The Limitations of LEO Uplink

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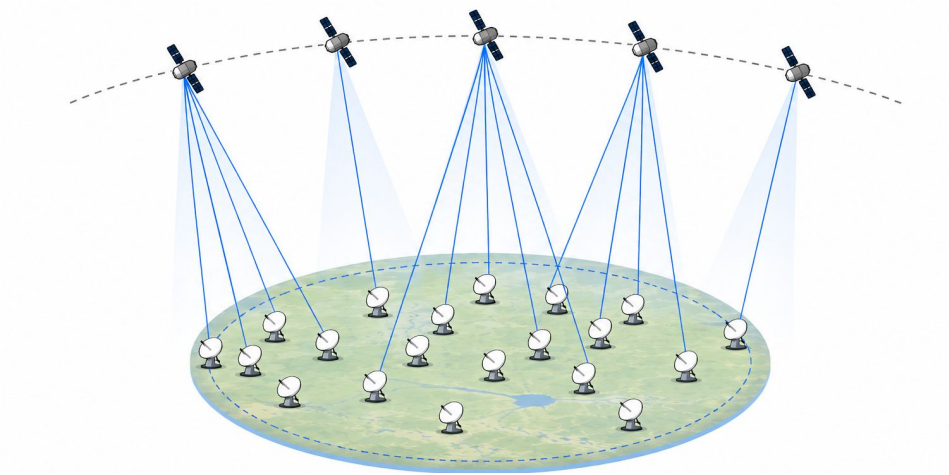
LEO uplink enables important applications

- Real-time video conferencing
- Large file uploads and cloud backup
- Remote sensing and live video upload
- Interactive cloud and edge applications

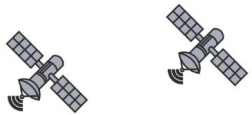
LEO uplink is a limited, shared and dynamic resource

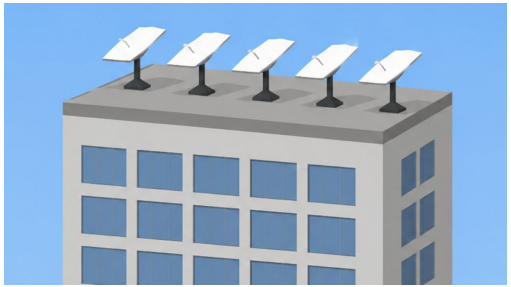
- ISPs provide significantly less uplink capacity (10%) compared to downlink (90%)
- Multiple dishes (from you or your neighbor) in the same geographic cell may contend for the same satellites
- Each dish can experience sudden bursts of workload



How does balancing load across multiple dishes affect LEO uplink performance?

