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Research article

Comparison of LEO satellite constellation systems for global broadband communications

Comparación de sistemas de constelaciones de satélites LEO para comunicaciones de banda ancha globales

Kleiverg Eulalio Encino Morales, Miguel Ángel Sidón Ayala, Rolando Díaz Castillo

Instituto Tecnológico de Ensenada, Boulevard Tecnológico No. 150, Ex-Ejido Chapultepec, 22780 Ensenada, Baja California, México

Corresponding author: Kleiverg Eulalio Encino Morales, Instituto Tecnológico de Ensenada, Boulevard Tecnológico No. 150, Ex-Ejido Chapultepec, 22780 Ensenada, Baja California, México. E-mail: kencino@ite.edu.mx. ORCID: 0009-0002-4878-8477.

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Abstract. – *This paper introduces a quantitative framework designed to evaluate and compare Low Earth Orbit (LEO) satellite constellations for global broadband communications. The analysis considers four representative systems: Starlink, OneWeb, Telesat, and Amazon's Project Kuiper, capturing both orbital configuration and network architecture as key design characteristics. The proposed methodology integrates a geometric coverage model together with a latency formulation that accounts for propagation delay and routing effects including Inter-Satellite Links (ISL). In addition, a service density metric is introduced to characterize the spatial distribution of satellites and its impact on system capacity. These metrics are combined into a normalized multi-criteria performance index, allowing a consistent and reproducible system-level comparison. The results reveal that, while coverage is primarily governed by orbital altitude, network architecture plays a dominant role in effective latency, with ISL-enabled constellations achieving improved routing efficiency compared to bent-pipe designs. The integrated performance index shows that low altitude, high-density constellations achieve superior overall performance under latency sensitive scenarios. Starlink ranking highest due to its reduced delay and high spatial density. Project Kuiper exhibits balanced performance across all metrics, while OneWeb and Telesat are constrained by higher latency and lower density despite their broader coverage.*

Keywords: LEO constellations; Global broadband communications; Network architecture; Coverage modeling; Latency performance; System comparison.

Resumen. – *Este artículo presenta un marco cuantitativo diseñado para evaluar y comparar constelaciones de satélites en órbita terrestre baja (LEO) para comunicaciones de banda ancha globales. El análisis considera cuatro sistemas representativos: Starlink, OneWeb, Telesat y el Proyecto Kuiper de Amazon, considerando tanto la configuración orbital como la arquitectura de red como características clave de diseño. La metodología propuesta integra un modelo de cobertura geométrica junto con una formulación de latencia que tiene en cuenta el retardo de propagación y los efectos de enrutamiento, incluidos los enlaces intersatelital (ISL). Además, se introduce una métrica de densidad de servicio para caracterizar la distribución espacial de los satélites y su impacto en la capacidad del sistema. Estas métricas se combinan en un índice de rendimiento multicriterio normalizado, lo que permite una comparación consistente y reproducible a nivel de sistema. Los resultados revelan que, si bien la cobertura está gobernada principalmente por la altitud orbital, la arquitectura de red juega un papel dominante en la latencia efectiva, y las constelaciones con ISL habilitado logran una mayor eficiencia de enrutamiento en comparación con los diseños de tubería curva. El índice de rendimiento integrado muestra que las constelaciones de baja altitud y alta densidad logran un rendimiento general superior en escenarios donde la latencia es un factor crítico. Starlink obtiene la mejor posición gracias a su menor retardo y alta densidad espacial. El Proyecto Kuiper presenta un rendimiento equilibrado en todas las métricas, mientras que OneWeb y Telesat se ven limitadas por una mayor latencia y menor densidad, a pesar de su mayor cobertura.*

Palabras clave: constelaciones LEO; Comunicaciones de banda ancha globales; Arquitectura de red; Modelado de cobertura; Rendimiento de latencia; Comparación de sistemas.

