On the Value of Context Awareness for Relay Activation in Beyond 5G Radio Access Networks

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Abstract— **This paper envisions to augment the Radio Access Network (RAN) infrastructure in Beyond 5G (B5G) systems by exploiting relaying capabilities of user equipment (UE) as a way to improve the coverage, capacity and robustness. Despite the concept and enabling technologies have been in place for some time, their efficient realization requires the conception and development of new features in B5G systems. Among them, this paper focuses on the Relay UE (RUE) activation decision making, in charge of deciding where and when a UE is suitable to be activated to relay traffic from other UEs. Specifically, the paper analyses seven RUE activation strategies that differ on the criteria and the type of context information considered for this decision-making problem. The considered strategies are evaluated through system level simulations in a realistic urban scenario with the objective of assessing the value of each type of context information. Results reveal that the most efficient strategies from the perspective of outage probability reduction are those that account for the number of UEs that would be served by a RUE based on the experienced spectral efficiency.**

Keywords*— *Beyond 5G, Radio Access Network, User Equipment, UE-to-network relaying.

I. INTRODUCTION

Fuelled primarily by the huge demand in video traffic, which currently accounts for 69% of all mobile data traffic and is forecast to further increase in coming years [1], mobile network operators (MNOs) are forced to respond promptly with decisive capacity scaling on their Radio Access Network (RAN) deployments to face the high traffic demands. This requires large capital expenditure (CAPEX) on network improvements (e.g., deploying 5G RAN infrastructure). However, dwindling average revenues per user, market saturation and intensifying competition make the MNOs seeing their finances stretched. Therefore, MNOs need to find not only new revenue streams (e.g., capitalizing on emerging vertical markets) but also new and creative ways of managing and deploying their 5G and beyond RAN infrastructures.

At the same time, an unprecedented technological evolution in user equipment (UE) has occurred in recent years, leading to the availability of UEs with very powerful communication and computational capabilities. These UEs can be in the form of personal use devices, such as smartphones and high-end wearables, or equipment integrated in other platforms such as cars and drones.

Embracing the two abovementioned trends, our recent paper [2] presented a vision of a Beyond 5G (B5G) scenario where the UE can also be exploited to augment the RAN infrastructure as a source of distributed capacity and network intelligence. This vision foresees the UE taking a more active role in network service provisioning and actively complementing the RAN infrastructure, e.g. by relaying traffic from other UEs towards the network. This is expected to positively impact MNOs in terms of a significant reduction in the number of fixed base stations to deploy, as it was estimated in the initial results obtained in [2]. Moreover, the RAN will be empowered with more flexibility for supporting different use cases, such as enhancing the performance in front of mitigating objects' obstructions in millimetre wave deployments, augmenting capacity in high-density areas, providing coverage extension, or improving resilience.

Certainly, the option of deploying relay stations for providing a cost-effective way to extend the coverage and capacity in a cellular network has been well considered in the literature for a number of years (see e.g., [3]), although with practical implementation limited to rather specific use cases (e.g., extending coverage in a tunnel). However, the interest for relays has more recently revamped. For example, the Third Generation Partnership Project (3GPP) has introduced a new relaying technology, referred to as Integrated Access and Backhaul (IAB), which provides an alternative to fibre backhaul by extending 5G New Radio (NR) to support wireless backhaul [4][5]. Similarly, a recent study item in 3GPP Release 18 also considers the use of vehicle-mounted relays [6], which had also been studied in some works of the literature [7][8]. In turn, the capability of UE-to-network relaying, in which a UE relays the traffic of another UE to/from the network in a two-hop communication has been included among the connectivity models of [9] in 3GPP Release 18, identifying different scenarios for the use of relay UEs (in home, smart farming, smart factories or public safety), together with requirements and key performance indicators.

While the UE-to-network relaying concept and enabling technologies have been in place for some time, their efficient realization requires the conception and development of new features in B5G systems. These span from top level service layer capabilities for MNOs and UE owners to interact with each other to settle the conditions for engaging the UEs as part of the RAN, down to the necessary management and control layer capabilities for exploiting the connectivity brought by the UEs. In this respect, a key functionality within this bunch of research challenges is the so-called “Relay UE (RUE) activation”, that is, the criteria to decide where and when a UE is suitable to be activated to act as a relay, thus integrating this UE as another interoperable component of the RAN.

