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Comparison of different distributed scheduling strategies for Static/Dynamic LTE scenarios

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Comparison of different distributed scheduling strategies for Static/Dynamic LTE scenarios.

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Abstract— this paper explains the main results of a system simulator software tool, specifically oriented to allow a comparison of different distributed LTE scheduling strategies for static/dynamic scenarios and therefore under different traffic patterns. Full Buffer (static) as well as VoIP and WebTraffic (dynamic) UEs have been considered through the simulations. Tested algorithms include Fixed Reuse R1, Reuse R3, a mixed scenario (with R1/R3 for high/low SINR UEs), a scenario with three type of UEs, fixed reuse and correspondingly three different transmitted power levels, Soft Frequency Reuse and Reuse Partitioning. Analyzed parameters are the SINR, Cell Throughput and UE throughput distribution that can be studied globally or separately by user type.

I. INTRODUCTION

A regular cell layout is considered, where for each cell the BS scheduler assigns the physical resource blocks (PRBs) to the UEs determining also the modulation type and coding. There are M UEs distributed along the whole scenario (B eNBs) so the number of UEs served by eNB b is M_b. Each eNB has available N PRBs, P_N is the receiver thermal noise at PRB, î is the serving eNB for user i, L_{ib} is the path loss (including shadowing fading) between eNB b and user i and P_{bn} is the transmitted power by eNB b in PRB n. With these considerations, SINR measured by user i on PRB n is:

$$SINR_{in} = \frac{P_{\hat{i}n} / L_{\hat{i}i}}{P_N + \sum_{\substack{b=1 \\ b \neq \hat{i}}}^{B} \left(\sum_{m=1}^{M_b} u_{mn} \cdot P_{bn} / L_{ib} \right)}$$

where u_{mn} is 1 if PRB n is assigned to user m and 0 if not.

Scheduling strategies analyzed here can be implemented in a complete distributed system, with no coordination, because it has been decided previously which are the subbands and the power levels associated to each cell and subband. So the eNBs only have to choose the best PRB (and the number of PRBs) for a given UE based on its quality indicators (in this case on its SINR).

- $SINR_{in,worst}$, assuming that all eNBs use all PRB simultaneously is obtained for all the UEs. After this UEs are classified according to internal, intermediate and cell edge eUEs (for some algorithms just two types is enough).
- Assign one PRB per UE, starting with the one with highest $SINR_{in,worst}$ and recalculating SINRin,real (with real interference level) of all the UEs that have been assigned the same PRB.
- If there are still free PRBs when finishing, a RR (Round Robin) scheme can be used starting again with the UE with the best $SINR_{in,worst}$, or a PF (Proportional Fair) scheme starting with the UE with worst $SINR_{in,worst}$.
- After doing the same with all the UEs of the scenario, main parameters are stored and the procedure starts again ordering randomly the eNBs (to start the assignment with a different one). This is repeated 500 times.

II. SCHEDULING ALGORITHMS TESTED

Most of the algorithms were already described in [1,2], so they are only named here.

<u>Fixed Reuse (Fig1 and 2)</u>: R1 and R3 with constant power per PRB (P_{max}). In principle R1 should be better for scenarios with low traffic while R3 improves the SINR of cell edge eUEs.

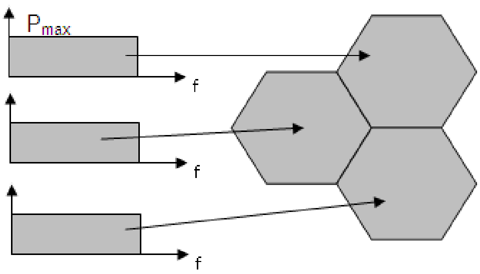

Fig. 1: Reuse 1 (R1) assignment scheme

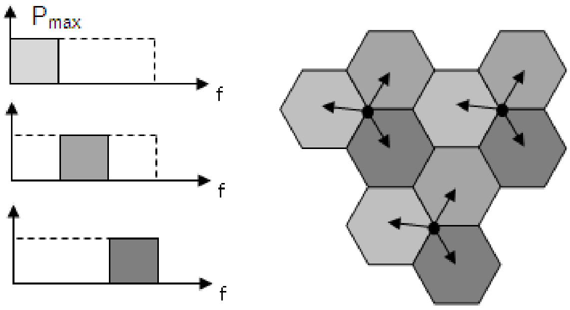

Fig. 2: Reuse 3 (R3) assignment scheme.