1. Introduction

The increasing demand for global broadband communications has driven significant advancements in satellite-based connectivity systems. Traditional geostationary satellites (GEO) present inherent limitations in terms of latency and scalability, which restrict their ability to support high-throughput and low-latency applications [1], [2]. Low Earth Orbit (LEO) satellite constellations have emerged as a solution with reduced propagation delay and improved spatial reuse [3], [4]. LEO constellations operate at altitudes typically ranging from 500 km to 1500 km, which significantly impacts latency, coverage, and satellite visibility [5], [6]. Recent developments in the space industry have led to the deployment and planning of large-scale LEO constellations by major operators, including Starlink, OneWeb, Telesat, and Project Kuiper. These constellations encompass a wide range of design approaches, including architectures with and without Inter-Satellite Links (ISL), as well as distinct orbital configurations in terms of altitude, inclination, and satellite distribution [7], [8].

Despite the rapid development of these systems, studies typically focus on evaluating isolated aspects such as latency estimation or coverage analysis, without providing an integrated evaluation of multiple performance dimensions [9], [10]. Furthermore, comparative analyses that explicitly incorporate architectural effects, such as the role of Inter-Satellite Links, and emerging systems such as Project Kuiper remain limited in the current literature. This highlights the need for updated evaluation capable of capturing the interaction between orbital geometry, network architecture, and system-level performance. To address this need, this work proposes a comparative framework that integrates both geometric and operational characteristics of LEO constellations. The methodology incorporates key orbital parameters such as coverage and a minimum elevation angle, along with a latency model that accounts for propagation delay and routing effects associated with different network designs, including ISL-enabled and bent-pipe configurations [11], [12]. These elements are further combined with a service density metric to capture the spatial distribution of satellites and its implications for capacity and resource availability. The main contribution of this paper lies in the development of a normalized multi-criteria performance index that enables a reproducible comparison among LEO constellations. By jointly evaluating coverage, latency, and service density, the proposed framework captures the fundamental trade-offs that characterize large-scale satellite systems. The remainder of this paper is organized as follows. Section 2 presents the background and related work on LEO satellite systems. Section 3 describes the proposed methodology. Section 4 discusses the comparative results. Finally, Section 5 summarizes the main conclusions of this study.

2. Background and related work

2.1 Inter-Satellite Links and coverage model

LEO satellite networks can be broadly classified into bent pipe, ISL-enabled, and hybrid architectures. As illustrated in Figure **1**, bent pipe systems rely on ground gateways for data routing, whereas ISL-enabled constellations enable direct communication between satellites, allowing data to be routed in orbit. Hybrid architectures combine both approaches depending on system requirements and deployments stages. The choice of architecture has a significant impact on system performance, particularly in terms of latency, routing efficiency, and dependency on ground infrastructure [13], [14].

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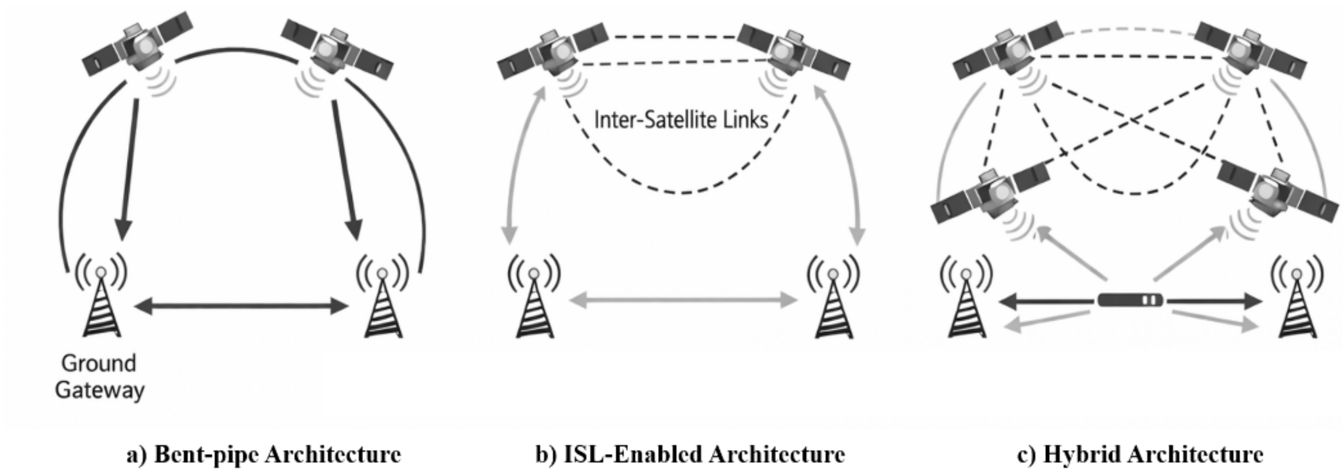