The RUE activation decision making can consider context information that is local to the UE (e.g. battery status, propagation and interference conditions, etc.), knowledge on a global view of the network (e.g., other UEs in the proximity that can benefit from the RUE, or other existing RUEs in the surroundings) or context information obtained from activity or mobility forecasting models that can anticipate e.g. bad coverage situations. Given the multiplicity of inputs to the problem, it is envisaged that Machine Learning (ML) solutions and, more specifically, deep reinforcement learning (DRL) could become good candidates for this function.

With all the above, this paper addresses the RUE activation problem in views of assessing to what extent the information and knowledge about the context bring value in order to take more intelligent decisions, thus leading to more efficient operation. Thus, instead of formulating e.g. a DRL-based algorithmic solution straightaway, the approach followed in this paper is to define a set of reference strategies with various levels of information/knowledge associated to each of them. In this way, the relevance of each component can be better assessed and, eventually, the interest for formulating specific ML-based algorithms as part of future work can be better motivated.

The rest of the paper is organised as follows. Section II presents the considered system model and, based on this, Section III presents the analysed RUE activation strategies. These are then assessed by means of simulations in a realistic urban scenario in Section IV. Conclusions and future work are summarized in Section V.

II. SYSTEM MODEL

This work considers a RAN infrastructure deployed by the MNO (Mobile Network Operator) consisting in a set of base stations (BS) operating with 5G NR technology. The RAN can be augmented with a number of UEs that can be dynamically activated to act as RUEs. Then, a UE can access the core network either through a direct radio link with a BS or through a RUE, as illustrated in Fig. 1.

In order to support the new RUE service management functionality, as seen in Fig. 1, the MNO retains at the Service Management and Orchestration (SMO) layer the database with the list of UEs that can be used to augment the RAN (i.e. "candidate" RUEs) together with their contributed features and usability restrictions (e.g. allowance to use relaying feature only when the battery level is above a given threshold, locations where the UE uses to remain stationary, etc.). This information is considered by the RUE activation function, in addition to further context information as discussed in Section III. Then, the RUE activation decisions are centrally taken at the SMO and communicated through a management interface to be specified between the UEs and the SMO.

In order to characterise the coverage conditions experienced by a UE, the spectral efficiency metric is considered. Considering the downlink direction, when a UE is directly connected to a BS, the spectral efficiency denoted as S_D can be estimated using the Shannon formula as:

$$S_D = \min\left(S_{\max}, \log_2\left(1 + SINR_{BS-UE}\right)\right) \qquad (1)$$

where $SINR_{BS\text{-}UE}$ is the Signal to Interference and Noise Ratio (SINR) in the link between the BS and the UE and S_{max} is the spectral efficiency corresponding to the maximum Modulation and Coding Scheme (MCS) of 5G NR, defined in [10]. It is assumed that the serving BS for the direct connection of a UE is the BS with the highest SINR.

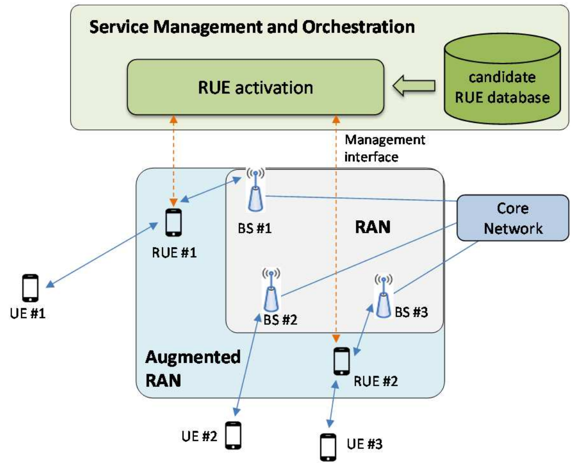

Fig. 1. Considered system model

When the UE is connected to one of the activated RUEs the achievable spectral efficiency will be limited by the segment (i.e., BS to RUE or RUE to UE for the downlink) exhibiting the worst spectral efficiency, so it becomes:

$$S_R = \min\left(S_{\max}, \log_2\left(1 + \min\left(SINR_{BS-RUE}, SINR_{RUE-UE}\right)\right)\right) \quad (2)$$

where $SINR_{BS\text{-}RUE}$ and $SINR_{RUE\text{-}UE}$, denote, respectively, the SINR in the BS-RUE and RUE-UE links. It is assumed that the activated RUEs and the BSs operate at different frequencies, so that simultaneous transmission in these two links is possible.

