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# STEREOGRAPHIC PROJECTION AND STATIC DIGRAPH FOR INFORMATION ROUTING IN SATELLITE CONSTELLATIONS

**Abstract**

Recently, Earth constellations are being deployed that include a large number of satellites. They may act as routing nodes connected by Inter-Satellite Links (ISL), thus enabling the rapid dissemination of information among ground stations and targets, or within the constellation itself. However, the determination of routing nodes and their correlation with the satellites orbit elements becomes dramatically more complex, which requires time-consuming numerical algorithms. This study presents innovative solutions for two critical aspects for large constellations, i.e. (a) rapid determination of routing nodes and (b) identification of optimal routing paths in relation to specific objectives. Problem (a) is solved through the stereographic projection of the satellite orbits onto the equatorial plane. In the projection plane, the determination of the times and corresponding position coordinates of ISL are determined as intersections between ellipses, computed through simple analytical relations. These incorporate the perturbing effects of the Earth oblateness and allow very fast determination of all the routing nodes. With regard to problem (b), a new approach is proposed that models information routing as a Markov decision process. States of the process correspond to ISL or satellite-ground connections, and the two possible actions (for each state) are represented by either (i) sharing or (ii) keeping the information; an adequate reward is assigned to each action/state combination. The actions corresponding to the minimum information transfer time (i.e. the optimal policy) are determined through a value iteration algorithm. Then, a refined Markov chain is generated using the states associated with the optimal policy as its nodes, while the connecting arcs represent possible transitions between two states. This new chain — also termed static digraph hence forward — considers only feasible one-way transitions on the basis of sequential mutual connectivity events, unlike typical approaches in the literature that introduce time-varying graphs, which instead consider each satellite as a node. In contrast, the static digraph incorporates all the connectivity events – otherwise described by time-varying graphs – within a specified horizon. Using the static digraph, an effective routing algorithm is proposed, to identify the path associated with maximum reward, able to convey information between collection and terminal points (e.g., a ground station). Different rewards are defined, in relation to distinct operational constraints or requirements, such as the need of minimizing the transfer time or limiting the number of information exchanges. Simulations prove that the methodology at hand is effective for rapid information sharing in large constellations.