Performance of SON for RSRP-based LTE/WLAN access network selection

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Abstract —**Carrier-grade Wireless Local Area Network (WLAN) is becoming an important complementary system to cellular networks for Mobile Network Operators (MNOs). Network controlled access network selection between cellular and WLAN is an essential functionality to optimize network performance and user experience. Automated configuration and optimisation of the network selection mechanism is of utmost importance in the emerging complex heterogeneous networks. In this article, we present and evaluate a Self-Organizing Network (SON) scheme for optimizing autonomously the access network selection between the Long Term Evolution (LTE) and WLAN systems. The adopted access network selection mechanism uses the standard LTE Received Reference Signal Power (RSRP) measurements available at the User Equipment (UE) and a set of simple rules based on network-provided RSRP thresholds. The proposed SON mechanism is using the LTE cell load estimated at the evolved NodeB (eNB) to update the RSRP thresholds in order to achieve the best load balancing in the network. Simulation results in a realistic network highlight the benefits of the proposed SON mechanism and possible further improvements.**

Keywords—LTE, self-organizing network, WLAN, network selection, network optimization.

I. INTRODUCTION

Driven by the explosive growth in data traffic during the past few years, the limited availability of new licensed spectrum, and the increasing number of mobile devices [1], [2] supporting both cellular and WLAN interfaces, MNOs are currently exploiting the offloading of mobile data traffic to WLAN networks. Today, the network selection between cellular and WLAN networks is manually controlled by the users, and typically set as "connect to WLAN if available". However, to meet the high user expectations in terms of service availability and quality, and to efficiently exploit the available resources, MNOs are more and more enabling WLAN as an integrated and controlled part of their networks. Because of the challenges posed by the emerging heterogeneous cellular networks, with multiple cellular layers e.g., macro, micro, WLAN, it is crucial to develop intelligent access selection mechanisms between WLAN and the cellular layers.

Access network selection in heterogeneous wireless networks is a research topic extensively studied in academia. A common approach found in literature optimizes a multi-dimensional utility function in order to select the most suitable access network for a particular user, in a given location, requesting a particular service [4]. Various parameters such as load, throughput, Quality of Service (QoS), resource utilization costs, battery lifetime or even specific user preferences might be used in the definition of the utility function [5], [6].

Access selection approaches proposed in [7] rely on IEEE 802.21 Media Independent Handover (MIH) standard [8]. The potential of this standard is however limited due to its restricted support from network/user equipment. 3GPP has specified the Access Network Discovery and Traffic Steering Function (ANDSF) framework as an advanced policy control to assist UE in network discovery and selection [9]. A UE supporting ANDSF can acquire the list of access networks available in the vicinity as well as operator preferences on network selection and traffic steering. The Wi-Fi Alliance Hotspot 2.0 specifications aim at improving user experience by means of seamless and secure Wi-Fi connectivity [10]. Hotspot 2.0 allows devices to acquire information on 3GPP cellular networks in order to ease network discovery and selection process. The main limitation of most of the currently deployed access network selection mechanisms is their static behaviour, i.e. the lack of adaption to dynamically changing traffic conditions, which makes them unsuitable to optimally exploit the available LTE and WLAN cell radio resources.

The contribution of this paper is twofold. First, based on an acceptable balance between algorithm complexity and performance, this paper adopts an access network selection (ANS) mechanism between LTE and WLAN which uses the standard LTE RSRP measurements available at the UE and a set of simple rules based on network-provided RSRP thresholds; second, it proposes and evaluates an *automated*, SON based, configuration and optimisation of the ANS mechanism with the goal of efficient resources utilization and fulfilment of the desired operator policy. The automation component is crucial in dynamic heterogeneous networks, characterized by different cell sizes and including diverse WLAN deployments, to achieve minimal operational effort and cost. The general idea behind using SON [3] for ANS is that a SON closed-loop control function autonomously tunes the network control parameters, which control the ANS mechanism according to the changes in the network and to the desired overall operator policy. The SON function continuously monitors a number of relevant Key Performance Indicators (KPIs), e.g. the LTE cell load, WLAN utilization, cell throughput, and evaluates on a regular basis the opportunity for adapting the network parameters.

The remaining of the paper is organised as follows. The system modelling approach and assumptions are illustrated in

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Section II. The performance evaluation of the RSRP-based ANS is presented in Section III. The SON results are presented and discussed in Section IV. The paper is finalized with the conclusions and recommendations in Section V.

