A RADIO RECONFIGURATION ALGORITHM FOR DYNAMIC SPECTRUM MANAGEMENT ACCORDING TO TRAFFIC VARIATIONS

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ABSTRACT

The deployment of different RATs (Radio Access Technologies) that coexist temporally (i.e. at the same time) and geographically (i.e. on the same area), gives the opportunity to network operators to jointly manage the resources, in order to adapt the network to the behavior of the traffic and to globally maximize the capacity. For instance, in a certain geographical area (e.g. a city), it could occur that the offered traffic is not uniform in time and in space. In addition, in case of deployment of two or more RATs in the same area, the traffic offered to each deployed RAT could be differently distributed in time and space with respect to the traffic offered to the other deployed RATs.
This paper focuses on this dynamic context, describing a new algorithm for the Radio Resource optimization to be used in a network deployed with Reconfigurable Base Stations. The aim of the new algorithm is to give network operators a mean for optimally managing the radio and hardware resources among different RATs and increasing the overall capacity of the whole network. In the paper some preliminary performance results obtained by means of simulation are also presented.

1. INTRODUCTION

The last few years have seen the deployment of different RATs (Radio Access Technologies) covering the same geographical area at the same time. A typical example is the network operator that already owned a network and deployed a new one related to a new generation system (e.g. a network operator deploying an UMTS network and already having a GSM one). In this scenario, network operators owning two or more RATs are discovering the new opportunity to jointly manage the resources of the deployed RATs, in order to adapt the network to the behavior of the traffic and to globally maximize the capacity.
It is well-known that in a certain geographical area (e.g. a city), the offered traffic could be not uniform in time and in space. This usually leads to a congestion situation (i.e. high blocking percentage) in some portions of the considered area in which the traffic is more heavy (typically these portions are called hot-spots), while the other portions of that area may be characterized by lower blocking percentages since they are less loaded. In addition, in case of deployment of two or more RATs in the area, the traffic offered to each deployed RAT could also be differently distributed in time and space with respect to the traffic offered to the other deployed RAT.
In this context, the availability of reconfigurable nodes in the networks (i.e. nodes whose hardware resources can be reconfigured in order to be used with different RATs, frequencies, channels, etc.) will give the network operators the means for managing in a globally efficient way the radio and hardware resource pool, with the aim to adapt the network itself to the dynamic variations of the traffic offered to the deployed RATs and to the different portions of the area. As an example, it could be considered the deployment of GSM and UMTS systems in a geographical area with a network built with reconfigurable nodes. In this kind of network, the reconfigurable hardware resources are shared between GSM and UMTS functionalities. During the daily life of the network, it could be needed, for instance due to different traffic loads on the two RATs, to increase the percentage of hardware resources devoted to the over-loaded system while decreasing the resources given to the other (supposed under-loaded). In Figure 1, a reconfiguration example increasing UMTS resources is depicted.

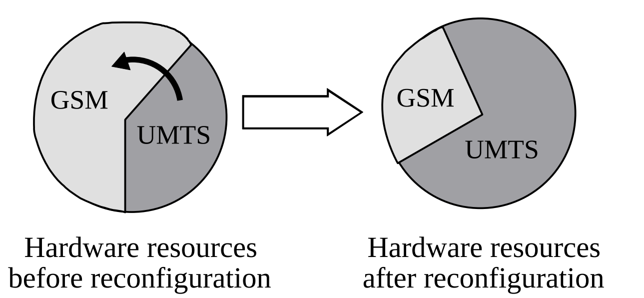

Figure 1: Reconfiguration example

This paper focuses on this context describing a new algorithm for the Radio Resource optimization to be used in a network deployed with Reconfigurable Base Stations and reporting some preliminary performance results obtained via simulations. In particular, in the second section of this paper the reference architecture for the reconfigurable network is described; in the third section, the main principles of the optimization algorithm are reported; in the fourth section, the performance results obtained by means of simulations in a single-RAT scenario are reported.

2. REFERENCE ARCHITECTURE

The reference network architecture considered in the study described in this paper is reported in Figure 2 and is constituted by a radio controller node of the access network of a radio cellular system (e.g. BSC in the case of GSM system, or RNC in the case of UMTS system) and one or more base stations BS1,…,BSk. The radio controller node is connected to a Core Network.