Figure 1. Representative architectures of LEO satellite networks: (a) bent-pipe architecture dependent on ground gateways, (b) Inter-Satellite Link (ISL)-enabled architecture, and (c) hybrid architecture integrating both approaches

Figure **2** depicts the geometric relationship used to determine the footprint of a Low Earth Orbit (LEO) satellite. The parameters include the Earth's radius R_e, the satellite altitude h, and the minimum elevation angle ε at the edge of the coverage. The central angle φ defines the angular radius of the spherical cap, which is essential for calculating the total service area. The slant range d_{slant} represents the direct line-of-sight distance between the satellite and a ground terminal at the boundary of the coverage area C_{sat}. This model is critical for determining the terrestrial reach and the required constellation density for continuous global connectivity [15], [16].

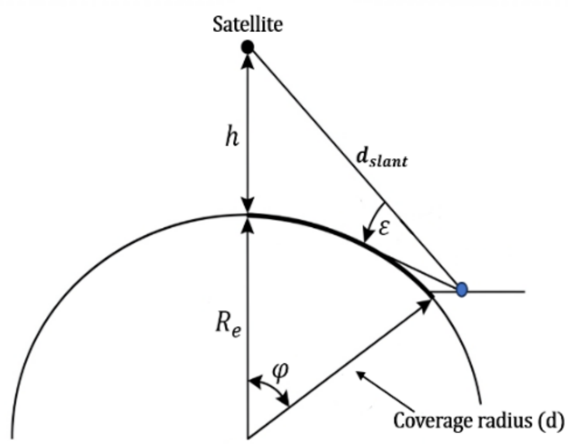

Figure 2. Geometric model of LEO satellite coverage illustrating the relationship between satellite altitude, Earth radius, central angle, and minimum elevation angle

2.2 Description of selected constellations

The systems considered in this work represent different design approaches in terms of orbital configuration, deployment strategy, and network architecture. Starlink is characterized by a large-scale deployment strategy involving multiple orbital shells at relatively low altitudes. This configuration enables

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reduced latency and increased spatial density. Additionally, the system incorporates Inter-Satellite Links (ISL), allowing data routing directly in orbit and reducing dependency on ground infrastructure [17]. OneWeb employs a constellation with fewer satellites operating at higher altitudes compared to Starlink. Its architecture is primarily based on a bent-pipe approach, in which satellites act as relay nodes and data routing is performed through ground gateways stations [18]. Telesat is designed to support enterprise and backhaul services, integrating ISL capabilities with optimized orbital configurations. This approach seeks to balance coverage, latency, and network efficiency [19]. Project Kuiper represents an emerging system with a planned deployment across multiple orbital planes and its architecture is intended to support global broadband services. The limited availability of comparative studies involving this system highlights its relevance within the context of this analysis [20], [21].

2.3 Related work

Several studies have investigated different aspects of LEO satellite systems, including latency modeling, coverage estimation, and network performance analysis. Existing works typically focus on individual parameters, such as propagation delay or coverage footprint, without integrating multiple dimensions into a unified framework [22]. Other research efforts have explored routing mechanisms and the role of Inter-Satellite Links in improving network performance, highlighting their importance in reducing end-to-end latency and enabling global connectivity [23]. However, comprehensive comparative studies that jointly consider orbital parameters, such as coverage, latency, density service and network architecture remain limited. Additionally, most analyses focus on established constellations, while emerging systems such as Project Kuiper are not included, emphasizing the need for updated evaluation approaches.

