Journal of Theoretical and Applied Information Technology
31st October 2017. Vol.95. No 20

ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

AUTO-OPTIMIZATION IN SELF-ORGANIZING NETWORK (SON) FOR 4G LTE CELLULAR SYSTEMS

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ABSTRACT

In this paper, we propose to implement functions of self-organizing networks (SON) for Auto-optimization related to load balancing for LTE mobile radio-cellular systems through ns-3 simulation. The implementation is carried out through two algorithms dynamically adjusting the parameters of the handover (HO) based on the measurements of the received signal strength (RSRP). This adjustment is made as a function both of the load of the congested cell and of the neighboring cells less loaded and arranged to cooperate for a better distribution of the load.

The numerical results obtained by simulation for the two load balancing algorithms implemented and a handover algorithm (already implemented in ns-3) based on the A3 event highlight the advantages of load balancing in terms overall throughput (across the network), loss rates, and number of handovers. It also shows the necessary compromises between these different metrics in order to achieve an efficient load balancing.

Keywords: *Self-Organizing Networks (SON), 4G Mobile Networks (LTE), Load Balancing (MLB), Dynamic Adjustment, Handover.*

1. INTRODUCTION

The rapid development of wireless communications and the emergence of new standards call for convergence towards the fourth generation of mobile communications. Originally planned for the years 2010, it would seem to present its very first commercial achievements slightly earlier. This advance in relation to the forecasts is due in particular to the fact that the fourth generation will not be the outcome of a revolution in communications (as in the second and third generation), but rather the convergence of different Standards, applications and products. Indeed, it seems relevant to consider 4G as the convergence of standards and technologies covered by 3G and wireless local area networks (WLANs). The goal of 4G is to improve the performance of the third generation, without fundamentally changing the content or applications originally planned for 3G.

Recently the demand for traffic in cellular radio networks has evolved in a dizzying manner. To meet this demand, the 3rd Generation Partnership Project (3GPP) has introduced the new 4G Long Term Evolution (LTE) cellular radio system. It adopts simplified all-IP architecture and should provide spectral efficiency which is approximately two to three times higher than that of 3GPP version 6 [1]. LTE will also offer up to 100 Mbit/s downlink (DL) throughput with a spectral bandwidth of up to 20 MHz. LTE systems use the multiplexing and coding technique of the Orthogonal Frequency Division Multiple Access (OFDMA) data in the downlink transmission of the radio interface and the Single Carrier Frequency Division Multiplexing Access (SC-FDMA) on the uplink (UL). For this type of network, the main challenges are the response to user needs in terms of throughput, end-to-end delays and quality of service (QoS) required, especially for real-time traffic. These challenges also relate to meeting the requirements of cellular radio operators in terms of radio resource management (RRM), control and rationalization of operational expenditure, but also in terms of overall network efficiency. In order to meet these challenges, SON technologies have been introduced in LTE networks from Release 9 of the 3GPP specifications [2]. These technologies aim to achieve a high level of operational performance through the automation of a number of tasks such as configuration, optimization and healing (repair) so that LTE networks benefit from the virtues of the self-organization. Automation particularly concerns the dynamic adjustment of network parameters based on radio measurements. The aim is to quickly and flexibly deploy the base stations (ENodeBs) and thus avoid manual adjustments that are often costly, tedious, inefficient and error prone. It is also necessary to reduce capital expenditure (CAPEX) and operational expenditure (OPEX) in order to cope with inter-operator concurrence.

The remainder of this paper is divided into six sections. After introducing, related works are presented in Section 2. The architectures and the SON functionalities in LTE networks is presented in Section 3. Section 4 describes the proposed MLB algorithms. In section 5, an analysis of results of the simulations is presented. Finally, this paper is concluded in Section 6.

2. RELATED WORKS

Numerous works have been developed in the literature to study the capacity of wireless networks. In [14], Li et al. Develops a downlink admission control of the broadband 4G network based on the adaptation of the radio link of the air interface. They decompose the cell into a finite number of regions taking into account a simple propagation model operating with only a path loss as a function of the distance between the mobile and the base station. They consider in their study a single class of service and model the system by the network of queues of type BCMP [15], [16] whose number of active users is fixed. The authors assume that the arrival rates of calls in each region only depend on the average number of mobile that move in that region. Thus, they consider that the average time of service depends only on the time that the mobile remains in the region.

