

CISCO *Live!*

GO BEYOND

#CiscoLiveAPJC



Low Earth Orbit Satellites

Leveraging Cisco Technologies
to Improve Your LEOsat Deployments

Dave Zacks, Distinguished Engineer

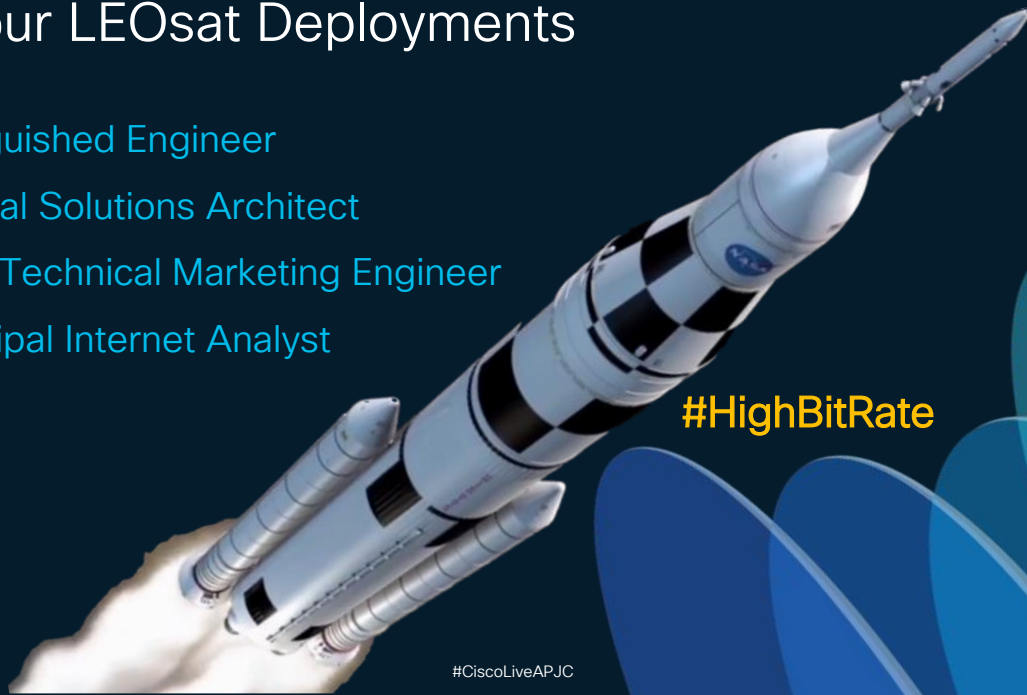
Ian Procyk, Technical Solutions Architect

Anthony Belcastro, Technical Marketing Engineer

Kemal Sanjta, Principal Internet Analyst

BRKOPS-2586

CISCO *Live!*



#HighBitRate

#CiscoLiveAPJC

Cisco Webex App

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How

- 1 Find this session in the Cisco Live Mobile App
- 2 Click “Join the Discussion”
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- 4 Enter messages/questions in the Webex space

Webex spaces will be moderated by the speaker until November 15, 2024.



<https://ciscolive.ciscoevents.com/ciscolivebot/#BRKOPS-2586>



by way of Introduction ...

I am a **Distinguished Engineer** in the Cisco Security CTO team, and have been with Cisco for 25 years.

I work primarily with large, high-performance Enterprise network architectures, designs, and systems. I have over 39 years of experience with designing, implementing, and supporting solutions with many diverse network technologies.

I have a strong background in, and focus on, customer requirements, and integrating these into the products and solutions Cisco builds.

I have a special interest in **Flexible Hardware, Fabrics, Assurance and ML/AI**.

Dave Zacks
Distinguished Engineer
dzacks@cisco.com



by way of Introduction ...

I joined Cisco in 2011 and have remained **focused on wireless technologies** since. I apply over 20 years of field experience helping customers architect, implement and support complex wireless deployments across all verticals.

Internally, I lead the Cisco's Mobility Technical Advisory Group, a global team of wireless specialists helping to ensure that customer's feedback crosses paths with engineering's priorities and new product development.

Before coming to Cisco, I held positions with a start-up IT consulting firm based in Vancouver and the Canadian Coast Guard. I started my career in IT at the University of British Columbia where I was involved in one of the first **large scale WLAN deployments** in the country.

Ian Procyk

Technical Solutions Architect
iprocyk@cisco.com



by way of Introduction ...

I am a Technical Marketing Engineer for the MXIG platform and have been with **Cisco Meraki** for over 7 years.

I started my career in the partner / systems integrator space, moving to the end customer and now vendor. Before taking on the TME role, I worked on the customer success team looking holistically at the customer journey and helping customers build simpler, smarter systems.

I take everything I've learned from these roles, **simplifying routing and IPv6 technologies and bring them to life** in the dashboard.

Anthony Belcastro
Technical Marketing Engineer
anbelcas@cisco.com



by way of Introduction ...

I am a result-oriented engineer focusing on **designing, operating and troubleshooting large-scale networks**. I am a passionate Linux user with a deep understanding of SRE/NRE practices, and have been with Cisco since 2018.

Over the last two decades, I have worked at several large-scale companies applying NRE practices and automating remediation actions.

As a Principal Internet Analyst at ThousandEyes, **I focus on research and providing deep and meaningful insights** into outages through the lenses of ThousandEyes.

Kemal Sanjta
Principal Internet Analyst
kemals@cisco.com



Agenda

- Introduction to LEOsats
- LEOsat Operational Details
- What's Up There?
- Phased Array Antennas
- Mobility And Laser Inter-Satellite Links
- Real World Deployments – Dave
- Real World Deployments – Anthony
- Starlink – Performance Analysis
- Real World Deployments – Ian
- LEOsat Programmability
- LEOsat Futures And Opportunities
- Conclusion





We all know
that the future is in the Cloud(s), right?



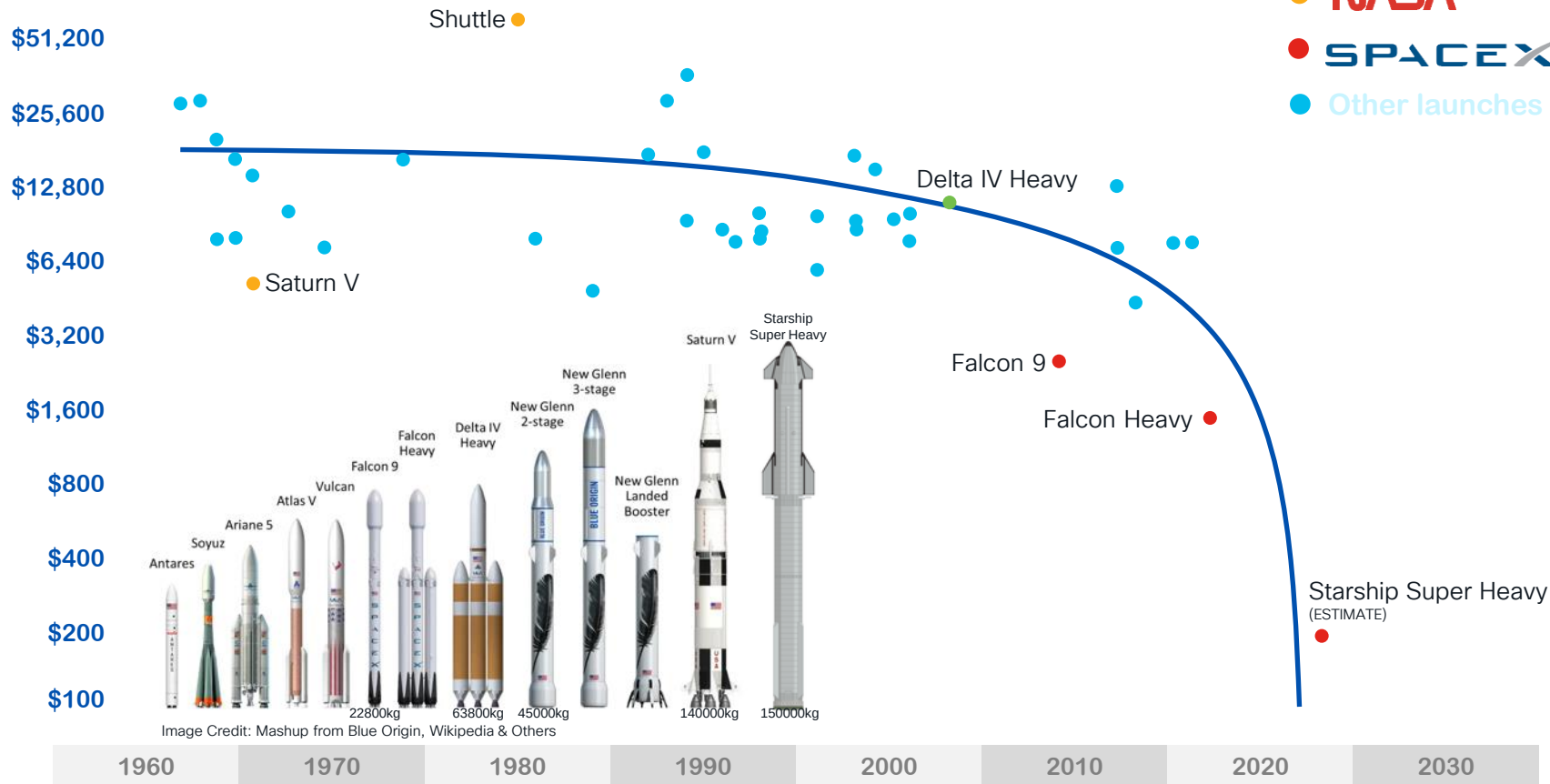
but look beyond that...
and you just might conclude that it's in SPACE too!

Low Earth Orbit Satellites (LEOsats)

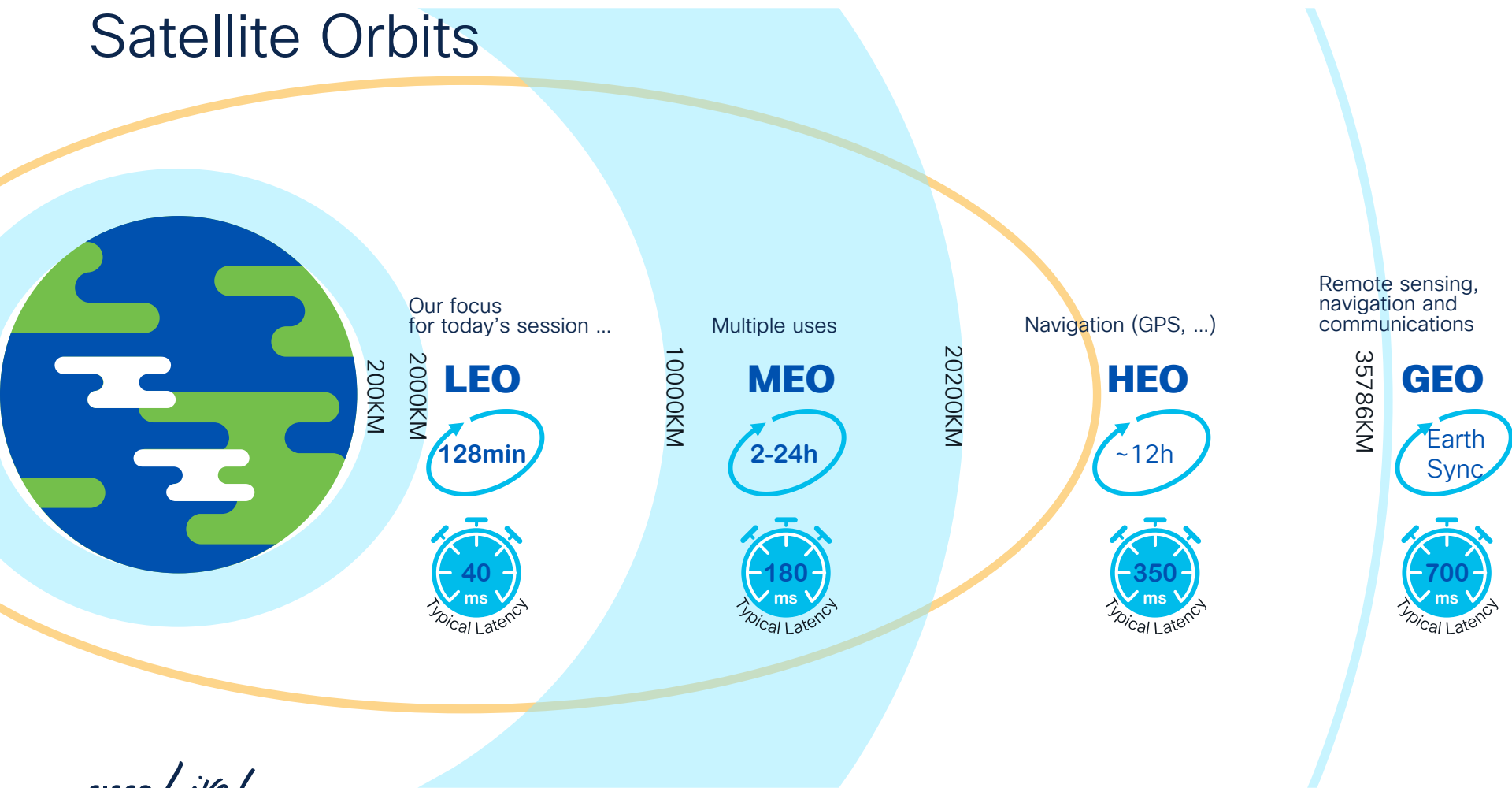
Changing the Game



Space Launch Economics



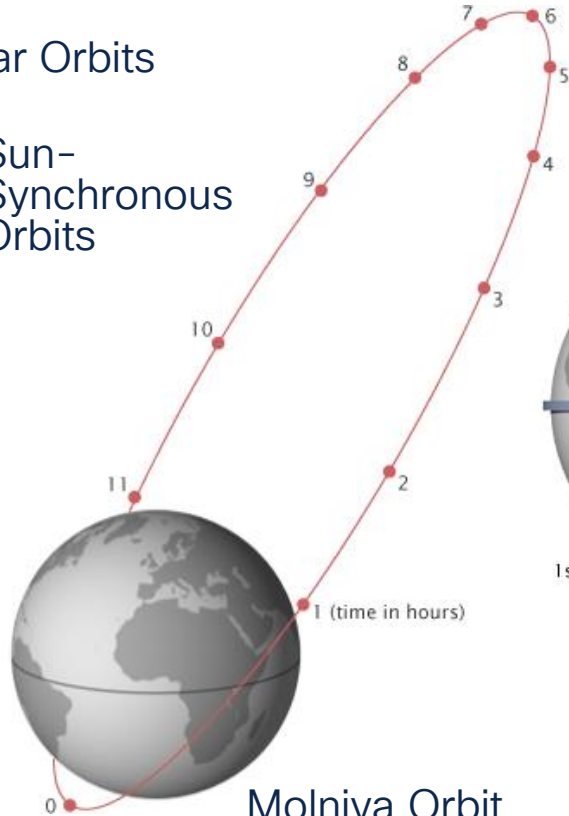
Satellite Orbits



More about Orbits

Polar Orbits

Sun-Synchronous Orbits

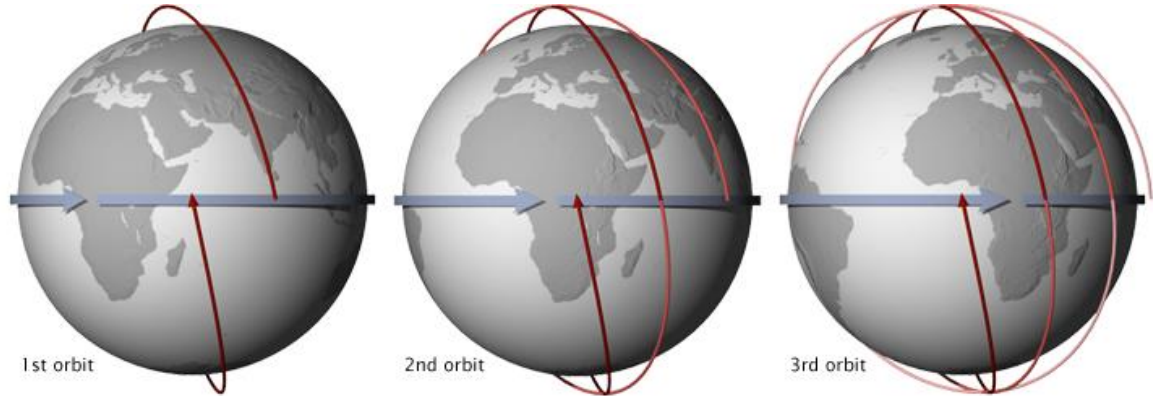


Molniya Orbit

Comms and remote sensing over high latitudes

Remember, the Earth rotates ...

So satellites in lower orbits are constantly passing over different areas of the Earth on every orbit ...



Traditional View of Satellite Communications

Geosynchronous Operation



Geosynchronous Orbit

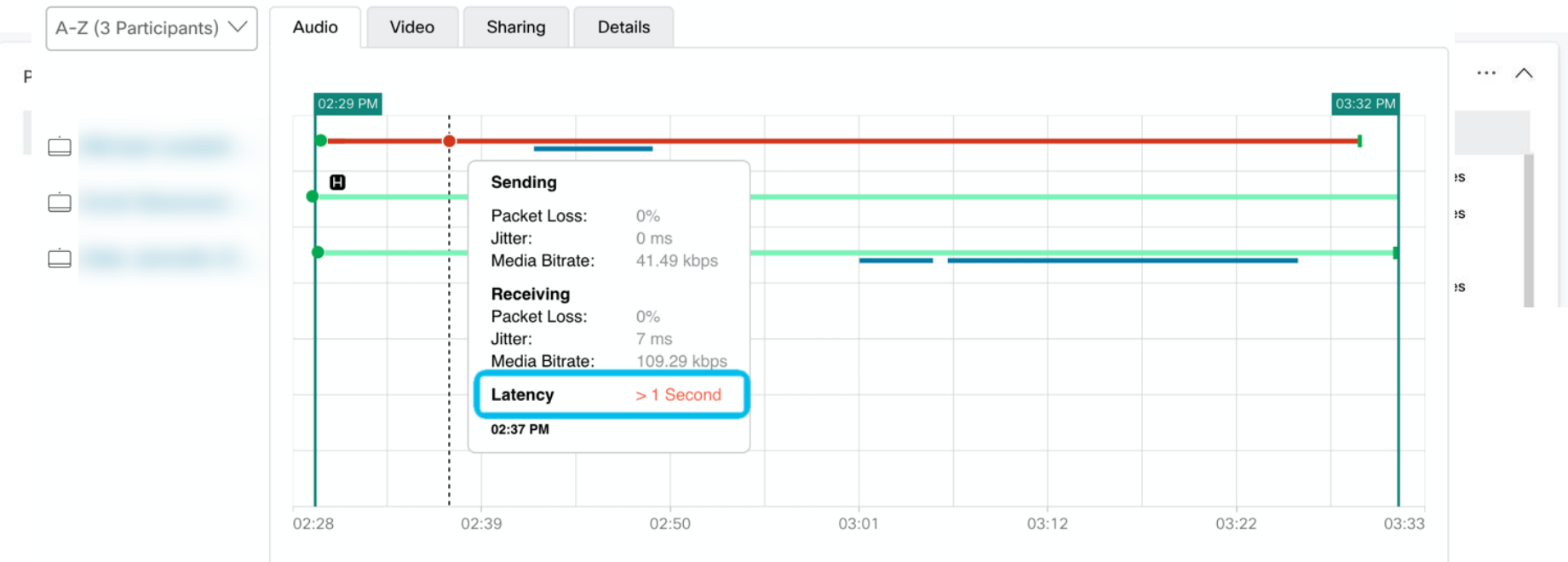
- Rotates in sync with Earth rotation
- Around 35,000 km altitude
- Static location in the sky from ground observation

Moderate Performance

- Throughput: 0-100Mbps max, 5-10Mbps typical
- Latency: ~120msec each way
- Roundtrip: ~477 msec round-trip latency
- Typical: ~600+ msec latency
- Large spot coverage due to limited geosync satellites

Traditional View of Satellite Communications

Geosynchronous Performance – Real-World



Low Earth Orbit (LEO) Satellite Constellations



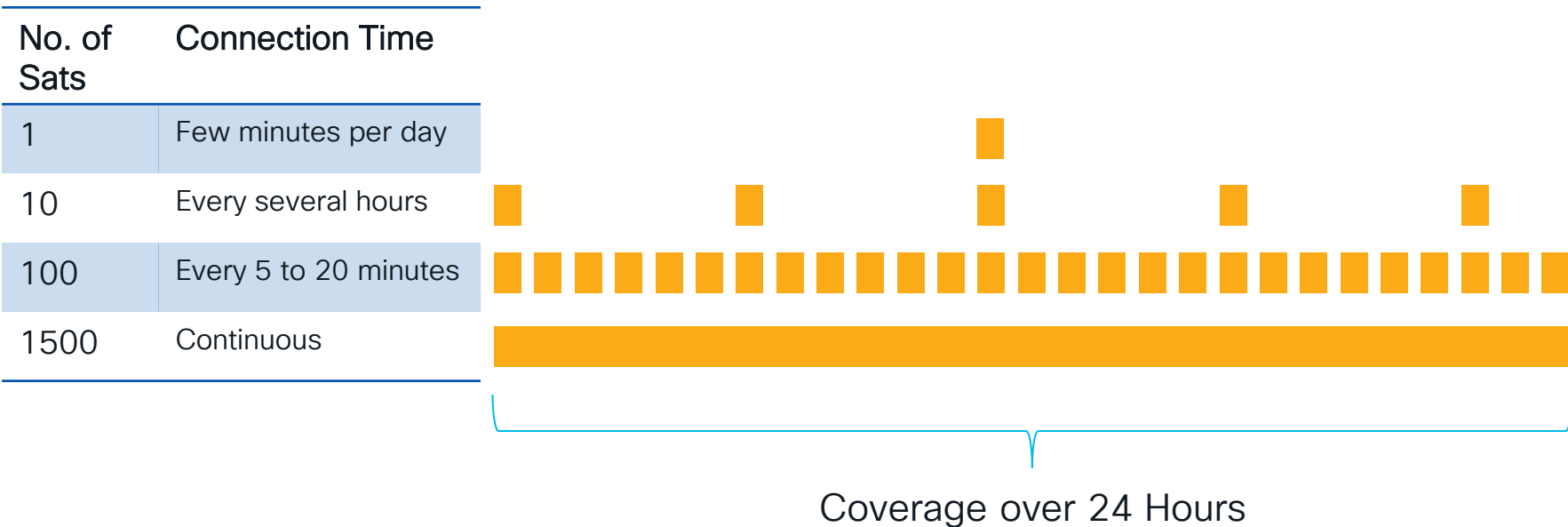
Low Earth Orbit Operation

- Located at ~500km altitude (varies)
- Constantly moving from ground observer viewpoint
- Many LEO satellites in constellation
- Starlink = 4,425 in initial planned deployment)

