The bridge to possible

Starlink Security Advanced

Andrew Benhase, Federal Architect
@CyberSecOps

BRKSEC-2150

cisco Live!

#CiscoLive

Cisco Webex App

https://ciscolive.ciscoevents.com/ciscolivebot/#BRKSEC-2150

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How

1. Find this session in the Cisco Live Mobile App
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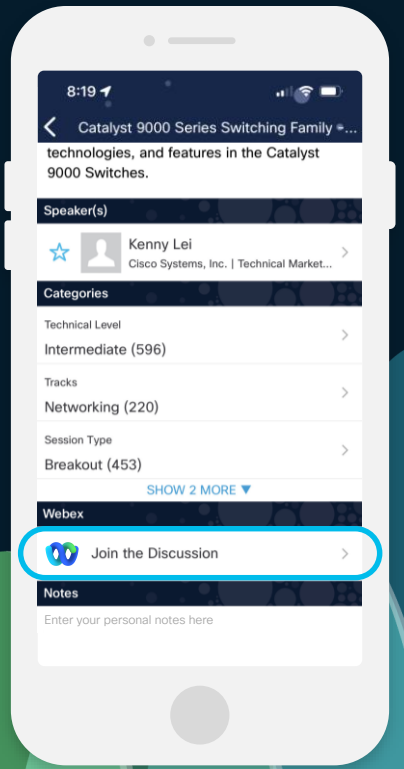
Webex spaces will be moderated by the speaker until June 7, 2024.



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Agenda

- Catch up on current events
- What is Starlink
- Starlink Security
- Deployment Models
- SDWAN
- Conclusion

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What I do here @cisco

- Federal Security Architect
- At Cisco >24 years, supporting US Federal Government
- 32 years primarily supporting US Defense, Civilian and Intelligence Communities
- Deep focus on defensive cyber operations, advanced encryption, making security work!
- My first Networkers was in 1995…
- https://www.linkedin.com/in/andrewbenhase/

@CyberSecOps
@ThreatCowboy
abenhase@cisco.com

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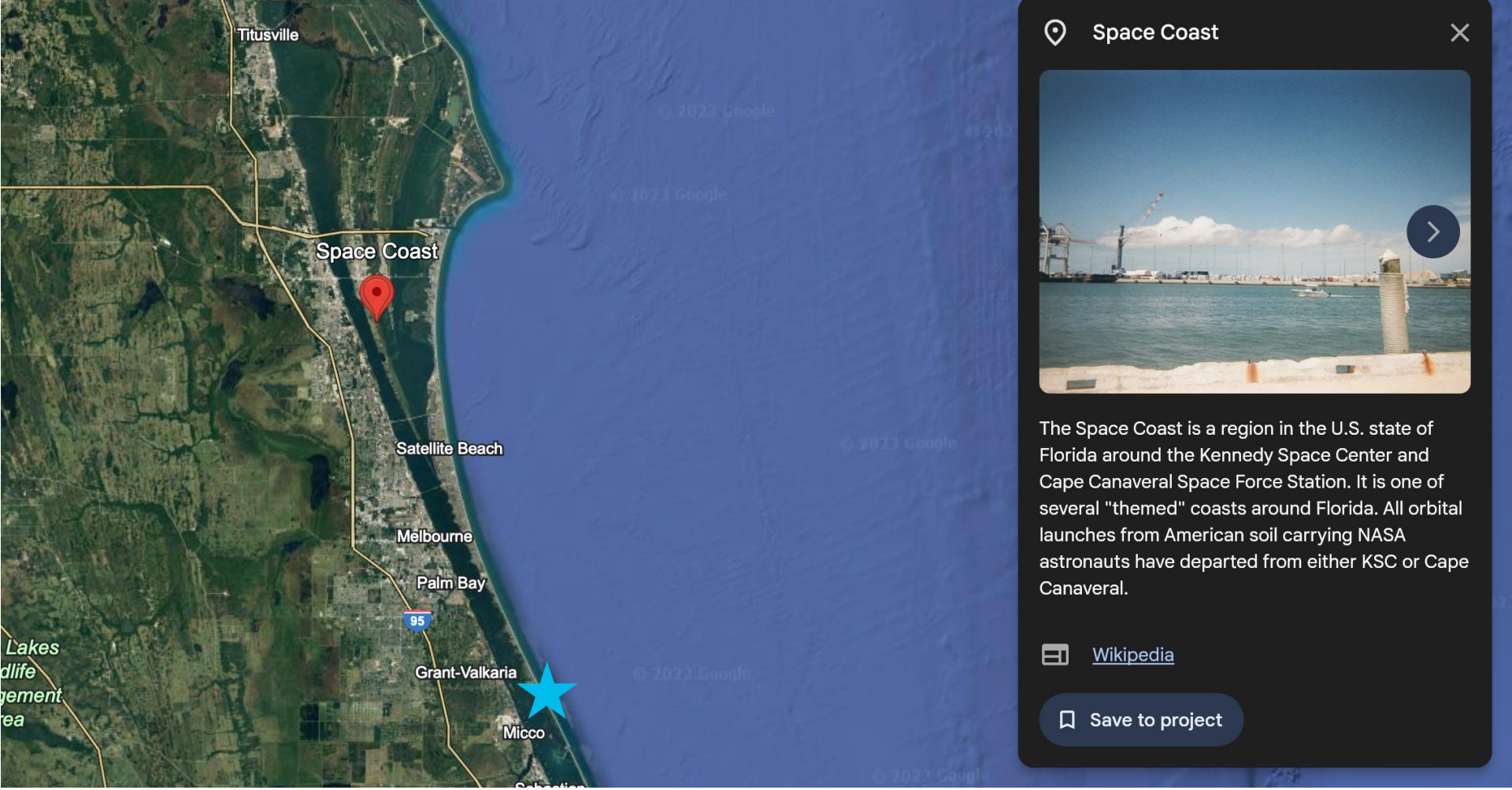

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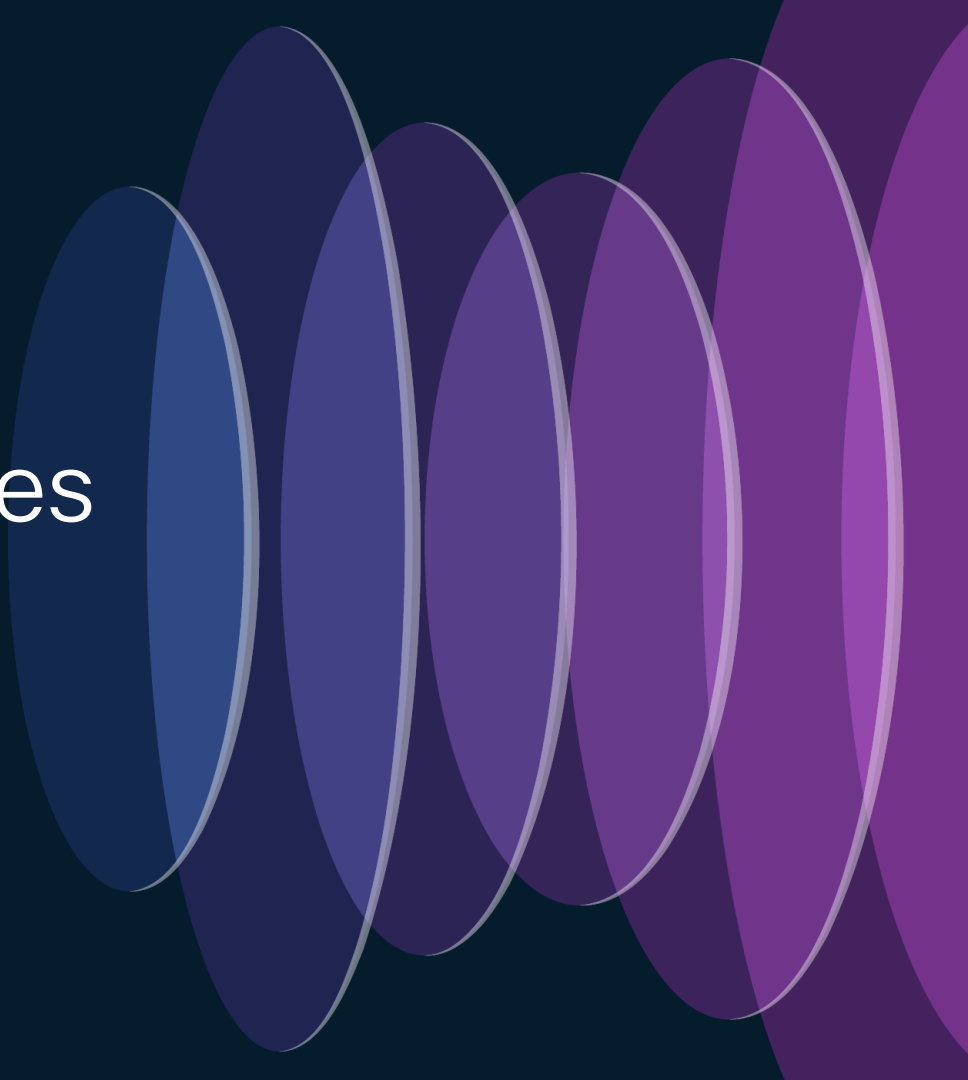
Latest News Updates (since last year)



plane will be better than their
connection at their house

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Credit: SpaceX

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SpaceX Announces a Starship Version Two is in the Works

By Jack Kuhr November 28, 2023

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13:07 5GE

We call them “V2 Mini”. They represent a step forward in Starlink capability

12:37 · 2/26/23 · **843K** Views

6,931 Likes **815** Retweets **91** Quotes

SpaceX @SpaceX · 29m

V2 minis include key technologies—such as more powerful phased array antennas and the use of E-band for backhaul—which will allow Starlink to provide ~4x more capacity per satellite than earlier iterations

24 115 1,681 166K

SpaceX @SpaceX · 29m

This means Starlink can provide more bandwidth with increased reliability and connect millions of more people around the

Tweet your reply

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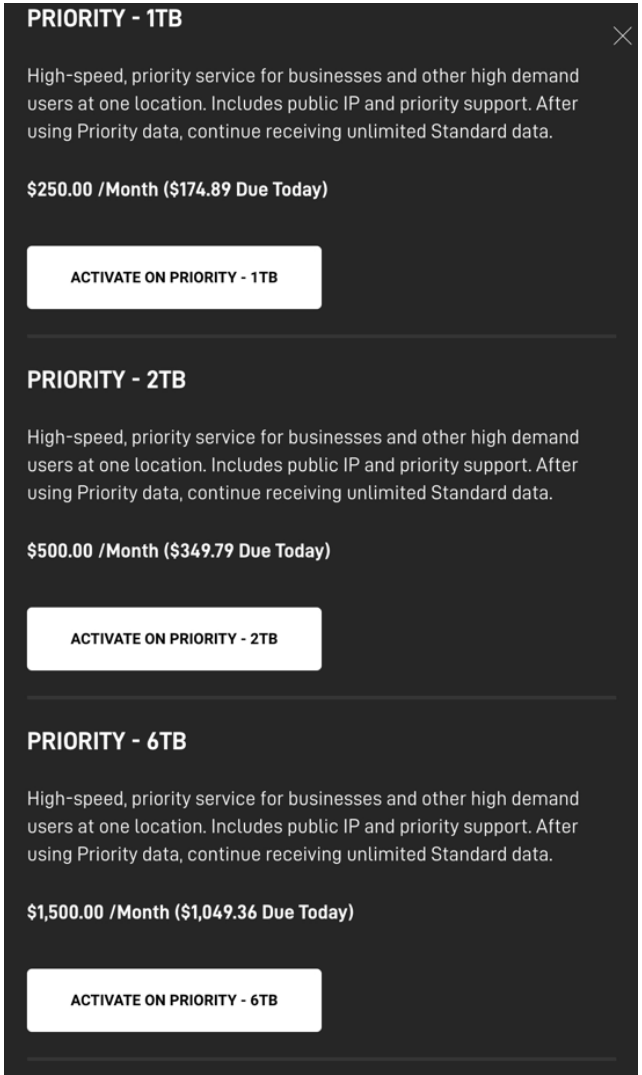
Services Changes – Public IP



STARLINK

You're Invited!

Enjoy an opportunity to experience the next generation Starlink!

The next generation Starlink is slimmer and more portable, with a more elegant design than its predecessor. This Starlink Kit also includes our Gen 3 router with improved range and speeds.

The cost of the Starlink Standard kit is **$599** + Tax and Shipping.

EARLY ACCESS SPECIAL OFFER:
Enjoy your first month of service on us!*

ORDER NOW

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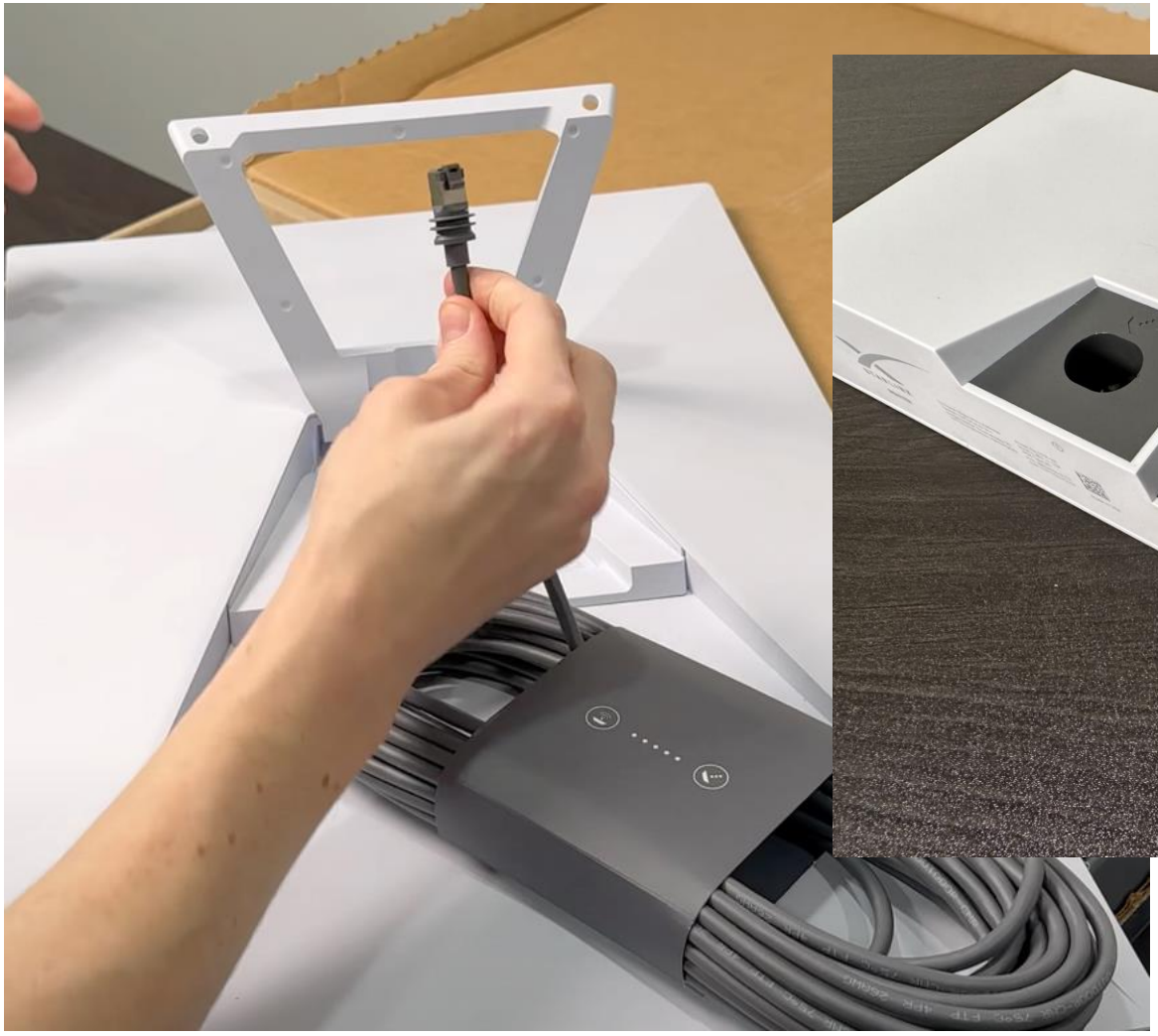

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Cats love Starlink

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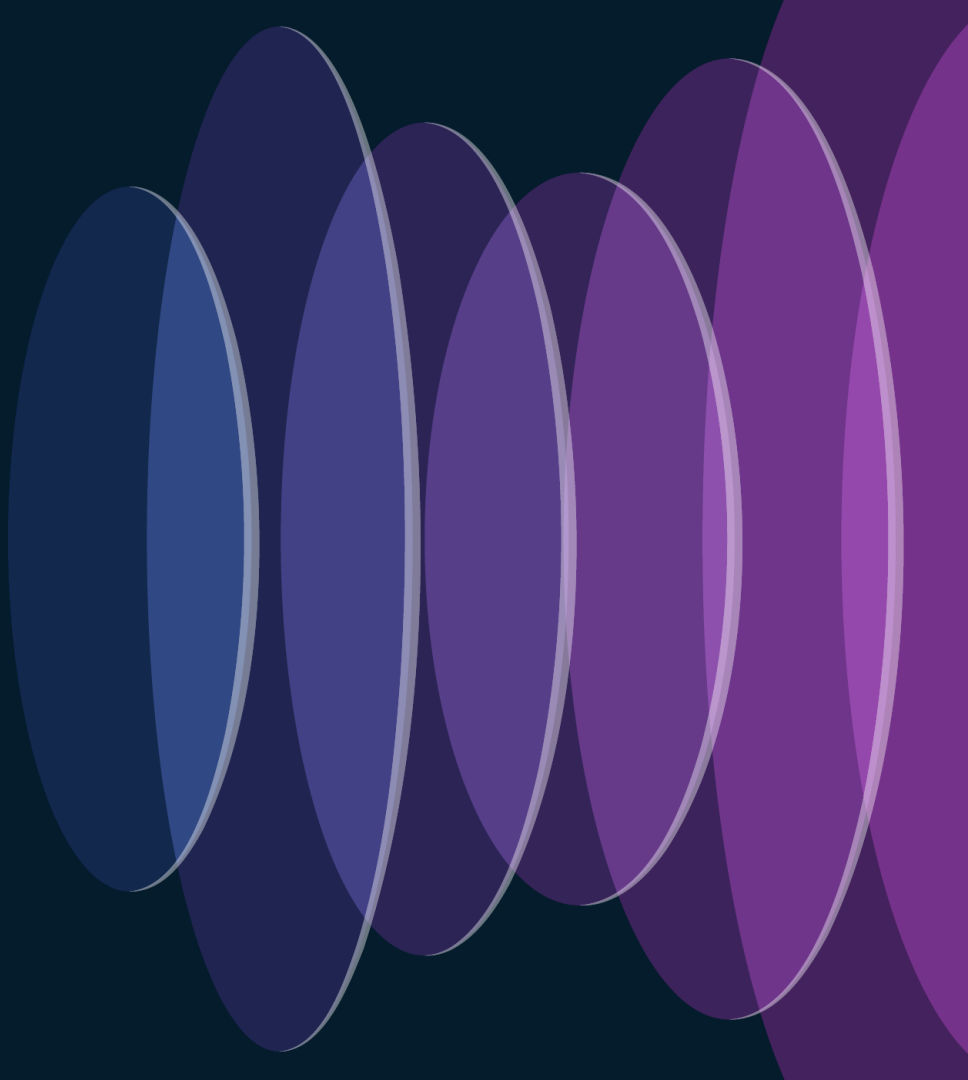
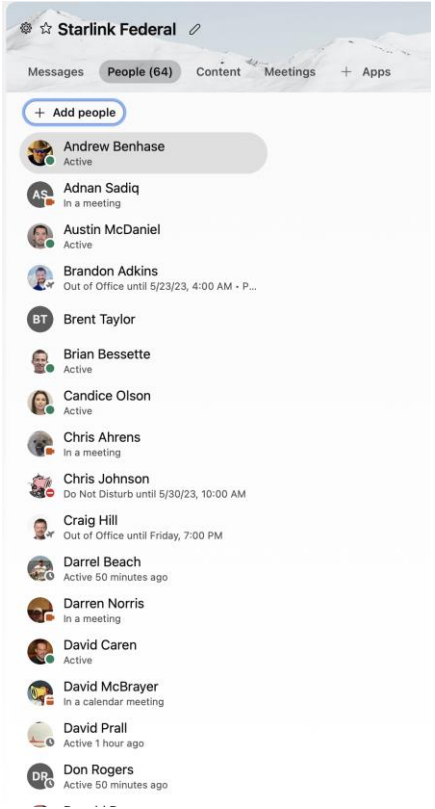
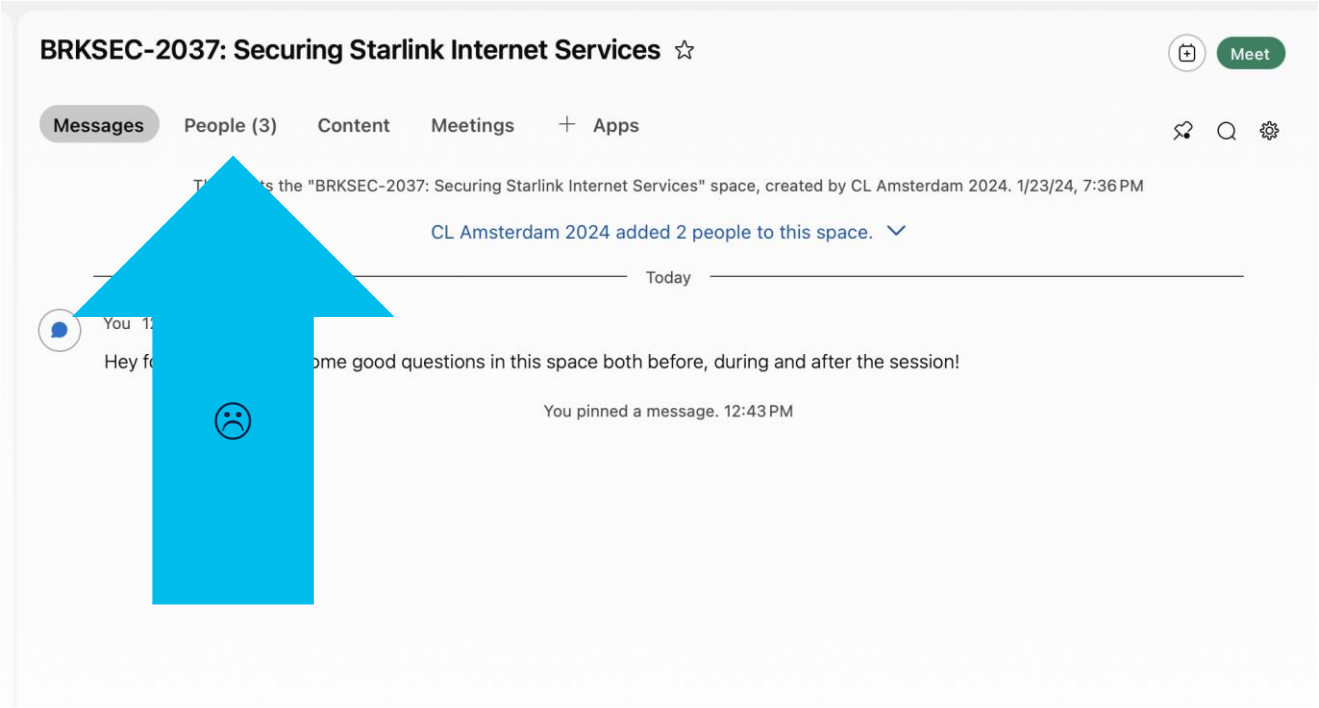
How do you keep up?



Starlink Federal Room (SL-OSINT)





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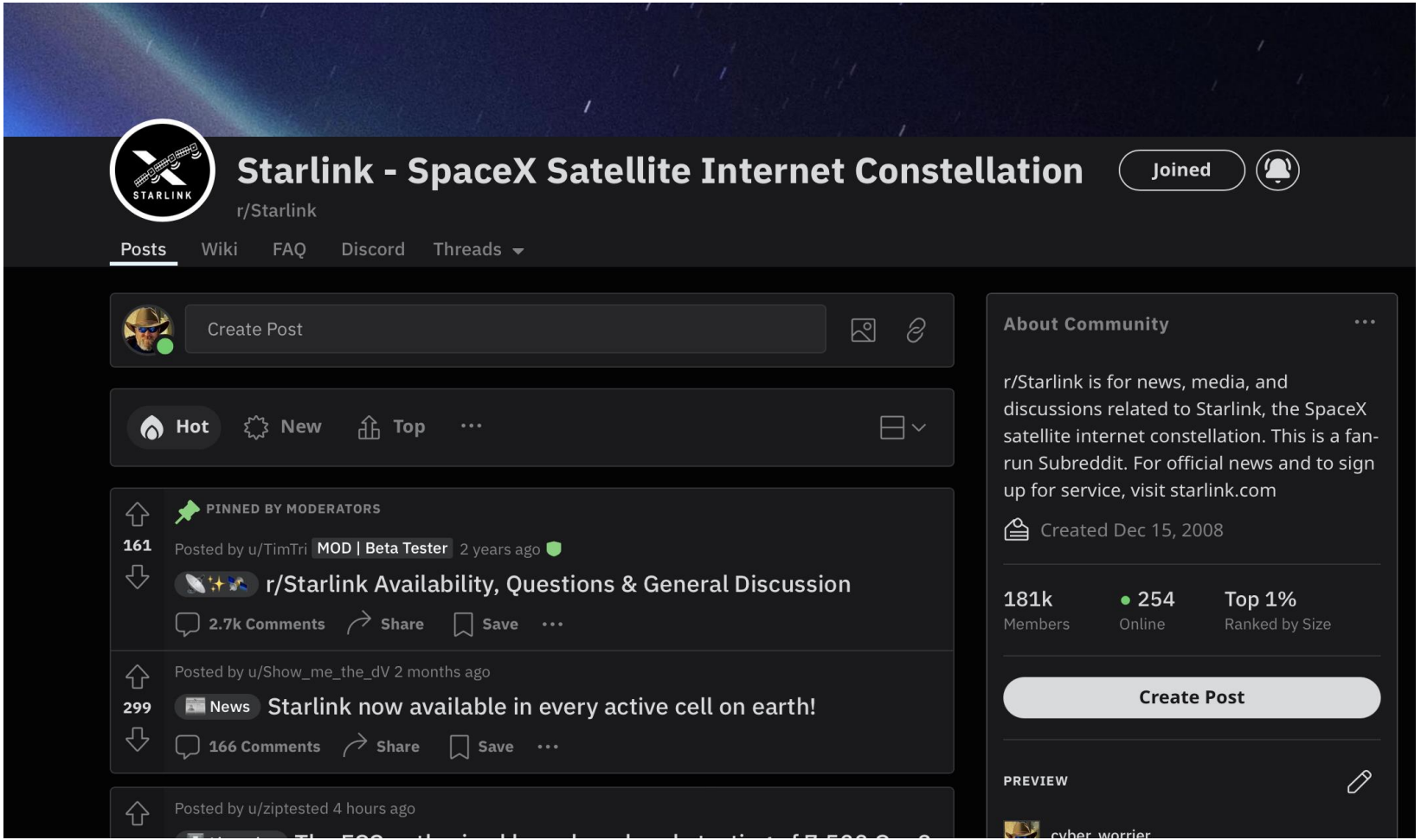

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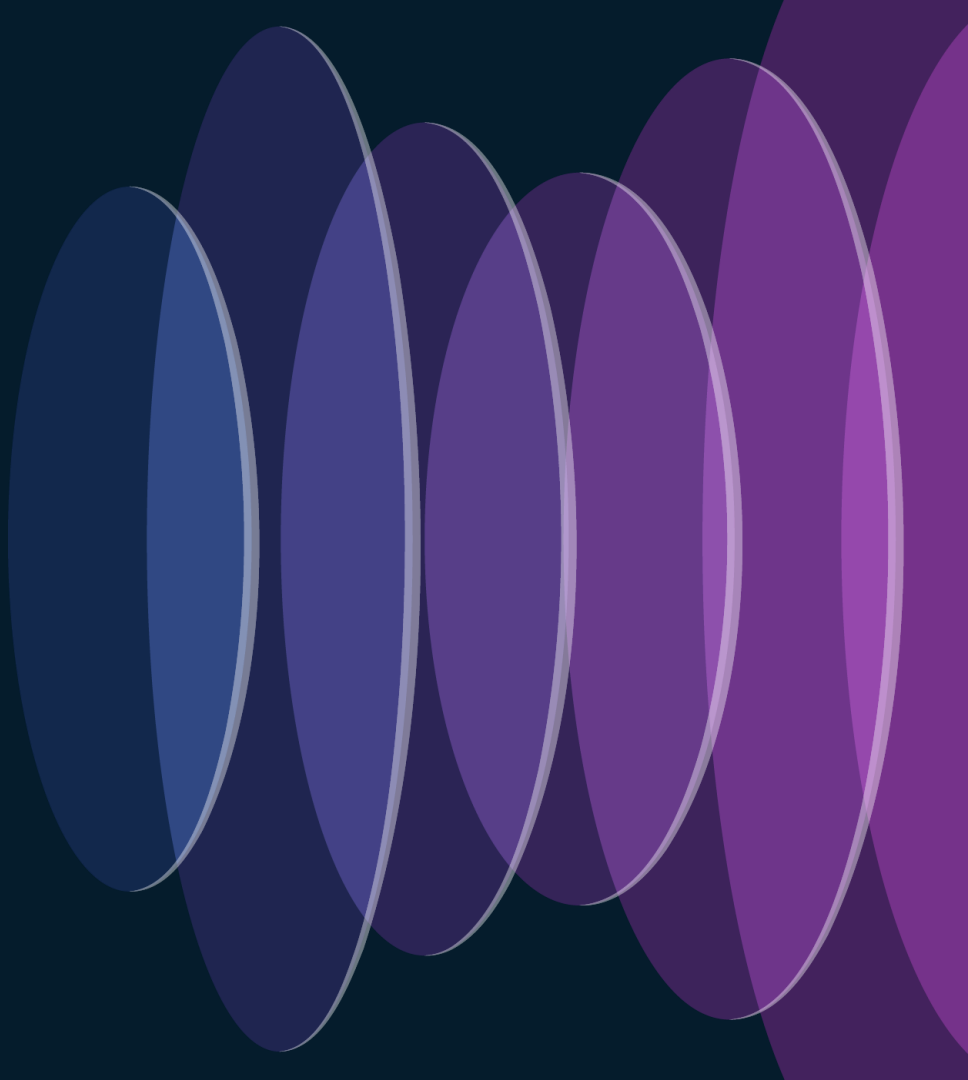
Whats happening with Kuiper?



First Kuiper Launch

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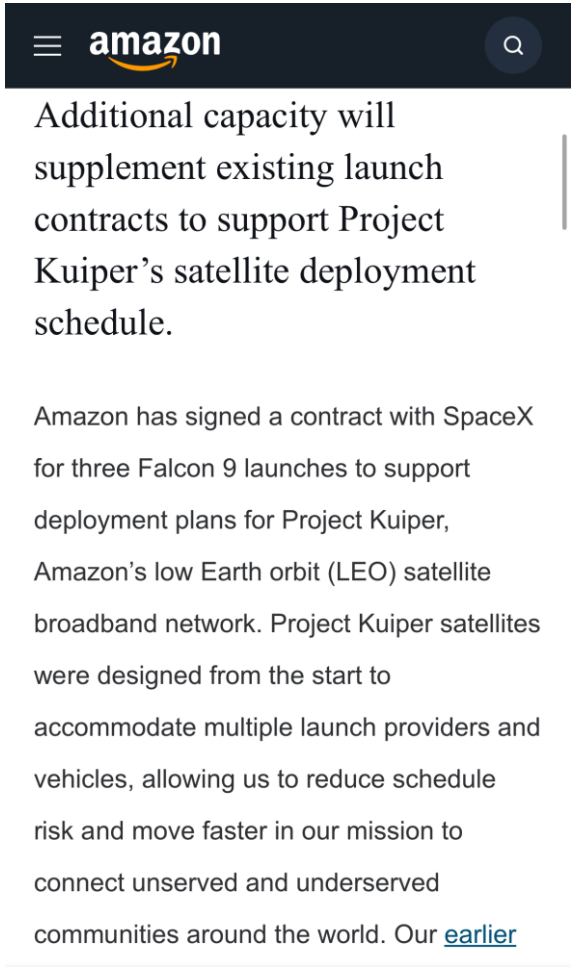
December 2 2023



amazon

Additional capacity will supplement existing launch contracts to support Project Kuiper's satellite deployment schedule.

Amazon has signed a contract with SpaceX for three Falcon 9 launches to support deployment plans for Project Kuiper, Amazon's low Earth orbit (LEO) satellite broadband network. Project Kuiper satellites were designed from the start to accommodate multiple launch providers and vehicles, allowing us to reduce schedule risk and move faster in our mission to connect unserved and underserved communities around the world. Our earlier

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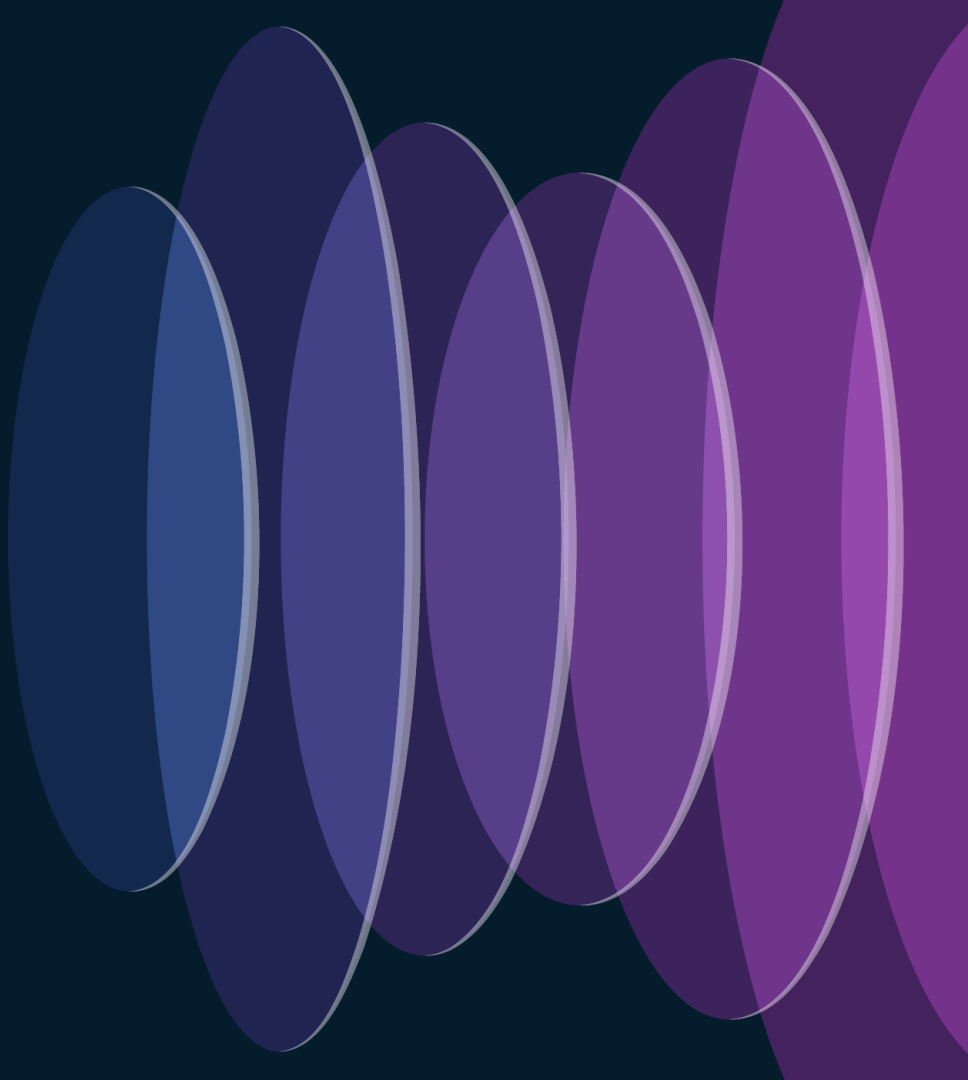
Whats happening with OneWeb?



