TABLE II
GAIN BORDERLINES IN CASE OF NON-PERMANENTLY ACTIVE USERS

α_1	α_2	N_2^+ $(\delta = 0.01)$	N_2^+ $(\delta = 0.0001)$
0.75	0.5	$N_2^+ \simeq 6.6 - 0.42N_1$	$N_2^+ \simeq 13.3 - 0.42N_1$
0.75	0.25	$N_2^+ \simeq 3.3 - 0.21N_1$	$N_2^+ \simeq 6.6 - 0.21N_1$
0.75	0.1	$N_2^+ \simeq 2 - 0.12N_1$	$N_2^+ \simeq 4 - 0.12N_1$
0.5	0.25	$N_2^+ \simeq 3.3 - 0.5N_1$	$N_2^+ \simeq 6.6 - 0.5N_1$
0.5	0.1	$N_2^+ \simeq 2 - 0.3N_1$	$N_2^+ \simeq 4 - 0.3N_1$
0.25	0.1	$N_2^+ \simeq 2 - 0.6N_1$	$N_2^+ \simeq 4 - 0.6N_1$

For instance, consider $\alpha_1 = 0.25$ and $\alpha_2 = 0.1$ for $\delta = 0.0001$. Separation of both groups means $N_1^+ \simeq 6.6$ and $N_2^+ = 4$. If both groups were integrated and $N_1 = 6$ users existed, the gain borderline for group 2 was decreased to $N_2^+ \simeq 0.4$, which clearly denotes the extra gain obtained from the sharing of the resources when activity factors are low.

VI. CONCLUSIONS

We considered resource sharing issues in virtualized network environments. Going beyond exclusive assignment of resources to users, we investigated careful overbooking in the sense that (a) full availability, i.e. the full amount of required resources, and (b) limited availability of at least a certain share of required resources is (statistically) guaranteed at given degrees. In particular, we paid attention to cases in which one extra user can be accommodated without sacrificing the desired degrees of full and/or limited availability, typically specified through the number of nines in the decimals.

Assuming an on-off user model with geometrically distributed phases of activity and inactivity, we first considered – in terms of parameters – homogeneous users. We calculated quantitative results for the maximal number of users in order to keep the desired degree of full availability. We furthermore investigated the minimal number of users for which a gain can be realized, called the gain borderline. We derived a closed formula for that gain borderline, revealing that large activity levels and many nines provide hinders for gain. No advantage over exclusive allocation is obtained unless the system becomes very large.

We also investigated the relationship between the degrees of full and limited availability, and the reduction of resource allocation related to limited availability. We found that at the gain borderline, the numbers of nines provide a hint on the capacity reduction factor related to limited availability, which also serves as worst-case estimation. In particular, the numbers of nines should neither be too small nor differ too much between full and limited availability.

Considering two groups of heterogeneous users with different activity levels, we investigated the conditions under which it makes sense to integrate both groups in order to yield gain. As in the homogeneous case, this makes sense for comparably small activity levels. As soon as at least one group is very active, it is advisable to keep the groups apart capacity-wise, as hardly any additional gain can be obtained.

Although the topic of overbooking has been well-researched in other areas such as the dimensioning and control of broadband networks, is has hardly been addressed in the NV context so far. Overbooking might be a problem in many kinds of systems, and this study could have been presented in a much more generic setting. Still, we perceive some value in tailoring known approaches to NV in order to highlight specific chances and risks when being tempted to applying overbooking, as it has implies the chance to reduce resource blocking at the expense of limited availability. In many cases – small systems, high activity factors, and high desired availability – overbooking has shown to be non-efficient. Still, with this paper, we have some simple formulae at hand to assess the circumstances under which overbooking is an option.

Thus, there are a couple of options for future work. Amongst others, we might consider refined user models matched to traces; validation of the findings of this paper through measurements in real NV systems, or through simulations; and some detailed investigation of potential gains beyond the gain borderline, or the dependency of gains from eventual correlations of the resource requests. As a generic topic even beyond the area of NV, a quantitative study of the coexistence of performance criteria for full and limited availability, in particular related to user-expressed Quality of Experience, is of interest.

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