Quality management and performance evaluation in the MAC layer of the 4G network were largely performed in simulation; And few analytical results have been proved in the literature. In [17], the authors analyze the performance of the random access protocol in an OFDMA-CDMA environment using contention intervals for connection engagement, as a function of the average MDT delay. In [18], the authors define a performance model based on an adaptive control of the size of each family of codes: initialization of connections (IR), periodic demand (PR) and bandwidth demand (BR), In order to improve the efficiency of competitive access.

We are interested on self-optimization and more particularly load balancing in LTE mobile radio networks. Several studies have been proposed in the literature to address the load balancing problem between LTE cells and can be classified into two categories. In the first category, hot-spot cells try to borrow available resources (radio channels) from neighboring cells with the least load and to cooperate [1]. Yao et al. proposed in [3] a method that falls into this category and which is based on neural networks and fuzzy logic. The proposed method performs a number of learning, optimization, robustness and fault tolerance capabilities. It aims to satisfy effectively the quality of service requirements of multimedia traffic.

For the second category, the overloaded cells try to transfer the excess traffic to the least loaded neighboring cells by adjusting the handover parameters (hysteresis, Time To Trigger (TTT) ...) or by using the cell breathing technique [4]. The principle of the latter is to shrink the cellular coverage as the load increases. Several research studies have dealt with this subject in the literature. New power control algorithms have been proposed in [5] and [6], in order to dynamically adjust the range of both over-exploited and under-exploited cells.

An algorithm to improve the joint performance of HO and load balancing (LB) by introducing a weighted co-satisfaction factor was proposed in [7]. In [8], the authors presented a typical transfer approach to implementing load balancing. It chooses as the source cell the one with the highest utilization rate of the physical resource blocks (PRB) and the neighboring target cell the one with the lowest PRB utilization rate. Arnott et al.[9], adjusted the specific offset of the cell according to the load of the source cell and that of the neighboring target cell. In [10], the load after handover was estimated. This method is based on the prediction of the SINR and on the measurement of the signal quality of the user.

3. ARCHITECTURES AND FEATURES OF SON IN 4G MOBILE NETWORKS

3.1 Self-Organizing Network Architectures

We distinguish three types of self-organizing network architectures in 4G Mobile Networks [11], each trying to find a compromise between stability, scalability and agility.

The first architecture, called Centralized SON (C-SON), performs the algorithms at the Network Management System (NMS) level (Figure 1). In this approach, SON algorithms can gather information from all network entities under consideration. This means that the parameters of all centralized SON functions can be optimized together. The aim is to provide a global optimization providing more stability. The latter is especially effective for networks with characteristics which vary slowly.

The centralized SON architecture also facilitates coordination between the SON features. On the other hand, the disadvantages of C-SON are high backbone traffic, a singular failure point and slow response times. The long duration of response times and lack of agility can affect the rate of adaptation of the network and caused problems of instability.

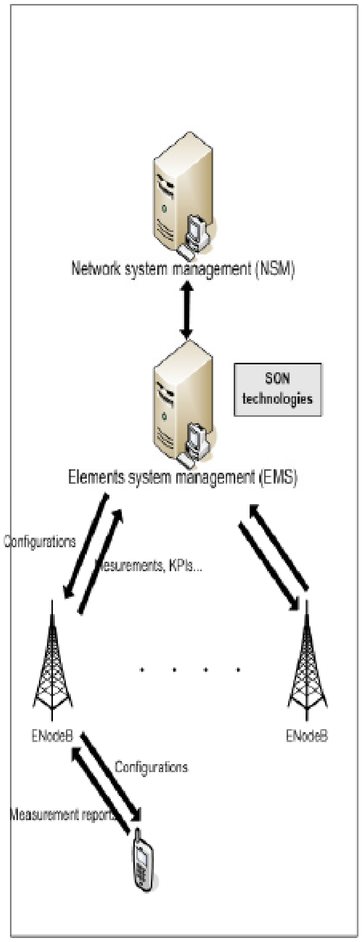

Figure 1: Centralized SON Architecture (C-SON)

In distributed (D-SON) architectures (Figure 2), the algorithms are rather executed in the nodes of the network. Thus the SON messages exchange can be carried out directly between the ENodeBs of the LTE network. Unlike the centralized architecture, the D-SON architecture provides more dynamics for the SON functionalities and has more agility and scalability in the network. Nevertheless, the optimizations carried out at the cell level will not cause global optimizations, which may lead to undesirable instabilities.

