Coexistence of LEO Satellite Communication Systems under Regulatory Protection Constraints

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***Abstract*—This paper investigates the coexistence of two low Earth orbit (LEO) satellite communication systems sharing the same frequency band: a *primary* system with regulatory precedence over the spectrum and a *secondary* system that must not cause excessive interference to the primary system's ground users. This spectrum sharing paradigm was recently formalized by the United States Federal Communications Commission (FCC) through short-term and long-term *protection criteria* that limit primary-link unavailability and throughput degradation due to interference inflicted by the secondary system. To facilitate coexistence, we propose a satellite selection mechanism that associates the secondary system's satellites with clusters of ground cells at each handover to maximize secondary-user throughput while abiding by these regulatory constraints. Our mechanism enforces both constraints through a cumulative assessment that combines past primary-link performance with predicted performance over the upcoming handover interval. Simulation results show that our proposed method achieves up to 31% higher secondary-user throughput than prior work that imposes interference-to-noise ratio (INR) constraints, even when its constraints are tuned to satisfy the FCC's throughput-based protection criteria.**

***Index Terms*—Coexistence, spectrum sharing, satellite selection, low Earth orbit (LEO) satellite communication systems, non-terrestrial networks.**

I. Introduction

Low Earth orbit (LEO) satellite systems deployed by operators such as SpaceX, Amazon, and OneWeb share portions of the Ka-band spectrum under non-exclusive spectrum allocations by the United States Federal Communications Commission (FCC) [1]. The FCC groups applications for satellite system authorization into *processing rounds* based on their filing dates [1], [2]. Under this framework, the FCC grants spectrum priority to systems authorized in earlier processing rounds, referred to as *primary* systems, over those authorized in later rounds, referred to as *secondary* systems. In the absence of a coordination agreement, the secondary system must protect primary ground users from excessive interference.

To mitigate interference between coexisting LEO satellite systems, prior work has proposed adaptive receive beamforming/nulling at ground users [3], [4]. While these methods can be effective, they naturally face limitations when a user's serving satellite is in direct angular alignment with an interfering satellite. Satellite selection complements these receive beam control techniques by exploiting the spatial diversity of available satellites to increase the angular separation between serving and interfering satellites as viewed from ground users, thereby reducing interference. This concept was investigated in [5], which examined the feasibility of in-band coexistence through secondary satellite selection and showed that multiple secondary satellites can often satisfy interference-to-noise ratio (INR) constraints for primary-link protection. Recently, the work in [6] proposed a secondary satellite selection mechanism to enhance secondary-user throughput while protecting primary ground users under time-averaged and instantaneous INR constraints.

To formalize inter-round protection without a coordination agreement, the FCC recently adopted throughput-based protection criteria in late 2024 [2]. The short-term criterion limits the increase in primary-link unavailability to 0.4%, while the long-term criterion limits the average throughput degradation of primary links to 3% [2]. Unlike INR-based criteria, these criteria directly limit the degradation in primary-link performance caused by secondary transmissions. An INR value alone does not determine whether these criteria are satisfied, since the resulting performance degradation also depends on the primary-link signal-to-noise ratio (SNR).

In this work, we propose a satellite selection mechanism for a secondary satellite operator that explicitly considers the FCC's newly adopted throughput-based protection constraints. Given the primary satellite associations, our proposed mechanism updates secondary satellite-to-cluster associations at handover instants to maximize secondary-user throughput while satisfying these constraints. To enforce both short-term and long-term criteria, we employ a cumulative assessment that combines past primary-link performance with predicted performance over the upcoming handover interval under each candidate secondary association.

II. System Model

A. Network Geometry and Satellite-to-Cluster Associations

We consider two dense LEO satellite communication systems, the primary and secondary systems, that share the same frequency band and independently provide downlink service to their respective ground users within their overlapping coverage area. Let $\mathcal{P}^t = \{p_i^t : i = 1, \ldots, N_{\mathrm{P}}\}$ and $\mathcal{S}^t = \{s_k^t : k = 1, \ldots, N_{\mathrm{S}}\}$ denote the sets of all satellites in the primary and secondary constellations at time t, respectively.