OneWeb- catering towards Enterprise

- Polar Orbits
- Higher Orbit
- >600 satellites in orbit
- Broad Coverage over Australia
- Focused towards Enterprise Networking

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Agenda

- Orbital Mechanics 101
- What is Starlink today?
- How does Cisco work with Starlink?
- Securing Starlink
- Things you need to know

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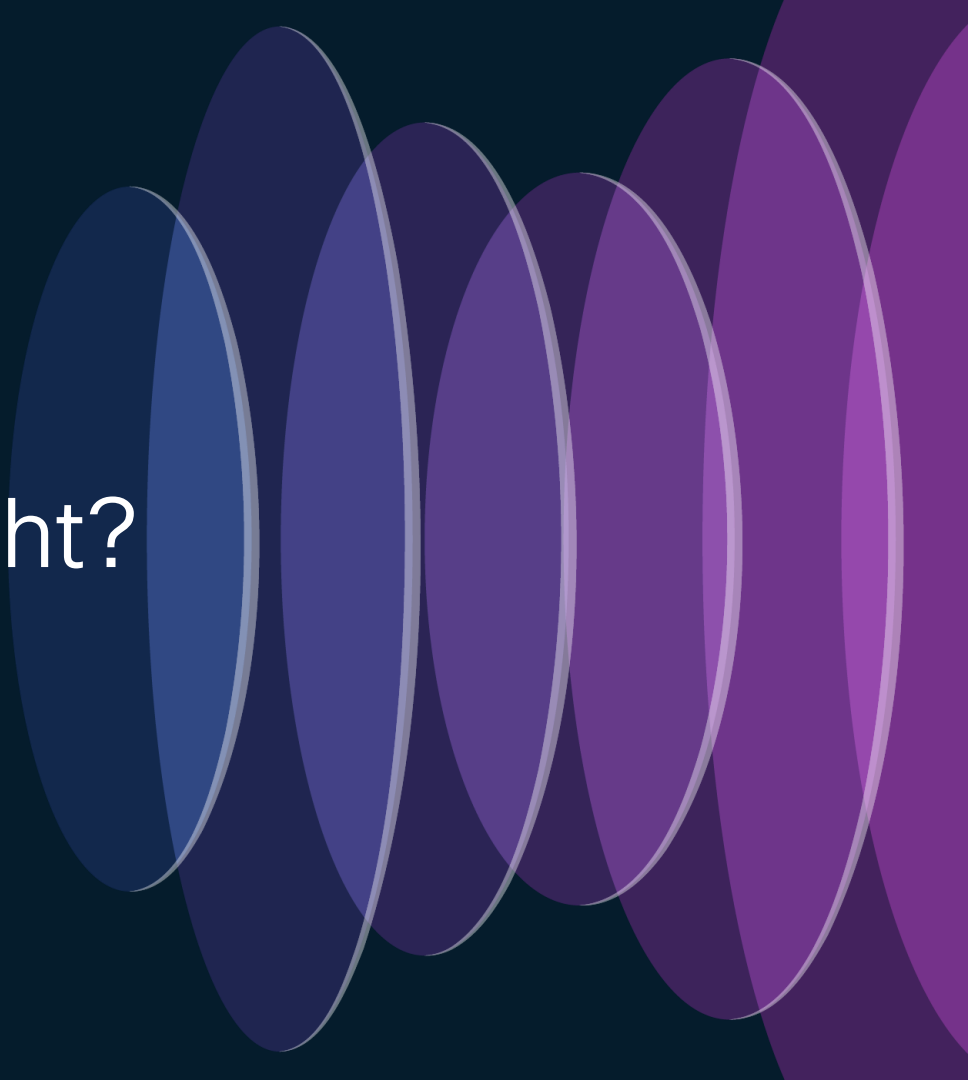
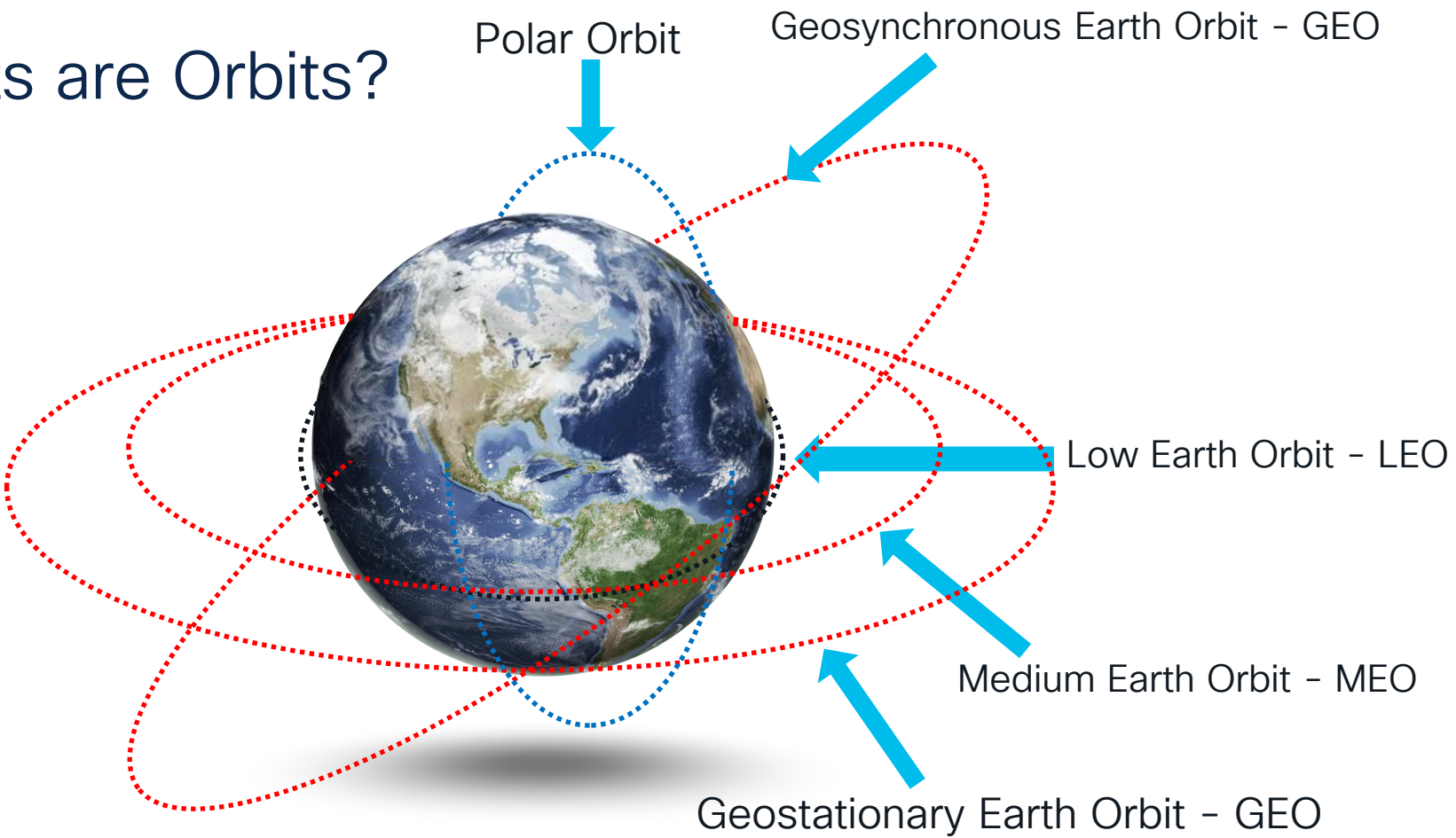
Orbits are orbits right?



Orbits are Orbits?



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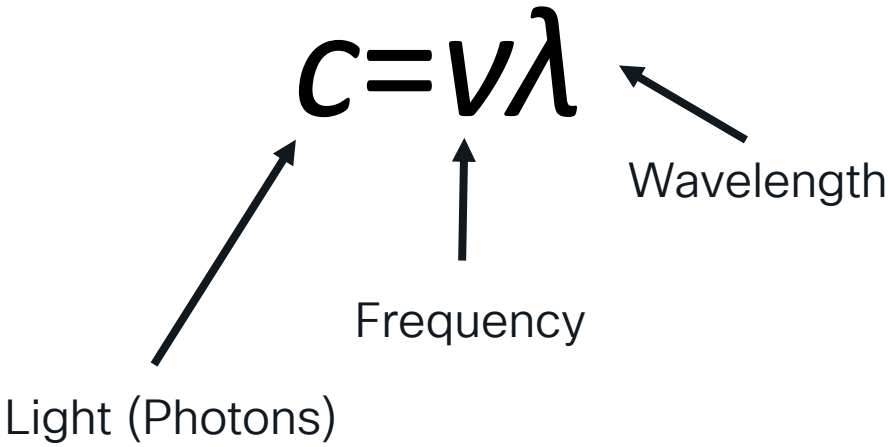
Hey Andrew, this is Cisco Live....
Why do I need to know about physics, orbits, altitudes and latency?

Answer: Because this is an Engineering discussion, not a sales and marketing pitch ☺

Speed of Light in a Vacuum



300,000 km/s

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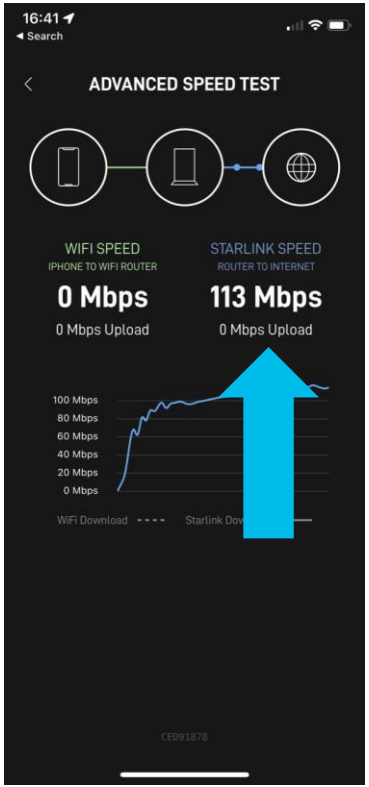

Speed of Light in a Vacuum

Speed of Light in an Atmosphere

Loss Calculation

40ms Great

700ms Not-Great

Terrestrial Ground Delay

10-200ms

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Orbits and Networking

- LEO – 1000 kilometers and below
  - Starlink 540km (345 miles)
  - One way latency – ~12-25ms
  - RTT - ~25-50ms

Happy Network Zone

- MEO – 8000 kilometers (5,000 miles)
  - ~RTT 350ms

Sad Network Zone

- GEO – 36,000 kilometers (22,000 miles)
  - ~RTT 725ms

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Physics Matters

700ms

350ms

40ms

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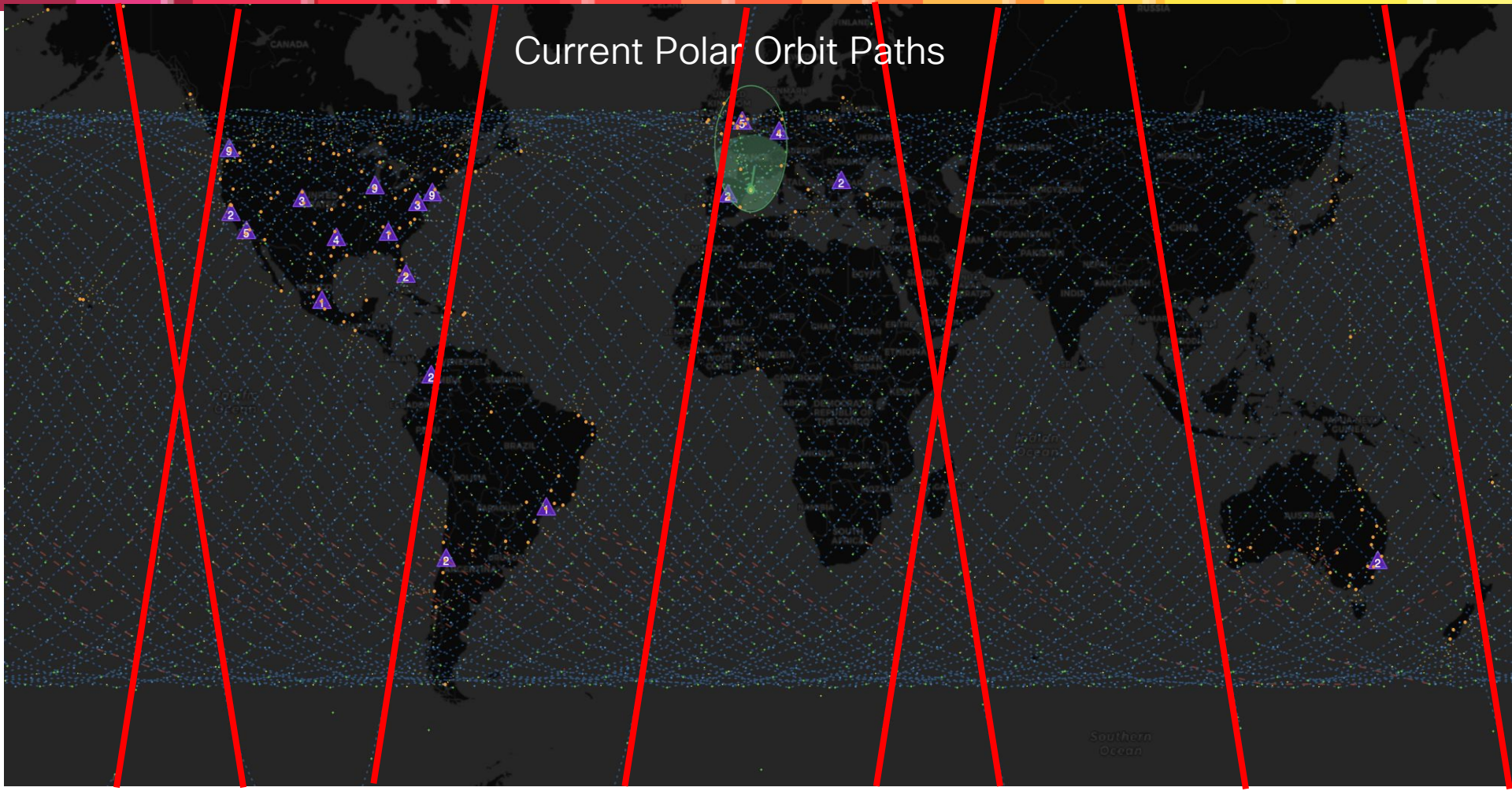
Current Polar Orbit Paths



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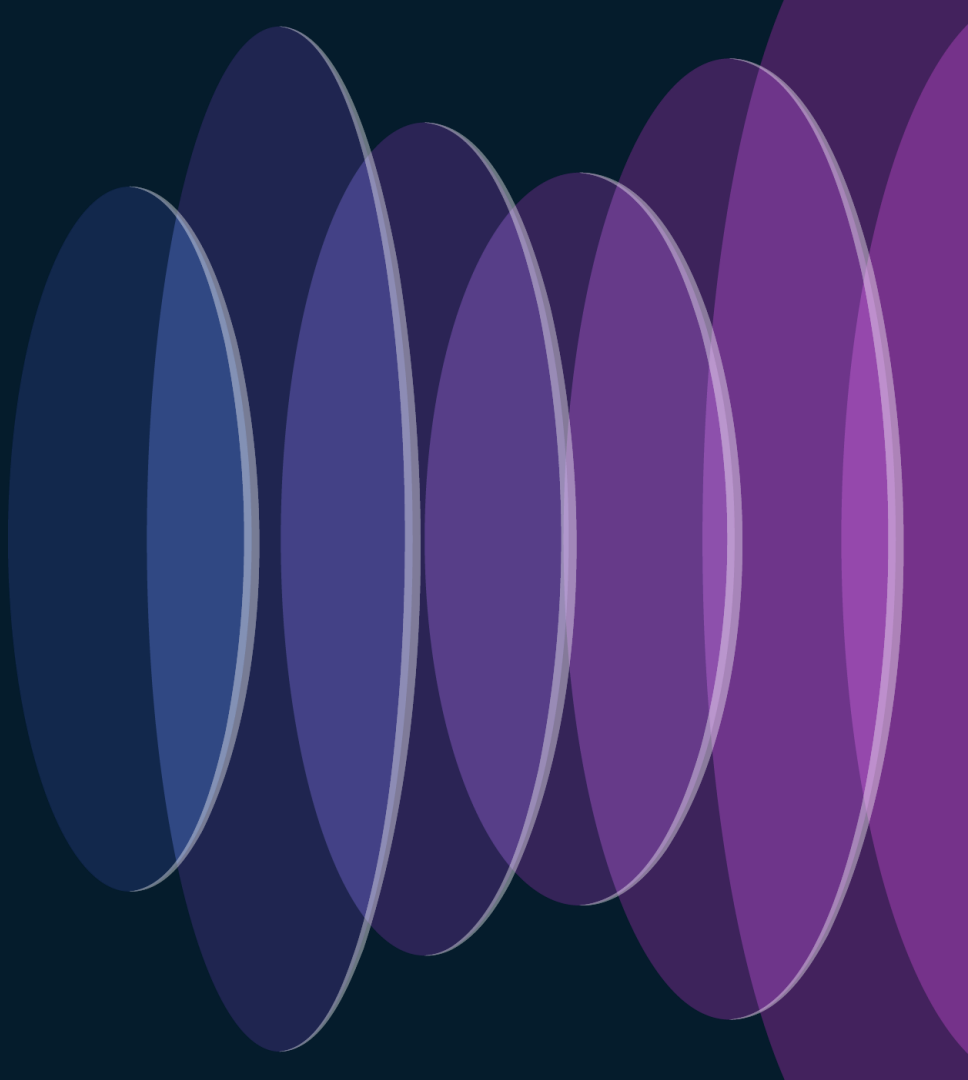
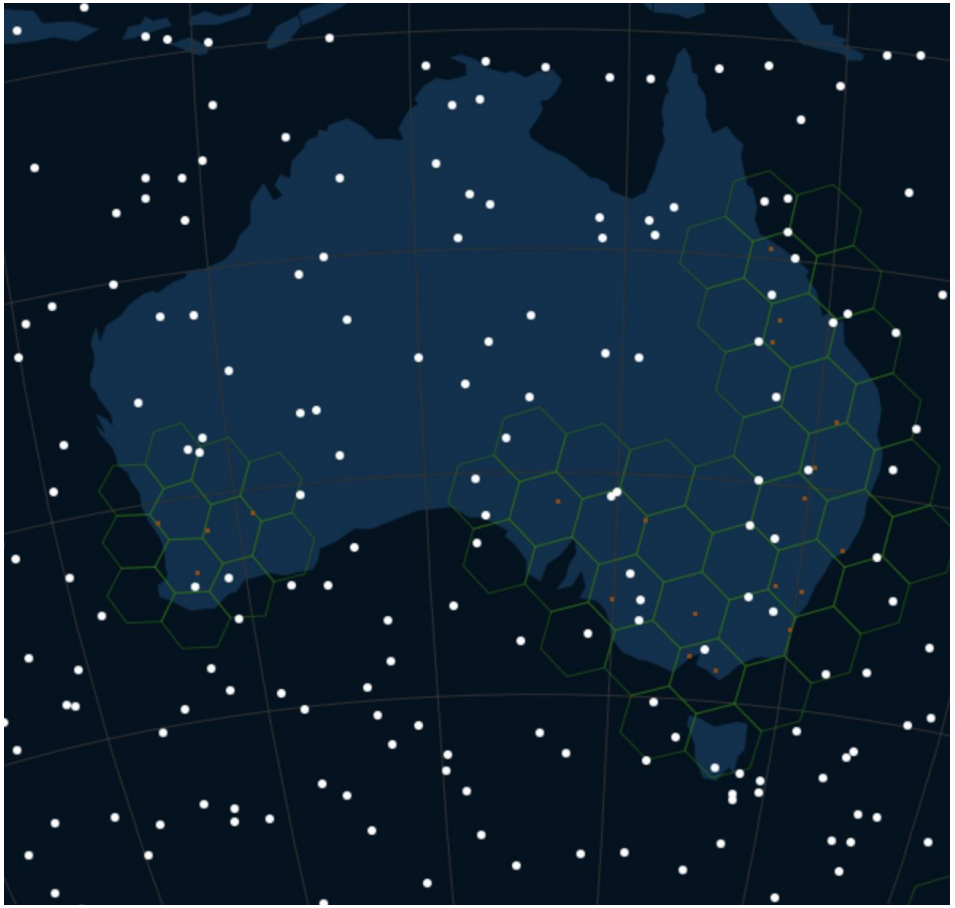
What really is Starlink?



Starlink Australia

- Estimation of pathing using currently published ephemeris
- Broad coverage of urban areas
- Rural areas would be serviced by polar orbits
- Coverage in remote area may be inconsistent



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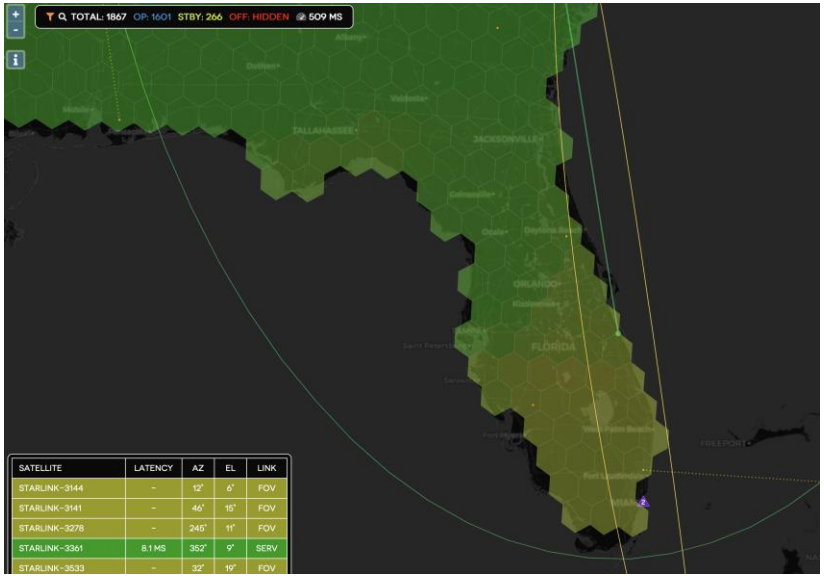
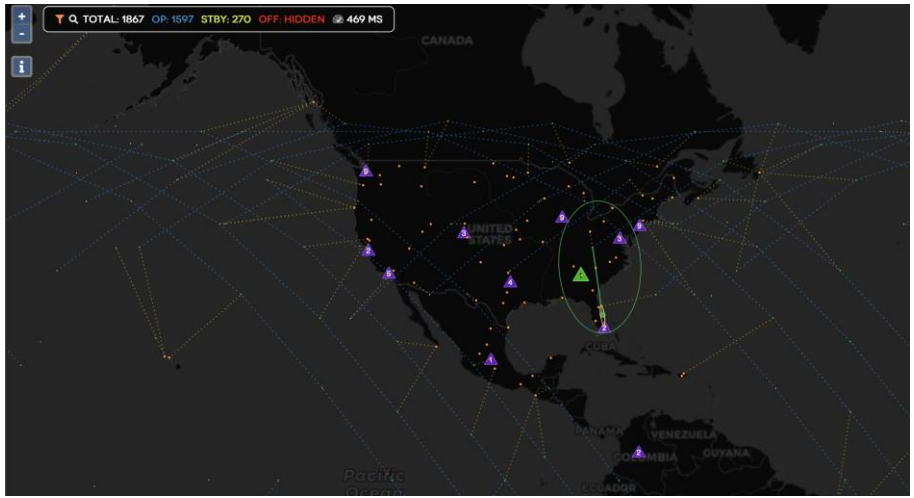
What is Starlink?

- A global satellite network in Low Earth Orbit currently consisting of ~3000 satellites*





*groups of 53 being launched on a regular basis

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Satellite v1.5

- Each satellite features four antennas in Ku band, one for uplink, three for downlink
- Each antenna is capable of projecting eight beams in two polarizations (RHCP/LHCP), for a total 48 downlink beams and 16 uplink beams.
- The maximum bandwidth available to Starlink in Ku band is 8x 250 MHz channels in downlink (total 2 GHz), and 8x 62.5 MHz channels in uplink (total 500 MHz)
- Each Satellite nominally operates at 10Gbps capacity with future expansion to 20Gbps

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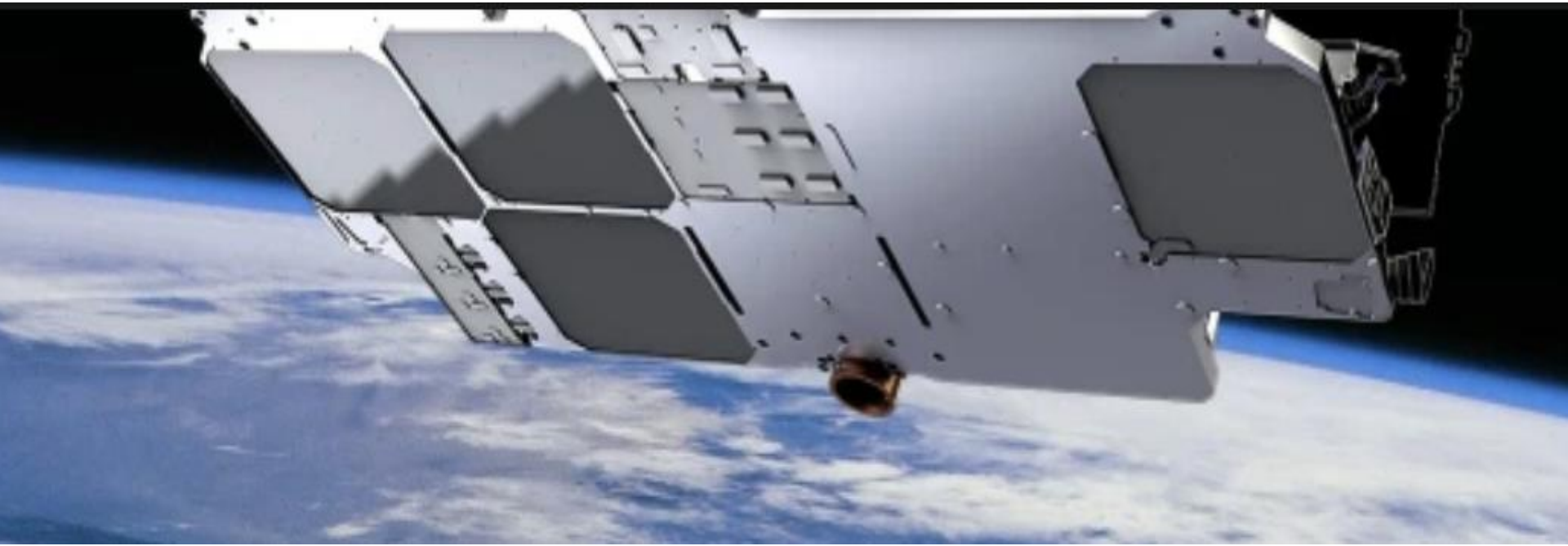
Faced towards Ground



Credit: Starlink

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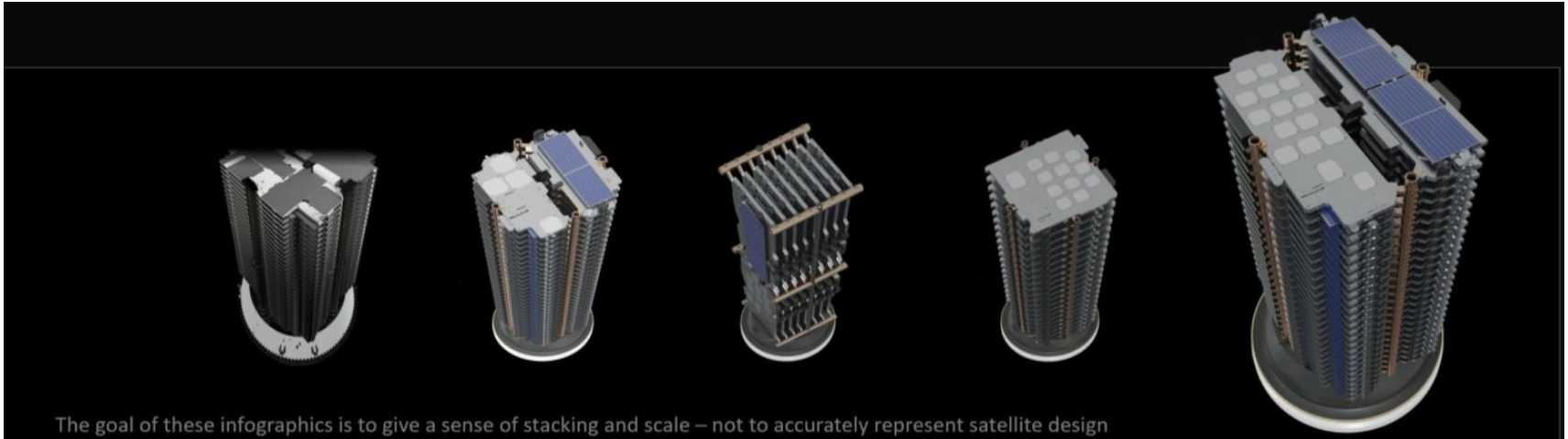

The goal of these infographics is to give a sense of stacking and scale – not to accurately represent satellite design

Assumptions

Designation	Starlink V1.5	Starlink V2 F9-1	Starlink V2 F9-2	Starlink V2 mini	Starlink V2 Starship
Status	Launched	FCC filing – may not realize	FCC filing – may not realize	Launched	FCC filing
Mass kg	306	303	800	800	2000
Gbps / sat	15	18	70	60	170
Launch	60 units per Falcon 9	60 units per Falcon 9	16 units per Falcon 9	21 units per Falcon 9	50 units per Starship
Tbps / launch	0.9	1.1	1.1	1.3	8.5
m$ / launch	Sats 18 + launch 30 = 48m$	Sats 18 + launch 30 = 48m$	Sats 11 + launch 30 = 41m$	Sats 15 + launch 30 = 45m$	Sats 60 + launch 15 = 75m$
$ / Mbps	53	45	37	35	9

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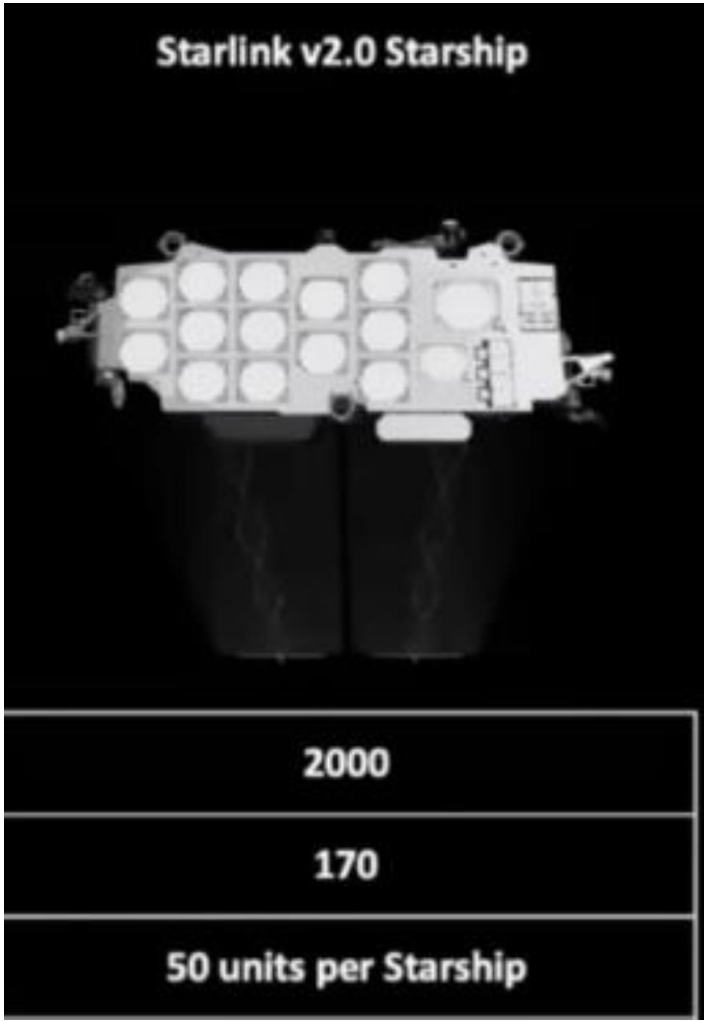
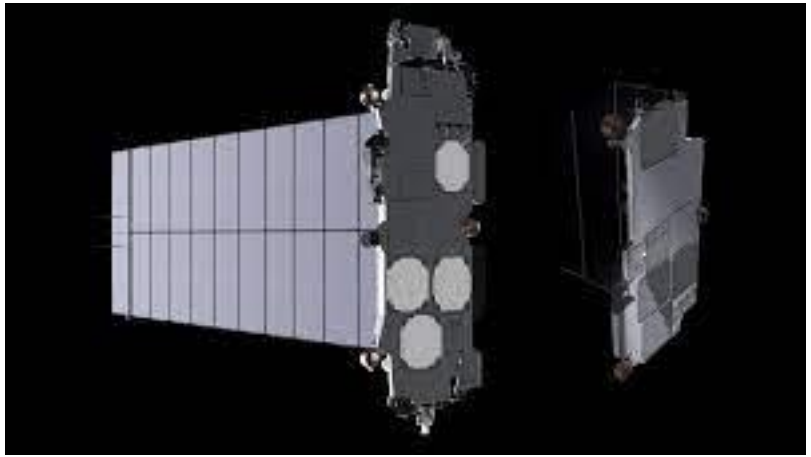
V2.0 Satellite





V1.5 Satellite

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Observations of the Starlink Network

- CGNAT Employed
- Array to Satellite to Ground Station are all Flat
- Appears that Ground to NAP is a series of Exit MPLS Networks
- Exit Routing is based on your specific Terminal
- *Network Configuration changes are frequent and unannounced

- Exit Path is currently static based on your Service Class
- Portabililty, Marine, RV, Aviation means that you can be placed in different exit VPNs, we assume dynamically

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Infrared “Space Lasers”

- 3 Beam Optical Head using Infrared Laser
- Same Orbital Plane Operation
- Theoretically could offload to parallel polar plane satellite

Credit: SpaceX/Starlink

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Ground Station

- Each gateway antenna has available a maximum of 4x 500 MHz channels (total 2 GHz) in uplink, and 5x 250 MHz channels (total 1.25 GHz) in downlink
- In this configuration – where 8 antennas are active – would be 10Ghz total active Down and 6Ghz Up per site
- Ground stations are positioned on top of existing Fiber Paths
- Each Parabolic Antenna can support 10Gbps x 2)
- So that's up to 1.6Tbps theoretical bandwidth for a site with 8 active

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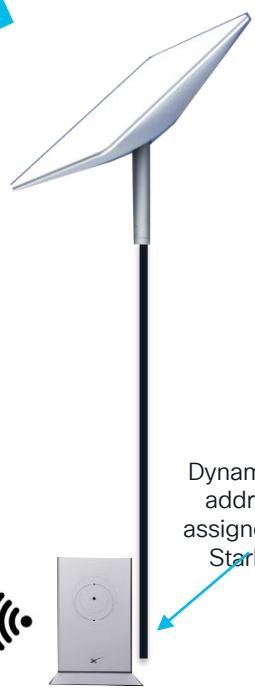
Basic Networking

Internet



Dynamic IP address assigned by Starlink

NAT Router

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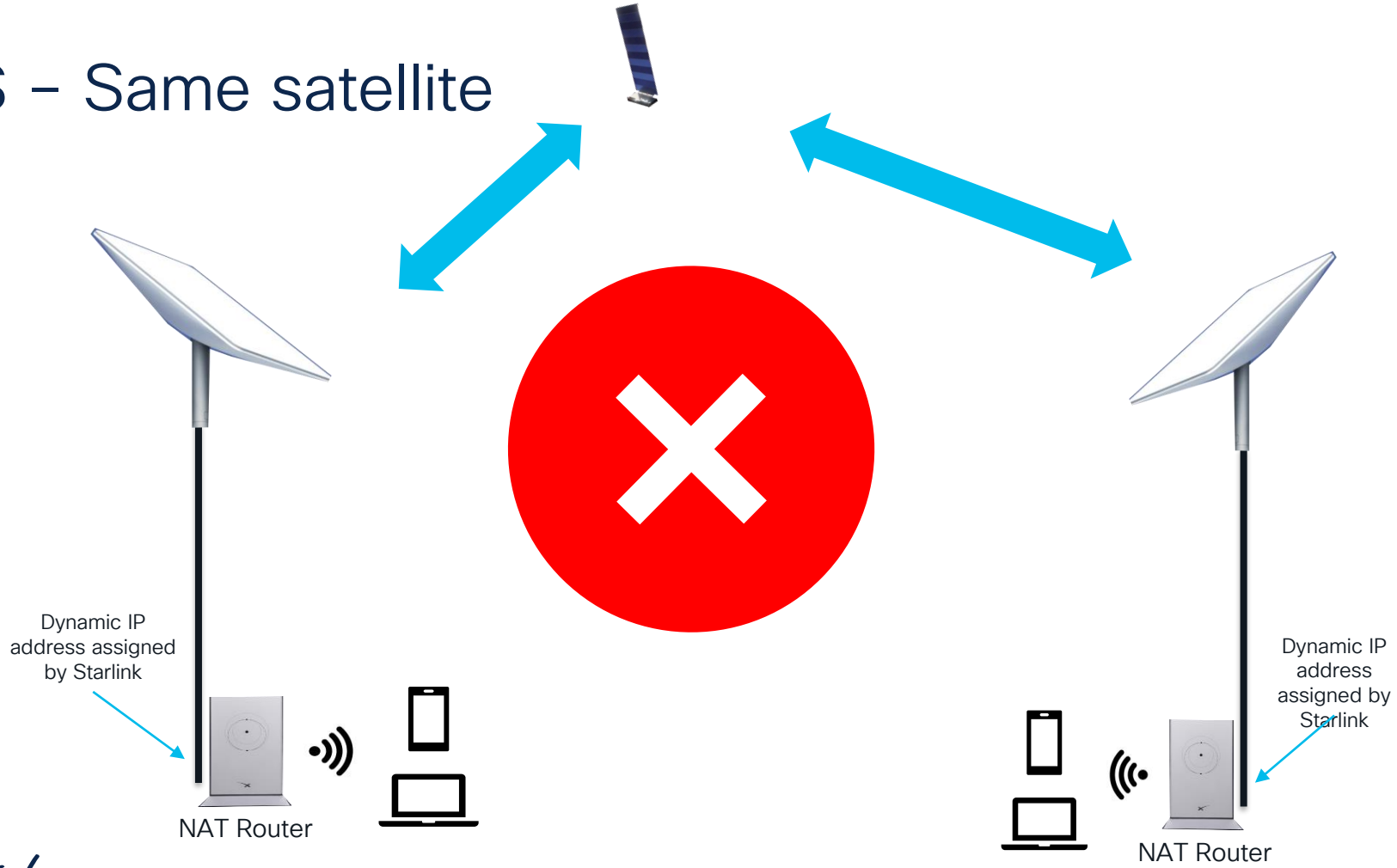
BLOS – Same satellite



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List of Australian Starlink Ground Stations

Cataby, WA
Merredin, WA
South West of Coolgardia, WA
Wagin, WA
Ki Ki, SA
Pimba, SA
Broken Hill, NSW
Boorowa, NSW
Calrossie, NSW
Canyonleigh, NSW
Cobargo, NSW
Springbrook Creek, NSW
Tea Gardens, NSW
Ki Ki, SA
Anankie, VIC
Koonwarra, VIC
Torrumbarry, VIC
West of Emerald, QLD
Toonpan, QLD
Warra, QLD
Willows, QLD
Bulla Bulling, WA

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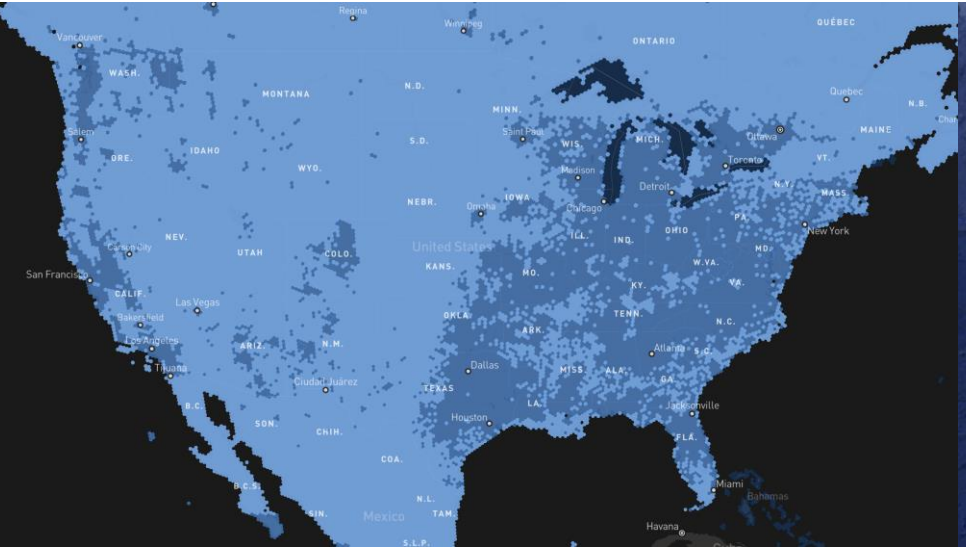
US Gateway Locations



