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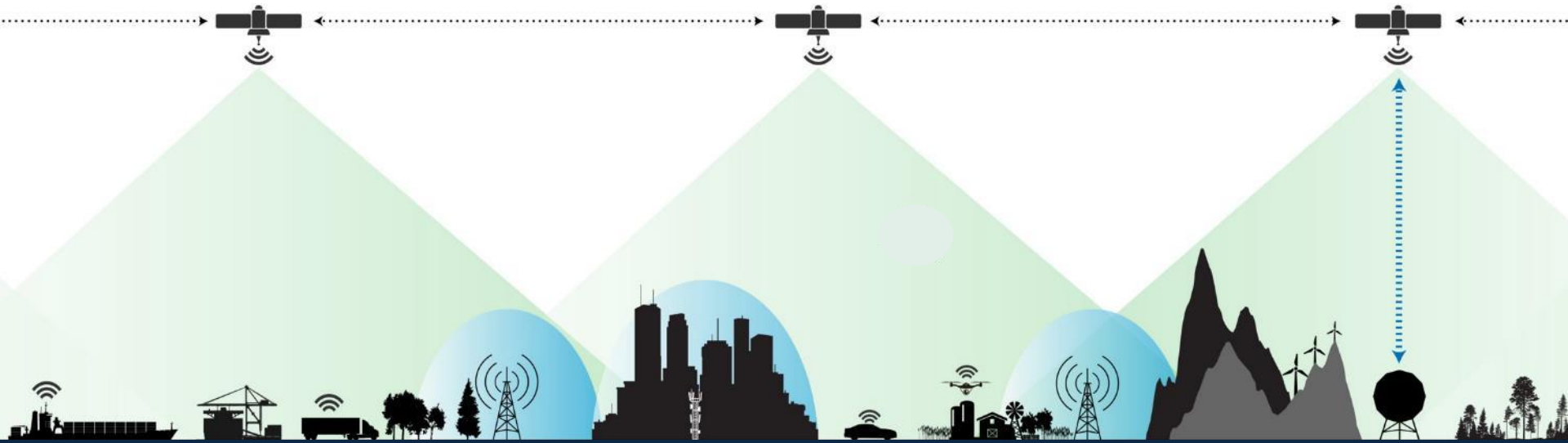
QoS and QoE in Emerging Satellite Technologies

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Alex Orange, VP Technology and Spectrum
aorange@omnispace.com



D2D Connectivity Total Addressable Market (TAM)



Large Annual Market Opportunity for Satellite Connectivity Solutions*

2035	2035	2035	2035
~\$28.4B+	~\$10.8B+	~\$2.1B+	~\$41.3B+
400M+ Subscribers	1.9Bn+ IoT Devices	1.5M+ Devices	2.3Bn+ Devices
5G NTN Mobile Roaming Opportunity	5G NTN IoT Opportunity	5G NTN Government Opportunity	Total Annual Opportunity

* Independent market assessment conducted in 2022



D2D Use Cases: QoS/E Benchmark Set by Terrestrial Operations

Mobile Communications

Application(s):

- § Messaging
- § Voice/audio
- § Mobile transactions
- § Social media
- § Email



PPDR Services

Application(s):

- § Messaging
- § Voice/audio
- § Drones
- § Low-res video
- § Broadcast
- § Weather



Asset Tracking

Application(s):

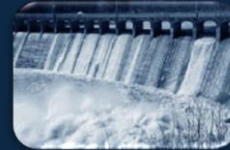
- § Location reporting
- § Logistics
- § Asset status
- § Environmental monitoring
- § Agriculture & Farming