II. SYSTEM MODELLING FOR SON EVALUATION

A. RSRP-based Network Access Selection mechanism

The ANS mechanism adopted in this paper exploits the standardized 3GPP LTE RSRP measurements that are available at the UE and the RSRP threshold introduced in [11]. Here, we propose two different thresholds, labelled *RSRP Thr_High* and *RSRP Thr_Low*, to be used in two simple rules evaluated at each UE to determine whether to connect or not to WLAN when a new active session starts:

1) *UE served on WLAN if RSRP > RSRP Thr_High and RSS>RSS_min, otherwise UE served on LTE.* This rule is applied in case of co-located LTE small-cells (micro) and WLAN acess point and with this approach an UE is served on WLAN when the UE RSS is above certain level but without the need to specify an explict WLAN RSS threshold.
2) *UE served on WLAN if RSRP < RSRP Thr_Low and RSS>RSS_min, otherwise UE served on LTE.* This rule is applied in case of LTE macro cells without a co-located WLAN acess point.

The *RSS_min* value denotes the WLAN Radio Received Signal Strength (RSS) minimum connectivity level.

B. Proposed SON Algorithm

The RSRP-based SON algorithm we propose in this paper is a single control parameter mechanism, which uses the LTE cell load[1] as input KPI to adjust the RSRP threshold values per cell. By using standardized RSRP measures, we avoid the need for additional standardization support. The flowchart of the algorithm is shown in Figure 1. A target range for the LTE cell load (green range in Figure 1) is predefined by two configuration parameters, called *CellLoad Thr_High* and *CellLoad Thr_Low*.

At the start, the two RSRP thresholds (*High* and *Low*) are initialized to their default values. During the execution of the SON function, the LTE cell load is periodically calculated and filtered. At each SON step, the high LTE load condition is checked, and if met, the corresponding RSRP threshold (*High* or *Low*) is adjusted with the target to direct new sessions to WLAN to avoid LTE congestion. Specifically, *RSRP Thr_High* is decreased in micro cells and *RSRP Thr_Low* is increased in macro cells. If the high LTE cell load condition is not met, the low LTE cell load condition is checked, and if met, the corresponding RSRP threshold (*High* or *Low*) is adjusted with the target to direct new sessions to LTE. No adjustments of the RSRP thresholds are made if the LTE cell load is in the target range. After every update of the RSRP thresholds, their new values are assumed to be signalled to the UEs that are in the coverage area of the LTE cell, and to be

[1] In this paper the LTE cell load is defined as the required fraction of physical resource blocks to serve the existing users when providing a minimum user throughput of 10 Mbps.

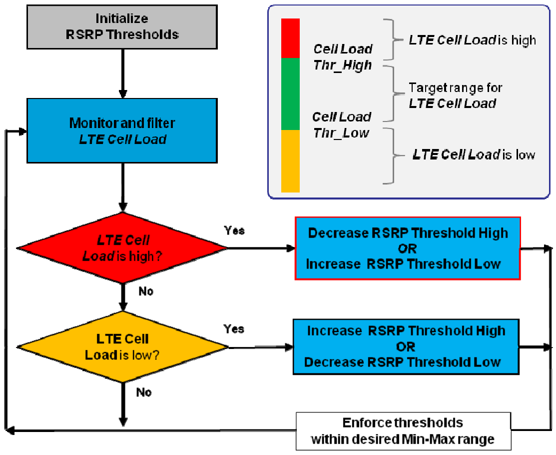

Figure 1: Flow chart of the SON mechanism for RSRP-based LTE/WLAN access network selection.

used in the NAS mechanism in the UE as described in Section III.A.

The targeted heterogeneous network deployment and assumed higher traffic distribution around the small cells, makes possible to design our SON algorithm based on the principle of *separation of time scales*. Accordingly, the *RSRP Thr_Low* values in all macro cells should be updated at slower rate compared to the *RSRP Thr_High* values in the micro cells to allow convergence of the *RSRP Thr_High* values between two consecutive updates of the *RSRP Thr_Low* values in the macro cells. Thus, the overall SON becomes stable.

C. Evaluation Scenario and Modelling

The evaluation scenario is characterized as an outdoor high traffic shopping street area in the city centre of Hannover which is covered by three network layers as shown in Figure 2. The deployment includes 28 co-sited outdoor LTE micros and WLAN APs at lamp post height (5m) in addition to 4 LTE macro sites. Stationary outdoor users are assumed. User datagram protocol (UDP) type traffic with fixed file size and Poisson distributed call arrival (downlink only) is simulated. The simulated WLAN access corresponds to operation, under interference from one additional 'external' WLAN network.

