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De l'intérêt d'utiliser des stations de base mobiles pour les premiers secours !

Zhiyi Zhang¹ et Razvan Stanica¹ et Fabrice Valois¹

¹Univ Lyon, INSA Lyon, Inria, CITI, EA3720, 69621 Villeurbanne, France

En cas de catastrophe naturelle, comme en France en décembre 2023, ou dans d'autres situations d'urgence, les stations de base du réseau cellulaire peuvent être endommagées. Le rétablissement des réseaux de communications pour permettre l'intervention des forces de secours est alors une des premières opérations d'urgence à réaliser. En plus des stations de base fixes, nous avons la possibilité d'embarquer les fonctions d'une station de base sur une plateforme mobile (e.g., un drone). Le réseau devient alors agile et dynamique, afin de s'adapter à l'évolution du trafic. Dans ce travail, nous étudions l'apport d'une station de base mobile pour suivre un groupe d'utilisateurs par rapport à une station de base fixe. Nous montrons que le gain apporté peut aller jusqu'à un facteur 4 en termes de débit.

Mots-clefs : Cellular network, Movable base stations, Network performance

1 Introduction

In cellular networks, the radio access network is composed of fixed base stations (FBS). As the location of FBS is pre-defined, a detailed study on choosing the location needs to be conducted. Moreover, the resources allocated to each FBS are fixed and cannot be dynamically adapted to the traffic evolution: when FBS resources are insufficient, network performance fluctuates. For example, in case of natural disasters, a cellular network is not resilient because of the potential impact on FBS.

Movable base stations (MBS) [MSBD15] are expected to be deployed automatically, anytime and anywhere. MBS can be used to add resources and capabilities to an existing mobile network, or to help in the deployment of an isolated cellular network. MBS can move to be closer to the user demand, and allow to dynamically add base stations when the environment changes. These key features are well suited to the needs of emergency networks. Therefore, a challenge arises: how to manage the movement of MBS to achieve the best network performance? However, before focusing on controlling MBS, we first need to figure out what they can bring us, the advantages and the limitations compared to FBS. In this work, we compare the network performance of an MBS and an FBS in an emergency scenario with a group of users, such as first responders. The results show that the use of MBS can increase the throughput by 4. To reach the same throughput, the required transmit power of MBS can be about 50dBm smaller than that of FBS.

2 Related Works

Several works are focused on the integration of MBS in the cellular network. Some of them discuss placement optimization for static MBS with one [ABM22] or multiple [ATHY21] MBS. Some research works prove that repositioning the MBS can improve the network performance. Fotouhi *et al.* [FDH16] show that the MBS moving towards the target users will improve the spectral efficiency. Contrarily, some research works show that using the MBS can also have a negative impact. The movable platforms are energy-constrained, and continuous movement of MBS reduces the system lifetime. Kalantari *et al.* [KSY17] argue that, if the initial position of MBS is well studied, the MBS can remain static for long periods. However, to the best of our knowledge, no one has quantified the benefits in network performance, even in simple scenarios, when an MBS replaces an FBS in the cellular system.

A	P_t	h	R	f	Bandwidth	T	Δt	N	V_{max}	v_{max}
20km \times 20km	40dBm	30m	20m	3.5GHz	5MHz	30 min	1s	15	2m/s	0.2m/s

TABLE 1: Simulation parameters

3 System Model

Our objective is to evaluate the network performance in a scenario with a group of first responders conducting operations in an area served by only one base station, either FBS or MBS. We assume a group of N users deployed in a given area A . Among these users, there is 1 group leader and $N - 1$ group members. The simulation has a duration of T . At the beginning of the simulation, the group members are randomly placed around the group leader, also randomly placed in the area A . We adopt the Reference Point Group Mobility as the group mobility model [HGPC99]. We define the user dispersion R as the maximum distance between the group leader and the edge group members. The FBS is fixed and located at the center of the area A . The MBS follows the group of mobile users by tracking the group leader. For a fair comparison, the altitude h and the transmission power P_t of FBS and MBS are the same. However, we consider there may be an estimation error E_{err} when localizing the group leader.

We consider different radio propagation environments. Firstly, a line-of-sight (LoS) propagation is considered, based on the Friis equation allowing us to compute the free-space path loss (FSPL). However, because non LOS (NLoS) conditions also appear depending on the first responders intervention scenario, and based on an ITU recommendation, we also consider four NLoS environments: suburban, urban, dense urban and high-rise urban [IR12].