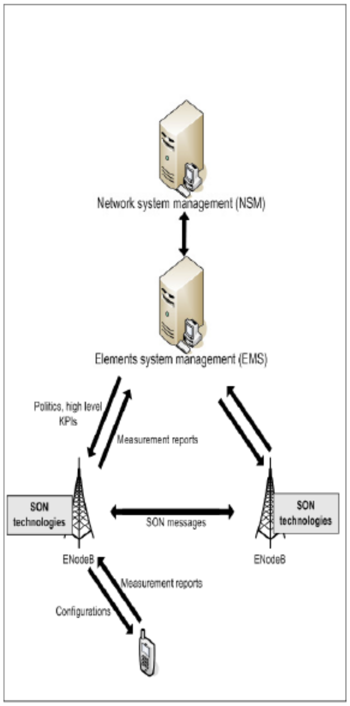

Figure 2: Distributed SON Architecture (D-SON)

The hybrid SON architecture (Figure 3) executes the SON algorithms both at the level of the network management system and at the level of the network elements. This type of architecture tries to take advantage of the two previous architectures without recurring the disadvantages, which is not always easy to define.

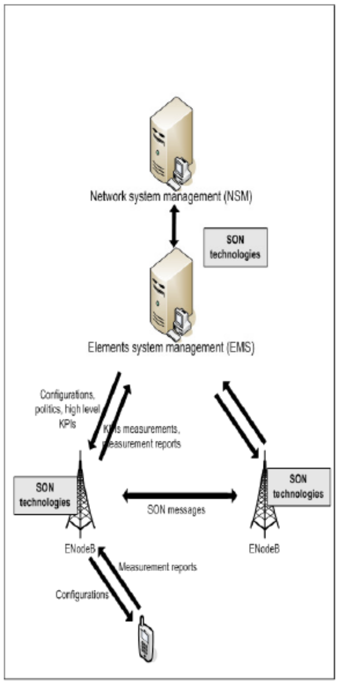

Figure 3: Hybrid SON Architecture

3.2 Self-Organizing Network functionalities

The SON functionalities in LTE include self-diagnosis, self-configuration, self-healing and self-optimization. The purpose of SON technologies is to automatically adjust network parameters, based on EU and ENodeB measurement reports, in order to guarantee a better quality of service of the network.

Self-optimization is algorithms that aim to maintain the quality and performance of the network with minimal human intervention. The auto-optimization functions automatically and dynamically trigger optimization actions on the affected network elements if necessary. Among the most important functions of auto-optimization is the optimization of load balancing in mobile networks (MLB) and optimization of mobility robustness (MRO). The latter is used in conjunction with the MLB to ensure more stability and minimize the ping-pong phenomenon. The adjustment of MLB and MRO parameters may be subject to conflicting objectives which are often harmonized through the search for compromise. In this article we are interested in MLB load balancing.

3.3 Load balancing (MLB) in LTE mobile networks by dynamically adjusting handover setting

Handover is one of the key procedures for radio-mobile networks to ensure that users move freely across the network while maintaining connectivity and continuous access to services [12]. Since the success rate of handover is a major indicator of network performance, it is essential that this procedure happens as quickly and efficiently as possible. Optimizing the handover aims to dynamically adjust its parameters (offset, hysteresis ...). In LTE networks, several measurement events can trigger [13]. In this paper, we are interested on event A3. It stipulates that the difference between the level of the signal received from the current cell and that of the neighboring cell must be greater than a given threshold.

In LTE networks, the traffic demand of some cells may be much higher than the acceptable level, while other cells may have enough resources to serve more users, resulting in load imbalance, Dissatisfaction of users. To trigger load balancing between hotspot cell and a less-loaded nearby cell B (Figure 4), two conditions must be satisfied:

- The charge rate of the source cell A exceeds a predefined threshold (in the case of hot spots).
- The neighboring cell B has sufficient resources available to agree to cooperate and take over the excess traffic from cell A.

As soon as these conditions are satisfied, cell A first selects the appropriate users from amongst those attached to it to switch to cell B. Users will then adjust their own settings (handover, reselection, ...) corresponding to cell B.

