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QoS Considerations for Satellite Networks

Agenda

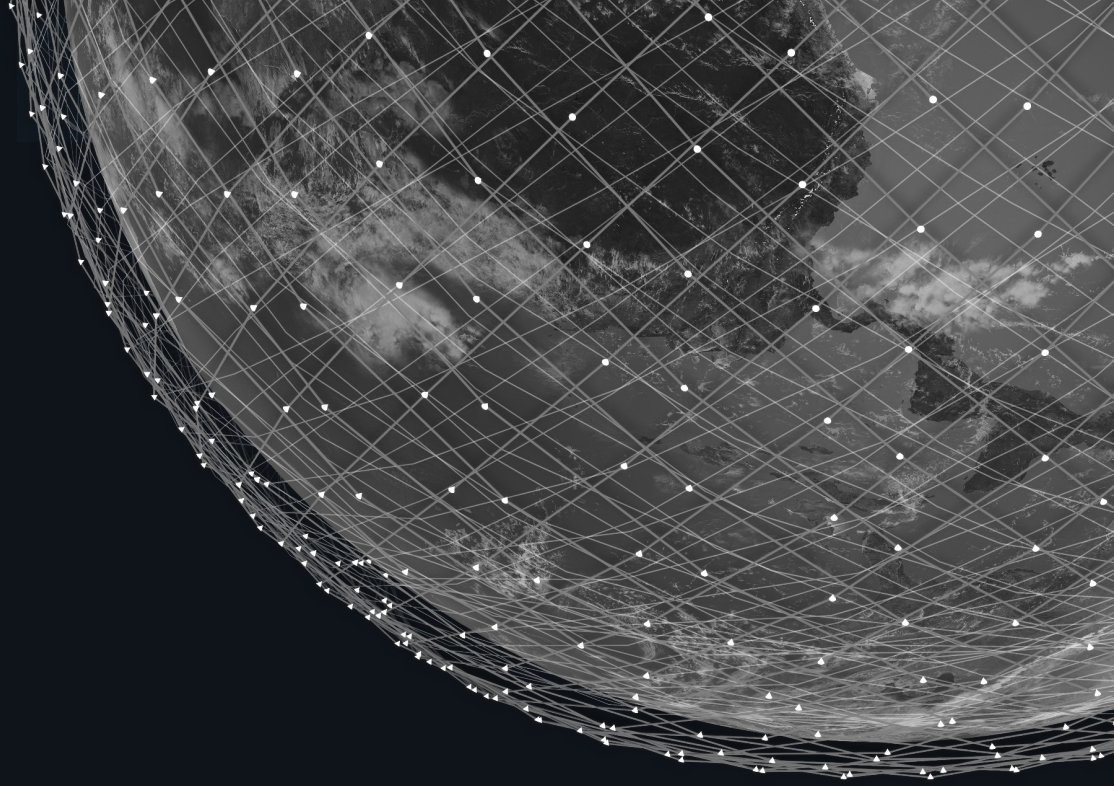
Amazon Leo Satellite System

Systems Dynamics & Sources of Variance

Common Satellite Network Metrics

Applicability of Current ITU-T Standards

Overview of Amazon Leo



6 shells of satellites
590 – 650 km, including polar

~400 ground gateway sites around the world

1 Gbps downlink speeds to enterprise terminals

30-50 milliseconds round trip latency

Vertical Integration

From custom ASICs to software, antennas to satellites and ground infrastructure, our technology is designed, optimized, and built by Leo.

Affordable Antennas

High performance and affordable antenna portfolio will support broad range of customer needs.

Space-to-space Communications

Satellites will use high-speed optical inter-satellite links (4x100 Gbps) for secure, resilient, mesh-based networking in space.

Robust Ground Network

Satellites will communicate from space to ground and back, using Ka-band for customer and gateway station links. The satellite constellation will scale to tens of millions of endpoints.