3. Methodology

3.1 Coverage model

The coverage of a LEO satellite is determined by the geometric relationship between the Earth radius, the satellite altitude and the minimum elevation angle. The central angle that defines the coverage region on Earth's surface can be expressed as [24], [25]:

$$\varphi = [cos^{-1}(\frac{R_e}{R_e+h} cos\varepsilon)] - \varepsilon \qquad (1)$$

where R_e is the Earth radius, h is the satellite altitude, and ε is the minimum elevation angle. The ground coverage radius is then obtained as:

$$d = R_e * \varphi \qquad (2)$$

where d represents the arc length over the Earth's surface corresponding to the satellite footprint. The coverage area is computed using a spherical cap model, which accurately represents the Earth's curvature, and is defined as:

$$C_{sat} = 2\pi {R_e}^2(1 - cos\varphi) \qquad (3)$$

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3.2 Latency model

The end-to-end latency in LEO satellite communication systems is modeled as the sum of multiple delay components, following standard formulations in communication networks [26], [27]. In general, the total latency can be expressed as:

$$T_{total} \approx T_{prop} + T_{proc} + T_{queue} + T_{routing} \quad (4)$$

where T_{prop} represents propagation delay, T_{proc} corresponds to processing delay, T_{queue} accounts for queueing effects, and $T_{routing}$ captures delays associated with path selection and forwarding. If processing and queueing delays are assumed to be similar among systems and are neglected, the latency model can be simplified as:

$$T_{total} \approx T_{prop} + T_{routing} \quad (5)$$

The propagation delay is determined by the signal travel time between ground users and the satellite system. In this work, propagation delay is modeled using a geometric formulation based on the slant range between a ground terminal and a satellite. The slant range d_{slant} is defined as the direct line-of-sight distance between the ground user and the satellite, taking into account the Earth's curvature and the minimum elevation angle. It is expressed as:

$$d_{slant} = \sqrt{{R_e}^2 + (R_e + h)^2 - 2R_e(R_e + h)cos\varphi} \quad (6)$$

where R_e is the Earth's radius, h is the orbital altitude, and φ is the Earth central angle corresponding to the coverage boundary. The propagation delay is approximated as the time required for a signal to travel from the ground terminal to the satellite and back, resulting in:

$$T_{prop} \approx \frac{2d_{slant}}{c} \quad (7)$$

where c is the speed of light ($3x10^8\ m/s$).

The routing component depends on the architectural design of the constellation. In bent-pipe systems, communication is relayed through ground gateways without in-orbit routing. Therefore, no additional on-board inter-satellite routing delay is introduced, and the routing component is assumed negligible for the purpose of this analysis ($T_{routing} \approx 0$). In contrast, constellations equipped with inter-satellite links (ISLs) enable direct satellite-to-satellite communication, where the routing delay is determined by the cumulative propagation across multiple satellite hops [28], [29]:

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$$T_{routing} = \sum_{i=1}^{N} \frac{d_i}{c} \tag{8}$$

where d_i represents the distance of each inter-satellite link segment and N is the number of hops.

3.3 Service density metric

The satellite availability over a given coverage area (service density metric) is defined as:

$$\rho = \frac{N_{sat}}{C_{sat}} \tag{9}$$

where N_{sat} is the number of satellites and C_{sat} is the coverage area. This metric provides a simplified and uniform representation of spatial service capability in large-scale constellations [30], [31].

3.4 Normalized performance index

To achieve a consistent comparison across constellations, a normalized performance index is proposed as:

$$PI = w_1 C_{norm} + w_2 T_{norm} + w_3 \rho_{norm} \tag{10}$$

where C_{norm}, T_{norm} *and* ρ_{norm} are the normalized coverage, normalized latency, and normalized service density, respectively, and w_i is the weighting coefficients. The normalized metrics are computed using a min-max normalization approach. For metrics where higher values indicate better performance, such as coverage and service density, normalization is defined as:

$$C_{norm} = \frac{C - C_{min}}{C_{max} - C_{min}} \tag{11}$$

$$\rho_{norm} = \frac{\rho - \rho_{min}}{\rho_{max} - \rho_{min}} \tag{12}$$

where C represents the coverage area and ρ denotes the service density.

For latency, lower values correspond to better performance, and an inverse normalization is applied:

$$T_{norm} = 1 - \frac{T - T_{min}}{T_{max} - T_{min}} \tag{13}$$

where T represents the total latency.

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This normalization ensures that all metrics are mapped into a unified range between 0 and 1, with higher values representing better system performance [32], [33]. A numerical evaluation framework integrating the models described above was implemented using MATLAB for Starlink, OneWeb, Telesat, and Project Kuiper. Parameters such as satellite altitude, number of satellites, orbital planes, and minimum elevation angle are defined based on publicly available data. The framework computes coverage radius, propagation delay, service density, and the normalized performance index.