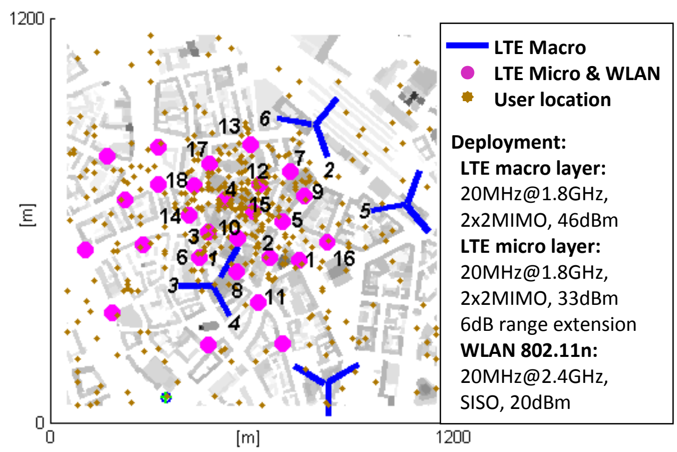

Figure 2: Investigated site specific dense urban scenario: network deployment layout and user locations.

Parameter	Description	Setting
P_SON	Periodicity of SON algorithm execution	1 sec
P_LTE	Periodicity of LTE load calculation	0.5 sec
α	LTE load (L) filtering factor, in $L(n) = (1-\alpha) * L(n-1) + \alpha * L_{measured}(n)$	0.7
CellLoad Thr_Low/High	LTE cell load thresholds Low/High	60%/ 80% or 70% / 90%
Min. RSS level	Minimum RSS level for WLAN connectivity	-92 dBm
RSRP Thr_High Step	Step size of RSPP Threshold High adjustments (up or down)	{1, 2, 5, 10} dB
RSRP Thr_High Initial	Initial value of the RSRP threshold High	-70 dBm
RSRP Thr_Low Min / Max	Minimum and maximum values of the RSRP Threshold Low	-100 dBm / -50 dBm
RSRP Thr_High Min / Max	Minimum and maximum values of the RSRP Threshold High	-110 dBm / -40 dBm
Traffic model	DL UDP with fixed file size and Poisson distributed call arrival	D_{size} = 40Mbit *λ = 16 calls/s*

Table 1: Adopted simulation and modelling parameters.

Table 1 summarizes the simulation parameters. The simulation tool has been developed using the Matlab platform.

III. Performance with Fixed RSRP Thresholds

The first step in our study was to analyze the behaviour of the proposed ANS algorithm using global configurations for the two RSRP thresholds, i.e. the same value applied to all cells. The main targets of this exercise were: i) to verify the impact of the RSRP thresholds on the system performance and to select a reference scenario, and ii) to identify the correct range for the RSRP threshold parameters.

The first performance metric analyzed was the ratio of the user sessions offloaded to WLAN, see Figure 3. These results show that the system behaves as expected when changing the RSRP thresholds, i.e. the offloading rate is increased for lower *RSRP Thr_High* values and/ or for higher *RSRP Thr_Low* values. The scenario which emerges from these results is an obvious reference case is the one where the WLAN access selection is maximized, up to 90%, indicated in Figure 3, when the RSRP–based selection conditions are practically disabled and a UE connects to WLAN when available (with RSS above -92 dBm, see Table 1). As a second performance metric Figure 3 shows the user session throughput performance when varying the RSRP thresholds.

Analyzing the results in Figure 3, we can conclude that the global settings which maximize the WLAN offloading rate *do not* maximize the user session throughputs (average or 5%-ile) and vice versa. Alternatively, it is also tempting to draw the conclusion that by utilizing global settings of *RSRP Thr_Low* = -90 dBm for all macro cells and *RSRP Thr_High* = -80 dBm for all micro cells it is possible to maximize the average and 5%-ile, user session throughput. While this latter settings would indeed yield an acceptable good overall performance, due to the non-uniform spatial traffic (see Figure 2), the individual LTE cells are likely under/ overloaded, thus their performance is suboptimal. When the SON algorithm is enabled, the network selection can be better tuned to the local traffic load conditions in each cell, as presented in the following section.