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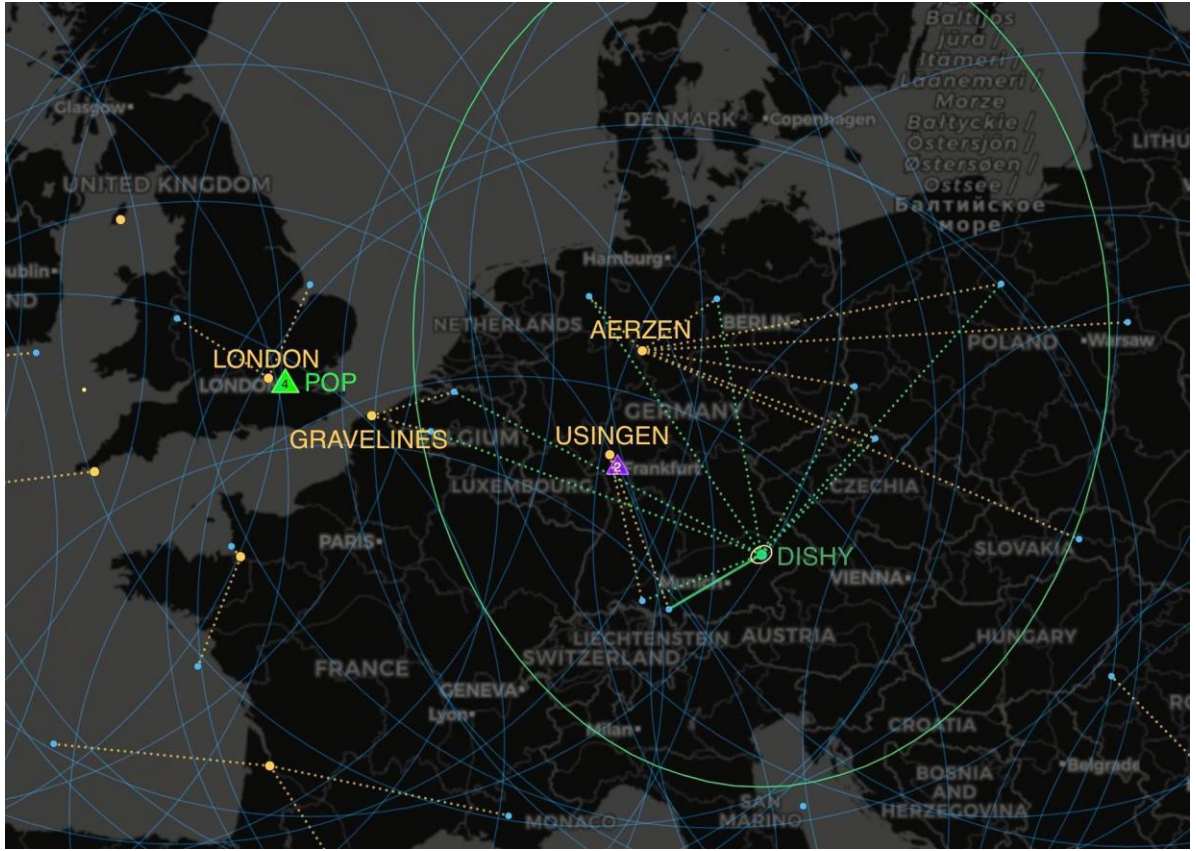
EMEA Gateway Locations



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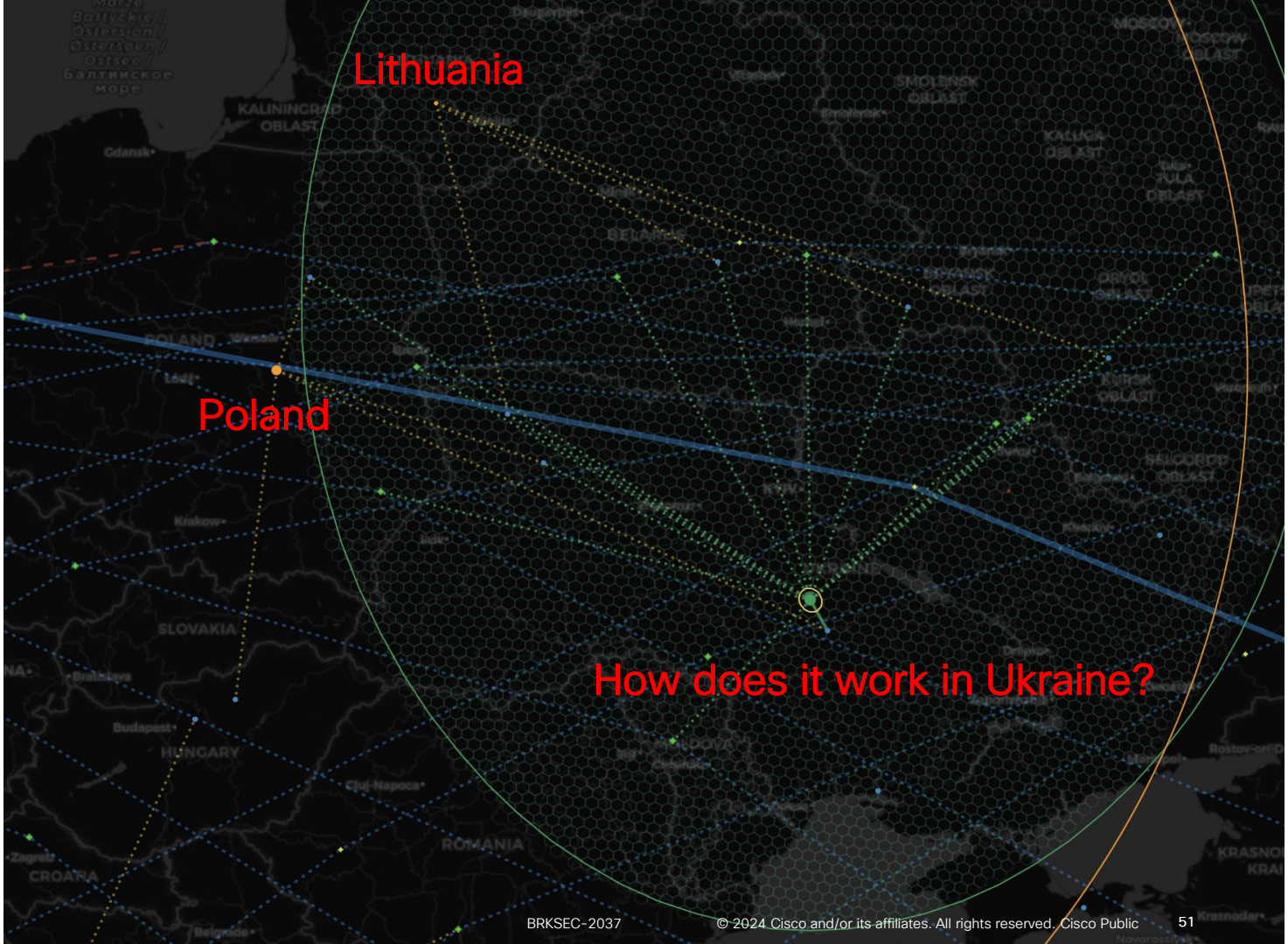
Radio Gateways

Lithuania
Poland

Internet Gateways

Frankfurt
London



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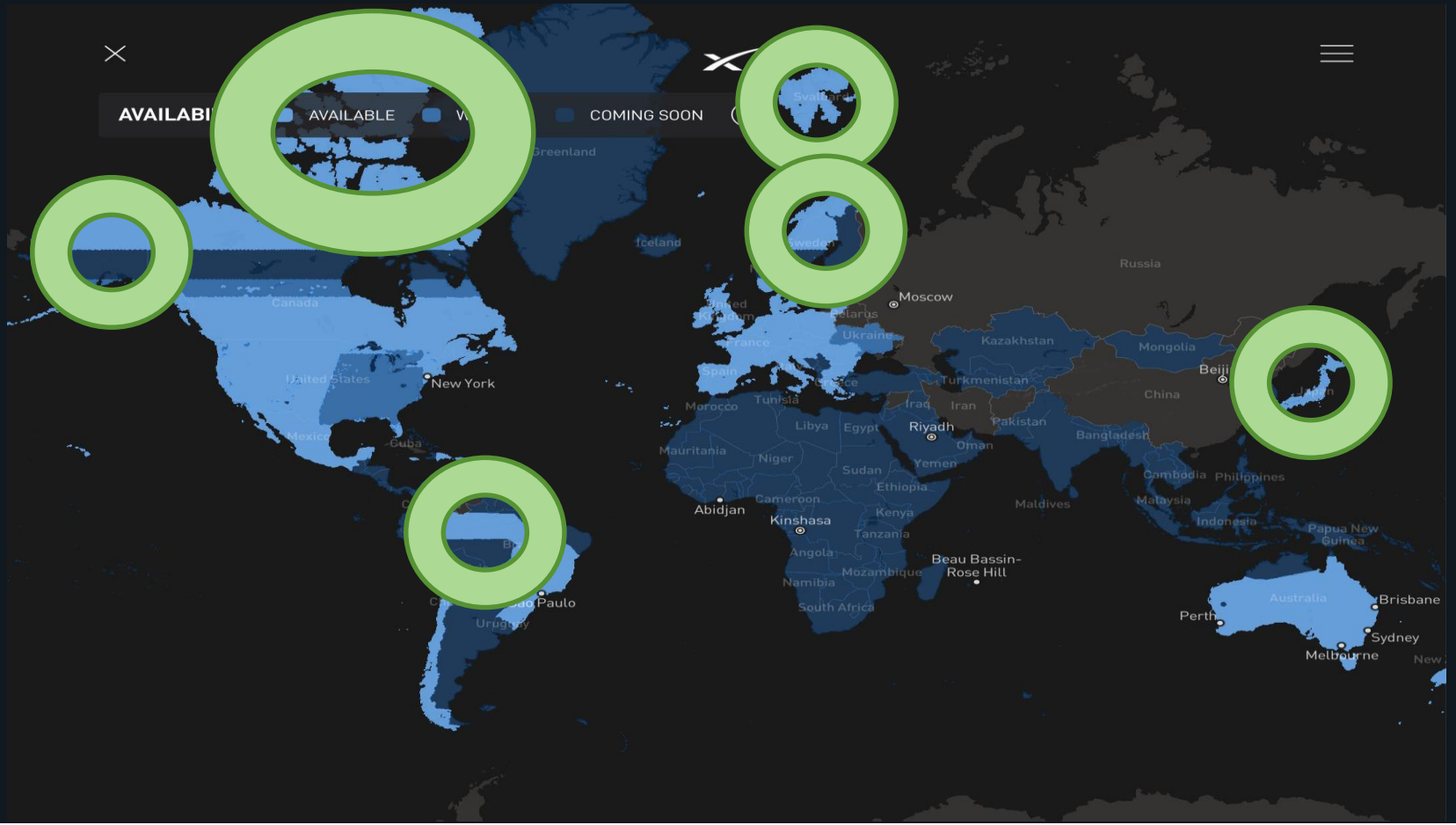

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Things we know

- Dense Orbital shells are extremely robust
- Frequency shifts can be simple software operations
- Receive only satellite arrays are critically important
- Low observability packages are important
- Low cost Software Defined Radios (SDRs) are being used for offensive hunt operations

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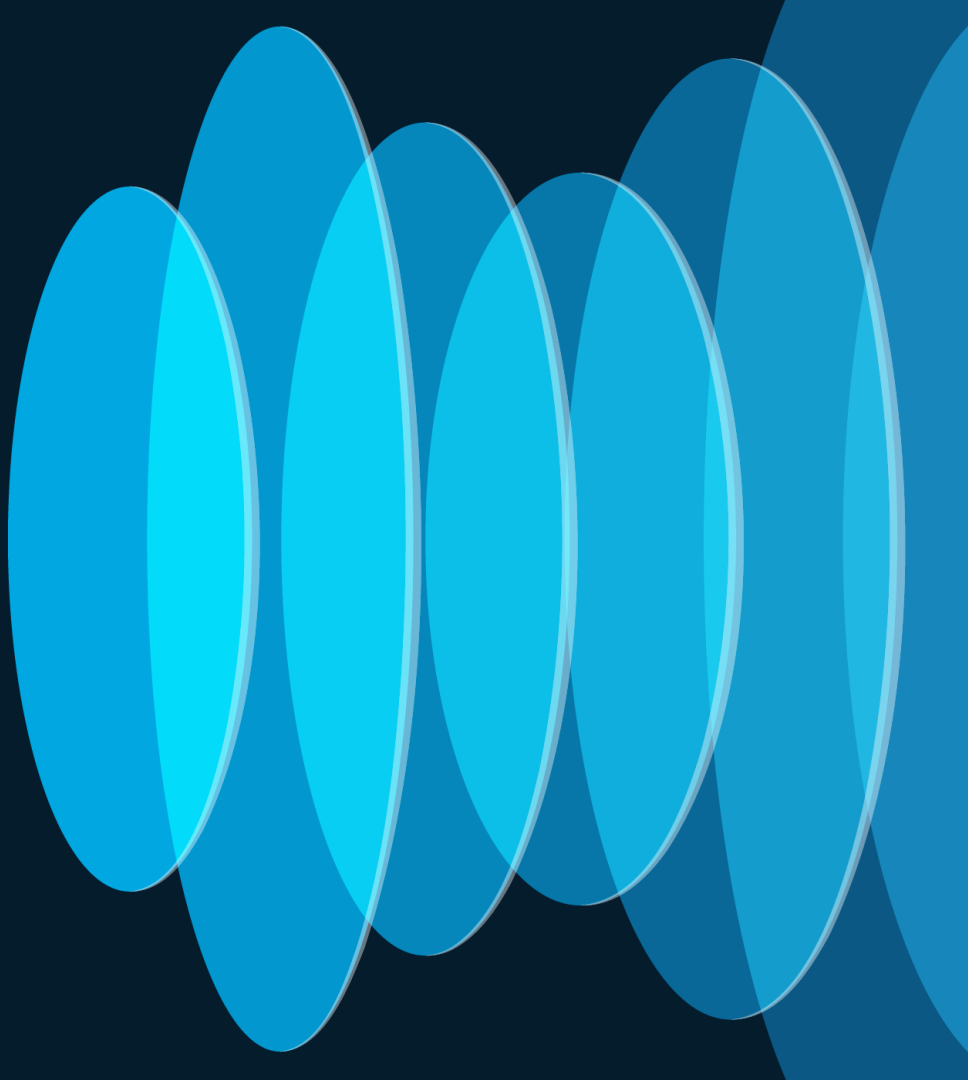
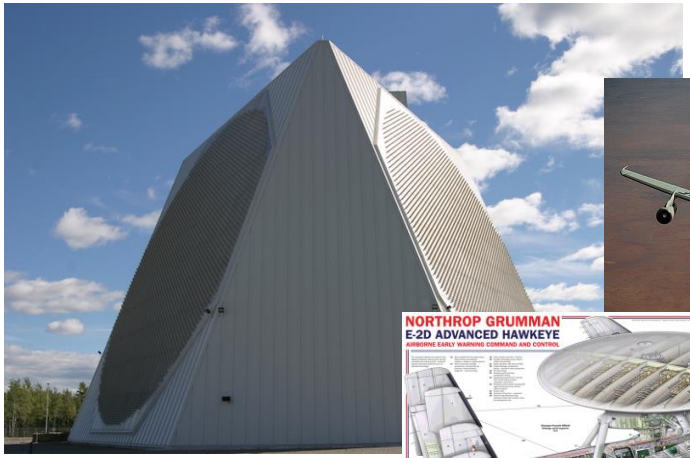
Phased Array Antenna

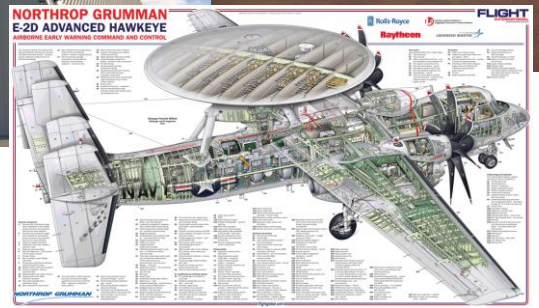


Examples of Phased Arrays

- Space Observation Radar



E-3 Sentry
AWACS



E-2D
Early Warning

- AN-SPY-1 Phased Array
- AEGIS Deployed and Ashore

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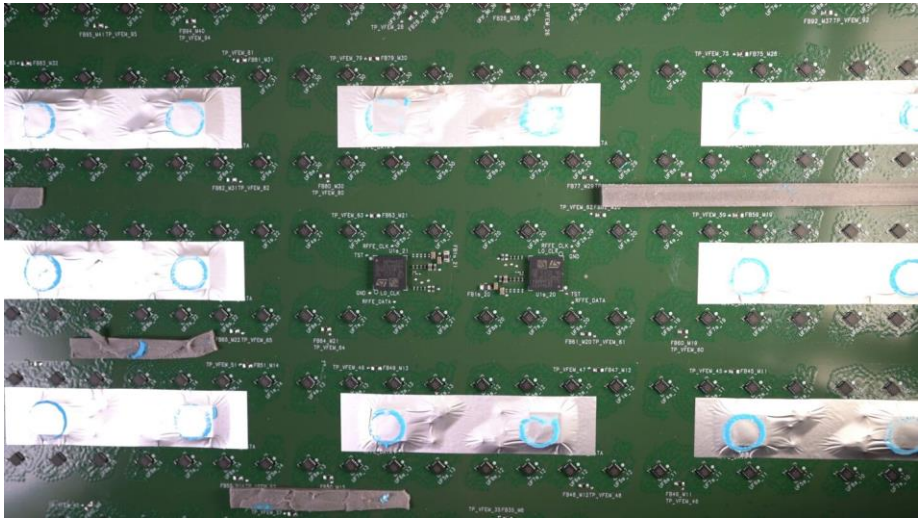
How does Starlink work?

- Up / Down configuration
- Ground Terminal is a phased array antenna in one of two current configurations – Round (Gen1) or Rectangle (Gen2)
- Each array has hundreds of transceivers



- 12-18 and 26.5-49 GHz bands

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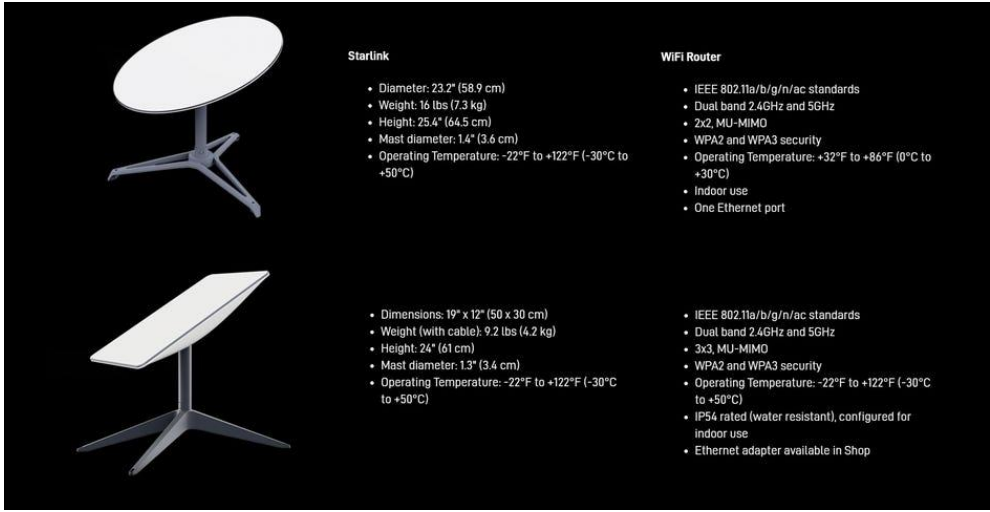
Ground Terminal

- Phased Array Antenna
- Starlink Router (more on that later)
- Ethernet Cable with proprietary ends



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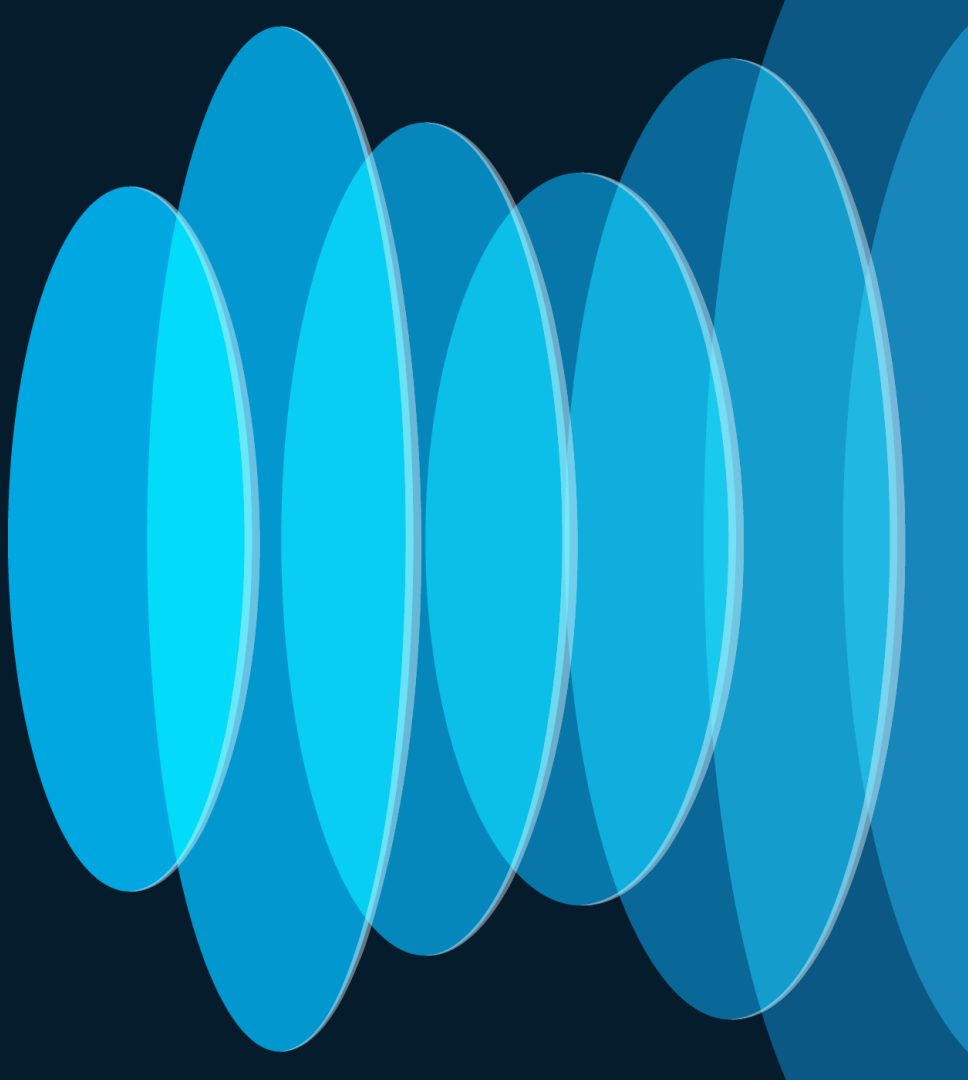
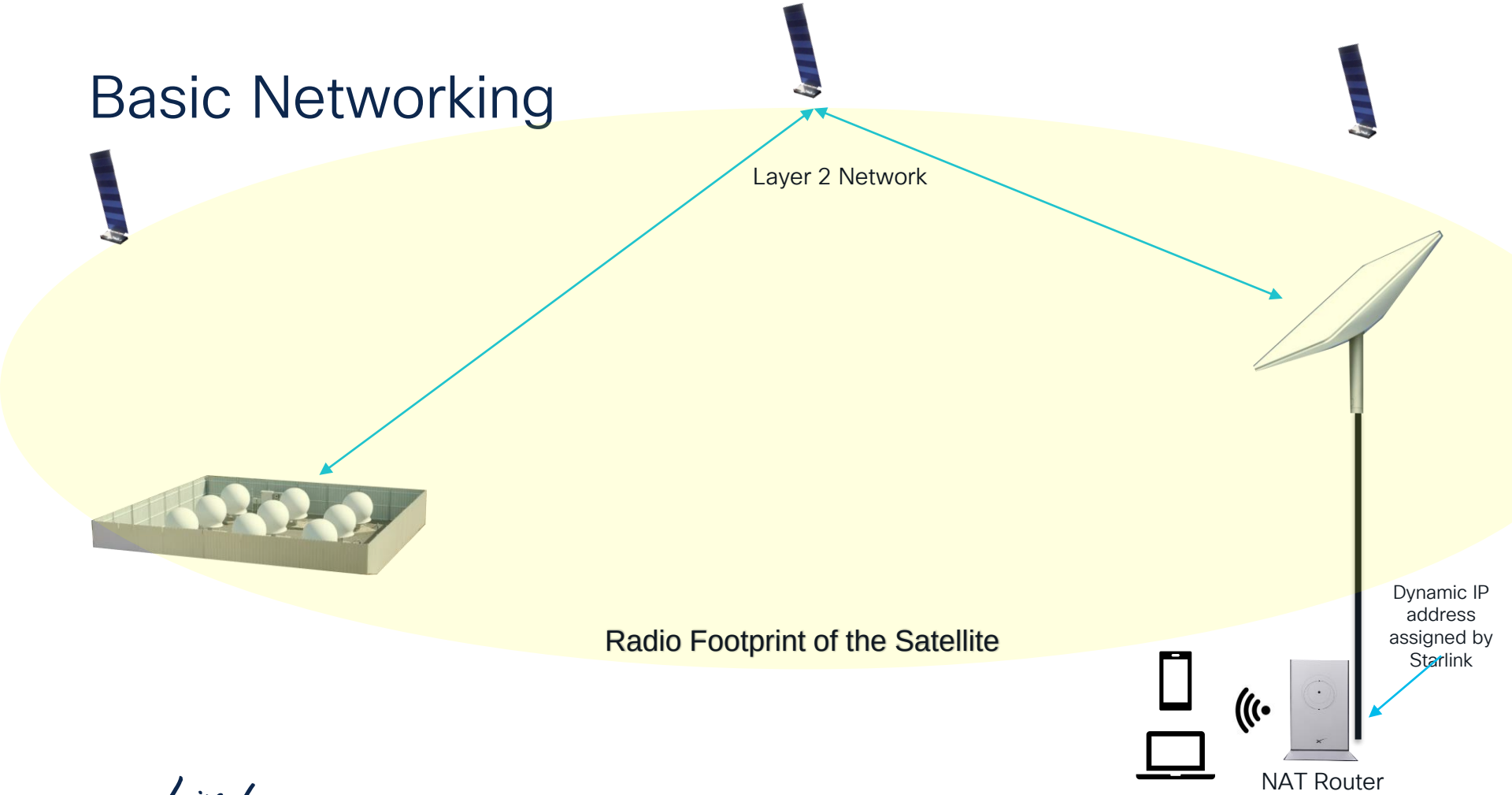
Basic Networking



Basic Networking



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Starlink Router

- Micro Linux Router
- NAT Operations
- 60 second boot time
- 192.168.128.0 NAT Pool

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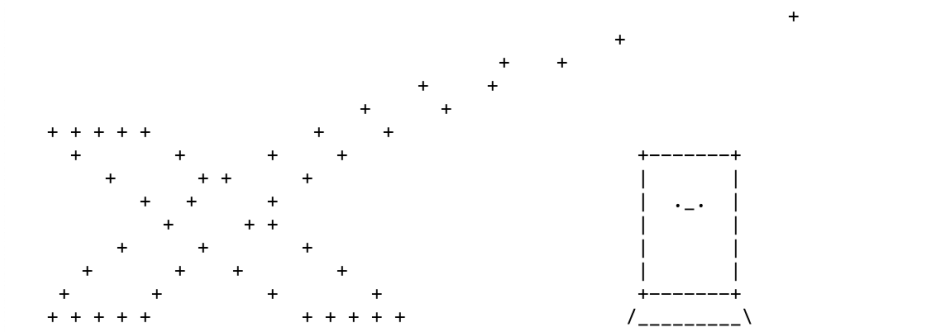
Starlink Router



```
When I was a kid, I wanted to be a WiFi router more than anything in the world.
I stretched my arms out wide, and I hid in the corner. I tried to glue antennas
to my head, I had ethernet cables, I had an LED indicator. Everybody knew me
and was afraid of me. And one day, my dad said, "Bobby, you're 17. It's time to
throw childish things aside," and I said, "OK, Pop." But he didn't really say
that. He said, "Stop being a WiFi router and become a Dishy."

  2022.19.0.mr13442                      Router-01000000000000001F2F12
```

```
abenhase@192.168.1.1: Permission denied (publickey,keyboard-interactive).
abenhase@ABENHASE-M-526H .ssh %
```

- Nmap scan report for 192.168.1.1
- Host is up (0.0040s latency).
- Not shown: 994 filtered tcp ports (no-response)
- PORT STATE SERVICE
- 22/tcp open ssh
- 53/tcp open domain
- 80/tcp open http
- 9000/tcp open cslistener
- 9001/tcp open tor-orport
- 9002/tcp open dynamid

- Nmap done: 1 IP address (1 host up) scanned in 45.68 seconds

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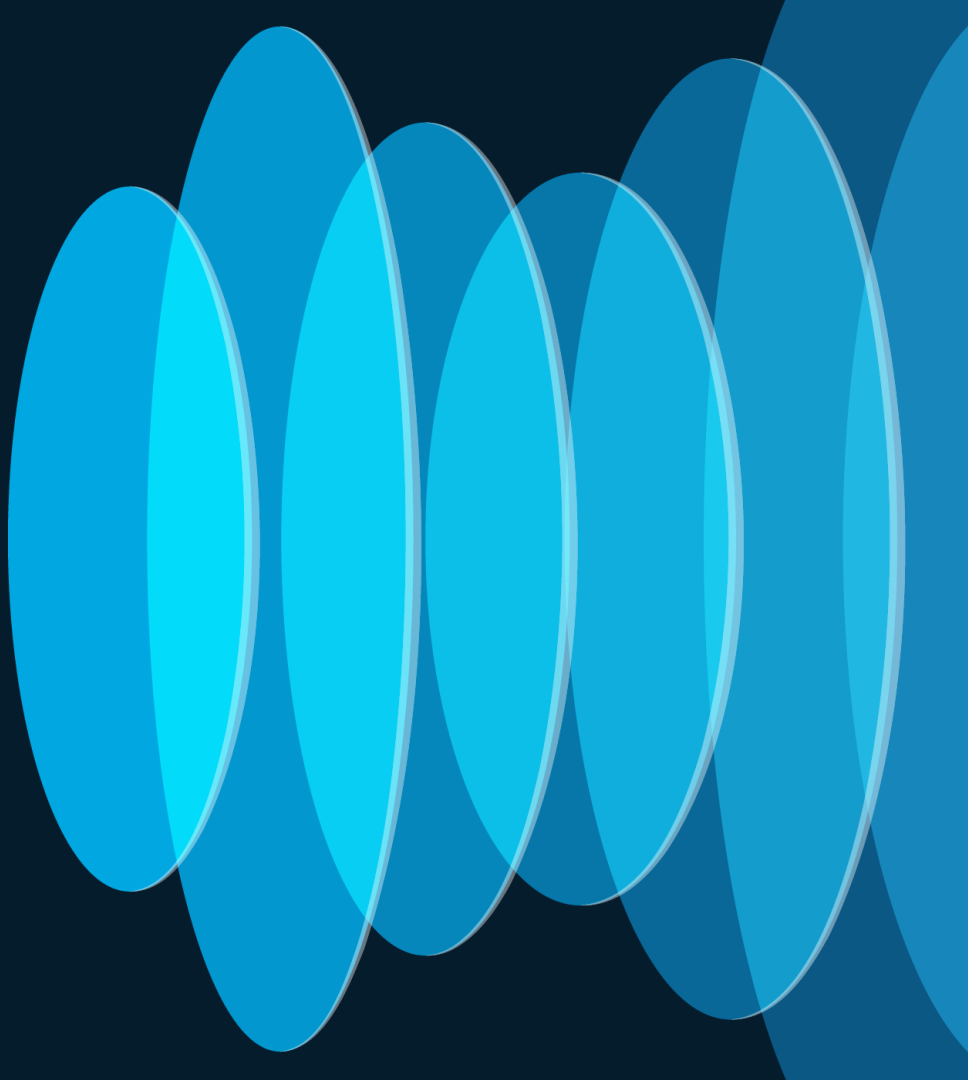
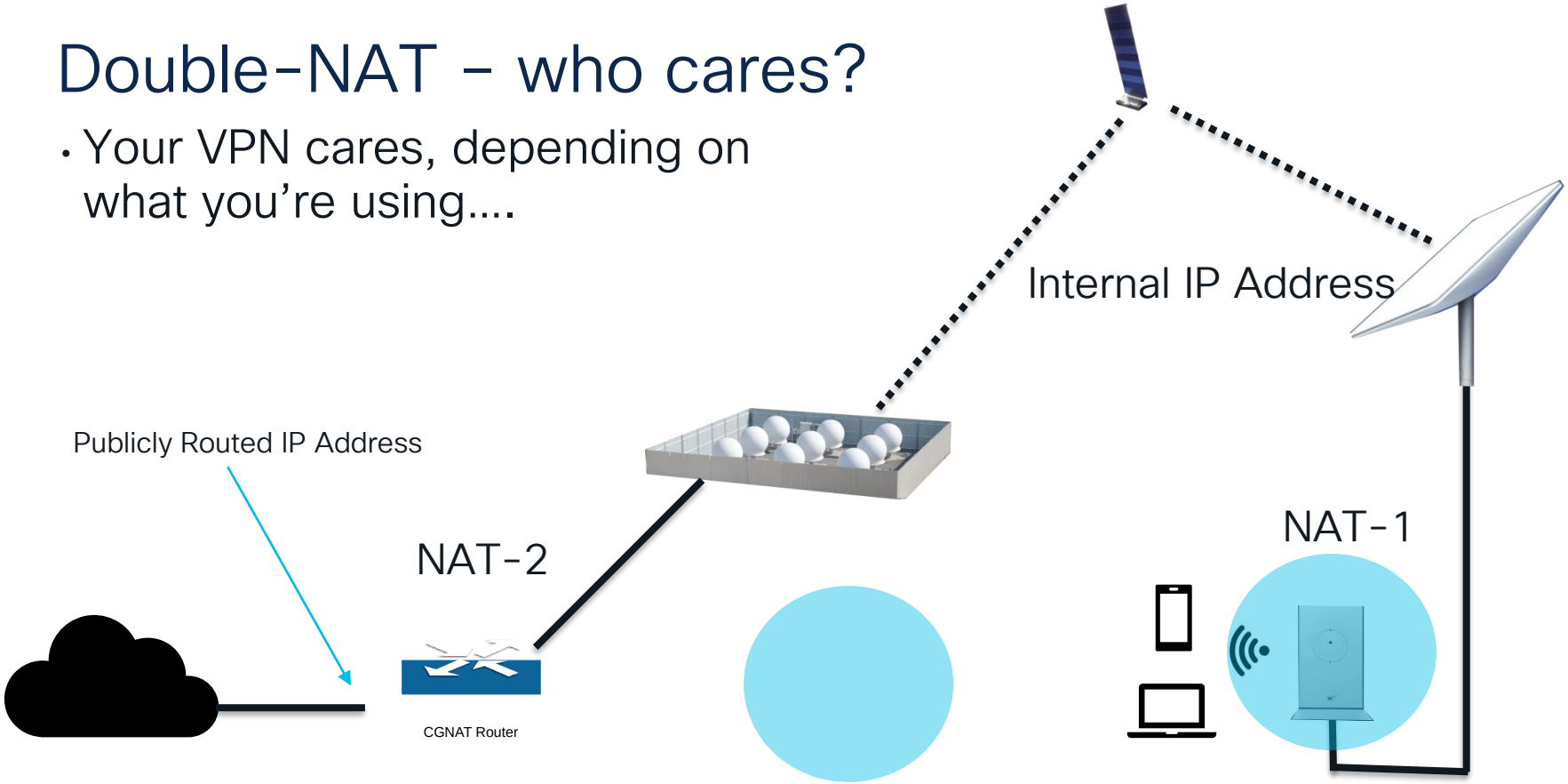
Double/Triple NAT



Double-NAT – who cares?

- Your VPN cares, depending on what you're using....



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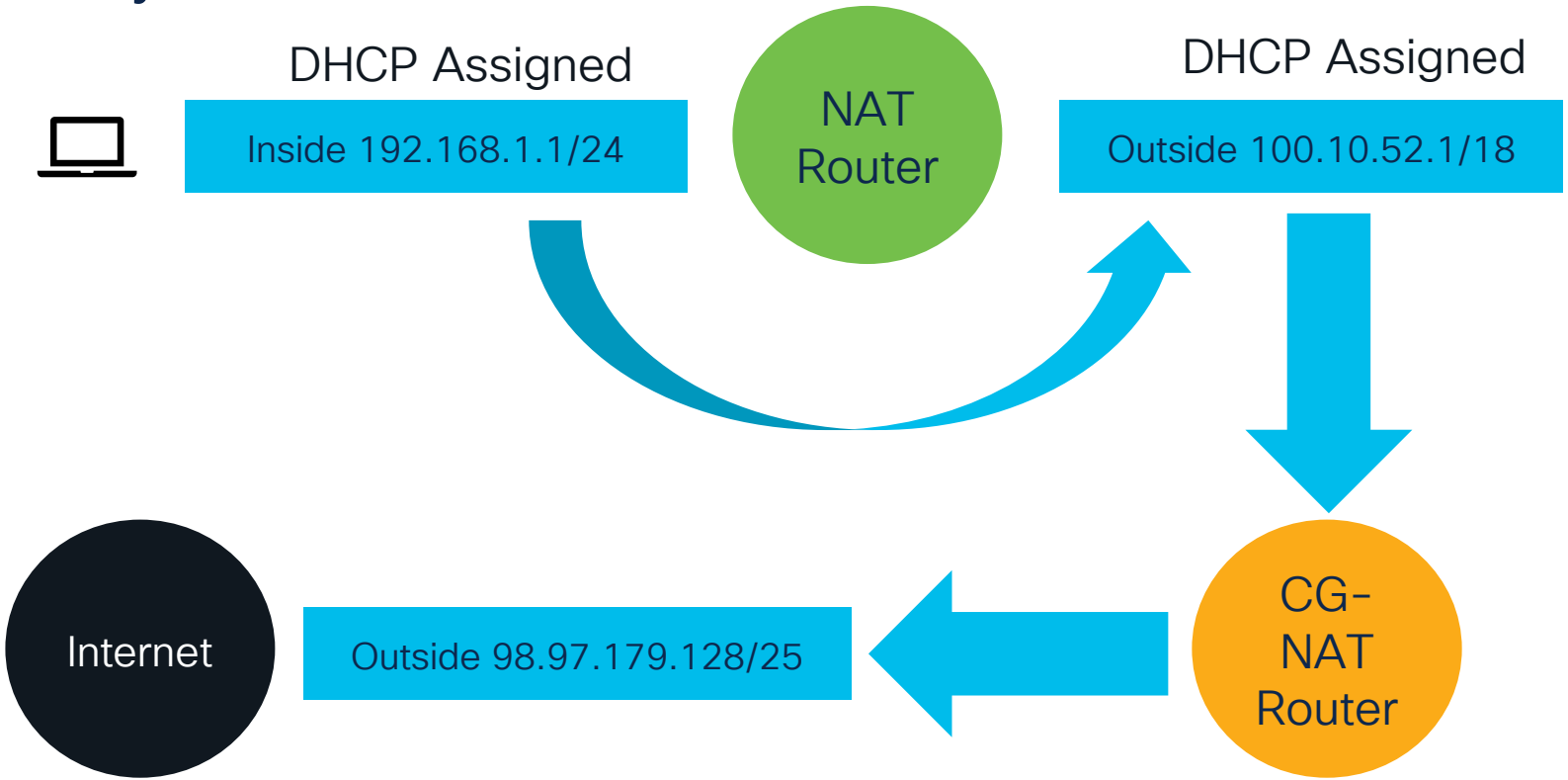
Why is NAT an issue?



