Economics of UAV-provided Mobile Services

Xuehe Wang
Singapore University of Technology and Design
xuehe_wang@sutd.edu.sg

Lingjie Duan
Singapore University of Technology and Design
lingjie_duan@sutd.edu.sg

CCS CONCEPTS

• **Networks** → Network economics;

KEYWORDS

UAV, Mobile Services

ACM Reference Format:
Xuehe Wang and Lingjie Duan. 2018. Economics of UAV-provided Mobile Services. In *NetEcon'18: Economics of Networks, Systems and Computation, June 18, 2018, Irvine, CA, USA,* Irvine, California, USA, 1 page. https://doi.org/10.1145/3230654.3230663

Due to the fast deployment and controllable mobility, the unmanned aerial vehicle (UAV) emerges as a promising technology to rapidly provide mobile services (e.g., wireless coverage, edge computing, and local caching) to ground users. For example, Verizon has developed a drone-based cell service system to provide 4G LTE cell service for the area out of service. By endowing with edge computing capabilities, the UAV can be also used to offer computation offloading services to mobile users with limited local processing capabilities. Moreover, cache-enabled UAV is implemented to improve the quality-of-experience of mobile devices by caching and distributing the popular content to them. The global revenue of such UAV-enabled services is expected to increase from \$792 million in 2017 to \$12.6 billion by 2025.

The recent literature focuses on the technological issues of the UAV-provided mobile services such as improving air-to-ground communication to enlarge wireless coverage and addressing UAV energy constraints. However, the economic issues of such services are largely overlooked. As a UAV's hovering in the air and its local service provision to ground users are both energy-consuming, a longer hovering time helps meet more demands yet leaving less energy for servicing users. How to balance the hovering time and service capacity under the limited energy budget is critical to ensure the economic viability of UAV-provided mobile services. Further, when hovering in a hotspot for a given finite time period, how to dynamically price the capacity-limited service to ground users for profit-maximization is another issue. This is challenging under incomplete information about the mobile users' randomness in arriving and their private service valuations. What's more, when facing multiple hotspot candidates with different user occurrence rates and flying distances, the optimal deployment of multiple UAVs to cooperatively serve the chosen hotspots needs to be studied.

NetEcon'18, June 18, 2018, Irvine, CA, USA

ACM ISBN 978-1-4503-5916-0/18/06.
https://doi.org/10.1145/3230654.3230663

This paper proposes a three-stage decision making model to study these economic issues: In Stage I, multiple UAVs' deployment to cooperatively cover heterogeneous hotspots is discussed; In Stage II, we study the energy allocation of each UAV to balance hovering time and service capacity for its chosen hotspot; In Stage III, we analyze each UAV's dynamic pricing under incomplete user information for a given hovering time at a given hotspot. It should be noted that dynamic pricing of generic products or services are studied. However, these works assume a fixed service capacity and do not consider users' randomness in arrivals, while in our UAV-provided services scenario, each UAV has interchangeable energy capacities for hovering and servicing and the users are also randomly moving on the ground.

In this paper, we use backward induction to analyze the UAV's decision at each stage. In Stage III, under the incomplete information regarding users' random arrivals and private service valuations, we design a dynamic pricing scheme for each UAV and prove that the UAV should ask for a higher price if the leftover hovering time is longer or its service capacity is smaller, and its expected profit approaches to that under complete user information if the hovering time is sufficiently large.

In Stage II, though a longer hovering time ensures a higher service price under incomplete information, it leaves a smaller service capacity under the energy budget, the UAV should balance its hovering time and service capacity to maximize its profit. To tell the trade-off, we derive an optimal threshold-based energy allocation policy. We show that as the hotspot's user occurrence rate increases, a smaller hovering time or a larger service capacity should be allocated.

In Stage I, we study the deployment of multiple cooperative UAVs to heterogeneous hotspots for maximizing the total profit. A hotspot's high user occurrence rate helps ensure a large demand for the service yet its flying distance should not be far for a UAV to reach under energy constraint. Hence, we should consider the trade-off between different hotspots' user occurrence rates and flying distances for UAV deployment. We prove that it is optimal for a single UAV to only serve one hotspot. When multiple cooperative UAVs are deployed to the same hotspot, they can pool their service capacities yet waste more energy in hovering at the same time. We show that the UAVs should fork to serve different hotspots especially when hotspots are more symmetric or the UAV number is large.

We refer the reader to [1] for more details.

REFERENCES

[1] http://people.sutd.edu.sg/~lingjie_duan/wp-content/uploads/2018/05/eco-UAV.pdf.