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REGIONAL GEOLOCATION WITH LOW EARTH ORBIT SATELLITE CONSTELLATIONS

Abstract

Time difference of arrival-based geolocation allows for the position estimation of a terrestrial emitter by measuring its signals with 3 or more receivers. This type of geolocation, also known as a hyperbolic fix, is used by a variety of satellite and aircraft systems worldwide. Existing systems do not provide continuous coverage of a target area, instead relying on infrequent passes of satellites or keeping aircraft in flight for extended periods of time. In this study, we design constellations of satellites which can provide continuous geolocation services in a specific target region. The problem of time difference of arrival-based geolocation is described in detail, and several estimation algorithms are proposed for its solution. These estimators include the extended Kalman filter, and two versions thereof which incorporate the Earth surface constraint. The lower bounds of the estimation errors are developed in the form of the Cramér-Rao lower bound and the position dilution of precision.

The constellations are then designed using global optimization techniques of exhaustive search and genetic algorithms with the aim of minimizing the position dilution of precision, which is a variant of the Cramér-Rao lower bound. The constellations resulting from the initial optimization are then analyzed in terms of the main constellation cost drivers - the number of orbital planes and the number of satellites. The regional coverage of the constellations is also tested, as the initial optimization does not take into account the entire region of interest. The design methodology and the efficacy of the estimation algorithms are demonstrated with Monte Carlo simulations of geolocation with one of the resulting constellations. The constellation is shown to provide consistent coverage with a low estimation error, and the estimator is shown to be efficient.

An overview of the many aspects of constellation design is given, with a discussion of how these considerations pertain to the specific problem at hand. With the choice of constellation types the study proceeds to focus on the methods of selecting the constellation parameters. Despite the chosen constellations already greatly reducing the dimensionality of the design space, an exhaustive search would still have been prohibitively time intensive without further constraints. Thus, a constraint reducing the number of ground tracks in the constellation was implemented for the exhaustive search. The genetic algorithm approach is significantly more efficient, and as such no such constraint is necessary.