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Things that Fix NAT Problems

- Static NAT configuration – impossible with Starlink and CG-NAT carriers
- GRE/IPSec+NAT-T Tunnels
- Straight NAT-T Tunnels
- IPv6**** (maybe)
- TCP VPN Tunnels

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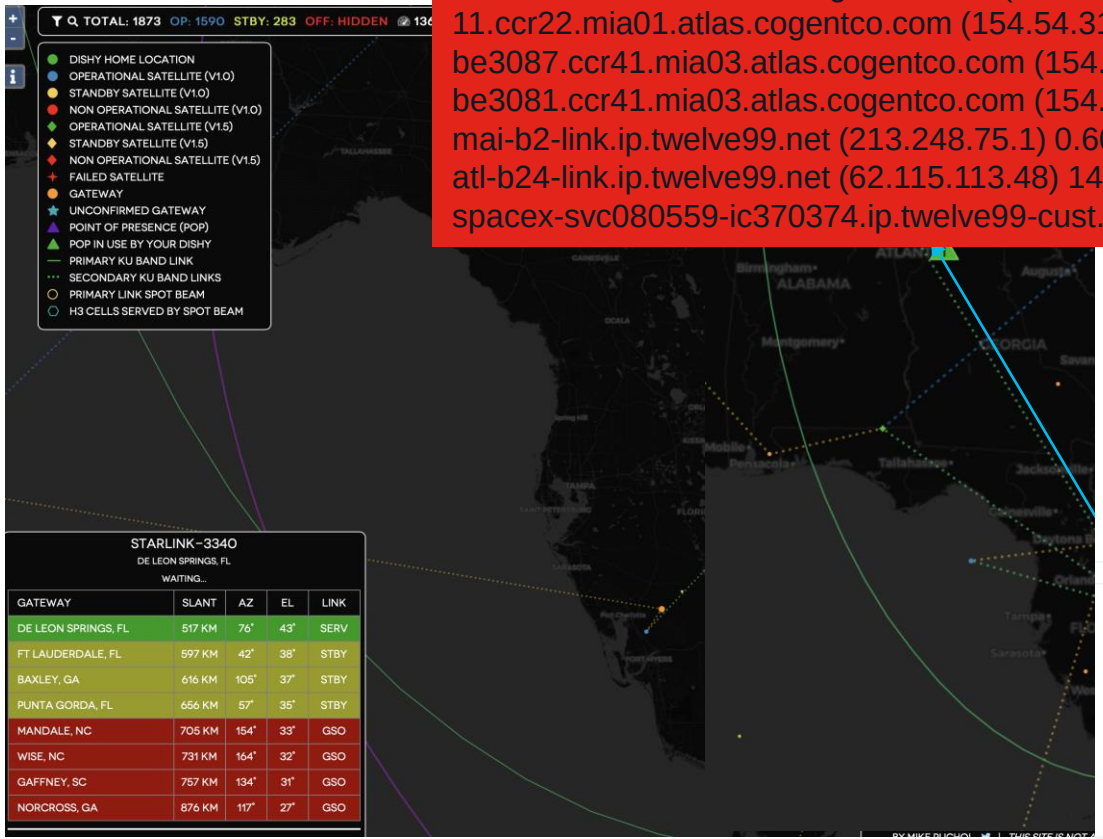
How the network works

```
1 gi0-0-0-18.221.agr13.mia01.atlas.cogentco.com (66.28.3.217) 0.661 ms 0.727 ms 2 te0-5-0-1.ccr21.mia01.atlas.cogentco.com (154.54.6.57) 0.896 ms te0-0-0-11.ccr22.mia01.atlas.cogentco.com (154.54.31.229) 0.998 ms 3 be3087.ccr41.mia03.atlas.cogentco.com (154.54.88.234) 0.839 ms be3081.ccr41.mia03.atlas.cogentco.com (154.54.88.226) 0.843 ms 4 mai-b2-link.ip.twelve99.net (213.248.75.1) 0.606 ms 0.625 ms 5 atl-b24-link.ip.twelve99.net (62.115.113.48) 14.858 ms 14.762 ms 6 spacex-svc080559-ic370374.ip.twelve99-cust.net (62.115.146.55) 14.741 ms 14.796 ms
```



Summary

Country	United States
Domain	spacex.com
ASN	AS14593
Registry	arin
Hosted IPs	128
ID	NET-SUB-98-97-178-0

WHOIS Details

```
NetHandle:      NET-98-97-178-0-1
OrgID:          C08091088
Parent:         NET-98-97-128-0-1
NetName:        NET-SUB-98-97-178-0
NetRange:       98.97.178.0 - 98.97.178.255
NetType:        reassignment
OriginAS:       14593
RegDate:        2021-11-05
```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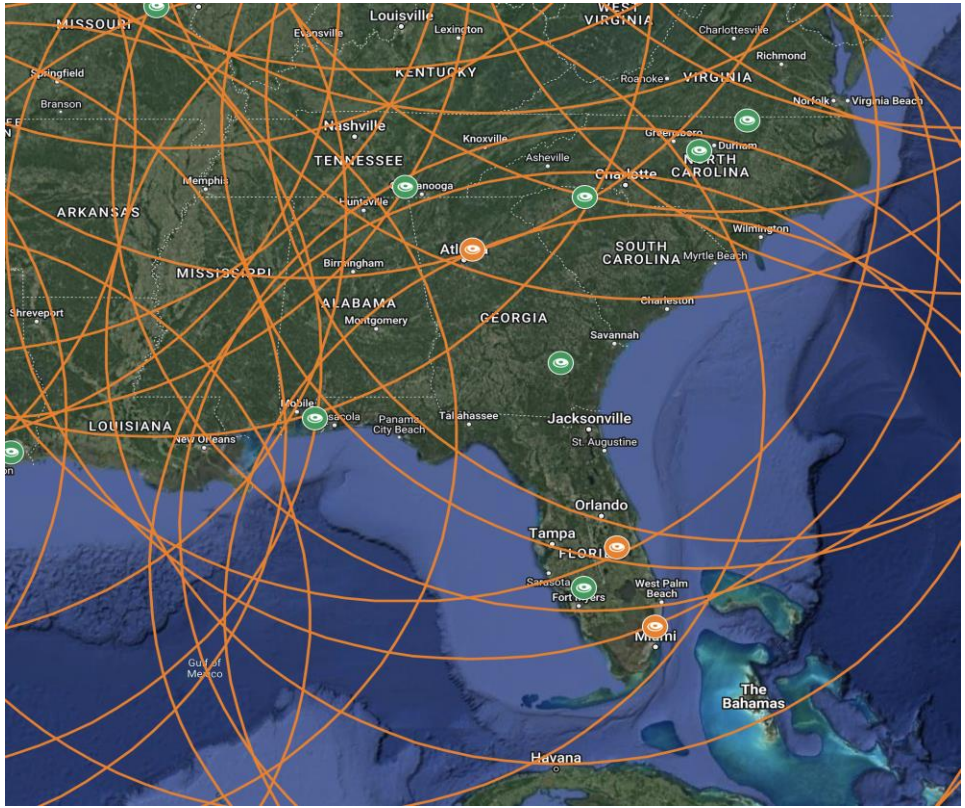
How the network works



IP range details

98.97.179.128/25

AS14593 · Space Exploration Technologies Corporation

Summary

Country	United States
Domain	spacex.com
ASN	AS14593
Registry	arin
Hosted IPs	128
ID	NET-SUB-98-97-178-0

WHOIS Details

```
NetHandle:      NET-98-97-178-0-1
OrgID:          C08091088
Parent:         NET-98-97-128-0-1
NetName:        NET-SUB-98-97-178-0
NetRange:       98.97.178.0 - 98.97.178.255
NetType:        reassignment
OriginAS:       14593
RegDate:        2021-11-05
```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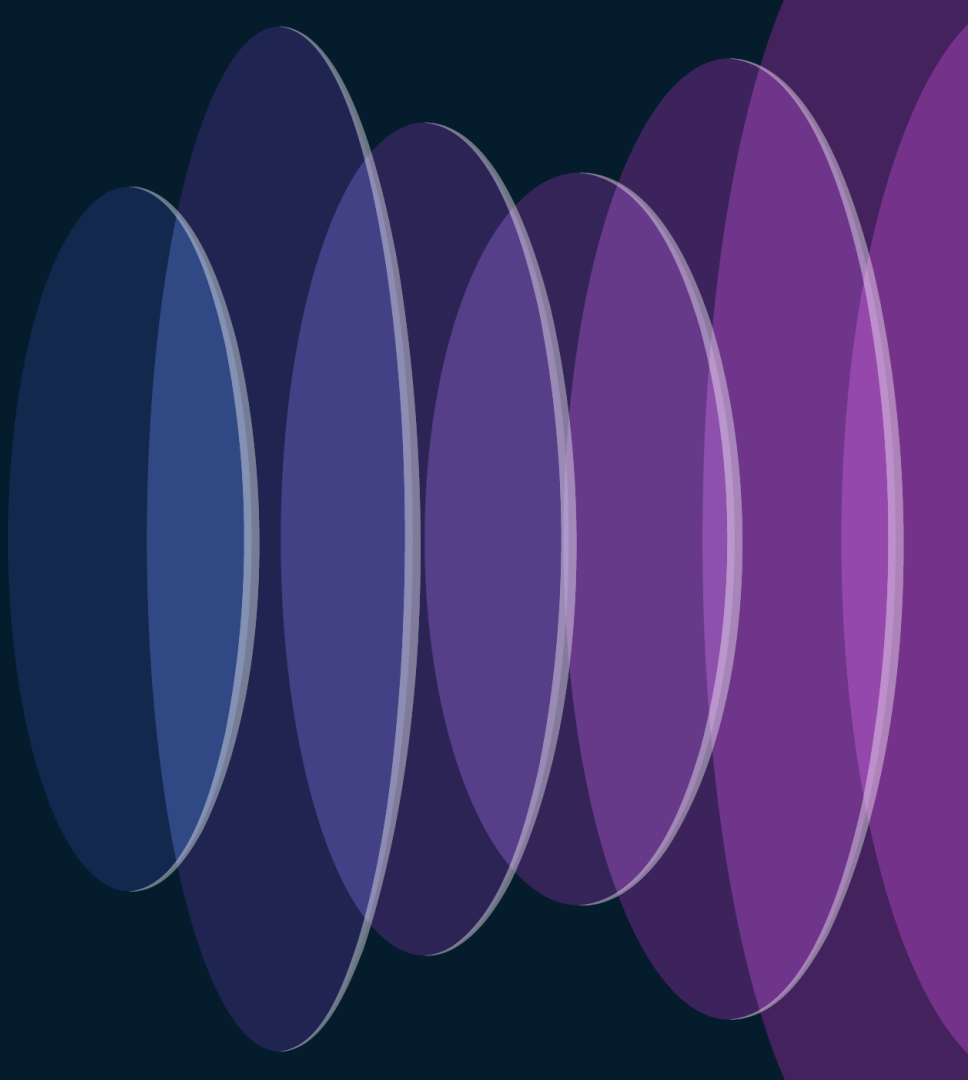
Polar Orbits and “Space Lasers”



Satellite Truths and Myths

- All Starlink Satellites have “Lasers” – FALSE
- All Starlink Satellites can cross communicate to each other – FALSE
- Some Starlink Satellites have laser based optics that can point ahead of them to the next satellite – TRUE
- On-orbit Satellites can calculate multi-planar ephemeris to dynamically communicate to satellites in different orbits – FALSE

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Polar Orbit Satellites and Free Space Optics

- Generation 1 Satellites are Radio Only
- Generation 1.5 and 2.0 Satellites are capable of Inter-Satellite Links (ISL)
- ISL Links work currently in a follow-me configuration
- A polar string of satellites provide hop to hop communications in single file
- Closest Radio Gateway provides the downlink for the chain of satellites
- Only use for satellites in polar orbits and where there is a Gateway connection
- You may not pop-out onto the Internet in a country that you expect
- You may not come out in a country you want

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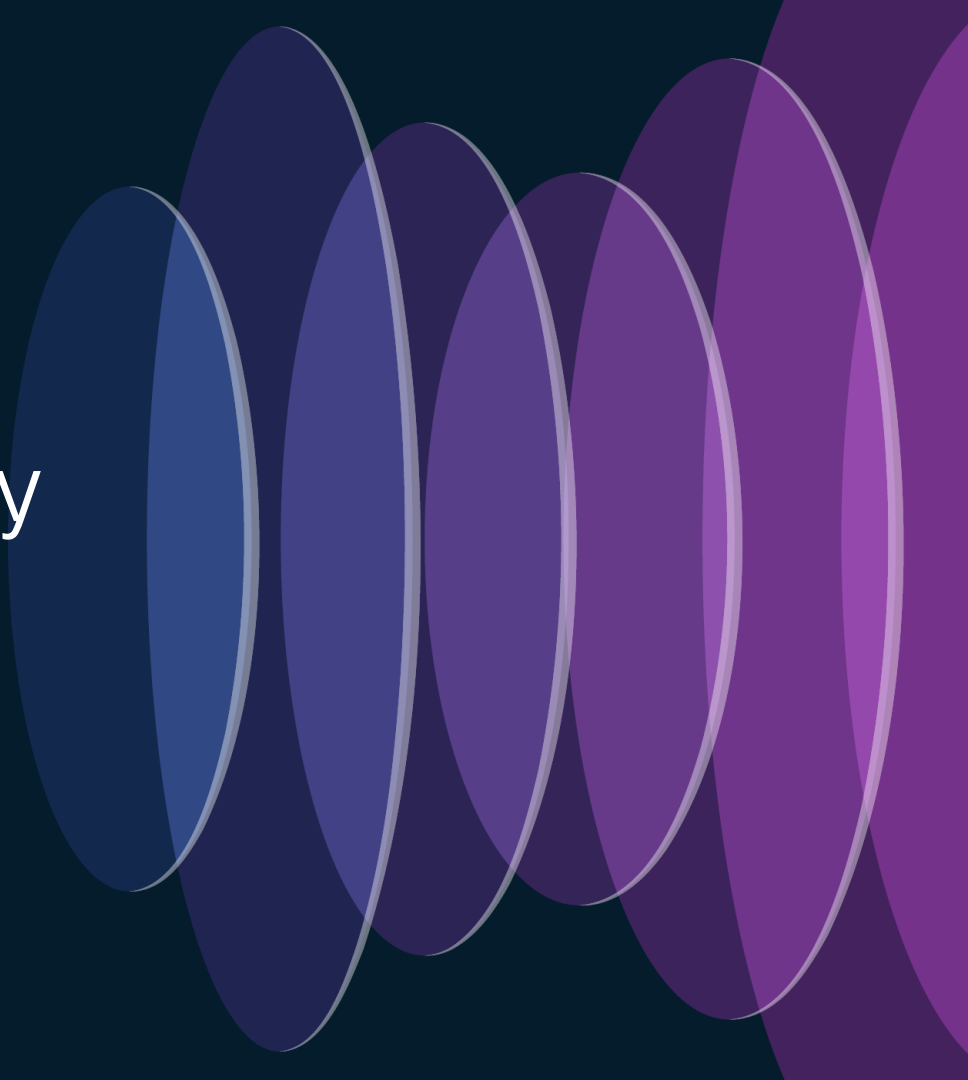
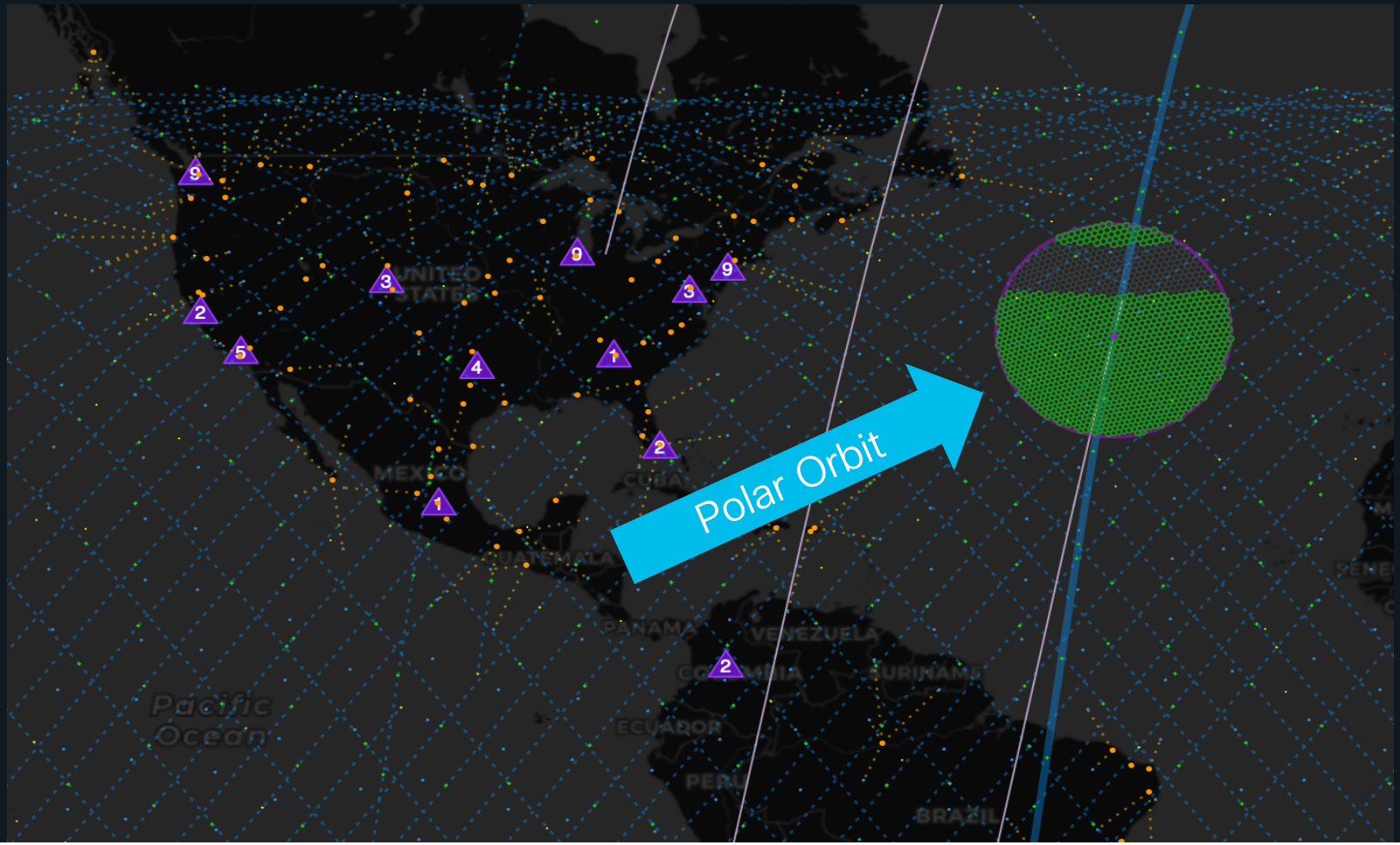
Space Lasers fix my networking issues



cisco Live!



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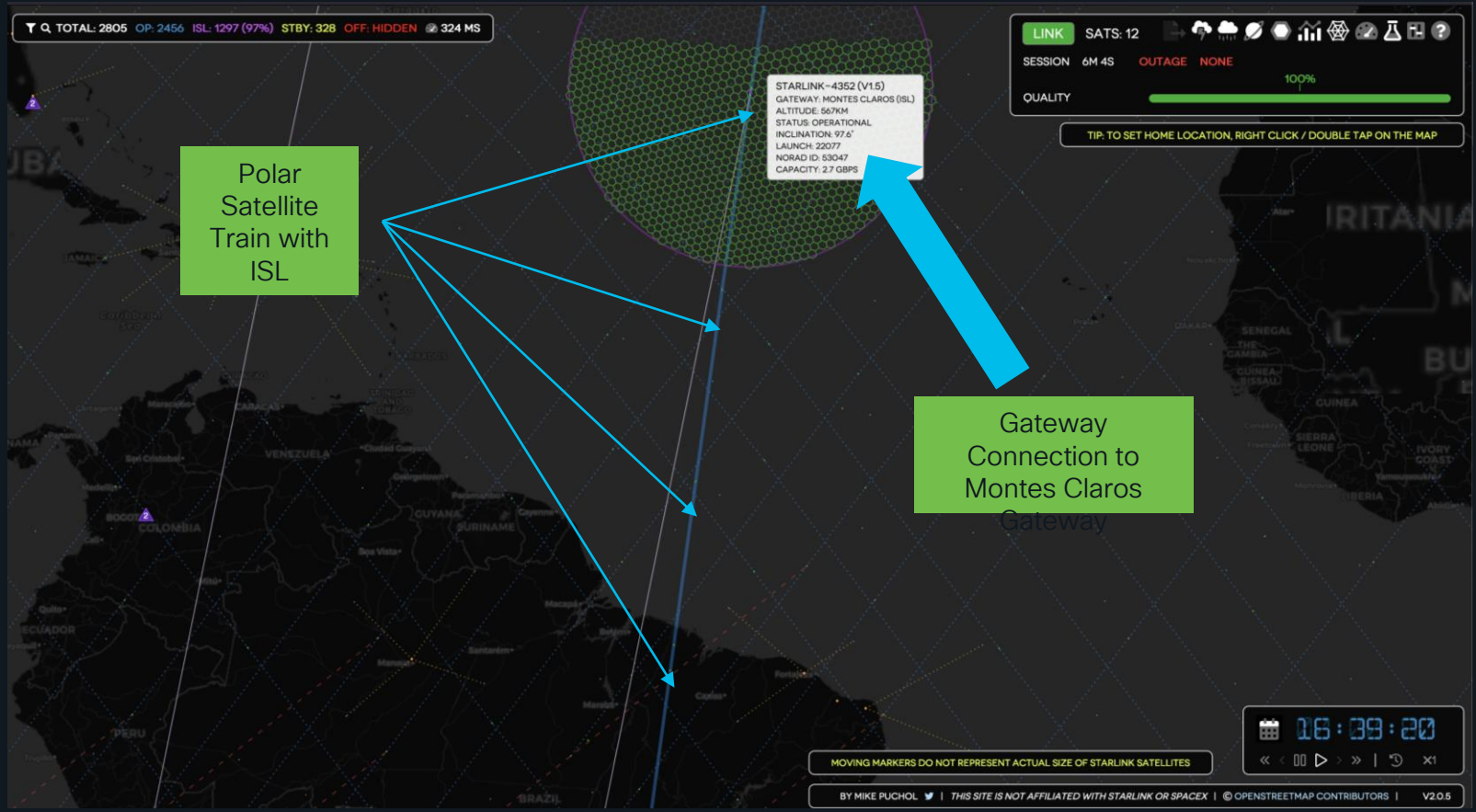

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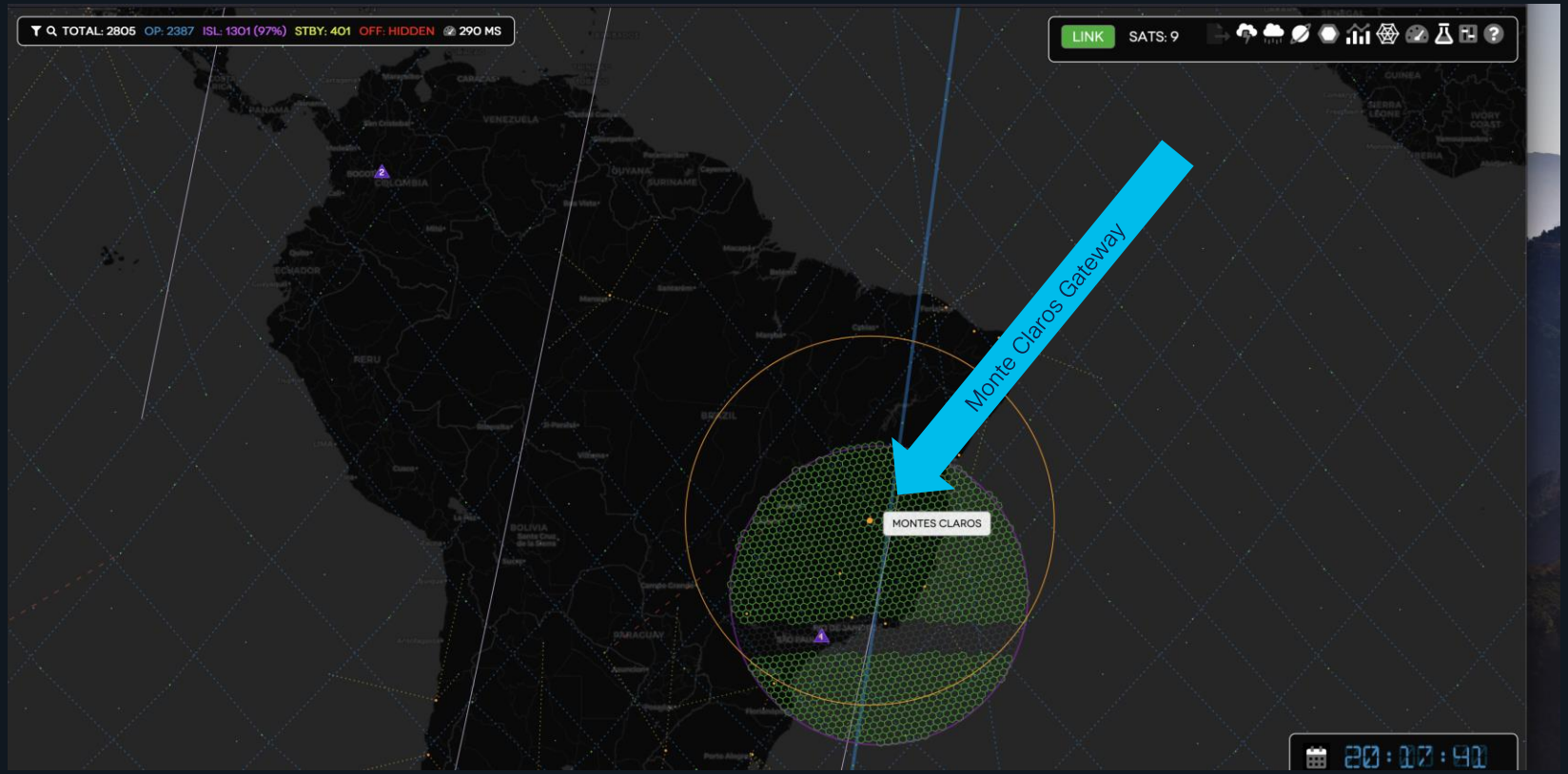

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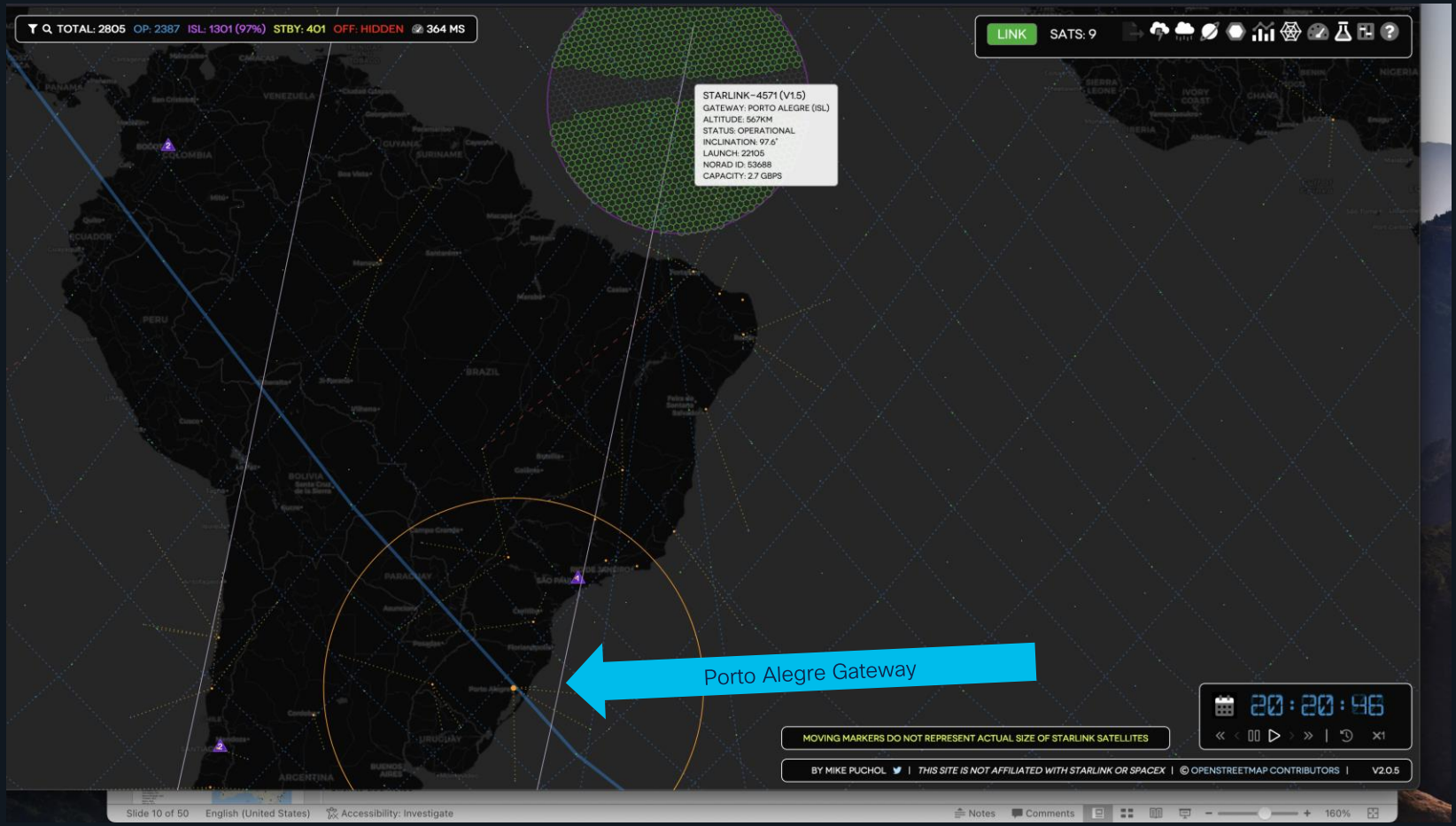

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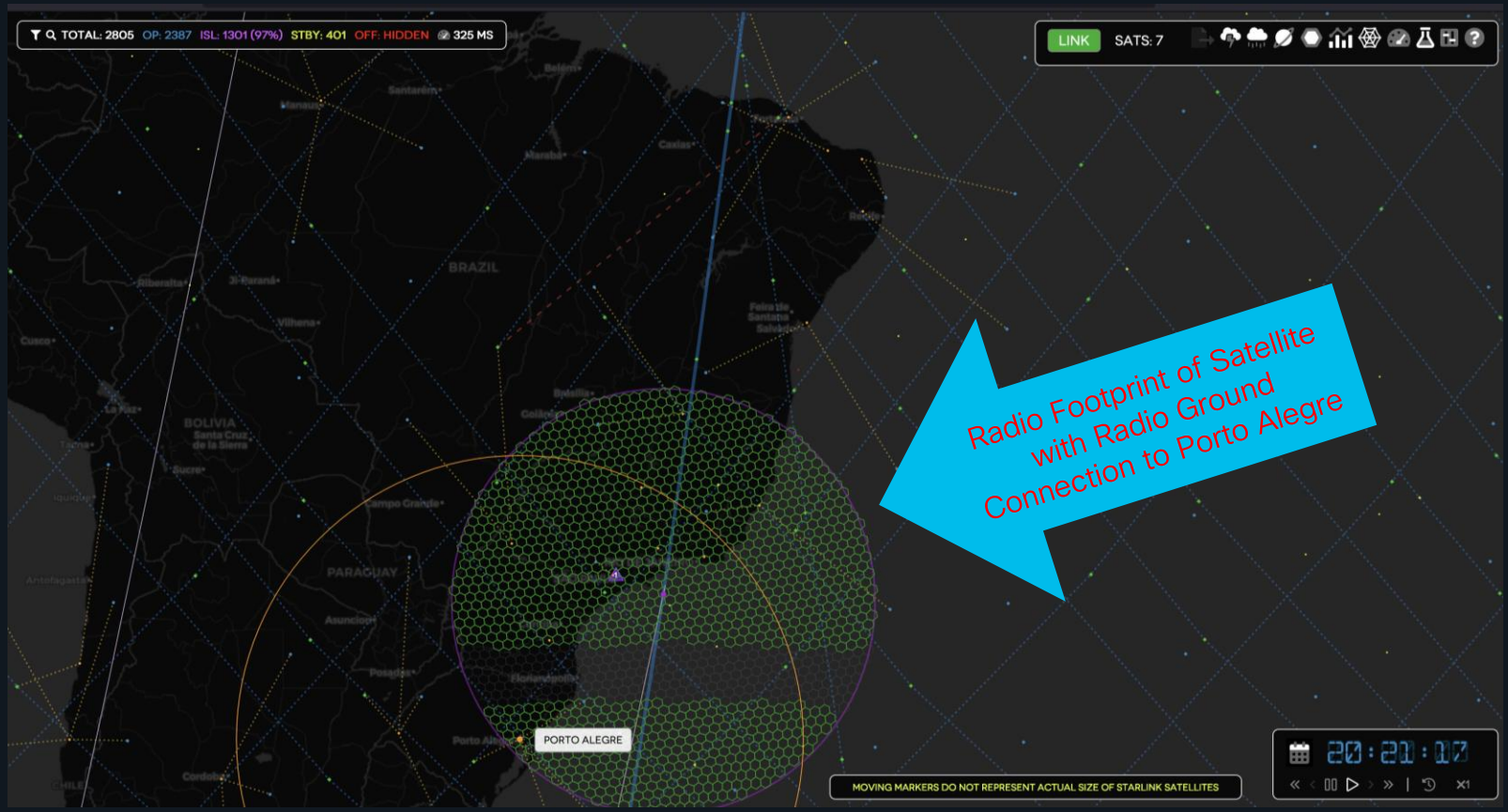

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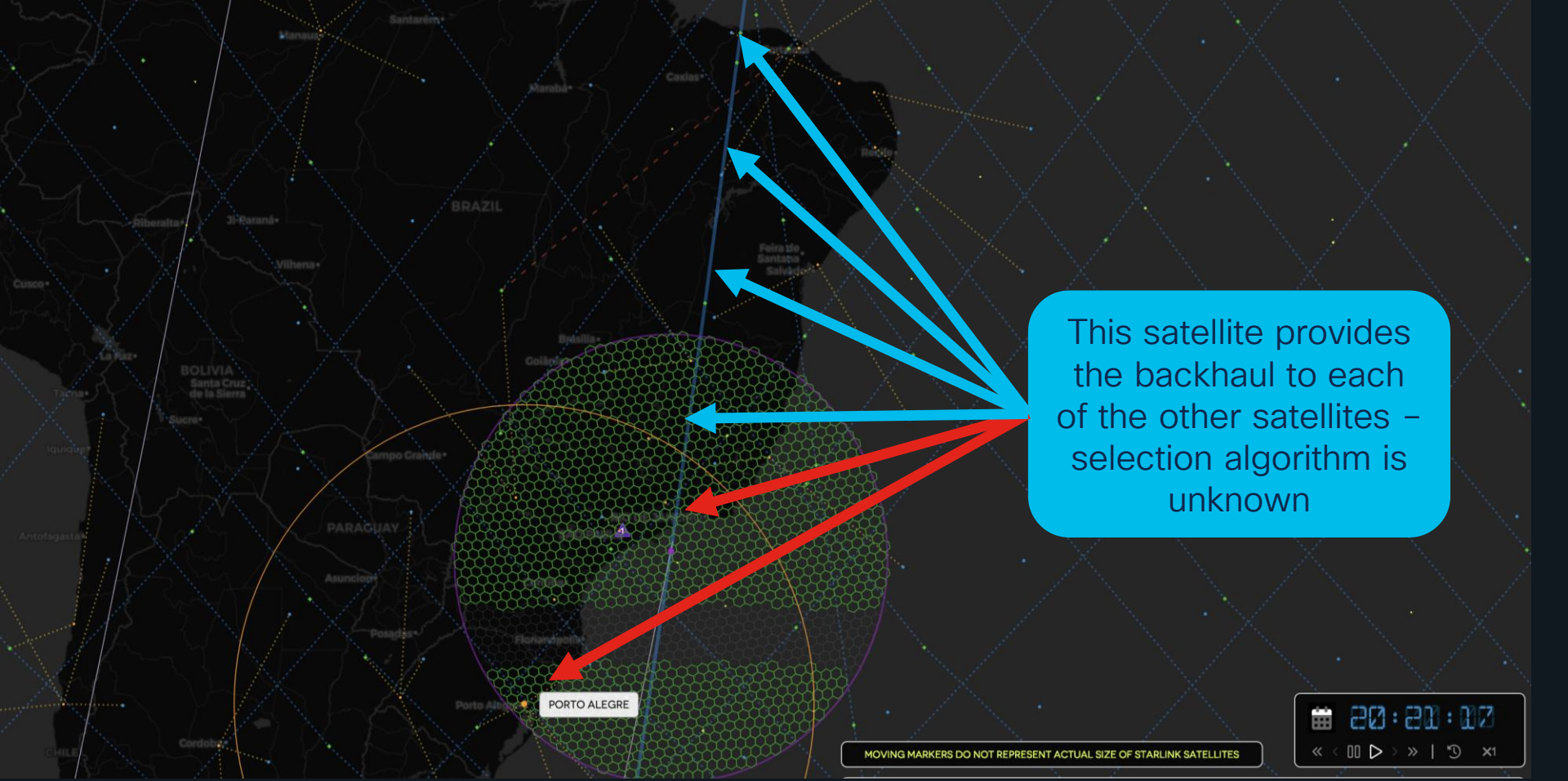