As shown in Fig. 1, the geographical area is partitioned into a set $\mathcal{G} = \{g_n : n = 1, \ldots, N_{\mathrm{G}}\}$ of N_{G} clusters, with each cluster $g_n = \{c_{n,\ell} : \ell = 1, \ldots, N_{\mathrm{C}}\}$ containing N_{C} cells. In practical dense LEO satellite communication systems, a ground cell may have multiple candidate serving satellites,

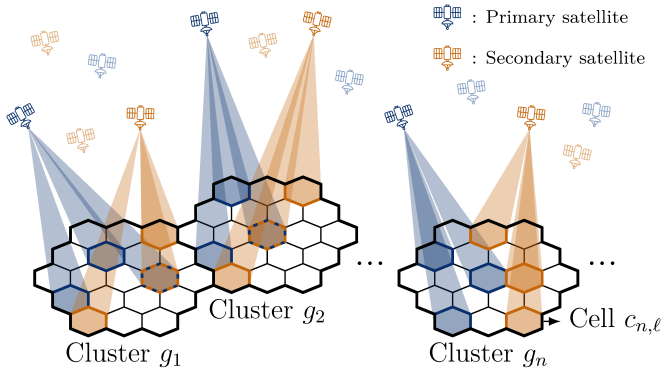


Fig. 1. Satellite-to-cluster associations and spot-beam transmissions in coexisting primary and secondary LEO satellite communication systems.

resulting in many possible satellite-to-cell associations across the network. As in [6], we consider satellite associations at the cluster level rather than the individual cell level. At time t, the primary and secondary candidate satellite sets for cluster g_n are defined using the minimum elevation angle required for communication, $\epsilon_{\min}$, as

$$\mathcal{P}_n^t = \left\{p_i^t \in \mathcal{P}^t : \epsilon(g_n; p_i^t) \geq \epsilon_{\min}\right\}, \tag{1}$$

$$\mathcal{S}_n^t = \left\{s_k^t \in \mathcal{S}^t : \epsilon(g_n; s_k^t) \geq \epsilon_{\min}\right\}, \tag{2}$$

where $\epsilon(g_n; z)$ denotes the minimum elevation angle of satellite z over all cell centers in cluster g_n. Given the primary satellite associations, we investigate how to select secondary satellites from the secondary candidate satellite sets and associate them with clusters while protecting primary ground users. At each handover instant τ, the secondary satellite-to-cluster associations are updated and remain fixed over the handover interval $\mathcal{T}^\tau = [\tau, \tau + T_{\mathrm{H}})$, where T_{H} denotes the handover period. The corresponding secondary satellite association matrix is defined as $\mathbf{X}^\tau = [x_{k,n}^\tau] \in \{0,1\}^{N_{\mathrm{S}} \times N_{\mathrm{G}}}$, whose (k,n)-th entry $x_{k,n}^\tau$ equals 1 if secondary satellite s_k^τ is associated with cluster g_n and 0 otherwise. Thus, the association variable at time t satisfies $x_{k,n}^t = x_{k,n}^\tau$ for all $t \in \mathcal{T}^\tau$. Within each system, we assume that each satellite is associated with at most one cluster and each cluster is associated with at most one satellite at a time.

Because a cluster contains N_{C} cells, each satellite serves its associated cluster via beam hopping, illuminating up to N_{B} cells at a time using highly directional spot beams directed toward the selected cell centers. Accordingly, let $y_{k,n,\ell}^t \in \{0,1\}$ indicate whether secondary satellite s_k^t illuminates cell $c_{n,\ell}$ at time t when associated with cluster g_n, where $\sum_{\ell=1}^{N_{\mathrm{C}}} y_{k,n,\ell}^t \leq N_{\mathrm{B}}$. We assume that beam-hopping schedules are coordinated within each system to mitigate intra-system interference, and we neglect the residual interference in the INR and signal-to-interference-plus-noise ratio (SINR) calculations.