<u>Mixed Scenario (Fig.3)</u>: combines R1 for internal users and R3 for cell edge users at a constant power P_{max}. The eNB starts assigning resources to central users on the other two subbands. If there are no cell edge users or they do not need all the assigned subband, central UE can expand.

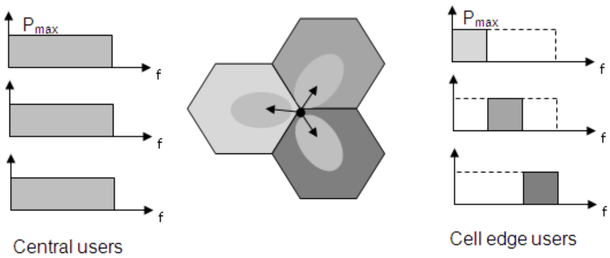

Fig.3: Mixed Scenario assignment scheme

<u>*Three type of UEs (Fig.4)*</u>: The cell uses all the band but restricted to different type of UEs and with different power levels. Central UEs are served first with the low power subband (if it's not enough next subband can be used but maintaining the low power level). Then intermediate and finally cell edge UEs are served with the same criterium.

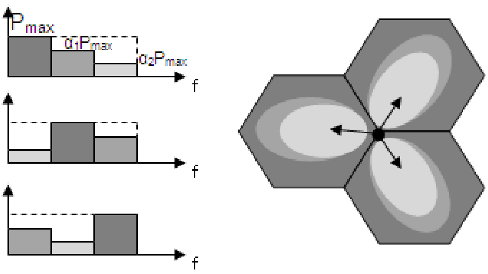

Fig.4: 3 type of UEs assignment scheme

Soft Frequency Reuse (Fig.5): it's like mixed scenario but with different power levels. Each eNB has available the whole band but 1/3 with P_{max} (for cell edge UEs) while the other 2/3 use αP_{max}. A variation of *α* allows to adapt to different load conditions.

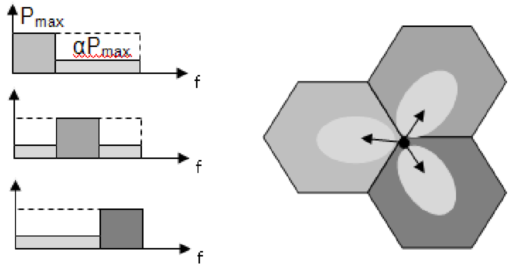

Fig.5: Soft Frequency Reuse assignment scheme.

Reuse Partitioning (Fig.6): Divides also the band in low and high power subbands, but introducing another parameter *b* indicating the % of the total band devoted to low power level (central UEs).

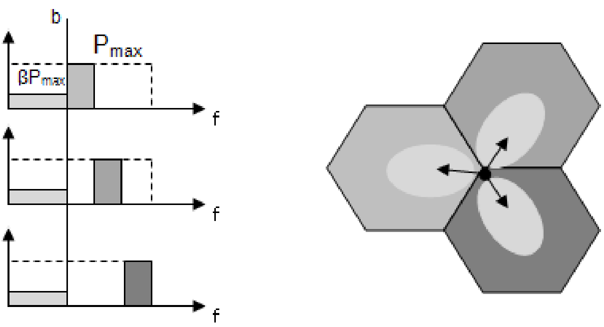

Fig.6: Reuse Partitioning assignment scheme

III. STATIC SIMULATIONS AND RESULTS

Main simulation parameters are given en in Table1 [3,4]. As can be observed in Fig.6 R3 presents the best results in terms of SINR being the worst R1. The mixed scenario represents an intermediate case but obtains a better throughput (Fig.10). The other scheduling schemes (three type of UE, soft frequency reuse and frequency partition schemes) have SINR cdf that lay in between R1 and R3 results, and for this reason they have not been included in the paper.

Representing the histogram of the cell throughput in Fig.7 it can be appreciated that the mixed scenario outperforms R1 and R3. This can be also seen in the cell throughput cdf (Fig.10). Looking to the users throughput distributions (Figs. 8 and 9), it can be seen that there are more users with lower rates compared with R1 and R3 strategies, but there are also more users with very high throughputs (compared with R1 and R3 schemes). From this analysis we can conclude that even if the SINR distribution is a bit worse than in R3 scheme, the scheduling algorithm is efficient in terms of global cell throughput and also in terms of individual UE throughputs.