Improved performance

- Throughput~: 200Mbps down, 25Mbps up (Starlink ~8x increase)
- Latency~: 20-40 msec typical, ~10x+ decrease
- Smaller spot coverage due to closer satellite location
- Per-satellite bandwidth of ~20Gbps currently (estimated)
- Aggregate bandwidth of ~80Tbps+ across 4,425 satellites

Connection Coverage



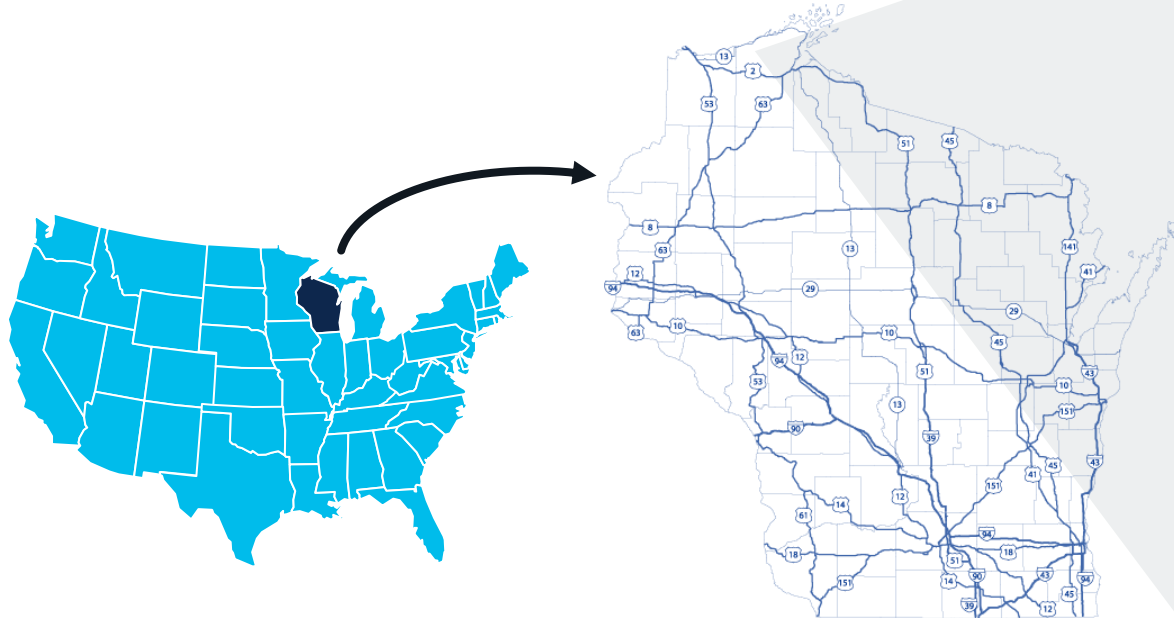
LEOsat View of Satellite Communications

Example of Performance – Real-World

Date: Feb, 2, 2021

Location: Remote part of Wisconsin, USA

Setup: < 10 minutes to establish uplink



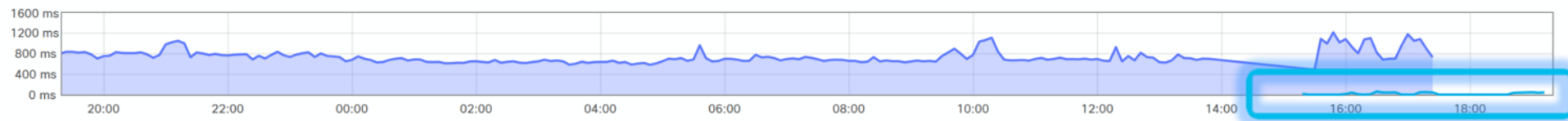
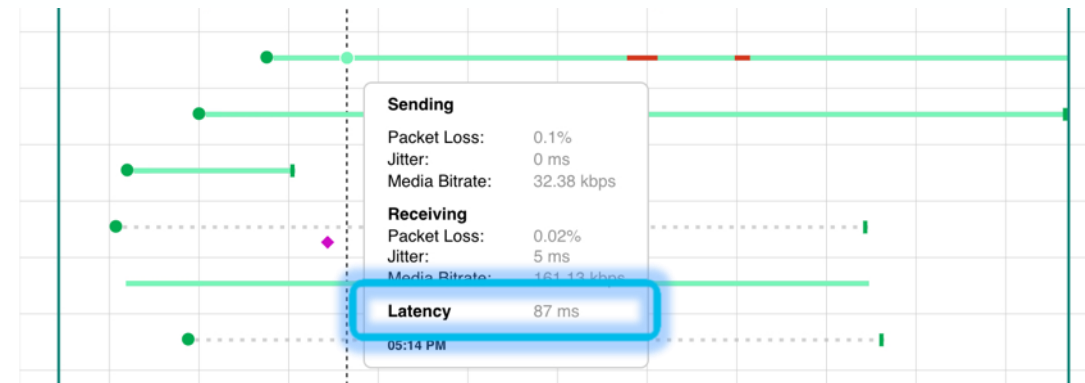
LEOsat View of Satellite Communications

Example of Performance – Real-World

Historical device data for the last day ▾

Connectivity to 8.8.8.8 ▾ ⓘ

Latency



WAN1 is an existing GEO satellite

WAN2 is Starlink

Substantial improvement! 😊

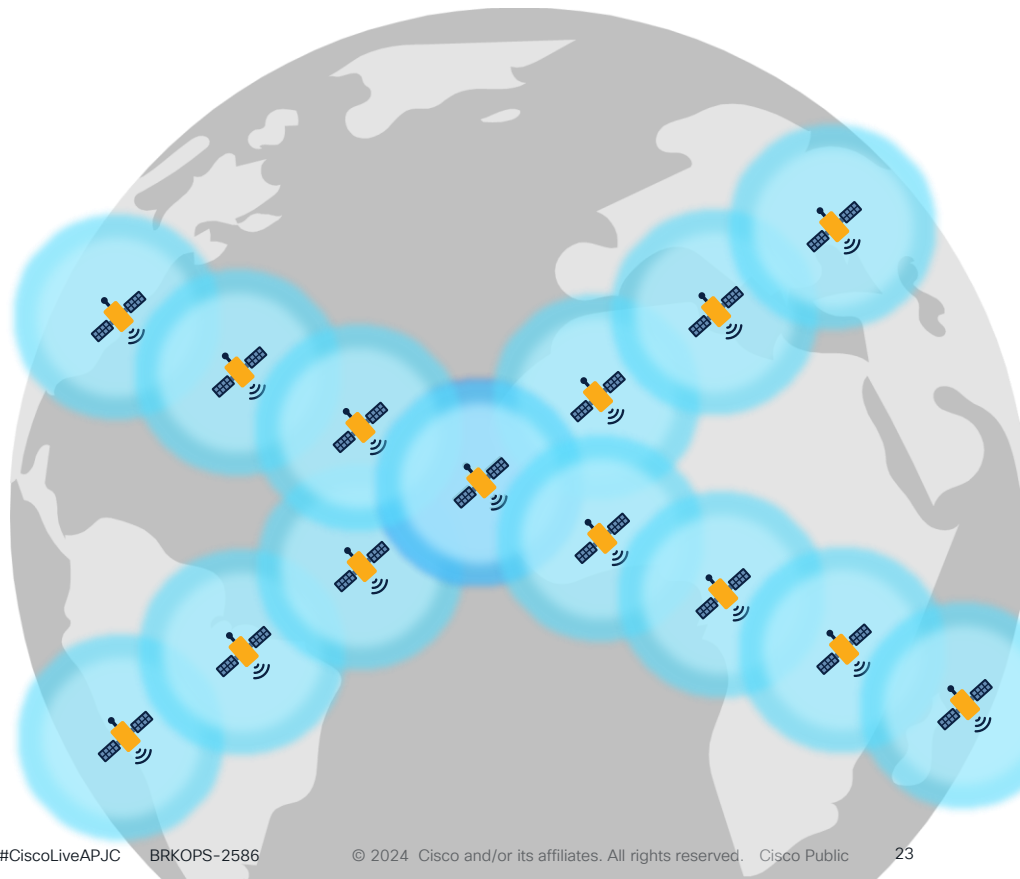
Starlink Operational Details



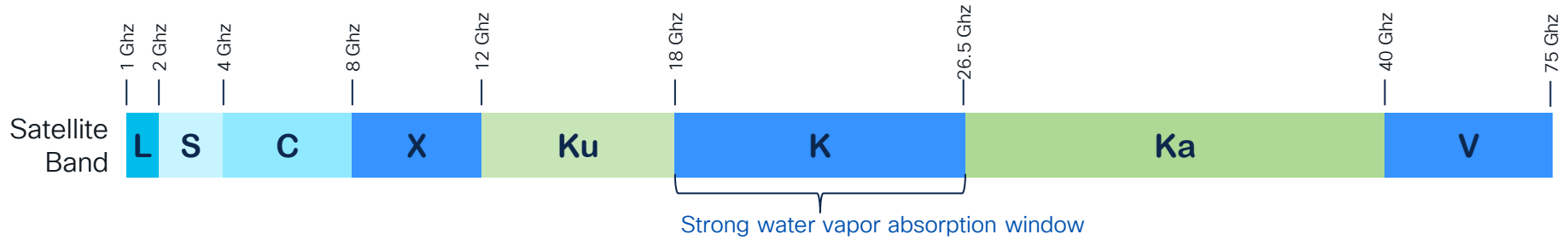
SpaceX Starlink – Initial Deployment

First launch Feb 22nd, 2018 – Operational since November, 2019

2020 Public Testing	6426 Satellites in Orbit*	Available in most locations on Earth
Ka Band 26.5–40 GHz	4M+ Active Subscribers*	Ku Band 12–18 GHz



Satellite Bands



Bandwidth

Lower

Higher

Antenna Size

Larger

Smaller

Rain Fade Susceptibility

Less

More

Signal Propagation*

Further

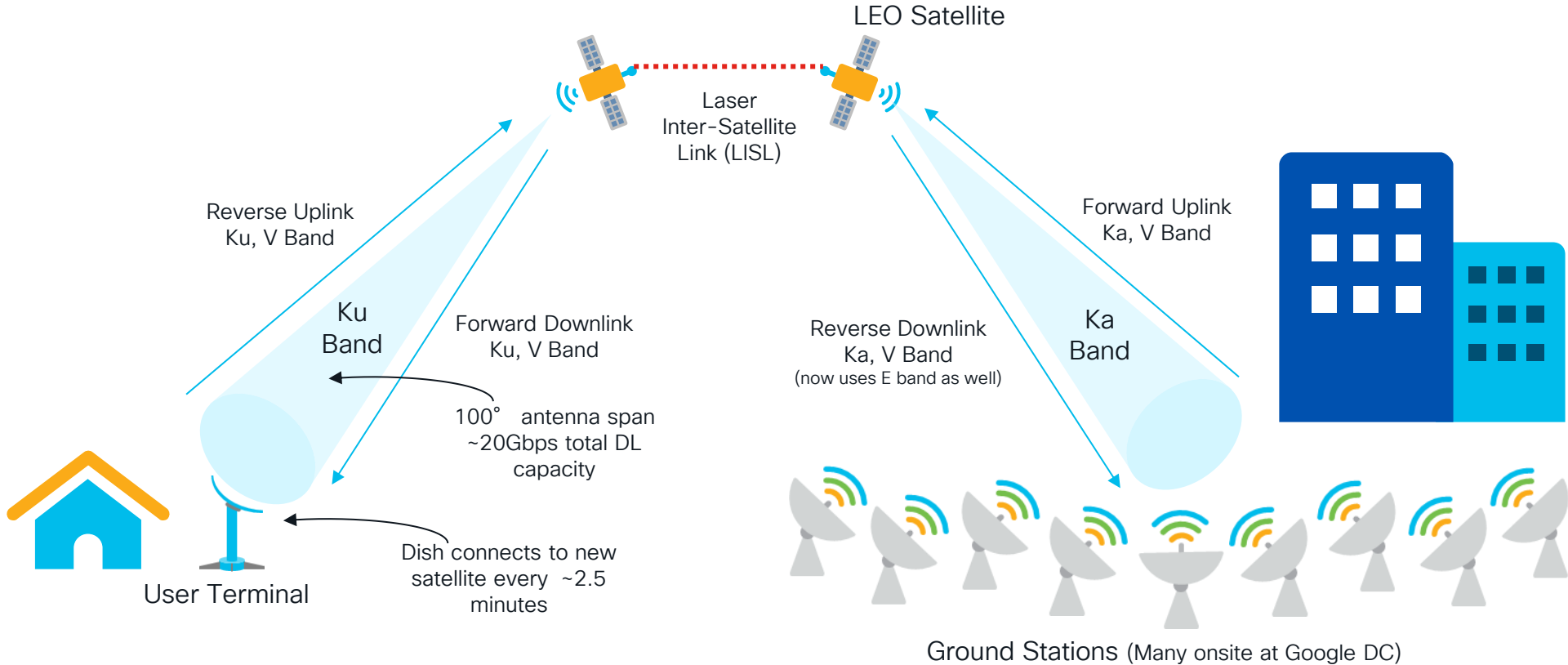
Shorter

Spectrum

Narrower

Wider

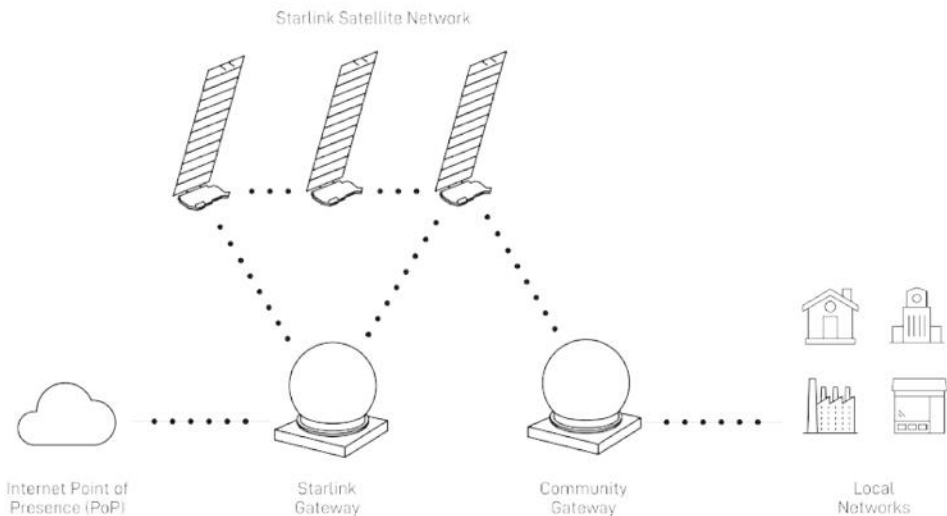
Starlink Operational Architecture



Source: <https://www.redorbit.com/spacex-plans-to-reduce-number-of-v-band-starlink-satellites/>
Source: <https://dgtlinfra.com/elon-musk-starlink-and-satellite-broadband/>

Ground Stations

<https://www.starlinkinternet.info/community-gateway>



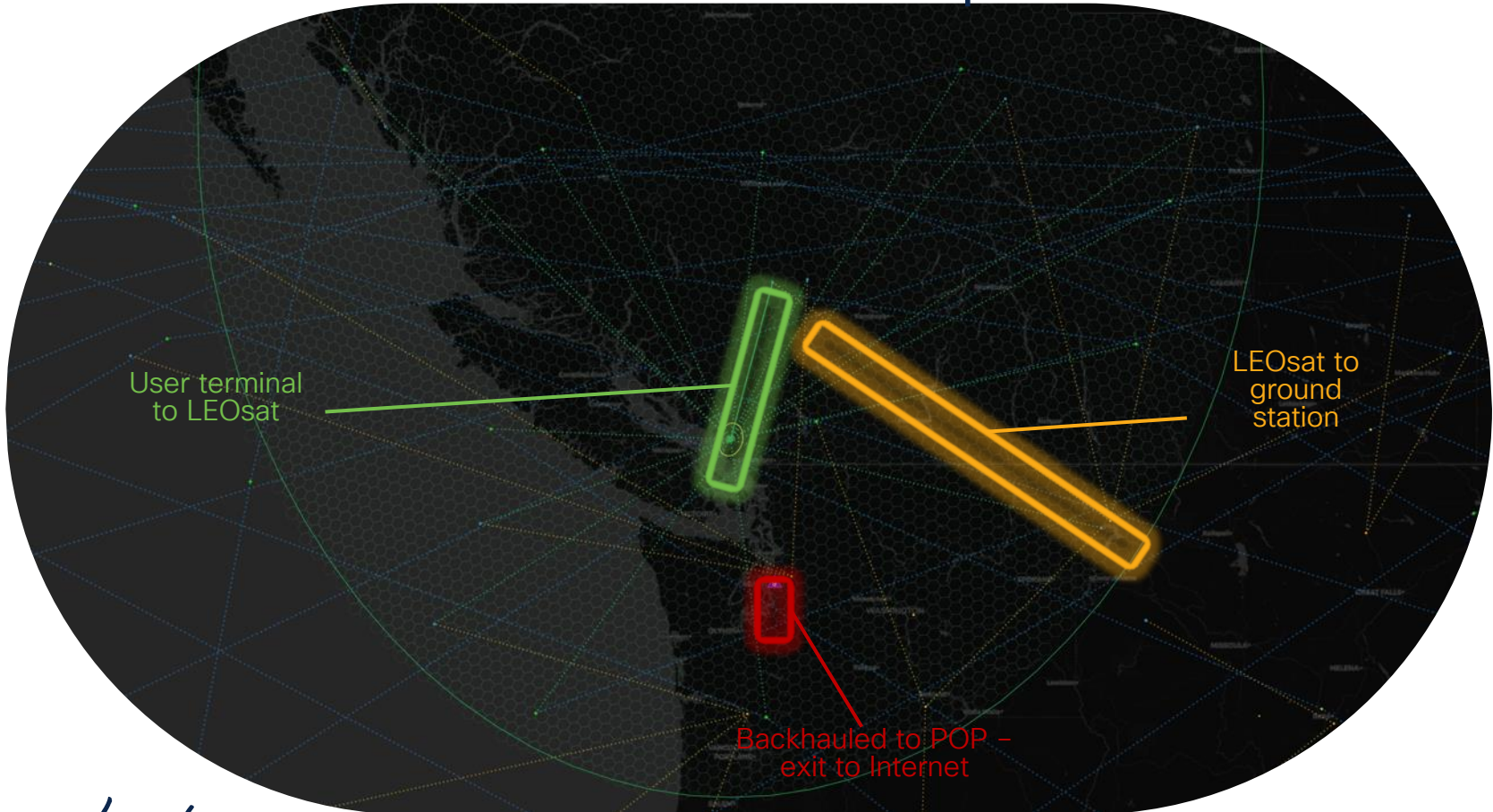
Starlink Community Gateways

With Community Gateways, Starlink satellites are able to deliver fiber-like speeds with local providers distributing connectivity to homes, businesses, and governments using last-mile fiber, fixed wireless and mobile wireless.

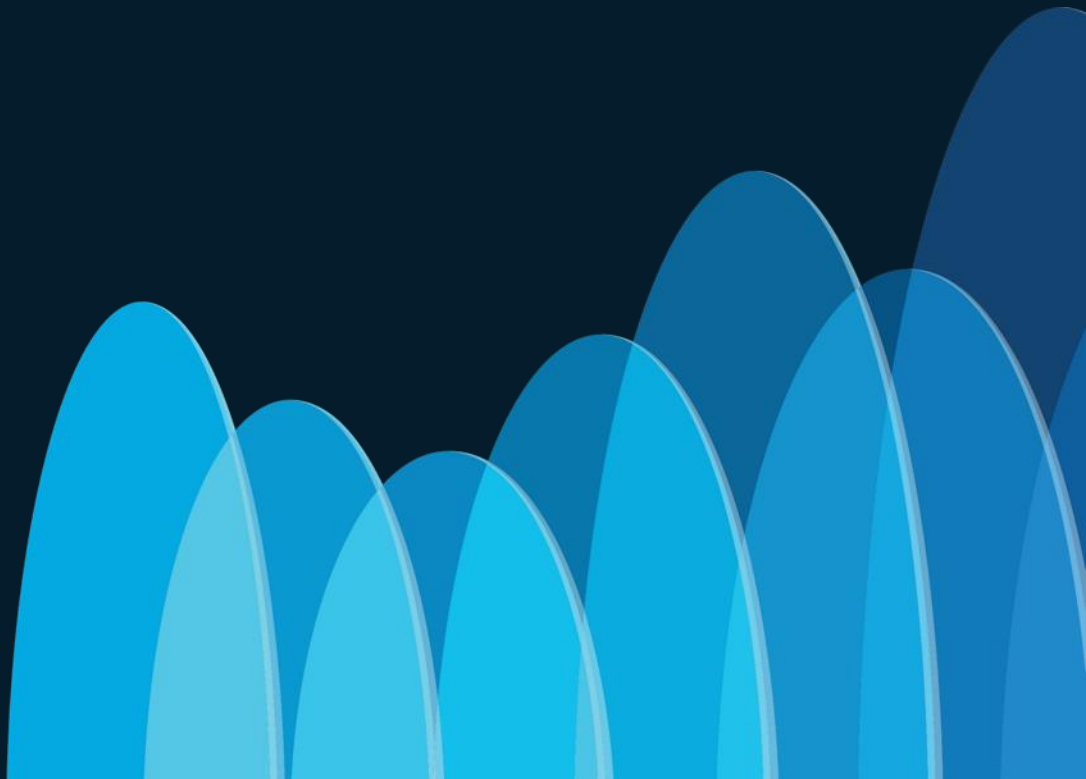
The Community Gateway traffic transits through Starlink's global laser mesh network and utilizes our high bandwidth Gateways operating in a dedicated Ka spectrum band.