For proper service provisioning it is assumed that a minimum spectral efficiency of S_{min} is required, so that UEs with spectral efficiency lower than S_{min} are considered in outage.

As a result of the decisions made by the RUE activation function there will be a number of activated RUEs that are available to the rest of UEs. Then, UEs will be able to either connect directly to a BS or take advantage of an activated RUE. The criterion for a UE to connect to an activated RUE or to a BS is that a UE will only attempt to connect to a RUE if its direct link with its serving BS is in outage, i.e. $S_D < S_{min}$. In this case, the UE will connect to the activated RUE that provides the highest spectral efficiency S_R provided that it is $S_R \geqslant S_{min}$. If no activated RUE provides this condition, the UE is considered to remain in outage connected to its serving BS. Moreover, it is also assumed that a RUE can only be in the list of candidate RUEs if the spectral efficiency with respect to its serving BS is higher or equal than S_{min}.

III. RUE ACTIVATION STRATEGIES

This section presents different RUE activation strategies in order to assess the most relevant criteria and context information that have to be considered when deciding which of the candidate RUEs to activate. The considered strategies are described in the following, assuming a scenario with B base stations numbered b=1,...,B, U active UEs numbered u=1,...,U, and K candidate RUEs numbered k=1,...,K at a certain time. The k-th candidate RUE is served by the $b(k)$-th BS, where $b(k) \in \{1,...,B\}$. For notation purposes, $S_D(u)$ denotes the spectral efficiency in the direct link of the u-th UE with its serving BS, computed from (1). Moreover, $S_R(u,k)$ denotes the spectral efficiency experienced by the u-th UE when served through the k-th RUE, computed from (2).

A. Strategy A: Blind RUE activation

This strategy simply consists in activating randomly N out the K candidate RUEs. Due to its simplicity, it is just taken as a reference for the lower performance bound. The pseudo-code is shown in Algorithm A.

Algorithm A - Blind RUE activation

```
1   $list\_RUEs$= list of $k$={1,...,$K$} candidate RUEs
2   sort $list\_RUEs$ in random order
3   activate the top $N$ RUEs in the sorted $list\_RUEs$
```

B. Strategy B: BS-based RUE activation

This strategy intends that each BS has the same number of activated RUEs inside its coverage area. For this purpose, it classifies first the K candidate RUEs according to their serving BS (lines 2-4 in Algorithm B). Then, it activates randomly $N_B=\lfloor N/B \rfloor$ RUEs among the candidates in each BS, where $\lfloor x \rfloor$ denotes the highest integer lower or equal than x. In case that a BS has less than N_B candidate RUEs all of them are activated.

Algorithm B - BS-based RUE activation

```
1   init: $list\_RUEs(b)$=empty list, for BS $b$=1,...,$B$
2   for candidate RUE $k$=1,...,$K$
3       add candidate RUE $k$ to $list\_RUEs(b(k))$
4   end for
5   for BS $b$=1,...,$B$
6       sort $list\_RUEs(b)$ in random order
7       activate the top $N_B$ RUEs in the sorted $list\_RUEs(b)$
8   end for
```

C. Strategy C: Distance-based RUE activation

This strategy makes the decision on which RUEs to activate considering as context information the distance between the UEs in outage and the different candidate RUEs, assuming that a RUE will be helpful to solve the outage situations of those UEs that are located its proximity. The pseudo-code of this strategy is detailed in Algorithm C. Denoting as $d(u,k)$ the distance between the u-th UE and the k-th RUE, the strategy counts the number of UEs at distance lower than d_{max} for each candidate RUE k (lines 1 to 8) and then it activates the top N RUEs with the highest number of these UEs. Only the candidate RUEs with at least one of these UE are considered in this process (line 9), so it is possible that the number of activated RUEs is eventually lower than N.