B. Link-Quality Metrics

Given the satellite-to-cluster associations and beam-hopping schedules, we characterize the desired signal and aggregate interference from the other system at each user. For both systems, we assume line-of-sight propagation between satellites and users. Doppler effects due to the rapid motion of LEO satellites are assumed to be compensated, with negligible residual impact on link performance.

Let $L(u,z)$ denote the path loss from satellite z to user u. Let $G_{\mathrm{tx}}(u,z;c)$ denote the transmit antenna gain of satellite z toward user u when its beam is steered toward the center of cell c, and let $G_{\mathrm{rx}}(u,p_i^t)$ denote the receive antenna gain of user u toward its serving satellite p_i^t. Let $P_{\mathrm{tx}}(z)$ denote the transmit power per active beam of satellite z, and let $P_{\mathrm{n}}(u)$ denote the receiver noise power at user u. Let c_u and c_v denote the cells containing primary ground user u and secondary ground user v, respectively. For a primary ground user u served by satellite p_i^t, the SNR at time t is given by

$$\mathsf{SNR}^t(u, p_i^t, c_u) = \frac{P_{\mathrm{tx}}(p_i^t) G_{\mathrm{tx}}(u, p_i^t; c_u) G_{\mathrm{rx}}(u, p_i^t)}{P_{\mathrm{n}}(u) L(u, p_i^t)}. \tag{3}$$

For an interfering secondary satellite s_k^t, let $G_{\mathrm{rx}}(u, p_i^t; s_k^t)$ denote the receive antenna gain toward satellite s_k^t when the receive beam of user u is steered toward its serving satellite p_i^t. Using the satellite association indicators $x_{k,n}^t$ and cell illumination indicators $y_{k,n,\ell}^t$, the aggregate INR at primary ground user u served by satellite p_i^t at time t can be expressed as

$$\mathsf{INR}^t(u, p_i^t) \triangleq \sum_{k=1}^{N_{\mathrm{S}}} \sum_{n=1}^{N_{\mathrm{G}}} \sum_{\ell=1}^{N_{\mathrm{C}}} x_{k,n}^t y_{k,n,\ell}^t \cdot \frac{P_{\mathrm{tx}}(s_k^t) G_{\mathrm{tx}}(u, s_k^t; c_{n,\ell}) G_{\mathrm{rx}}(u, p_i^t; s_k^t)}{P_{\mathrm{n}}(u) L(u, s_k^t)}. \tag{4}$$

The corresponding SINR at time t is given by

$$\mathsf{SINR}^t(u, p_i^t, c_u) = \frac{\mathsf{SNR}^t(u, p_i^t, c_u)}{1 + \mathsf{INR}^t(u, p_i^t)}. \tag{5}$$

For the secondary system, the SNR and INR are defined analogously. The SINR of secondary ground user v served by satellite s_k^t is given by

$$\mathsf{SINR}^t(v, s_k^t, c_v) = \frac{\mathsf{SNR}^t(v, s_k^t, c_v)}{1 + \mathsf{INR}^t(v, s_k^t)}. \tag{6}$$

III. Proposed Secondary Satellite Selection

A. Primary Throughput-Based Protection Criteria

In 2024, the FCC adopted short-term and long-term protection criteria under 47 CFR § 25.261(d) [2], limiting increases in link unavailability and time-weighted average throughput degradation, respectively. For a given evaluation interval T, the two criteria are defined as follows.[1] For brevity, let $\mathsf{SNR}_u(t) \triangleq \mathsf{SNR}^t(u, p_i^t, c_u)$ and $\mathsf{SINR}_u(t) \triangleq \mathsf{SINR}^t(u, p_i^t, c_u)$ denote the SNR and SINR of primary ground user u at time t.

