SMARTSAT
COOPERATIVE RESEARCH CENTRE

DEAKIN UNIVERSITY

Dynamic Spectrum Allocation of Coexisting GEO-LEO

Rakshitha De Silva[1]

Introduction

Sharing spectrum between multi-orbit GEO LEO Satellite constellations significantly enhances spectral efficiency. Recognizing the importance of frequency reuse, the 3GPP emphasized its necessity for efficient spectrum utilization in NTNs starting with Release 17 [1]. We propose leveraging an Advantage Actor Critic (A2C) algorithm with continual transfer learning to dynamically reuse GEO frequencies in LEO satellites, thereby minimizing user interference and maximizing network utility.

Aim

Develop a DSA to optimally reuse GEO satellite spectrum in LEO satellites.

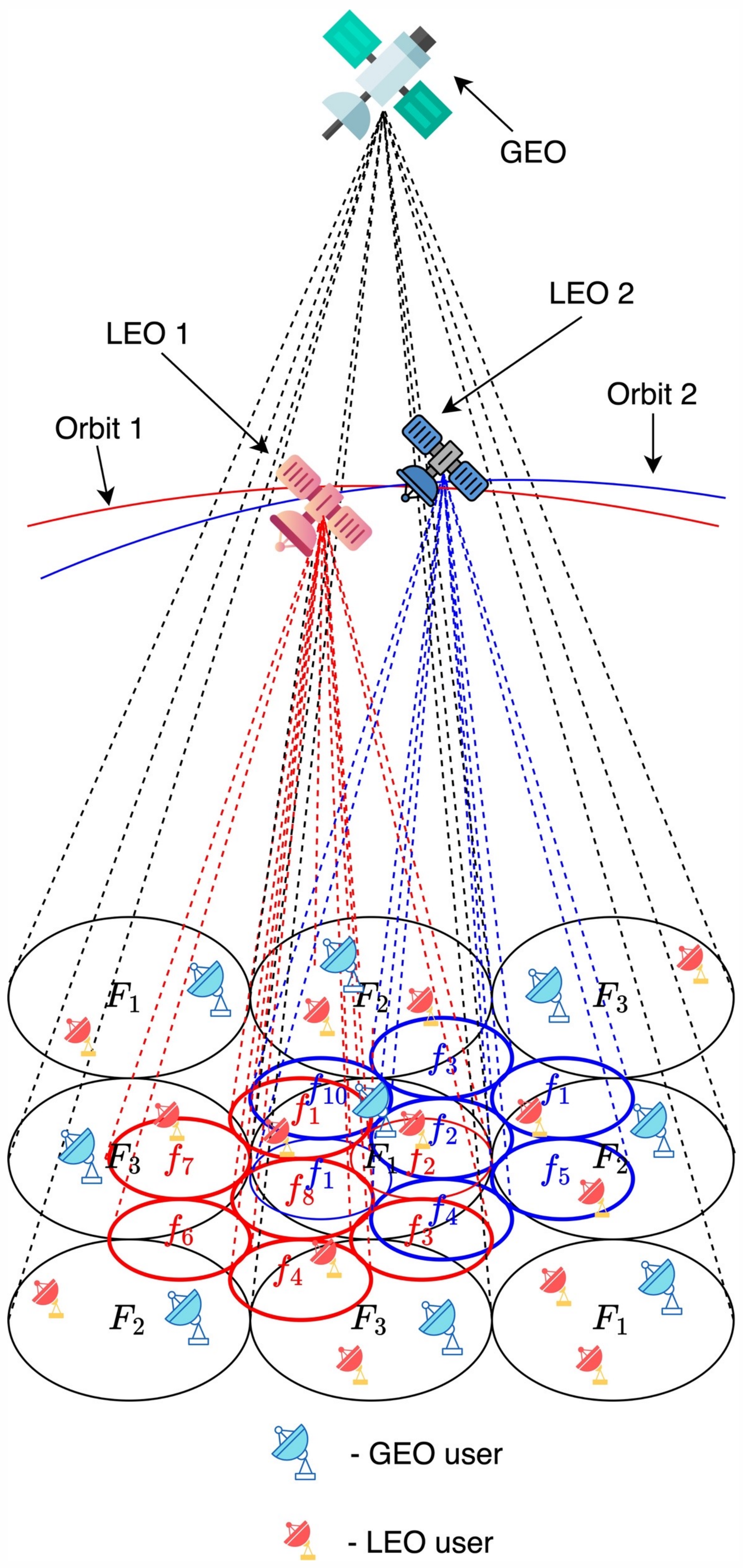

Fig. 1: LEO and GEO satellite coexisting scenario [2].