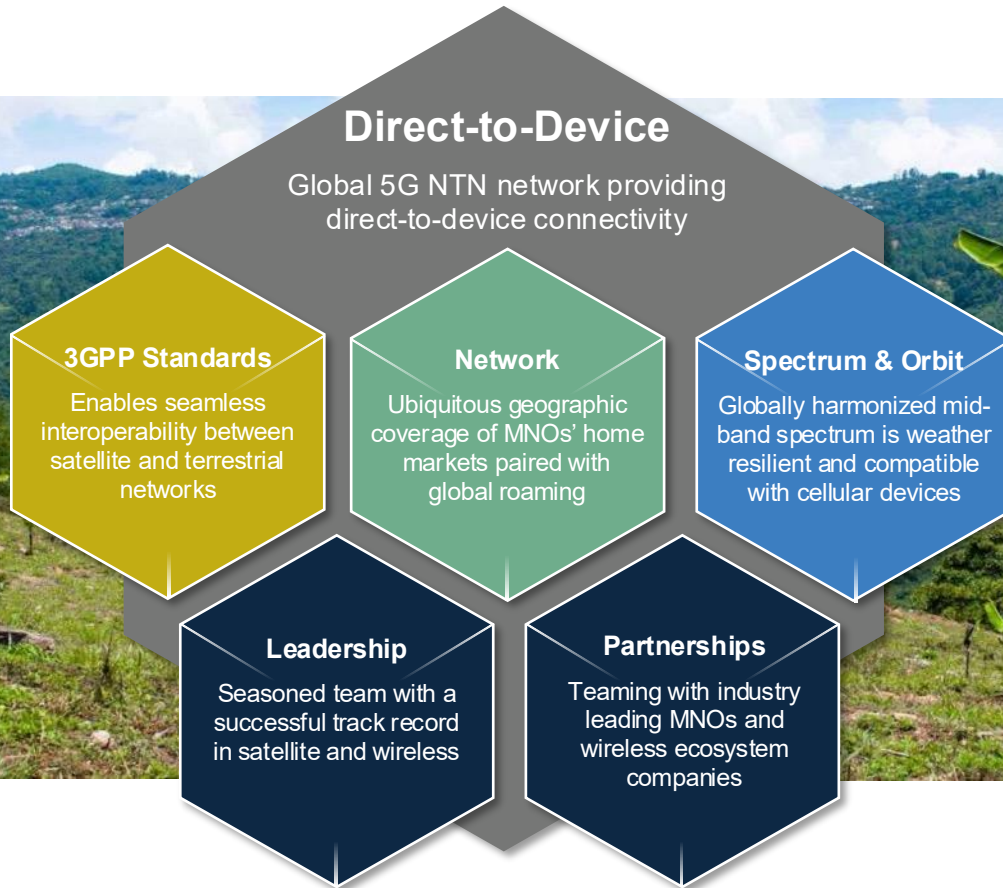
Smart Infrastructure

Application(s):

- § Hydraulics
- § Condition monitoring
- § Environmental monitoring
- § Command and control
- § Configuration/software management
- § Broadcast



Global Hybrid Network Requisites for QoS and QoE



Two Paths to Direct-to-Device: IMT vs. MSS Spectrum

Both regulatory models deliver D2D connectivity to unmodified handsets. They differ in the spectrum used, the regulatory mechanism, and the coordination burden. Lyrnk Global — through its merger with Omnispace — will operate under both.

IMT / SCS – DC-MSS-IMT

Spectrum: Terrestrial mobile bands (e.g., <2700 MHz) under agreement from an MNO licensee.

Regulatory mechanism: Spectrum-lease / SCS framework; satellite authorized under partner MNO's national license, and internationally authorized using RR Art. 4.4.

Coverage model: Supplemental / gap-fill within a single MNO's footprint, country by country.

Strengths: Works with some 3GPP handset on the leased band - may require software updates; MNO commercial alignment; uses spectrum already allocated for mobile use in-country.

Challenges: Present international framework incomplete requires satisfaction of WRC-278 AI 1.13 to complete, Requires national licensing framework per market; cross-border interference coordination (satellite and terrestrial); no global harmonized footprint, presently unable to support "E911" QoS for services.

Satellite component of IMT – MSS path

Spectrum: Globally harmonized MSS allocations (e.g., S-band 2 GHz, L-band) with shared access coordinated using ITU filings.

Regulatory mechanism: International framework complete, Satellite operator's own market access / landing rights;

Coverage model: International, Regional, Wide-area, multi-country footprint with consistent spectrum across borders.