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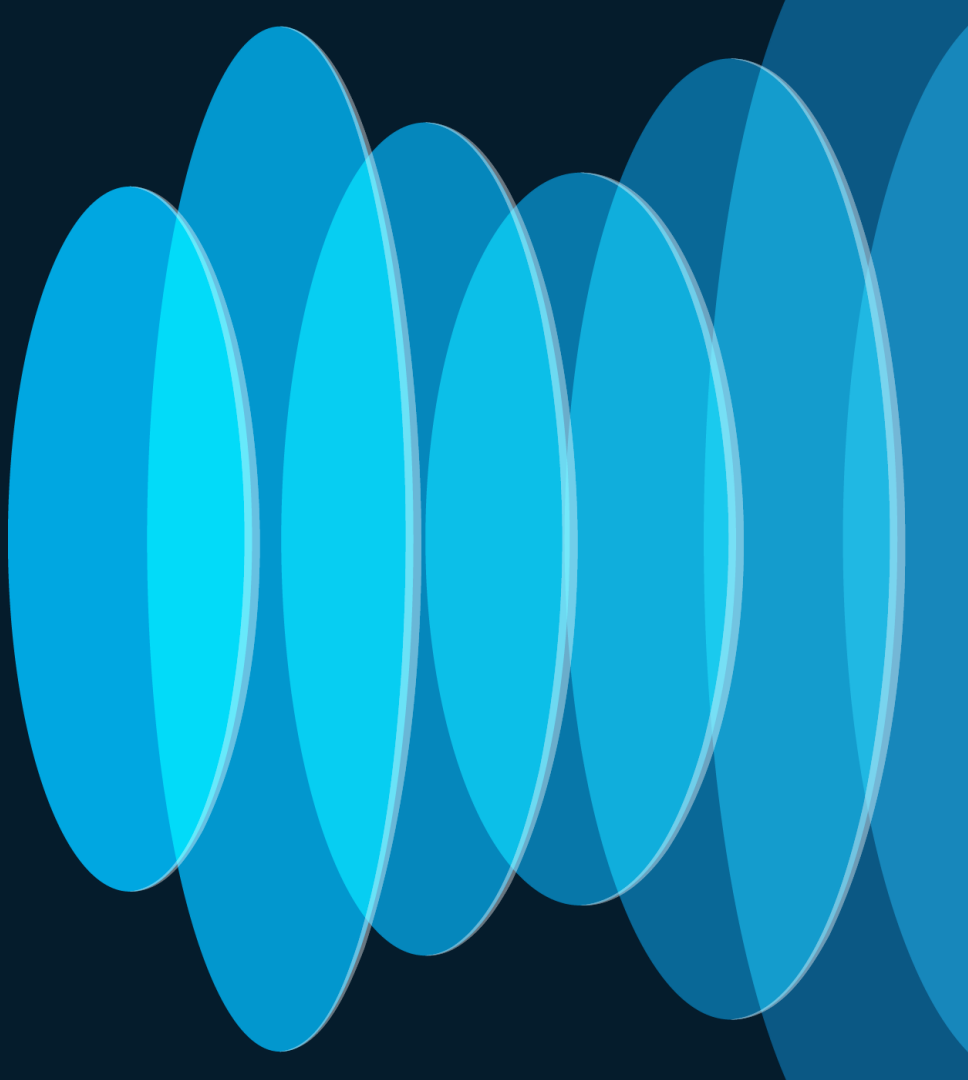
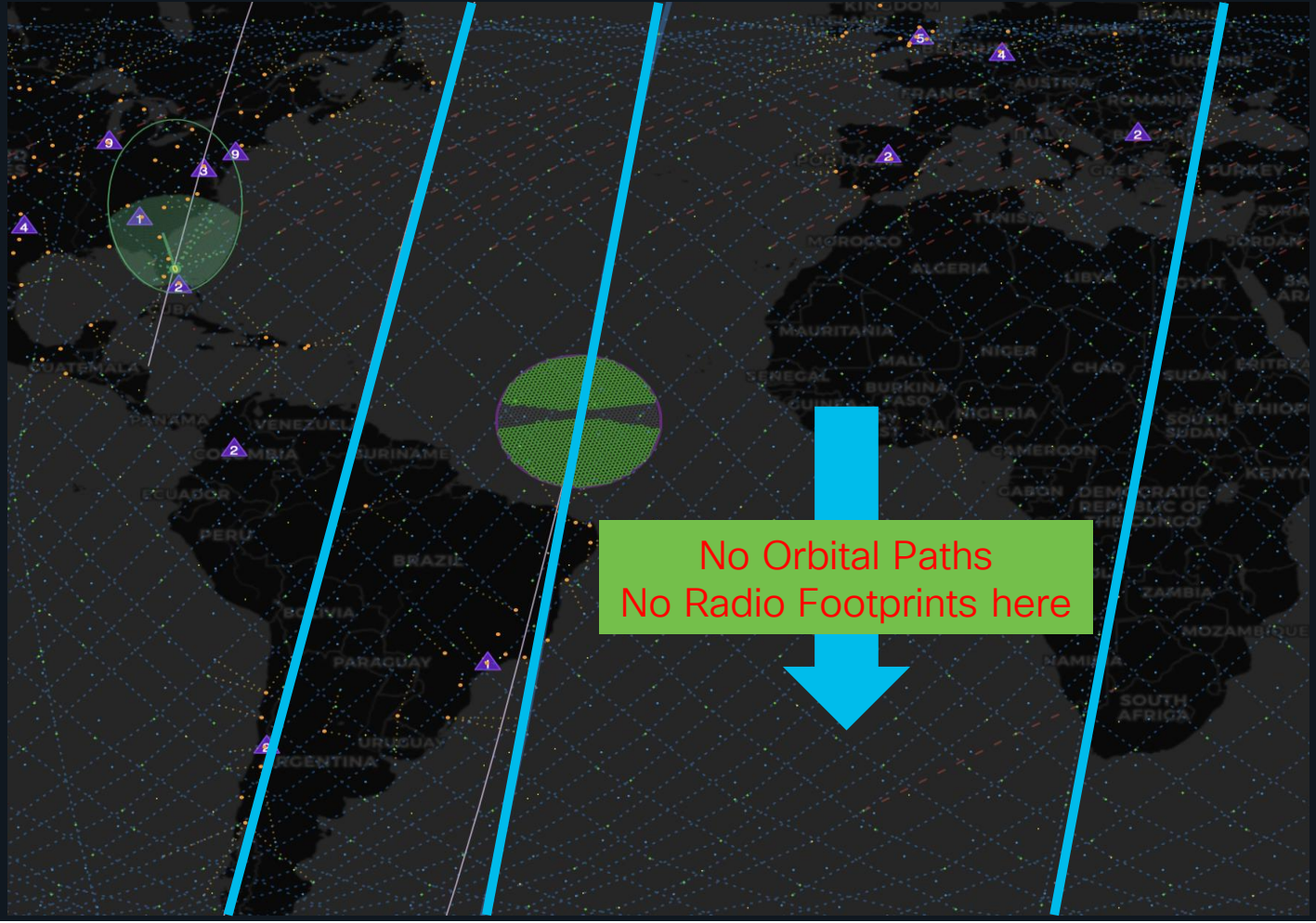
Challenges with Polar Orbits





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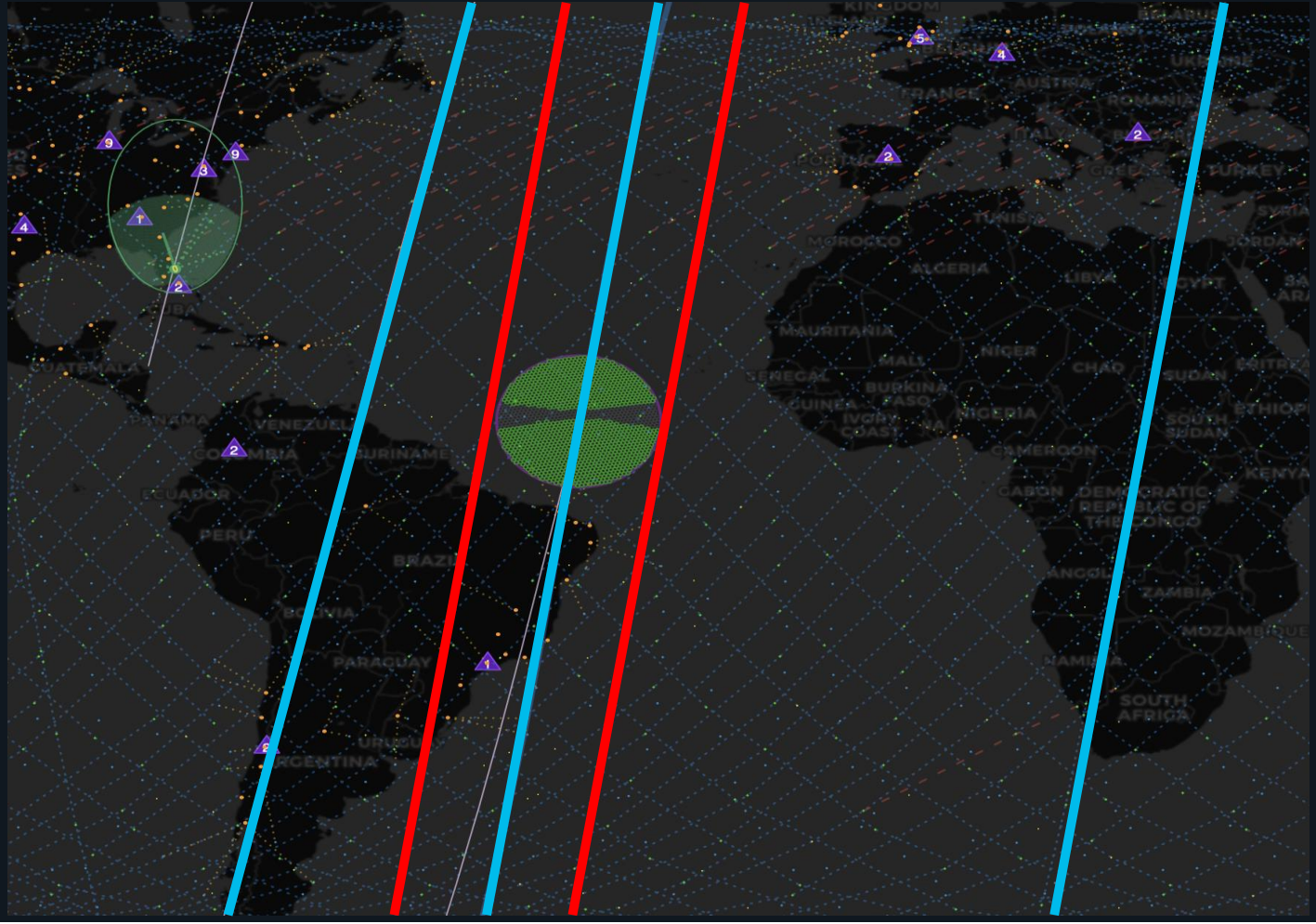

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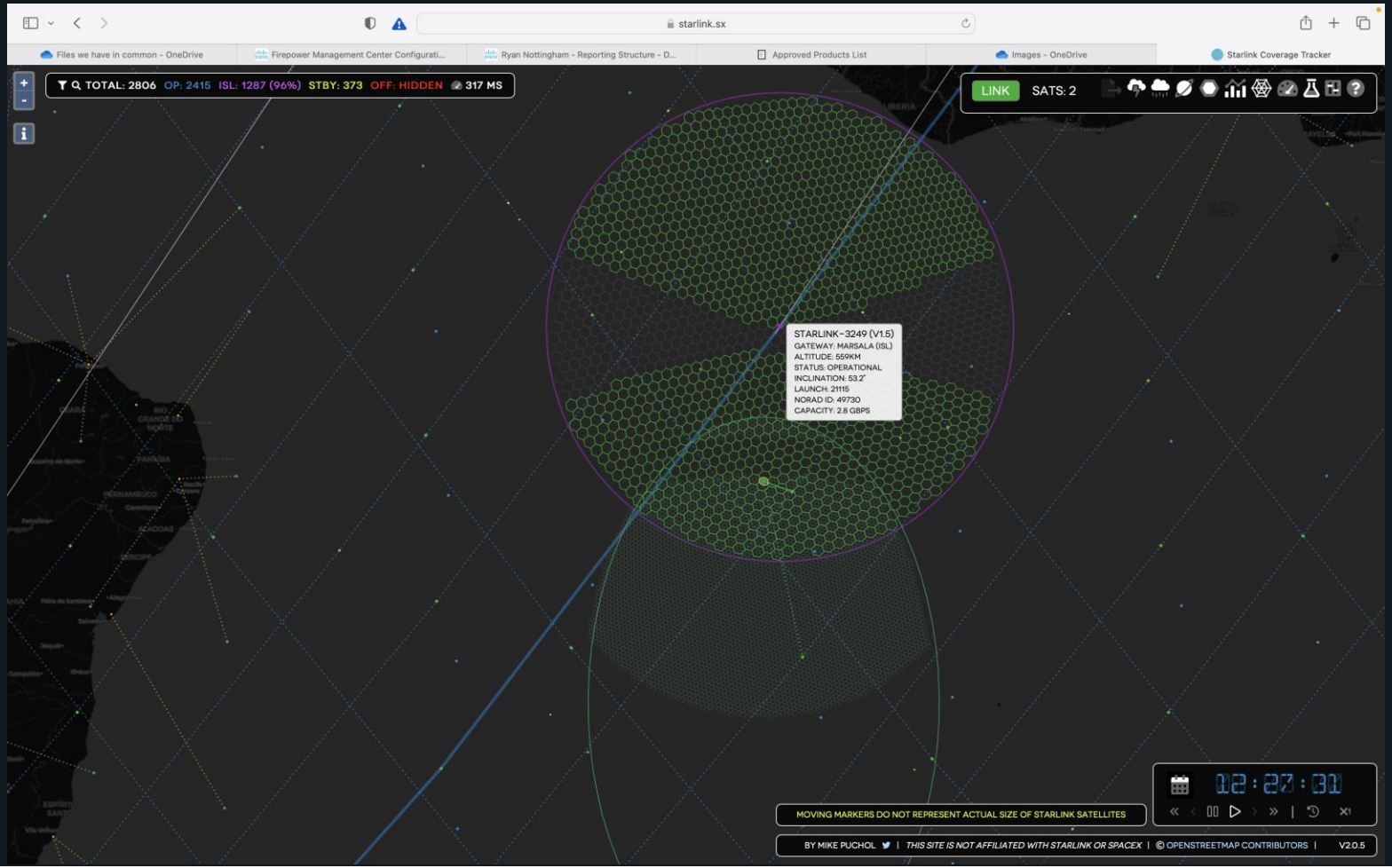

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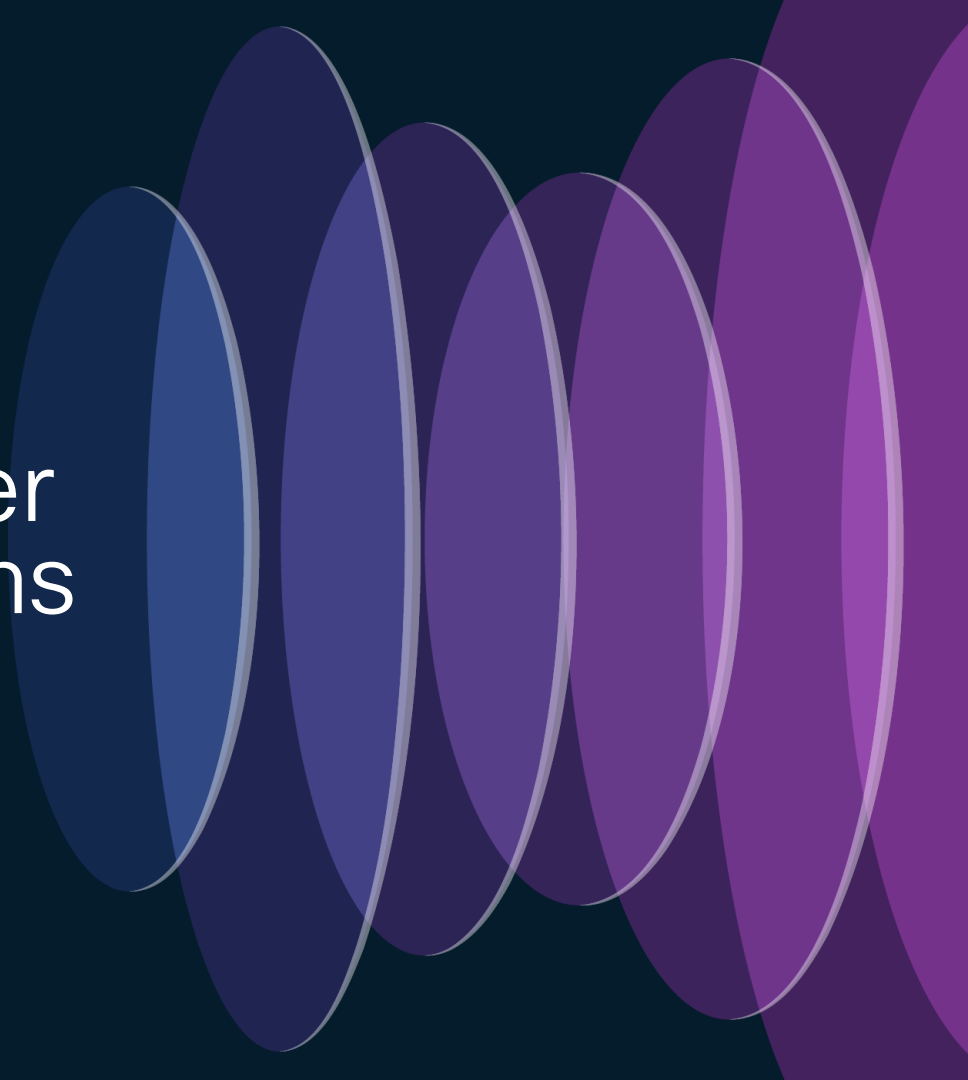
Enterprise Customer Service Assumptions



Setting Expectations

- You like Customer Service
- You want a phone number to call
- You like an email address for your SE
- You have normal Enterprise customer networking and security requirements
- You want security transparency over WAN operations
- You want to be able to control your path to the Internet

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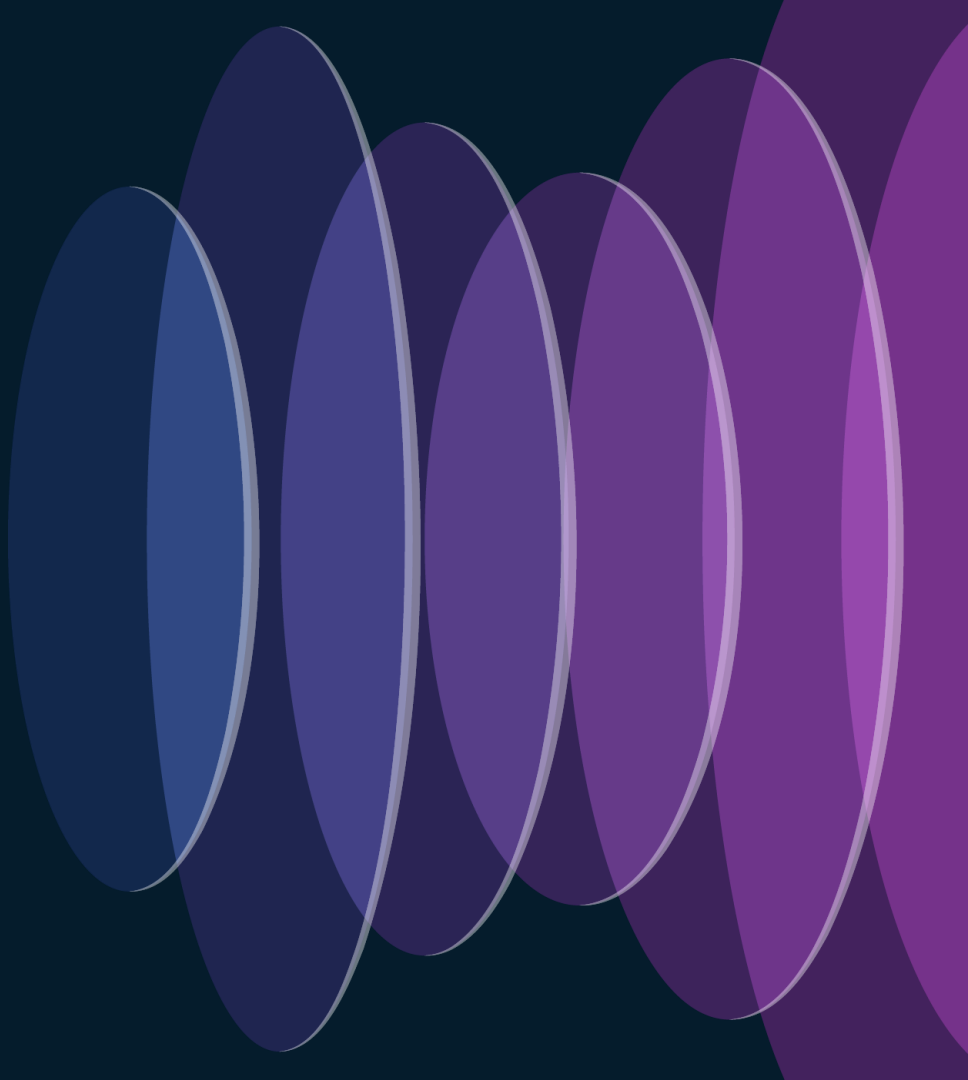
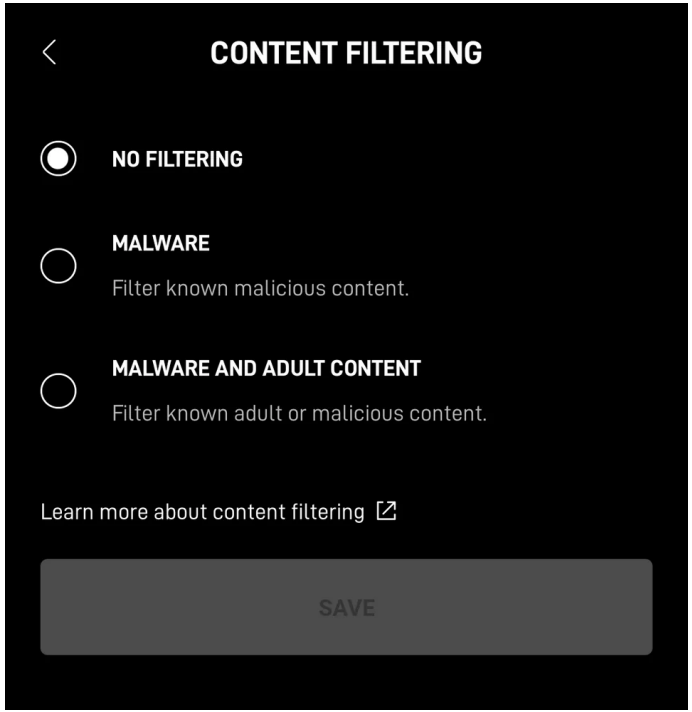
Starlink Security



Sum Total of available Security



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Starlink Security

BYOS – Bring Your Own Security

There is “very limited" security other than what you bring yourself

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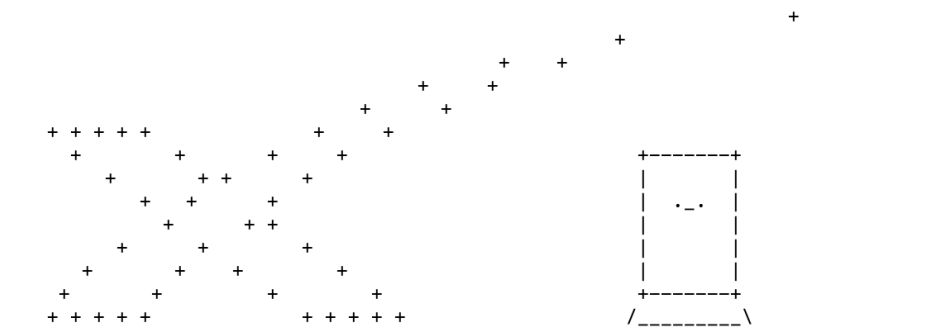
Starlink Router



- Nmap scan report for 192.168.1.1
- Host is up (0.0040s latency).
- Not shown: 994 filtered tcp ports (no-response)
- PORT STATE SERVICE
- 22/tcp open ssh
- 53/tcp open domain
- 80/tcp open http
- 9000/tcp open cslistener
- 9001/tcp open tor-orport
- 9002/tcp open dynamid

- Nmap done: 1 IP address (1 host up) scanned in 45.68 seconds

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Things we know about Starlink Network

- Carrier Grade NAT (CGNAT) at the Internet Gateway
- IPv4 DHCP is assigned across the network
- IPv6 Prefix Delegation works on some Gateways
- Layer 2 network from terminal to ground to exit point (MPLS)
- Native IPSec will not work (CGNAT)
- IPSec Encapsulation works – NAT-T (udp4500)
- TLS VPNs work
- There is NO local NAT configuration possible on the SL Router

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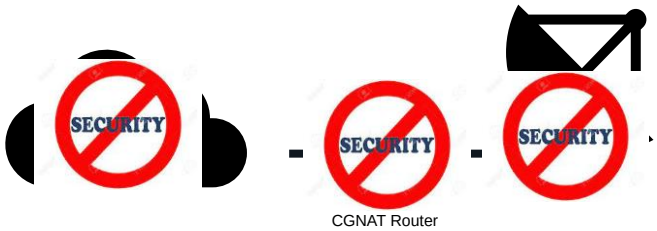
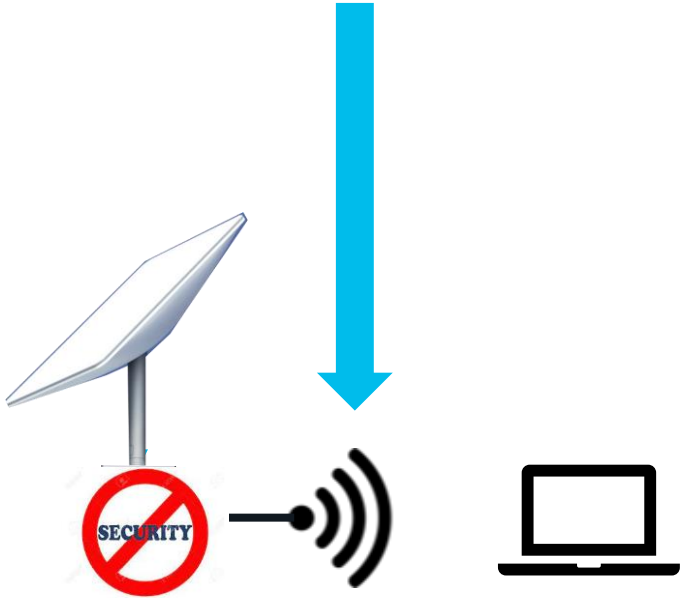
Starlink Security Today



WPA2 Implemented here



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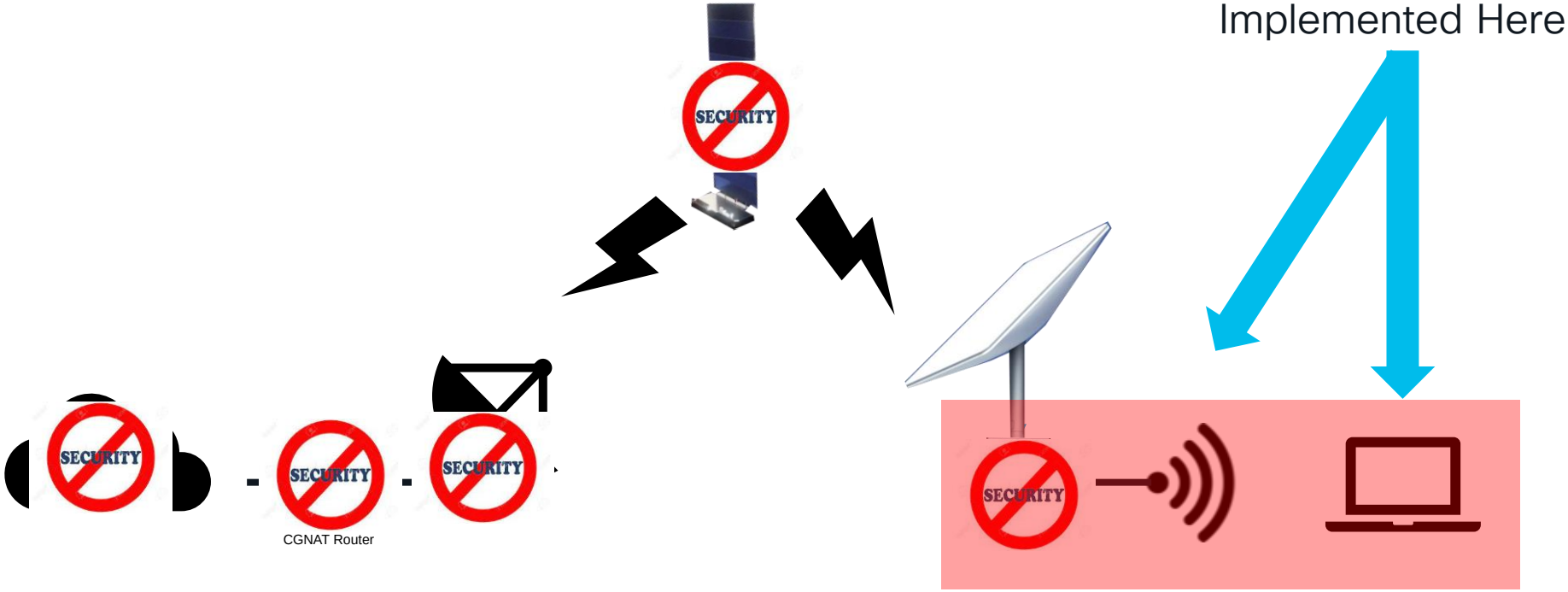
Starlink Security Today



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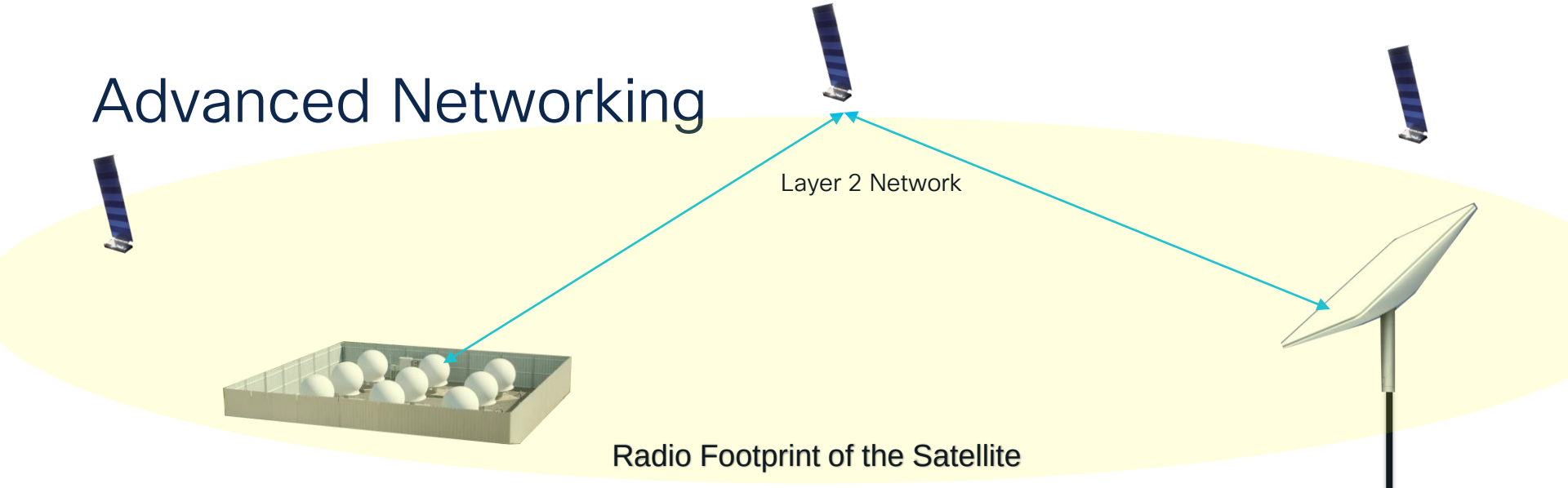
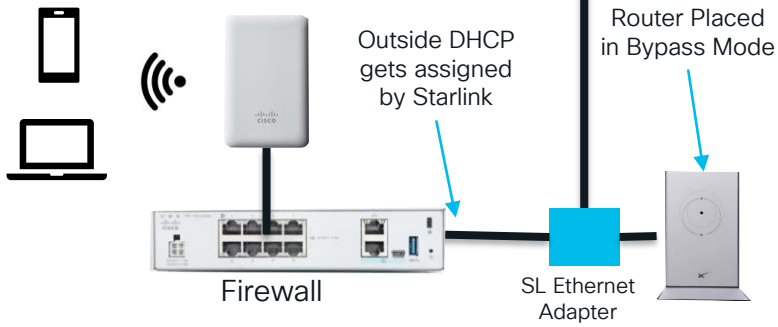
Advanced Networking



SL Router in Bypass Mode:
WIFI Gets disabled
Router is no longer locally accessible
Statistics are stored in SL Cloud
Array connects to SL Cloud and delivers updates



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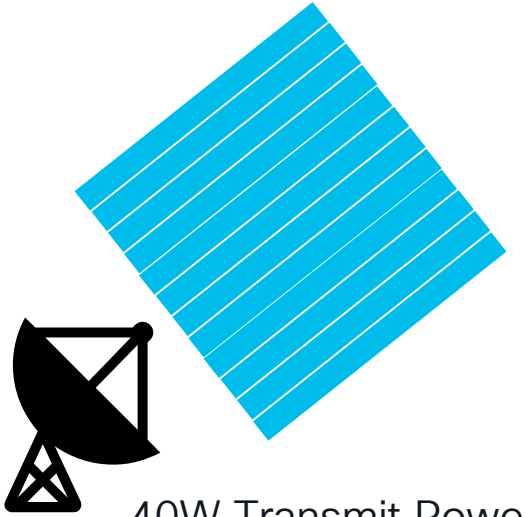
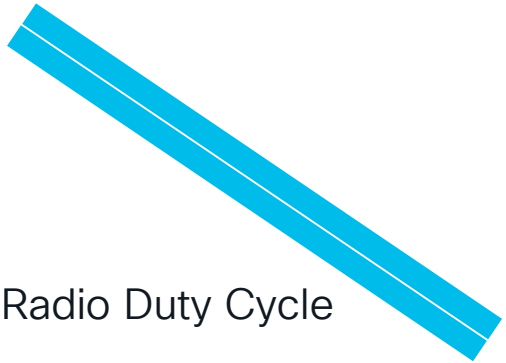
What is really happening (radio nerds)



40W Transmit Power



17% Radio Duty Cycle

43-50 input watts runtime

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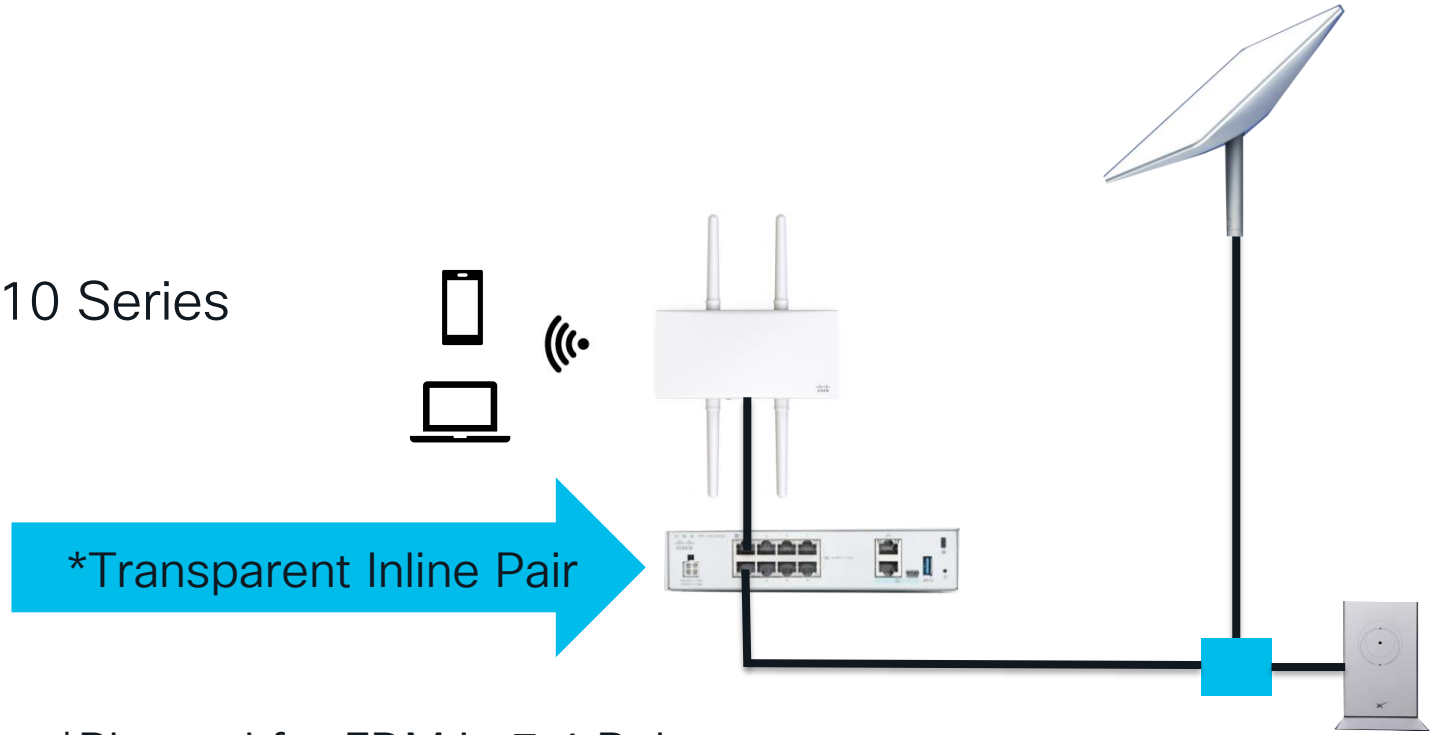
Cisco Security + Starlink

Meraki+Firepower Deployment

- MX Series
- MR Series
- Z3 Series
- Firepower 1010 Series



*Planned for FDM in 7.4 Release

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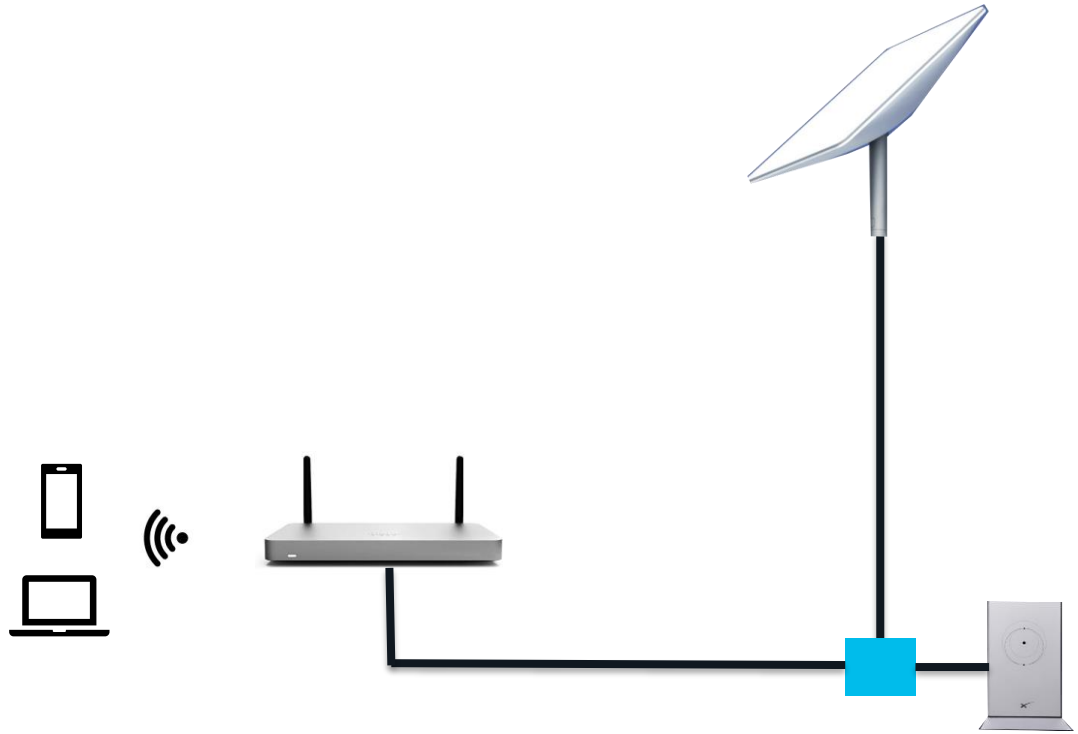
Meraki MX/MR/Z3 Deployment

- MX Series
- MR Series
- Z3 Series



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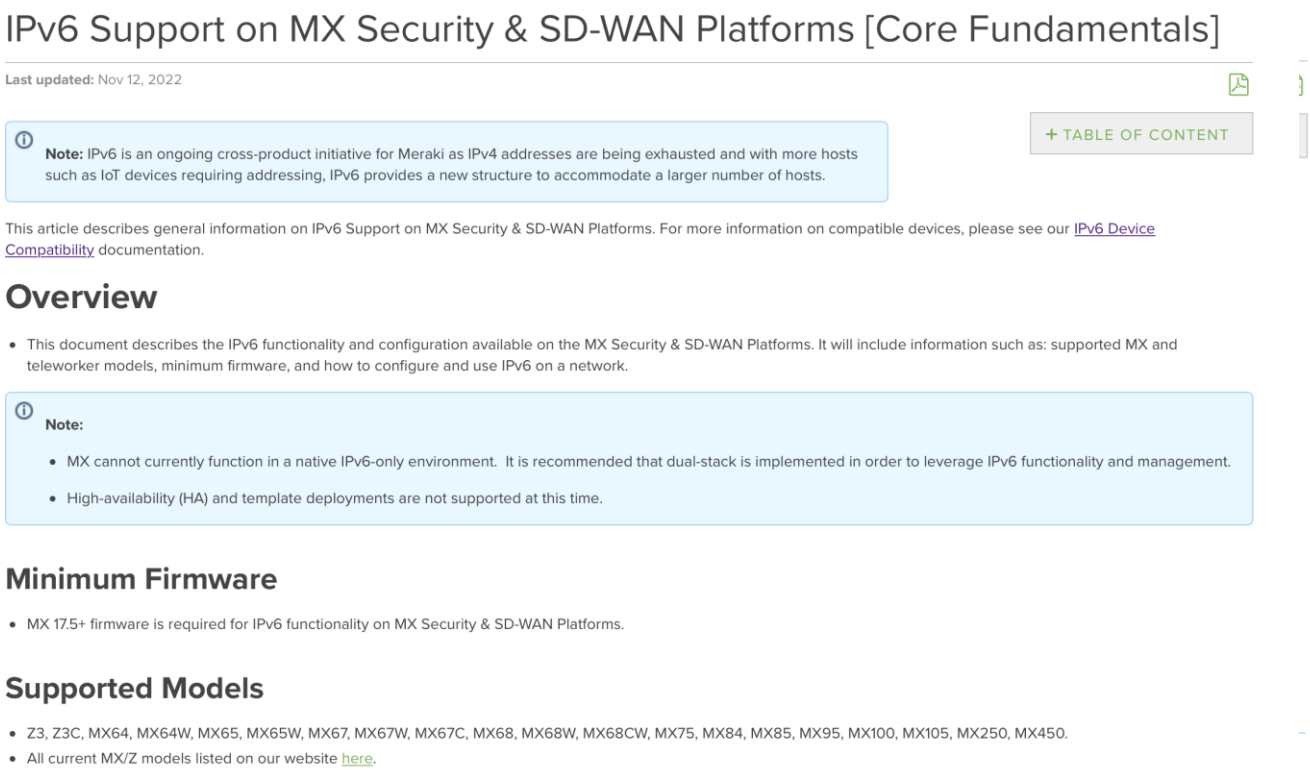
Native IPv6 Support on MX and MR Platforms



IPv6 Support on MX Security & SD-WAN Platforms [Core Fundamentals]

Last updated: Nov 12, 2022

+ TABLE OF CONTENT

Note: IPv6 is an ongoing cross-product initiative for Meraki as IPv4 addresses are being exhausted and with more hosts such as IoT devices requiring addressing, IPv6 provides a new structure to accommodate a larger number of hosts.