How the LEOsats Move - Example

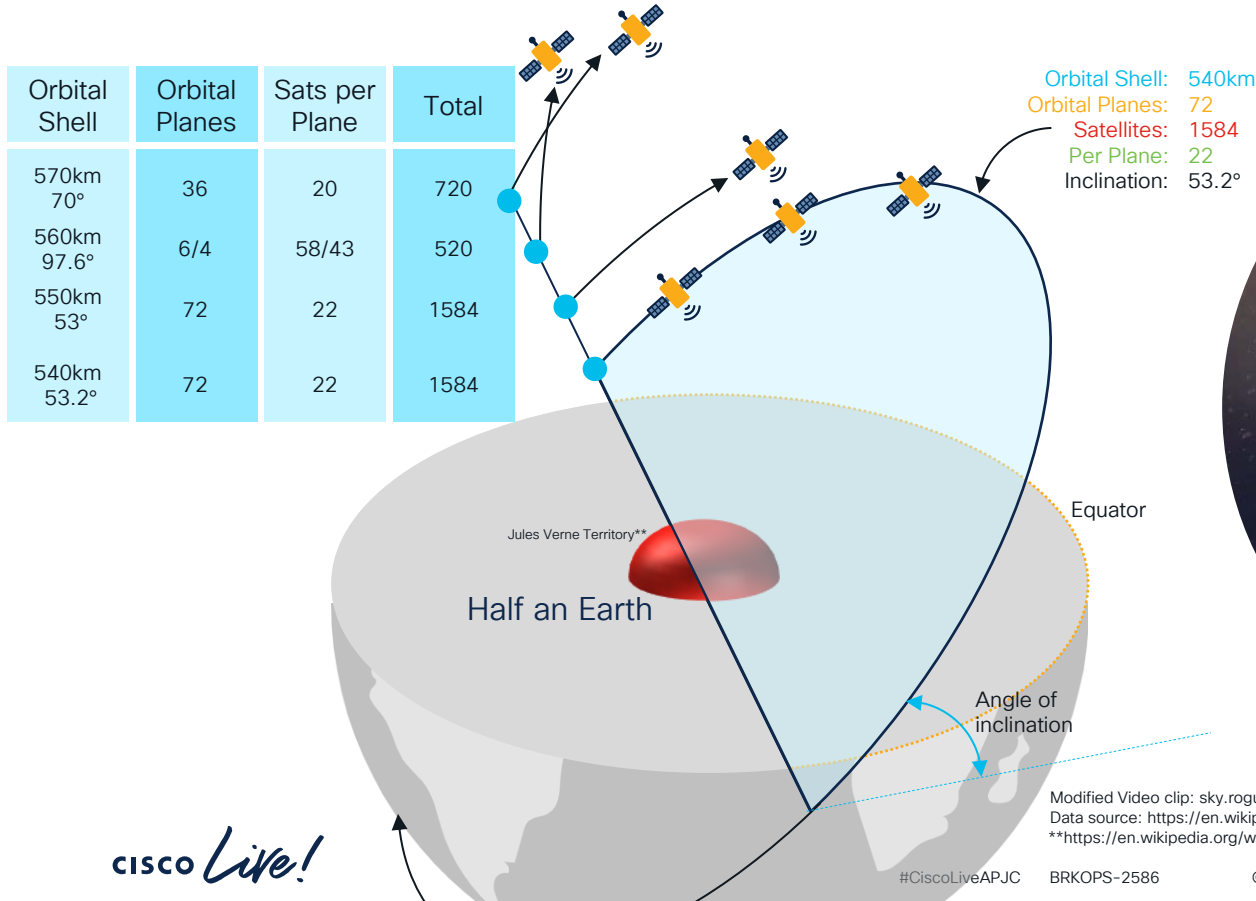
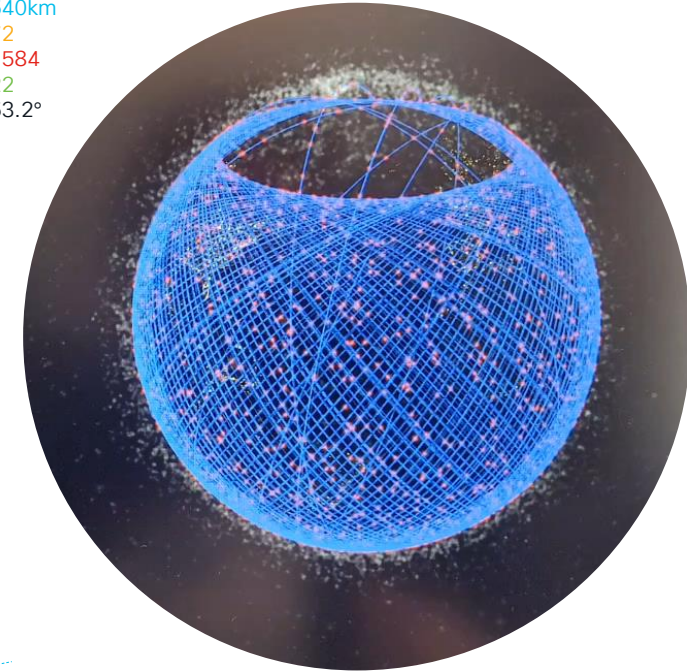


What's Up
There?



Starlink Phased Deployment

Starlink Constellation
as of September, 2024 there are
6,400+ satellites in orbit



Modified Video clip: sky.rogue.space
Data source: https://en.wikipedia.org/wiki/Starlink#Constellation_design_and_status
**https://en.wikipedia.org/wiki/Journey_to_the_Center_of_the_Earth

How Often does SpaceX Launch New LEOsats?



Constantly!

I tune in for a lot of the launches



SCIENCE • EDITORS' PICK

SpaceX Launches Rocket With 143 Satellites – The Most Ever Flown On A Single Mission

Jonathan O'Callaghan Contributor @

Jonathan is a freelance space journalist that covers commercial spaceflight, space exploration, and astrophysics

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Jan 24, 2021, 10:14am EST

Source: <https://www.forbes.com/>

Source: Dave's Man Cave

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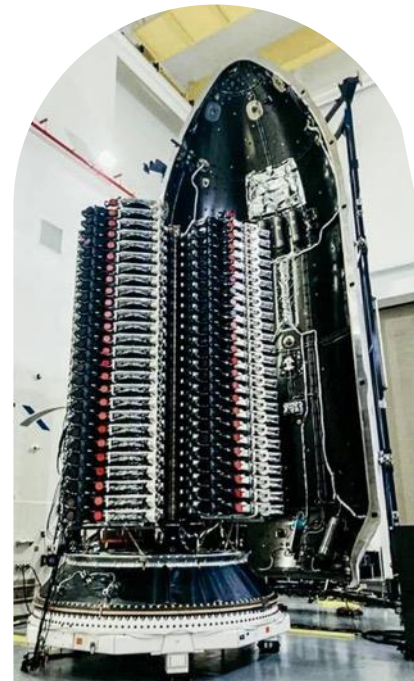
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30

Starlink Launch Config



60 typically deployed in a single launch



Starlink Next-Gen Sats



Elon Musk 
@elonmusk · [Follow](#)



Replying to @kevinrose

And it will improve significantly when Starship starts launching the third generation satellites at 350km altitude (5 ms speed of light round trip latency) with larger antennas that allow for multi-gigabit bandwidth

9:47 PM · Oct 21, 2024



3.1K



Reply



Copy link

[Read 110 replies](#)

LEOsat Players are Growing



Amazon marks breakthrough in Project Kuiper development

LEOsat Competitor Space

Starlink 
6,400+ LEO Active
(4396 – Phase 1)
(7518 – Phase 2)
~12000 in total by 2027

GeeSpace
240 LEO Planned



OneWeb
634 LEO
Active
(as of May, 2023)



AST SpaceMobile
170 LEO Planned




Lynk
5110 LEO Planned


TeleSat
15 GEO Active


VIASat
4 GEO Active


Iridium Certus
75 LEO Active

AMAZON Kuiper
3236 LEO planned 

Source:
<https://interestingengineering.com/innovation/Starlink-here-are-6-of-spacexs-biggest-rivals-for-satellite-internet-dominance>

6300

rocket launches
since 1957

14450

satellites launched

32160

debris regularly
tracked

9610

Satellites
still in space

630

collisions resulting
in further debris

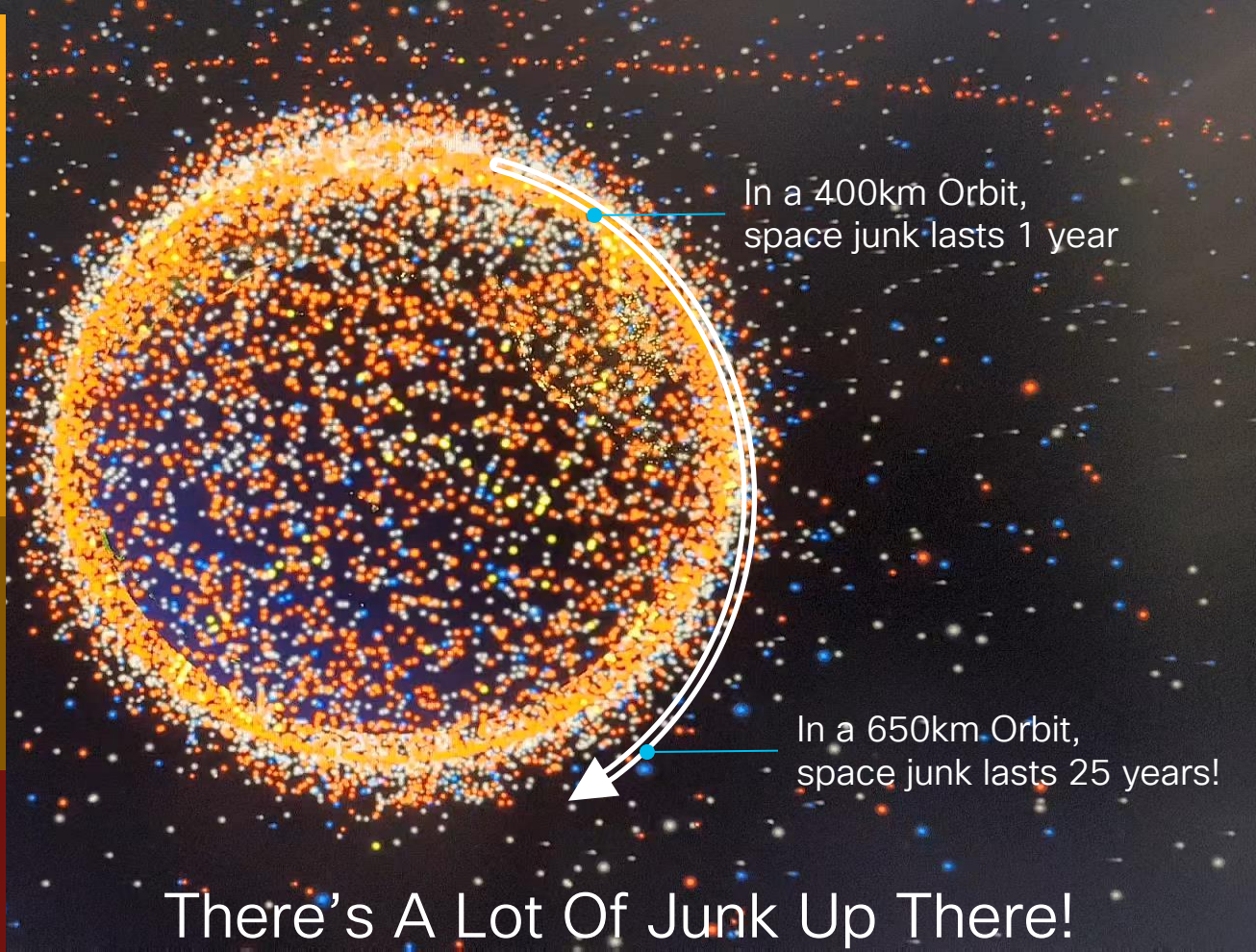
6800

satellites still
functioning

10400

tonnes of debris

https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers

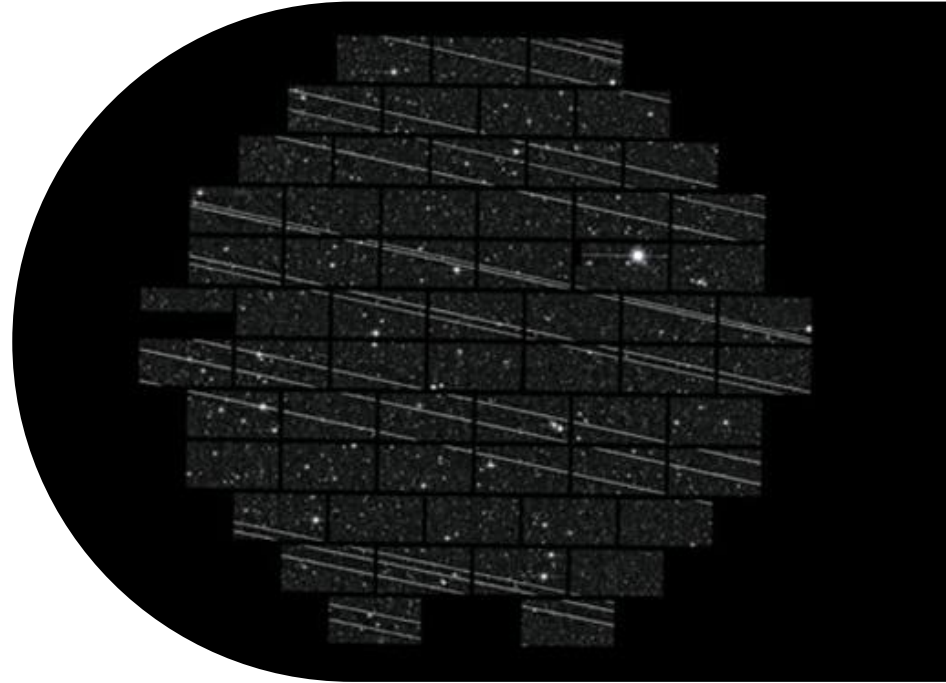


Modified Video clip: sky.rogue.space

Astronomer's Issue – Sky Clog



NATIONAL OPTICAL-INFRARED ASTRONOMY RESEARCH LAB/NSF



DELVE SURVEY, CTIO/AURA AND NS

Example of Starlink satellites leaving 19 trails of light on a telescope image

Phased Array Antennas

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Ian



Basic Antennas

A basic antenna will transmit the same power in all directions



Phased Array Antennas – Multiple Elements

Phased array antennas can contains 100s of antenna elements.

As the waves travel outward from the antennas they constructively and destructively interfere with each other



Phased Array Antennas – Narrow Beam

Phased array antennas can contain 100s of antenna elements.

Through software we can concentrate the beam in one specific direction and cancel out in all other directions

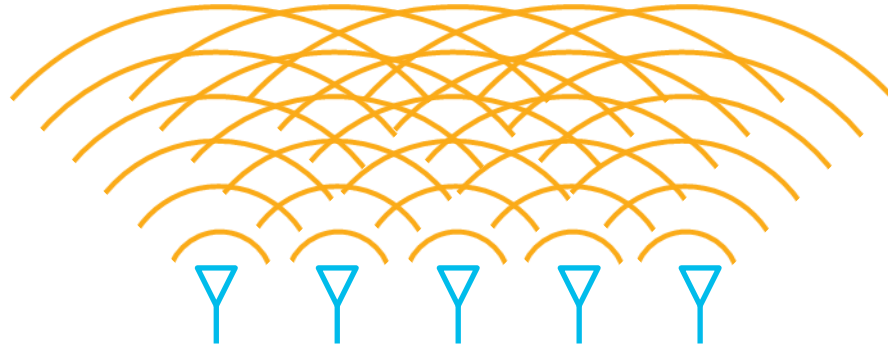


The result is a single composite antenna with a very narrow beam perpendicular to the antenna

Phased Array Antennas – Controlling Direction

Phased array antennas can contain 100s of antenna elements.

By adding a slight delay to each signal



Phased Array Antennas – Controlling Direction

Phased array antennas can contain 100s of antenna elements.



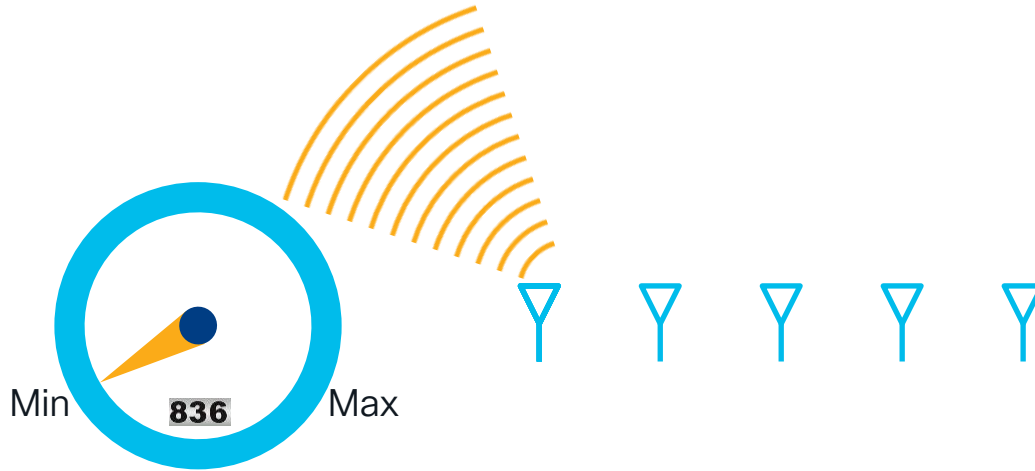
We can change the direction of the beam to optimally follow the path of the LEO Sat



The result is a single composite antenna with a very narrow beam perpendicular to the antenna

Phased Array Antennas – Throughput

Throughput will vary whilst connecting and as the LEOsat moves across the sky



For illustrative purposes only.



Starlink Phased Array Antennas

**GEN 1
User Terminal**



**GEN 2
User Terminal**



Size	D58.9cm	50cm x 30cm
Weight	7.3kg	4.2kg
Height	64.5cm	61cm
Op. Temp	-30°C to +50°C	-30°C to +50°C
Power	PoE	PoE
Outdoor	IP54 (Modem indoor only)	IP54 (Modem outdoor)
Heating	Integrated	Integrated
WiFi Modem	2 x MU-MIMO	3 x MU-MIMO
Ethernet Port	Onboard dish	Requires adaptor
Price	USD599 + USD90-120pm	USD599 + USD90-120pm

Cat Butt
Attenuation

(Different to
dBi – Dog Butt
Interference)



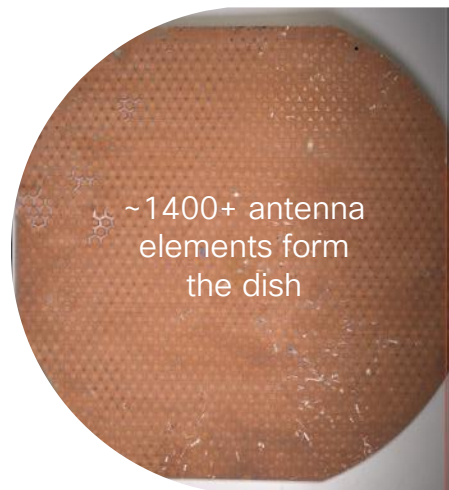
<https://soyacinau.com/2022/01/10/cats-are-very-fond-of-the-self-heating-Starlink-satellite-dish-by-spacex-and-its-a-big-problem/>

... and more
antenna options
for mobile
applications ...

