

# Optimizing the Energy Consumption of an Unmanned Aerial Base Station

Manuel Eugenio Morocho-Cayamcela  
Department of Electronic Engineering  
Kumoh National Institute of Technology  
Gumi-si, Republic of Korea  
eugeniomorocho@kumoh.ac.kr

Wansu Lim  
Department of IT Convergence Engineering  
Kumoh National Institute of Technology  
Gumi-si, Republic of Korea  
wansu.lim@kumoh.ac.kr

**Abstract**—Unmanned aerial vehicles have the potential to be used as aerial base stations (ABSs) for the telecommunication industry to serve locations where a high number of users convene temporally (i.e., stadiums, concerts, or other massive attendance events). However, the positioning of the ABSs is still an open research area. In this study, we propose a path-finding vector-quantization algorithm that displaces the ABSs according to the iterative minimization of the power received by the users. We illustrate the path of multiple ABSs running our algorithm and compare the power consumption over iterations.

**Index Terms**—Disaster scenario, massive MIMO, path planning, unmanned aerial vehicle, user association.

## I. INTRODUCTION

In the telecommunications industry, the traditional wireless scenario involves multiple terrestrial base stations (TBSs), usually deployed on top of mountains or high buildings, and user equipment (UE) assigned to a particular TBS [1], [2]. The TBS sends and receives information to its assigned UEs. The growth of UEs brings diverse challenges to the wireless network, especially when a large number of UEs congregates in a small geographical area for short periods (i.e., stadiums, concerts). These scenarios with a high density of UEs, saturates the available electromagnetic spectrum, reducing the data rate, and the overall quality of service (QoS) perceived by the UE in the network. The temporal deployment of TBS to serve these highly-dense scenarios represent a significant capital expenditure (CapEx) for network providers. To reduce the CapEx, unmanned aerial vehicles (UAVs) have been proposed to act as aerial base stations (ABSs) to reduce the energy required for the UE to connect to the infrastructure of its network provider [3]–[5]. This emerging technology has disclosed new research challenges in the area of ABSs positioning [6], [7]. In this study, we propose a vector-quantization iterative method to find the optimal location of the ABSs that minimizes its consumed power.

## II. ENERGY OPTIMIZATION FOR ABS NETWORKS

### A. Wireless System Model

We consider a system with  $L$  ABSs, serving  $K$  UEs. The position of the ABSs can be described as

$$T = \{z_1, \dots, z_L\} = |L|, \quad (1)$$

where  $z_l$  represents a 3-dimensional location of the  $l$ -th ABS. Similarly, the position of the UEs can be described as

$$S = \{x_1, \dots, x_K\}, \quad (2)$$

where  $x_k$  represents the position of the  $k$ -th UE. We assume a non-interference system, where the link budget where the power (dBm) received by each UE can be expressed as

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - 20\log_{10}(d) + 20\log_{10}(f) - 27.55 + G_{RX} - L_{RX}, \quad (3)$$

where  $P_{TX}$  represents the transmitter output power in dBm,  $G_{TX}$  represents the transmitter antenna gain in dBi,  $L_{TX}$  represents the transmitter losses due to coaxial cables and connectors in dB,  $d$  represents the link distance in m,  $f$  is the operating frequency in MHz,  $L_M$  represents miscellaneous losses in dB (i.e., fading margin, body loss, and polarization mismatch),  $G_{RX}$  represents the receiver antenna gain in dBi, and  $L_{RX}$  represents the receiver losses due to coaxial cables and connectors in dB [8].

### B. Energy Optimization Algorithm

Our algorithm starts with the location information of the  $l$ -th ABSs and  $k$ -th UEs. The goal is to find the positioning matrix  $T$  for the  $L$  ABSs iteratively. The algorithm tries to minimize the power consumed by the multiple ABSs by locating them in an optimal position that minimizes the channel losses. Algorithm 1 presents an overview of the proposed solution.

## III. SIMULATION RESULTS AND DISCUSSION

The links are simulated to enable communication over the 2.4 GHz operating frequency. To test our algorithm, we position the users in 3 synthetically generated clusters and run Algorithm 1 in 3 different ABSs. Figure 1 illustrates the initial and final positions of the ABSs. We show that our algorithm finds the trajectory to a location where the power consumption is minimized after approximately 10 iterations. This differs from previous works, where the authors used the Euclidean distance as cost function. Note that the minimization of the Euclidean distance does not necessarily mean a minimization of the consumed power since the wireless link can be obstructed with buildings, trees, etc. After convergence, the average

**Algorithm 1** ABSs Consumed Power Minimization**Input:**  $L$ , and initial  $T$ .**Output:**  $T$ .

```

1: repeat (for each iteration)
2:   get  $S$ .
3:   for all UEs do
4:     for all ABSs do
5:       calculate  $P_{RX}$  with (3)
6:       assign UE to highest  $P_{RX}$  ABS
7:     end for
8:   end for
9:   for all ABSs do
10:     $z_l \leftarrow$  mean of UEs positions assign. to its respect. ABS
11:  end for
12:   $T \leftarrow$  updated  $z_1, \dots, z_L$ 
13: until convergence
14: return  $T$ 