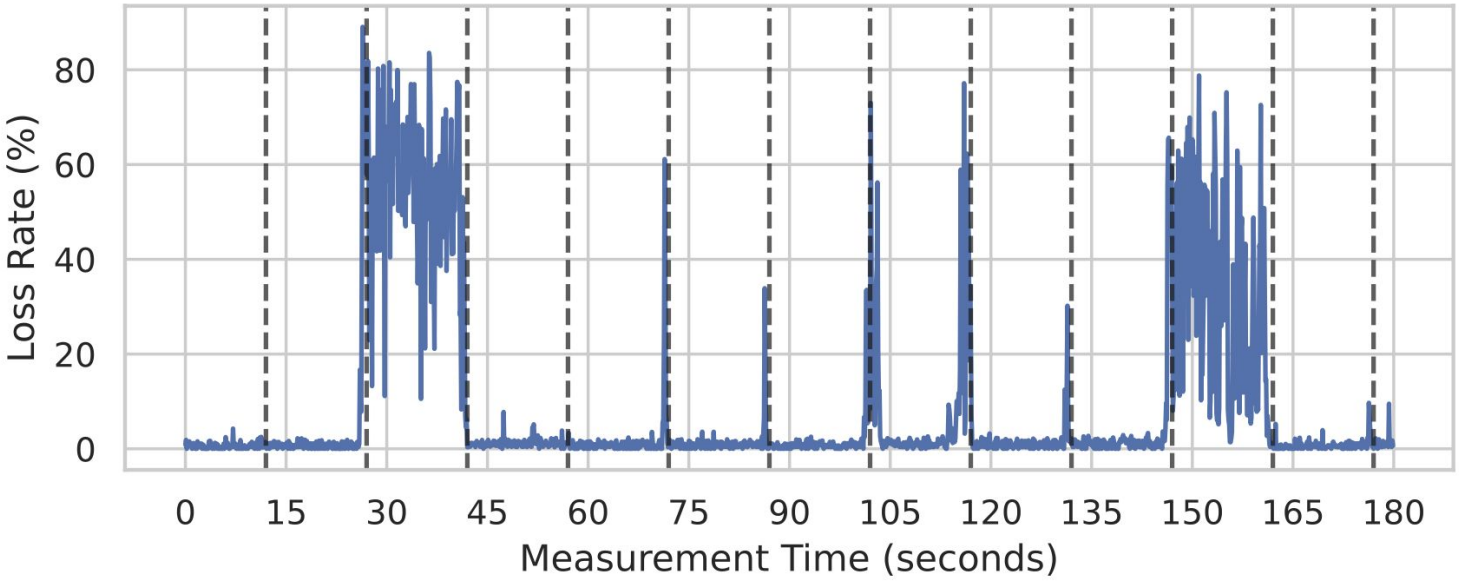
Set-Up for Measuring LEO Uplink



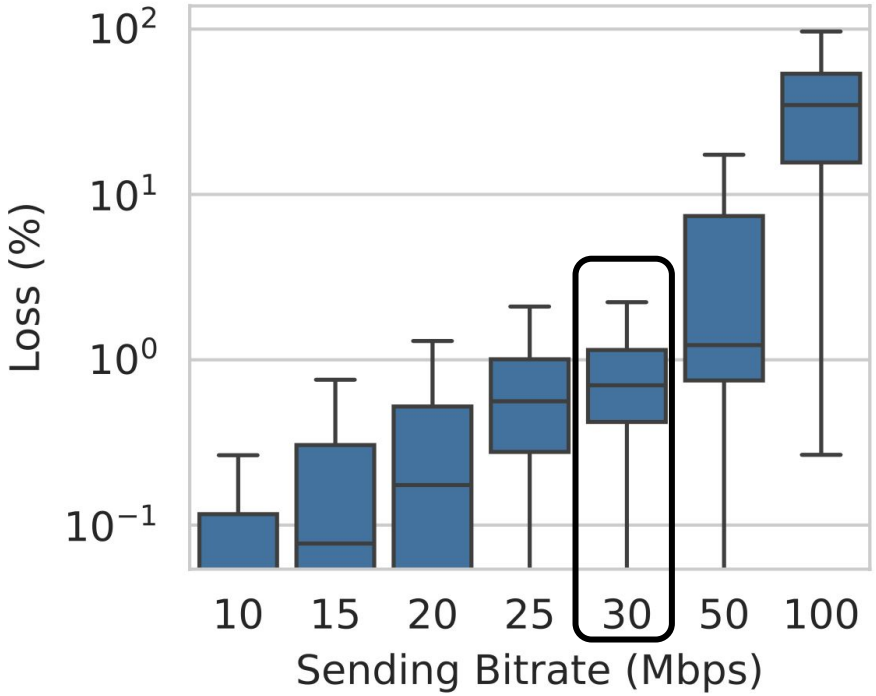


- Starlink Business Priority Plan
  - Downlink: 130–300 Mbps
  - Uplink: 20–40 Mbps
- Send UDP iperf3 with 100 ms granularity
- Location: Los Gatos, CA

