Simulation and Analysis of Inter-satellite

Communication for Real-Time Data Downloading

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*Abstract* — Nowadays, 4,700 Low Earth Orbit (LEO) satellites are launched into space [1]. The LEO satellites made for communication benefit from the lower signal propagation delay in LEO [2]. However, the communication range of LEO satellites exist a coverage issue, and there is a limited number of ground stations. It results in an LEO satellite may fly for many hours to end up in the communication scope of a ground station and taking a long time for an LEO satellite to download the data to the ground. Which is not able to meet real-time constraints. The solution is inter-Satellite communication, which able the satellite can transfer the data to another satellite that can communicate with some ground station. This project is to analyze can the inter-satellite communication helps data downloading meet real-time constraints.

Keywords — LEO Satellite, inter-Satellite communication, real-time

# Introduction

LEO satellites have limited communication coverage compared to higher-altitude satellites, requiring ground stations to communicate with them only within their visibility range. This can result in long wait times for data transfer [3], making it difficult to meet real-time constraints. However, inter-satellite communication offers a potential solution by allowing data to be transferred to a satellite within the communication range of a ground station. To evaluate this option, we will simulate the communication behavior between LEO satellites, ground stations, and multiple satellites to analyze communication capability and delay

# design/methodology/implementation

The Project Simulation consists of the visibility Model, Communication Delay Model, and Path Decision Model.

## LEO Satellite Space Geometry Modeling

Using Earth-Centered Inertial (ECI) to local the ground target and Satellite in space. ECI is a is a 3-dimensional Cartesian coordinate system with the original fixed center in the Earth's mass center, which remains fixed with respect to the stars. The position of an object is constantly changing due to the Earth's rotation

## Visibility Modeling

By comparing the position of two objects, an off-nadir angle can be calculated. When the off-nadir angle is smaller than the limitation, then both object can access each other.

## Communication Delay Modeling

To calculate the Delay of a communication, transmission delay, propagation delay, buffer delay, and process delay is considered. The transmission delay is the time taken to transmit a single data packet at the data rate of the Satellite. The propagation delay is the time taken for the signal to travel from satellite to satellite or ground station. The buffer delay is caused by cell queuing at each point in the network. The process delay is occurred by the level of onboard switching and processing.

## Path Decision Modeling

The path decision Modeling is used to calculate the path of data transmission. The algorithm in this model will use A\*, Dijkstra, and a self-design algorithm Orbit Base.

# evalauation and Results

The goal of this project is to create a simulator that can accurately simulate LEO satellite communication. The simulator takes into account various parameters, such as LEO satellites, ground stations, observation points, and data transmission. By using a path decision algorithm, the simulator calculates the best path for efficient data transfer to the ground station. Result as below.

To the traditional method to transmit data with multiple ground station. The time range from 13.053 to 3672.955 seconds.

To test the result of each path algorithm, the average time is 0.545 seconds for A\*, 0.542 seconds for Dijkstra, and 0.639 seconds for the Orbit Base Path Algorithm.

# conclusion

The experiment results show that the path decision algorithm is a stable solution that meets real-time system constraints. The path algorithm used in this project provides stable transmission delays within a second, making it a reliable solution for meeting real-time system constraints.

##### References

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