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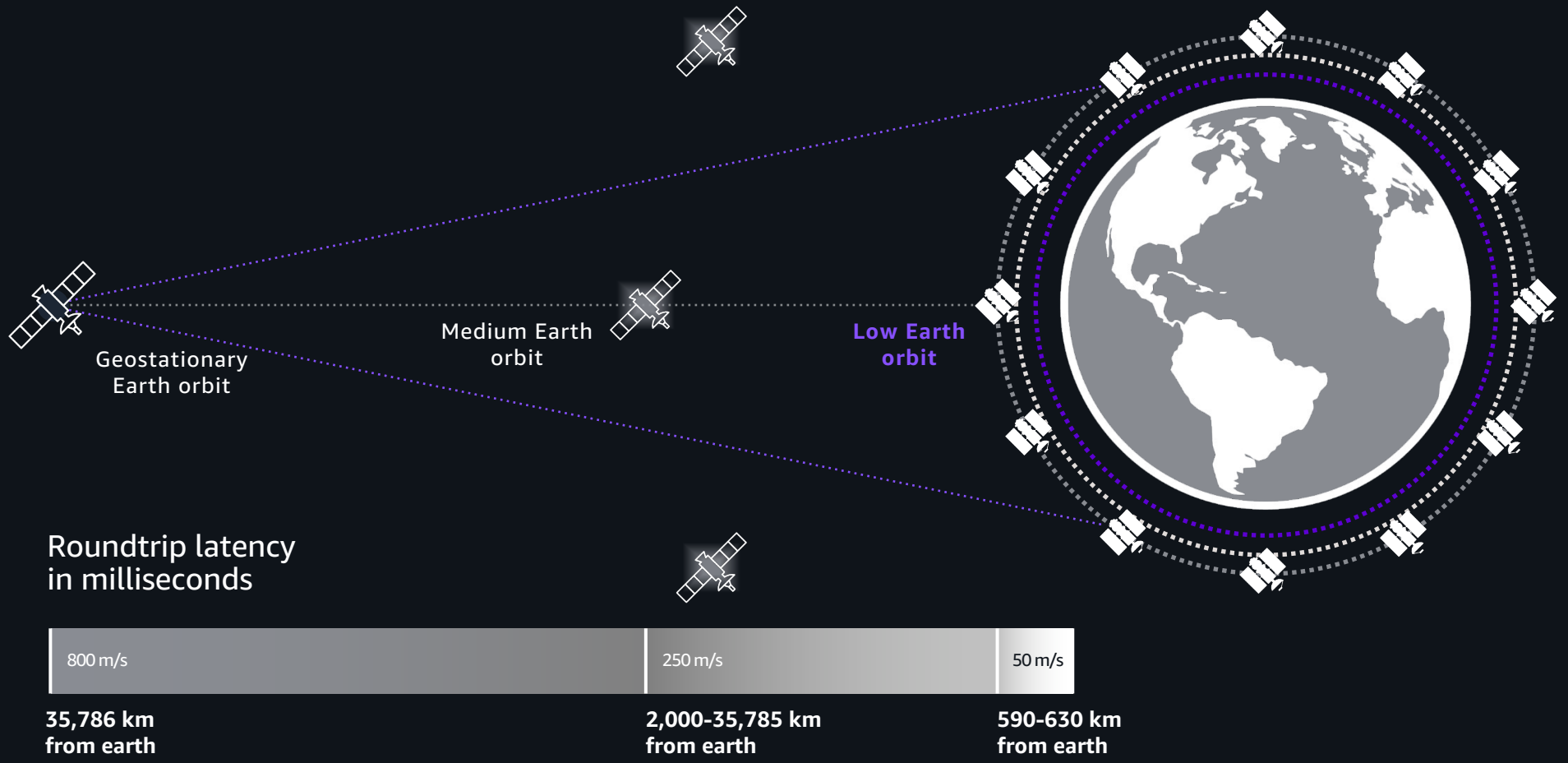
Low Earth Orbit is a **Significant Leap** Forward

Lower latency

More cells, more capacity

Increased resilience

Sustainable operations



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Amazon Leo Customer Terminals