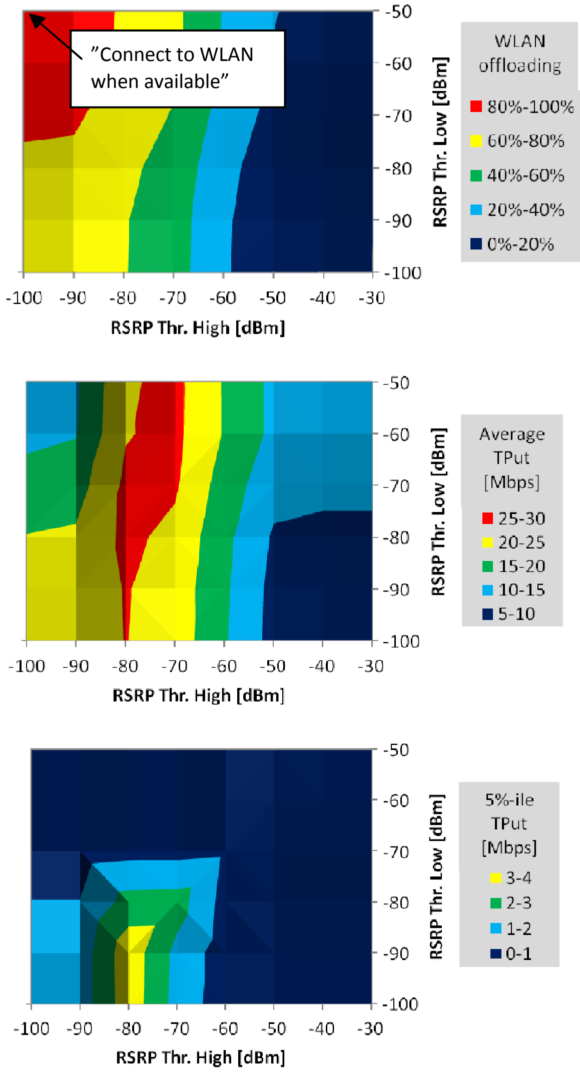

Figure 3: User session WLAN offloading ratio, average and 5%-ile throughput vs. RSRP Threshold *High/Low*.

IV. SON Algorithm Evaluation

A. Performance results with optimized settings

Considering the deployment scenario, see Figure 2, where there are only a few analyzed macro cells and with similar traffic conditions, we use fixed and global *RSRP Thr_Low* values for all macro cells. This approach is also motivated by the overall SON design presented in Section II.B, i.e. the *RSRP Thr_Low* values are assumed constant for sufficiently long time in order to allow for the *RSRP Thr_High* values to converge in all micro cells.

We start our SON analysis by varying three key configuration parameters, which influence the overall system performance (see Table 1):

i) *LTE Cell load Threshold Low/High,*
ii) *RSRP Threshold High Step Size*, and
iii) *RSRP Threshold Low*

The obtained results corresponding to the setting *CellLoad Thr_Low-High* of 60%-80% are summarized in Figure 4 in

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terms of average and 5%-ile user session throughput gains relative to the reference scenario "Connect to WLAN when available" presented in Section III.

In all the analysed cases for the SON configuration parameters, a gain of 30% to 50% in average user session throughput has been obtained. However, the main observation from Figure 4 is that the *RSRP Thr_Low* and *RSRP Threshold High Step Size* values have a significant impact on the 5%-ile user throughput, and can even cause a loss in performance. To better understand these results we show in Figure 5 the user session distribution across the different network layers.

For the case with *RSRP Thr_Low* = -70dBm there is a clear trend visible in Figure 5 indicating that for increasing *RSRP Threshold High Step Size* the number of users served by the micro layer decreases due to increasing WLAN selections triggered by the high load in the micro cells. For *RSRP Threshold High Step Size* values up to 2dB, due to the slow convergence to the optimal *RSRP Thr_High*, the SON algorithm in the micro cells cannot trigger enough WLAN selections hence the performance in the micro cells is suboptimal. For *RSRP Threshold High Step Size* values 5dB and above, the number of WLAN selections is higher and the 5%-ile user throughput performance of the micro layer improves sufficiently to result in an overall gain up to 140%. The mechanism described above is visible also for *RSRP Thr_Low* = -80dBm. In this scenario the number of macro users moved to WLAN is less and they are in better signal conditions towards the serving WLAN APs, hence they degrade less the overall WLAN layer performance compared to the *RSRP Thr_Low* = -70dBm case. The combined performance of the micro and WLAN layers is sufficiently high to compensate for the lower performance in the macro cells (due to its higher UE population when *RSRP Thr_Low* decreases) and this yields an overall 5%-ile throughput gain in the order of 150%. For *RSRP Thr_Low* = -90dBm, the overall network performance does not depend on the *RSRP Threshold High Step Size* values up to 5dB. Beyond this step size value there is a small performance degradation, coming from highly loaded micro cells, where the users to be moved to WLAN cannot be selected with sufficient accuracy. The results for *CellLoad Thr_Low-High* of 70%-90% show similar trends as presented for the case *CellLoad Thr_Low-High* of 60%-80%.