Strengths: Globally harmonized shared access – no regulatory changes required; no per-country IMT lease required; aligned with NTN-capable devices, NTN device testing covered by Global Certification Forum (GCR)

Challenges: Limited MSS bandwidth; device ecosystem still growing

Global Policy Landscape: How Regions Are Approaching D2D

UNITED STATES — FCC

SCS framework (March 2024; effective May 2024). First-of-its-kind rules letting terrestrial licensees lease IMT spectrum to a satellite operator for D2D. Adopts interim 911 routing and per-band eligibility. Separate proceedings address MSS market access and band-by-band coexistence. International operation legitimized using RR Art. 4.4

EUROPE — CEPT / EU

RSPG Opinion (June 2025) + EC mandate to CEPT (Oct 2025). CEPT is developing harmonized technical conditions for D2D-IMT in EU-harmonised ECS bands while protecting incumbent satellite and terrestrial use and cross-border services. MSS-based D2D follows existing harmonised 2 GHz MSS rules.

AMERICAS — CITEL

PCC.II considering both paths. Member states recognize MSS-based D2D can deploy under existing frameworks, while IMT-based D2D raises sharing and authorization questions under WRC-27 AI 1.13. Regional view emphasizes digital inclusion and emergency comms.

ASIA-PACIFIC — APT

Diverse national approaches. Japan, Australia, and New Zealand completed permissive D2D rules internationally authorized using RR Art.4.4; India's TRAI consultations ongoing. Singapore, Malaysia and Thailand consulting on future D2D frameworks. Satellite connectivity essential for maritime environment, and archipelagic nations, APT focusing on harmonization for WRC-27 preparation.

Common thread: enable IMT-based D2D under national rules and protect MSS-based D2D under globally harmonized allocations.

Multi-orbit Network of Tomorrow

GEO

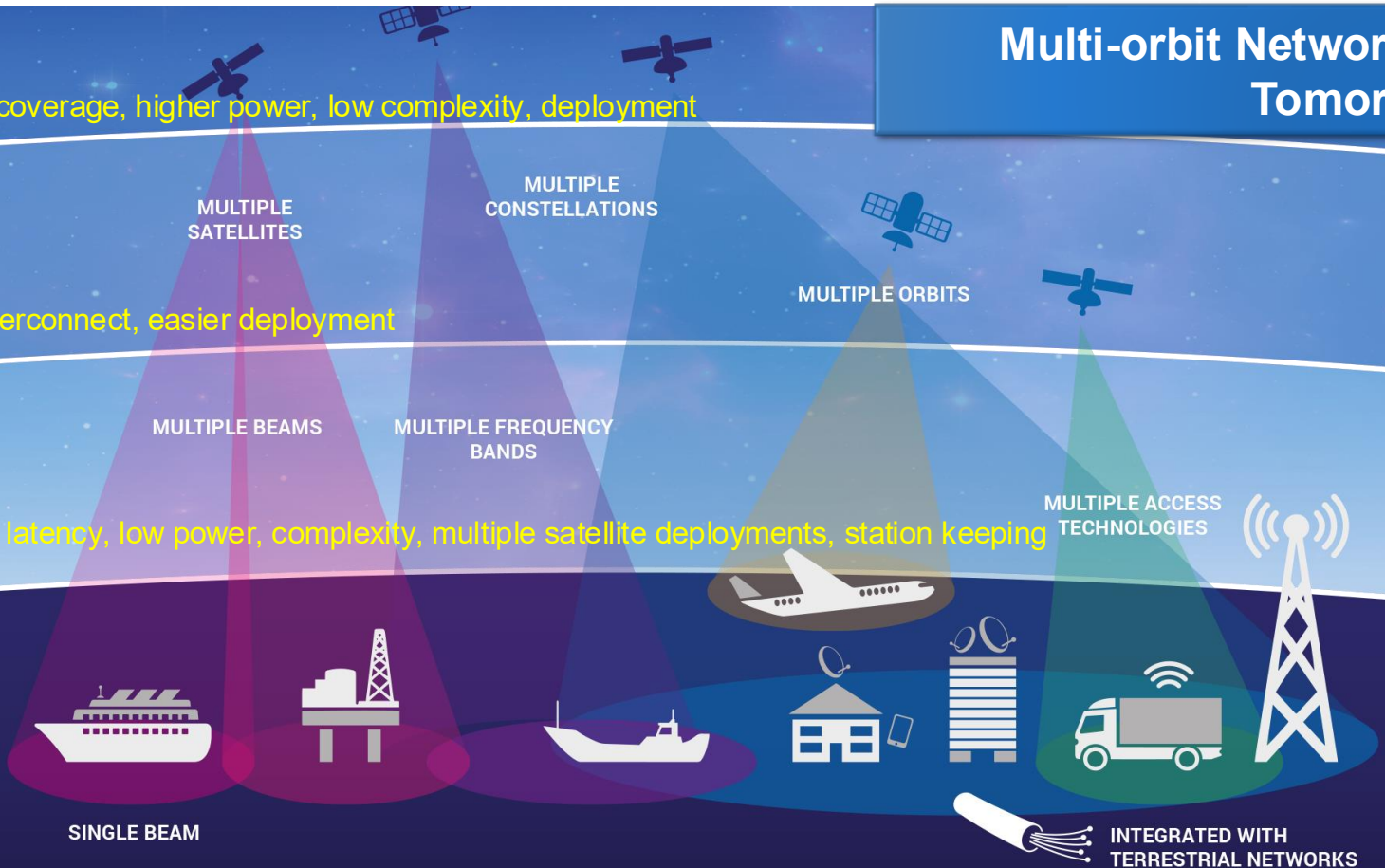
Hemispheric coverage, higher power, low complexity, deployment