This article describes general information on IPv6 Support on MX Security & SD-WAN Platforms. For more information on compatible devices, please see our IPv6 Device Compatibility documentation.

Overview

- This document describes the IPv6 functionality and configuration available on the MX Security & SD-WAN Platforms. It will include information such as: supported MX and teleworker models, minimum firmware, and how to configure and use IPv6 on a network.

Note:

- MX cannot currently function in a native IPv6-only environment. It is recommended that dual-stack is implemented in order to leverage IPv6 functionality and management.
- High-availability (HA) and template deployments are not supported at this time.

Minimum Firmware

- MX 17.5+ firmware is required for IPv6 functionality on MX Security & SD-WAN Platforms.

Supported Models

- Z3, Z3C, MX64, MX64W, MX65, MX65W, MX67, MX67W, MX67C, MX68, MX68W, MX68CW, MX75, MX84, MX85, MX95, MX100, MX105, MX250, MX450.
- All current MX/Z models listed on our website here.

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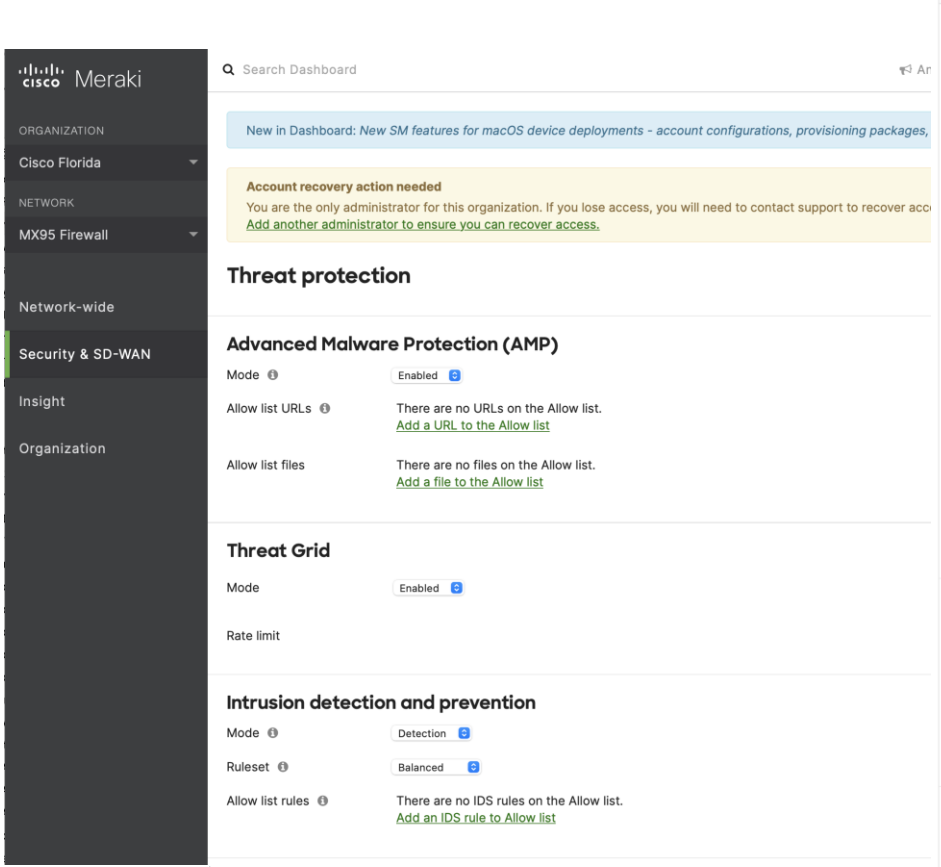
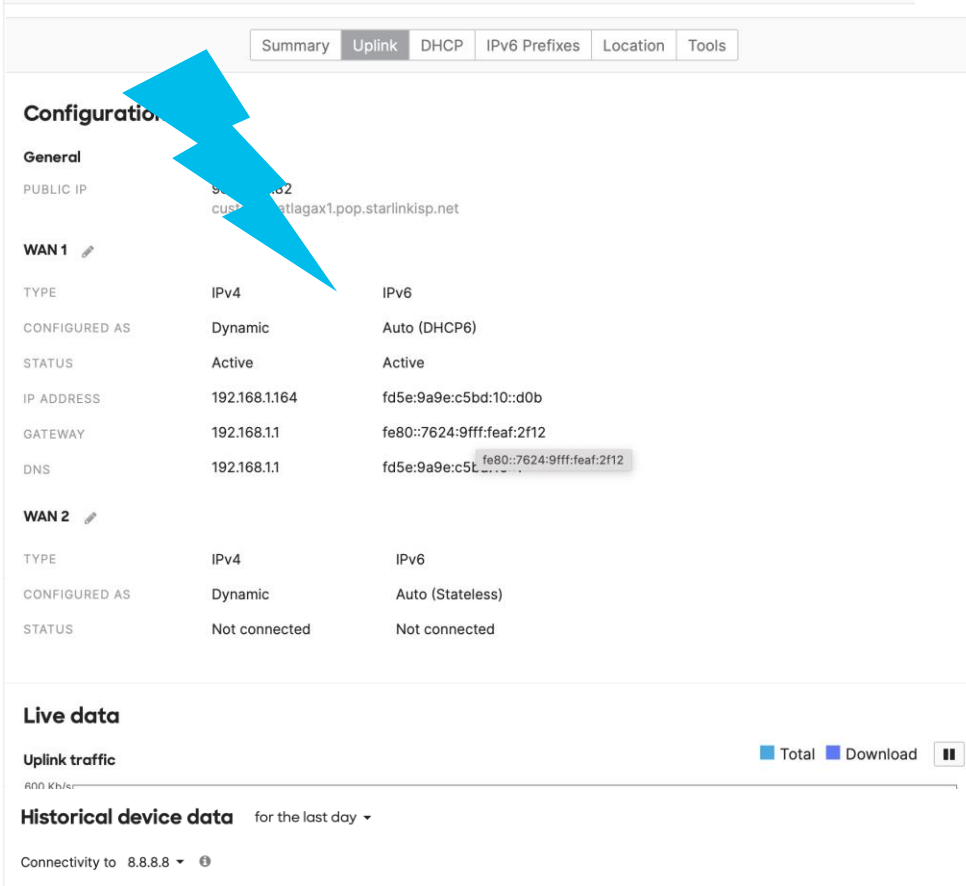
Meraki is the simplest security option





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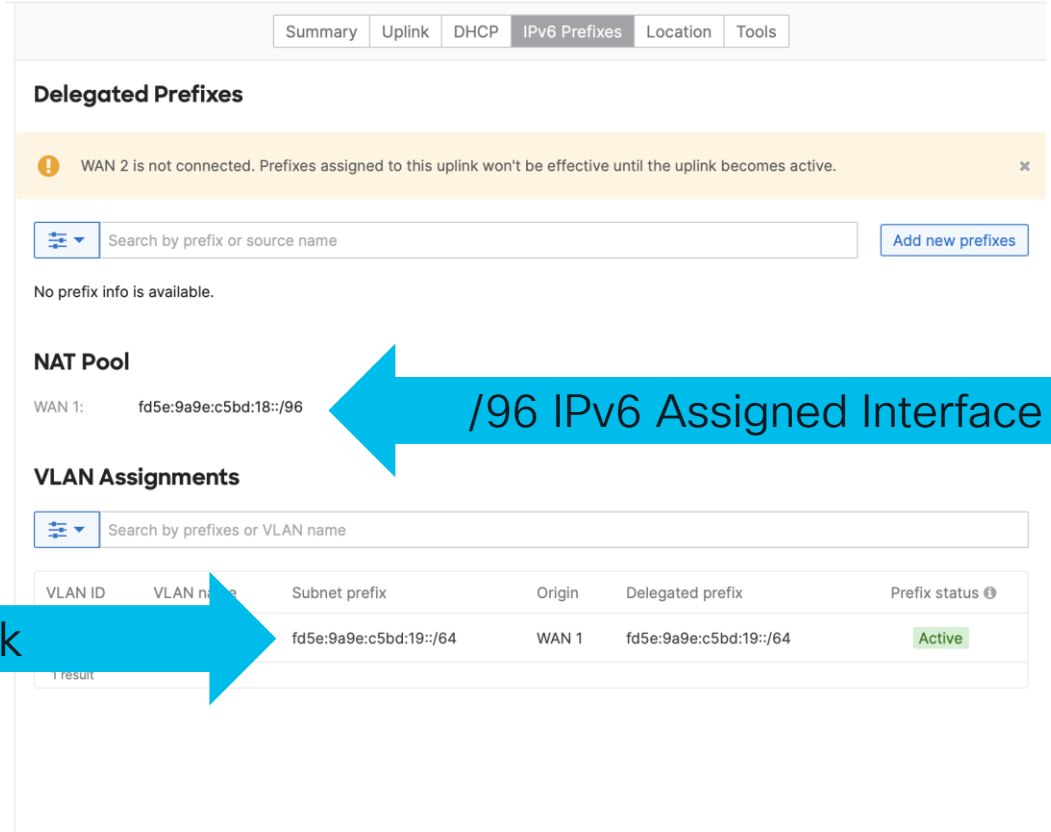
Meraki is the simplest IPv6 Deployment Option

- Takes the downstream Prefix Delegation
- Automatically deploys it to the downstream networks
- Clients will be assigned IPv6 address out of your assigned Prefix



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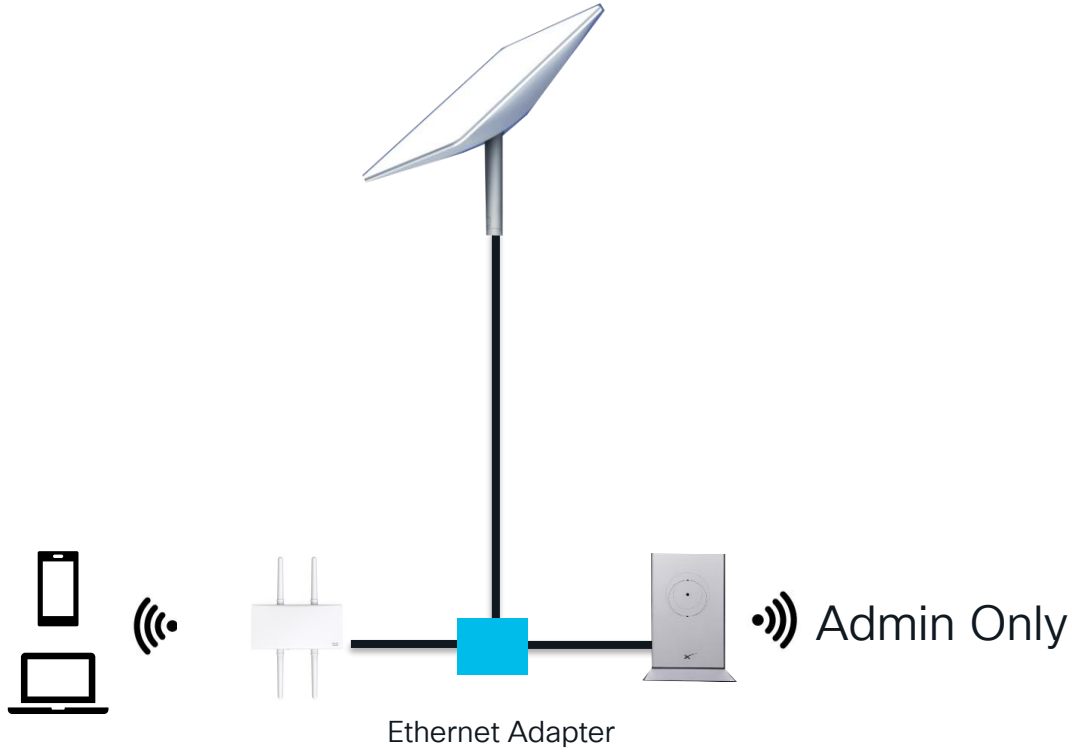
Keep it simple, don’t overcomplicate things



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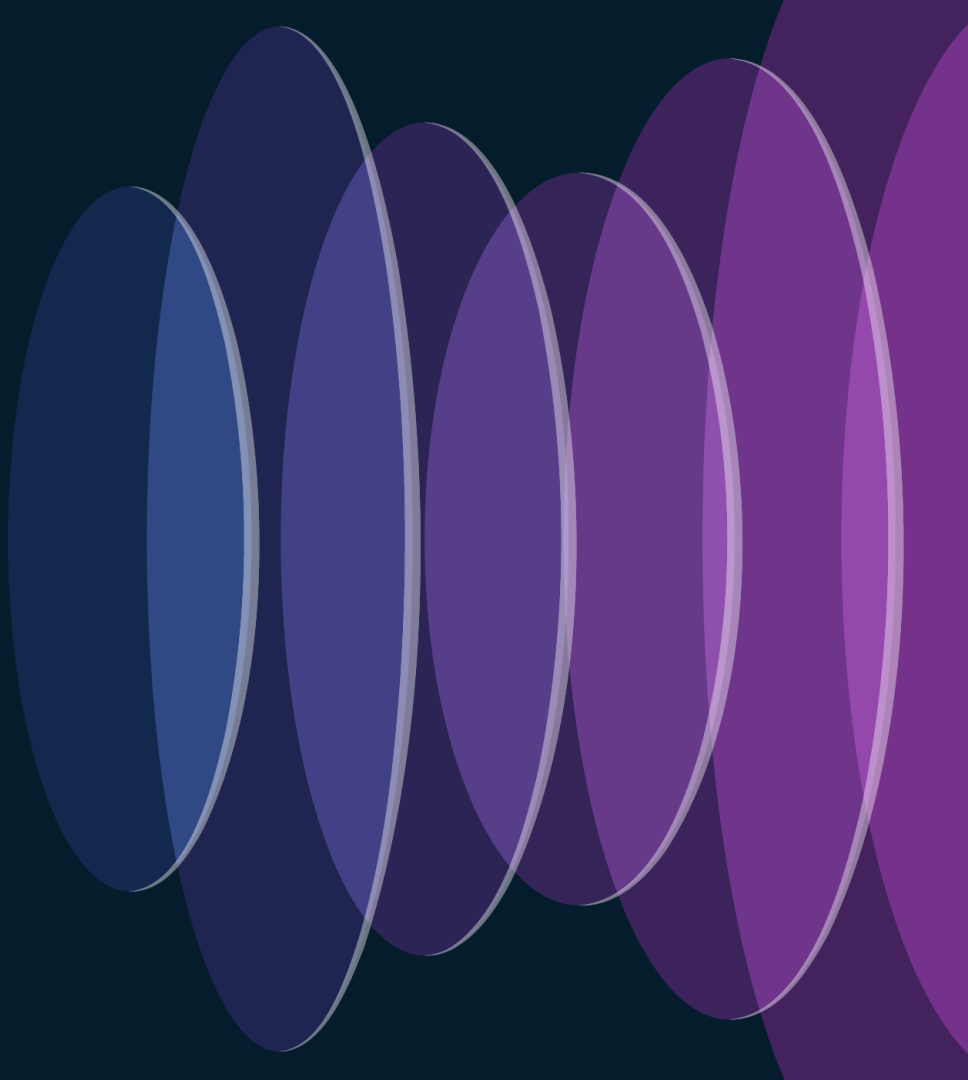
Actual Working Things



Add another administrator to ensure you can recover access.

Global Overview

Organization
Cisco Florida

Network
MX95 Firewall

Network-wide

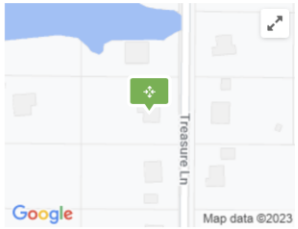
Security & SD-WAN

Insight

Organization

Starlink-MX95

MX95 a8:46:9d:3c:b6:d2



ADDRESS
5840 Treasure Lane, Grant, Florida 32949

WARM SPARE
Configure warm spare

WAN 1
98.97.181.203 Active
2605:59c8:6087:3a10::d0b Active

WAN 2

HOSTNAME
grant-florida-rckhqznmqc.dynamic-m.com

SERIAL NUMBER
Q2XN-CRBC-3HG5

TAGS

NOTES

Configuration

General

PUBLIC IP

WAN 1

TYPE

CONFIGURED AS

PREVIOUS STATUS

IP ADDRESS

GATEWAY

DNS

WAN 2

TYPE

CONFIGURED AS

STATUS

Live data

Uplink traffic

1 b/s
0.75 b/s
0.5 b/s
0.25 b/s
0 b/s

peplink | Dashboard | SFC Protect | Network | Advanced | AP | System | Status | Apply Changes

General

Logout

WAN Connection Status

Independent from Priority		
Starlink	Connected via Starlink	192.168.1.21
1 Verizon-Cisco	Connected to Verizon LTE-A	100.103.182.178
2 WAN-WIFI	Connected to GigE-Spectrum	192.168.1.108
Priority 1 (Highest)		
1 WIFI-WAN 2.4Ghz	Scanning...	(No IP Address)
Priority 2		
2 T-Mobile	No Device Detected	(No IP Address)
Priority 3		
Drag desired (Priority 3) connections here		
Disabled		
VLAN WAN 1	Disabled	(No IP Address)

LAN Interface

Router IP Address: 192.168.50.1

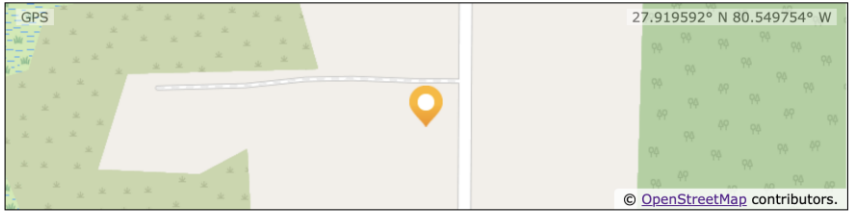
Wi-Fi AP ON Status

2.4 GHz 5 GHz Pepwa (United ...	2.4 GHz 5 GHz Pepwa (United ...	2.4 GHz 5 GHz Pepwa (United ...	2.4 GHz 5 GHz Pepwave-WIFI

SpeedFusion Connect Protect

SFC-ATL	Established
SFC-CHI	Established
SFC-MIA	Established

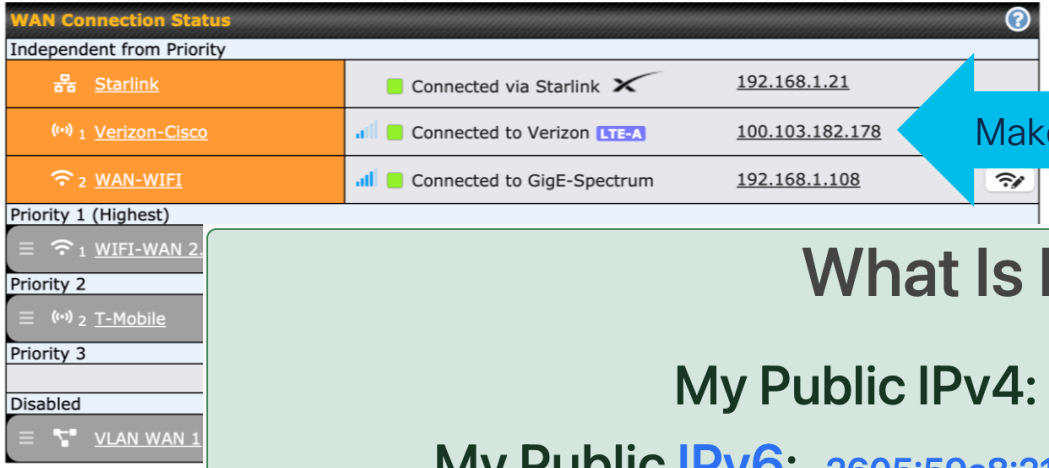
Data usage allowance: 1003.20 GB (Expiry date: Apr 11, 2024)



Device Information

Model: Peplink MAX Transit Duo Pro

cisco Live!



Makes forwarding decision based on API feedback

What Is My IP?

My Public IPv4: 98.97.18.37

CG-NAT IP

My Public IPv6: 2605:59c8:2103:7310:654e:1122:4a82:e20a

My IP Location: New York City, NY US

My ISP: SpaceX Services Inc.

Actually does API lookups

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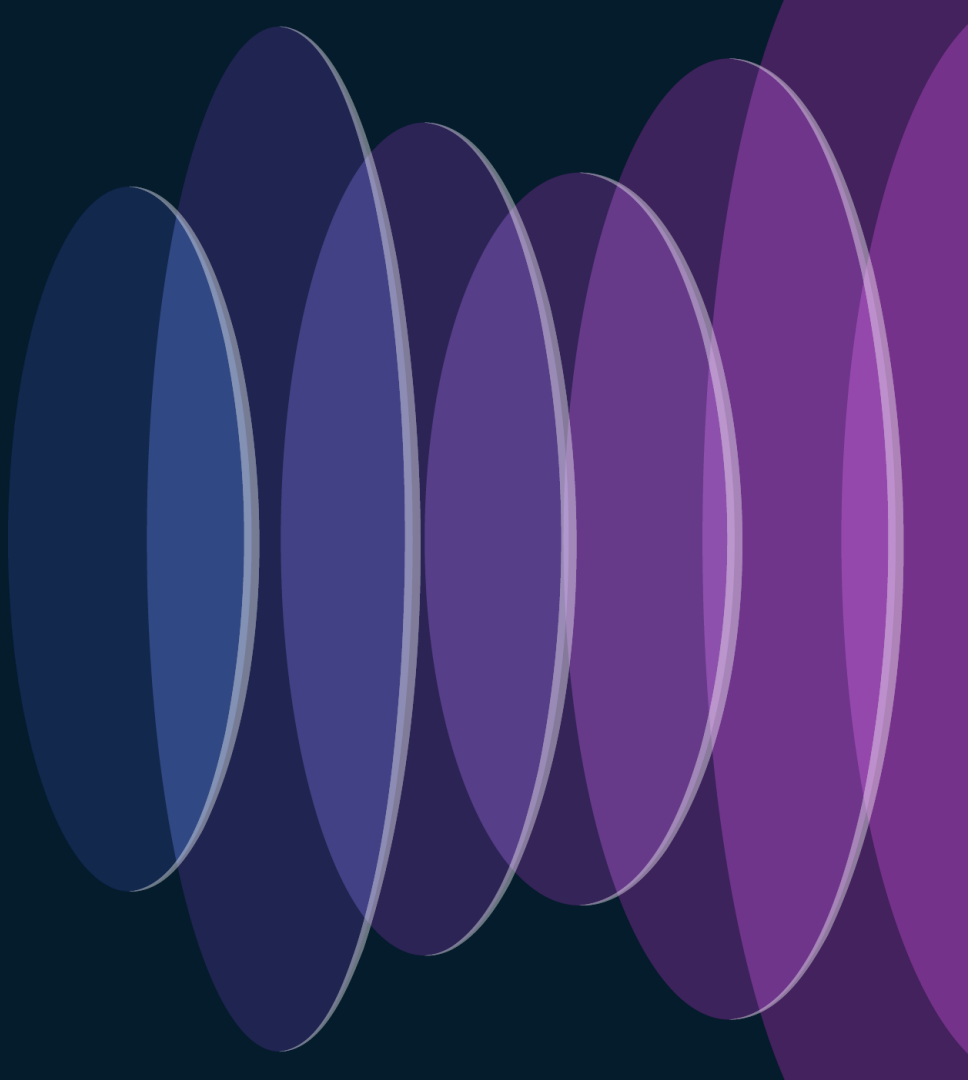
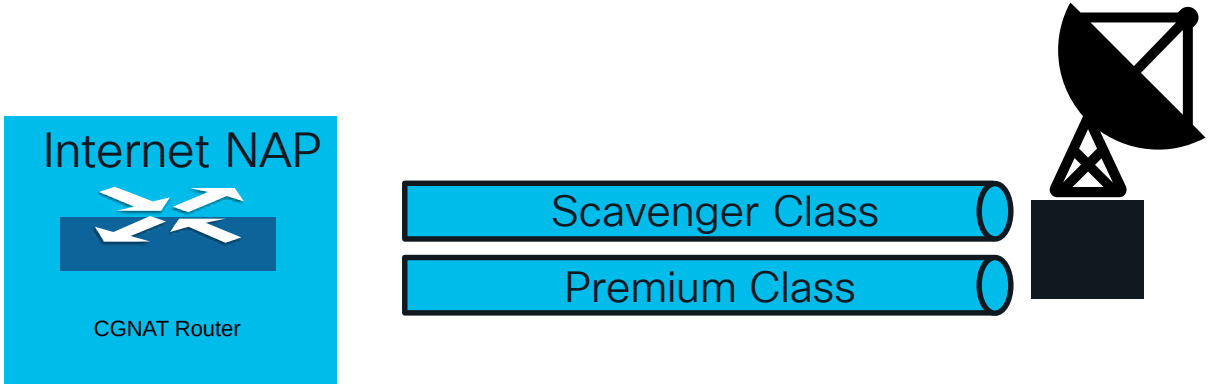
Deployment Considerations



QoS Observations

- Terminals (arrays) are statically linked to what we believe to be MPLS VPNs with static exits to the Internet

Scavenger class QoS



Residential QoS

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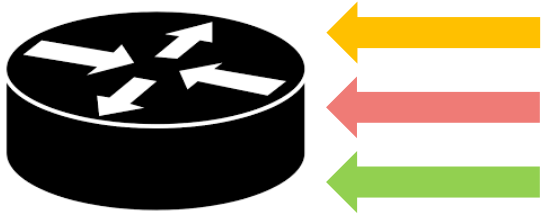
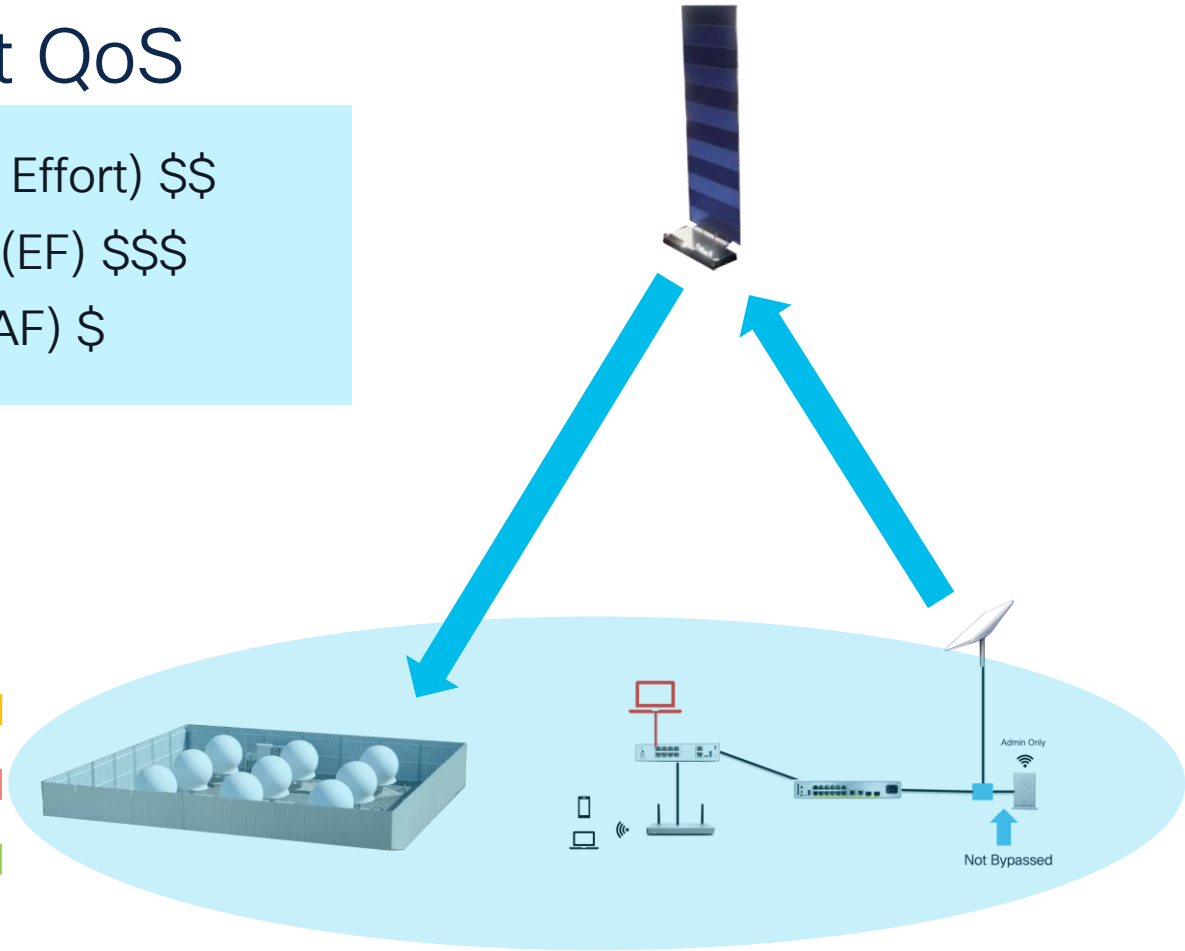
Observed Current QoS

Mobile (Best Effort) $$

Priority Data (EF) $$$

Residential (AF) $





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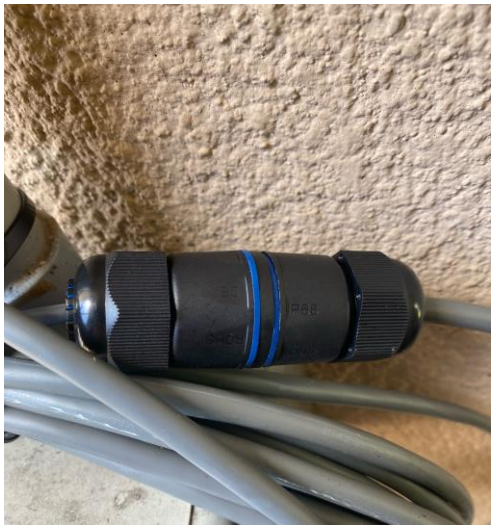
Deployment Considerations

- You will probably want a 150 foot cable
- You can make a 300+ foot cable easily by inserting Ethernet in the middle
  - Use High Quality watertight connectors



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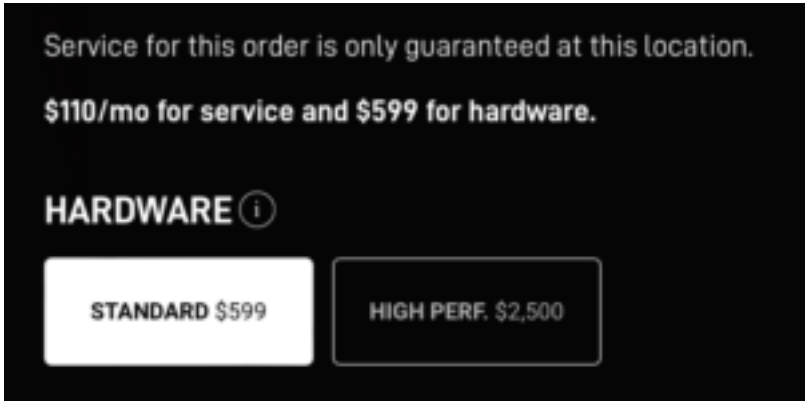
Decisions



- “High Performance” is simply double the array
- They have a single GigE output – but have doubled the transceivers
- They are clearly creating a Service Class for High Performance users and doing traffic engineering to support it

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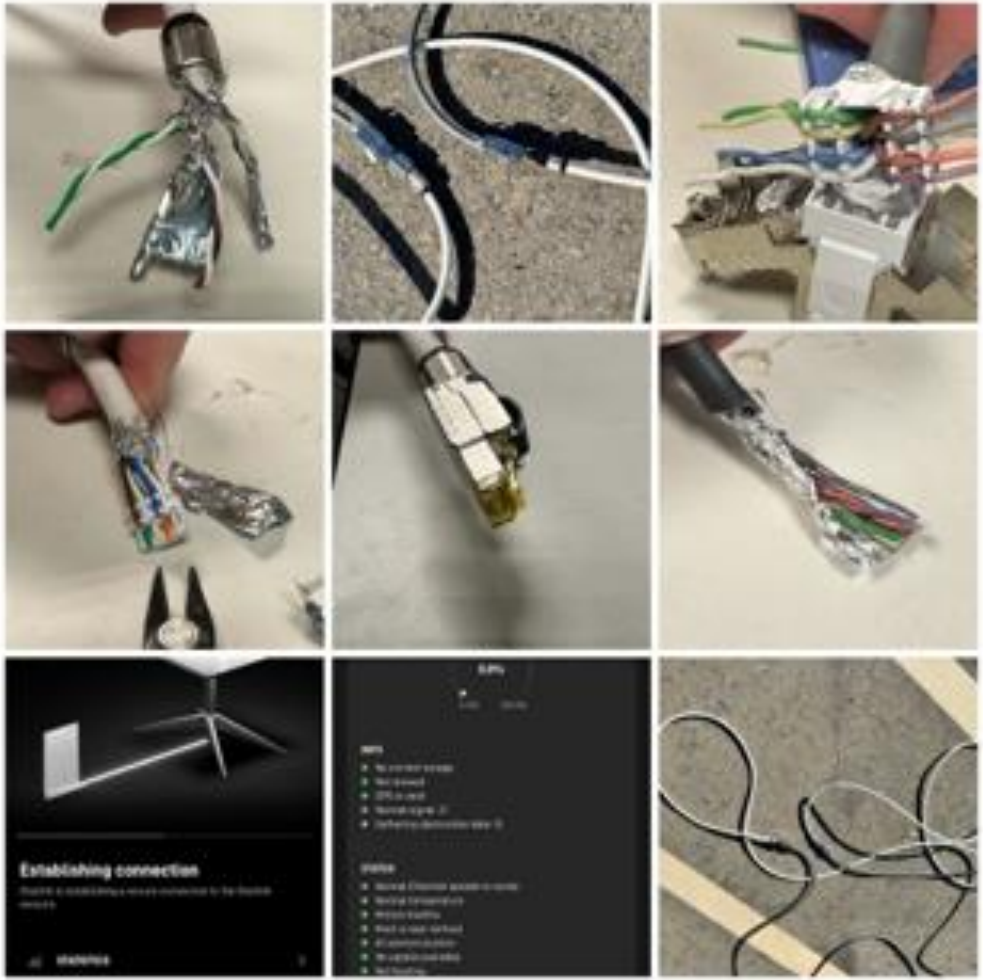
High Performance Terminal Considerations

HP Wires are 22AWG!

HP pin / Pot / Dish Wire Color / RJ-45 pin & Color using 568B standard
A1 + Green 1 Orange/White
A2 + Yellow 2 Orange
A3 + Blue 3 Green/White
A4 + White 6 Green
B1 - Orange 7 Brown/White
B2 - Purple 8 Brown
B3 - Brown 5 Blue/White
B4 - Gray 4 Blue
B5 × Shield / Shell

CAT8 22AWG STP RJ45



*Courtesy: Lyle Tanner

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I had a recent important meeting to attend but it conflicted with PTO....