... plus
Starlink
Business

(higher speed,
lower latency)

~1400+ antenna
elements form
the dish



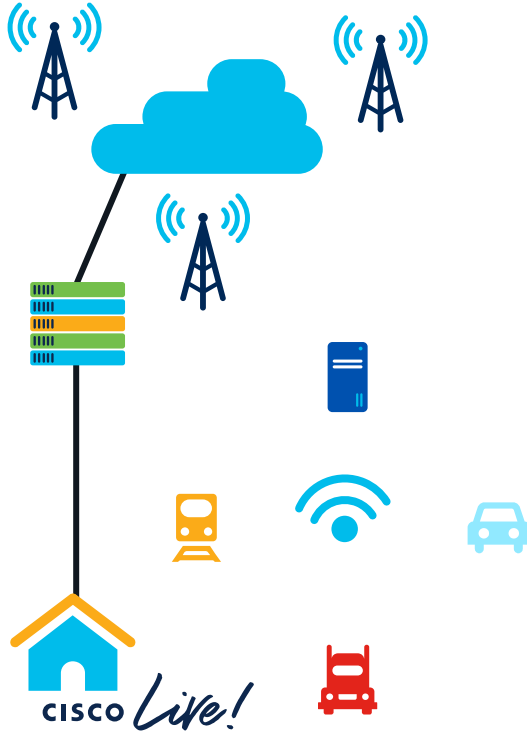
Mobility Support



Mobility

Traditional

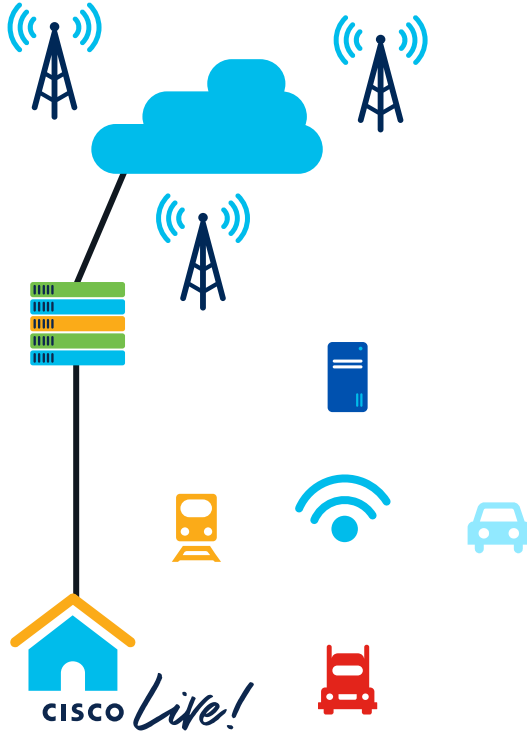
Network stationary
UE stationary/mobile



Mobility

Traditional

Network stationary
UE stationary/mobile



LEO

Network mobile
UE stationary



Mobility

Traditional

Network stationary
UE stationary/mobile



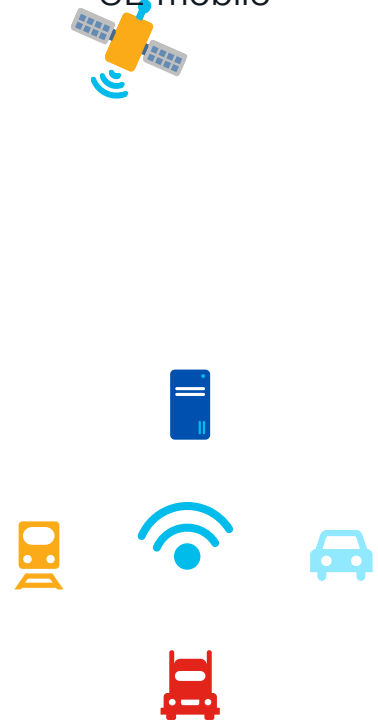
LEO

Network mobile
UE stationary



LEO Mobility

Network mobile
UE mobile



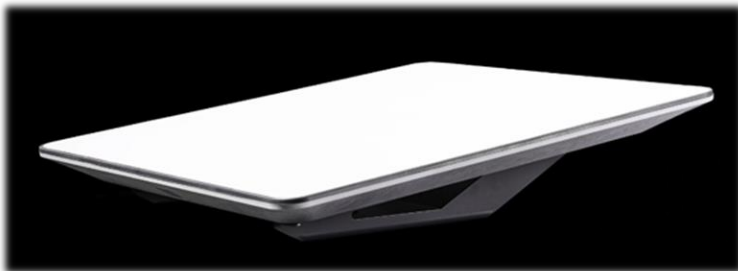
Starlink Mobility Offerings



Starlink RV



Flat
High-
Performance
antenna



Bad idea



cisco *Live!*

Roaming (Cell-phone) Mobility via LEOsats

Existing phones and mobile networks are set up to accommodate bullet train speeds not orbital velocities



320 km/h



V

7.8 km/s



AST
SpaceMobile

Technology Enhancements To Support Direct Handset Connectivity

Doppler Shift	Doppler compensation allows for a phone to see LEO as a fixed tower
Software Defined Radios	Allows for frequency hopping to connect various licenced spectrums
Larger LEO antennas	Allows communication with low-power, low-signal-strength phones
Cell Timing	Mobile phones require highly accurate timing

**No changes
to existing
cell phones**

Larger Antenna & More Power – Cell Phones



<https://ast-science.com/>

AST Spacemobile
400sqm (Planned)
Several 1000kgs

Lynk
4sqm



Starlink Gen2
25sqm
1250Kgs



CISCO *Live!*

A Marriage Made In Low Earth Orbit

Many partnerships are being formed



Many MNO

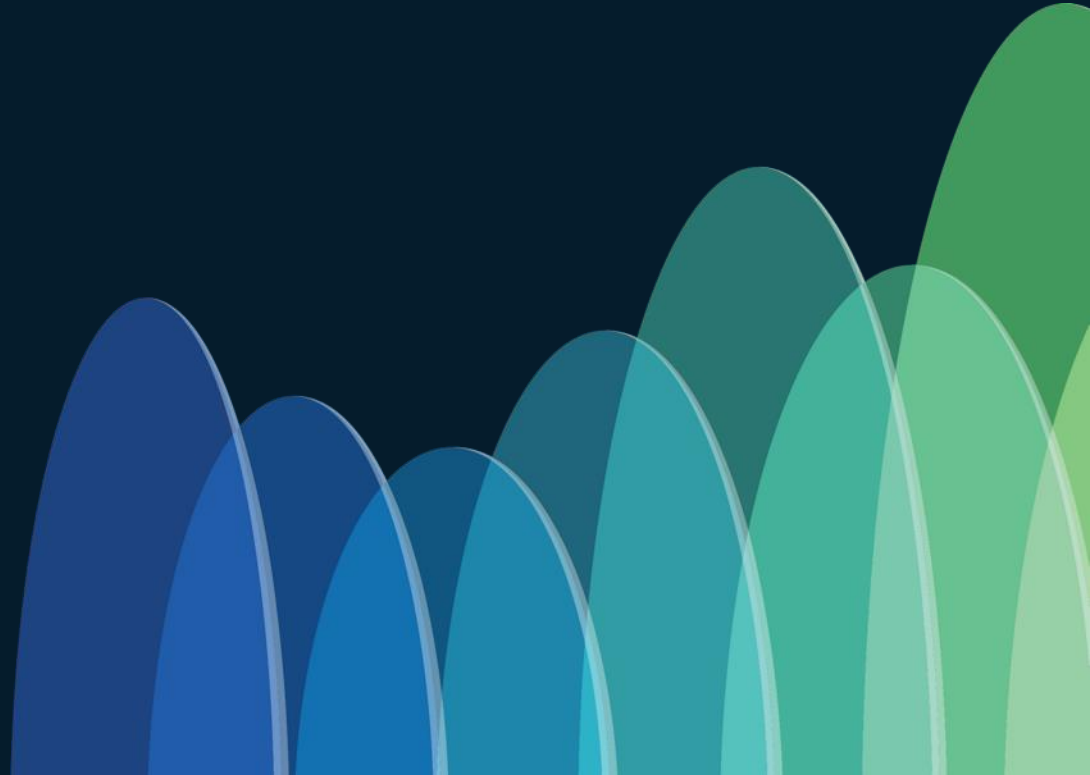


Many MNO



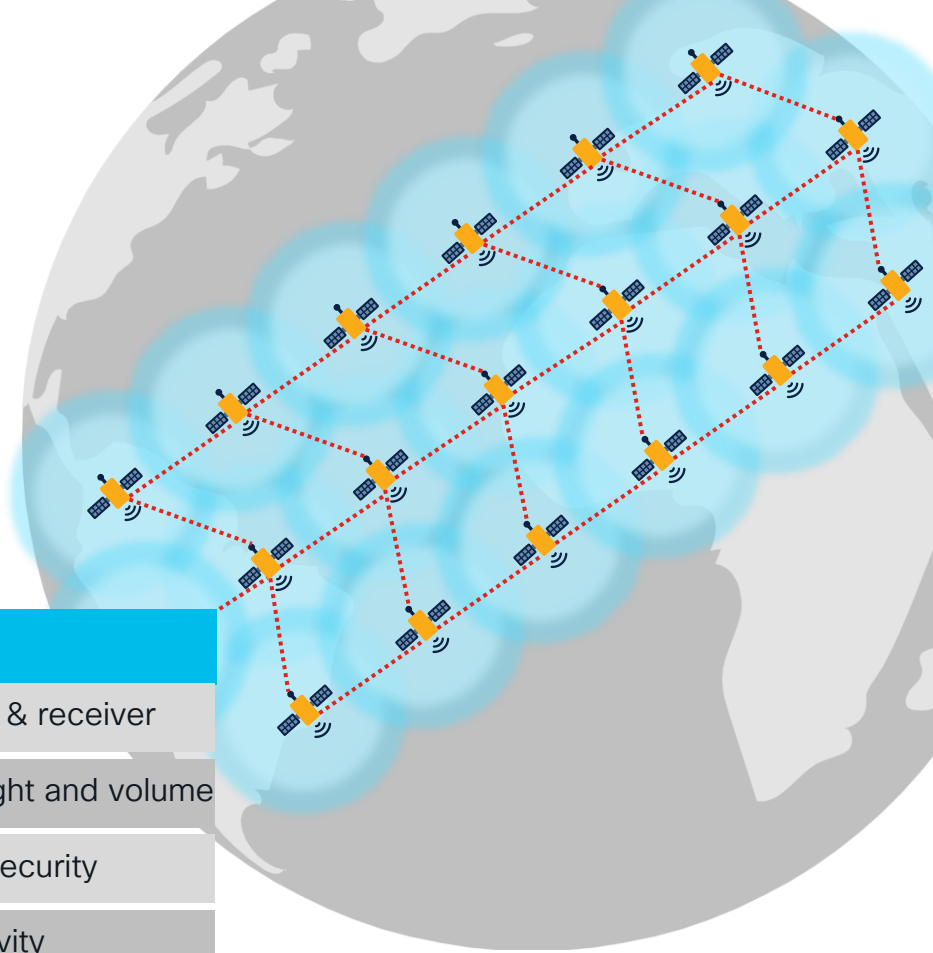
Initial offers are texting services and low bw
broadband

Laser Inter-Satellite Links



Laser Inter-Satellite Links

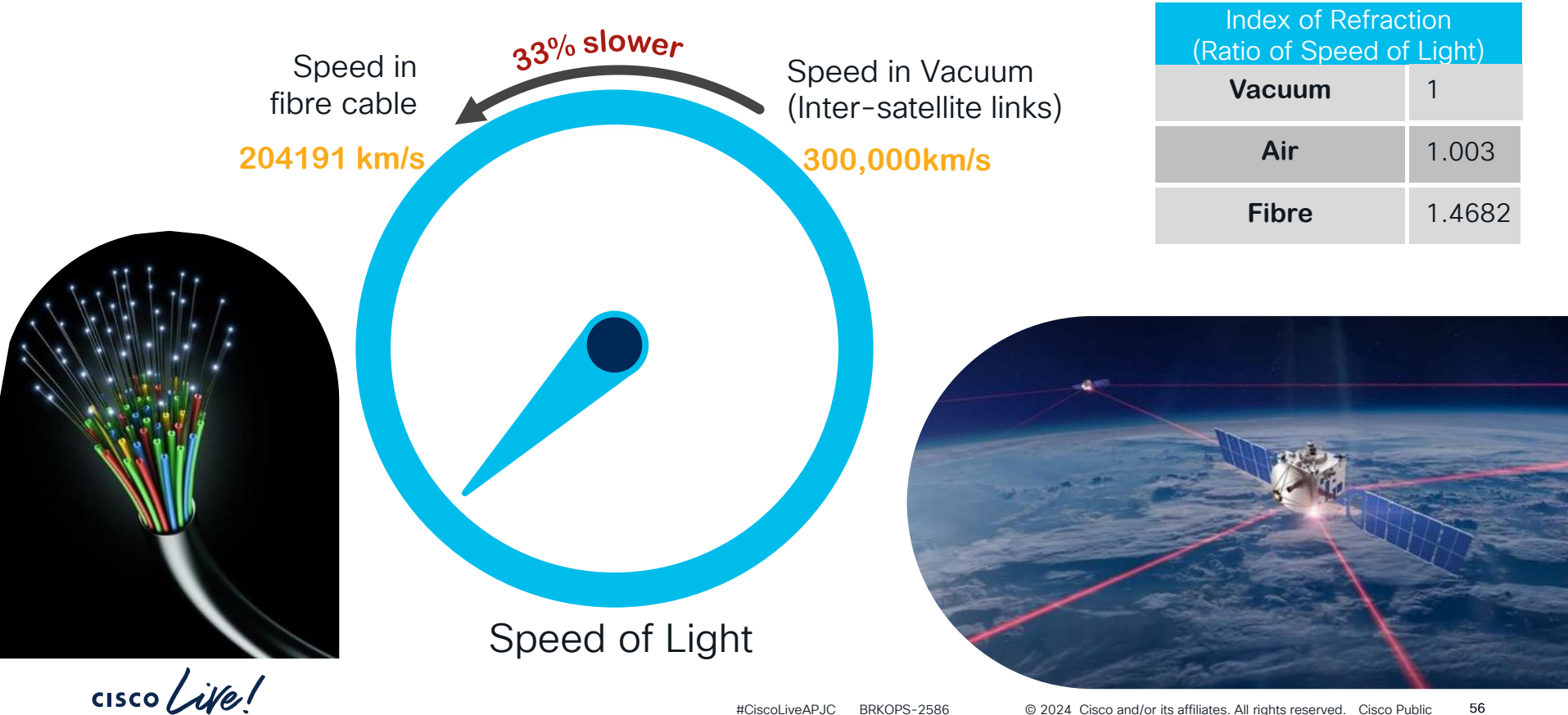
Signals in FREE SPACE
REDUCE LATENCY



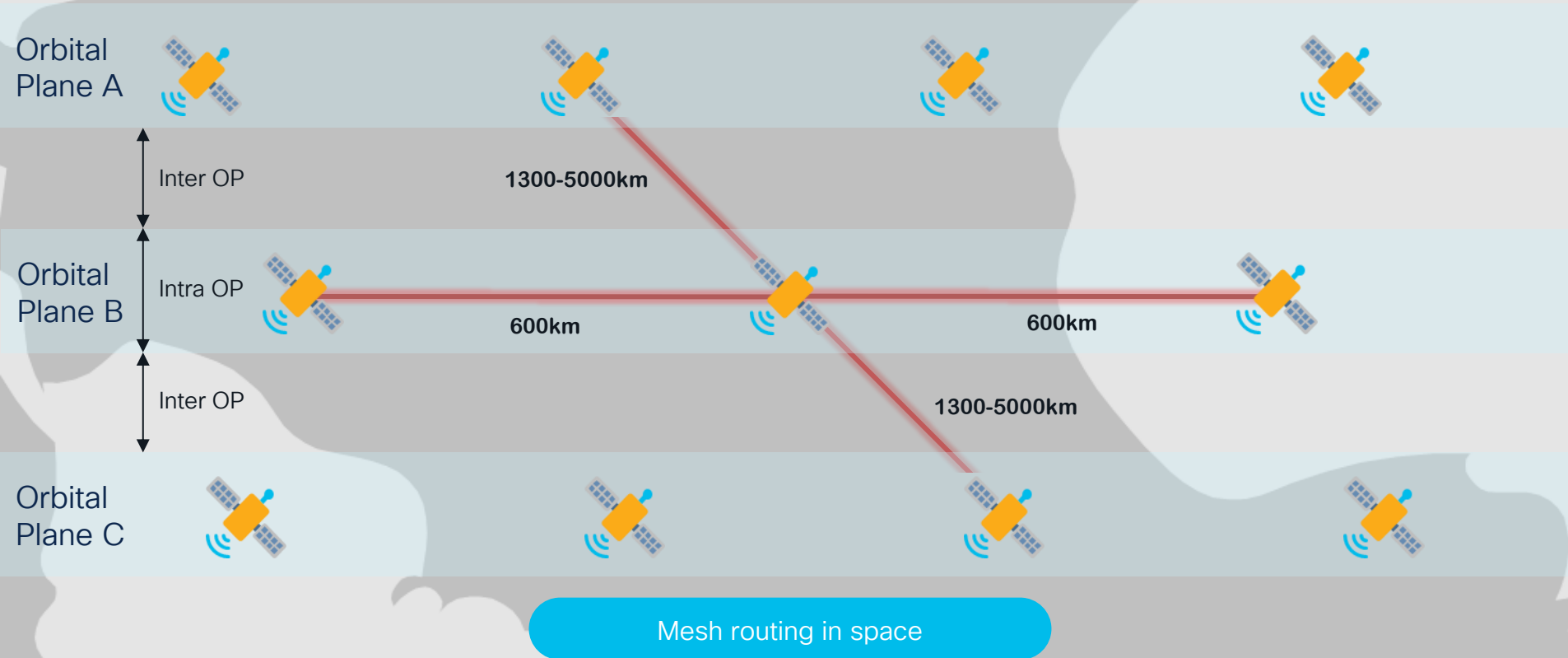
Advantages of Laser over RF

Higher Capacity	Up to 10 Gb/s between one laser transmitter & receiver
Antenna Size	Smaller antenna sizes, resulting in lower weight and volume
Narrow Beam	Eliminates interference and provides higher security
Low TX Power	Due to lower beam spread and higher directivity

Free Space and the Speed of Light



Starlink Laser Inter-Satellite Links



Starlink Laser Inter-Satellite Links – Fun Facts!

9000 Space lasers deployed

5.6Tbps+ peak throughput



**Delivering 42 PETABYTES
of customer data a day (42 million gigabytes)**

Laser Link Highlights

Longest link distance	5400 km
Number of acquisitions per day	266,141
Longest link duration	Weeks
Max. data rate	200Gbps
Fastest acquisition	12 seconds
Min. altitude link	122km <<< maintained while de-orbiting a satellite! ☺

Source: PCMag, <https://uk.pcmag.com/networking/150673/starlinks-laser-system-is-beaming-42-million-gb-of-data-per-day>

Real World Deployments

Dave ——— Dave's Deployment, Meraki, SD-WAN Demo

Anthony ——— Starlink and Meraki

Kemal ——— Starlink Performance Analysis

Ian ——— Starlink in Construction,
Disaster Response

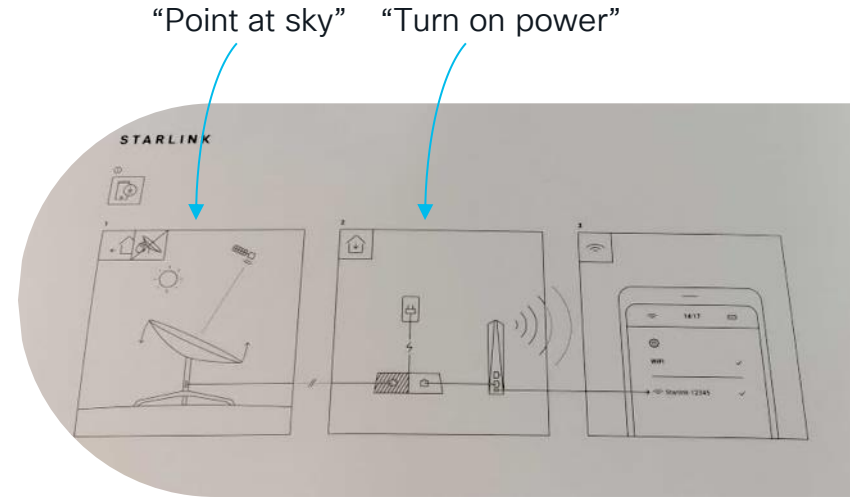
Dave's Deployment

CISCO *Live!*

Dave



Dave's Deployment @ Home



Installation Instructions

Dave's Deployment @ Home

Of course, there is always more to it than that ...

Finished the initial installation
as night fell in Vancouver, BC ...

[3D view from roof](#)



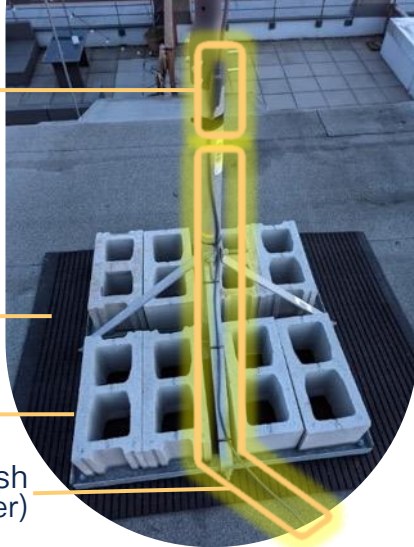
CISCO Live!

Pole adapter

Thick mat (to protect roof decking)

Ballast (for wind)

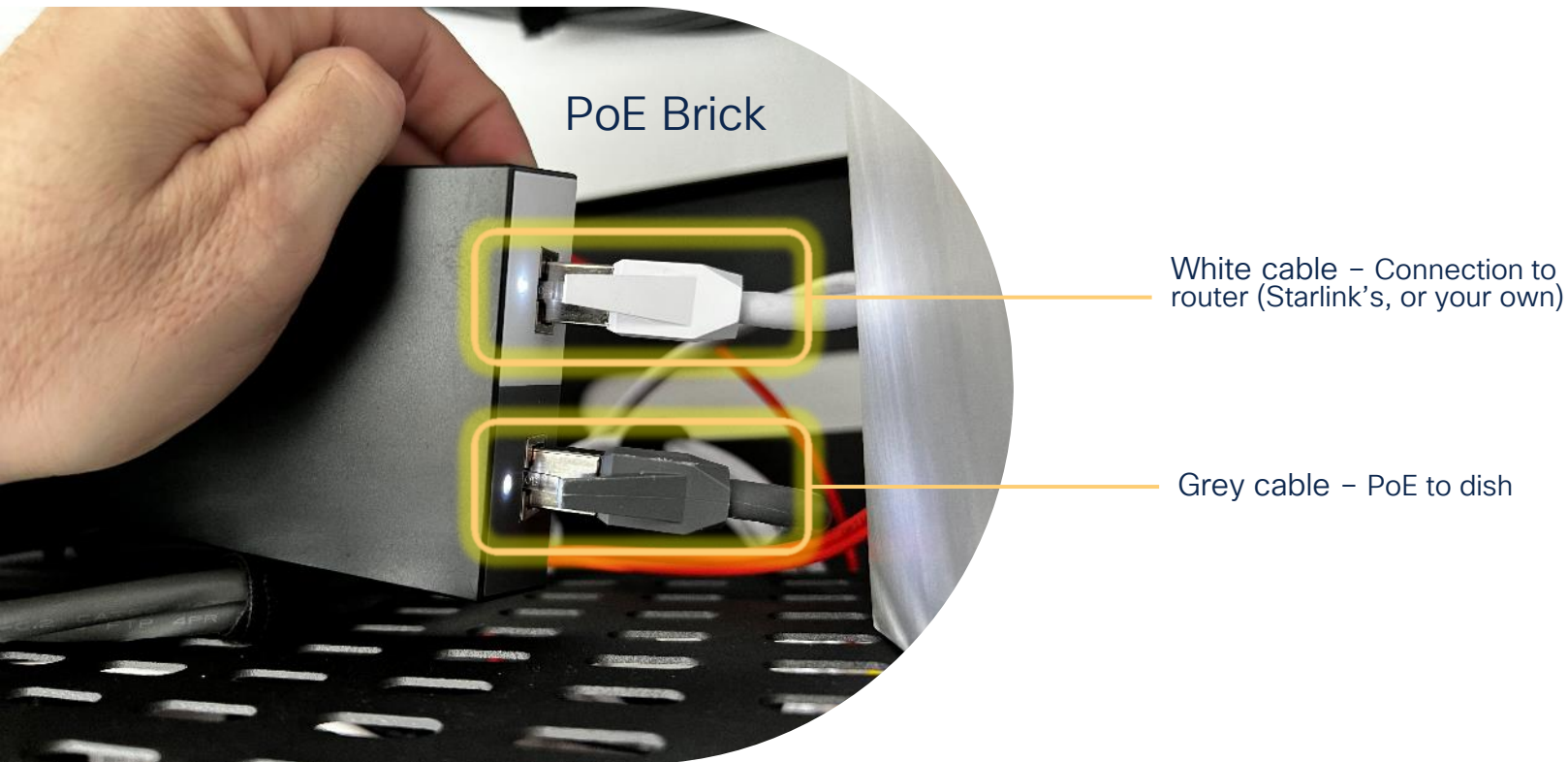
PoE cable to dish (100W+ power)



Heated Dish!