MEO

Coverage, interconnect, easier deployment

LEO

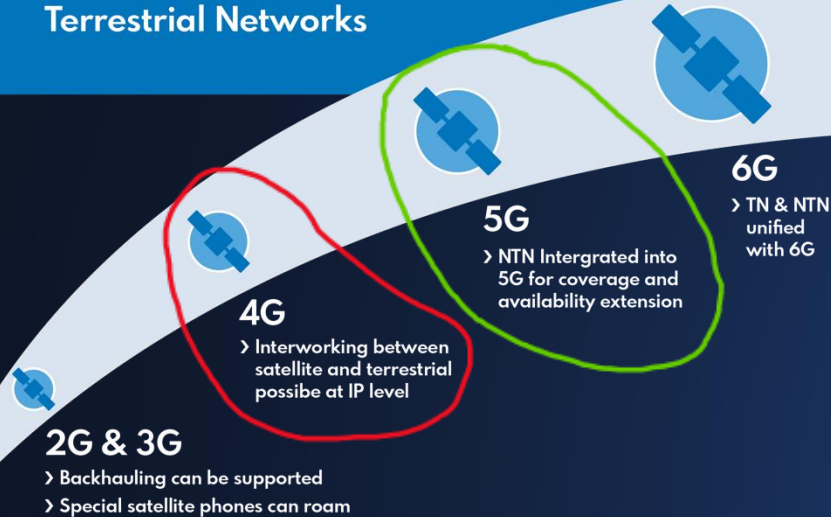
Capacity, low latency, low power, complexity, multiple satellite deployments, station keeping



*Global Satellite Operators Association GSOA, 2022 https://gsoasatellite.com/reports_and_studies/

Towards a fully integrated ecosystem

Terrestrial Networks



Expanding
Digital
Demand

Satellite
Innovation

Cross-
Sector
Application

- Recommendation ITU-R M.2177 (02/2026)
- ITU-R SG04 approved new Report on Development and Technology trends for the satellite component of IMT towards 2030 and beyond