- **Absolute Increase in Link Unavailability:** Link unavailability is the fraction of time during which a primary

[1]The protection criteria apply to primary links whose baseline availability is at least 99.0% at a 0 dB carrier-to-noise ratio (C/N) threshold, which all primary links considered in this paper satisfy. Throughout this paper, SNR denotes the C/N at the ground user receiver.

link's SNR (without secondary interference) or SINR (with secondary interference) falls below the outage threshold (assumed to be 0 dB per the FCC [2]). For each primary link, the absolute increase in link unavailability due to secondary transmissions must not exceed 0.4%. With $\mathbb{1}\{\cdot\}$ denoting the indicator function, $|T|$ denoting the duration of the evaluation interval, and 0 dB corresponding to 1 on a linear scale, this criterion is expressed as

$$\delta_{\mathrm{L},u} \triangleq \frac{1}{|T|}\int_T \Big[\mathbb{1}\{\mathsf{SINR}_u(t)<1\} - \mathbb{1}\{\mathsf{SNR}_u(t)<1\}\Big]\,\mathrm{d}t \le 0.004. \tag{7}$$

- **Time-Weighted Average Throughput Degradation:** The relative reduction in the time-weighted average throughput of each primary link due to secondary transmissions must not exceed 3%. The function $R(\cdot)$ maps instantaneous link quality to throughput.[2] This criterion is expressed as

$$\delta_{\mathrm{T},u} \triangleq 1 - \frac{\int_T R(\mathsf{SINR}_u(t))\,\mathrm{d}t}{\int_T R(\mathsf{SNR}_u(t))\,\mathrm{d}t} \le 0.03. \tag{8}$$

Fig. 2 shows the INR and corresponding throughput of a primary ground user under highest-elevation primary satellite selection and random secondary satellite selection without primary protection constraints. The black dashed line marks the outage threshold, while the light-blue shaded area illustrates the throughput loss relative to the interference-free case. In this particular realization, interference increases link unavailability from 0% to 3.2% and causes an average throughput degradation of 16.7%, exceeding the respective protection limits of 0.4% and 3%. These violations highlight the need for the proposed method, which explicitly enforces both primary-link performance constraints when determining secondary satellite associations.

B. Secondary Satellite Selection

For simplicity, we consider synchronized handovers across both systems. At each handover instant τ, the secondary operator optimizes its satellite-to-cluster associations $\mathbf{X}^\tau$ given the primary satellite associations over $\mathcal{T}^\tau$. Using known satellite trajectories and antenna patterns, we assume that the secondary system can reliably predict the SNRs and SINRs of primary and secondary ground users via (3)–(6) under each potential $\mathbf{X}^\tau$ over $\mathcal{T}^\tau$.

Let $\mathcal{C} = \bigcup_{n=1}^{N_\mathrm{G}} g_n$ denote the set of ground cells, and let u_c denote the representative primary ground user located at the center of cell $c \in \mathcal{C}$. For primary-link protection, we evaluate the SNR and SINR at each u_c, assuming that its serving primary satellite directs a spot beam toward the center of cell c. Using the resulting SNRs and SINRs, we evaluate the FCC protection criteria in (7) and (8) for each representative primary link over the cumulative evaluation interval

[2]For both systems, we model throughput as $R(\gamma) = B\log_2(1+\gamma)$, where B is the bandwidth and γ is the SNR or SINR.

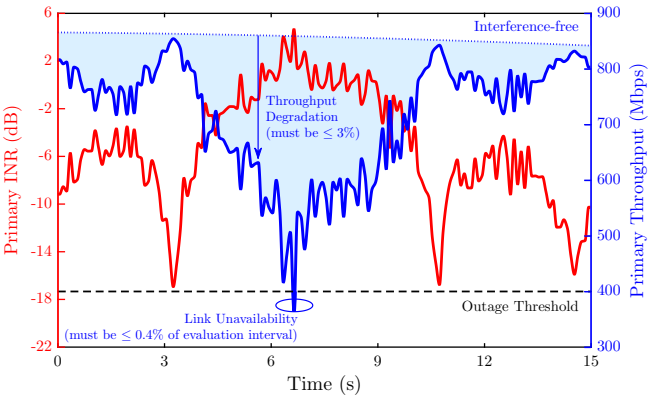


Fig. 2. INR and throughput at a primary ground user over a 15 s handover interval under fixed satellite associations determined by highest-elevation primary satellite selection and random secondary satellite selection, with $N_\mathrm{G} = 20$ and $N_\mathrm{B} = 16$.