Dave's Deployment @ Home



Dave's Deployment @ Home

Large spool of PoE cable to antenna (Gen 1 dish, hardwired)

To the firewall

... via fibre
(using media converter)

To antenna
via PoE brick

Starlink router –
if you choose to
use it (optional,
can use your own
if you prefer)

Dave's Deployment @ Home

Powering my home office

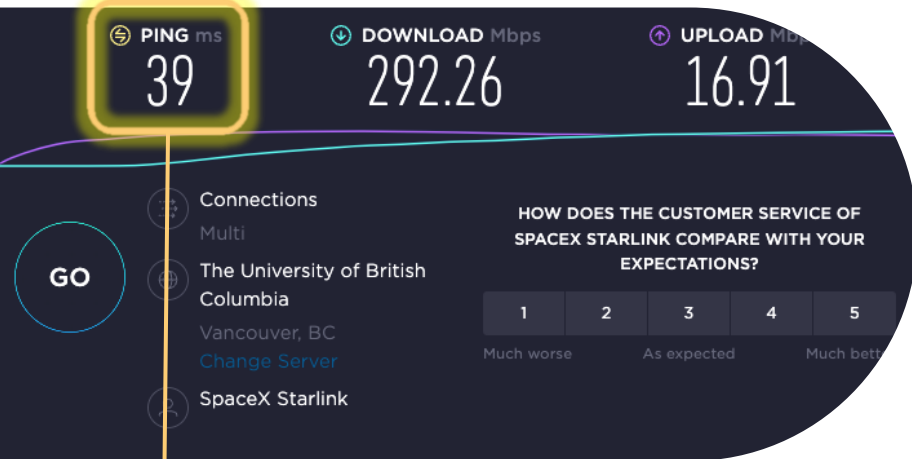


I have Gigabit via fibre, with Starlink as my secondary / failover / load-share link. But I can make it my primary uplink anytime I want to play. 😊

And I use Starlink as my primary uplink for many of my security camera feeds ...



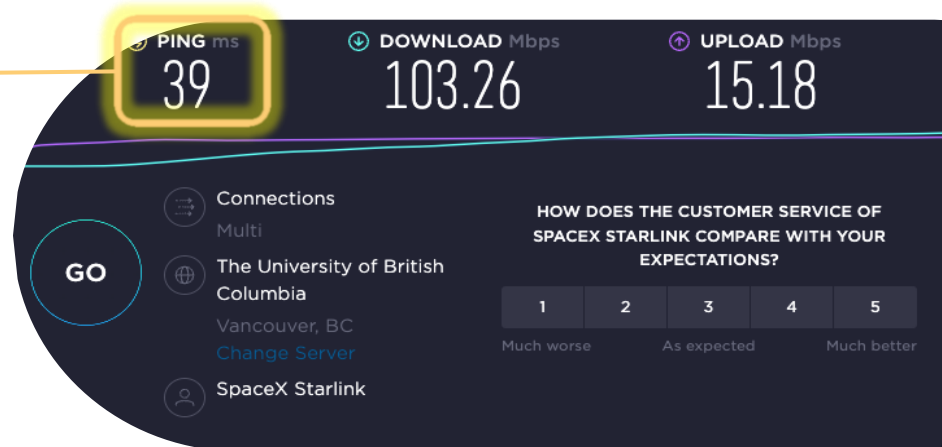
Dave's Deployment @ Home



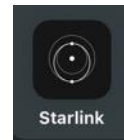
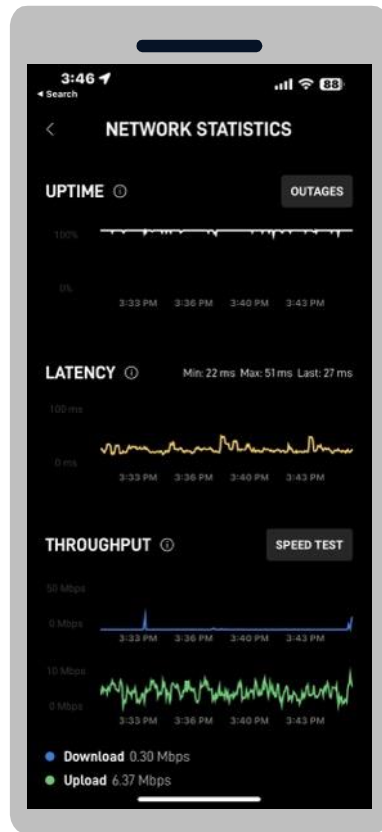
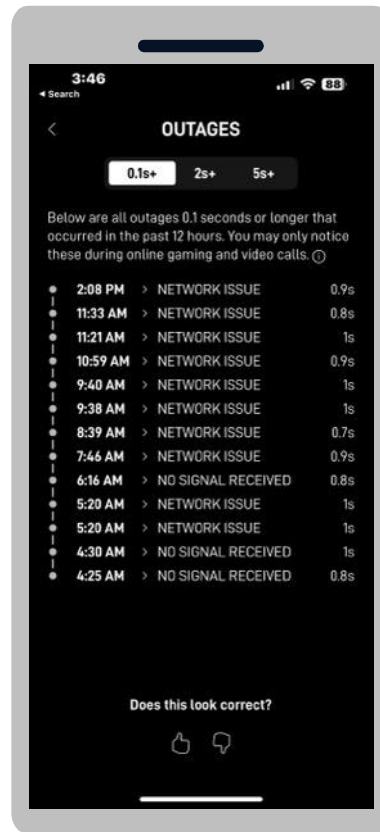
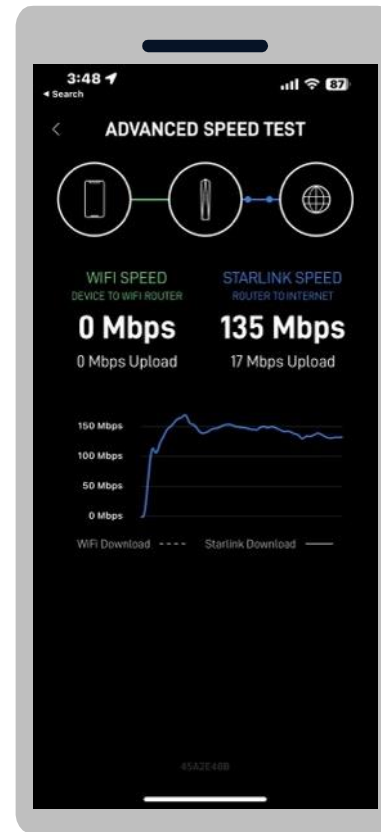
Low latency

Typical max speeds
I would see ...

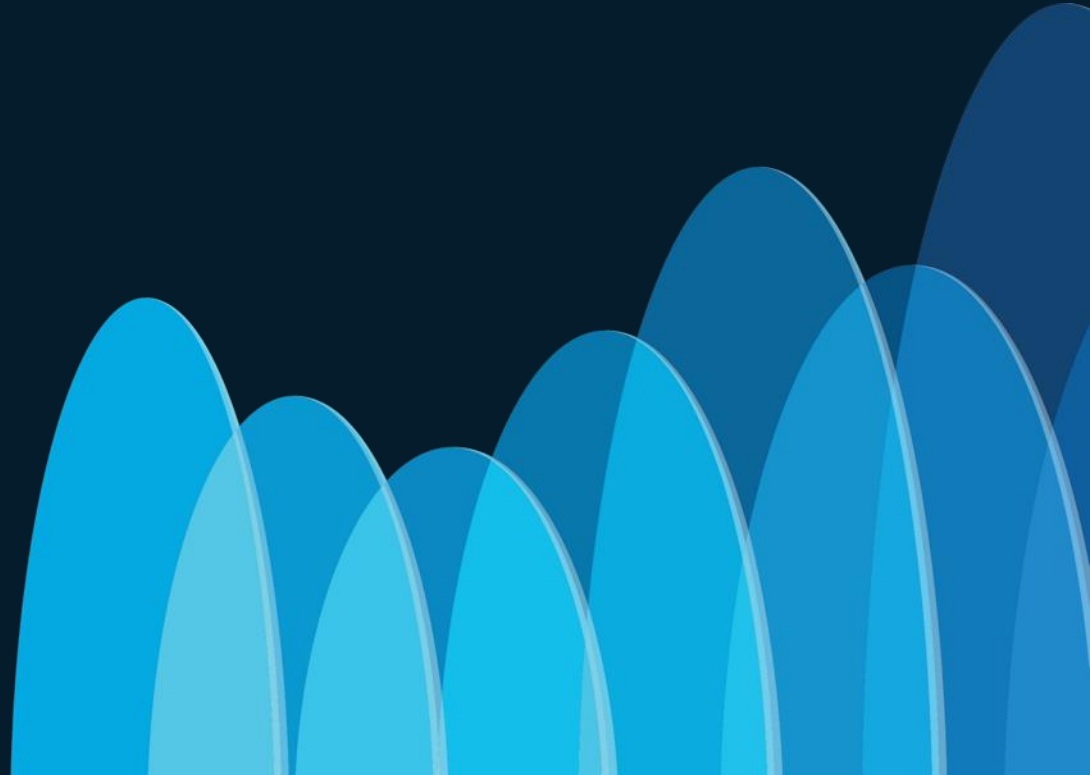
Average speeds



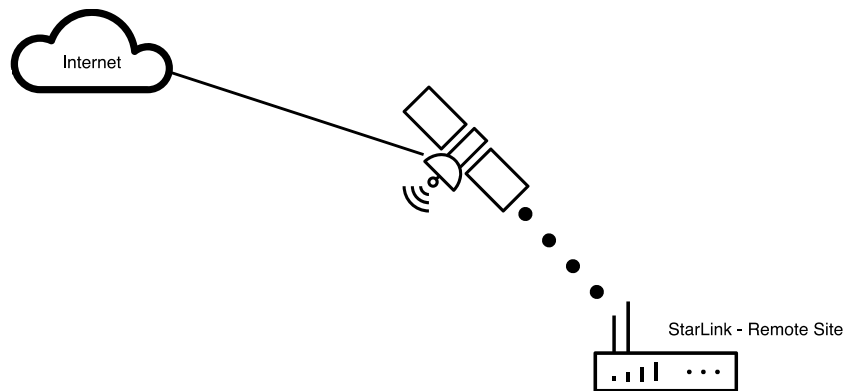
Starlink App



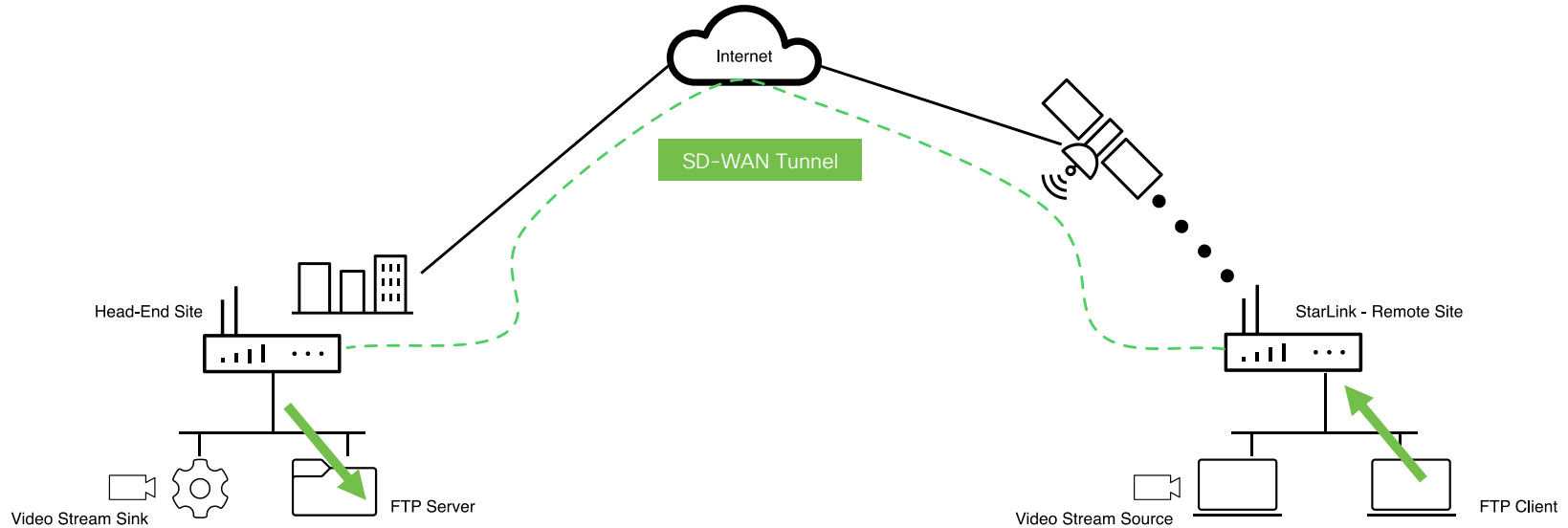
SD-WAN and Starlink



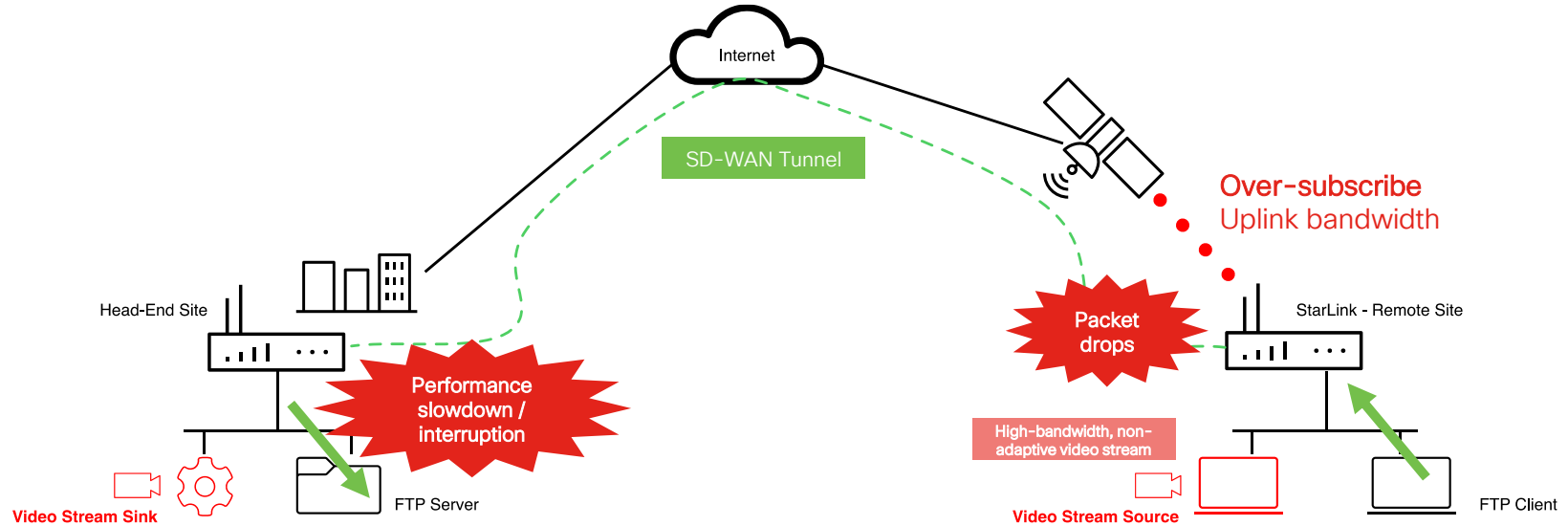
Starlink – SD-WAN Demo



Starlink – SD-WAN Demo



Starlink – SD-WAN Demo



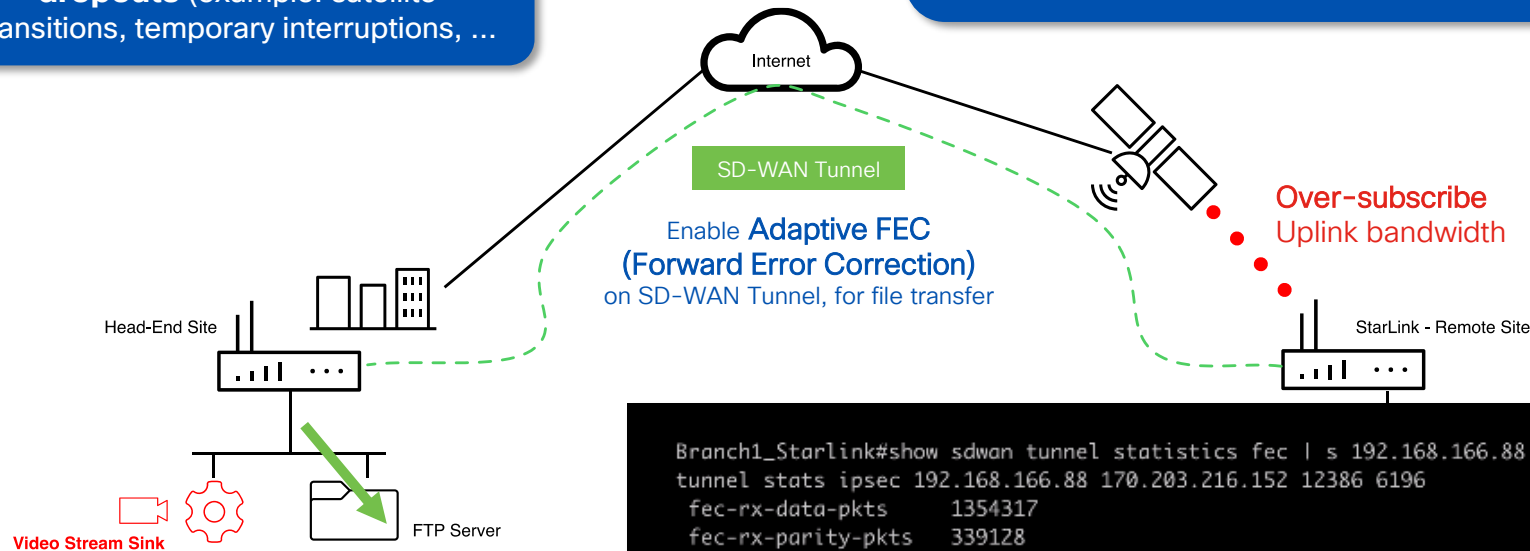
Starlink – SD-WAN Demo

Useful for occasional minor dropouts (example: satellite transitions, temporary interruptions, ...)