Algorithm C - Distance-based RUE activation

```
1   for candidate RUE $k$=1,...,$K$
2       $num\_UEs(k)$=0;
3       for UE $u$=1,...,$U$
4           if $S_D(u) < S_{\min}$ AND $d(u,k) \le d_{max}$
5               $num\_UEs(k)$=$num\_UEs(k)$+1
6           end if
7       end for
8   end for
9   $list\_RUEs$=candidate RUEs with $num\_UEs(k)$>0
10  sort $list\_RUEs$ in decreasing order of $num\_UEs(k)$
11  activate the top $N$ RUEs in the sorted $list\_RUEs$
```

D. Strategy D: Spectral efficiency-based RUE activation

This strategy considers as context information the spectral efficiency $S_R(u,k)$ that can be achieved by a UE in outage when connected to each candidate RUE. The objective is to activate the RUEs that can contribute to solving more outage situations. The pseudo-code is shown in Algorithm D. It follows a similar procedure as strategy C but now it counts, for each candidate RUE, the number of UEs whose outage condition would be solved if connected to this RUE, i.e. the UEs with $S_D(u) < S_{\min}$ and $S_R(u,k) \ge S_{min}$ (see lines 1-8). Then it activates the top N candidates with the highest number (and at least one) of these UEs.

Algorithm D - Spectral efficiency-based RUE activation

```
1   for candidate RUE $k$=1,...,$K$
2       $num\_UEs(k)$=0;
3       for UE $u$=1,...,$U$
4           if $S_D(u) < S_{\min}$ AND $S_R(u,k) \ge S_{min}$
5               $num\_UEs(k)$=$num\_UEs(k)$+1
6           end if
7       end for
8   end for
9   $list\_RUEs$=candidate RUEs with $num\_UEs(k)$>0
10  sort $list\_RUEs$ in decreasing order of $num\_UEs(k)$
11  activate the top $N$ RUEs in the sorted $list\_RUEs$
```

E. Strategy E: Served UEs-based RUE activation

This strategy accounts for the actual number of UEs that would be effectively served by each candidate RUE. First it determines, for each UE in outage, the candidate RUE that would serve this UE, i.e. the candidate RUE that provides the highest value of $S_R(u,k)$ and fulfils $S_R(u,k) \ge S_{min}$ (see lines 2-9 in Algorithm E). Then, the strategy activates the top N candidate RUEs with the highest number of served UEs. Only candidate RUEs with at least one served UE are considered, so the strategy can eventually activate less than N RUEs. It is worth mentioning that, although the operation principle of strategy E is similar to that of strategy D, in the latter a given UE can be counted in more than one RUE (i.e. if more than one RUE can solve the outage condition of this UE), while in strategy E each UE is counted only in one RUE.

Algorithm E - Served UEs-based RUE activation

```
1   init: $served\_UEs(k)$=0 for candidate RUE $k$=1,...,$K$
2   for UE $u$=1,...,$U$
3       if $S_D(u) < S_{\min}$
4           find candidate RUE $k$ with highest $S_R(u,k)$
5           if $S_R(u,k) \ge S_{min}$
6               $served\_UEs(k)$=$served\_UEs(k)$+1
7           end if
8       end if
9   end for
10  $list\_RUEs$=candidate RUEs with $served\_UEs(k)$>0
11  sort $list\_RUEs$ in decreasing order of $served\_UEs(k)$
12  activate the top $N$ RUEs in the sorted $list\_RUEs$
```

F. Strategy F: Min outage with min number of RUEs

This strategy intends to activate the minimum number of candidate RUEs that are needed to minimize the number of UEs in outage in the scenario. The principle of operation is similar to the one of strategy D: the process counts, for each candidate RUE, the number of UEs whose outage condition would be solved if connected to this RUE (see lines 2-11 in Algorithm F). Then, the candidate RUEs are progressively activated starting from the one with the highest number of these UEs (lines 13-23). Each time that a RUE is activated, the UEs that can be served by this RUE are removed from the list of UEs in outage that can be solved by a RUE (*list_outage_UEs* in line 17). The process is repeated until this list is empty (line 15). When this happens, the only UEs that will remain in outage in the scenario are those that cannot be solved by any RUE. This ensures that the algorithm reaches the minimum possible number of UEs in outage. Moreover, when activating a RUE, its served UEs are no longer considered when deciding the activation of subsequent RUEs (lines 18-21). Therefore, a candidate RUE will only be activated if its UEs cannot be served by other already activated RUEs. This drives the algorithm towards minimising the number of activated RUEs.