4. Results and discussion

4.1 Simulation parameters

Table **1** summarizes the nominal parameters used in this study. The values correspond to configurations commonly reported in the literature and are selected to provide a comparative analysis rather than an exact replication of operational deployments. To ensure comparability across systems, each constellation is represented by a single nominal orbital shell or layer derived from publicly available data. This approach avoids the complexity associated with multi-shell deployments and enables a fair system-level comparison. For this analysis, the Earth is modeled with a radius of $R_e = 6371\ km$, and a minimum angle of $\varepsilon = 25°$ is assumed to define satellite visibility and coverage.

Table 1. Representative nominal parameters of selected LEO constellations

System	Altitude (km)	Satellites	Orbital planes	Inclination (°)	Architecture
Starlink	550	1584	72	53	ISL-enabled
Project Kuiper	630	1296	36	51.9	Hybrid
Telesat	1015	198	6	98.5	ISL-enabled
OneWeb	1200	648	18	87.9	Bent-pipe

4.2 Coverage results

The coverage performance of the evaluated LEO constellations is determined using the geometric model described in Section 3.1. Figure **3** illustrates the variation of satellite coverage area as a function orbital altitude, computed using cap model for a fixed minimum elevation angle of 25°.

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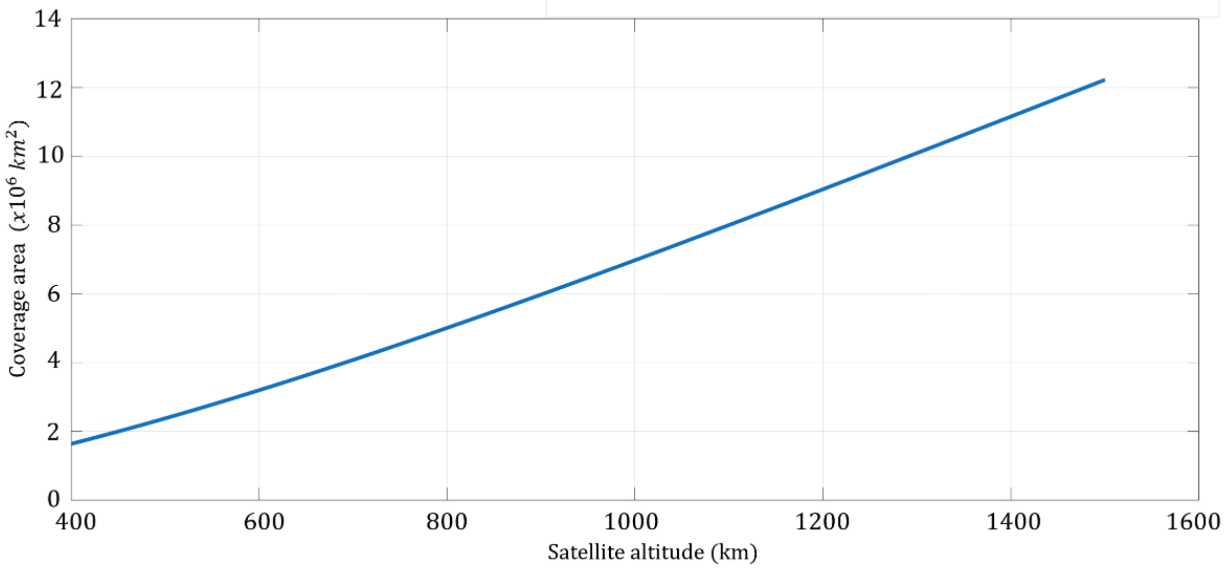

Figure 3. Variation of satellite coverage area as a function of orbital altitude

The analysis considers altitudes ranging from 400 km to 1500 km, which are representative of typical Low Earth Orbit (LEO) constellations. The results confirm the dependence of satellite footprint on satellite height. Table **2** summarizes the resulting coverage radius and footprint area for the selected constellations.

Table 2. Coverage radius and footprint area for selected LEO constellations (nominal configurations).