7” x 7” 18cm x 18 cm

- Ultra-small form factor
- 100 Mbps downlink

11” x 11” 28cm x 28cm

- Built for scale
- 400 Mbps downlink

30” x 20“ 76cm x 51cm

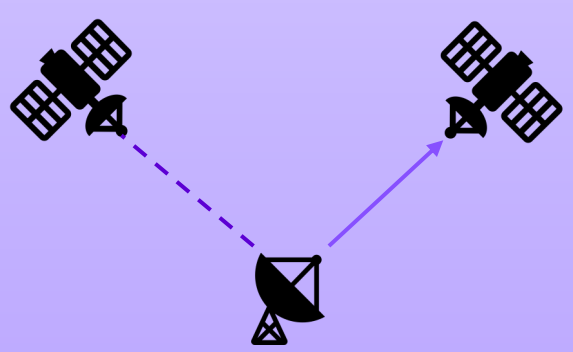
- Enterprise focused
- 1,000 Mbps downlink

Systems Dynamics & Sources of Variance

System Dynamics & Sources of Variance

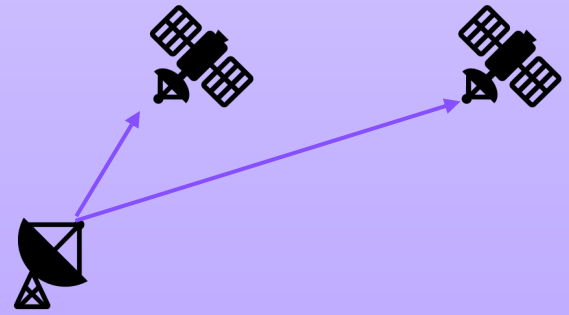
LEO networks must contend with non-congestive variance from rapid changes in geometry

1 Handover



2 Atmosphere

3 Orbit / Slant Range



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Handover: A Deterministic, Periodic Event