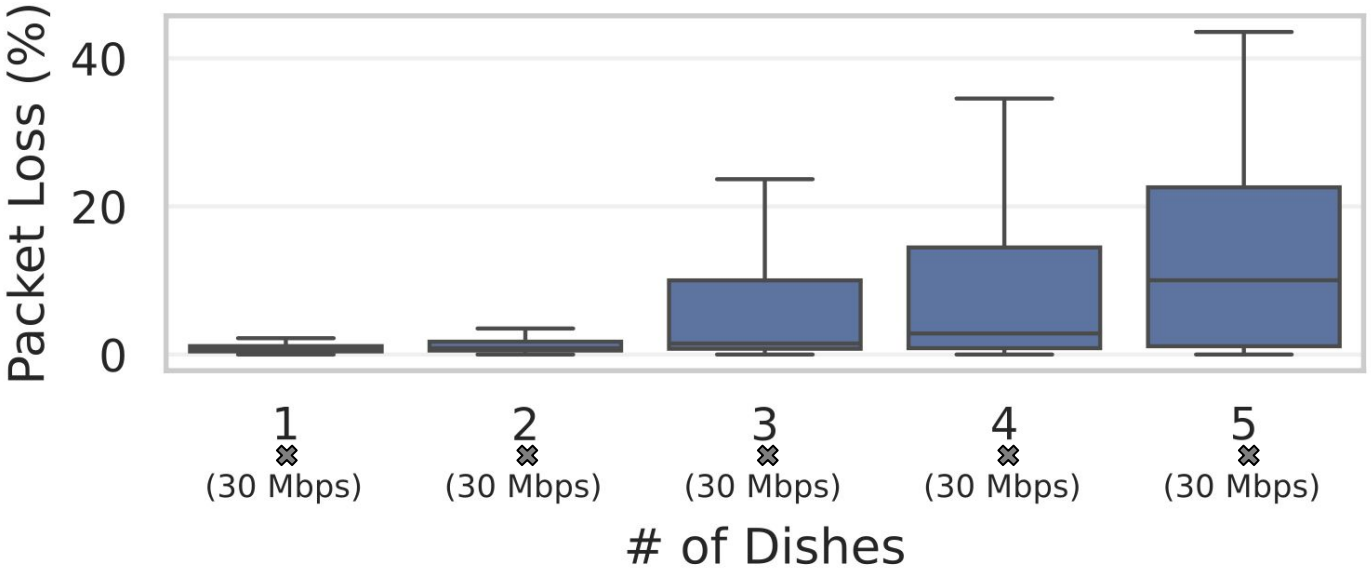
A single dish experiences bursts of sustained losses, when sending at 30Mb/s

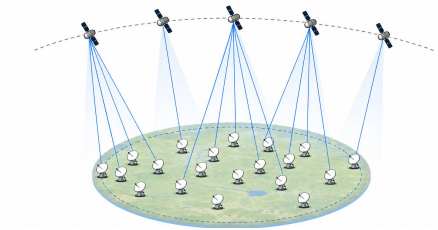


Single dish packet loss rates increase superlinearly with increased sending rate



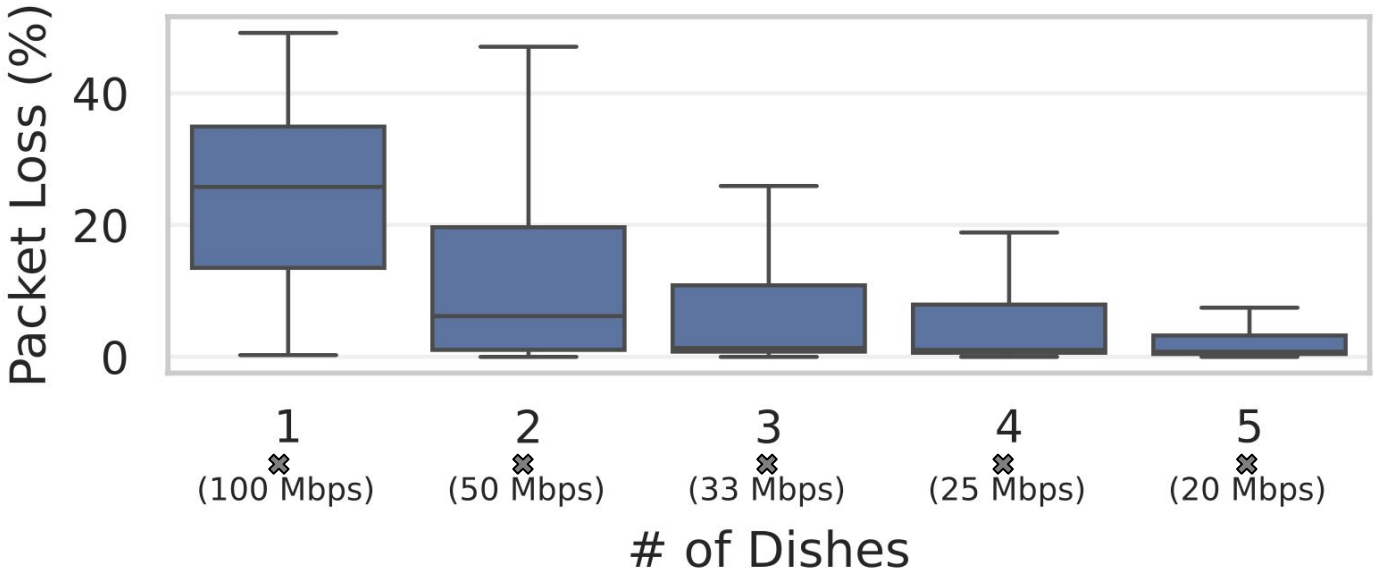
Nearby dish contention increases packet loss