System	**h (km)**	**d (km)**	**C_sat ($x10^6$ km^2)**
Starlink	550	~940	~2.78
Project Kuiper	630	~1049	~3.46
Telesat	1015	~1510	~7.12
OneWeb	1200	~1701	~9.05

OneWeb achieves the largest coverage footprint due to its higher orbital altitude, followed by Telesat and Project Kuiper. In contrast, Starlink exhibits the smallest coverage radius, which is consistent with its lower-altitude configuration. The footprint area of OneWeb is approximately 3.3 times the size of Starlink, highlighting the significant impact of altitude on coverage scalability. While higher-altitude constellations benefit from wider coverage per satellite, they reduce the level of spatial reuse, which limit capacity in high-demand regions.

4.3 Latency numerical estimation

The latency performance of the evaluated LEO constellations is analyzed using the propagation model described in Section 3.2. Figure **4** shows the propagation delay as a function of orbital altitude for values ranging from 400 km to 1500 km, considering a fixed minimum elevation angle of 25°.

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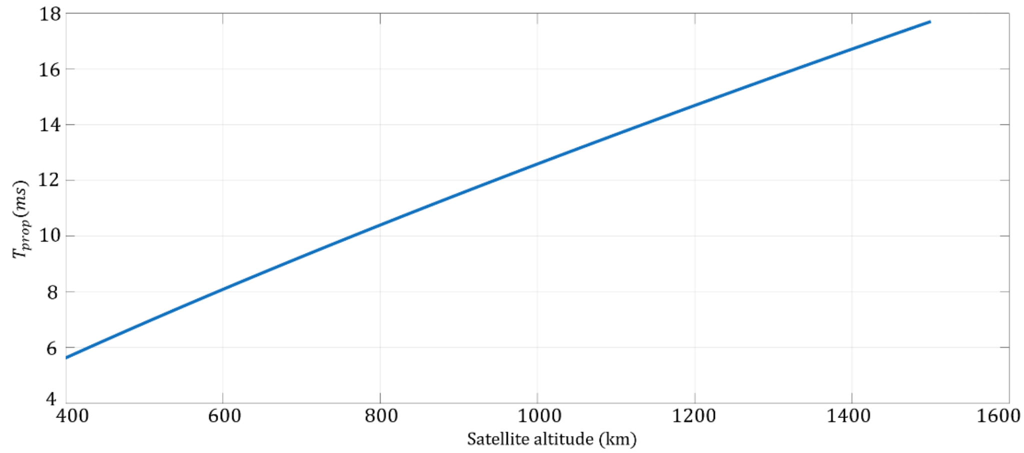

Figure 4. Variation of propagation delay as a function of orbital altitude

Table **3** summarizes the resulting latency values for the selected constellations. The results show a clear dependence of propagation delay on orbital altitude, with lower-altitude systems achieving reduced latency compared to higher-altitude configurations.

Table 3. Approximate propagation latency for selected LEO constellations.

System	Altitude (km)	Approximate Latency (ms)
Starlink	550	~7.5
Project Kuiper	630	~8.4
Telesat	1015	~12.8
OneWeb	1200	~14.7

Starlink achieves the lowest propagation latency due to its reduced orbital altitude, followed by Project Kuiper. Telesat and OneWeb exhibit higher latency values as a result of their higher orbital configurations. In particular, the presence or absence of Inter-Satellite Links (ISL) significantly influences how data is transmitted across the network. Table 4 summarizes the qualitative impact of network architecture on effective latency.

Table 4. Impact of network architecture on effective latency.

System	Architecture	Effective Latency Trend
Starlink	ISL-enabled	Reduced (optimized routing)
Project Kuiper	Hybrid (partial ISL deployment)	Moderate (dependent on ISL utilization)
Telesat	ISL-enabled	Moderately reduced (planned space-based routing)
OneWeb	Bent-pipe	Increased (gateway-dependent routing)

Constellations with Inter-Satellite Links, such as Starlink, enable direct communication between satellites, reducing the reliance on ground infrastructure and allowing more efficient routing paths. This results in lower effective latency, particularly for long-distance communications. In contrast, bent-pipe architectures, such as OneWeb, require signals to be routed through ground gateways, which can increase latency due to additional transmission segments and infrastructure constraints. Telesat, while designed

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with ISL, is expected to achieve moderate latency improvements depending on the extent of its deployment, similar to Project Kuiper.

