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DYNAMIC FREQUENCY ASSIGNMENT FOR MOBILE USERS IN MULTIBEAM SATELLITE CONSTELLATIONS

Abstract

The unprecedented levels of flexibility and scalability of the next generation of communication satellite systems call for new resource management algorithms that adapt to dynamic environments. The upcoming landscape of satellite communication services will be defined by an increased number of unique users, a large portion of which will correspond to mobile users such as planes or ships. The additional challenge introduced by these users is addressing the spatiotemporal uncertainty that comes in the form of delays, changes in their trajectory, or both. Given that mobile users will constitute an important segment of the market, satellite operators prioritize leveraging modern digital payloads to develop flexible resource allocation strategies that are robust against dynamic user bases.

One of the key problems in this context is how to manage the frequency spectrum efficiently. While numerous solutions address dynamic frequency assignment scenarios, the additional layer of complexity presented by mobile users has not been sufficiently studied, and it is unclear whether novel frequency assignment algorithms can address spatiotemporal uncertainty. Specifically, we argue that unexpected changes in the position of users introduce new restrictions into the frequency assignment, which previous algorithms in the literature might not be able to meet, especially if decisions need to be made in real-time and at scale.

To address this gap, we propose a dynamic frequency management algorithm based on linear programming that assigns resources in scenarios with both fixed and mobile users, accounting for the spatiotemporal uncertainty of the latter. Our method includes both long-term planning and real-time operation, a synergy that has not been sufficiently explored for satellite communications and proves to be critical when operating under uncertainty. To fulfill the problem's scope, we propose different strategies that extend a state-of-the-art frequency management algorithm. These strategies are divided into proactive strategies, which stem from robust optimization practices, and reactive strategies, which exploit a high degree of real-time control.

To assess the performance of our algorithm and determine which strategies work better under which context, we simulate operational use cases of non-geostationary constellations with increasing levels of dimensionality and uncertainty. The results identify the strategies that best leverage the capabilities of satellite systems to allocate resources efficiently. We find that the studied strategies present several tradeoffs when addressing spatiotemporal uncertainty and analyze them in-depth. Finally, given the

flexibility of our method, we discuss how additional constraints that are unique to certain constellations could be included in our formulation.