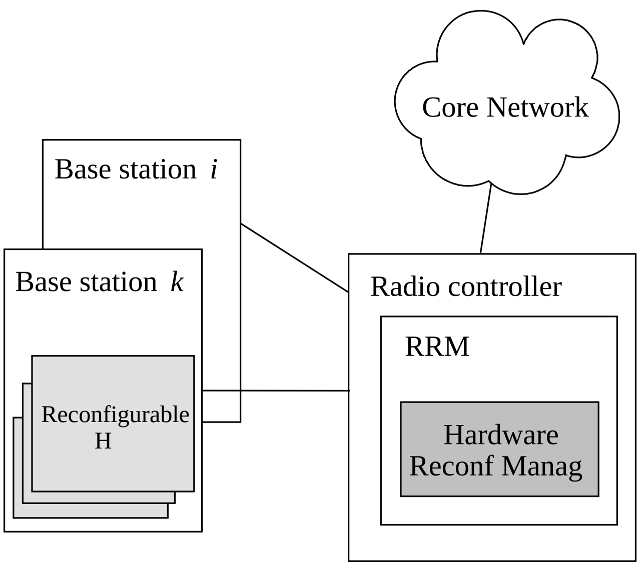

Figure 2: Reference network architecture

Each base station (BS1,…,BSk) is a multi-RAT base station, able to manage connections of different RATs at the same time (e.g. a multi-RAT GSM and UMTS base station is able to manage GSM and UMTS parallel connections for different users). In addition, the base station BS1,…,BSk are reconfigurable nodes, i.e. each one has its own reconfigurable hardware pool, constituted by hardware/software reconfigurable transceiver modules shared between supported RATs. In principle, each reconfigurable base station considered in this study can be reconfigured in two different dimensions:

- percentage of hardware resources devoted to each supported RAT
- active radio resources (e.g. frequency carriers) for each supported RAT.

The radio controller includes the RRM (Radio Resource Management) entity which aim is to assign the radio channels to the mobile terminals that are in the cells managed by the base station BS1, …, BSk. In addition, the RRM has a new functionality called Hardware Reconfiguration Manager. This functionality is devoted to:

- monitor the current traffic status of the cells for each supported RAT
- execute the reconfiguration algorithm, that decides which base station(s) are to be reconfigured
- manage and control the reconfiguration process of the hardware resources in the reconfigurable base stations.

The reconfiguration algorithm running inside the Radio Controller in the RRM entity determines which base station(s) are to be reconfigured, with the aim to adapt the percentages of hardware resources devoted to each supported RAT and to dynamically shape the active radio resources to the behavior of the traffic. Thus, the Radio Controller commands the hardware resource reconfiguration to the base station(s) through the interface between each base station BSk and the radio controller (e.g. Abis interface in the GSM network or Iub interface in the UMTS network). In order to support the reconfiguration, this interface requires an extension with a new protocol message bearing the information needed to the base station for the appropriate reconfiguration action (e.g. hardware resources and radio resources - such as frequency carriers - to activate/deactivate for each supported RAT). In Figure 3 an example of the reconfiguration procedure is depicted.

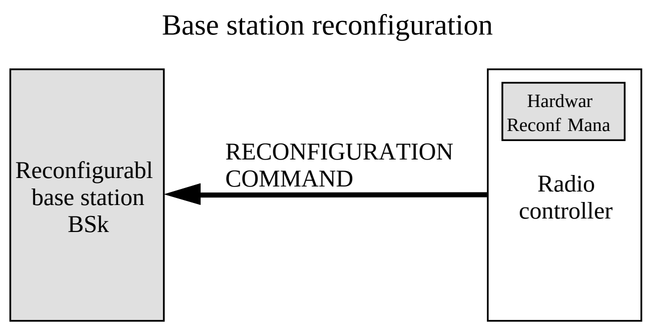

Figure 3: Reconfiguration command from radio controller to base station

The process described above is then repeated for each base station involved in the reconfiguration process.

In the next section, the algorithm behavior will be described, with the aim to clarify how the reconfiguration process is triggered.

3. ALGORITHM DEFINITION

The basic principle of the algorithm is to allow hardware and radio resources to be dynamically (re)distributed among and inside different RATs, according to traffic conditions and interference levels.