```

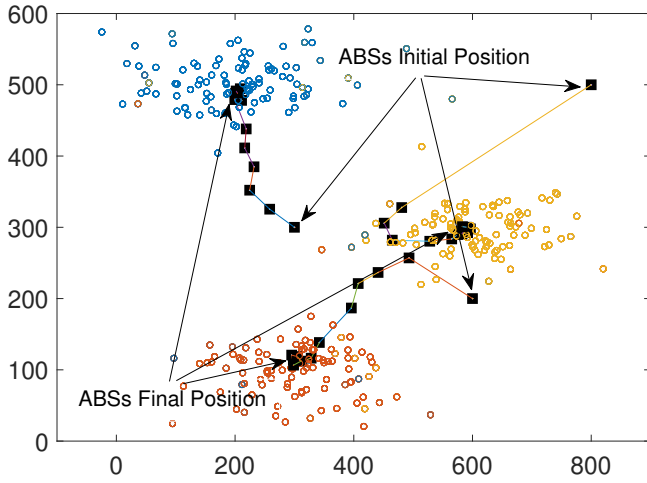


Fig. 1. Initial and final position of the ABSs running the proposed path-finding algorithm.

transmitted power required to establish a communication link between the ABSs and each assigned set of UEs decreases exponentially. Figure 2 exemplifies the reduction of power consumption (in dBm) on the ABSs after 20 iterations.

#### IV. CONCLUSIONS AND FUTURE WORK

We have proved our hypothesis that the use of the power received by each UE as a cost function in an iterative-learning algorithm can estimate the path for ABSs to the location that minimizes the power consumption required to establish a wireless communication link. The proposed algorithm can be further studied in diverse systems that use drones, like extending wireless coverage in military applications, recovering for damaged infrastructure, and providing service in disaster scenarios. Future works include the use of multiple-input multiple-output array of antennas, the study of different propagation scenarios, mobility of the UEs, the choice of the optimal number of deployed ABSs, and the decentralization of the algorithm.

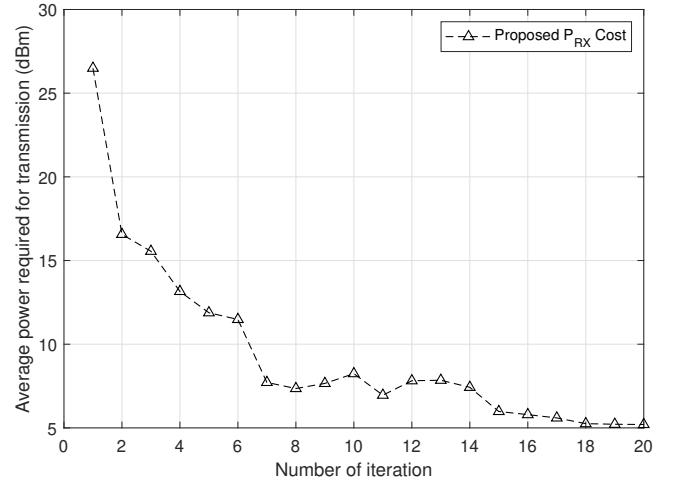


Fig. 2. Average power consumed by the ABSs after 20 iterations of the proposed algorithm.

#### ACKNOWLEDGMENT

This work was supported by the Technology development Program (S2829065) funded by the Ministry of SMEs and Startups (MSS, Korea), and by the Basic Research Program through the National Research Foundation of Korea (NRF) funded by the MSIT (2020R1A4A10177511).

#### REFERENCES

- [1] M. E. Morocho-Cayamcela, M. Maier, and W. Lim, "Breaking wireless propagation environmental uncertainty with deep learning," in *IEEE Transactions on Wireless Communications*, doi: 10, 2020.
- [2] M. E. Morocho-Cayamcela, H. Lee, and W. Lim, "Machine learning to improve multi-hop searching and extended wireless reachability in v2x," in *IEEE Communications Letters*, doi: 10, 2020.
- [3] A. Akarsu and T. Girici, "Resilient deployment of drone base stations," *International Symposium on Networks, Computers and Communications (ISNCC)*, Istanbul, Turkey, vol. 10., pp. 1–5, 2019.
- [4] A. Fotouhi, M. Ding, and M. Hassan, "Flying drone base stations for macro hotspots," in *IEEE Access*. doi: 10, 2018, vol. 6, pp. 19 530–19 539.
- [5] L. Wang, B. Hu, and S. Chen, "Energy efficient placement of a drone base station for minimum required transmit power," in *IEEE Wireless Communications Letters*, doi: 10, 2018.
- [6] I. Bor-Yaliniz, S. S. Szyszkowicz, and H. Yanikomeroglu, "Environment-aware drone-base-station placements in modern metropolians," in *IEEE Wireless Communications Letters*. doi: 10, Jun. 2018, vol. 7, no. 3, pp. 372–375.
- [7] M. E. Morocho-Cayamcela, H. Lee, and W. Lim, "Machine learning for 5g/b5g mobile and wireless communications: Potential, limitations, and future directions," in *IEEE Access*. doi: 10, 2019, vol. 7, pp. 137 184–137 206.
- [8] W. Khawaja, I. Guvenc, D. W. Matolak, U. Fiebig, and N. Schneckenburger, "A survey of air-to-ground propagation channel modeling for unmanned aerial vehicles," in *IEEE Communications Surveys Tutorials*. doi: 10, 2019, vol. 21, no. 3, pp. 2361–2391.