Based on these results, henceforth we use the following parameter settings that provide a good trade-off between average and 5%-ile UE throughput: *CellLoad Thr_Low* = 60%, *CellLoad Thr_High* = 80% and *RSRP Thr_High Step* = 5dB. The global *RSRP Thr_Low* = -80 dBm value is selected to equalize the average numbers of user sessions between the macro and micro network layers.

Figure 6 shows the corresponding results on a per cell basis in terms of average cell load and average *RSRP Thr_High* (for cell indices see Figure 2). Therefore, as expected, correlation between the average *RSRP Thr_High* value determined by the SON algorithm for a given micro cell and the experienced cell load can be observed. That is, the higher the average cell load e.g., in cell index 2, 4, 7, the lower the *RSRP Thr_High,* and vice-versa. As explained earlier, the *RSRP_Thr_High* is not applied to macro cells and it is disabled with the setting of -40 dBm. An important observation is that the offloading opportunities of macro cell index 3 are only partial as this cell

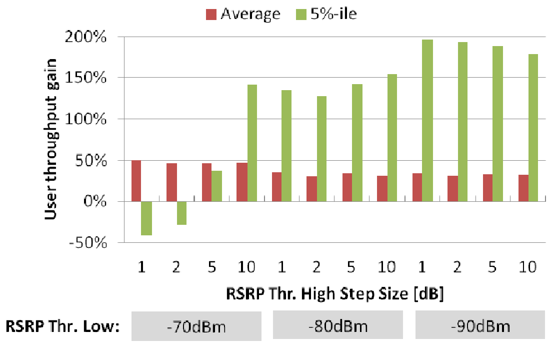

Figure 4: User session throughput gains relative to "Connect to WLAN when available" reference case for different SON parameter settings.

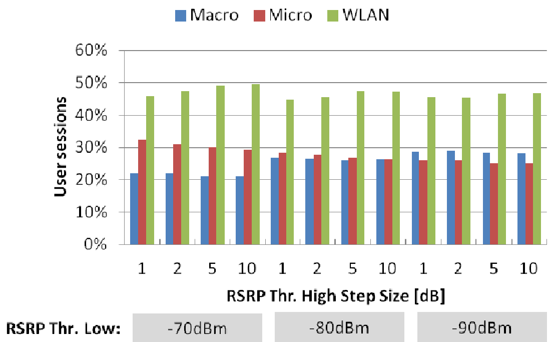

Figure 5: User session distribution across the network layers for different SON parameter settings.

covers a substantially large area with no micro cells nor WLAN deployment, hence its high load. Thanks to the SON algorithm most of the micro cells have average load below the set *CellLoad Thr_Low-High* range, which indicates that, potentially, even higher offered traffic can be accommodated in the network.

Figure 7 shows an example of the time trace for a highly loaded micro cell under the selected SON settings. The evolution of the cell load and the corresponding *RSRP Thr_High* adjustments are illustrated. The SON algorithm achieves the desired tuning, i.e. the value of the *RSRP Thr_High* is increased when the averaged load falls below *CellLoad Thr_Low* and it is decreased when the load exceeds *CellLoad Thr_High.* The Figure 7 illustrates also that the algorithm is able to react quickly to large load fluctuations. With the selected SON settings for *P_SON* = 1 sec (see Table 1) and *RSRP Thr_High StepSize = 5 dB,* the maximum delay in the adjustment of the *RSRP Thr_High* value across its full *Range* (between -40 dBm and -110 dBm) is equal to *Range / RSRP Thr_High StepSize * P_SON* = 14 seconds. This value can also set the minimum possible update period for the *RSRP Thr_Low* threshold.