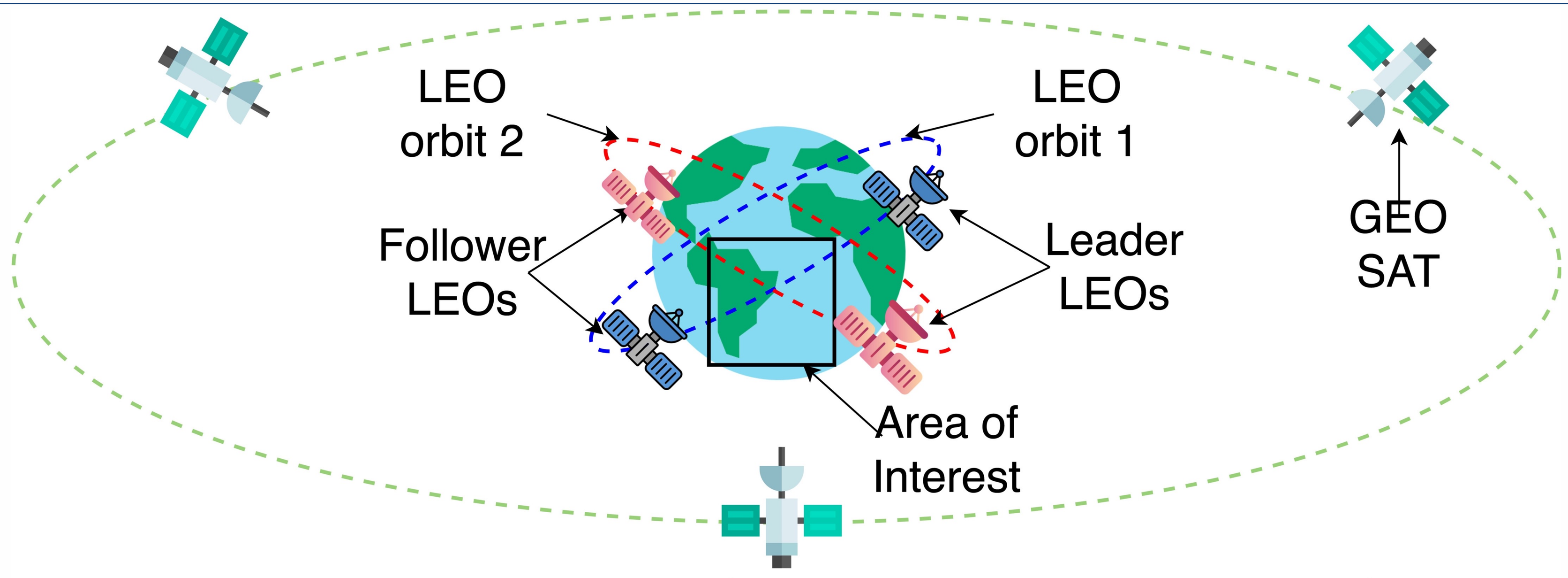

Fig. 2: A high-level view of the proposed continual transfer learning A2C scheme for GEO-LEO coexisting environment.

<u>A2C Framework -</u>

Action space: GEO frequency sub-bands

State Space:
- Coordinates of the center of LEO beams at time
- Previous actions
- Time step

Reward Function: Avg. LEO user throughput – Weighted Avg. LEO to GEO user interference (1)

A2C based DSA

Algorithm 1: Proposed A2C algorithm with continual transfer learning.