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IR1101 Ruggedized Router

IR1101 – Starlink Integration

- Ruggedized Router meant for harsh conditions
- Pluggable LTE – including Multi-SIM
- New LTE P-LTEA7-NA= capable of support T-Mobile waveform for Starlink Direct to Cell frequencies

- SDWAN Capable
- 802.1AE MACSEC on LAN
- IPSec on WAN
- Runs full IOS-XE – 17.15

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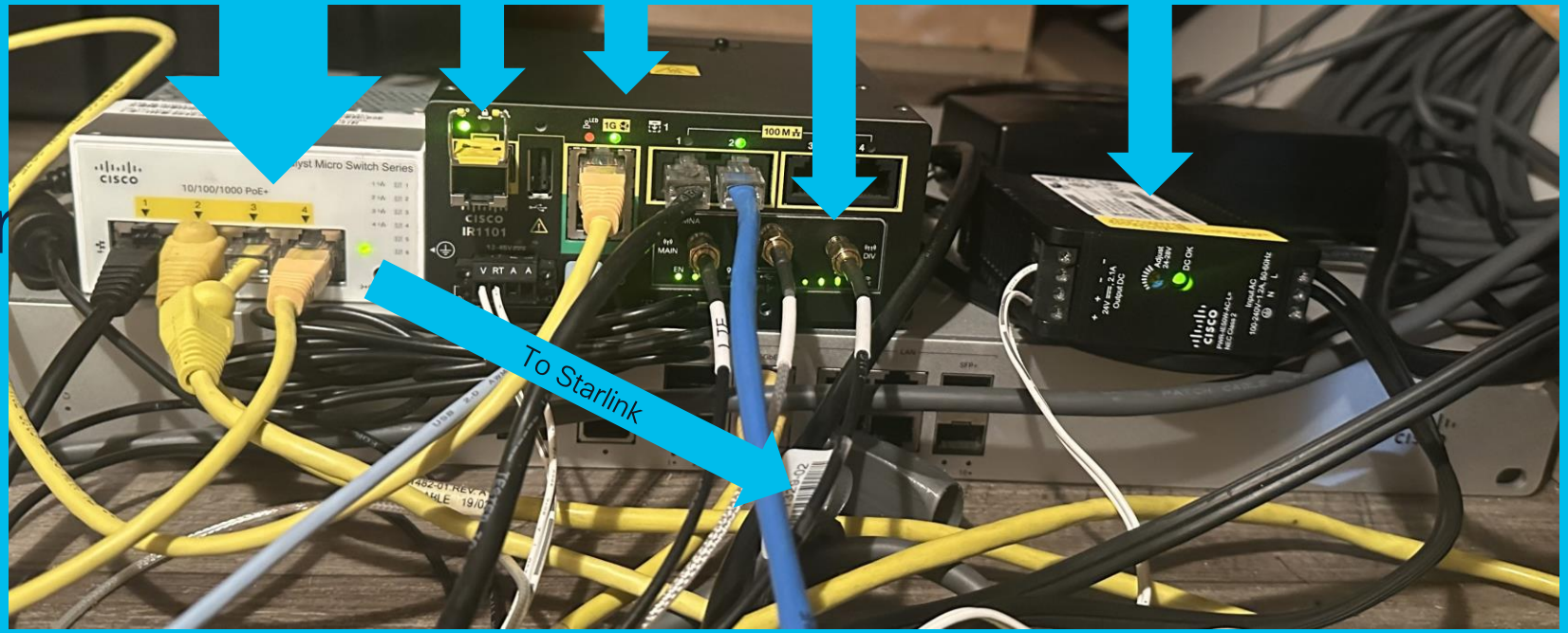
AC to DC Power Brick

GigE to Catalyst

Pluggable LTE Radio

Catalyst Micro Switch
Single VLAN

SFP



Fir ..

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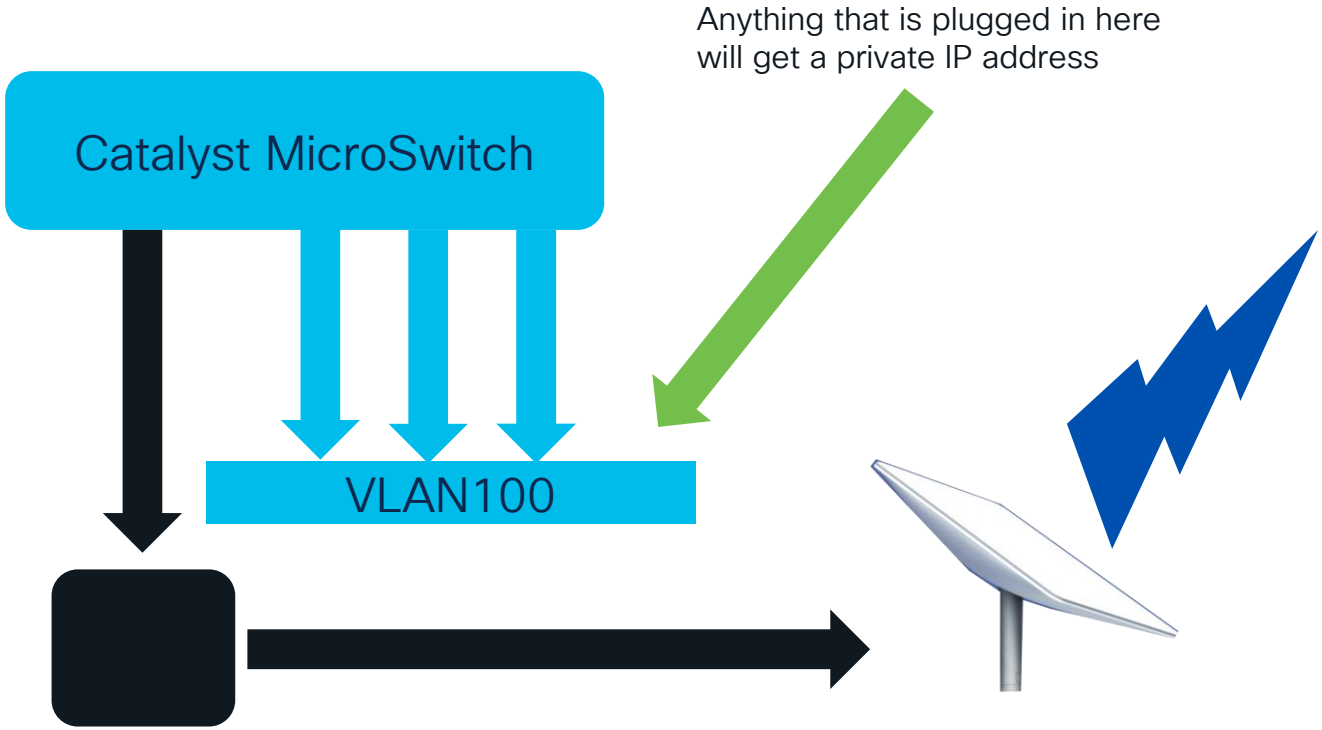
How it works



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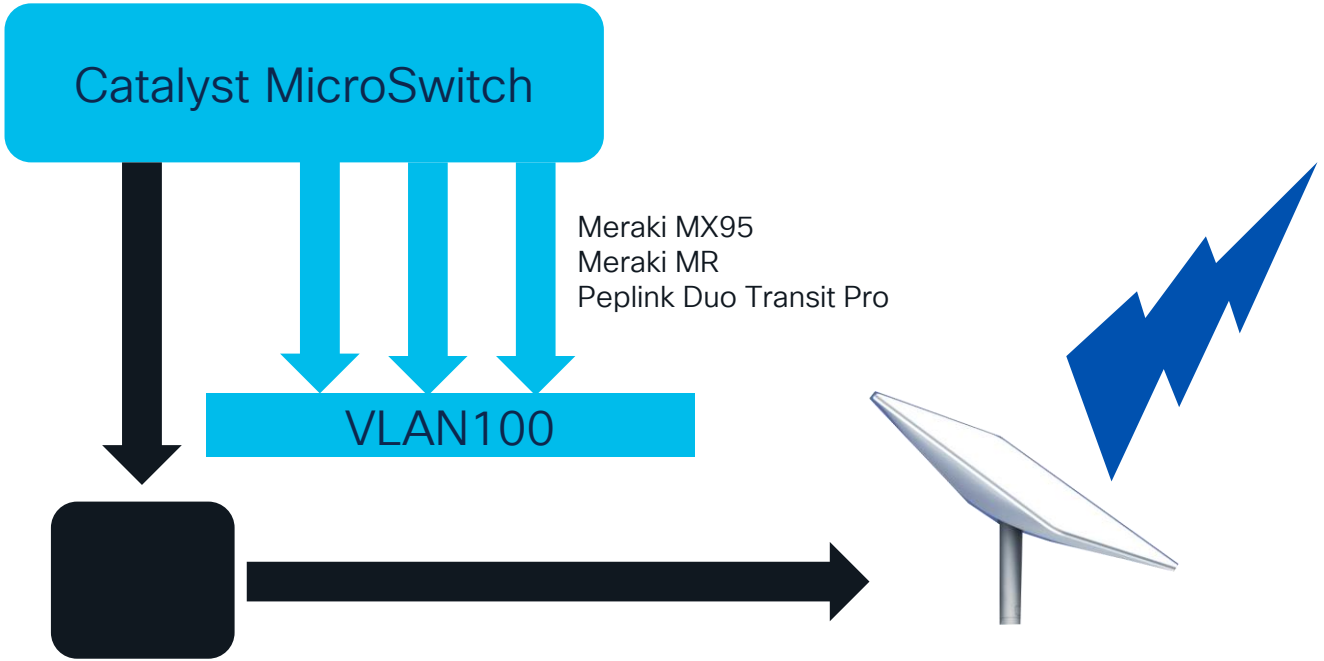
How it works



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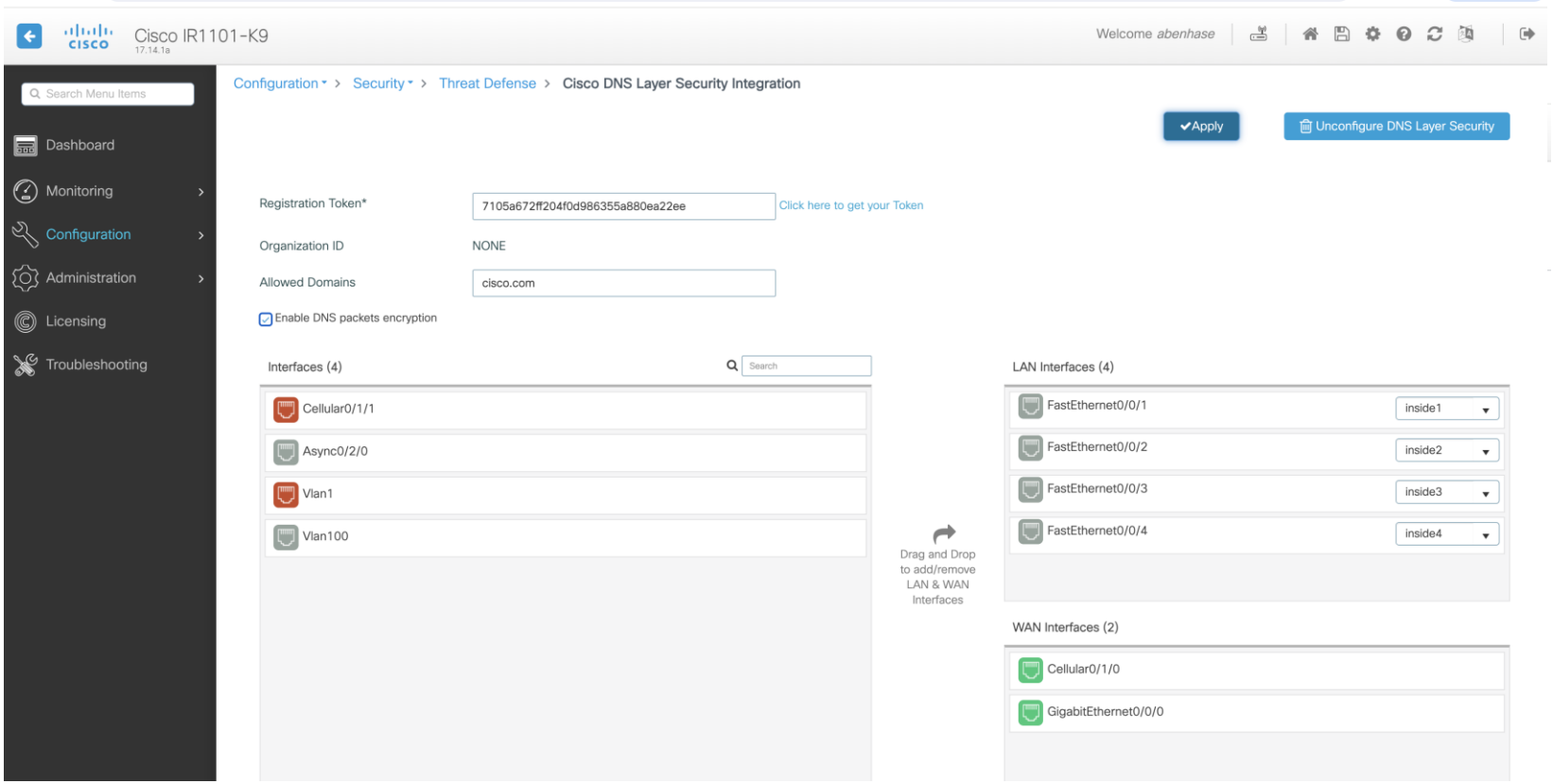
What can I do with an IR1101 to secure SL?



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Cellular Gateway/Starlink

- Starlink can be primary link using phased array
- LTE model can be secondary backup in the event that primary waveform fails
- LTE failover to cellular network if primary path fails

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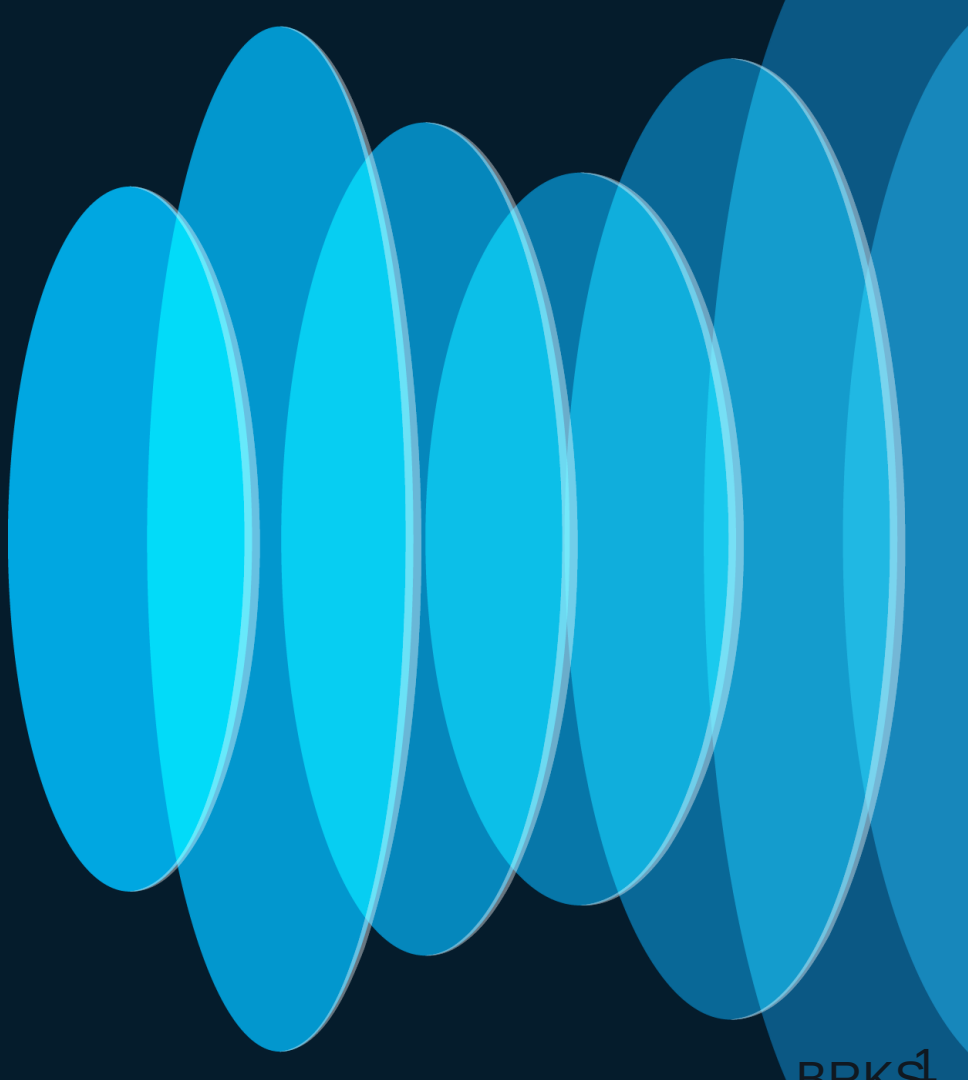
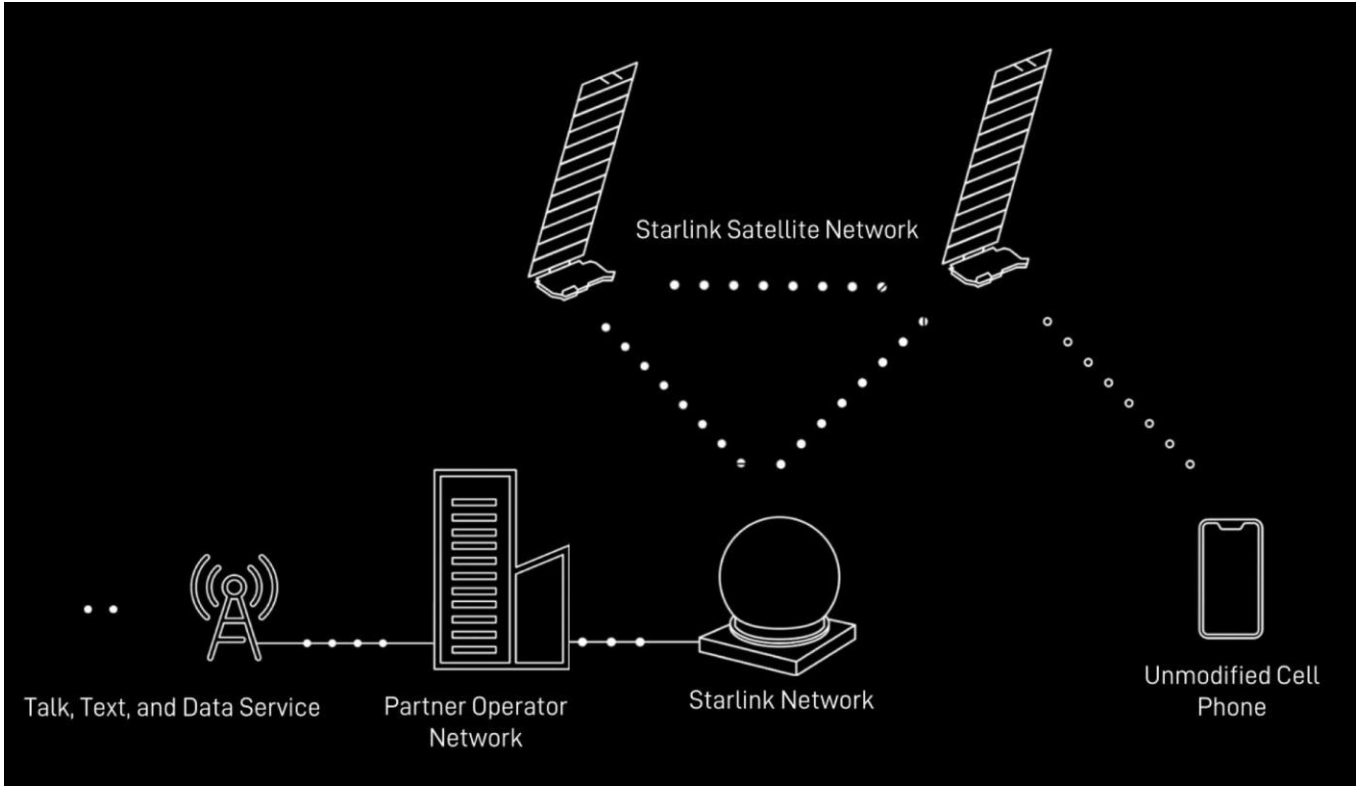
Starlink Direct to Cell (DTC)



Direct to Cell



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Starlink – Direct to Cell

- Contract with T-Mobile to provide capability in CY2025
- Operates at 1.6Ghz to 2.7Ghz
- No Phased Array required!!!
- ~38 satellites in orbit currently
- New satellites are being launched each week
- Starlink v2 MINI Only capability
- Starship will be a critical enabler

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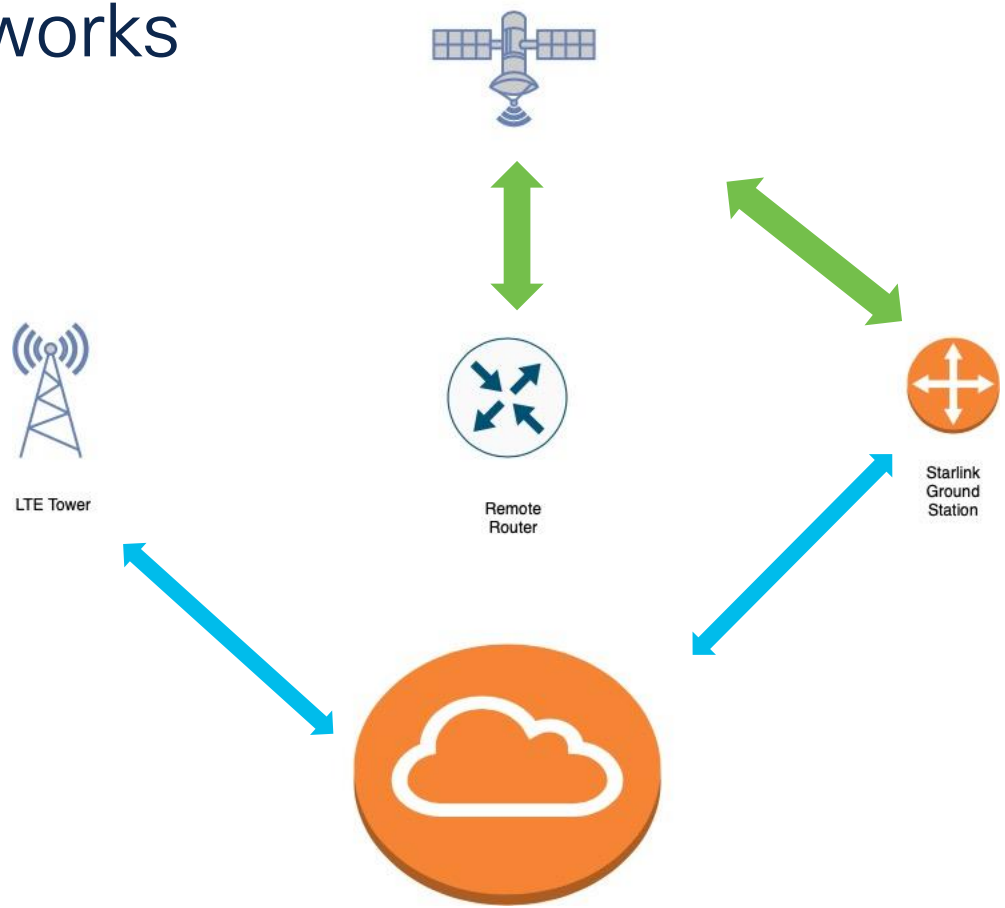
How this works



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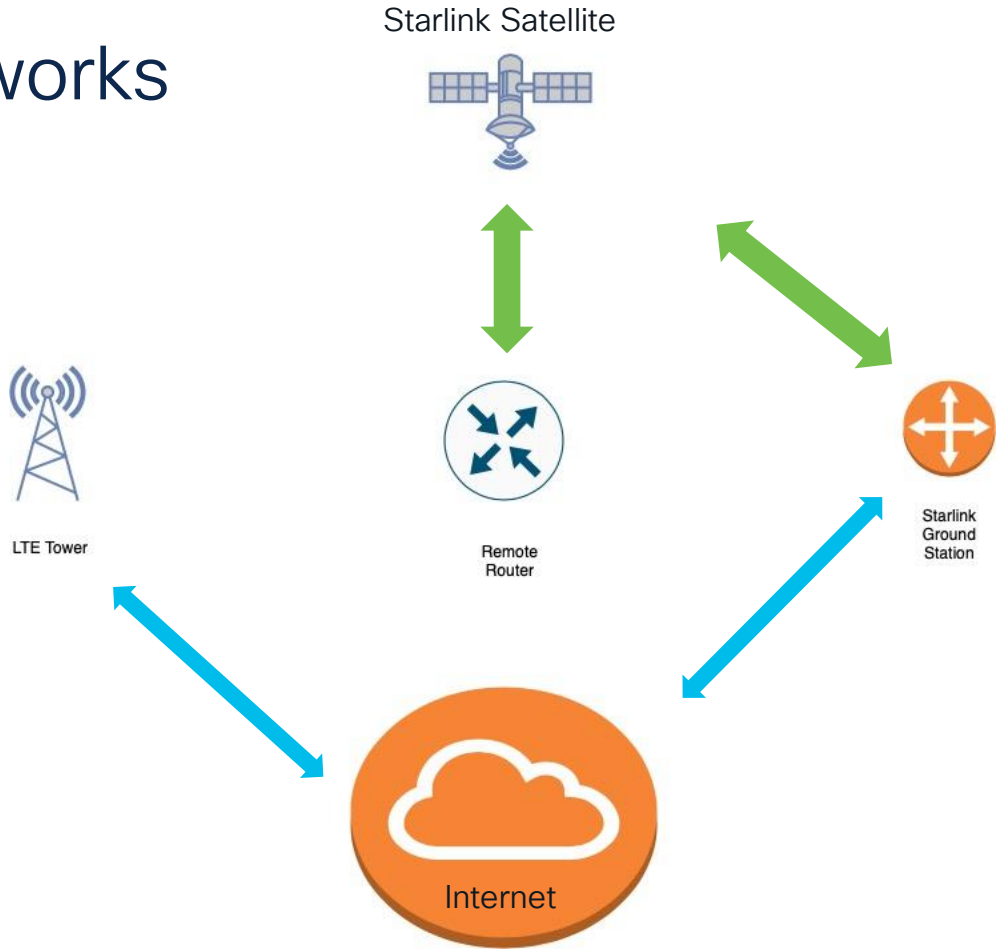
How this works



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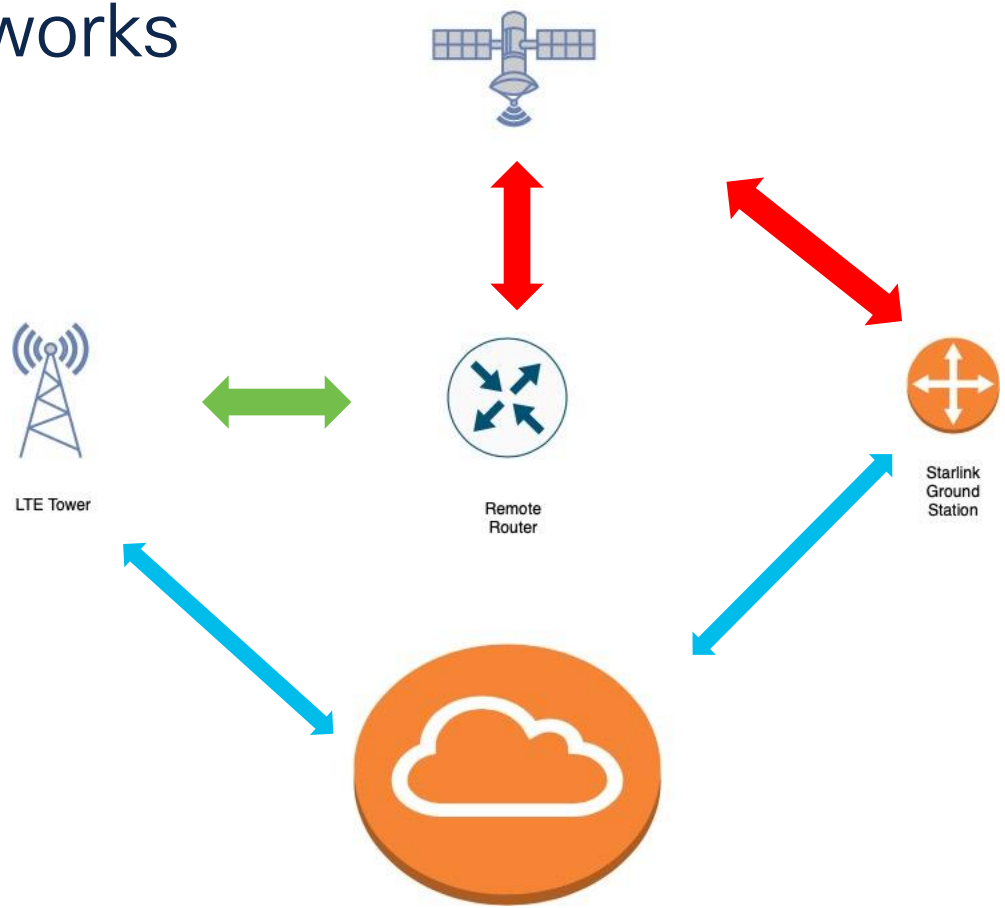
How this works



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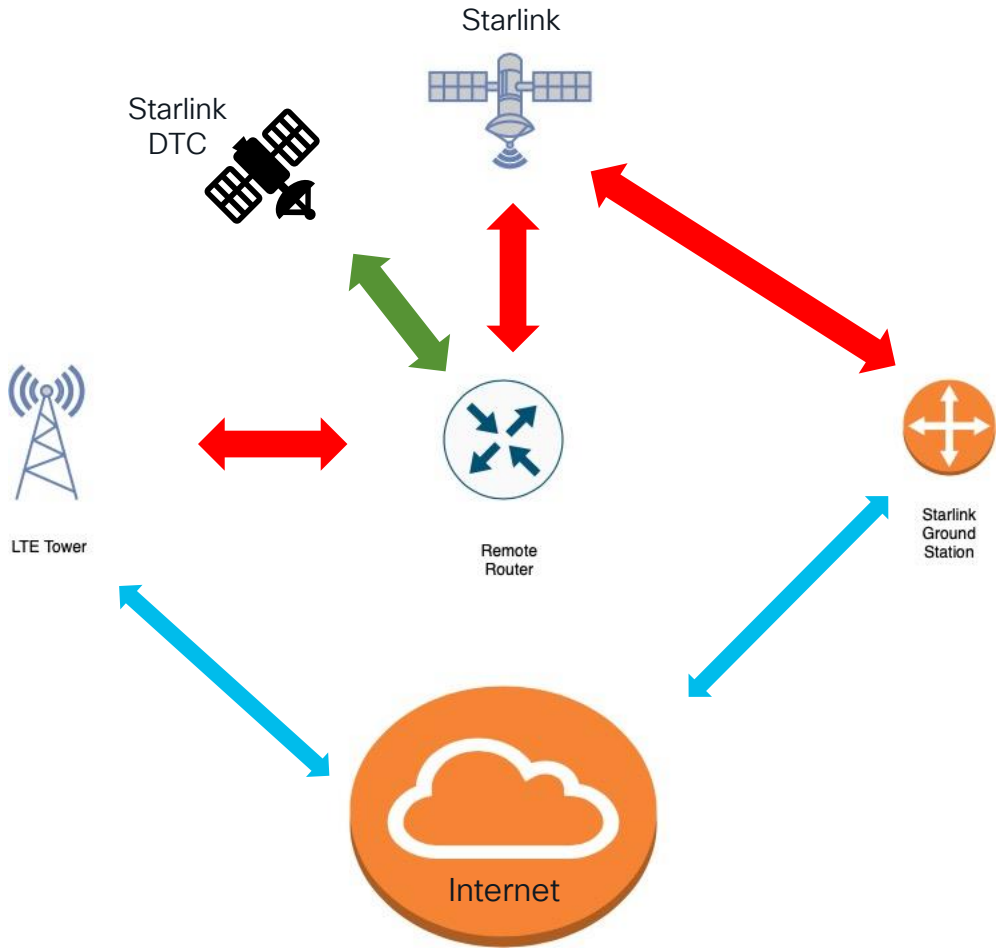

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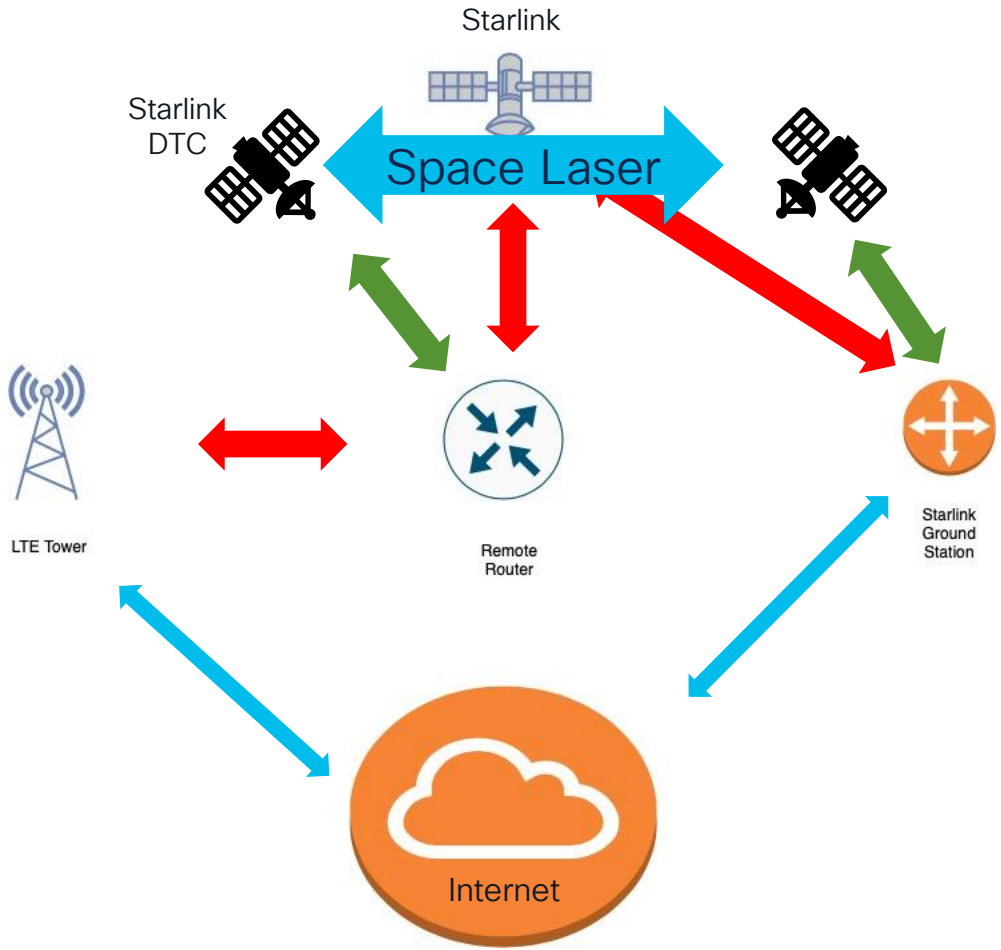

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Remote Sensor Package Details

- Low power Router+Radio combination
- Man portable
- **Requires no external phased array!**
- **Low bandwidth use cases – sub 7mbps**
- **Remote Sensor packages are a huge use case**
- **With LiFEPO4 battery, 30w solar array and a scheduled power on, you could collect, upload and run indefinitely**

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We are rapidly approaching a time when there will be no place on Earth that will be without Internet access.

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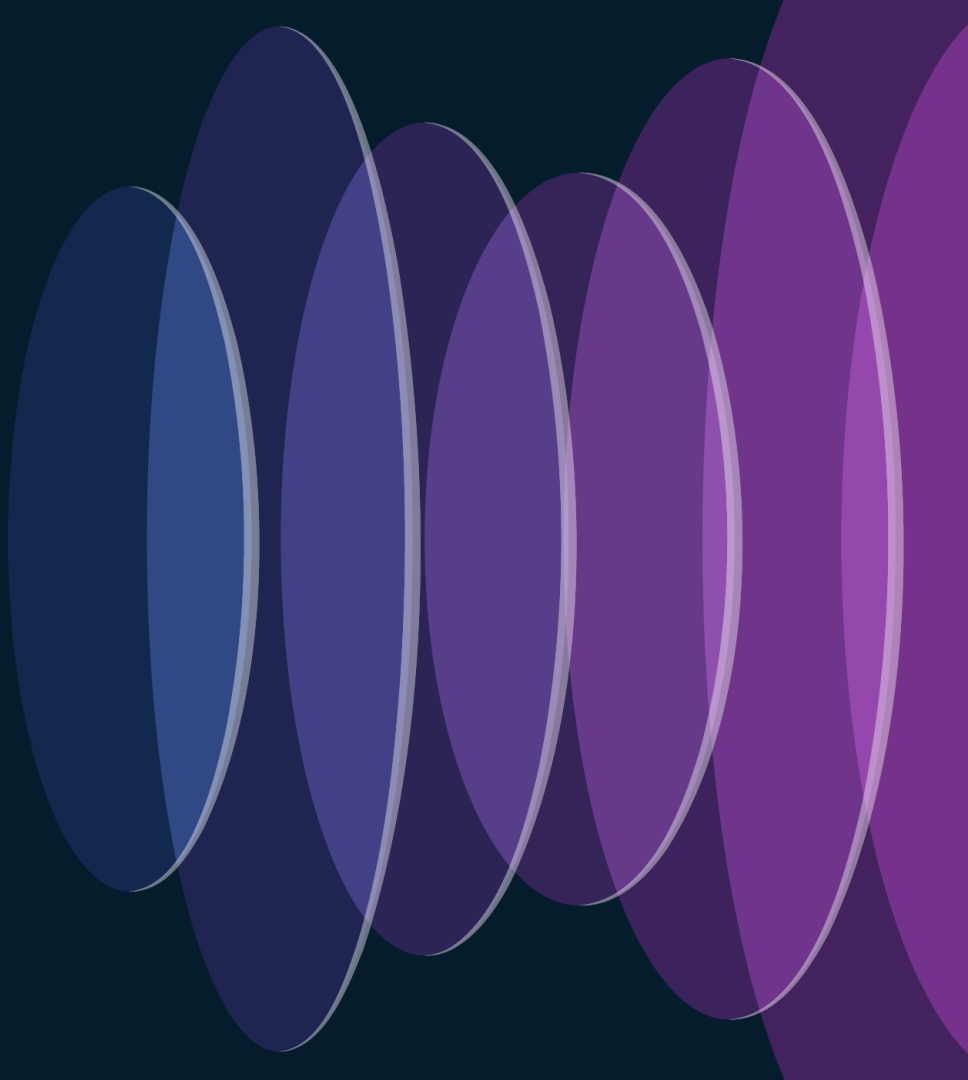
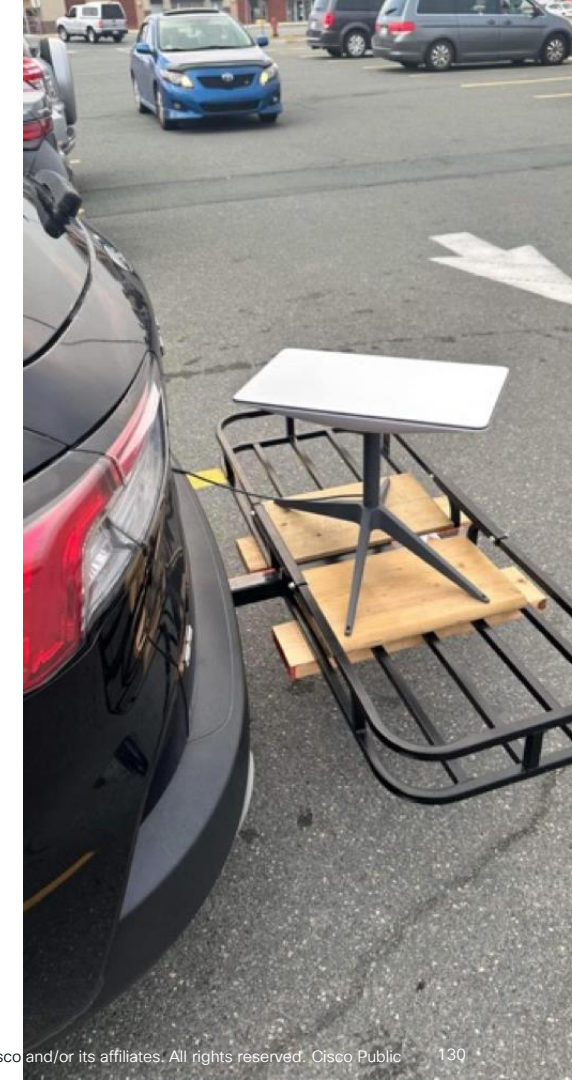
Austere Deployment Options





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Disclaimer

I make 100% zero guarantees or warranty you won’t damage something....