4.4 Service density evaluation

The service density of the evaluated LEO constellations is analyzed using the model introduced in Section 3.3, where density is defined as the ratio between the total number of satellites and the effective coverage area per satellite. This metric provides an equivalent spatial representation of how densely satellites are distributed within their respective coverage regions.

Table 5 presents the resulting service density values for the selected constellations, computed using the updated coverage areas derived from the geometric model.

Table 5. Service density for selected LEO constellations (nominal configurations).

System	Satellites (nominal)	C_{sat} ($x10^6$ km^2)	ρ ($sat/10^6$ km^2)
Starlink	1584	~2.78	~569
Project Kuiper	1296	~3.46	~375
OneWeb	648	~7.12	~91
Telesat	198	~9.05	~22

Starlink exhibits the highest service density by a wide margin due to its large number of satellites combined with a relatively small coverage footprint. Project Kuiper follows as the second system, while OneWeb and Telesat show lower density values. The service density of Starlink is approximately 6 times higher than that of OneWeb and more than 27 times higher than that of Telesat. This highlights the different design philosophies between low-altitude, high-density constellations and higher-altitude, lower-density systems. Higher service density is associated with improved spatial reuse and increased capacity in high-demand regions. Dense constellations enable more simultaneous connections and better load distribution, which is critical for broadband and low-latency applications. However, increasing density also introduces system-level challenges, including higher deployment costs, increased complexity in management, and more requirements for interference coordination and resource allocation. Systems with larger coverage footprints per satellite, such as OneWeb and Telesat, exhibit lower spatial density, whereas systems with smaller footprints compensate through greater number of satellites. This trade-off plays a central role in the overall performance evaluation and directly influences the results of the integrated performance index.

4.5 Normalized performance index

The normalized performance index defined in Section 3.4 was used to integrate the effects of coverage, latency, and service density into a single comparative metric. This index allows an evaluation by combining metrics with different physical meanings into a unified framework. In this study, the weighting

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coefficients were defined as $w_1 = 0.3$ for coverage, $w_2 = 0.4$ for latency, and $w_3 = 0.3$ for service density. The reason behind this specific allocation is rooted in the operational performance requirements defined by the International Telecommunication Union (ITU) for IMT-2020 and emerging 5G networks, which position latency as the critical bottleneck for next-generation interactive services. In satellite-terrestrial integrated networks, achieving ultra reliable low-latency communications (URLLC) is very important for applications such as real-time edge computing, autonomous vehicle routing, and interactive cloud protocols [34], [35]. Therefore, latency is assigned a higher priority to penalize systems whose orbital configurations or routing mechanisms introduce propagation delays. Concurrently, coverage and service density represent a structural trade-off in orbital design: higher altitudes maximize individual footprints but degrade spatial density and capacity reuse [36]. To ensure that no single dimension dominates the performance index, both metrics are treated with equal relevance, balancing the network's geographical reach with its capacity potential.

The normalization of the evaluated metrics was performed using a min–max approach as defined in Section 3.4, ensuring that all variables are mapped into a common range between 0 and 1. Based on the values obtained in Tables 2, 3 and 5 for coverage area, latency, and service density, the normalized performance index was calculated for each constellation. The resulting values are summarized in Table 6.

Table 6. Normalized performance index for selected LEO constellations.

System	C_{norm}	T_{norm}	ρ_{norm}	Performance Index
Starlink	0.00	1.00	1.00	0.70
Project Kuiper	0.11	0.87	0.64	0.57
OneWeb	1.00	0.00	0.12	0.33
Telesat	0.69	0.26	0.00	0.31

The results indicate that Starlink achieves the highest overall performance index, primarily driven by its superior latency and service density. Despite having the smallest coverage footprint, its high satellite density and low propagation delay enable strong overall performance, particularly for latency-sensitive and high-capacity applications. Project Kuiper ranks second, benefiting from a balanced combination of moderate coverage, relatively low latency, and intermediate density. This positioning reflects a design strategy that seeks to balance performance across multiple dimensions rather than optimizing a single parameter. OneWeb and Telesat exhibit lower performance index values. Telesat benefits from relatively high coverage but is limited by lower density and higher latency, whereas OneWeb achieves the largest coverage footprint but is significantly penalized by its higher latency and lower spatial density. These results highlight that maximizing a single metric, such as coverage, does not necessarily translate into superior overall performance. Instead, effective system design requires balancing factors including coverage, latency and service density. Please note that the adopted weighting scheme influences the resulting ranking. While the selected weights prioritize latency due to its critical role in next-generation communication services, alternative weight configurations could shift the relative performance of the evaluated systems. For instance, increasing the weight associated with coverage would benefit higher-

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altitude constellations such as OneWeb, while increasing the weight of service density would further favor dense constellations like Starlink.