Parameter	Value
Carrier frequency	2 GHz
Transmission bandwidth	20 MHz
Sub-carrier spacing	15 KHz
OFDM PHY parameters	CP of 4.69 µs 7 modulation symbols/sub-frame (2 for control)
FFT size	2048
Number of useful sub-carriers	**1200**
OFDM symbol duration	71.43 µs
Number of sub-carriers per PRB	12
Sub-frame duration	0.5 ms
TTI length	1 ms
Number of OFDM symbols per TTI	14 (4 for control)
Frame duration	10 ms
Superframe duration	600 ms
Transmission model	Localized
Power delay profile	EPA channel model Pedestrian speed 3 km/h

Table1: Scenario parameters

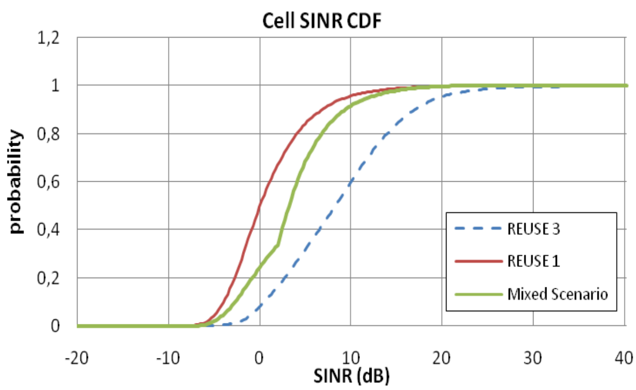

Fig.6: SINR Cumulative Distribution Function

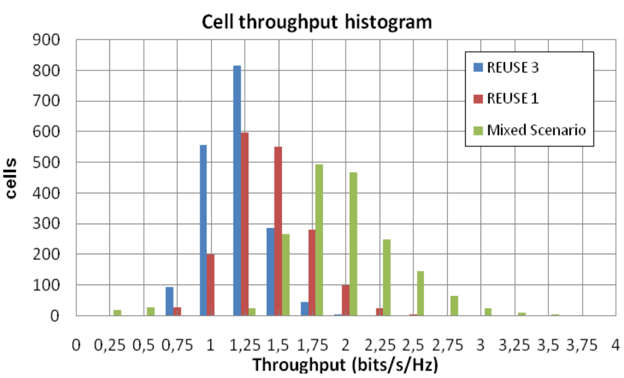

Fig.7: Cell Throughput histogram

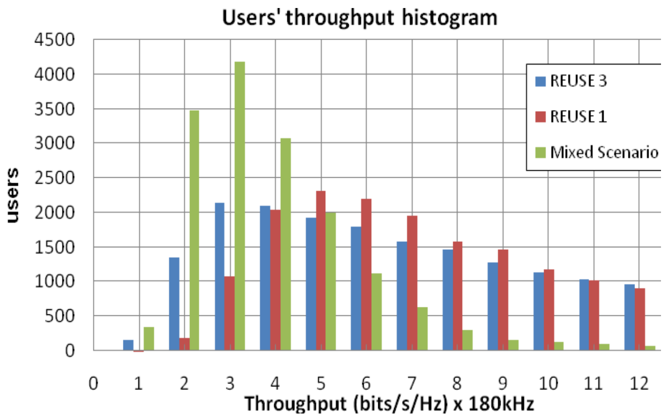

Fig.8: Users throughput histogram (low throughput)

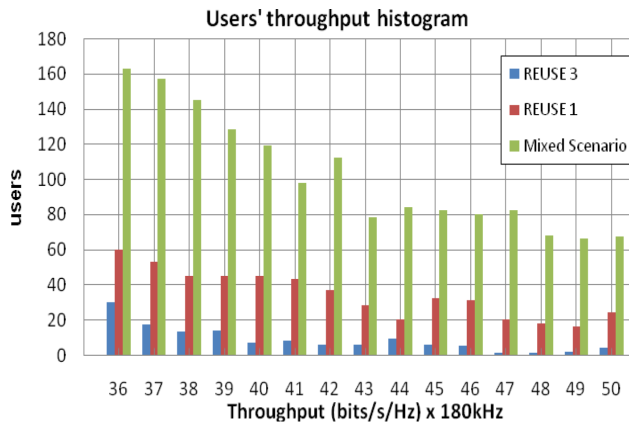

Fig.9: Users throughput histogram (high throughput)