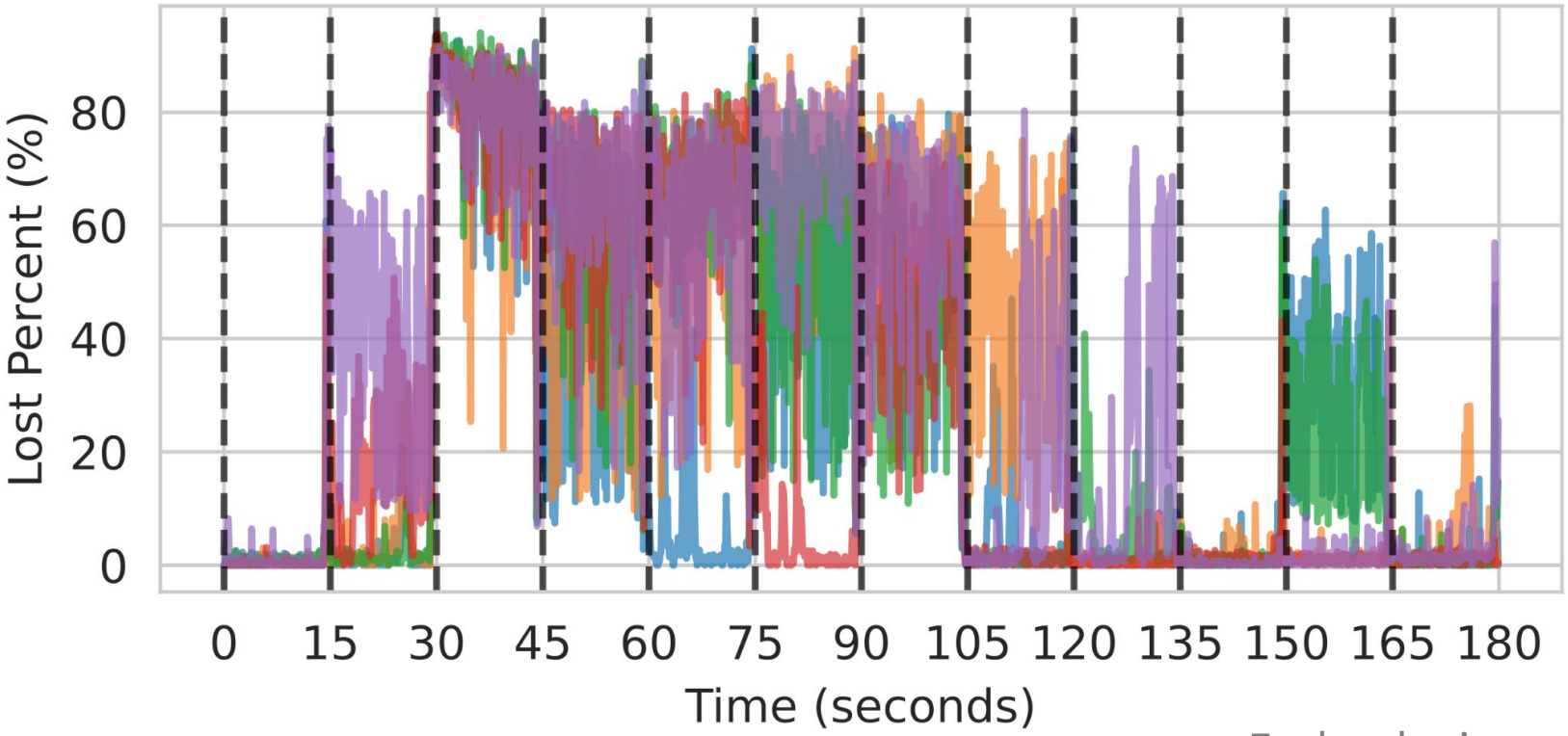


How does *distributing* total traffic sending across dishes help decrease packet loss?