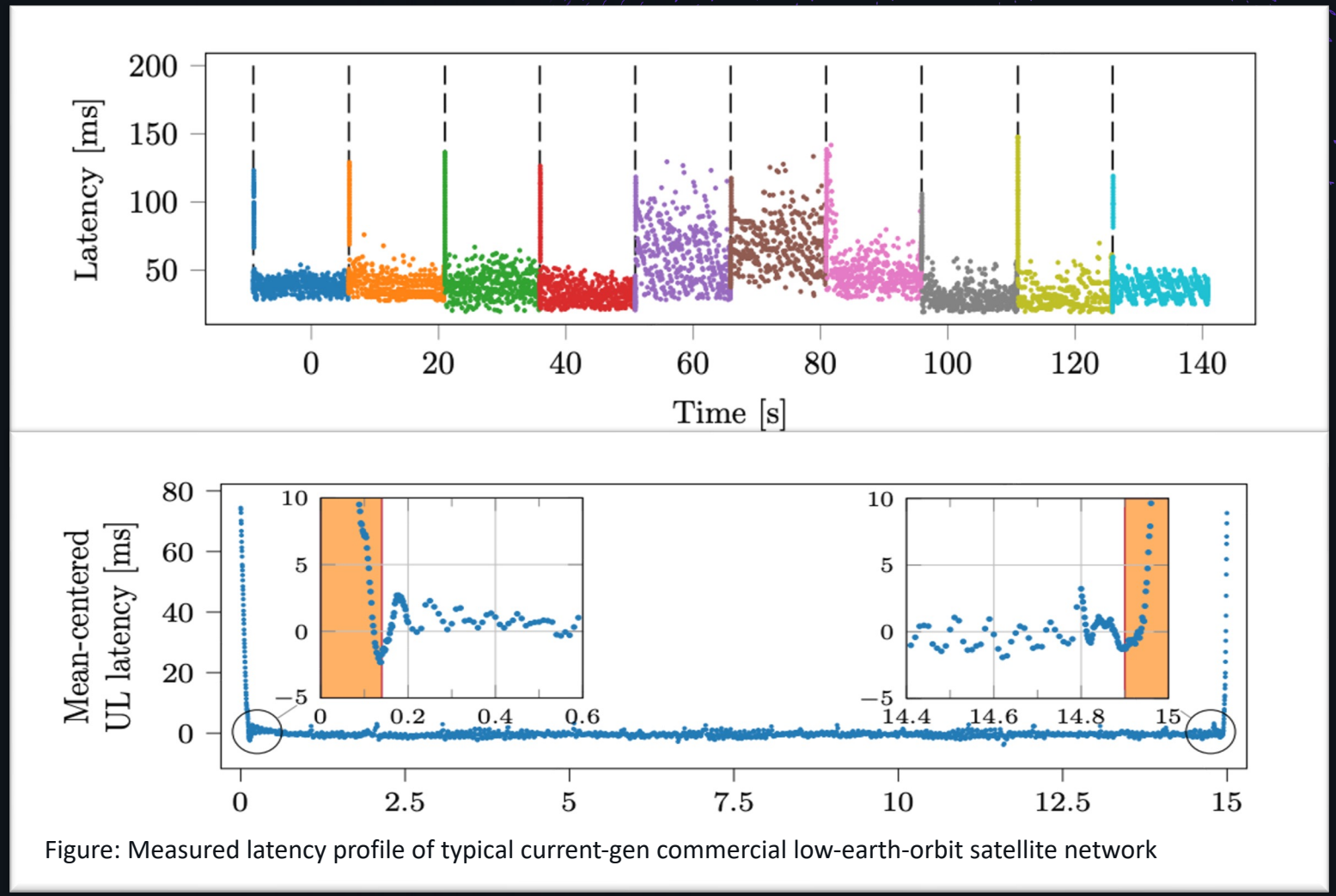

Figure: Measured latency profile of typical current-gen commercial low-earth-orbit satellite network

Source: Source: Casparsen et al., "Statistical Characterization and Prediction of E2E Latency over LEO Satellite Networks," arXiv:2601.08439, 2026

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Common Satellite Network QoS Metrics

Common Satellite Network QoS Metrics

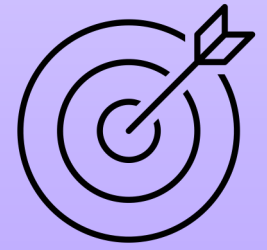
Speed — **Throughput**

Delivered vs offered throughput is measured per connection to ensure service level agreements are satisfied in any load condition.

ITU-T Y.1540: Flow-related Parameters

Accuracy — **Packet Loss**

Packet loss is measured and characterized to minimize unintended loss.



ITU-T Y.1540: IPER, IPLR

Dependability — **Latency, Jitter**

Delay statistics are measured. Leo aims to deliver latency competitive with terrestrial broadband.

ITU-T Y.1540: IPTD, IPDV

Availability — **Availability**

Transparent UI indicates geographic service availability to customers. Service launch occurs only after sufficient availability.