How FEC works in Cisco SD-WAN

For every 4 data packets, transmit an extra **parity packet**

Any single packet loss within the group of four packets can be **re-built dynamically** from the other packets + parity data



Can be “on-always”, or operate as FEC-Adaptive which only kicks in on detecting packet loss

```
Branch1_Starlink#show sdwan tunnel statistics fec | s 192.168.166.88 170.203.216.152
tunnel stats ipsec 192.168.166.88 170.203.216.152 12386 6196
fec-rx-data-pkts      1354317
fec-rx-parity-pkts    339128
fec-tx-data-pkts      328859
fec-tx-parity-pkts    82213
fec-reconstruct-pkts  16523
fec-capable           true
fec-dynamic           false
Branch1_Starlink#
```

Example of operation

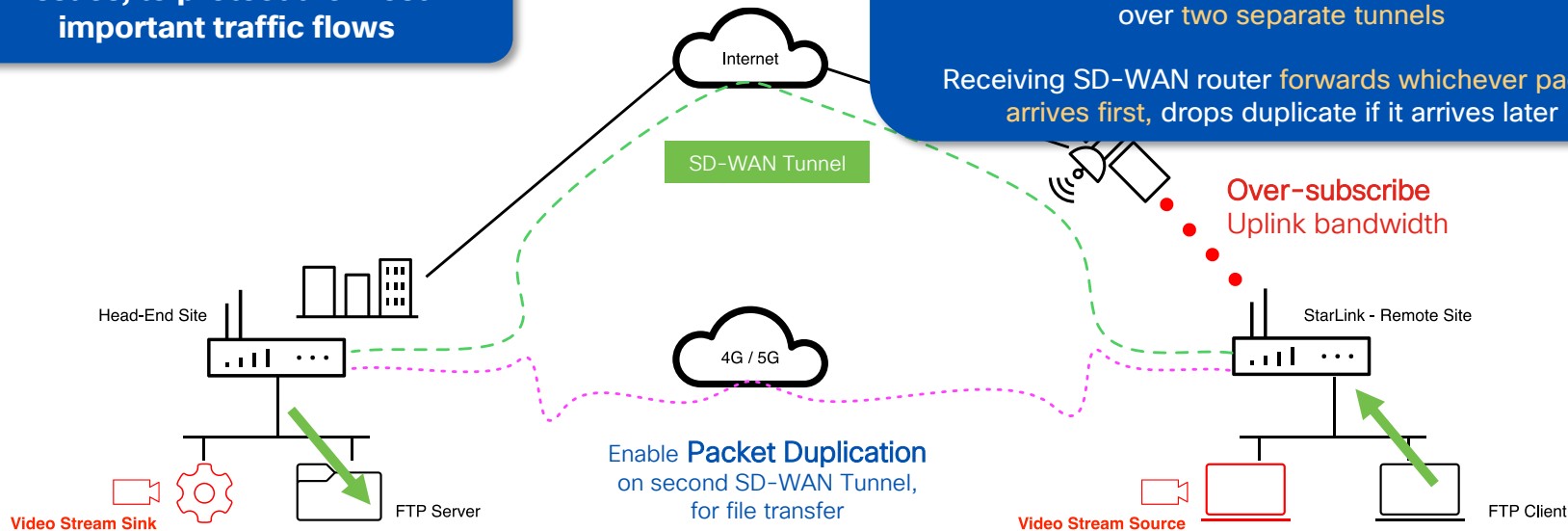
Starlink – SD-WAN Demo

Useful for longer-term possible issues, to protect the most important traffic flows

How Packet Duplication works in Cisco SD-WAN

Designate **all**, or **a portion**, of traffic to duplicate
Send copies of matching packets (with sequence numbers) over **two separate tunnels**

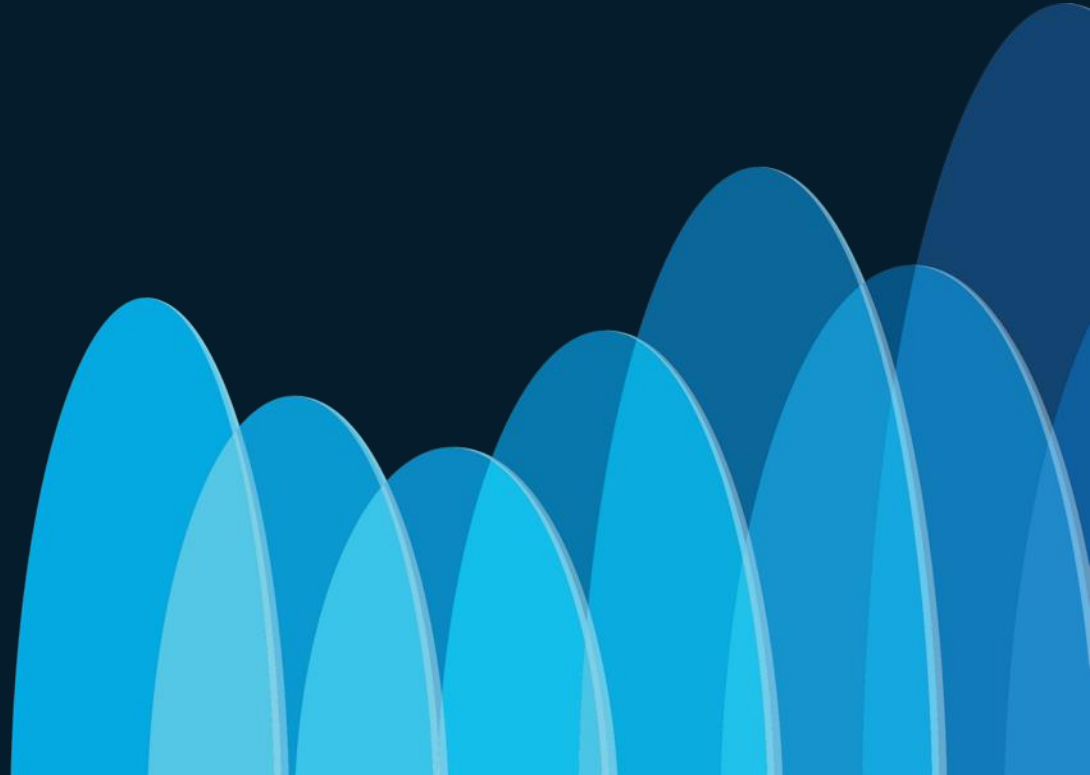
Receiving SD-WAN router **forwards whichever packet arrives first**, drops duplicate if it arrives later



Operates as “on-always”, but can be selective about what traffic is duplicated (via policy)

Demo of operation! 😊

Starlink and Meraki



Improving Connectivity (and Life!) in Rural Germany



Oli Boehmer
Principal Engineer, CX

Dual Internet Uplinks

With Starlink
being
the active
one

The screenshot shows the Meraki dashboard for a network named 'Heimiheim'. The left sidebar contains navigation links for Network, Network-wide, Security & SD-WAN, Switching, Wireless, and Organization. The main content area is divided into 'Configuration' and 'Live data' sections. The 'Configuration' section shows two WAN interfaces: WAN 1 and WAN 2. WAN 1 is configured with a public IP of 145.224.73.212, a dynamic IP address, and is currently active. WAN 2 is configured with a public IP of 192.168.2.254, a static IP address, and is currently ready. The 'Live data' section shows the current status of the WAN interfaces: WAN 1 is active and WAN 2 is ready. The 'Warm Spare' section shows a warm spare configuration for WAN 1.

WAN	Type	Configured As	Status	IP Address	Gateway	DNS
WAN 1	Dynamic	Active	Active	145.224.73.212	100.126.49.73	100.64.0.1
WAN 2	Static	Ready	Ready	192.168.2.254	100.126.49.73	100.64.0.1

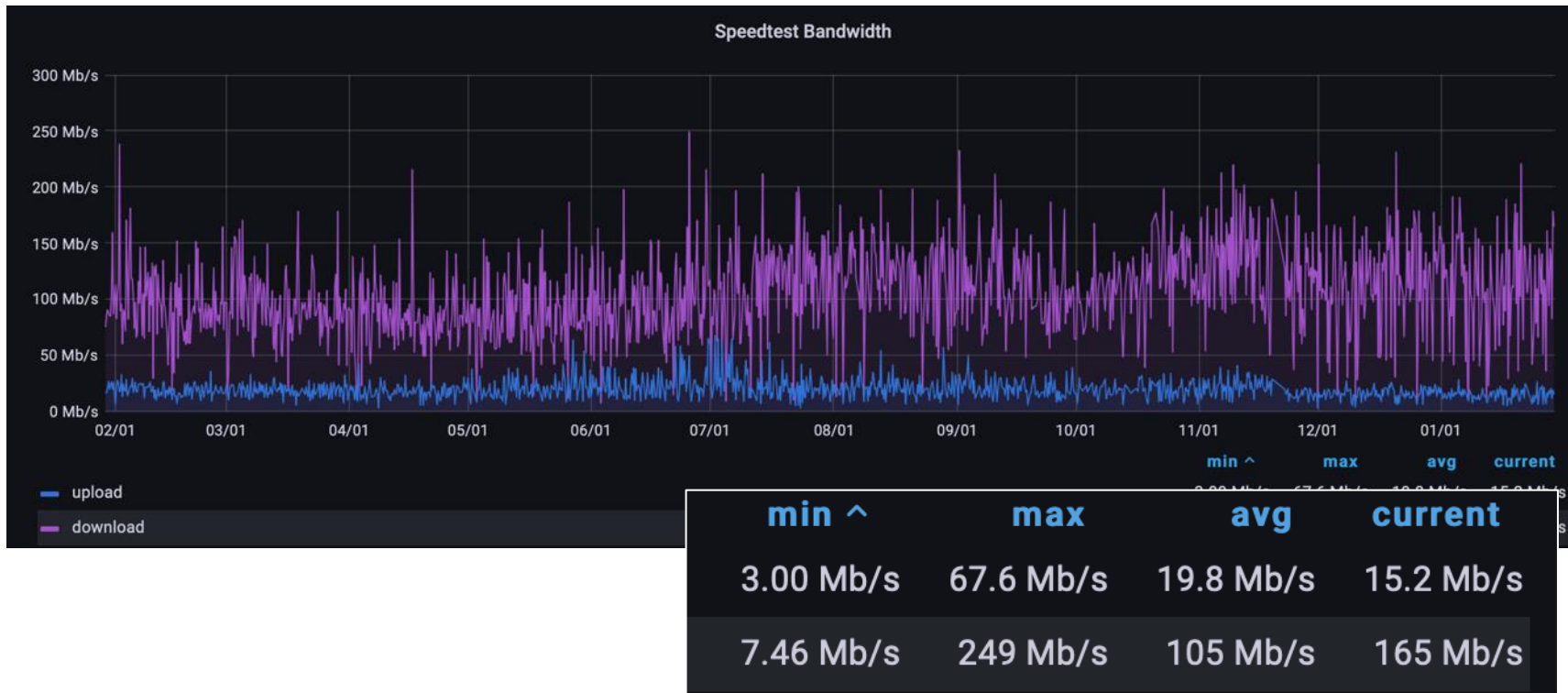
Links run in Active/Standby

Starlink Gateway Frankfurt Carrier-Grade NAT (CG-NAT) outside address

Starlink DHCP CG-NAT inside address

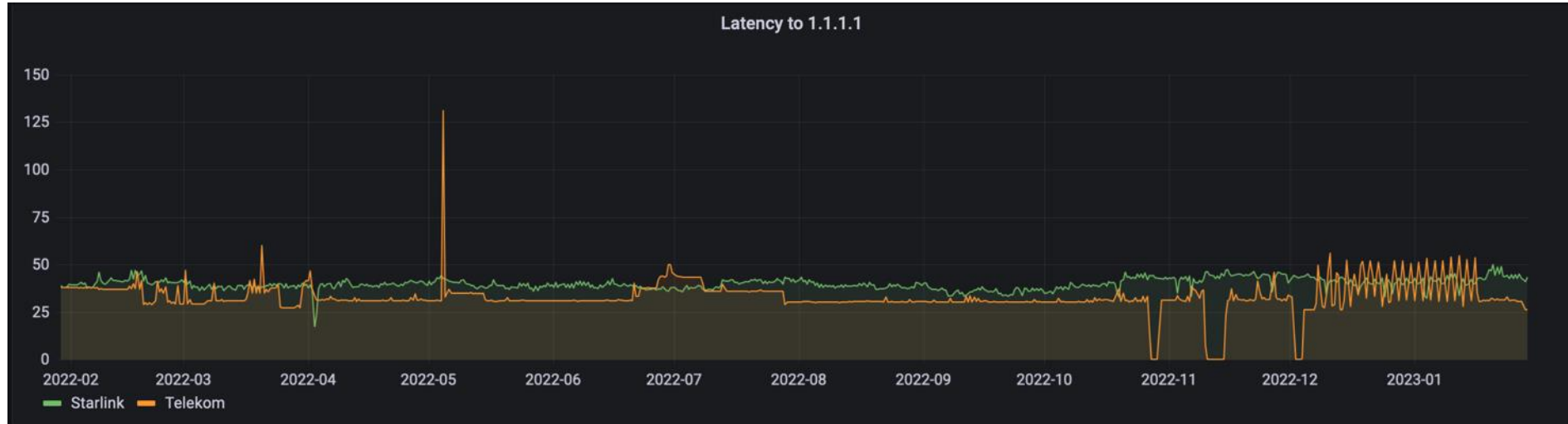
Deutsche Telekom Router

Throughput over the past ~12 months

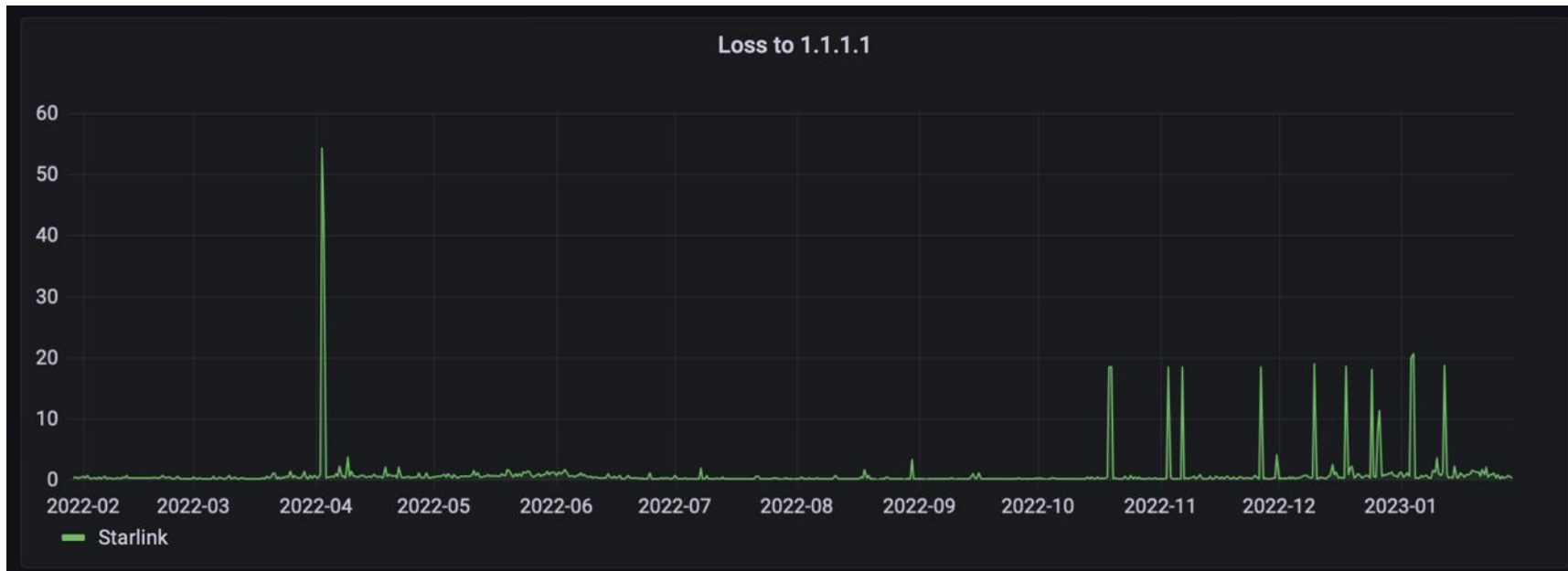


Excellent Latency (as expected)

LEO (green) shows more constant RTT vs. terrestrial link (orange)



Overall Reliability



Zooming out ... Meraki and Starlink, Overall – at a Glance

as of June, 2024

Starlink MXs

17,167 MX online with a
Starlink IP during June

Only Uplink

64% of those nodes using
Starlink as their only connection

IPv6

52% of Starlink nodes with an
IPv6 WAN IP address

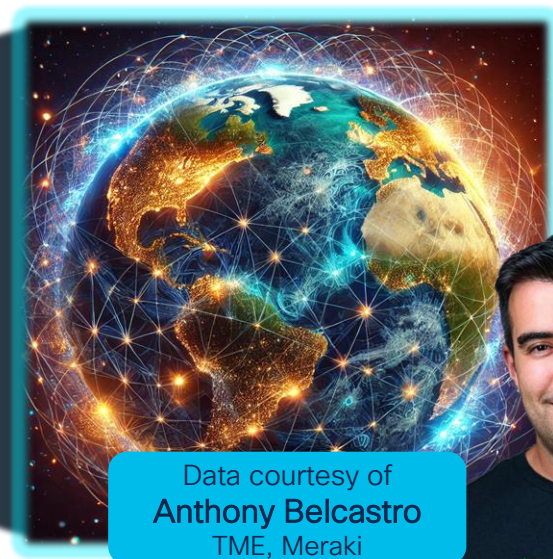
Top Models

MX68	23.0%
MX67	22.4%
MX64	20.2%
Z3	11.3%
MX65	4.5%

(Includes C & W Variants)



CISCO *Live!*



Data courtesy of
Anthony Belcastro
TME, Meraki



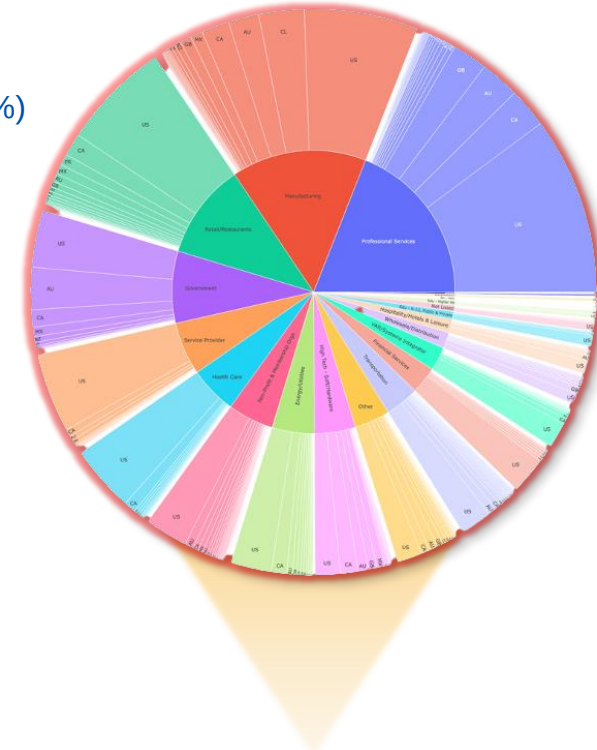
Zooming out ... Meraki and Starlink, **by Industry**

as of June, 2024

Starlink MXs

17,167 MX online with a
Starlink IP during June

Professional Services: 3,263 (19.01%)
Manufacturing: 2,649 (15.43%)
Retail/Restaurants: 1,873 (10.91%)
Government: 1,410 (8.21%)
Service Provider: 1,039 (6.05%)
Health Care: 931 (5.42%)
Non-Profit & Membership Orgs: 898 (5.23%)
Energy/Utilities: 828 (4.82%)
High Tech - Soft/Hardware: 810 (4.72%)
Other: 694 (4.04%)
Transportation: 665 (3.87%)
Financial Services: 531 (3.09%)
VAR/Systems Integrator: 463 (2.70%)
Wholesale/Distribution: 313 (1.82%)
Hospitality/Hotels & Leisure: 270 (1.57%)
Edu - K-12, Public & Private: 150 (0.87%)
Not Listed: 126 (0.73%)
Edu - Higher Ed: 100 (0.58%)
Edu - Other: 64 (0.37%)
Media/Entertainment: 53 (0.31%)
Arts/Recreation: 33 (0.19%)
Library: 3 (0.02%)
VAR/Security Integrator: 1 (0.01%)



Zooming out ... Meraki and Starlink, **by Industry / Country**

as of June, 2024

Starlink MXs

17,167 MX online with a
Starlink IP during June

Top industries in US:

Professional Services: 32.54%

Manufacturing: 20.89%

Retail/Restaurants: 19.92%

Service Provider: 14.49%

Health Care: 12.17%

Top industries in CA:

Professional Services: 31.67%

Manufacturing: 22.29%

Retail/Restaurants: 18.04%

High Tech - Soft/Hardware: 14.20%

Government: 13.80%

Top industries in AU:

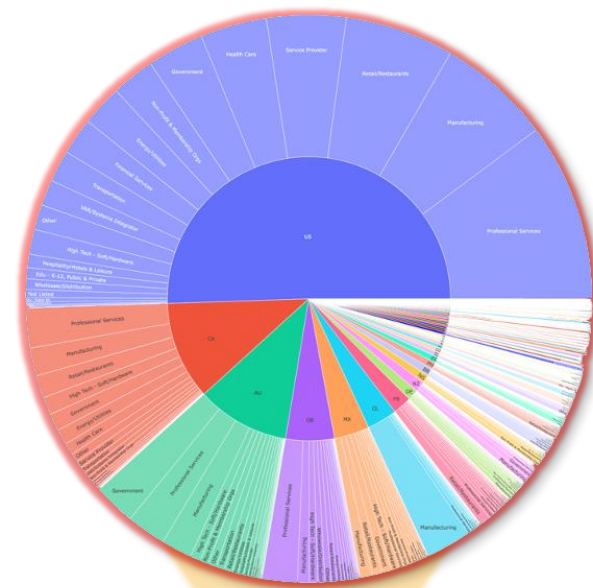
Government: 32.14%

Professional Services: 30.04%

Manufacturing: 23.35%

High Tech - Soft/Hardware: 7.86%

Non-Profit & Membership Orgs: 6.61%

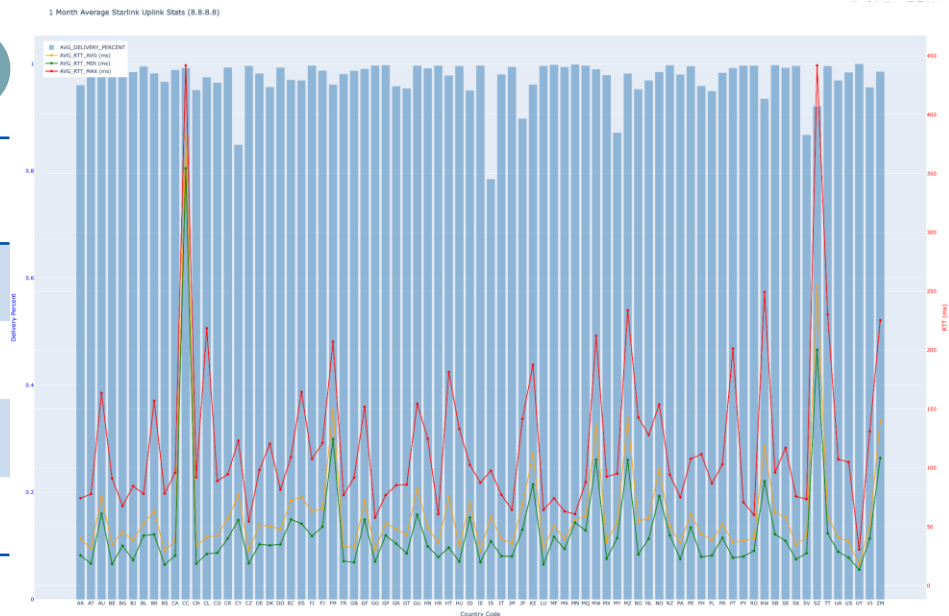


Zooming out ... Meraki and Starlink, Performance Overview

as of June, 2024

30 Day Performance
Uplink Monitor to 8.8.8.8

REGION	AVERAGE DELIVERY %	AVERAGE RTT	AVERAGE RTT MIN Values	Average RTT MAX Values
APJC	95.60%	106.48	89.18	164.32
AMERIC AS	97.75%	48.77	33.67	111.19
EMEA	97.42%	61.39	44.19	117.97
Total	96.92%	72.21	55.69	131.16