We know the location of the base station and the users during T , so we can compute the distance between the base station and the users at each Δt . As we only have one base station in the target area, there is no radio interference considered. We account for thermal noise in our system, constant for a certain bandwidth. Then, as the transmit power is a known constant, the FSPL can be computed depending on the environment, and we can calculate the received power for each user at each time step. We choose the throughput as the metric of network performance. Based on received power and noise, we can compute the maximum theoretical throughput for each user (given by the Shannon-Hartley theorem). The default values of the simulation parameters are shown in Table 1. The results are based on 100 simulations and the confidence interval is set as 95%.

4 Results

As shown in Fig. 1, we evaluate the impact of transmission power on the average user throughput in different radio propagation conditions. For the same transmission power, if we consider only the LoS conditions, the average throughput of MBS is up to 4 times higher than the average throughput given by FBS. In the other sense, to achieve a target throughput, the required transmission power of MBS is much lower than that of FBS, the difference reaching almost 50dBm. We also study several NLoS propagation models to deal with different environments. The NLoS conditions have a significant impact on the FBS network, but not on the MBS network. Compared to the user throughput in a LoS environment, the throughput with FBS in suburban, urban and dense urban environments has a heavy fluctuation. In the high-rise urban environment, the throughput is very low for FBS. In the case of MBS, the suburban, urban and dense urban environments do not have a significant impact on network performance. In the high-rise urban environment, network performance is significantly reduced, but it remains high compared to FBS. This is because the MBS follows the users, hence reducing the probability of encountering obstacles on the radio propagation path.

We evaluate the impact of user dispersion R on network performance in a LoS environment in Fig. 2a. Overall, the user throughput of MBS is higher than for FBS. As the MBS follows the mobility of the group leader, when user dispersion increases, the distance between the MBS and the group members also increases. Thus, the performance decreases with the increase of the dispersion for MBS network. The FBS is fixed at the center of the target area, its performance depends on the random position of users. However, the user average throughput in FBS network is stable at 2.5 Mb/s. We remark that, if the user dispersion is relatively small, such as less than 1 km in our simulation, using an MBS is a better choice, as it hovers over

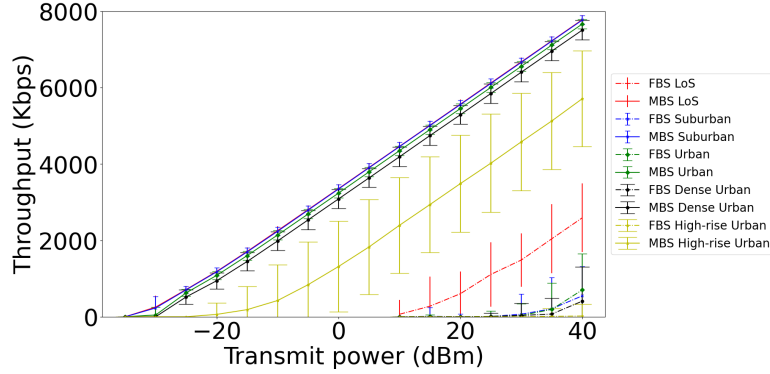


FIGURE 1: Average throughput of different radio propagation models (CI=95%).

the group leader. But, with the increase in user dispersion, the advantage of using MBS will decrease, the two solutions reach similar performance for a user dispersion of around 5 km.

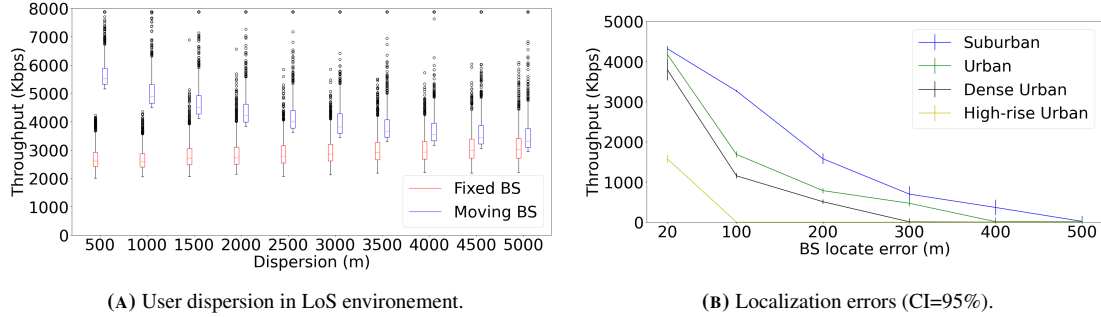


FIGURE 2: Average user throughput function of different parameters.

