said that in broad terms either scheme would seem suitable for the speed adaptation. At the same time there has been made analyses implying (starting from [1]) that there could be some challenges to properly configure the mobility state detection with three states. Reducing the number of state to two alleviates this, but there is still some additional work requited compared to dual triggering based approach in selecting parameters.

5. Conclusion

In this contribution we have presented additional system level results evaluating the performance of the two schemes considered for Rel-9 speed detection. This evaluation was carried out in two scenarios; with ISD of 500ms UE velocity dynamically varying between 3 to 120km/h and with ISD of 3000m velocity dynamically varying from 3 km/h to 350km/h. The evaluated metrics were amount of reselections and portion ping-pong reselections together with the portion of time spent in best cell. Overall, the performance of the two schemes was very similar and no major differences are detected.

Additionally a short overview of the findings made in previous evaluations was done in order to have more concise summary of the possible benefits of either scheme. Final decisions of course depends on the weight put on each performance area and as noted performance wise discussed schemes seem to be more or less equal with dual triggering having some merit in simpler parameter configuration.

As raised in earlier discussions in RAN4, there seems to be some consensus in RAN4 that only single scheme should be determined for the speed dependent scaling. Thus if it is decided to introduce dual triggering based scheme to Rel-9 specification, mobility state detection based scheme should be removed. This should also be extended to connected state where the mobility state detection scheme is also used to adjust the TTT. To avoid further duplicate implementation work and unnecessary IOT testing the handling of speed dependent scaling in Rel-8 should be considered. As the Rel-8 ASN.1 has been frozen it does not seem practical to introduce dual triggering based scheme to Rel-8. Therefore it would seem best to disable the mobility state detection based approach from Rel-8 if dual triggering based approach is used to replace mobility state detection in Rel-9.

References

[1] R4-080725, Initial evaluations of mobility state detection in UE, Nokia, Nokia Siemens Networks

[2] R4-081119, Mobility state detection in UE, Nokia, Nokia Siemens Networks

[3] R4-081120, Further results of the mobility state detection in UE, Nokia, Nokia Siemens Networks

[4] R4-081121, Initial results for the dual filter based mobility adaption, Nokia, Nokia Siemens Networks

[5] R4-091354, Further evaluation of dual filtering and cell reselection based mobility state detection, Nokia, Nokia Siemens Networks

[6] R4-091287, Evaluation methodology and time plan for studying mobility state detection-based cell reselection, Ericsson

[7] R4-091866, Simulation results for mobility state detection cell reselection, Ericsson

[8] 3GPP TS 36.133, “Requirements for the support of radio resource management”, v. 8.5.0

Annex A: Simulation parameters

Feature/Parameter		Value/Description
Bandwidth		5 MHz
IFFT/FFT length		512
Duplexing		FDD
Number of sub-carriers		300
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, 3000 m
	Minimum distance between UE and cell site	35 m
	Antenna pattern	70-degree sectored beam
Distance-dependent path loss		$128.1 + 37.6\log_{10}(r)$
Shadowing standard deviation		8 dB
Shadowing correlation between cells/sectors		0.5 / 1.0
Multipath delay profile		Typical Urban
UE Velocity		Variable UE velocity ISD 500: [3, 50, 120 kmph] ISD 3000: [3, 50, 120, 250, 350 kmph]
Handover Measurement	Measurement period	1280 ms
	Measurement bandwidth	6 RBs
	Measurement error	3 dB
	Sliding window size	2 samples
	Window length for mobility state detection (T_{CRmax})	ISD 500: 30 seconds ISD 3000: 60 seconds
	The amount of cell reselections per window for HIGH state (N_{CR_H})	2
Receiver diversity		2RX MRC
Number of UEs/cell		10 (570 UEs in the whole network)
Interference load		50% of full RB load