4.6 Validation of the Evaluated Framework

To verify the mathematical accuracy of the proposed framework, a multi-stage validation process was conducted. First, the formulation utilized to determine the satellite coverage footprint (C_{sat}) and coverage radius is directly grounded on established orbital mechanics and satellite communication theory. The same geometric equations applied in this study (Equation 1, 2 and 3) have been widely adopted and validated in recent literature for evaluating Low Earth Orbit (LEO) topologies, such as in the analytical models presented in [37], confirming the rigor of our theoretical foundation.

The latency values in this work were cross-referenced with established simulations models in the literature. Specifically, the end-to-end latency metrics calculated by our framework for the Starlink constellation converge with the performance reported in [10]. This agreement with a widely accepted Starlink benchmark validates the operational integrity of the numerical model, thereby confirming its use and accuracy for evaluating the remaining LEO constellations.

Furthermore, despite the diverse operational constraints found in commercial deployements (such as variable elevation angles or variable routing protocols, the nominal operational specifications, along with the service density metric, were standardized based on the methodology described in Section 3. This was to maintain a consistent and reproducible platform for comparison under identical environmental conditions.

5. Conclusions and future work

This paper presented a unified framework for the evaluation of Low Earth Orbit (LEO) satellite constellations based on three key performance dimensions: coverage, latency, and service density. By integrating these metrics into a normalized performance index, the proposed approach enables a comprehensive and consistent comparison across different constellation architectures. The evaluation demonstrated that coverage is strongly influenced by orbital altitude, with higher-altitude constellations achieving larger footprint areas per satellite. However, this advantage comes at the expense of increased propagation delay and reduced spatial density. In contrast, lower-altitude systems exhibit smaller coverage regions but benefit from significantly lower latency and higher satellite density, enabling improved spatial reuse and potential capacity gains.

The results obtained from the integrated performance index indicate that constellations such as Starlink achieve superior overall performance under latency-sensitive and high-density scenarios, primarily due to their low orbital altitude and large number of deployed satellites. Systems such as Project Kuiper present a balanced performance across all metrics, while higher-altitude constellations such as OneWeb and Telesat offer advantages in coverage but are penalized by higher latency and lower density. A key contribution of this work lies in the consistent formulation of the coverage model, which incorporates the minimum elevation angle to provide realistic footprint estimations. Additionally, the adoption of a simplified latency model, along with an equivalent spatial density metric, enables a tractable and coherent

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system-level analysis. The proposed framework also highlights the critical role of design trade-offs in LEO constellation performance. The results show that optimizing a single parameter is insufficient, and that effective system design requires balancing coverage, latency, and spatial density according to application requirements. Furthermore, the weighting-based formulation of the performance index provides flexibility to adapt the analysis to different operational priorities. Overall, this work provides a robust and scalable methodology for the comparative evaluation of LEO satellite constellations and offers valuable insights into the trade-offs that define next-generation satellite communication systems.

Despite its contributions, this study is constrained by specific limitations which are inherent to first-order analytical models. The geometric coverage framework relies on a static minimum elevation angle, neglecting dynamic link-blocking condition and atmospheric attenuation, which can induce severe link degradation during adverse meteorological events. Furthermore, the latency formulation assumes deterministic shortest-path propagation, omitting stochastic queueing fluctuations and processing overheads during peak traffic congestion. In highly loaded operational scenarios, this can introduce transient latency jitters, increasing the total end-to-end delay, which are not captured by a static model. Future work will focus on transitioning this analytical framework into a dynamic network simulation environment. Technical extensions will consider time-variant topologies to evaluate the impact of non-uniform traffic demands. Furthermore, a systematic sensitivity analysis of the weighting coefficients will be conducted to assess the stability of the performance index under different operational scenarios and service requirements.

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