In the next section, we describe the principle of MLB algorithms in mobile networks that we proposed and implemented in ns-3.

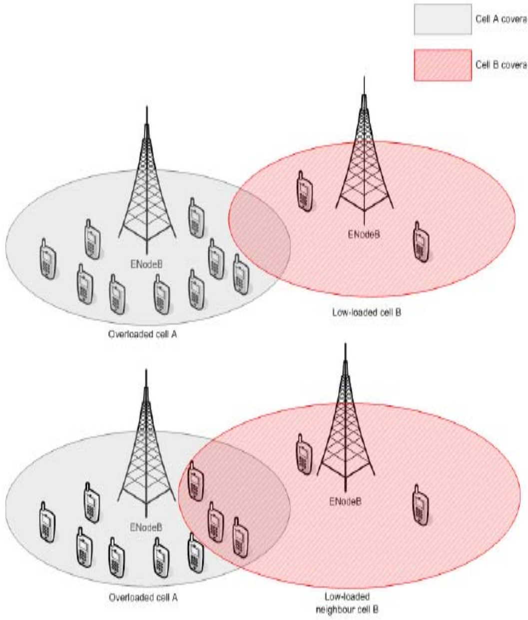

Figure 4: Load Balancing with Dynamic Handover Adjustment

4. PROPOSED LOAD BALANCING ALGORITHMS

We proposed two LB algorithms (Alg_LB1 and Alg_LB2) based on the dynamic adaptation of the handover settings: hysteresis value (Figure 4). The handover of the LB concerns the passage of the current cell (overloaded cell A) to one or more neighboring cells (cell B less charged) and arranged to cooperate. The performances of these two algorithms will be compared with those of a standard algorithm of the handover without LB (Alg_ sans_ LB).

The both algorithms with and without LB are based on the measurement of the received signal power (RSRP) and use event A3 of the 3GPP specification [1] to trigger the handover. The origin of the HO in the networks that implement the LB can be of two different natures. The first concerns the realization of the event A3, while the second type relates to a disparity of charge between two neighboring cells. Before specifying the principe of the two algorithms of LB, we will define in the following some preliminary notations that will be used commonly in the description of the two algorithms Alg_LB1 and Alg_LB2:

- $V_{AR}(i)$ (Available Resources) The amount of resources available in the i^{th} cell.
- $V_{TR}(i)$ (Total Resources) The amount of total resources in the i^{th} cell. Let us denote by convention that $i = 0$ is the index indicating the current cell and $i > 0$ is the index of a neighbor cell of index i.
- $V_{AR}(i)/V_{TR}(i)$ The relative amount (in %) of available resources in cell i.
- Th_{PreLB} The predefined threshold of the LB initiation request.
- Th_{postLB} The LB deactivation threshold.
- $Th_{AvailLB}$ The acceptance threshold of the LB's request.

The current cell is assumed to be overloaded if the following condition is true:

$$V_{AR}(0)/V_{TR}(0) < Th_{PreLB}$$

If this condition is true, the LB procedure is triggered. The overloaded cell dynamically configures the new handover hysteresis thresholds of the various neighboring cells according to their relative quantities of available resources. The new thresholds are calculated from the above equation [7]:

$$Th_{Hys}(0, i) = \alpha_i Th_{Hys}(0), \ (0 \leq \alpha_i \leq 1)$$

With :

$$\alpha_i = \begin{cases} 0, & if \ \frac{V_{AR}(i)}{V_{TR}(i)} > Th_{PostLB} \\ \beta_i, & if \ Th_{AvailLB} \leq \frac{V_{AR}(i)}{V_{TR}(i)}_{PreLB} \\ 1, & if \ \frac{V_{AR}(i)}{V_{TR}(i)} < Th_{PAvailLB} \end{cases}$$

And:

$$\beta_i = \begin{cases} 1 - \frac{Th_{AvailLB} - \frac{V_{AR}(i)}{V_{TR}(i)}}{Th_{AvailLB} - Th_{PostLB}}, for \ Alg\_LB1 \\ 0.5, for \ Alg\_LB2 \end{cases}$$

With $Th_{Hys}(0)$ the handover hysteresis threshold of the current cell before LB activation. $Th_{Hys}(0, i)$ is the new handover hysteresis threshold for passing the current cell (from index 0) to the neighboring cell (index i).