Initialize actor network $\pi(a|s,\theta_a)$ and critic network $V(s,\theta_b)$ with random weights θ_a and θ_b
for $episode = 1$ to $MAX\_episodes$ **do**
  Reset the environment and receive initial state s_0
  for $t = 1$ to T **do**
    Select action a_t using the policy $\pi(a_t|s_t,\theta_a)$
    Execute action a_t, observe reward r_t: Eq. (1)
    Update critic by minimizing loss, $L(\theta_b) = \frac{1}{N'}\sum_{t=1}^{N'}(\hat{V}(s_t) - V(s_t))^2$
    Compute advantage $A(s_t, a_t)$
    Update actor by maximizing expected return, $L(\theta_a) = -\mathbb{E}_\pi\left[\log(\pi(a_t|s_t,\theta_a))A(s_t,a_t)\right]$
    $s_t \leftarrow s_{t+1}$
  end for
end for
Derive the optimal policy π^* from the final actor network
Implement the optimal actions according to π^*
Transfer the optimal policy to Follower LEOs as π^{pre}
Load pre-trained weights θ_a^{pre} and θ_b^{pre} from a received model and repeat the training

Results

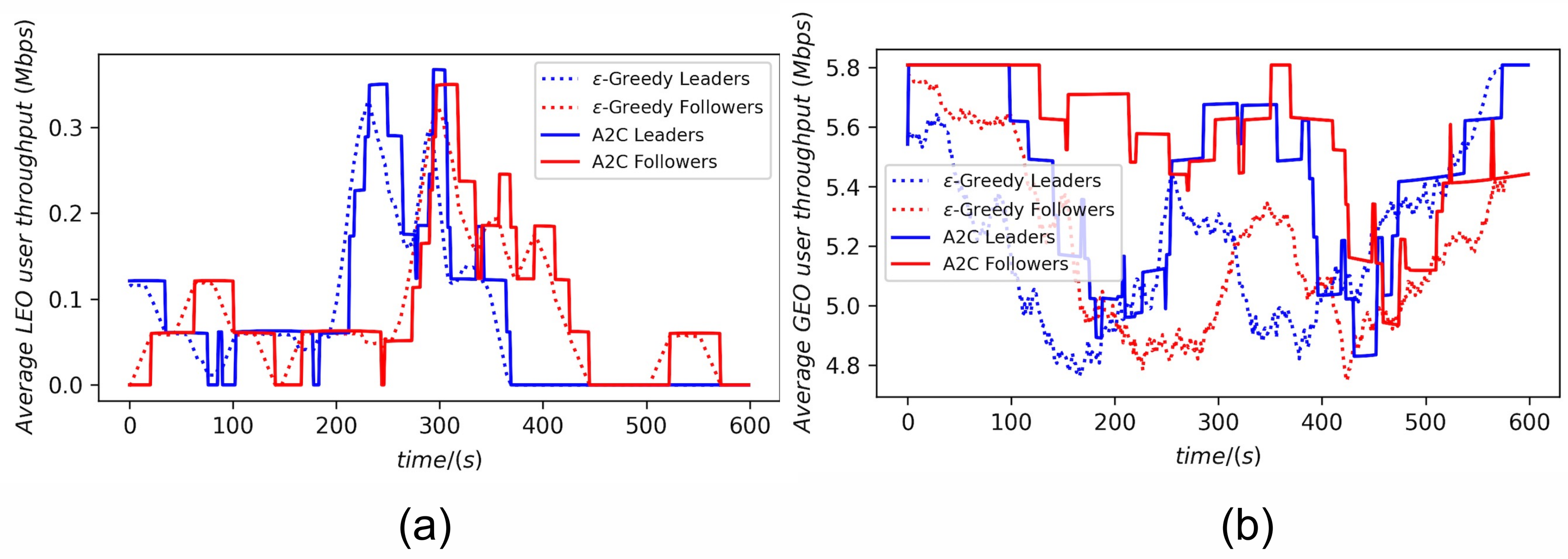

Fig. 3: Evaluating A2C and ε-Greedy allocation methods: Temporal evolution of the a) LEO user throughput b) GEO user throughputs.

Conclusions

Our continual transfer learning with A2C by exploiting leader-follower approach surpasses existing spectrum allocation methods by maintaining optimal LEO user throughput with impacting GEO user throughput significantly. We addressed energy and computational constraints of onboard processing in satellites by the design.

References

[1] 3GPP. "3GPP Release 17." 2021. Accessed: 2024-06-30. https://www.3gpp.org/specifications-technologies/releases/release-17.

[2] E. Trachtman, "An Introduction to BGAN," Nov. 2006, International Workshop For B3G/4G Satellite Communications, Seoul. [Online]. Available: https://www.yumpu.com/en/document/view/ 7234508/an-introduction-to-bgan

[1]School of Information Technology, Deakin University, Geelong, Australia

Australian Government
Department of Industry, Science and Resources
Cooperative Research Centres Program