In principle, when the traffic condition on one RAT increases and the blocking probability accordingly increases above a threshold, the algorithm evaluates the most appropriate action to be taken on the involved cells, in order to decrease (or cancel) the blocking probability:

- if the traffic situation allows it, the hardware resources devoted to other RATs could be reduced and the saved amount will be given to the RAT which has an increased blocking probability
- the shifting of hardware resources from one RAT to another RAT involves to also reshape the planning of radio resources (e.g. frequency carriers) in the different supported RATs. The algorithm acts with the aim to keep the interference at an acceptable level, taking into account the first tier of cells of each involved cell.

As an example, considering a geographical area covered with two RATs such as GSM and UMTS with a fifty-fifty distribution of hardware resources between these two systems, in a portion of this area an high offered traffic situation (i.e. overloading and congestion situation with high blocking probability on new connections) is experienced for the UMTS system while a low offered traffic situation (i.e. null blocking probability on new connections) for the GSM system is obtained. In this context, the algorithm running inside the Hardware Reconfiguration Entity will operate on the transceivers of the involved base stations for reconfiguring the hardware and radio resources of the cells in order to reserve to the UMTS system more processing capacity and more radio resources.

In Figure 4 it is depicted the example described above. Before the reconfiguration, a given percentage HU' of hardware resources is devoted to UMTS system and a given percentage HG' of hardware resources is devoted to GSM system, with an amount of radio resources RRU' assigned to UMTS and an amount of radio resources RRG' assigned to GSM. After the reconfiguration due to increased traffic on UMTS system, the percentage of hardware resources devoted UMTS systems is increased to HU", with an increased amount of radio resources RRU" assigned, while the hardware resources devoted for the GSM are decreased to HG" with a decreased amount of radio resources RRG" assigned.

The Hardware Reconfiguration Entity is performing a periodical monitoring activity, in order to derive the evolution of the traffic conditions in each cell of the supported RATs.

For each monitoring period and for each cell, the Hardware Reconfiguration Entity collects the current carried traffic and at the end of the monitoring period, the entity evaluates for each cell if it is needed to perform a reconfiguration in the Base Station, analyzing the current carried traffic:

- the cells with a low carried traffic condition (below a threshold THRlow set by the operator) will be reconfigured in order to free hardware resources and related radio resources that could be used by the neighbor cells
- the cells with a high carried traffic condition (above a threshold THRhigh set by the operator) will be reconfigured in order to increase their hardware resources and radio resources if there are some available resources from the neighbor cells.

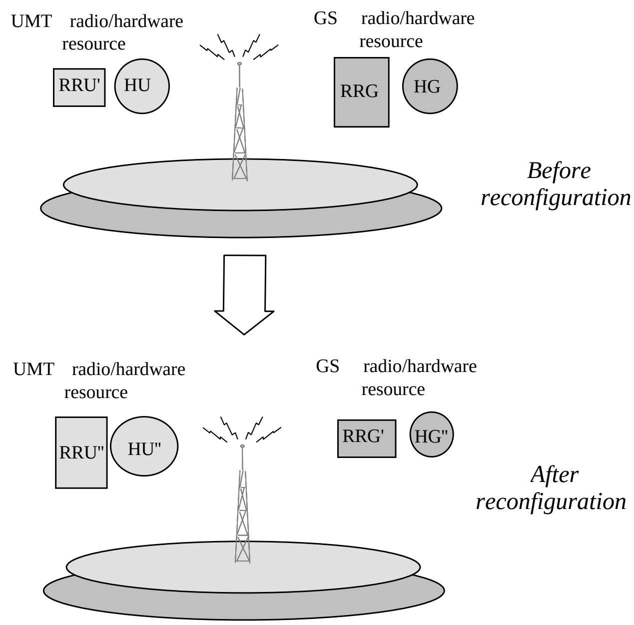

Figure 4: Hardware and radio reconfiguration example

The algorithm verifies also if the involved base stations have enough hardware resources for the foreseen reconfiguration and if the active connections on all the supported RATs will not be affected by the reconfiguration.

An example of the algorithm flow-chart referring to the case of the GSM is reported in Figure 5. In the flow-chart, the first block of the diagram reports the steps used to evaluate if to increase the number of GSM radio resources inside a particular cell, while in the second block the steps required to evaluate if the number of radio resources in a cell may be decreased are reported.

The algorithm takes also into account the BCCH carriers and the original (i.e. initial) planning made by the operator. More in detail, if, during the analysis, a frequency carrier bearing the BCCH channel should be removed, the algorithm avoid to perform the reconfiguration in order to maintain the same level of coverage in the considered area.