$[0, \tau+T_\mathrm{H})$. The primary-link performance accumulated before τ is already determined, while the predicted performance over the upcoming handover interval $\mathcal{T}^\tau$ depends on $\mathbf{X}^\tau$. We denote the resulting increase in link unavailability and throughput degradation by $\delta_{\mathrm{L},u_c}(\mathbf{X}^\tau)$ and $\delta_{\mathrm{T},u_c}(\mathbf{X}^\tau)$, respectively.

For each handover interval $\mathcal{T}^\tau$, the time-average aggregate secondary-user throughput when satellite s_k serves cluster g_n is defined as

$$\overline{R}^\tau_{k,n} = \frac{1}{T_\mathrm{H}}\int_{\mathcal{T}^\tau} \sum_{v\in\mathcal{V}^{t,\mathrm{act}}_{k,n}} R\big(\mathsf{SINR}^t(v, s^t_k, c_v)\big)\,\mathrm{d}t, \tag{9}$$

where $\mathcal{V}^{t,\mathrm{act}}_{k,n}$ denotes the set of secondary ground users that would be served at time t using up to N_B active spot beams if satellite s_k were assigned to cluster g_n.

Our goal is to find the secondary satellite association that maximizes the average aggregate secondary-user throughput over $\mathcal{T}^\tau$ while satisfying the FCC protection constraints and the satellite-to-cluster association constraints. Accordingly, the optimization problem at handover instant τ is formulated as follows:

$$\underset{\mathbf{X}^\tau}{\text{maximize}} \quad \sum_{k=1}^{N_\mathrm{S}}\sum_{n=1}^{N_\mathrm{G}} \overline{R}^\tau_{k,n} x^\tau_{k,n} \tag{10a}$$

$$\text{s.t.} \quad \delta_{\mathrm{L},u_c}(\mathbf{X}^\tau) \le 0.004, \qquad \forall c\in\mathcal{C}, \tag{10b}$$

$$\delta_{\mathrm{T},u_c}(\mathbf{X}^\tau) \le 0.03, \qquad \forall c\in\mathcal{C}, \tag{10c}$$

$$\sum_{n=1}^{N_\mathrm{G}} x^\tau_{k,n} \le 1, \qquad \forall k, \tag{10d}$$

$$\sum_{k=1}^{N_\mathrm{S}} x^\tau_{k,n} \le 1, \qquad \forall n, \tag{10e}$$

$$x^\tau_{k,n} \in \{0,1\}, \qquad \forall k, \forall n. \tag{10f}$$

Constraints (10b) and (10c) enforce the primary-link protection criteria on the absolute increase in link unavailability and throughput degradation, respectively. Constraints (10d) and

Algorithm 1 Throughput-Based Secondary Satellite Selection.

At handover instant τ:

Input: Primary satellite associations, satellite trajectories, and accumulated primary-link performance

Output: Secondary satellite association matrix $\widehat{\mathbf{X}}^{\tau}$

Step 1: Predict primary-link and secondary-link performance

1: For each cluster g_n, determine candidate secondary satellites satisfying the minimum elevation angle requirement at each $t \in \mathcal{T}^{\tau}$ using (2), i.e., $\mathcal{S}_n^t$.

2: Compute $\overline{R}_{k,n}^{\tau}$ for each g_n and candidate secondary satellite s_k using (9).

3: Compute primary-link SINRs for each potential secondary satellite association matrix $\mathbf{X}^{\tau}$, for all $c \in \mathcal{C}$ over $\mathcal{T}^{\tau}$ using (3)–(5).

Step 2: Optimize secondary satellite-to-cluster associations

4: Form $\delta_{\mathrm{L},u_c}(\mathbf{X}^{\tau})$ and $\delta_{\mathrm{T},u_c}(\mathbf{X}^{\tau})$ for each potential $\mathbf{X}^{\tau}$ using accumulated and predicted primary-link performance for all $c \in \mathcal{C}$.

5: Solve (10) using SCIP via PySCIPOpt [7] to obtain $\widehat{\mathbf{X}}^{\tau}$.

Step 3: Apply associations and update primary-link and secondary-link performance

6: Apply $\widehat{\mathbf{X}}^{\tau}$ over $\mathcal{T}^{\tau}$.