ITU-T Y.1540: IP Service Availability, PIA

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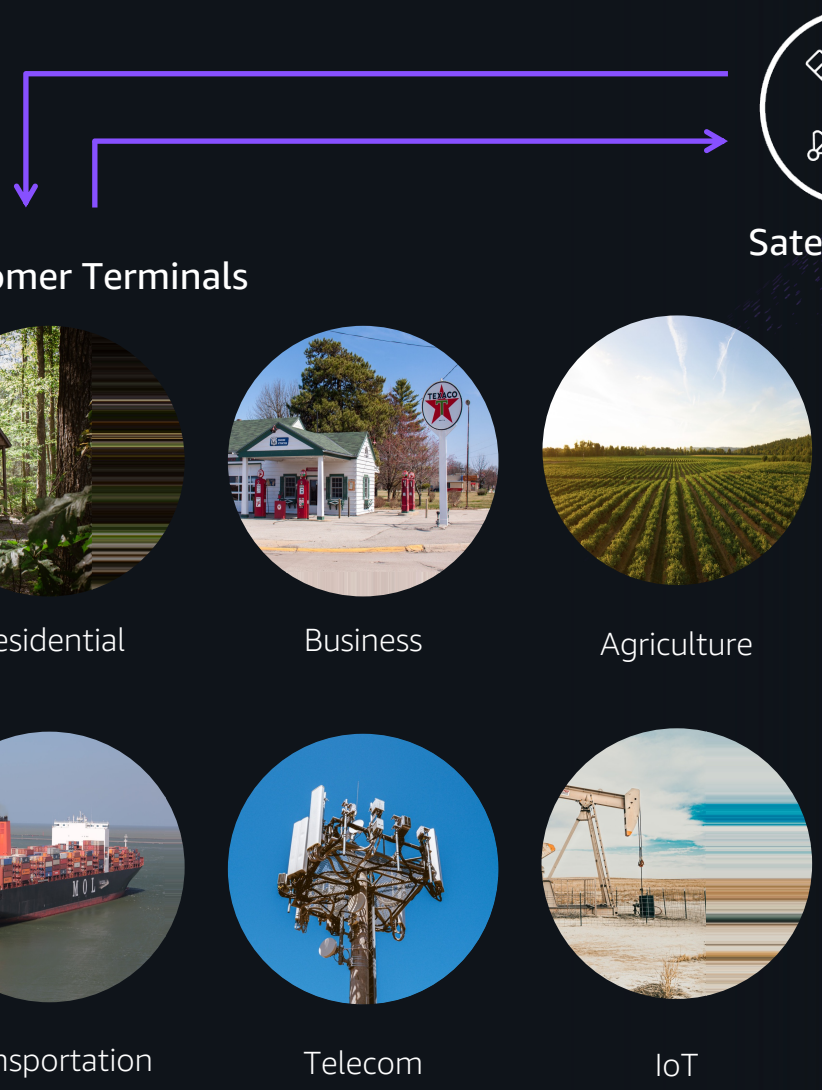
QoS Management via Traffic Shaping



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Applicability of Current ITU-T Standards

Relevant ITU-T Recommendations

Recommendation	Summary	Applicability to Satellite Networks
Y.1540 (2019) *IP packet transfer and availability performance parameters*	• Defines the standard set of IP performance metrics (delay, loss, jitter, availability) to be used when measuring IP packet transfer quality. • Does not prescribe a specific percentile for IPDV measurement.	✅ Applicable.
Y.1541 (2011) *Network performance objectives for IP-based services*	• Sets the actual numerical performance targets for those metrics, organized into QoS classes, for use in service agreements between providers. • Sets the 99.9th percentile ($1-10^{-3}$ quantile) as the primary IPDV metric.	⚠️ Partially applicable.
Y.1543 (2018) *Measurements in IP networks for inter-domain performance assessment*	• Specifies how to practically measure IP performance across multiple provider domains using both active and passive techniques. • Specifies measurement methods using multiple DV percentiles (DV90, DV99, DV99.9). • Explicitly acknowledges that "network delay characteristics may be multi-modal."	✅ Preferred approach.

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ITU-T Y.1540/Y.1541: IPDV Captures Handover

$$\text{IPDV} = 99.9\text{th percentile IPTD} - \text{minimum IPTD} \quad (\text{within evaluation interval} \geq 60\text{s})$$

Within any 60-second window:

- Multiple handover events may occur
- 99.9th percentile captures handover variance
- Reported IPDV reports higher variance than actual system performance

Result: A network compliant 99% of the time appears non-compliant

Actual Performance

Steady-state IPDV: <5ms
99% of measurement interval

≠

Reported Metric

Combined 99.9% IPDV: ~105ms
Exceeds Class 0 threshold (50ms)

This is a measurement methodology problem, not a network performance problem.
The metric conflates deterministic orbital transients with sustained network degradation.