Algorithm F - Min outage with min number of RUEs

```
1   list_outage_UEs=empty list
2   for candidate RUE $k=1,...,K$
3       num_UEs($k$)=0;
4       for UE $u=1,...,U$
5           if $S_D(u) < S_{\min}$ AND $S_R(u,k) \geq S_{min}$
6               num_UEs($k$)=num_UEs($k$)+1
7               add UE $u$ to list_outage_UEs
8               add UE $u$ to list_RUE($k$)
9           end if
10      end for
11  end for
12  list_RUEs=candidate RUEs with num_UEs($k$)>0
13  sort list_RUEs in decreasing order of num_UEs($k$)
14  $k'=1$
15  while list_outage_UEs is not empty
16      activate RUE in position $k'$ of sorted list_RUEs
17      remove UEs with $S_R(u,k') \geq S_{min}$ from list_outage_UEs
18      remove UEs with $S_R(u,k') \geq S_{min}$ from list_RUE($k$), $k!=k'$
19      if list_RUE($k$) is empty for any $k!=k'$
20          remove RUE $k$ from list_RUEs
21      end if
22      $k'=k'+1$
23  end while
```

G. Strategy G: Min outage with max spectral efficiency

Like strategy F, this strategy also targets the minimization of the number of UEs in outage in the scenario. However, as a difference from strategy F, it intends to provide the highest spectral efficiency to the UEs connected through the RUEs. To achieve this, the procedure, shown in Algorithm G, determines, for each UE in outage, the candidate RUE that provides the highest value of $S_R(u,k)$ and fulfils $S_R(u,k) \geq S_{min}$ (see lines 2-9). This is the candidate RUE that will serve the UE. Then, the strategy just activates all the RUEs that serve at least one UE. It is worth noting that this strategy follows the same principle like strategy D but, instead of restricting the number of activated RUEs to N, it activates all the RUEs with served UEs, in order to minimise the outage.

Algorithm G - Min outage with max spectral efficiency

```
1   init: served_UEs($k$)=0 for candidate RUE $k=1,...,K$
2   for UE $u=1,...,U$
3       if $S_D(u) < S_{\min}$
4           find candidate RUE $k$ with highest $S_R(u,k)$
5           if $S_R(u,k) \geq S_{min}$
6               served_UEs($k$)=served_UEs($k$)+1
7           end if
8       end if
9   end for
10  list_RUEs=candidate RUEs with served_UEs($k$)>0
11  activate all the RUEs in list_RUEs
```

IV. PERFORMANCE EVALUATION

A. Scenario description

The performance of the different RUE activation strategies has been evaluated by means of system level simulations considering a realistic urban scenario of 700 x 700 m in Barcelona city, with population density of 43300 inhabitants/km^2. The scenario, shown in Fig. 2, encompasses an area with different streets, avenues and a park, and with different seven floor buildings with 3.5 m floor height. We consider a mobile network operator with 20% market penetration, resulting in a density of 8660 UEs/km^2. The 5G NR deployment includes a total of B=6 outdoor microcell BSs placed at the yellow dots in Fig. 2. BS height is 10 m, frequency is 26 GHz and the total transmitted power is 25 dBm over a total bandwidth of 100 MHz. Beamforming with ideal beam steering is assumed with an antenna gain of 26 dB for the microcells and 10 dB for the UEs. UE height is 1.5 m. Only the downlink direction is considered, and the noise figure of the UE receiver is 9 dB. The propagation follows the UMi model of [11] with outdoor-to-outdoor and outdoor-to-indoor losses and 2D-spatially correlated shadowing. It is assumed that interference among cells is negligible due to the large amount of spectrum available in the 26 GHz band, which facilitates deployments with low frequency reuse, and to the interference coordination that can be achieved when transmitting with narrow antenna beams.

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Fig. 2. Considered scenario

Activated RUEs transmit at 3.5 GHz with the same power and bandwidth than the microcells and with antenna gain 3 dB. The UE-to-UE propagation model of [12] is used, but including the outdoor-to-indoor propagation losses of the UMi model and an additional loss of 21 dB per floor when UEs are located in different floors of the same building. Perfect interference coordination among RUEs is assumed. According to [10], S_{max}=7.4063 b/s/Hz. Moreover, a UE is considered in outage if the spectral efficiency is lower than S_{min}=1 b/s/Hz.