7: Update accumulated primary-link performance for the next handover.

8: **return** $\widehat{\mathbf{X}}^{\tau}$.

(10e) allow at most one association per satellite and cluster, respectively, while (10f) restricts the association variables to binary values, with $x_{k,n}^{\tau} = 0$ if $s_k^t \notin \mathcal{S}_n^t$ for any $t \in \mathcal{T}^{\tau}$. Algorithm 1 summarizes the proposed secondary satellite selection procedure at each handover instant τ.

IV. Performance Evaluation

A. Simulation Setup and Baselines

To assess our proposed scheme, we consider a hypothetical inter-round coexistence scenario using FCC-filed constellation geometries of Starlink Gen1 and Gen2 [8]–[10] as the primary system ($N_{\mathrm{P}} = 11{,}908$) and Kuiper [11] as the secondary system ($N_{\mathrm{S}} = 3{,}236$). Unless otherwise specified, the region contains $N_{\mathrm{G}} = 20$ clusters, each with $N_{\mathrm{C}} = 127$ Earth-fixed hexagonal cells of approximately 10 km edge length [12], [13]. Each cell has one representative user from each system, both located at its center. Candidate satellites are defined as those with elevation angles of at least $\epsilon_{\min} = 35^{\circ}$ at every cell center in a cluster [11]. Each serving satellite illuminates $N_{\mathrm{B}} = 16$ randomly selected cells in its associated cluster. Satellite positions are sampled every 0.02 s over $T = 120$ s, with associations updated every $T_{\mathrm{H}} = 15$ s [14].

We assume free-space path loss and neglect atmospheric attenuation and scintillation [5], [6]. Both systems share 400 MHz at 20 GHz and employ 64×64 satellite and 32×32 user uniform planar arrays with half-wavelength spacing. User antenna panels face the zenith, with receive beams steered toward serving satellites. For the default configuration, the maximum per-beam EIRP spectral densities are -54.3 dBW/Hz [15] and -53.3 dBW/Hz [16] for the primary and secondary systems, respectively. The receiver noise spectral density is -174 dBm/Hz, with a noise figure of 1.2 dB [17].

Under our proposed method, the primary system associates each cluster with its highest-elevation available satellite at each handover while the secondary system optimizes its satellite associations via Algorithm 1. We compare our proposed method against the following two benchmarks:

- Prior [6]: Uses the same highest-elevation primary satellite associations, but selects secondary satellites in each handover interval under time-averaged and instantaneous INR thresholds tuned to maximize secondary throughput while satisfying the FCC protection criteria.
- Centralized: Jointly optimizes both primary and secondary satellite associations to maximize their sum throughput under the same FCC protection criteria, representing the best-case performance under cross-system coordination.

B. Components of Secondary Throughput Gain

We decompose the secondary throughput gain into satellite-selection and utilization gains. Utilization is defined as the percentage of clusters associated with a secondary satellite, averaged over all handover intervals. For each method $m \in \{\mathrm{Prior}, \mathrm{Prop}\}$, let $\overline{R}^{m}$ denote the average aggregate secondary throughput over the total simulation period. Let $\overline{R}_{\mathrm{com}}^{m}$ and $\overline{R}_{\mathrm{only}}^{m}$ denote the corresponding contributions from cluster–interval pairs served by both methods and only by method m, respectively. Thus, $\overline{R}^{m} = \overline{R}_{\mathrm{com}}^{m} + \overline{R}_{\mathrm{only}}^{m}$. Both gain components are normalized by the prior method's average aggregate secondary throughput, $\overline{R}^{\mathrm{Prior}}$, and are defined as follows:

1) **Satellite-selection gain**: The normalized throughput difference over all cluster–interval pairs served by both methods is given by