B. Impact of traffic model parameters

We have shown in Section IV.A the impact of SON set-up parameters on the achieved system performance under the assumption of a given offered traffic and traffic model parameters. In real systems the offered load is a sum of various traffic types, with various packet sizes. Thus, in this section we

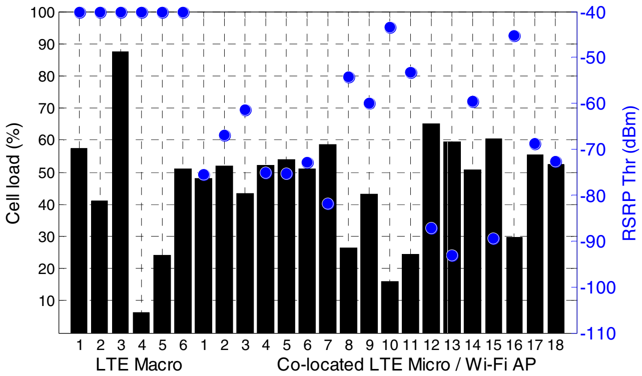

Figure 6: Per cell results of average cell load and RSRP Threshold *High* for selected SON parameter settings.

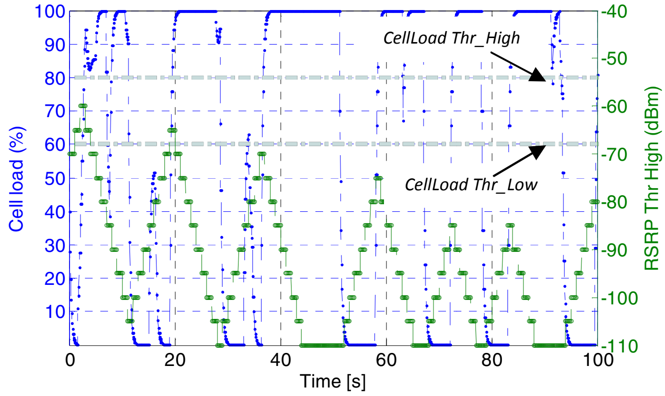

Figure 7: Time trace example for a highly loaded micro cell under the selected SON parameter settings.

analyse the system behaviour under constant total offered traffic load, by increasing the call arrival rate ($\lambda * N$) and decreasing the file size (D_{size} / N), while keeping constant the average packet inter-arrival time, where N = 1, 2, 4. Figure 8 shows the resulting average and 5%-ile user session throughput gains relative to N=1 reference case; we use the selected SON configuration parameter settings from Section IV.A. By increasing N, the instantaneous traffic load per scheduling interval is increased, thus all cells experience longer periods of times with high load and this leads to a degraded performance. The 5%-ile performance of the WLAN layer is significantly degraded because the WLAN utilisation increases while the AP's load is *not* controlled by the SON algorithm.

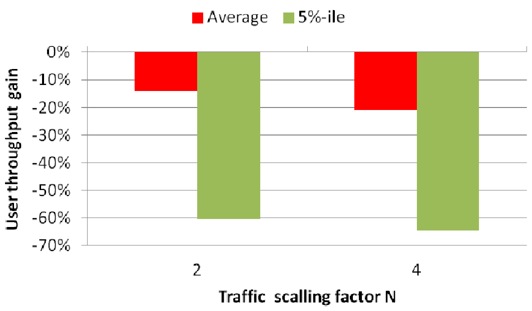

Figure 8: User session throughput gains relative to reference traffic scenario (N=1) vs. traffic scaling.

V. Conclusion and Future Work

We have presented and evaluated a Self-Organizing Network (SON) solution for optimizing autonomously the access network selection between the Long Term Evolution (LTE) and WLAN systems. The adopted access network selection mechanism (ANS) uses the standard 3GPP LTE Received Reference Signal Power (RSRP) measurements available at the User Equipment (UE) and a set of simple rules based on network-provided RSRP thresholds. The SON algorithm updates autonomously the RSRP thresholds values based on the estimated cell load level and a pre-defined target load range, thus achieving an optimal rate of WLAN ANS in each cell. The evaluation results show that with an optimal SON parameter configuration, gains in order of 50% and 150% can be achieved in the average and 5%-ile user session throughputs, compared to the "connect to WLAN if available" reference case, respectively. We also show that these performance gain numbers are dependent on the actual traffic type and an increase in the traffic burstiness results in significant loss of performance unless the SON algorithm allows direct control of the load on the WLAN layer.

For further improved performance in real-life mixed traffic scenarios a refined SON design is required. A combined evaluation including typical mobility and traffic steering mechanisms will be further needed in order to gain a complete understanding of the benefits of the proposed SON algorithm.

Acknowledgment

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