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OPTIMAL AND SCALABLE ALGORITHMS FOR USER GROUPING IN LEO-MEO-GEO HYBRID VERY HIGH THROUGHPUT SATELLITE CONSTELLATIONS

Abstract

Satellite communications are transforming the when and how people can access broadband Internet. Highly flexible satellite payloads combined with a massive increase in the number of spacecrafts allow operators to cover markets unreachable by terrestrial networks, such as isolated regions or connectivity on-the-go. Part of the new architectures' success relies on intricate constellation designs that involve several layers of satellites at different altitudes, such as combinations of LEO layers, as proposed by Starlink and Project Kuiper, or combinations across LEO, MEO, and GEO planes, as proposed by SES, ViaSat, and Boeing. Under the new systems, satellite operators will need automated and scalable mechanisms able to efficiently group and distribute individual customers across satellites (a.k.a. the User Grouping problem) to maximize satellite utilization and achieve increased constellation capacity. While previous studies propose methods for single-altitude designs, algorithms for hybrid systems are yet to be developed. This work aims to breach this gap by 1) formulating the User Grouping problem for hybrid constellations as a Mixed Integer Linear problem, and 2) developing an optimal approach for low-dimensional conditions and a scalable approach for high-dimensional scenarios to solve it. By using the Boeing 10-layer LEO-MEO-GEO constellation as an example, this work demonstrates that the scalable approach can provide high quality solutions in feasible time for scenarios with up to 50000 customers, which represents realistic operational conditions, with a 37% reduction in maximum satellite load compared to a maximum elevation heuristic. Even more, comparing the outcomes under low-dimensionality conditions shows how the scalable approach suffers only from a minor degradation in performance compared to the optimal method.