Davidson Technologies, Inc. (Davidson), a 29-year-old small business, leads in digital engineering, data-driven decision support, and mission-enabling algorithms. Davidson delivers agile solutions to the Department of Defense's (DoD) toughest challenges, focusing on multi-domain operations and contested environments. The work defined in this proposal can be performed in any location, and any intellectual property derived from this effort will remain with Davidson Technologies.

Project Introduction

The rapid expansion of satellite communication networks, especially low Earth orbit constellations, sets the stage for innovative solutions in the realm of space domain software applications. This study aims to tackle a central challenge: how to route data through a dynamic network of satellites in real time, ensuring that latency is minimized while data throughput to the intended recipient is maximized. By addressing these constraints, the application will contribute to more efficient inter-satellite communication, robust global connectivity, and improved performance for applications ranging from deep space exploration to real-time commercial communications.

Objectives

The primary goals of the study are as follows:

Minimize Latency: Develop algorithms that dynamically select the optimal routing path, accounting for the constantly changing positions and link conditions among satellites.

Maximize Data Throughput: Ensure that data packets travel via paths that not only offer low delays but also maintain high data transmission rates, adapting to bandwidth fluctuations or potential link disruptions.

Adapt to Network Dynamics: Create a solution that accounts for orbital dynamics, satellite handover events, and variable network loads, ensuring optimized performance even under fluctuating network conditions.

Real-Time Decision Making: Leverage advanced modeling and potentially machine learning techniques to allow the algorithm to learn from previous routing scenarios and adjust in real time.

Methodology

Modeling and Simulation:

Develop a simulation environment that accurately models the satellite constellation, including orbital trajectories, inter-satellite link variability, and communication channel characteristics. This simulation will serve as the testbed for algorithm development and evaluation.

Graph-Based Network Representation:

Conceptualize the satellite network as a dynamic graph, where each node represents a satellite and each edge embodies a communication link with attributes such as latency, bandwidth, and error rate. This abstraction will enable the application of graph theory algorithms for route optimization.

Algorithm Development:

Investigate a range of multi-objective optimization techniques—possibly blending deterministic methods (e.g., modified Dijkstra's algorithm) with adaptive heuristics or AI-based reinforcement learning—to design an algorithm that prioritizes both latency reduction and throughput enhancement. The proposed algorithm will dynamically adjust routing decisions in response to real-time telemetry data from the satellite constellation.

Performance and Scenario Analysis:

Define clear evaluation metrics and design various test scenarios that simulate peak network load, satellite outages, and rapid orbital transitions. Comparative studies with traditional routing strategies will be undertaken to highlight improvements in latency and throughput.

Expected Outcomes

Successful completion of this study will yield:

A Novel Routing Algorithm:

One that effectively minimizes latency and maximizes throughput across a dynamic satellite network in real-time.

Prototype Software Application:

A space domain software prototype ready for further integration and testing with real-world satellite communication systems.

Performance Benchmarks:

Detailed analyses quantifying improvements over conventional routing algorithms, accompanied by documented test scenarios and results.