When the condition of LB is satisfied, the current cell first updates the handover hysteresis threshold $Th_{Hys}(0, i)$ and sends it to the UEs attached to current cell via a message of Control of measurements. In turn, the UEs update the new hysteresis thresholds as long as the condition on event A3 is checked. On the other hand, as soon as the following condition is satisfied, the LB is deactivated:

$$V_{AR}(0)/V_{TR}(0) > Th_{PostLB}$$

It can be seen from these description that the LB is effective only if the following condition on the neighboring cell is also satisfied:

$$V_{AR}(i)/V_{TR}(i) \geq Th_{AvailLB}$$

Thus, we can distinguish an alternation between periods without LB and periods with LB as a function of the evolution in time of the relative load of both the current cell and that of the neighboring cells.

5. EXPERIMENTS AND RESULTS

To prove the performance of the algorithms of LB (Alg_LB1 and Alg_LB2), we will compare their performances with those of the algorithm without LB (Alg_sans_LB) for different densities of UEs (thus for different global loads of the network). Alg_sans_LB only implements the A3 event of the 3GPP specification and does not consider load balancing. This algorithm is considered as a standard algorithm. Alg_LB1 and Alg_LB2, associated with the A3 event, aim to ensure a better distribution of the overall load and to minimize losses in the network.

Since the LB algorithms are implemented at the eNodeBs sector level, we focus on the performance of the downlink (DL). We have chosen a simulation model consisting of 3 equidistant eNodeBs of distance equal to 500m. Each eNodeB includes 3 sectors. We choose to implement the LB algorithms in a distributed manner (D-SON) in each sector. These algorithms dynamically adjust the handover settings (Time To Trigger (TTT) and hysteresis) as a function of the load. Time To Trigger is a timing used in the 3GPP specification in order to provide on the one hand more robustness and to attenuate on the other hand the phenomenon of "Ping-Pong". In the simulation scenarios studied, we focused on the dynamic adjustment of the hysteresis in an interval varying between 0 dB and 3 dB with a step of 0.5 db for fixed values of the TTT.

The correspondence between the modulation and coding schemes and the total capacity of a cell in Mbps for a bandwidth of 5 MHz, are summarized in Table 1.

Table 1: Correspondence between the MCS and the total capacity of a cell in Mbps for a bandwidth equal to 5 Mhz.

MCS	Modulation	Total capacity of a cell (Mbps)
[0..9]	QPSK	13.2
[10..16]	16QAM	26.4
[17..28]	64QAM	39.6

The main simulation parameters used in our case study are summarized in Table 2.

Table 2: Simulation Parameters

parameters	Value
Duration of simulation	100
Number of eNodeB	3 (9 secteurs)
Distance between eNodeBs	500 m
Power transmitted by an eNodeB in DL	46 dBm
Nature of traffic	TCP
Density of the EU (37/56/75 EUs)	2/6/8 * E-05
Minimum travel speed of EU (60 Km/h)	16.6667 m/s
Maximal travel speed of EU (60 Km/h)	16.6667 m/s
Bandwidth in UL and DL	5 MHz (25 RBs)
Time To Trigger	256
Default hysteresis value	3dB
Hysteresis margin with LB	[0˜3dB]
Th_{Pre-LB}	0.2
$Th_{Avail-LB}$	0.3
$Th_{Post-LB}$	0.4

The average overall throughput provided by the algorithms Alg_LB1 and Alg_LB2 is greater than that provided by the algorithm Alg_sans_LB for different traffic loads (37, 56, 75 UEs) as shown in Figure 5. This is justified by the very principle of LB, which favors the transfer of part of the charge from congested cells to neighboring less-charged cells. Thus, the risk of loss of excess traffic in the overloaded cells will be reduced and, if necessary, avoided by best distributing this excess between the least loaded neighboring cells. The LB certainly improves the overall throughput for different loads but this improvement becomes minimal for high load. This can be interpreted that for such a load there is a good chance that the neighboring cells of an overloaded cell, requesting their cooperation for a possible load balancing, are themselves overloaded.