ITU-T Y.1541: QoS Classes and Performance Objectives

Class	Application	IPTD	IPDV	IPLR
0	VoIP / VTC (Real-time, Highly Interactive)	≤100 ms	≤50 ms	$\leq 10^{-3}$
1	Satellite VoIP (Real-time, Interactive)	≤400 ms	≤50 ms	$\leq 10^{-3}$
2	Signaling (Transactional Data, Highly Interactive)	≤100 ms	Unspec.	$\leq 10^{-3}$
3	Transaction data (Transactional Data, Interactive)	≤400 ms	Unspec.	$\leq 10^{-3}$
4	File Transfer / Video streaming (Low Loss)	≤1 s	Unspec.	$\leq 10^{-3}$

ITU-T Y.1543: Addressing Non-Standard Variance

Sections 6.1 and 6.2 explicitly acknowledge multi-modal delay distributions and prescribe multi-percentile measurement — increased adoption is the path forward

§6.1 — The Standard Chose Percentiles Because of Bimodal Distributions

> *"The percentile approach is used in preference to a standard deviation or variance model due to the occasional occurrence of bi-modal or multi-modal delay distributions."*

→ The ITU already recognized that standard deviation fails when delay is multi-modal — this is exactly the LEO scenario.

§6.2 — Multiple Percentile Readings Contextualize the Distribution

> *"By taking multiple percentile readings and a minimum delay reading, the distribution of delays can be better understood. This information is more useful than a simple standard deviation metric that can be easily used only when assuming a mathematically friendly underlying probability distribution function. In reality, network delay characteristics may be multi-modal."*

→ These three readings together reveal the shape of the distribution — separating steady-state performance from transient events like handovers without conflation.

Delay Variation Metrics

DV90

90th Percentile

Steady-state performance

DV99

99th Percentile

Orbital geometry effects

DV99.9

99.9th Percentile (

Handover / transient spikes

Increased adoption of Y.1543's existing multi-percentile framework gives LEO networks a context-aware QoS metric that handles bimodal delay.

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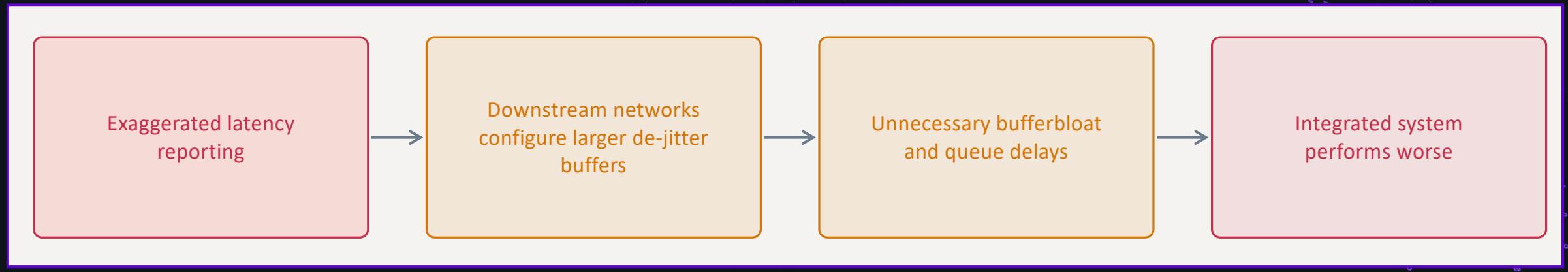
Precise QoS Characterization Enables Better Interoperability

Why this matters at the Network-to-Network Interface (NNI)



The Solution

Correctly conveying variance characteristics reduces end-to-end latency for everyone

Standards should encourage distribution-aware QoS signaling, not just worst-case reporting. This results in appropriately-sized buffers at the NNI, reducing queue delays for all packets in the integrated system.

Precise characterization benefits the entire interconnected ecosystem

Summary: Standards Are Adequate — Context Is Key

1

System Variance

Systems dynamics introduce non-congestive variance to performance metrics in satellite networks.

2

Contextual Awareness

Measurement methodologies need contextual awareness of predictable, deterministic variance

3

Adequate Framework

Current ITU-T standards provide an adequate framework for satellite QoS assessment

Customer Obsession

Leaders start with the customer and work backwards. They work vigorously to earn and keep customer trust. Although leaders pay attention to competitors, they obsess over customers.

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Thank You