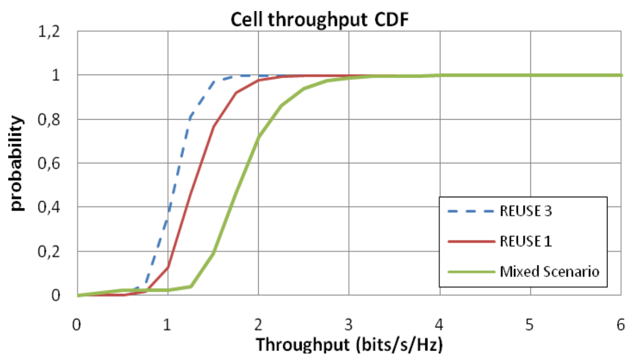

Fig.10: Cell throughput cumulative distribution function.

Figures 11, 12 an 13 compare the performance of cell throughput cdf, UEs throughput histogram and UEs throughput cdf for 3Type of Users giving also as reference the R1 and R3 results. This scheme shows worst results in both SINR and cell throughput distributions, being close to R3 values. In terms of UEs throughput also moves the histogram to higher values, as in Mixed Scenario but without achieving the same increment. In fact for values higher than 14 bits/s/Hz is worse than R1 and R3 strategies. This can also be appreciated in the figure where UE throughput cdf is represented. There is an improvement for low throughputs but at 50% crosses the R1 distribution and at 60% the R3 scheme being since then the worst option. We can conclude that this technique is worse in terms of global cell throughput but helps those UEs with low rates facilitating them a significant increase. This of course will depend a lot on the power levels considered in the simulation requiring a more detailed analysis that has been presented in another COST paper. We should remember that most of that techniques were introduced not to increase the global throughput, but to improve the performance of the cell edge UEs (those with in principle low SINR and consequently low throughput). Moving the figure to the right, to higher throughputs, means that the starting objective has been acomplished.

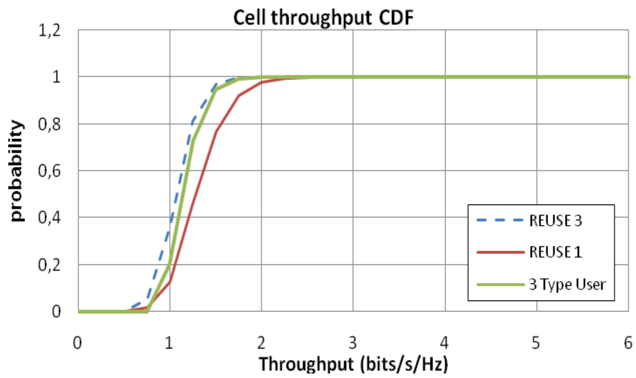

Fig.11: SINR c.d.f. for 3Type Users

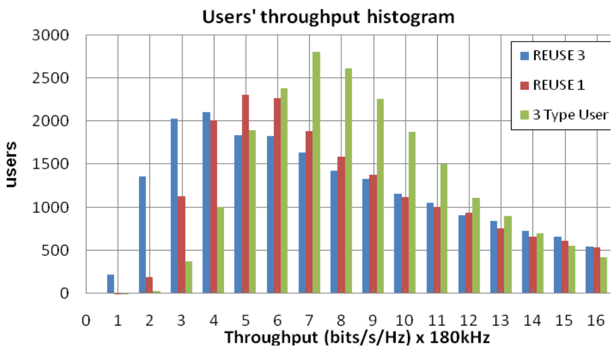

Fig.12: UEs throughput histogram for 3Type Users

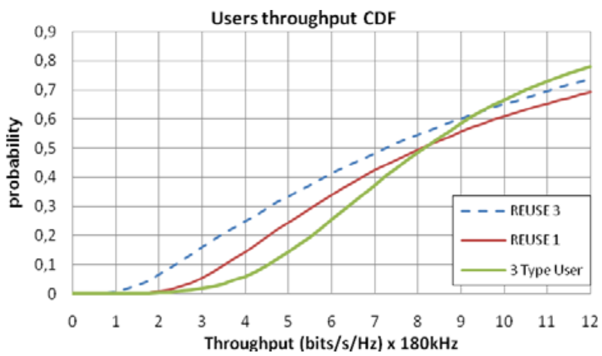

Fig.12: UEs throughput cdf for 3Type Users

Finally it seems interesting to be able to analyse in a separate way what happens to cell edge, intermediate and internal users.