Distributing an aggregate sending rate across multiple dishes *decreases* the aggregate packet loss



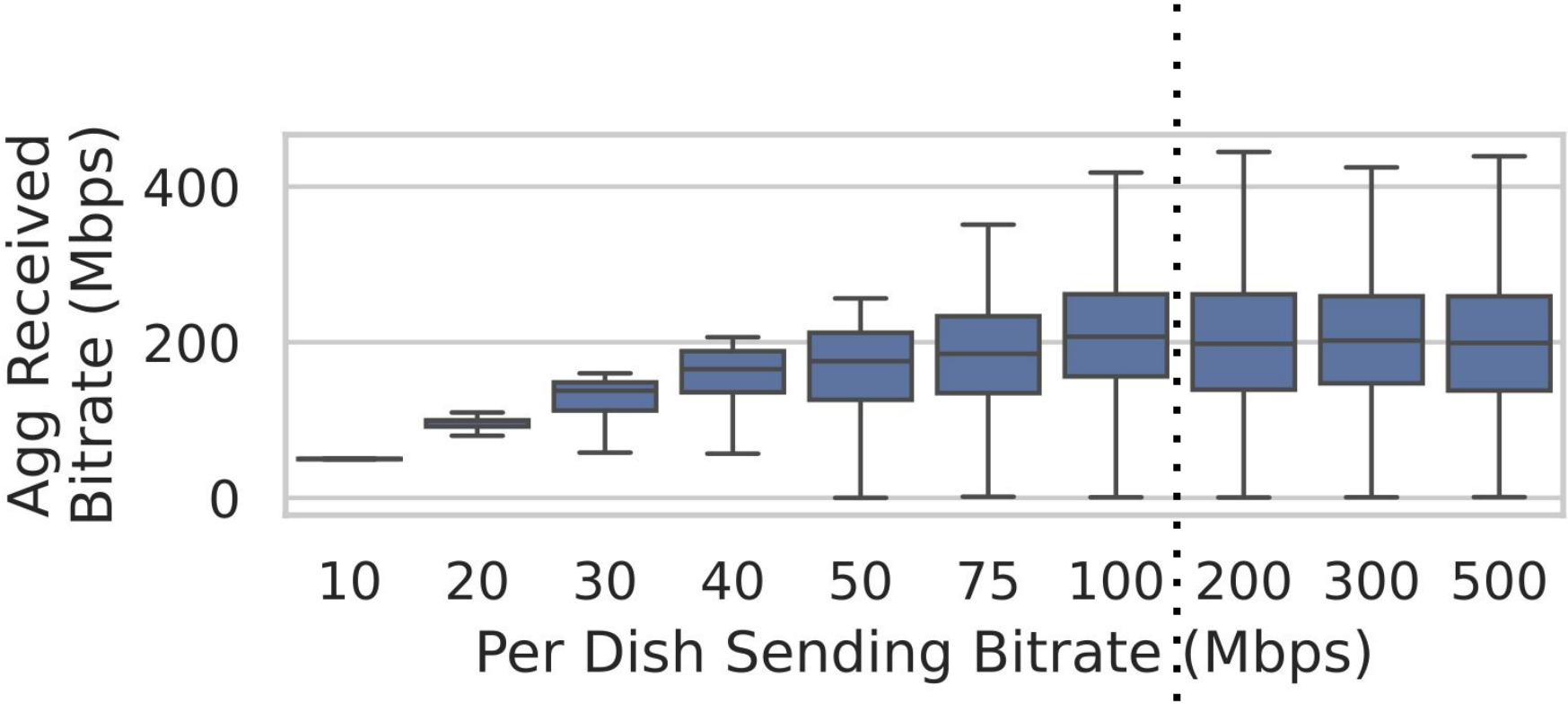
All five dishes can experience loss simultaneously



