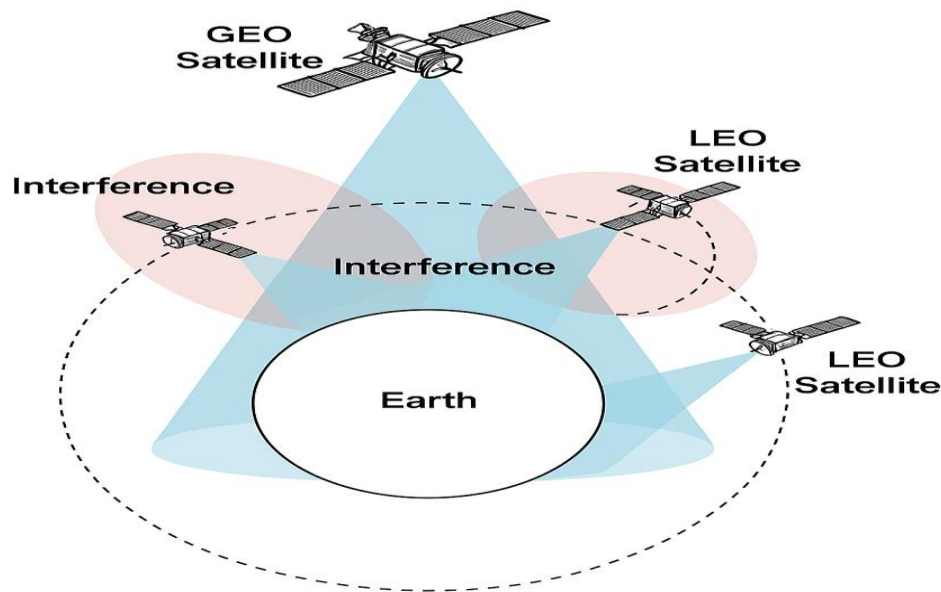


Efficient Management of Radio Interference in GEO–LEO Satellite Networks

Abstract

Hybrid satellite networks that combine Geostationary Earth Orbit (GEO) and Low Earth Orbit (LEO) systems face growing challenges in handling radio-frequency interference (RFI). This paper presents a flexible and integrated framework to locate interference sources, detect them in real time, and coordinate responses between GEO and LEO satellites. The framework uses modern techniques like Frequency of Arrival (FOA) for localization, attention-based deep learning for detection, and smart coordination strategies to improve system efficiency, reduce power use, and follow regulatory rules. Simulations using MATLAB, NS-3, and mathematical models will test how well the system works in supporting reliable communications in future 6G non-terrestrial networks.



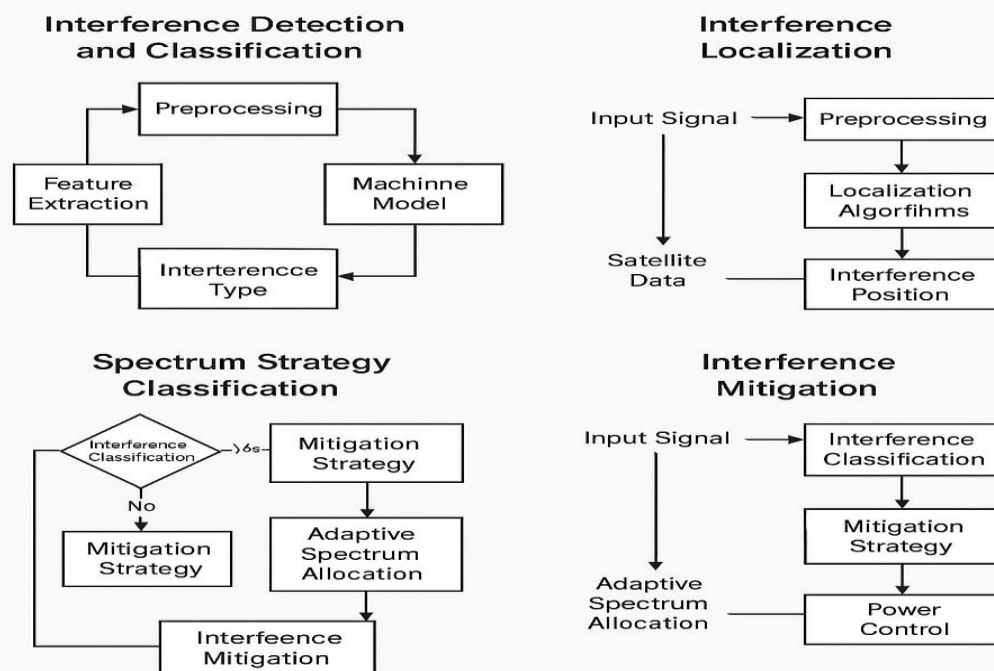
Introduction

using both GEO and LEO satellites together creates new challenges, especially in dealing with radio-frequency interference (RFI), which can happen when signals overlap in frequency, altitude, or orbit.

Traditional methods for avoiding interference, like fixed spectrum allocation or using different angles, are no longer enough for these complex systems. This makes it necessary to develop a smart and flexible system that can detect where interference is coming from, recognize it quickly, and manage it effectively across both GEO and LEO satellites.

Interference in hybrid GEO–LEO networks happen due to shared frequencies:

- Doppler shifts from fast-moving LEOs, signal reflections, and lack of coordination.
- Kalantari used FOA to locate interference, but it struggles with noise.
- Yang's DualAttWaveNet detects interference with AI but needs lighter models for satellites.
- Li's CIIM helps manage connections but doesn't track frequency changes.
- Other methods handle power and regulations but can't adapt in real time. So far, no single solution covers localization, detection, and coordination together.



Objectives

As we face degrading on service quality, increase packet loss, and lower spectral efficiency.

The existing methods fail to operate under dynamic real-world conditions.

Then our research objectives will be as follows:

- To Propose a Doppler- technique leveraging FOA and satellite kinematics.
- To Design a deep learning model for real-time interference detection using attention mechanisms.
- To Develop a cross-orbit coordination strategy integrating intra- and inter-system management.
- To Modeling hybrid network behavior using stochastic geometry under shared-spectrum conditions.
- To Evaluate the system using localization accuracy, detection latency, and compliance metrics.

Methodology

- Interference Localization with FOA.
- Interference Detection using DualAttWaveNet.
- Proposed Framework.
- Simulation Scenarios & Evaluation.

Performance Metrics:

- Localization error (in km)
- Detection F1-score and latency (ms)
- Throughput and spectral efficiency (bps/Hz)
- EPFD margin compliance (ITU thresholds)

Conclusion and Future Work

This research introduces a single, combined system to handle interference in hybrid GEO–LEO satellite networks. It brings together methods for finding where interference is coming from, detecting it quickly, and managing it across the network. Early models and simulations show that this approach can make the system more reliable and better at following communication rules. In the future, the plan is to test it with real satellite hardware, use real-world data to improve accuracy, and apply AI to help the system adapt in large satellite networks.

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