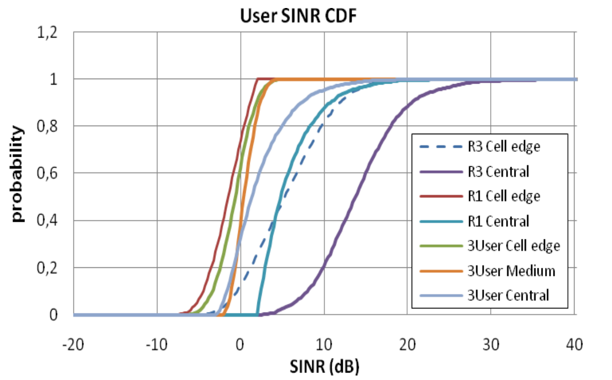

Fig.13: SINR Cumulative Distribution Function for different type of UEs

In fig.13 it can be clearly appreciated that central UEs always experience a better cdf than cell edge or intermediate UEs. What can cause misunderstanding is that there is some overlapping between results. We should remember that the UEs are initially classified according to their worst SINR (maximum interference). After applying the scheduling algorithm the final SINR of most of the users is higher than the worst value, but the UEs still belongs to the same category even if its SINR and its throughput are higher than the maximum values expected from this category (the do not change of category once they have been initially classified).

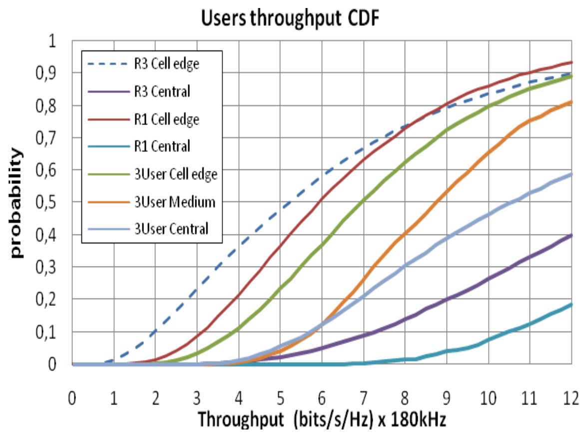

Fig. 14: UEs throughput cdf for different type of UEs

From fig.14 it can be seen that central R1 UEs achieve better rates than central 3type UEs mainly because they can use less PRBs. R3 central UEs cdf is also better because although they have less than 1/3 of the PRB, they have less interference and their transmission power is higher. But if we focus on cell edge UEs we can appreciate that t3Type UEs algorithm has clearly better performance than R1 and R3, because they transmit at maximum allowed power, they have more PRBs than R3 and less interference than R1.

Fig. 15 shows that for soft frequency reuse scheme for high utility factors (α close to one) the global cell throughput cdf is better than with all the previous algorithms, while for the minimum utility factor 0.3 (corresponding to α=0) is the worst case analyzed here.

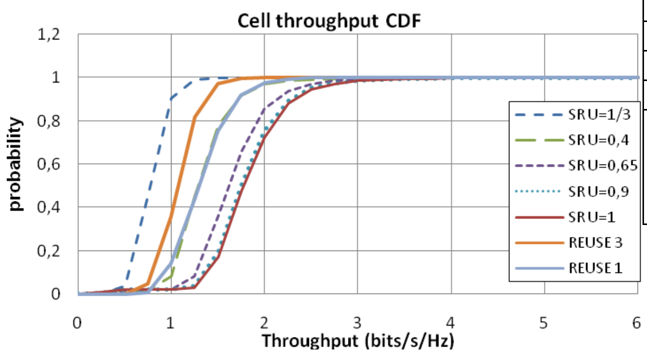

Fig.15: cell throughput cdf for soft reuse scheme with different utility factors.

The last figure corresponding to the static scenario is the one that corresponds to the global cell throughput cdf for reuse partitioning schemes with different utilities and partitions. We can appreciate that the effect of changing the partitions is considerable while changing the powers and therefore the utilities is not so determinant (for intermediate cases).