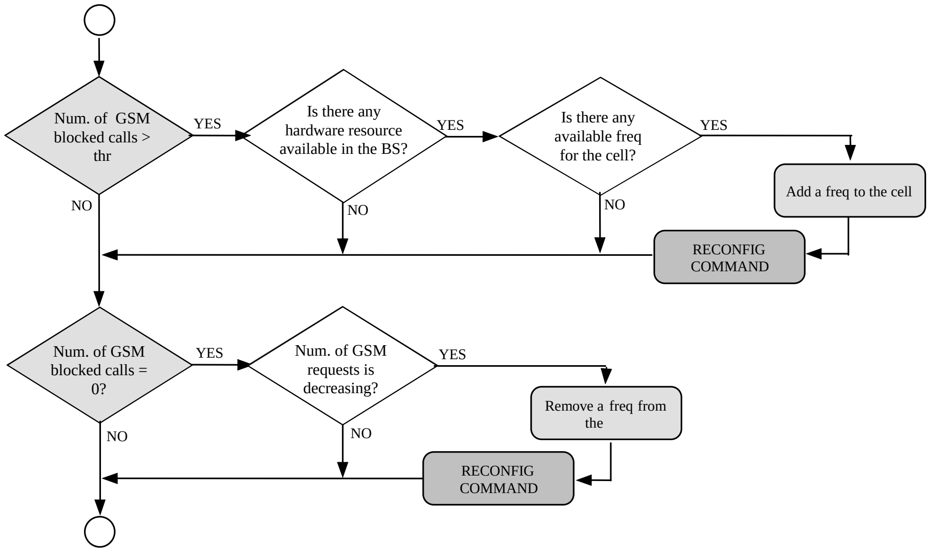

Figure 5: Algorithm flow-chart for the reconfiguration in the GSM system

In addition, the algorithm stores the original planning made by the network operator, that is the initial planning made when the network has been deployed. During the life time of the network, the actual planning could be different due to further reconfigurations of radio resources among cells.

4. PERFORMANCE ANALISYS

In this section, preliminary performance results obtained by means of simulations are reported. At this first stage, the analysis has been focused on the GSM system only, since the algorithm is in principle RAT-independent and does not require a multi-RAT scenario to operate correctly.

The GSM scenario considered in the simulations is a macro-cellular layout with an ideal regular hexagonal coverage. This scenario is characterized by one BSC that manages twelve base stations controlling three cells each. The cell radius is about 1150 m. The whole simulated area measures about 94.5 km^2 (9 km x 10.5 km). The spatial disposition of the base stations in the simulated area (where each site is tri-sectorial) is depicted in Figure 6.

In the figure, dashed circles highlight the hot-spots where the traffic is heavy (i.e. high blocking percentages is experienced), while surrounding cells are less loaded (i.e. characterized by null blocking percentages). The algorithm acts for reconfiguring the base stations related to the hot-spot areas in order to decrease the blocking percentage, taking some resources from the less loaded neighbor cells.

The following simulation parameters have been considered, with the aim to stress the reconfiguration functionalities of the algorithm:

- cells characterized by low traffic situation have an offered traffic of about 0.3 Erlang

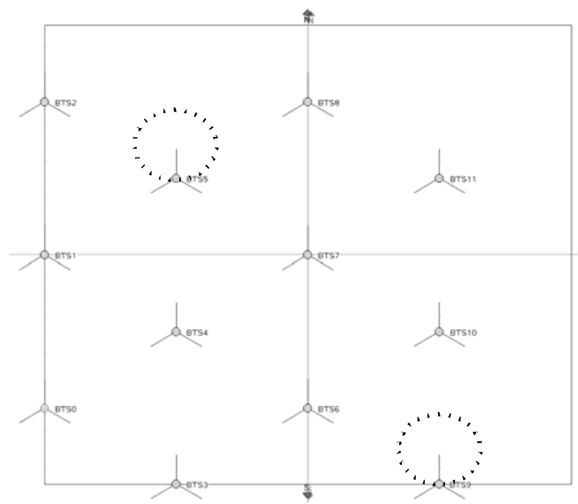

Figure 6: Simulated GSM scenario

- hot-spots have an offered traffic of about 100 Erlang
- the monitoring period T of the Hardware Reconfiguration Manager has been set to different values from 50 to 1400 s
- hardware resources for each cell have been set to 15 RES (it is supposed that one RES corresponds to the hardware resource necessary for one transceiver)
- in the initial planning each cell has five active frequency carriers, i.e. each cell initially has its own hardware configured to support five transceivers (TRX) with the channels allocation reported below:

		Time Slots							
		TS #0	TS #1	TS #2	TS #3	TS #4	TS #5	TS #6	TS #7
Frequencies	TRX #1	BCCH	SDCCH	SDCCH	TCH	TCH	TCH	TCH	TCH
	TRX #2	SDCCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH
	TRX #3	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH
	TRX #4	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH
	TRX #5	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH

Note: BCCH = Broadcasting Control CHannel, SDCCH = Stand-alone Dedicated Control CHannel, TCH = Traffic CHannel

In order to evaluate the efficiency of the algorithm, the following statistics have been analyzed in the hot-spots and in the surrounding cells:

- the effective blocking percentage
- the blocking situation estimated by the algorithm
- the number of active frequency carriers
- the number of available frequency carriers per cell (i.e. the frequency carriers that could be added to the cell since they are not used in the neighbor cells).

In the following, some relevant results are reported and analyzed.

Figure 7 depicts the temporal evolution of the blocking percentage in hot-spot cells, in case of T = 600 s. The behavior of the percentage is inline with the expectations, decreasing during the simulation time since new radio resources are added to the cell from about 60% to 10%. In addition, it can be noted that the percentage increases during the first period T and then decreases. The algorithm, indeed, requires an estimation of the blocking situation in each cell before acting and this operation is done during the first period T in which many of the incoming connections are blocked.

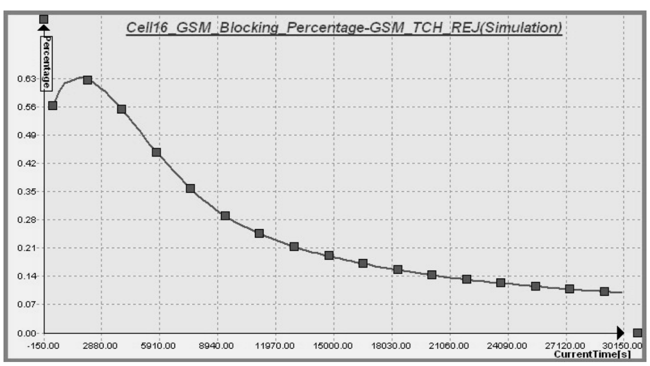

Figure 7: Blocking percentage evolution in hot-spot cells

Figure 8 reports the blocking situation estimated by the algorithm; comparing this curve with the blocking percentage depicted in Figure 7 it is clear that the former is correctly aligned with the latter.

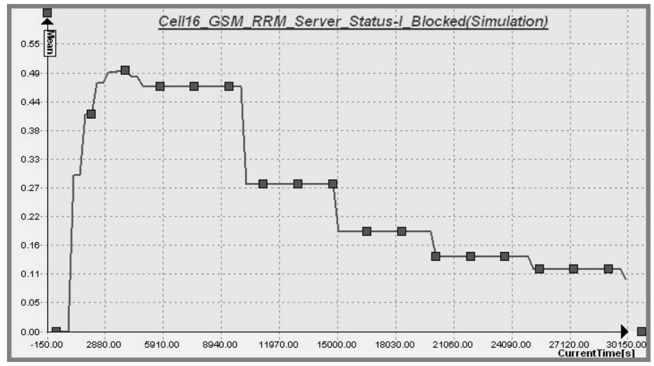

Figure 8: Estimated blocking situation in hot-spot cells

As further verification of the behavior of the algorithm, Figure 9 and Figure 10 report the temporal evolution of the number of active frequency carriers respectively in the hot-spot cells and in the other cells. Also in this case the results are coherent with the others and inline with the expectations: in the hot-spot cells the number of active frequency carriers increases during the simulation time from 5 up to 14 thanks to new activated hardware and radio resources, while in the other cells the number of active frequency carriers decreases during the simulation time from 5 to 1 since most of the hardware and radio resources have been deactivated.