Benefits of standardization and harmonization

- Lessons from terrestrial IMT:
 - Maximize ecosystem development with global 3GPP specifications:
 - 3GPP Rel. 17 complete specification for NTN/D2D
 - Improves consumer choice
 - Maximizes economies of scale -> lower consumer equipment cost
 - Ensures cross vendor interoperability (infrastructure and consumer equipment) – 3GPP -> GCF testing
 - Assists competitiveness and competition
 - Reduces cross border interference issues
 - Enables backwards compatibility
- Advantage of revisiting from satellite perspective
 - In addition to GSOA, GSA, GSMA have established Association dedicated to building NTN/D2D ecosystem – MSSA <https://www.mss-association.org/>
 - Reference Architecture - <https://www.mss-association.org/mssa-reference-architecture/>



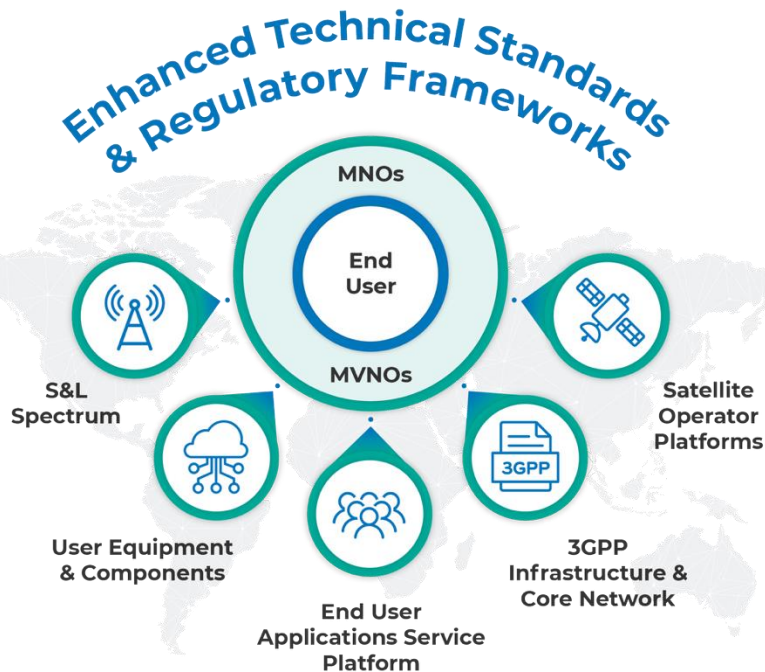
Building Together

Driving Scalable Growth and Expanding Choice in D2D and IoT Ecosystems Through Strategic Collaboration and Committee Initiatives

Members



Ecosystem



Regulatory Considerations to maximize QoS and QoE



REGULATORS HAVE A KEY ROLE

- Regulatory Certainty
- Spectrum Allocation and Management
- Adopt Global Standards – Satellite Component of IMT
- Licensing Frameworks
- Cross-Border Coordination
- Public-Private Partnerships



STANDARDS ARE CRITICAL

- Ensure native integration of satellite component in 6G/IMT
- To maximize potential, impact and benefits
- Prioritize NTN in Rel-20 study phase and Rel-21 normative phase on 6G
- Maximize efforts towards a unified NTN/TN ecosystem.