To assess the different RUE activation strategies, it is assumed that approximately 5% of the UEs in the scenario are actively generating traffic, corresponding to a total of U=200 active UEs. Moreover, a total of K=1000 candidate RUEs are assumed to be available, which corresponds approximately to 25% of the UEs of the operator in the scenario. The strategies A, B, C, D, E are configured to activate at most N=100 RUEs out of the K=1000 candidate RUEs. Strategy C is configured with d_{max}=100 m.

The performance of the different RUE activation strategies is obtained by conducting 1000 different random realizations, where the U active UEs and K candidate UEs are uniformly distributed in the scenario at each realization. The performance metrics are averaged over the 1000 realizations.

B. Results

As a reference case, Fig. 3 plots the obtained spectral efficiency in the direct link with the serving BS of each point in the scenario at the ground level when no RUEs are activated. The area in outage is depicted in white. It is observed that, while the outdoor performance is overall good, the indoor coverage is very poor, with many regions in outage. Although not depicted in the figure, this effect is exacerbated in higher floors of the buildings.

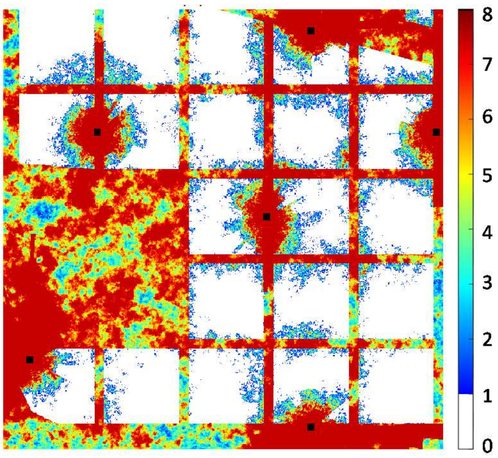

Fig. 3. Spectral efficiency in b/s/Hz obtained at the ground floor level.

Fig. 4, Fig. 5 and Fig. 6 plot, respectively, the outage probability observed by the U UEs with each one of the considered strategies, the average number of activated RUEs with each strategy and the average spectral efficiency. As a reference, the case without RUEs is also included in the results.

Fig. 4 shows that the outage probability for the case without RUEs is 48%, while the activation of the RUEs allows substantially decreasing this outage probability, but with significant differences among various activation strategies. The simpler strategies A and B, in which a random selection and a spatially uniform distribution of RUEs are respectively considered, achieve a 35% outage probability, which represents a small reduction compared to the no RUEs case. Strategy C, which only considers the distance to the UEs in outage only allows reducing the outage probability down to 29%. This is due to the fact that, given the random effects of the propagation among UEs such as shadowing, walls, floors, etc., the distance does not represent accurately the actual propagation that will be experienced. In contrast, the rest of strategies, which incorporate richer context awareness information provide more significant reductions. The best performance is obtained with the strategies E, F, and G that account for the actual UEs that would be served by each candidate RUE. They achieve the minimum outage probability of around 4.5%.