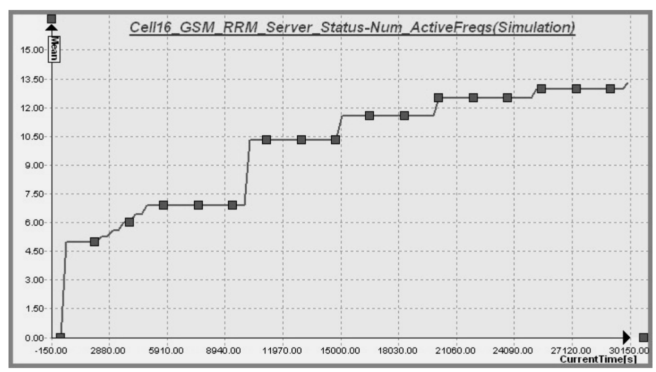

Figure 9: Number of active frequency carriers in the hot-spot cells

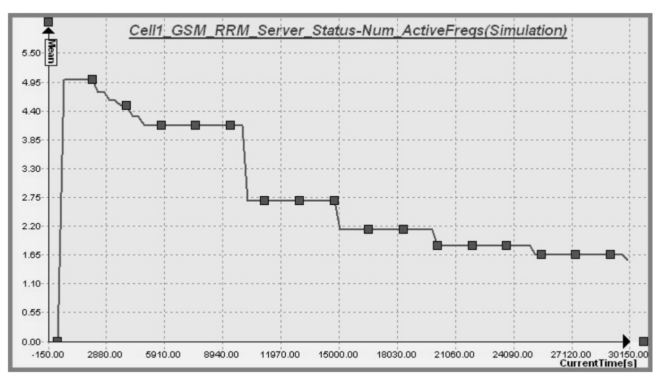

Figure 10: Number of active frequency carriers in the surrounding cells (no hot-spot cells)

The last analysis is related to the effects of the duration of the period T. The blocking percentage evolutions in hot-spots with different values of T (50, 200 and 600 seconds) are depicted in Figure 11. In principle the lower value of T the faster response of the network. Indeed, from the figure the blocking percentage obtained with T = 50 seconds has a curve very deep without any peak, since the reaction of the system to the congestion situation is very prompt. On the contrary, the curve obtained in the case with T = 600 seconds has a strong peak before decreasing, due to the latency of the algorithm as already explained above.

As a general remark, the network operator should take into account the following different factors and evaluating the trade-off of them when setting the value of T:

1. *reaction time of the network*: as described above, with small values of T the network is very reactive to blocking percentage variations
2. *reconfiguration impacts*: performing too many reconfigurations in a short time could require to send too many signaling messages for configuring and further reconfiguring base stations and could lead the system to a unstable situation due to too fast modifications of the planning; on the contrary, performing too few reconfigurations in a long time could be not much effective, since the time elapsed between the need of a reconfiguration and the time of the actual reconfiguration could be too long.

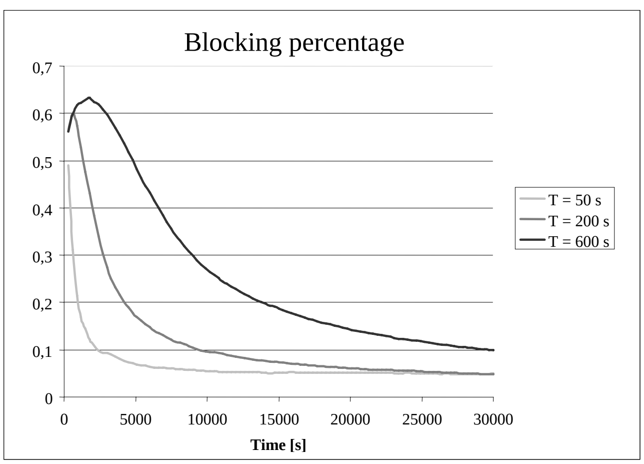

Figure 11: Blocking percentage evolution in hot-spot cells with different valued of period T

5. CONCLUSION

This paper focused on the context of the multi-RAT deployments in the same geographical areas, pointing out the new opportunity for network operators owning two or more RATs to jointly manage the resources of the deployed RATs, in order to adapt the network to the behavior of the traffic and to globally maximize the capacity.

In the paper a new algorithm for the hardware and radio resource optimization to be used in a network deployed with reconfigurable base stations has been described. The aim of this new algorithm is to give network operators a mean for optimally managing the radio and hardware resources among different RATs and increasing the overall capacity of the whole network. In case of GSM network, the paper presented some preliminary performance results, that highlighted the quality of the algorithm.

Further investigations are expected in the future, such as the performance evaluation of a multi-RAT GSM/UMTS network and some evolutions of the algorithms taking into account the obtained results.

6. ACKNOWLEDGMENT

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