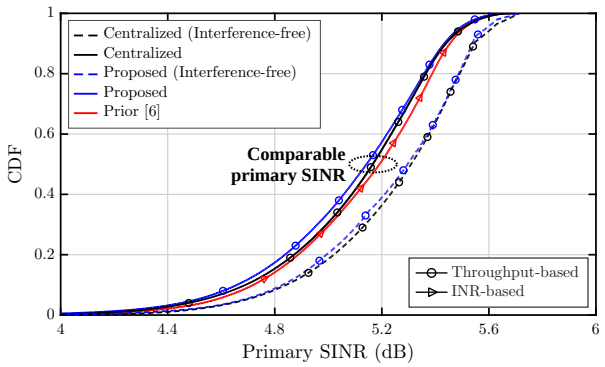
$$G_{\mathrm{sel}} = \frac{\overline{R}_{\mathrm{com}}^{\mathrm{Prop}} - \overline{R}_{\mathrm{com}}^{\mathrm{Prior}}}{\overline{R}^{\mathrm{Prior}}}. \tag{11}$$

2) **Utilization gain**: The normalized throughput difference over all cluster–interval pairs served by exactly one of the two methods is given by

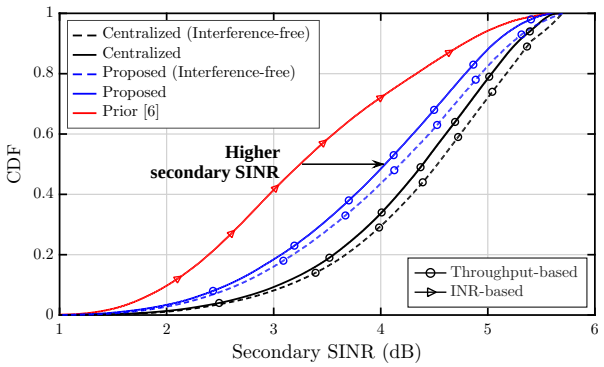
$$G_{\mathrm{util}} = \frac{\overline{R}_{\mathrm{only}}^{\mathrm{Prop}} - \overline{R}_{\mathrm{only}}^{\mathrm{Prior}}}{\overline{R}^{\mathrm{Prior}}}. \tag{12}$$

The total secondary throughput gain is then

$$\frac{\overline{R}^{\mathrm{Prop}} - \overline{R}^{\mathrm{Prior}}}{\overline{R}^{\mathrm{Prior}}} = G_{\mathrm{sel}} + G_{\mathrm{util}}. \tag{13}$$



(a) CDF of primary SINR.



(b) CDF of secondary SINR.

Fig. 3. CDFs of primary and secondary SINRs across actively served ground users and time under different satellite selection methods, with $N_{\mathrm{G}} = 20$ clusters and $N_{\mathrm{B}} = 16$ active spot beams per serving satellite.

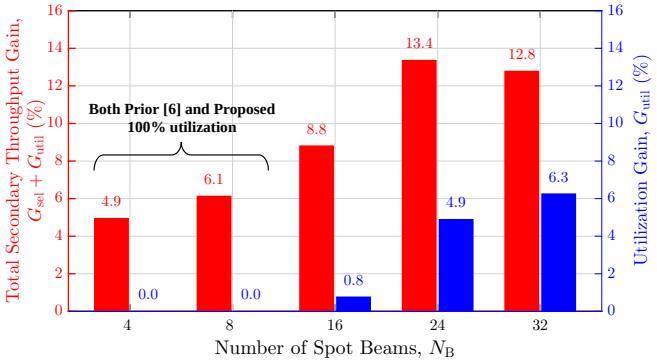


Fig. 4. Total secondary throughput gain, $G_{\mathrm{sel}} + G_{\mathrm{util}}$, of the proposed method over the prior method and its utilization component, G_{util}, versus the maximum number of active spot beams per satellite, with $N_{\mathrm{G}} = 20$. As N_{B} varies, each satellite's total transmit power is fixed at its default-configuration value and equally divided among its active spot beams.