In the previous results, we consider the MBS can somehow track the leader and follow the group. However, in practice, there might be an error when the moving MBS tries to locate the group leader. Therefore, the accuracy of the group leader localization by the MBS can be an important issue. We evaluate the impact of this parameter on the network performance by varying the localization error, E_{err} , from 20 m to 500 m. Fig. 2b presents the variation of the average user throughput for different localization errors, in different NLoS environments, with $P_t = 10$ dBm. Depending on the radio propagation environment, the MBS system seems to tolerate a localization error between 20 m and 200 m. With larger localization errors, the user throughput degrades considerably. While the impact of this parameter is clearly significant, we believe that realistic localization errors in practice are in the range of tens of meters, a value for which the MBS approach highly outperforms the FBS one.

Indeed, sometimes, a part of the first responders may need to stay outside the group and deal with specific issues. Therefore, we evaluate the FBS and MBS performance when there are static users in the field, together with a group of users moving together. To this end, we keep the original number of users the same and increase the number of static users proportionally. We denote the proportion of static users as α , thus, there are αN static users. We use a default value of 15 total users in our simulation so, for convenience, we choose 20, 40, 60, and 80 percent as the proportion of static users. To deal with the static users, we implement two possible MBS mobility control strategies. The first one consists of the MBS always following the leader of the mobile group, as in the previous results, despite the existence of static users. The second strategy is to place the MBS in the center of mass of all the users. In Fig. 3a, we evaluate the network performance for all these scenarios with a varying numbers of static users in a LoS environment. Overall, the MBS approaches perform better than FBS. However, as the proportion of static users increases,

the average user throughput of MBS gradually decreases, no matter which mobile control strategy is used. The strategy where the MBS follows the group leader movement has a slightly better performance than the strategy using the center of mass. However, for both strategies, the confidence intervals are very large, indicating significant user disparity.

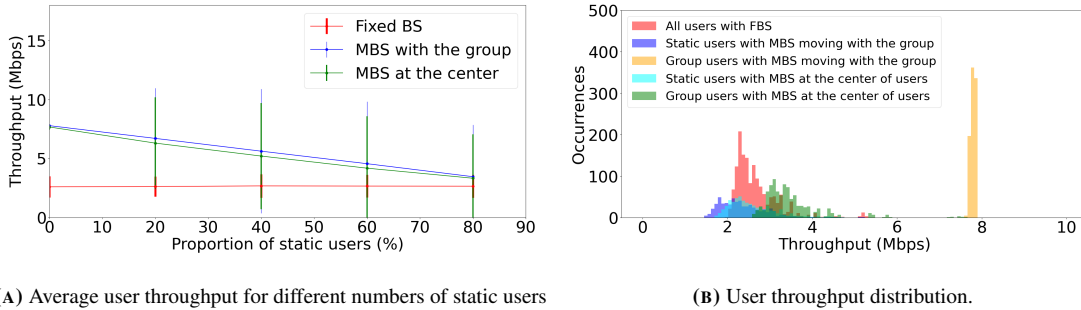


FIGURE 3: Evaluation with different number of static users in the first responders group in a LoS environment.

To better understand this phenomenon, we divide MBS users into static users and mobile group users and show the results of these two groups in Fig. 3b. The throughput of FBS users is also shown, for comparison, without distinguishing between mobile and static users in this case. When MBS closely follows the group of mobile users, the throughput of these users is guaranteed, and it is close to 8 Mb/s. The throughput of static users for this MBS scenario is slightly lower than the one of FBS users. When the MBS is placed in the center of mass of the users, the performance observed by the static users does not actually improve. However, the mobile group users observe a noticeable drop in performance in this case.

5 Conclusion and Perspective

In a first responders scenario, we show that a MBS is more suitable for covering a group of mobile users. Compared to a FBS, we can reduce the transmission power by 50dBm to achieve a target throughput with a MBS in LoS environment. In NLoS propagation environments, the advantage of MBS is more obvious. However, the advantage of MBS depends on the user dispersion and the group localization error. When both static users and mobile group users are present, the use of MBS provides a significantly better performance for group users than the use of FBS, with a slight performance degradation for static users.

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