Starlink – Performance Analysis

CISCO *Live!*

Kemal

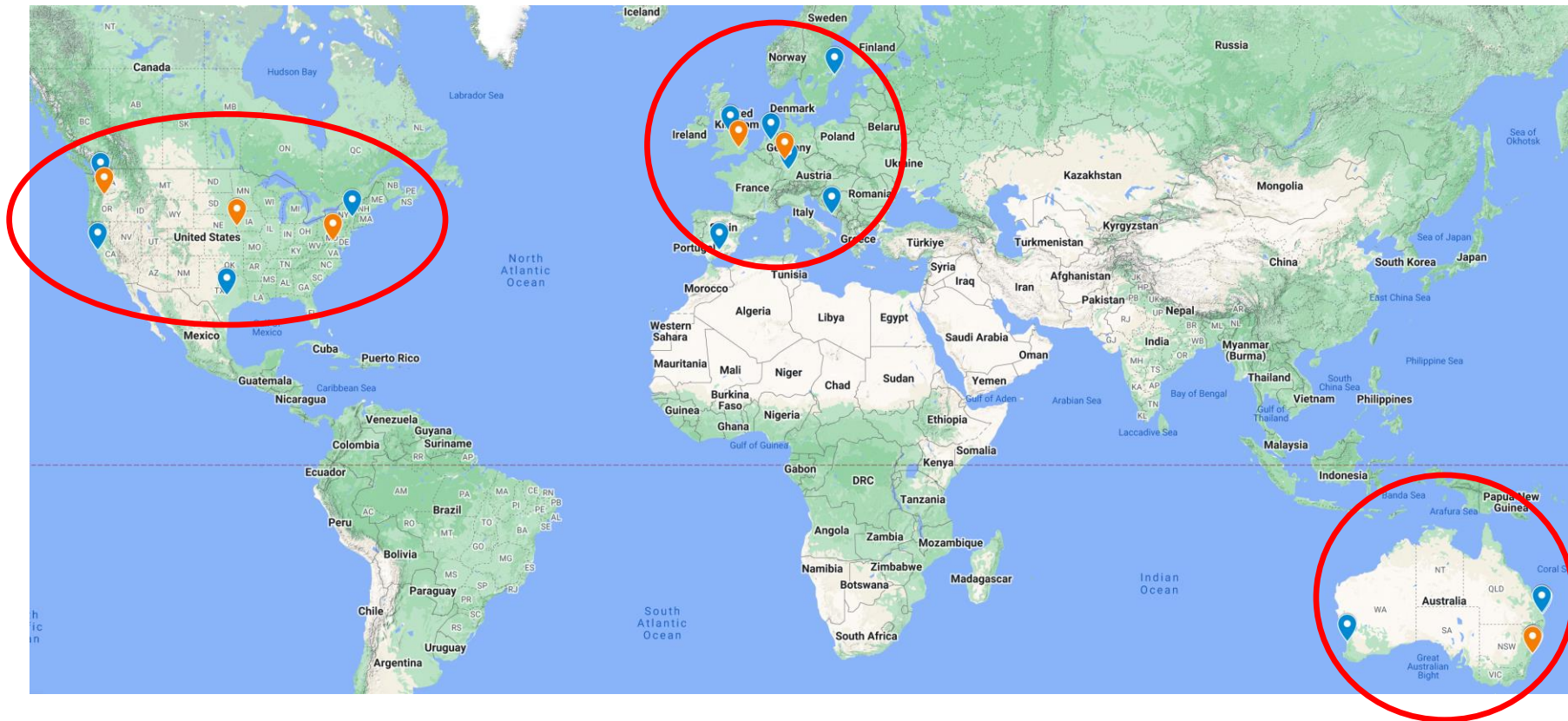


Starlink: Expected Speeds per Service Level

SERVICE PLAN	STANDARD (FIXED)	PRIORITY (FIXED)	MOBILE (MOBILITY)	MOBILE PRIORITY (MOBILITY)
AVAILABILITY	≥99%	≥99%	≥99%	≥99%
DOWNLOAD	25-100 Mbps	40-220 Mbps	5-50 Mbps	40-220 Mbps
UPLOAD	5-10 Mbps	8-25 Mbps	2-10 Mbps	8-25 Mbps
LATENCY*	25-60 ms	25-60 ms	<99 ms	<99 ms

SOURCE

Methodology: Starlink Deployments



Methodology

4 in United States:

- San Francisco, California
- North Bend, Washington
- Georgetown, Texas
- Selkirk, New York

6 in Europe:

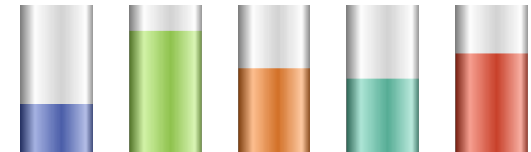
- Weinstadt, Germany
- Klek, Croatia
- Bakewell, United Kingdom
- Epe, Netherlands
- Jaen, Spain
- Stockholm, Sweden

5 in Australia:

- Perth
- Erskineville
- Kedron
- Brookvale
- Burpengary

- HP EliteDesk G2 Mini agents (i5, 16GB RAM, 200GB HDD, 1Gbps NIC) provisioned with Ubuntu 22.04 (latest LTS)
- Agent is connected to Starlink router using Starlink Ethernet adapter

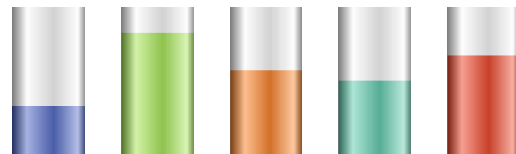
Testing and Performance Measurement



Methodology

- Tested upload/download speeds using Ookla's Speedtest
 - Captured 15 Speedtest measurements per agent (fair use, controlled test number/frequency)
 - Identified average values across 15 measurements
- **Deployed 6 iPerf servers around the globe within GCP:**
 - 3 in United States: US East (Virginia), US Central (Iowa), US West (Oregon)
 - 2 in Europe: EU East (London, UK), EU Central (Frankfurt, Germany)
 - 1 in Australia: AU East (Sydney, Australia)
- iPerf Server locations were selected based on proximity to Starlink POPs
- Each of iPerf servers had 1Gbps+ ingress/egress connectivity (as per GCP instance selection)
- **Sustained throughput measurements using iPerf3:**
 - 7200 data points (2 hours)
 - Tested download/upload separately
 - Each agent deployed behind Starlink tested to/from every iPerf server within the continent
- **Tests conducted using TCP**

Testing and Performance Measurement

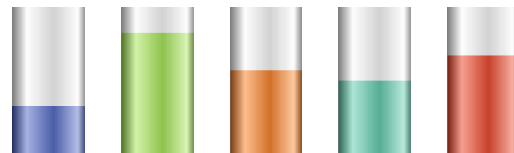


Important notes on Ookla's Speedtest

- Utilizes a large number of servers worldwide (~15k)
- Based on geolocation, utilizes servers with the lowest latency to the client executing probe
- Tests are short-lived and don't involve large file transfers
- We highlighted average download/upload speeds across 15 measurements
- 15 measurements to ensure fair and optimal use of third-party party service



Testing and Performance Measurement



Australia

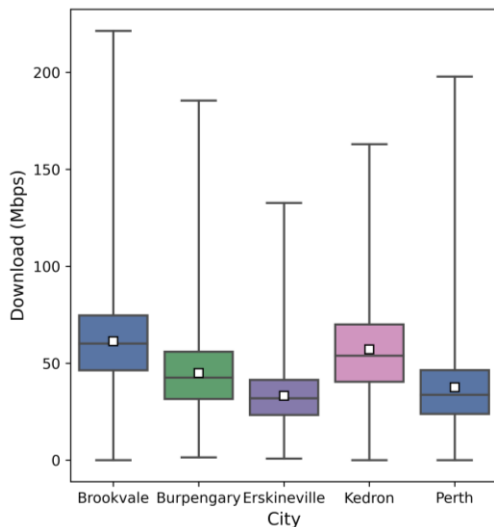
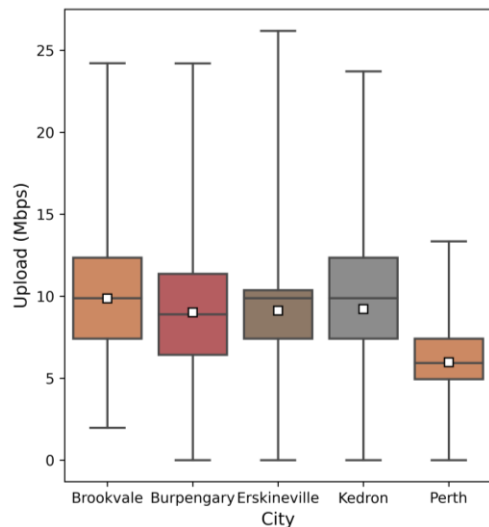
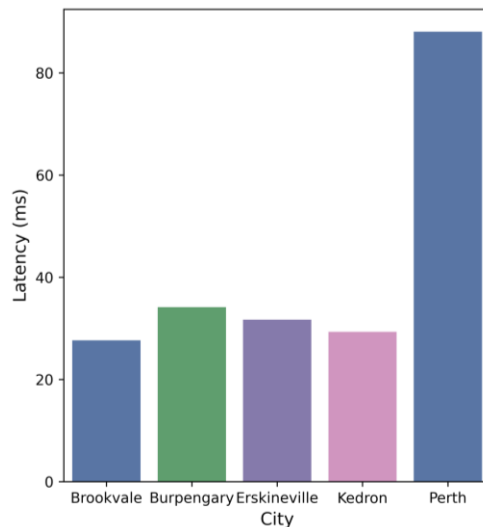


Speedtest Results: Australia



Location	Download	Upload	Latency
Perth, Australia	263.917 Mbps	21.997 Mbps	27.950 ms
Erskineville, Australia	196.262 Mbps	24.263 Mbps	23.611 ms
Brookvale, Australia	242.576 Mbps	19.681 Mbps	26.039 ms
Kedron, Australia	164.503 Mbps	11.630 Mbps	29.173 ms
Burpengary, Australia	170.674 Mbps	17.719 Mbps	29.566 ms

AU East Throughput Measurements



- Brookvale achieved highest Download (61.367 Mbps) and Upload (9.862 Mbps) with lowest latency (27.642 ms)
- Perth, unsurprisingly, had highest latency of 88.038 ms
- Erskineville had lowest Download (33.199 Mbps) while Perth had lowest Upload (5.972 Mbps)

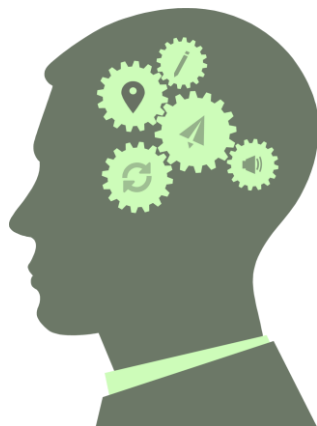
Updated Methodology



- The same methodology with a “small” configuration change
- We enabled **BBR**:
 - On Linux agents behind Starlink – tested Upload
 - On iPerf servers (within GCP) – tested Download

Brief refresher on **BBR**:

- **B**ottleneck **B**andwidth and **R**ound Trip
- **Congestion Avoidance Algorithm** developed by Google
- **Uses latency as an indicator** that the queue at the bottleneck is getting filled through different techniques
- **Less sensitive to packet loss**



AU East: Diff. between BBR and CUBIC



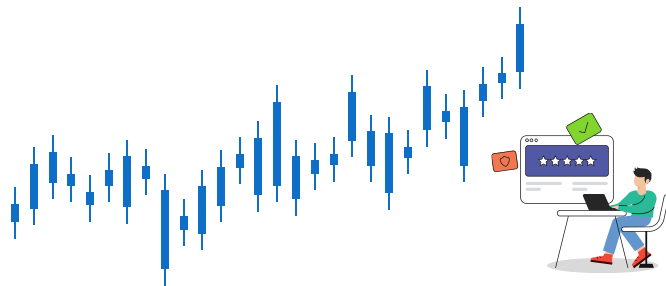
TCP CUBIC is called "CUBIC" because of its unique congestion control algorithm, which uses a **cubic function** to determine how the TCP congestion window size grows over time. Unlike older congestion control algorithms like TCP Reno or TCP NewReno, which use a linear increase after packet loss (to steadily open up the congestion window), TCP CUBIC's growth pattern follows a cubic curve.

CUBIC / BBR comparison						
Location	CUBIC Download	BBR Download 	Difference	CUBIC Upload	BBR Upload 	Difference
Perth	37.610	150.575	4X	5.972	12.988	2.1X
Erskineville	33.199	264.460	7.9X	9.118	11.320	1.2X
Brookvale	61.367	226.863	3.6X	9.862	13.800	1.3X
Kedron	57.161	158.254	2.7X	9.214	11.566	1.2X
Burpengary	44.947	256.011	5.6X	9.017	13.135	1.4X

Average Download/Upload speeds across 7,200 data points to/from AU East using iPerf

Conclusion

- **Starlink largely delivering on its promise** when it comes to expected vs. delivered speeds per service level
- **Lower latencies** translate to **better performance**
- Research shows that 70% of the content is served using CDN providers, heavily aiding Starlink performance given lower latencies
- Multiple different contributing factors for the discrepancy between Speedtest values compared to sustained throughput measurements



- **Underlying TCP mechanisms play a significant role** in Starlink performance
- Congestion avoidance algorithm **BBR** shows significantly better results:
 - Between **1.4x and 18.4x** difference when it comes to Download
 - Between **1.2x and 3.4x** difference when it comes to Upload
- **Time to switch to BBR as default congestion avoidance algorithm, on the major operating systems?**

9
6

Construction & Disaster Response Use Cases

CISCO *Live!*

Ian



In the Media...

TECH

CBS 8 San Diego using Starlink technology to steady TV live shots

CBS 8 San Diego deployed SpaceX Starlink technology to provide seamless connectivity to CBS 8 Studios for transfers, communication, and live television transmission.



Starlink wedge terminal feeds a Dejero link bonding Gateway

<https://www.cbs8.com/article/tech/cbs-8-san-diego-using-starlink-to-steady-tv-live-shots/509-49844a2e-4ac2-4de3-be1c-8330449122a9>

CISCO *Live!*



Building the Trans Mountain Expansion Project

Pipeline construction is now underway, with [Trans Mountain Corporation \(TMC\)](#) anticipating that construction will be completed by late 2023.



The Trans Mountain Corporation (TMC) has hired over 13,500 people to work on sites in Alberta and British Columbia.

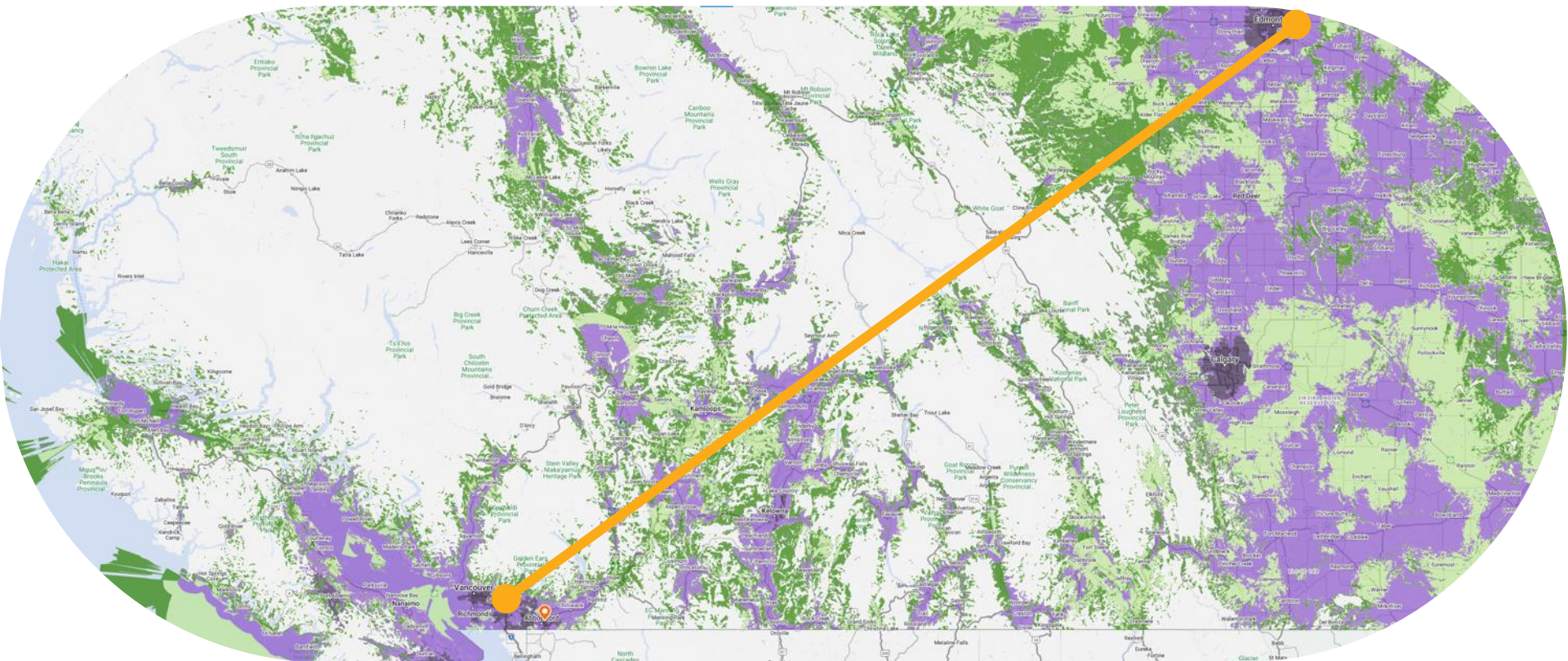
With a focus on Indigenous, local and regional workers, the project is providing good jobs for heavy equipment operators, trades people, environment and safety specialists, engineers and construction managers.

Source: <https://www.canada.ca/en/campaign/trans-mountain/building-the-pipeline.html>

But How Do You Deal With The Canadian Rockies?



Cellular Coverage Along The Route





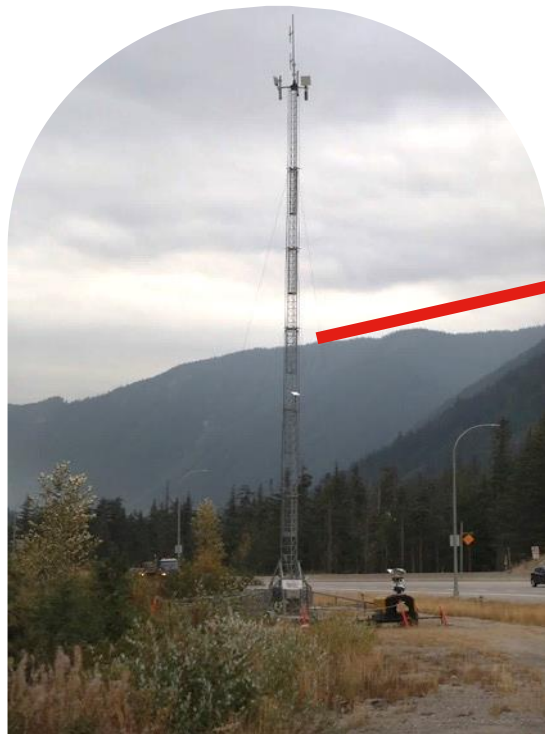
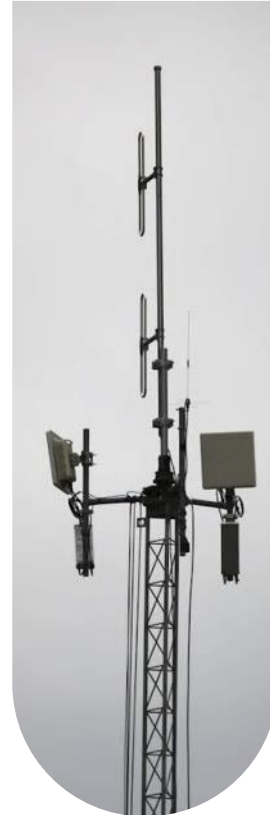
Portable Towers with Starlink Keep Crews Connected



Fixed / Portable Communications Infrastructure



What's On The Tower?



1. Starlink backhaul
2. VHF Repeater
3. 2.4 & 5GHz Wi-Fi (Sectorized)



Radio Over LEOsat ...