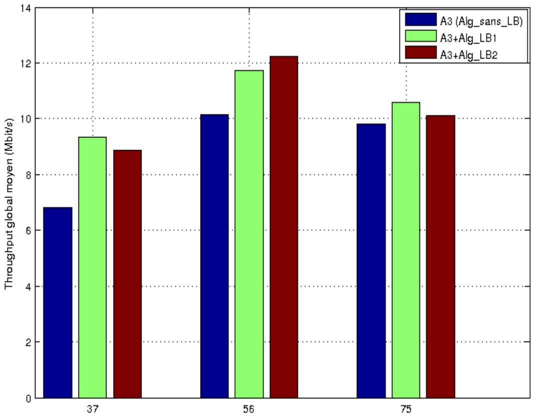

Figure 5: Average global Throughput in DL versus number of UEs

We also studied the distribution of the average throughput per sector in LD for different traffic loads (37, 56 and 75 UEs). Note that LB implementation improves the throughput of most sectors (2, 4, 7, 8 and 9) (Figure 6). The results for sectors 1, 3, 5 and 6 are mixed: i.e. one of the two LB algorithms has a better result than the one without LB.

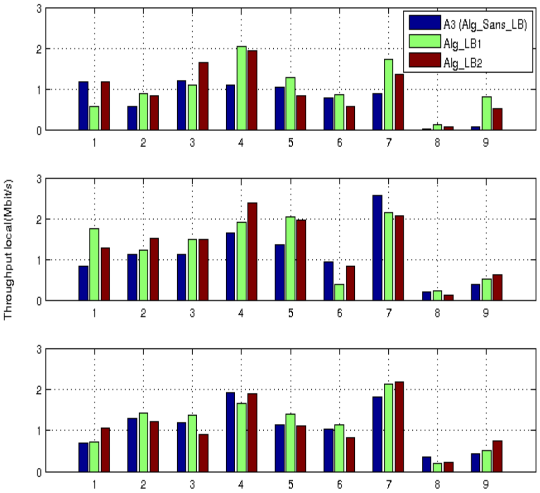

Figure 6: Average throughput per sector in DL

Figure 7 shows the evolution of the number of successful handovers as a function of the load for the three types of algorithms implemented. The load is quantified by the number of active UEs. Note that the number of handovers is significantly greater for the two algorithms with LB than for the algorithm without LB. This is due to the fact that during the triggering of the LB, a transfer of the excess traffic in the overloaded cell to the least loaded neighboring cells is carried out. This transfer of charge is achieved by adjusting the hysteresis value which favors the handovers. We note especially for the relatively low loads that the number of handovers for the algorithm Alg_LB1 is significantly lower than that for the algorithm Alg_LB2.

The comparison carried out between the two algorithms with LB shows that the algorithm Alg_LB1 certainly provides a loss rate lower than that for Alg_LB2 but instead causes a larger number of handovers.

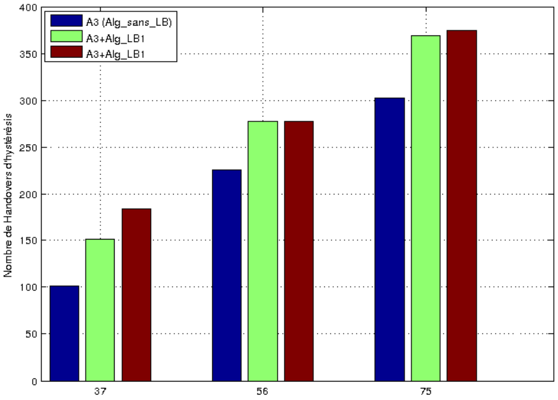

Figure 7. Number Of Successful Handovers Versus Network Load

6. CONCLUSION

In this paper we have implemented in ns-3 new load balancing algorithms at the ENodeBs of the LTE network. We also evaluated the performance of these algorithms by simulating discrete events for a scenario appropriate to LB. The performance evaluation focused on the study of the impact of the LB on the evolution of the average overall throughput, the average thrrourput by sector, on the loss rate, the number of HO, for different loads of traffic. The results obtained made it possible to carry out a comparative study between the results of the simulations with and without LB. This study allowed us to highlight the virtues of each algorithm and the compromises considered for each of them in terms of throughput, loss rates and number of handovers. As an outlook, we intend to carry out more thorough simulations on the joint optimization of the MLB and the MRO. This amounts to seeking the optimum value of the TTT for a given hysteresis value corresponding to a given charge of the cells. We also plan to model LB using the Markov decision process. This will make it possible to find the optimal values of the various thresholds for activation, acceptance and deactivation of the LB algorithm as a function of the load.

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