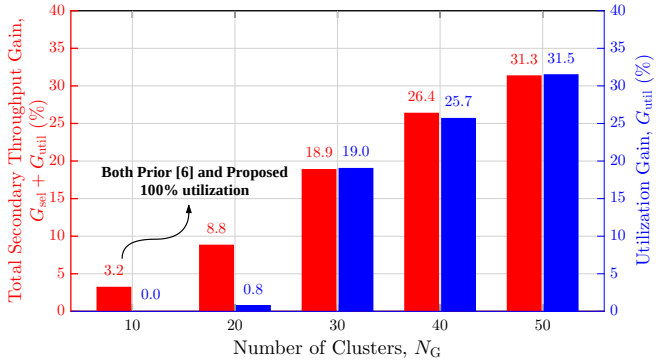


Fig. 5. Total secondary throughput gain, $G_{\mathrm{sel}}+G_{\mathrm{util}}$, of the proposed method over the prior method and its utilization component, G_{util}, versus the number of clusters, with $N_{\mathrm{B}} = 16$.

C. Simulation Results

Fig. 3 compares the primary and secondary SINR distributions across actively served ground users under different satellite selection methods. The interference-free curves for the centralized and proposed methods are obtained by removing interference while retaining their respective satellite-to-cluster associations. Under the same primary satellite associations and FCC protection criteria, the proposed method achieves primary SINRs comparable to those of the prior method, as shown in Fig. 3(a), while achieving higher secondary SINRs, as shown in Fig. 3(b). The proposed method also yields a secondary SINR distribution close to that of the centralized method, despite optimizing only secondary satellite-to-cluster associations. Since these CDFs include only actively served users, they do not capture the utilization gain G_{util}. We next examine how the satellite-selection gain G_{sel} and utilization gain G_{util} contribute to the total secondary throughput gain.

Fig. 4 shows the total secondary throughput gain of the proposed method over the prior method [6] and the contribution from utilization for different numbers of spot beams. When N_{B} is small, both methods can associate every cluster with a secondary satellite in each handover interval while satisfying their respective protection constraints, achieving 100% utilization. At $N_{\mathrm{B}} = 4$ and 8, G_{util} is therefore zero, and the 4.9% and 6.1% throughput improvements arise solely from the satellite-selection gain G_{sel}. As N_{B} increases under a fixed total transmit power per satellite, the per-beam transmit power decreases, reducing the primary-link SNR and its margin for tolerating interference. To satisfy the FCC protection criteria, the prior method's selected INR thresholds become more stringent as N_{B} increases, restricting feasible satellite associations and reducing utilization. However, the proposed method directly enforces the primary-link performance constraints, allowing more feasible satellite-to-cluster associations. Consequently, G_{util} grows from 0.8% at $N_{\mathrm{B}} = 16$ to 6.3% at $N_{\mathrm{B}} = 32$, yielding total throughput gains of up to 13.4% (at $N_{\mathrm{B}} = 24$).

Fig. 5 shows the total secondary throughput gain of the proposed method over the prior method and the contribution from utilization, G_{util}, for different numbers of clusters. As

the number of clusters increases, utilization decreases for both methods, but it decreases more rapidly for the prior method, widening the utilization gap between the two methods. The proposed method directly enforces the FCC protection criteria and exploits protection margins accumulated over previous intervals. This enables additional secondary satellite-to-cluster associations that satisfy these cumulative limits but are excluded by the prior method's INR-based constraints. Consequently, the utilization gain G_{util} becomes the dominant contributor to the total secondary throughput gain as the number of clusters increases. At $N_{\mathrm{G}} = 30$ and 50, G_{util} slightly exceeds the total gain ($G_{\mathrm{sel}} < 0$), as serving additional clusters leaves fewer candidate satellites and less primary protection margin for clusters served by both methods, though this minor trade-off yields up to a 31.3% total throughput gain.

V. Conclusion

This paper presented a secondary satellite selection mechanism for the in-band coexistence of primary and secondary LEO satellite communication systems under the FCC's recently adopted throughput-based protection criteria. To limit both primary-link unavailability and average throughput degradation, our mechanism employs a cumulative assessment at each handover that combines past primary-link performance with predicted performance over the upcoming handover interval. Simulation results demonstrated that directly enforcing these performance criteria allows the secondary system to select more favorable satellites and serve more ground clusters than an INR-based benchmark tuned to meet the same FCC limits, improving secondary-user throughput by up to 31.3%. Future work could extend this framework to coexistence among multiple secondary constellations and relax the assumption of known primary satellite associations.

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