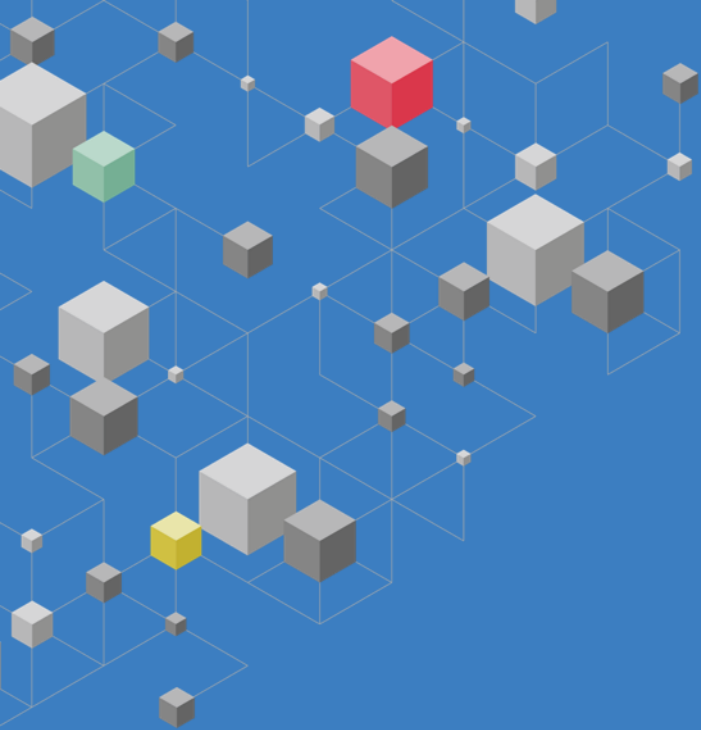


Thank you

Alex Orange

VP Technology and Spectrum

aorange@omnispace.com



Additional Information



Spectrum and Orbit Resources

- Access to suitable spectrum and the orbital resources are ESSENTIAL for D2D:
 - MSS D2D = Satellite Component of IMT – Resolution 225 (Rev. WRC-23), Resolution 254 (WRC-23), no additional regulatory issues
 - IMT D2D = complementary to Terrestrial IMT – “DC-MSS-IMT”, Resolution 253 (WRC-23), re
 - Pros and cons of 2 approaches:
 - <https://goa.space/wp-content/uploads/GSOA-D2D-Paper-Aug-24.pdf>
 - Best practice:
 - https://goa.space/reports_and_studies/satellite-licensing-best-practices/
 - <https://www.mss-association.org/spectrum-management-considerations-for-d2d-services/>
 - Band dictates bandwidth (and S/N) – low, mid, high band spectrum required
 - Bandwidth impacts capacity and capability (S/N) – low, mid and high bandwidth required
 - Orbit impacts: coverage, power, latency

NTN D2D Standardization and Spectrum

- Increased interest and opportunities in Direct-to-Device (D2D) developments
 - SCS and MSS routes: Omnispace focused on D2D in MSS bands route
- Omnispace plays very active role in 3GPP NTN standards development activity
- MSS S-band and L-band included in Release 17 of NTN standard

NR NTN satellite bands defined in 3GPP (TS 38.101-5)

REL	WI	NR band	Uplink (UL) operating band Satellite Access Node receive / UE transmit $F_{UL,low} - F_{UL,high}$	Downlink (DL) operating band Satellite Access Node transmit / UE receive $F_{DL,low} - F_{DL,high}$	Remarks
REL-17	NR_NTN_solutions	n256	1980 – 2010 MHz	2170 – 2200 MHz	FR1, FDD, S-band
REL-17	NR_NTN_solutions	n255	1626.5 – 1660.5MHz	1525 – 1559 MHz	FR1, FDD L-band
REL-18	NR_NTN_LSband	n254	1610 – 1626.5MHz	2483.5 – 2500MHz	FR1, FDD, LS-band
REL-18	NR_NTN_enh	n512*, n511*, n510*	27.5 – 30.0GHz 28.35 – 30.0GHz 27.5 – 28.35GHz	17.3 -20.2GHz 17.3 -20.2GHz 17.3 -20.2GHz	FR2, FDD, Ka-band



QoS and QoE in NTN Networks

- Non-GSO satellites factors affecting QoS and QoE:
 - Move relative to users and therefore introduce delay and doppler
 - Introduces propagation delays (lower for LEO compared to GEO) that needs to be accounted for
 - Frequent handovers between beams and satellites
 - Typically operate in [large > 500 satellite] constellations

QoS Metric	Comment
Throughput	Depends on constellation, handovers etc.
Handovers	Constellation size (GEO: Low, LEO: High)
Error Rate	Depends on propagation, mobility, Doppler
Availability (Link and service)	Redundancy & constellation dependent
Signal/Noise Ratio	Depends on satellite design & complexity
Packet delay (typical round-trip time)	LEO: 20ms GEO: 600ms

From latency aspect LEO has clear advantage over GEO