Each color is a unique dish

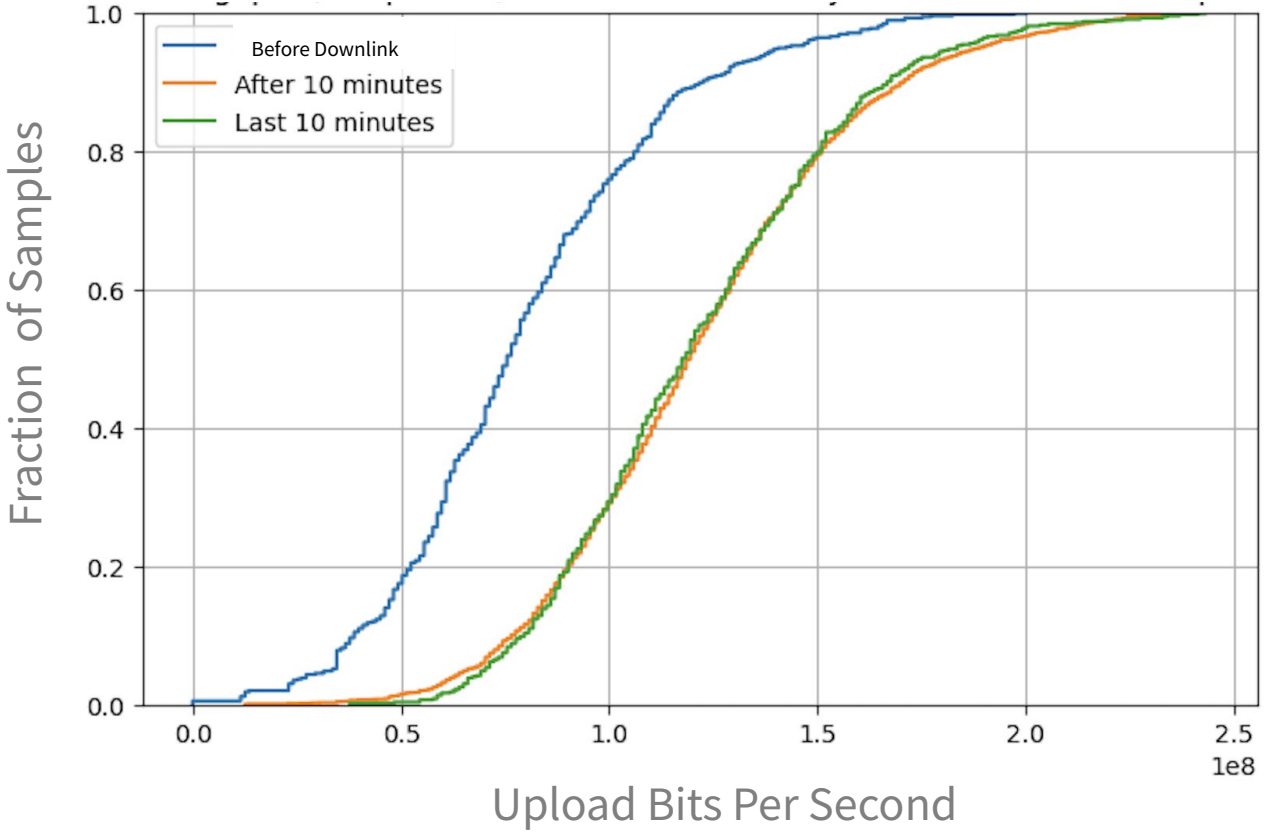
How does packet loss affect total uplink goodput?

Bonded capacity with 5 dishes scales, up to 100Mbps



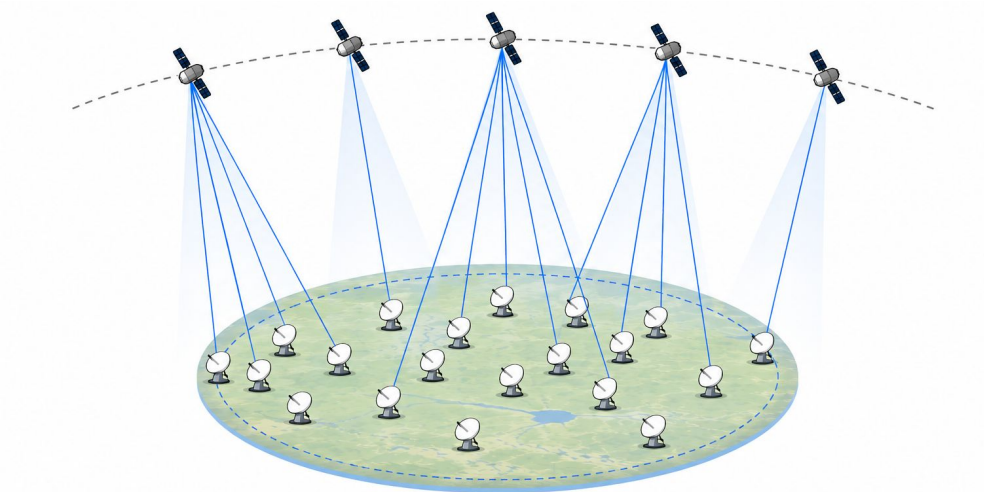
How does downlink usage affect uplink capacity?

When streaming 200Mb of downlink, upload capacity increases



LEO Uplink Contains Serious Bottlenecks…

1. Uplink traffic experiences multi-second bursts of packet loss due to neighboring congestion
2. Operating more dishes increase aggregate capacity, but does not eliminate shared loss events or contention.



We need protocols that adapt to the bottlenecks

- Most LEO users only have one dish…
- We need:
  - transport layer protocols that can recover from high losses
  - application-layer algorithms that can adapt to network fluctuations
  - better traffic engineering LEO-wide