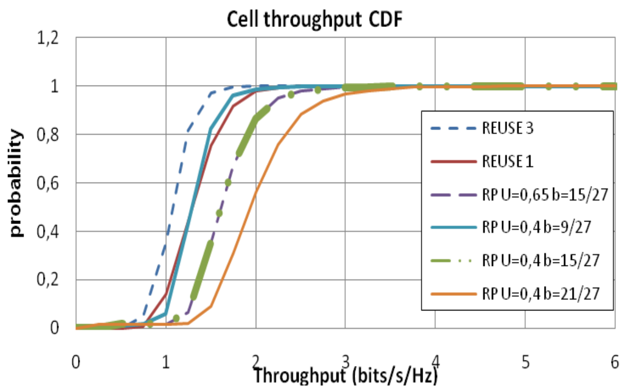

Fig.16: Cell throughput cdf for reuse partitioning.

IV. DYNAMIC SIMULATION AND RESULTS

Parameter	Value
Load	Average of 1, 4, 7, 10, 30 and 50 users per cell
Simulation time	1000 TTIs (1 TTI last 1 ms)
Web traffic	200 kB object size
VoIP traffic	32 B packet size 1 packet every 20 ms

Table 2: Specific dynamic scenario parameters

UEs are removed when they have finished their web download and then a new UE is created at a random position in the scenario to keep constant the average number of UEs [3].

Header	Web Traffic	VoIP traffic
TCP/UDP	24	24
IP	20	20
RLC	16	16
MAC	14	14
PHY	200 Kbytes/page	32 bytes every 20 ms(RTP Header of 12 bytes and 2 10 ms frames of 8 kbps coded speech.

Table 3: Traffic parameters

After running all the simulations the same performance parameters than in the static scenario have been obtained for the same scheduling schemes described previously. What can be in general appreciated is that in all the cases the results when considering 1 to 50 users per cell are in between those given for a static scenario, being closer to the static when the number of UEs increases. Another characteristic is that it has no sense to represent figures for different type of UEs because VoIP UEs generate a negligible traffic when compared with web UEs. For this reason we have only represented here fig.17, which corresponds to the soft frequency reuse algorithm with α=1. Comparing with fig.15 we can see that for 50 UEs the results are quite similar, while for lower number of UEs.

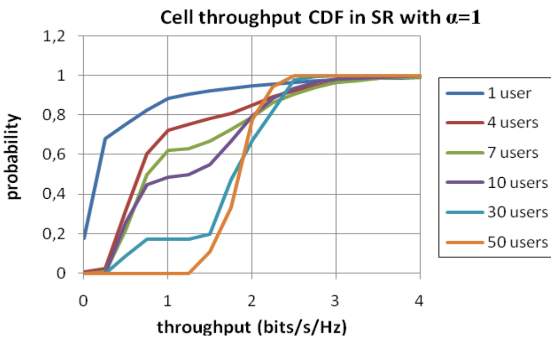

Fig.17: cell throughput cdf in soft frequency reuse with α=1

I. CONCLUSIONS

Regarding to the cell throughput what can be seen is that the Reuse Partitioning scheme with *b*=21/27 is the one that obtains better rates. For example, in the 60th percentile achieves 360 Kbits/s. The problem with this scheme is that cell edge users have "reserved" less than 1/3 of the band. If this supposes a problem, there are other systems that also provide high values like the mixed scenario achieving 290 Kbits/s and in the same way SR with *U*=1 or even with *U*=0.9.

It is difficult to find a scheduling that improves simultaneously the throughput of both type of UEs. A good option could be SR with *U*=0.4, where cell edge users have better rates tan R1 and R3, achieving in the 60th percentile 1.44 Mbits/s while central users' rates do not exceed the R1 and R3 results but obtains in the 40th percentile rates of nearly 2 Mbits/s.

Finally one of the drawbacks that commonly are attributed to the results given by static simulations is that a real scenario is always dynamic, and therefore significant differences could be observed. In our simulation of a dynamic scenario with two type of UEs and changing the number of UEs per cell, we have not appreciated bit differences, and so this could validate the use of static and therefore faster and easier simulation tools. Anyway a dynamic scenario requires the definition of other quality parameters, that have still not been programmed in this tool, and probably will allow a better understanding and analysis of the differences.

ACKNOWLEDGMENT

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