System Type	CONVENTIONAL	CONVENTIONAL IP NETWORK	SINGLE-SITE TRUNKING	MULTI-SITE TRUNKING	ENHANCED MULTI-SITE TRUNKING
			NXDN: Type-D TRKG	NXDN: Type-C TRKG P25: PHASE 1/2 TRKG	NXDN: Gen2 P25: PHASE 2 TRKG
					
No. of Radios					
Trunking	N/A	N/A	DECENTRALIZED CONTROL	CENTRALIZED CONTROL	CENTRALIZED CONTROL WITH SERVER BASED ARCHITECTURE
No. of Sites	SINGLE	UP TO 16 (unicast) UP TO 48 (multicast)	SINGLE	UP TO 48	UP TO 1000
Advantages	COST & CAPACITY BASELINE	COST EFFECTIVE COVERAGE	COST EFFECTIVE CAPACITY	CAPACITY AND COVERAGE	CAPACITY, COVERAGE AND CONTROL



LEOsat in Disaster Response

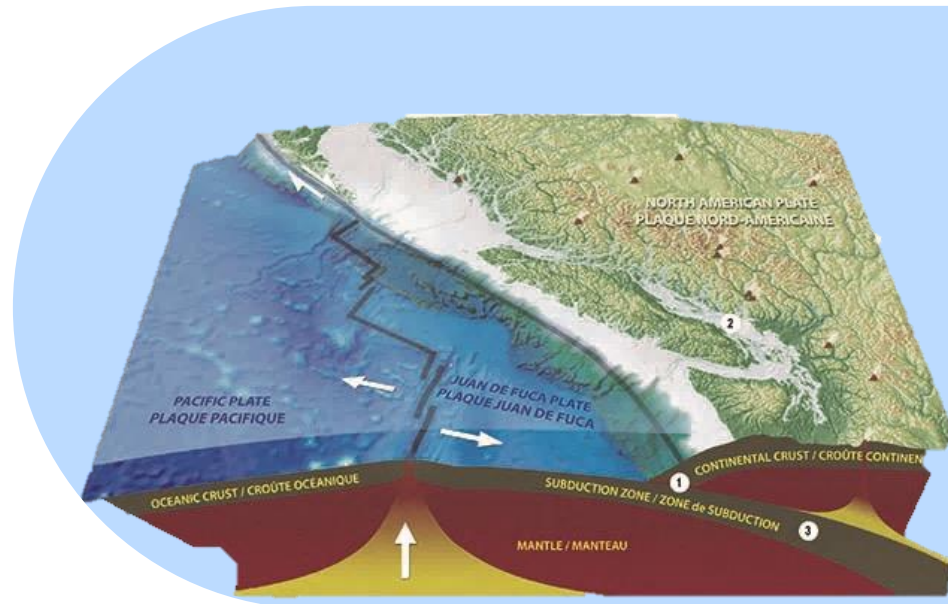


CISCO *Live!*

In 1964 all we lost was telephone...



<https://upload.wikimedia.org/wikipedia/commons/4/4e/AlaskaQuake-FourthAve.jpg>



<https://vancouver.ca/home-property-development/understanding-earthquakes.aspx>

9.2 Magnitude 1964 Alaska Quake

Problem Statement

Reliable communications (voice/data) is the **backbone** of disaster response

Layer 1 issues **will** prevent fast restoration of many wireline services

Cellular communications **impacted** due to power and uplink fragility.

Over the last 10 years agencies have become **dependent** on cloud hosted services (mapping, e-mail, documentation, video-conferencing etc).

VSAT to the rescue?



VSAT to the rescue?



<https://www.dishpointer.com>

How LEOsats Benefit Public Safety

- Trivial to setup and operate
- Highly portable
- Able to work in mountainous terrain vs geo-stationary



<https://star-mountsystems.com/>

Concerns

- Ease of access = lots of people = bandwidth contention
- Will my packets land outside the affected area?



https://www.reddit.com/r/Starlink/comments/kkrh0e/st_johns_nl_canada_Starlink_gateway_photos_and/
<https://www.telesat.com/wp-content/uploads/2020/07/teleport-calgary.jpg>



LEOsat Programmability

CISCO *Live!*

Dave



Telemetry and Starlink



There is an undocumented API, which is used by Starlink's mobile app

- Uses gRPC
 - Is not trivial to learn
 - Output is a binary and is not human readable

What if I don't want to learn how to interact with gRPC endpoints?

- [gRPCurl](#) << curl but for gRPC!
 - Output can be as simple as plaintext in a JSON array
 - `grpcurl -plaintext -d '{"getStatus":{}}' \`
`192.168.100.1:9200 SpaceX.API.Device.Device/Handle`

Great example project: [Sparky8512 Github - Starlink GRPC Tools](#)

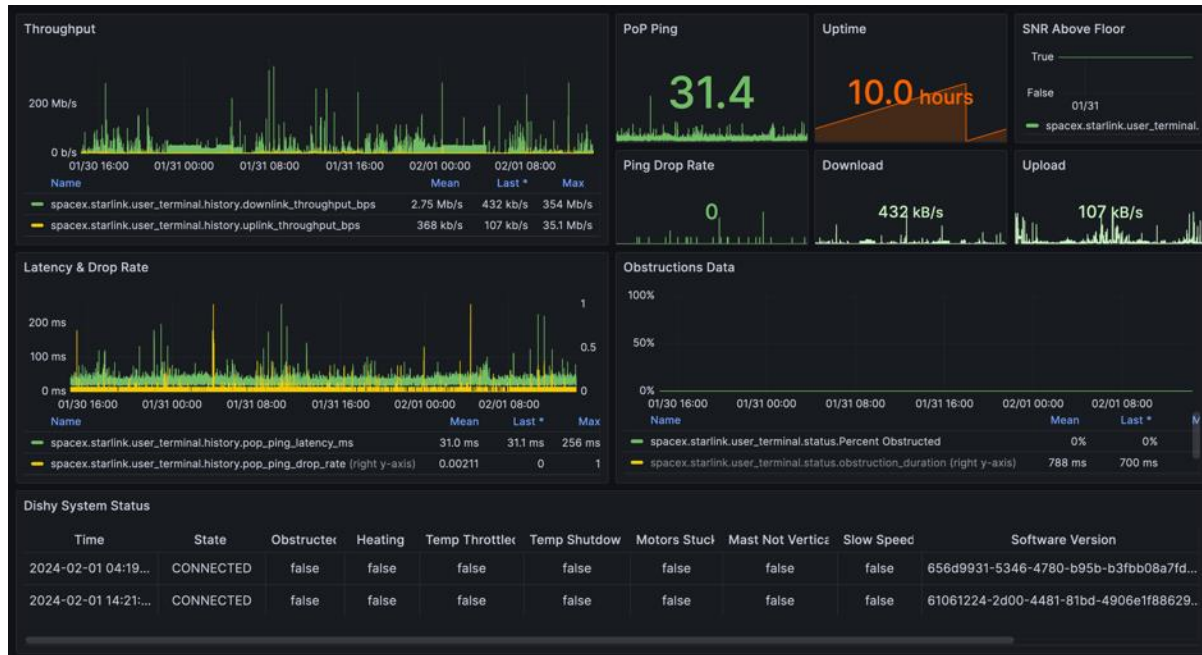


Alex Burger
Principal Engineer, Meraki

Sample Grafana Dashboard



dish_grpc_influx.py



Script: https://github.com/sparky8512/starlink-grpc-tools/blob/main/dish_grpc_influx.py

Dashboard: https://github.com/sponsianus/dishy_grafana/blob/main/grafana-provisioning/dashboards/starlink/starlink.json

cisco *Live!*

LEOsat Future & Opportunities



LEOsats will Democratize Connectivity

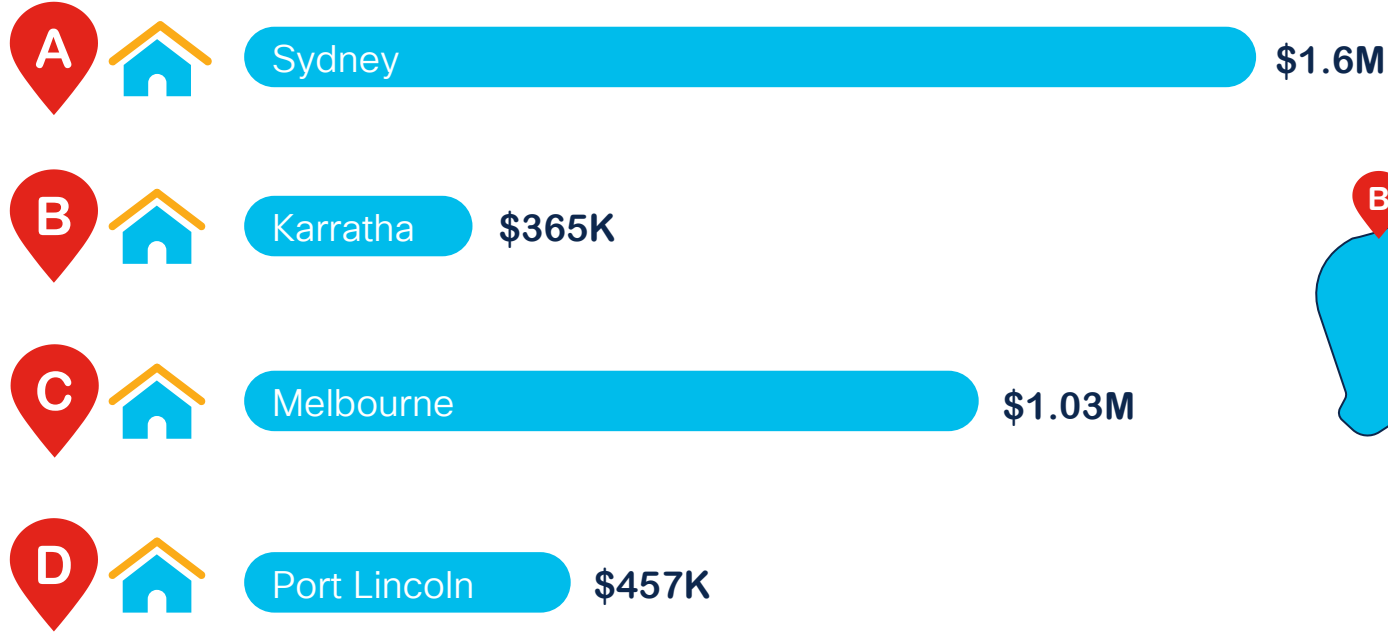
LEOsats will enable mass-scale Digital Nomadism ...

Work from a low-cost location, with better quality of life ...



Photos by Brina Blum, Airfocus and Persnickety Prints on Unsplash

Hybrid Work from Anywhere in the World



Starlink and Microsoft Azure Bring You Azure Space

Microsoft teams up with SpaceX to launch Azure Space to bring cloud computing into the final frontier

By [Chelsea Gohd](#) October 21, 2020

Azure Modular Data Centre

Self-contained

Deployable Anywhere

For remote connectivity or expansion of existing



Edge Computing in Space



**The New Space Age:
IBM Develops A
Unique, Custom Edge
Computing Solution in
Space**

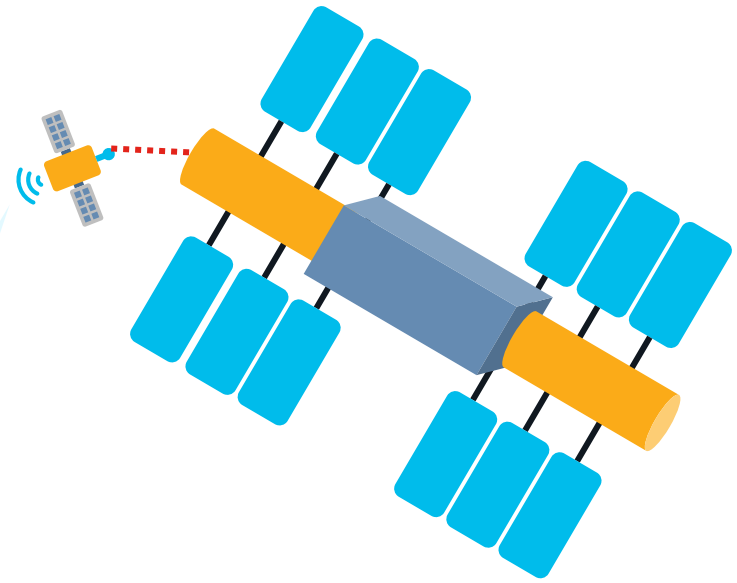
Automation Cloud

19 February 2021 4 min read

By: Naeem Altat, IBM Distinguished Engineer & CTO Space Tech

<https://www.ibm.com/cloud/blog/ibm-develops-a-unique-custom-edge-computing-solution-in-space>

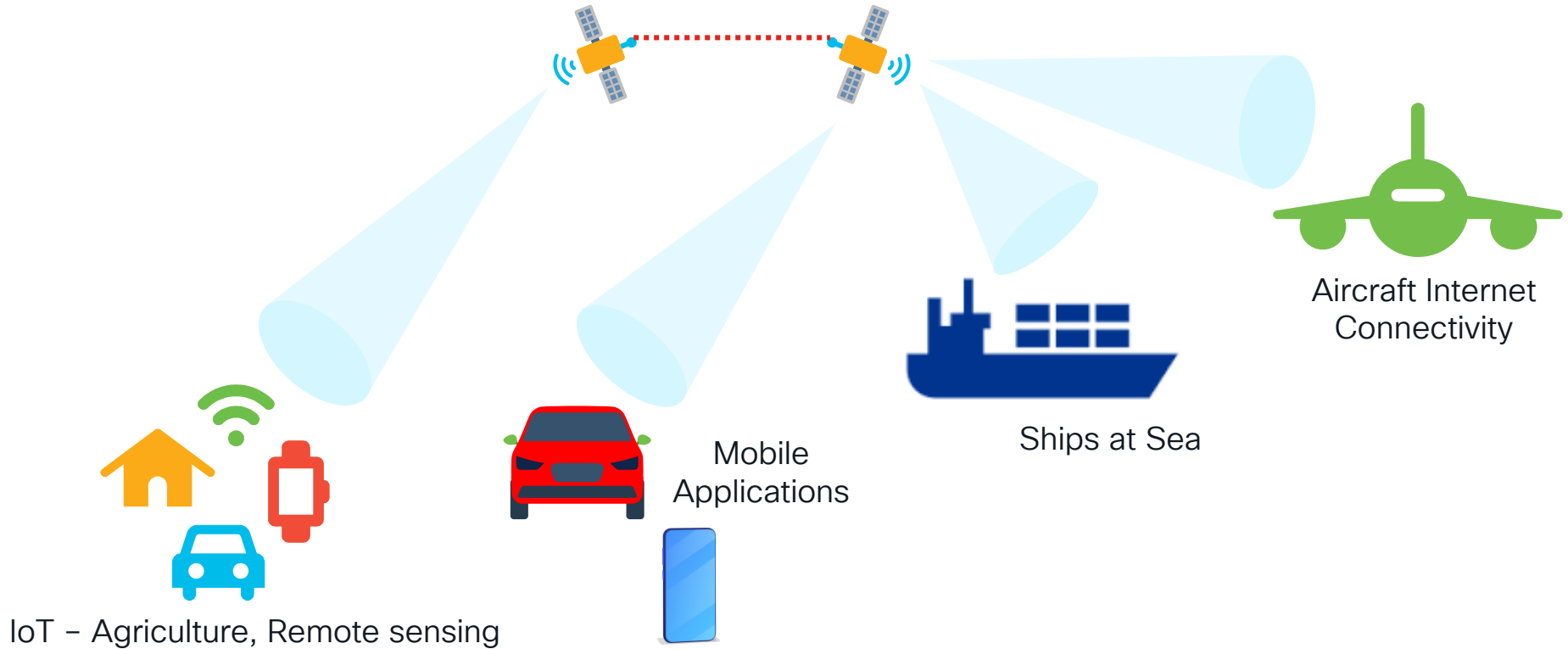
CISCO *Live!*



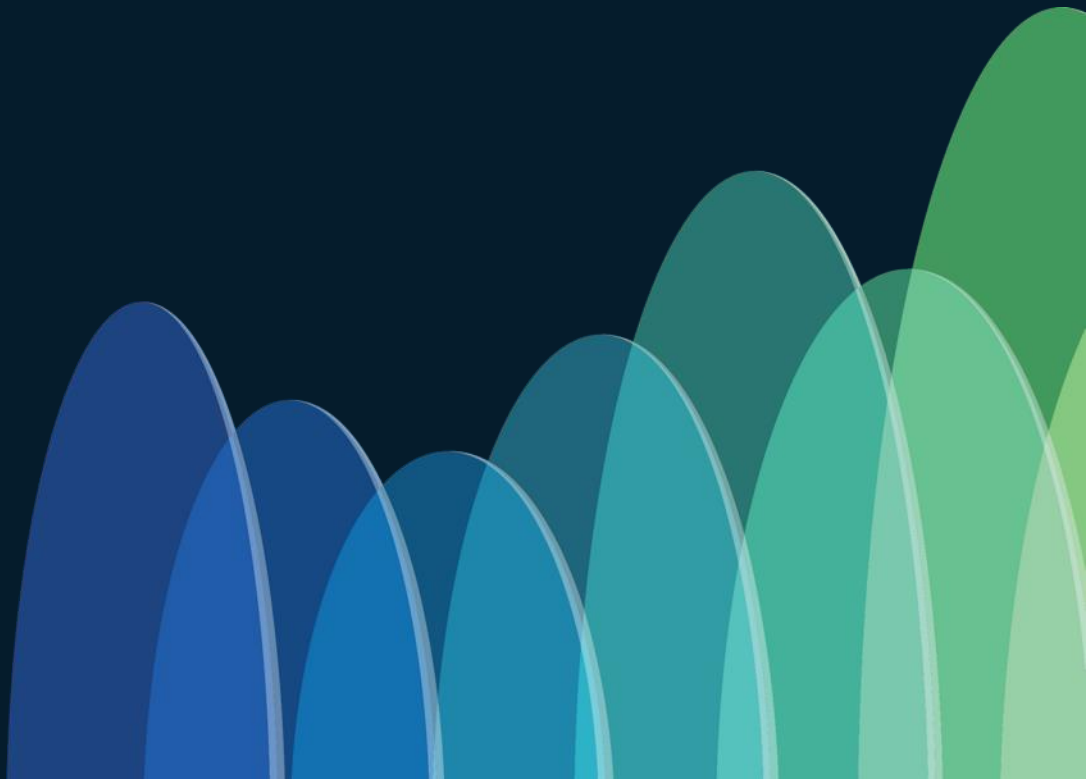
Possibility: Edge Compute on ISS

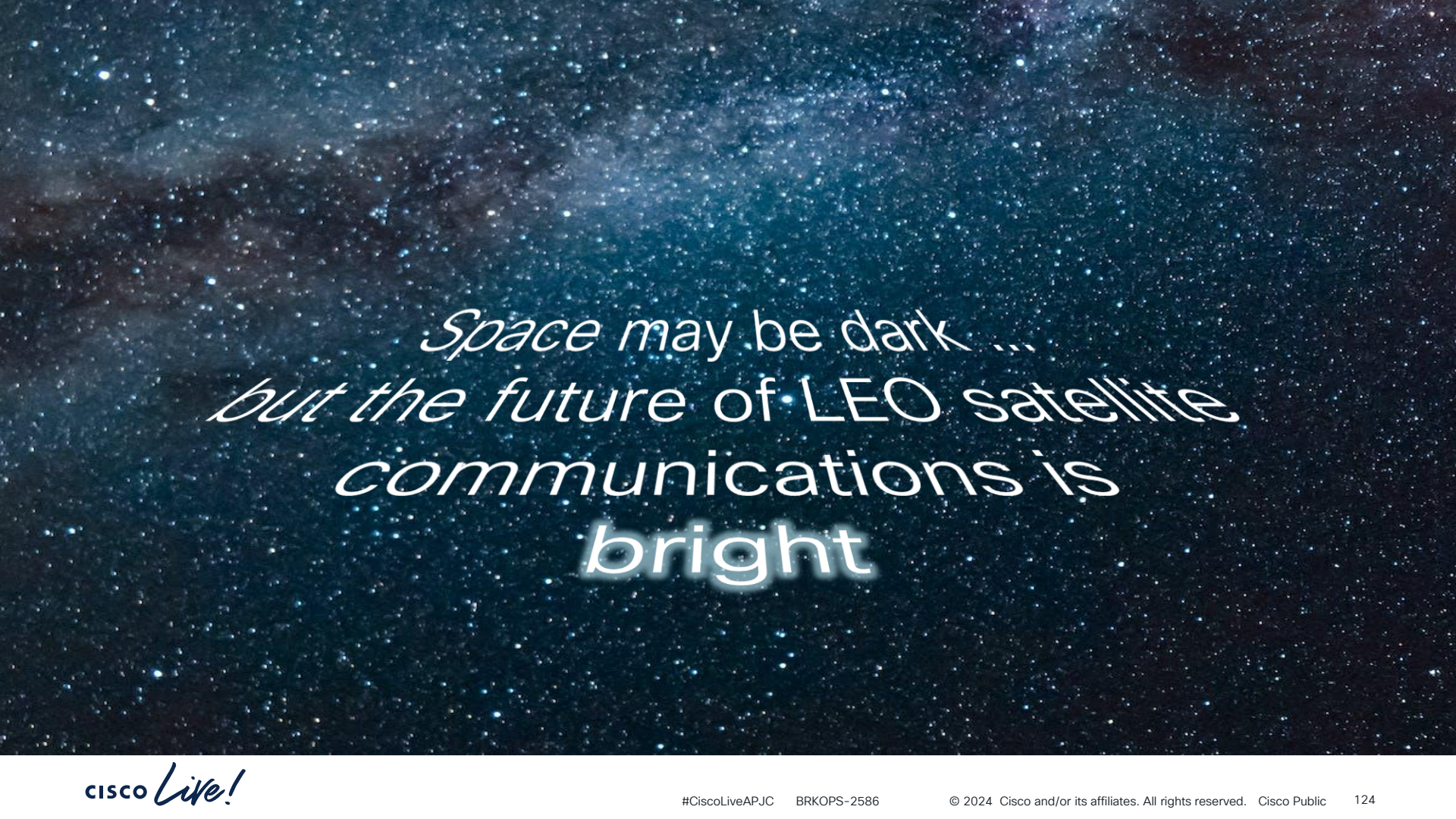
**What goes up, doesn't
necessarily have
to come down...**

The LEOsat Revolution – Unlimited Use Cases



The Beginning...





*Space may be dark ...
but the future of LEO satellite
communications is
bright*

Complete Your Session Evaluations



Complete a minimum of 4 session surveys and the Overall Event Survey to claim a **Cisco Live T-Shirt**.



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- Book your one-on-one Meet the Expert meeting
- Attend the interactive education with DevNet, Capture the Flag, and Walk-in Labs
- Visit the On-Demand Library for more sessions at www.CiscoLive.com/on-demand



Thank you

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#CiscoLiveAPJC

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GO BEYOND

#CiscoLiveAPJC