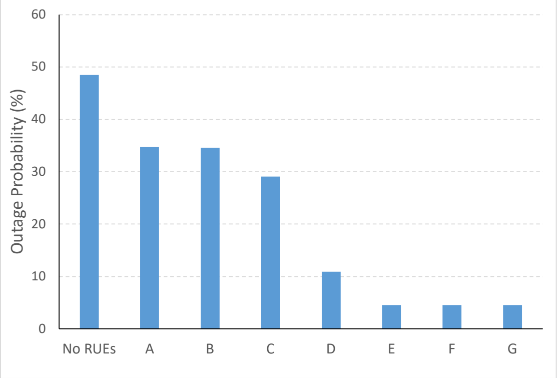

Fig. 4. Outage probability with the different RUE activation strategies

Fig. 5. Average number of activated RUEs with the different strategies

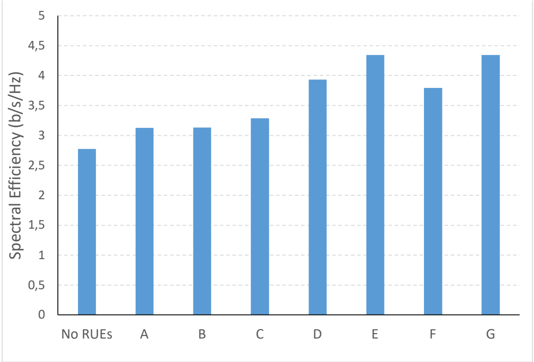

Fig. 6. Average spectral efficiency with the different RUE activation strategies

Moreover, the best behaviour of strategies E, F, G is achieved with significantly less activated RUEs, as observed in Fig. 5. Indeed, while strategies C and D activate the maximum of N=100 RUEs, strategies E and G achieve the minimum outage by activating only 74 RUEs on average, while strategy D, which targets the minimum outage but also with the minimum number of activated RUEs, only requires to activate approximately 54 RUEs on average. It is also worth noting that, for the considered value N=100, strategy E has exactly the same behaviour as strategy G, because it ends up by activating all the RUEs that serve at least one UE in outage and it can do so with less than the maximum of N=100 RUEs. In contrast, this is not the case of strategy D: since it only accounts for the spectral efficiency of the UEs that could be connected to a candidate RUE but without considering if the same UE could be served by a different candidate, it ends up with a less efficient activation of RUEs that reaches the maximum of N=100 RUEs without solving all the possible outage situations. As a result, the outage probability of strategy D is also larger than the one of strategies E, F, G, as seen in Fig. 4.

The spectral efficiency results of Fig. 6 reflect that, like in the case of the outage probability, the best performance is obtained by strategies E and G, because both strategies consider the candidate RUE providing the highest spectral efficiency to each UE in outage. As a result, they can maximize the obtained spectral efficiency at the expense of activating a larger number of RUEs than strategy F, which minimizes the number of activated RUEs but provides a smaller spectral efficiency than strategies E and G.

To assess qualitatively the impact of the RUE activation Fig. 7 plots the obtained spectral efficiency at the ground floor level including the positions of the UEs that are served by a RUE for the different realizations with RUE selection strategy G. The comparison with the case without RUEs shown in Fig. 3 reflects clearly the important reduction of areas in outage achieved thanks to the activation of the RUEs.

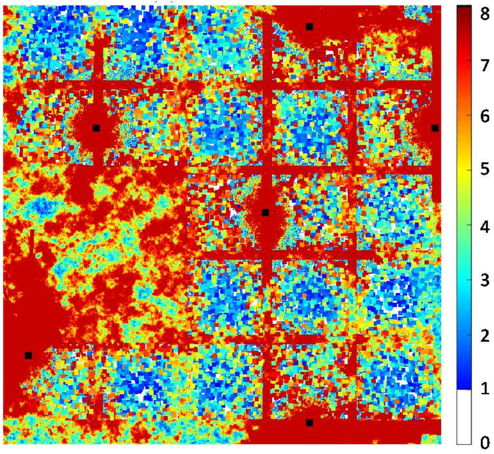

Fig. 7. Spectral efficiency in b/s/Hz obtained at the ground floor level after activating the RUEs with strategy G.

V. CONCLUSIONS AND FUTURE WORK

This paper has studied the relay UE (RUE) activation problem in a B5G scenario in which the UE is used to augment the RAN infrastructure through UE-to-network relaying capabilities. Specifically, seven RUE activation strategies have been studied that differ on the type of context information and on the criteria used for making the decisions. They have been evaluated through system-level simulations in a realistic urban scenario and it has been obtained that the most efficient strategies from the perspective of outage probability reduction are the ones that account for the number of UEs that would effectively be served by a RUE if it was activated, based on the spectral efficiency in the BS-RUE and RUE-UE links. These strategies, referred to as "Served UEs-based RUE activation", "Min outage with min number of RUEs" and "Min outage with max spectral efficiency", achieve a similar outage probability of around 4.5%, which represents reducing in a factor 10 the outage probability observed in a scenario without RUEs. Moreover, it is found that the "Min outage with min number of RUEs" strategy is able to provide this low outage probability with the lowest number of activated RUEs, although at the expense of a somehow lower average spectral efficiency than the other two.

Based on these promising results, future work will apply the lessons learnt from the comparison of these reference strategies to build a solution considering further contextual components such as the battery status or the mobility forecasting of the different candidate RUEs and UEs. Given the growth in the amount of context information embraced, the possibility of using Machine Learning-based tools such as deep reinforcement learning will be explored.

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