Paper ID: 77940
student

IAF SPACE OPERATIONS SYMPOSIUM (B6)
Large Constellations & Fleet Operations (5)

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IDENTIFYING KEY NODES OF MEGA LEO SATELLITE NETWORK BASED ON NODE EMBEDDING AND MACHINE LEARNING

Abstract

The boost of mega LEO constellations is a hot topic in the field of commercial aerospace, which proposes a pressing requirement on the space traffic surveillance. This paper presents a key node identification method of LEO satellite network from the perspective of complex network and its dynamics. Traditionally, the centrality measures are important ways to rank importance of network nodes. The computation of these metrics is time-consuming when the number of nodes remarkably increases, even with polynomial algorithms. This study probes into approximate and rapid calculations of centrality metrics using graph neural networks for mega LEO constellations. We study network constructions for satellite constellations using instantaneous interstellar distance and its corresponding collision probability as a connected edge when considering the two-body model plus classical J2 perturbations. The dynamic network of the satellite constellation is considered as multiple static network slices in time scale, and the regression models are trained to efficiently approximate arbitrary node centrality measures of the satellite network using neural network and graph embedding techniques. The proposed model, entitled Network Centrality Approximation using Graph Embedding (NCA-GE), employs the adjacency matrix of a graph and a set of features for each node (here, only the degree is used) as input and computes the desired centrality rank for each node. NCA-GE trains pretty fast, requiring only a set of a thousand small synthetic scale-free graphs (ranging from 100 to 1000 nodes each), and it works well for different node centralities, network sizes, and topologies. We compare our approach to previous centrality ranking methods using degree and eigenvector centralities as input, and the results show that the NCA-GE outperforms them in various scenarios. NCA-GE is trained only using small artificial scale-free graphs, which shows that the proposed approach is robust. These findings may be useful to manage and monitor a mega LEO constellation and its safety.