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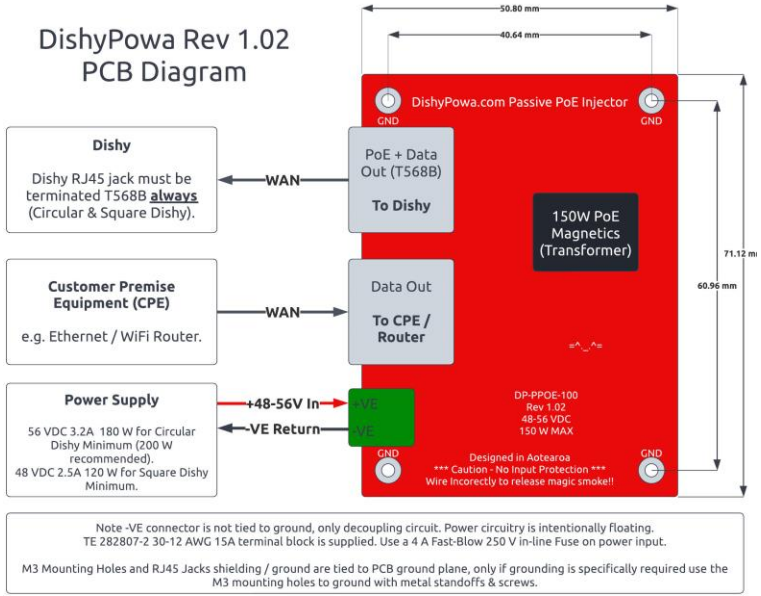
Ditching the Starlink Router

- https://dishypowa.com
- 48-56V DC passive PoE injector
- Allows you to remove Starlink Router entirely
- Connect up BYOS options
- Needs 48v DC Power



Credit: dishypowa.com

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Parts Needed

Roll over image to zoom in

DC 12V Step Up to 48V Boost Converter 3A 144W DC Voltage Regulator Power Converter Adapter Waterproof Module Transformer for Golf Cart Club Car LED Light

Brand: Protooma

★★★★★ 26 ratings | 4 answered questions

$17.99

FREE Returns

Get 40% off eligible products sold and shipped by Amazon when you pay with Discover rewards. Max discount $50. Activation required. Limited-time offer, see terms.

Color: **12V to 48V 3A**

Brand	Protooma
Model Name	Boost Converter
Color	12V to 48V 3A
Item Dimensions LxWxH	2 x 2 x 0.8 inches
Input Voltage	12 Volts

About this item

- Input Voltage:DC 12V nominal; Voltage Range: 9-20V(12V); Output Voltage: DC 48V 3A 144W; Maximum Efficiency:≥95%; Ripple Wave: 50Mv; Starting delay time:≤2s.
- Protection: Built in over-load, over-current, over-temperature and

Roll over image to zoom in

LiTime 12V 100Ah Lithium LiFePO4 Battery, Built-in 100A BMS, 4000-15000 Cycles, 10-year Lifetime, Perfect for RV, Solar, Backup Power, Off Grid Application, Boat, Trolling motor.

Brand: Litime

6 answered questions

$299.99

Pay $25.00/month for 12 months, interest-free upon approval for the Amazon Prime Rewards Visa Card

Size: **12V100Ah**

12V50Ah $179.98	**12V100Ah $299.99**
12V100Ah Smart $479.99	12V200Ah $599.99
12V300Ah $999.99	24V100Ah $649.99
48V100Ah $1,699.98	

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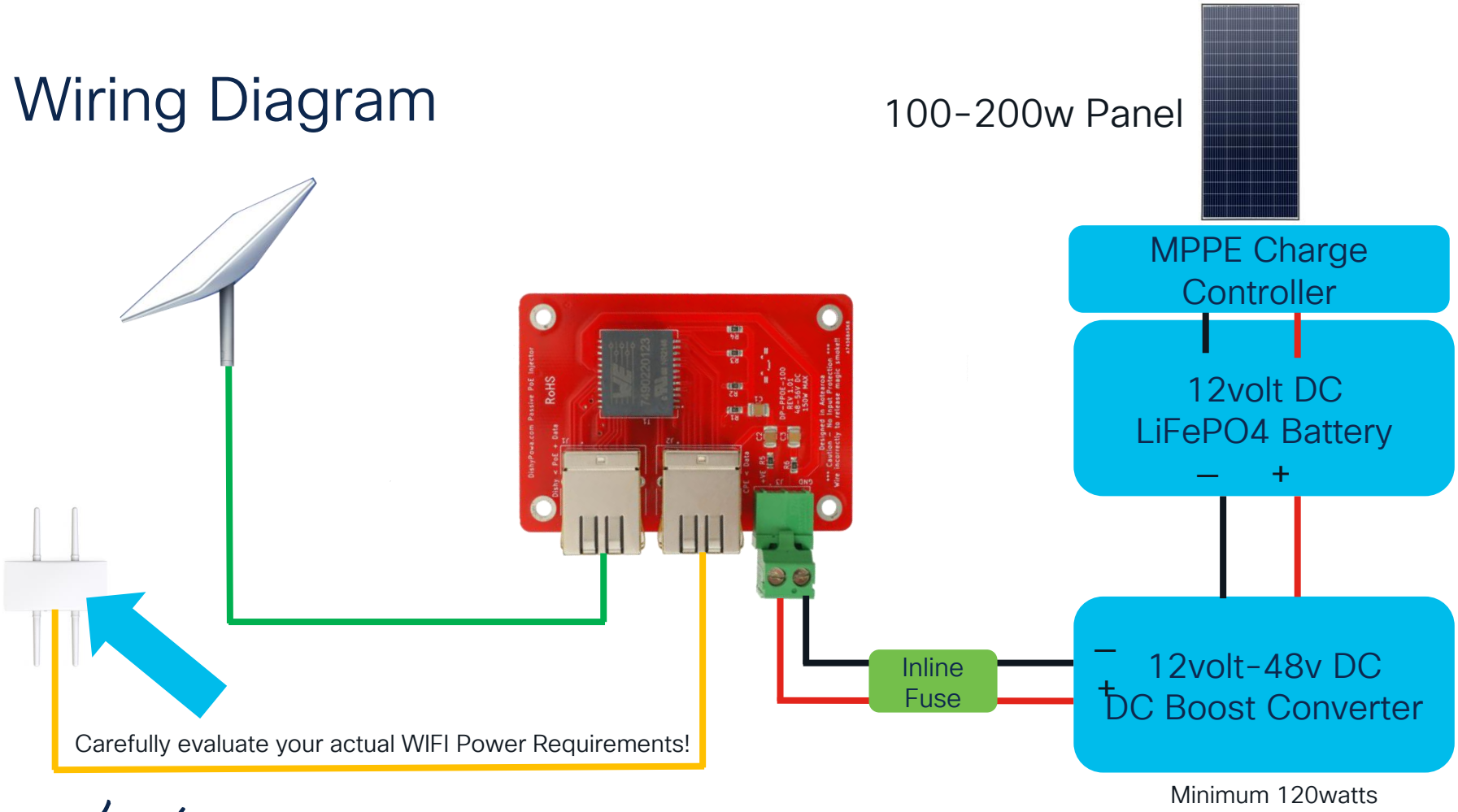
Wiring Diagram



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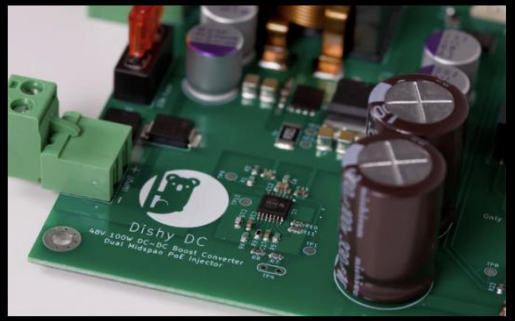
Dishy Dualie Products

Filter: Availability



Dishy Dualie DC Power Supply

$148.00 AUD

Dishy Dualie DC Enclosure

$68.00 AUD

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Cisco Crisis Response Deployment to Maui

-Requested to support Maui First Responders with Internet access

-Cisco Employees dispatched with High Performance Terminals

-Setup instant Internet access

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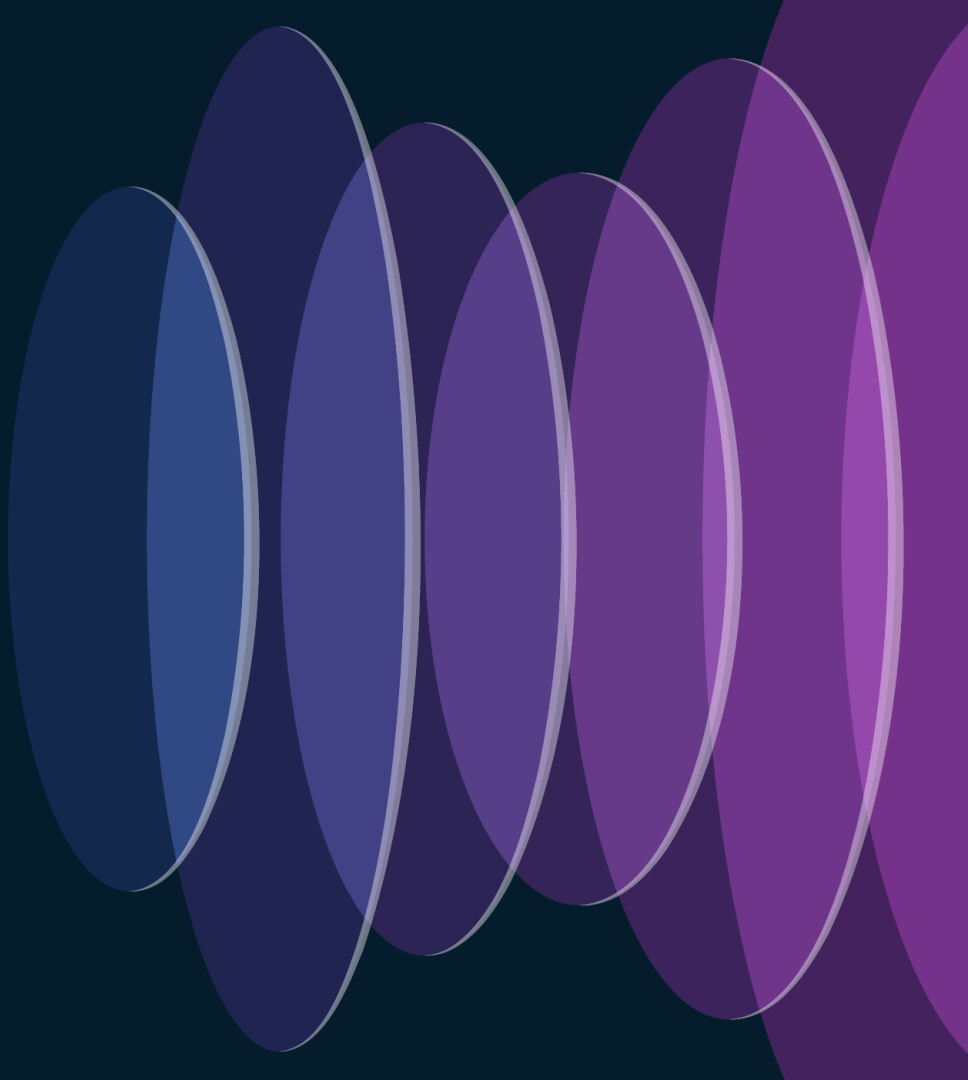
SOLAR POWER (last year)



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12:00

ADVANCED SPEED TEST

WIFI SPEED
IPHONE TO WIFI ROUTER

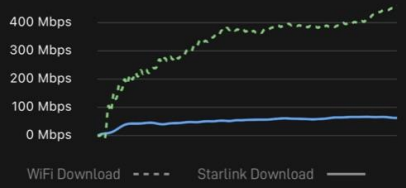
499 Mbps

388 Mbps Upload

STARLINK SPEED
ROUTER TO INTERNET

64 Mbps

4.4 Mbps Upload



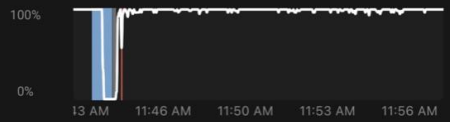
9F8E4566

11:58
◂ Search

NETWORK STATISTICS

Your Starlink just powered on. Network performance should stabilize after about 15 minutes.

UPTIME OUTAGES



Last 14 minutes:

- **Possibly Obstructed** 3s
- **Network Issue** 8s

LATENCY Min: 0 ms Max: 1383 ms Last: 40 ms

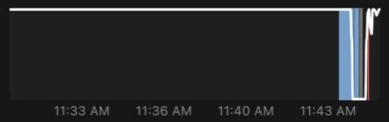
THROUGHPUT SPEED TEST

1:45
ch

NETWORK STATISTICS

Your Starlink just powered on. Network performance should stabilize after about 15 minutes.

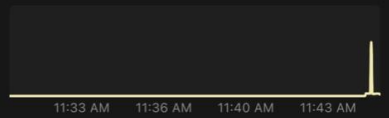
IME OUTAGES



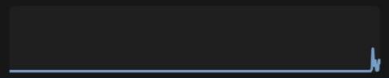
2 minutes:

- **ossibly Obstructed** 3s
- **etwork Issue** 8s

ENCY Min: 0 ms Max: 1383 ms Last: 38 ms



OUGHPUT SPEED TEST



11:46
◂ Search

EB3A2226002144201

Power off

72%

DC

AC

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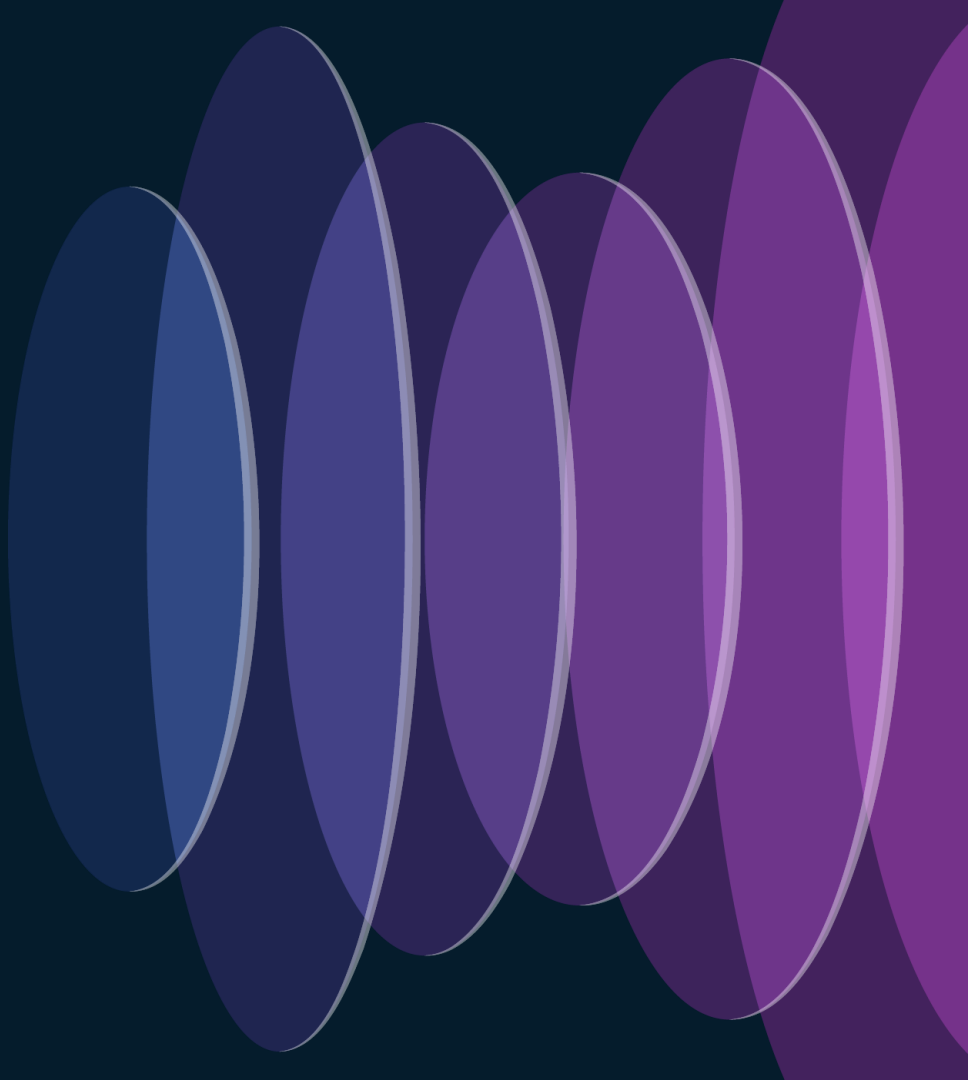
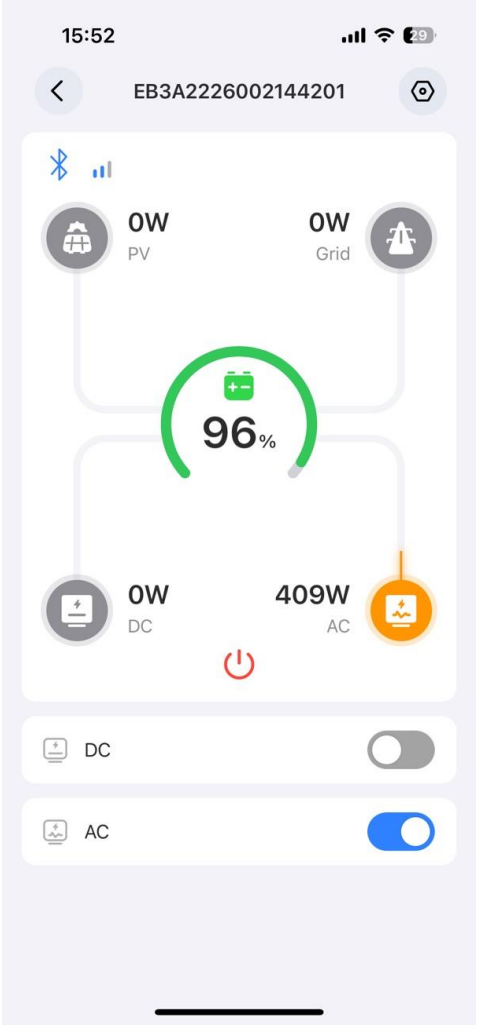
SOLAR POWER (this year)





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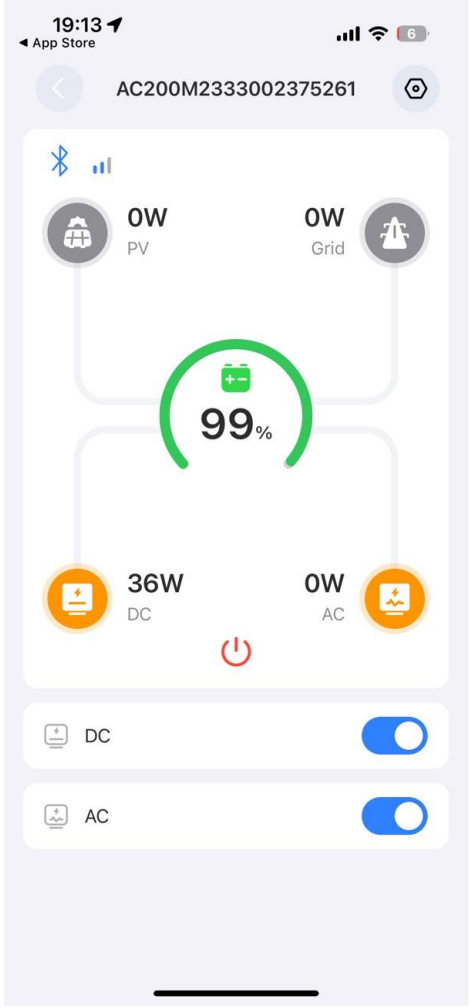

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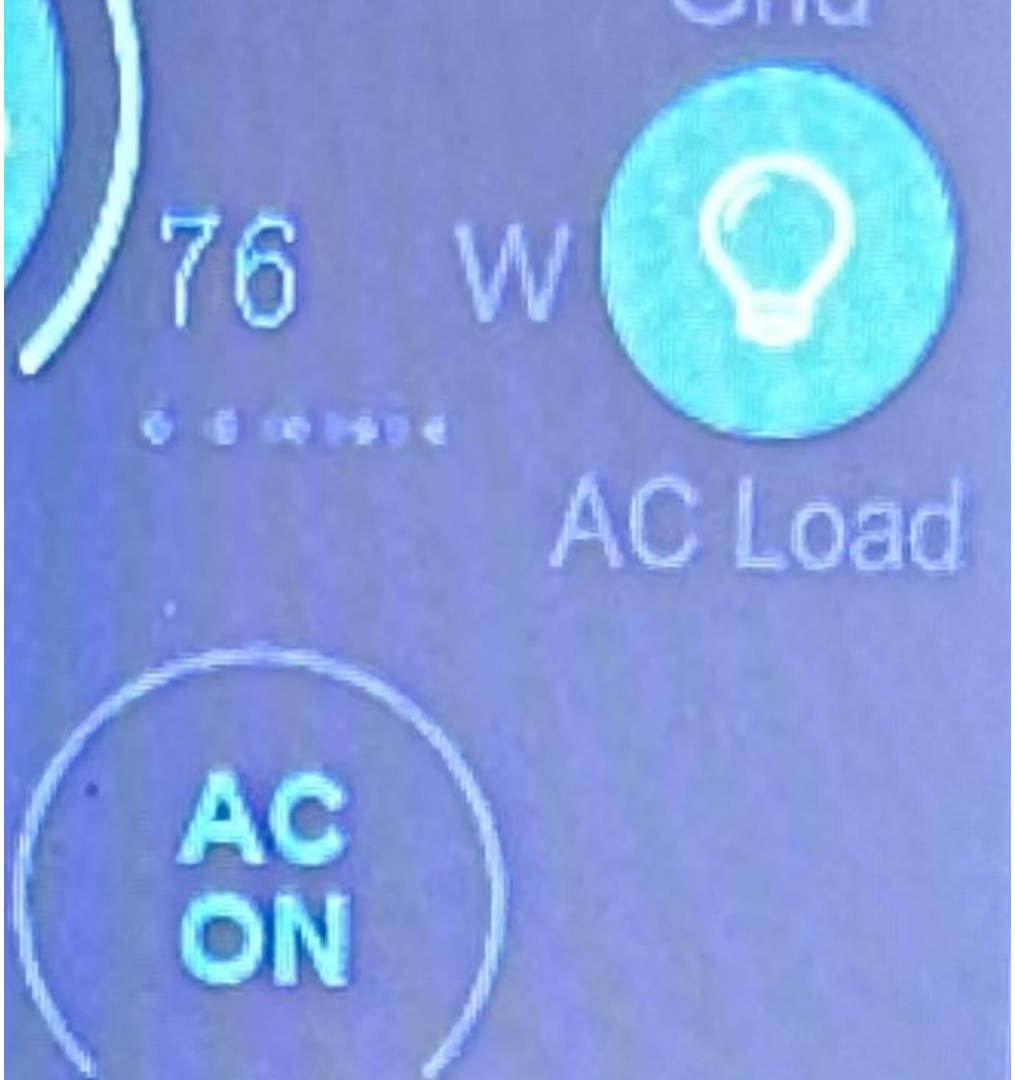

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Power/Solar Conclusions (from last year)

1

You will need more stored power than you think

2

You will need more solar power than you think

3

You will have to trial 24hr operation to be sure it works

4

You will have to account for lack of full solar cycles

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Updated Solar Guidance

- Minimum 1000Wh between solar cycles
- Gen 2 dish consumes between 43-50watts consistently
- 200watts of solar panel will reliably recharge 800Wh in 4-5 hours of direct sun
- 24 hour remote operation is completely achievable

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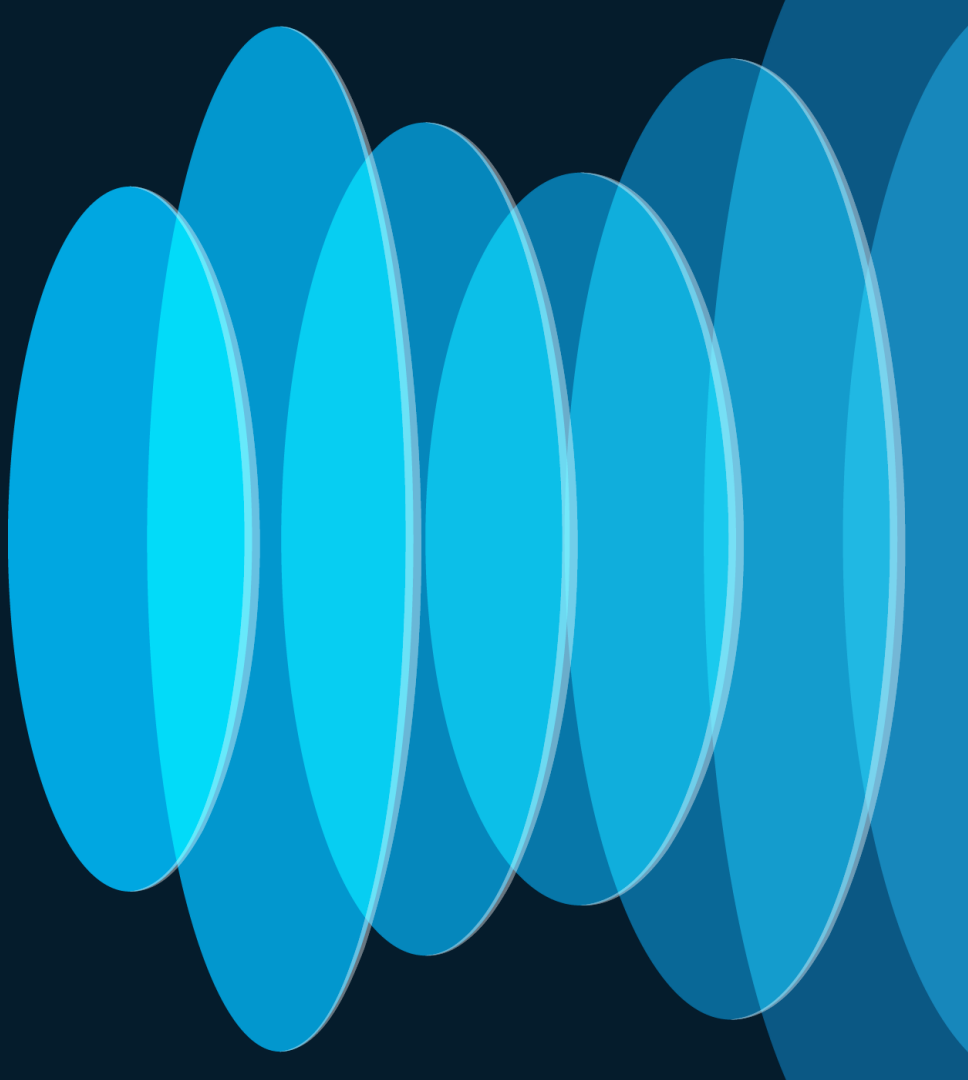
Debugging



Debugging at the CLI

```
abenhase@ABENHASE-M-526H starlink-grpc-tools-main % python3 poll_history.py | grep software_version
status: {'id': 'ut01000000-00000000-0008d16e', 'hardware_version': 'rev3_proto2', 'software_version': 'f562e306-0cd5-44c2-9058-9ab6800c4b50.uterm.release',
to_first_nonempty_slot': 0.0, 'pop_ping_drop_rate': 0.0, 'downlink_throughput_bps': 1429922.125, 'uplink_throughput_bps': 270549.375, 'pop_ping_latency_ms':
currently_obstructed': False, 'seconds_obstructed': None, 'obstruction_duration': None, 'obstruction_interval': None, 'direction_azimuth': 1.722228288650512
ise_floor': True}
status: {'id': 'ut01000000-00000000-0008d16e', 'hardware_version': 'rev3_proto2', 'software_version': 'f562e306-0cd5-44c2-9058-9ab6800c4b50.uterm.release',
to_first_nonempty_slot': 0.0, 'pop_ping_drop_rate': 0.0, 'downlink_throughput_bps': 2350362.25, 'uplink_throughput_bps': 232783.875, 'pop_ping_latency_ms':
currently_obstructed': False, 'seconds_obstructed': None, 'obstruction_duration': None, 'obstruction_interval': None, 'direction_azimuth': 1.747515082359314
e_floor': True}
status: {'id': 'ut01000000-00000000-0008d16e', 'hardware_version': 'rev3_proto2', 'software_version': 'f562e306-0cd5-44c2-9058-9ab6800c4b50.uterm.release',
to_first_nonempty_slot': 0.0, 'pop_ping_drop_rate': 0.0, 'downlink_throughput_bps': 6270954.0, 'uplink_throughput_bps': 481732.59375, 'pop_ping_latency_ms':
currently_obstructed': False, 'seconds_obstructed': None, 'obstruction_duration': None, 'obstruction_interval': None, 'direction_azimuth': 1.886579871177673
se_floor': True}
status: {'id': 'ut01000000-00000000-0008d16e', 'hardware_version': 'rev3_proto2', 'software_version': 'f562e306-0cd5-44c2-9058-9ab6800c4b50.uterm.release',
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ise_floor': True}
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'currently_obstructed': False, 'seconds_obstructed': None, 'obstruction_duration': None, 'obstruction_interval': None, 'direction_azimuth': 1.78820550441741
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status: {'id': 'ut01000000-00000000-0008d16e', 'hardware_version': 'rev3_proto2', 'software_version': 'f562e306-0cd5-44c2-9058-9ab6800c4b50.uterm.release',
to_first_nonempty_slot': 0.0, 'pop_ping_drop_rate': 0.0, 'downlink_throughput_bps': 2786863.25, 'uplink_throughput_bps': 344620.78125, 'pop_ping_latency_ms'
 'currently_obstructed': False, 'seconds_obstructed': None, 'obstruction_duration': None, 'obstruction_interval': None, 'direction_azimuth': 2.0890917778015
oise_floor': True}
status: {'id': 'ut01000000-00000000-0008d16e', 'hardware_version': 'rev3_proto2', 'software_version': 'f562e306-0cd5-44c2-9058-9ab6800c4b50.uterm.release',
to_first_nonempty_slot': 0.0, 'pop_ping_drop_rate': 0.0, 'downlink_throughput_bps': 822544.9375, 'uplink_throughput_bps': 182125.0625, 'pop_ping_latency_ms'
bstructed': False, 'seconds_obstructed': None, 'obstruction_duration': None, 'obstruction_interval': None, 'direction_azimuth': 2.058941125869751, 'directio
rue}
status: {'id': 'ut01000000-00000000-0008d16e', 'hardware_version': 'rev3_proto2', 'software_version': 'f562e306-0cd5-44c2-9058-9ab6800c4b50.uterm.release',
to_first_nonempty_slot': 0.0, 'pop_ping_drop_rate': 0.0, 'downlink_throughput_bps': 3287621.25, 'uplink_throughput_bps': 224588.203125, 'pop_ping_latency_ms
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oise_floor': True}
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to_first_nonempty_slot': 0.0, 'pop_ping_drop_rate': 0.0, 'downlink_throughput_bps' [illegible] link_throughput_bps': 485163.53125, 'pop_ping_latency_ms':
```
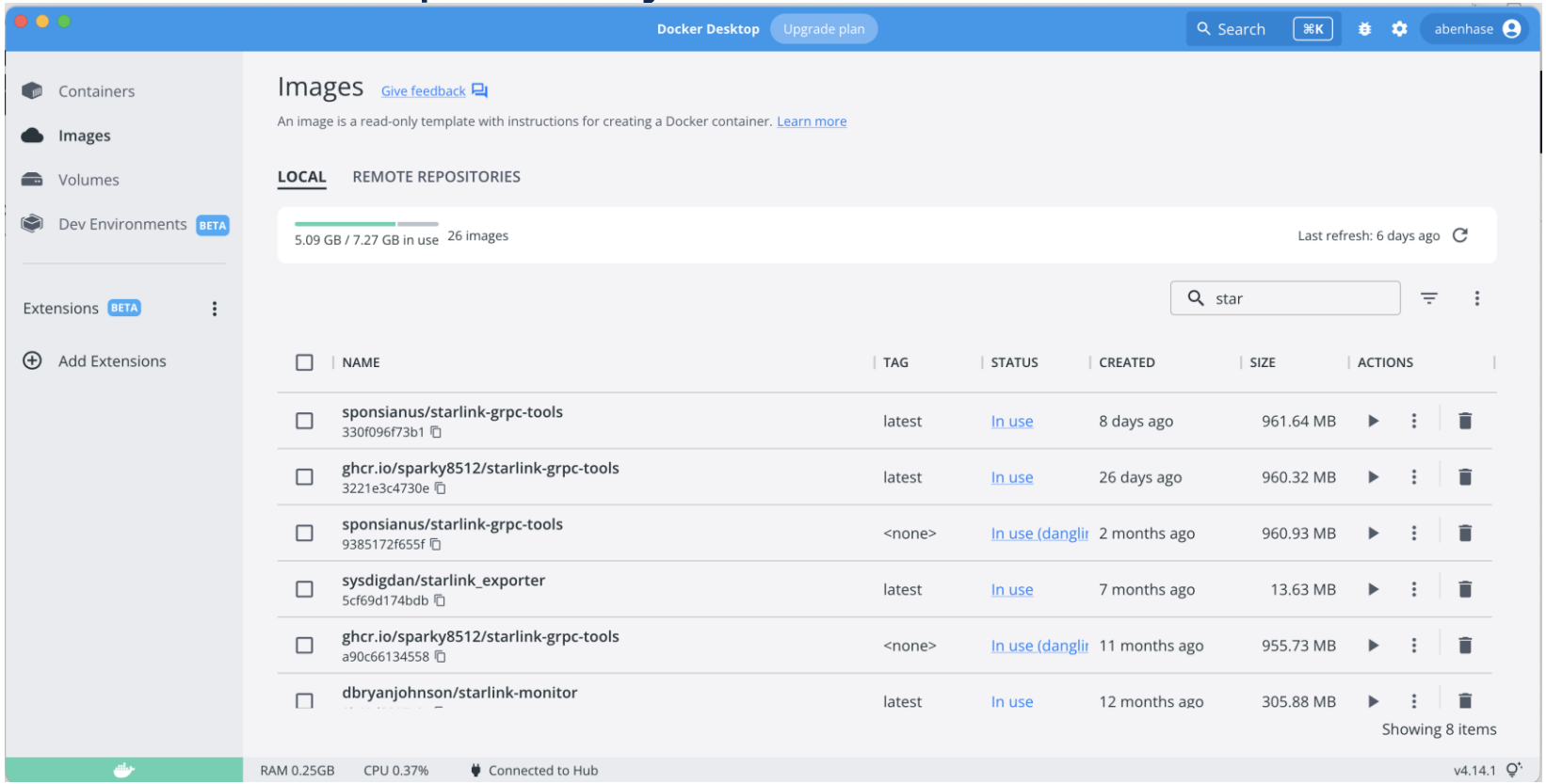

Docker Tools Repository



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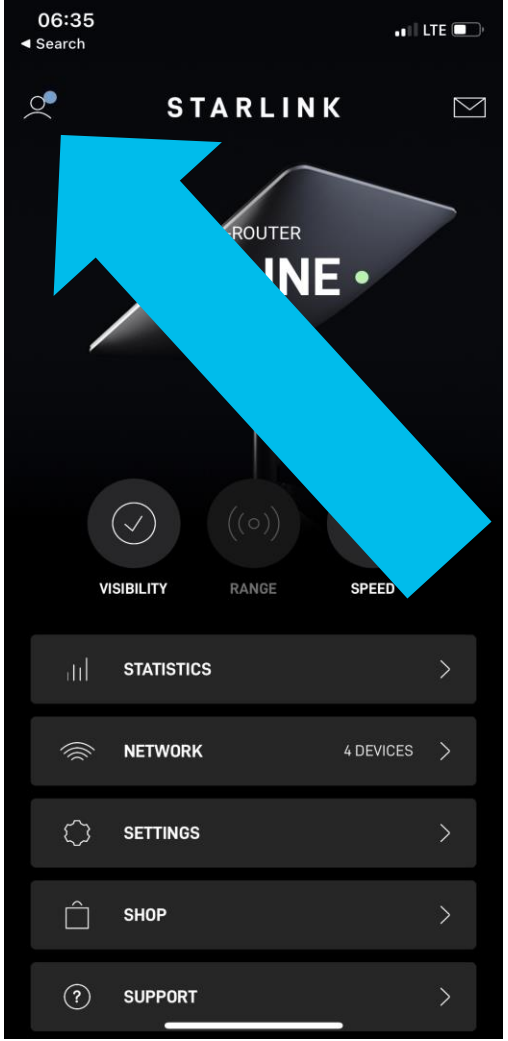
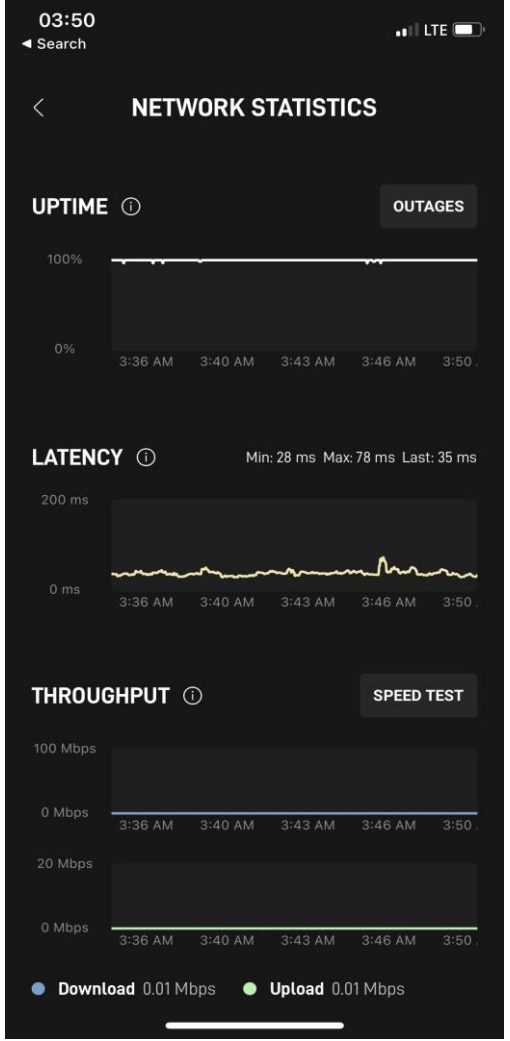
Remote Connections

- Performance Data is stored in the Starlink Cloud
- Allows remote access to data statistics from your local network without being there





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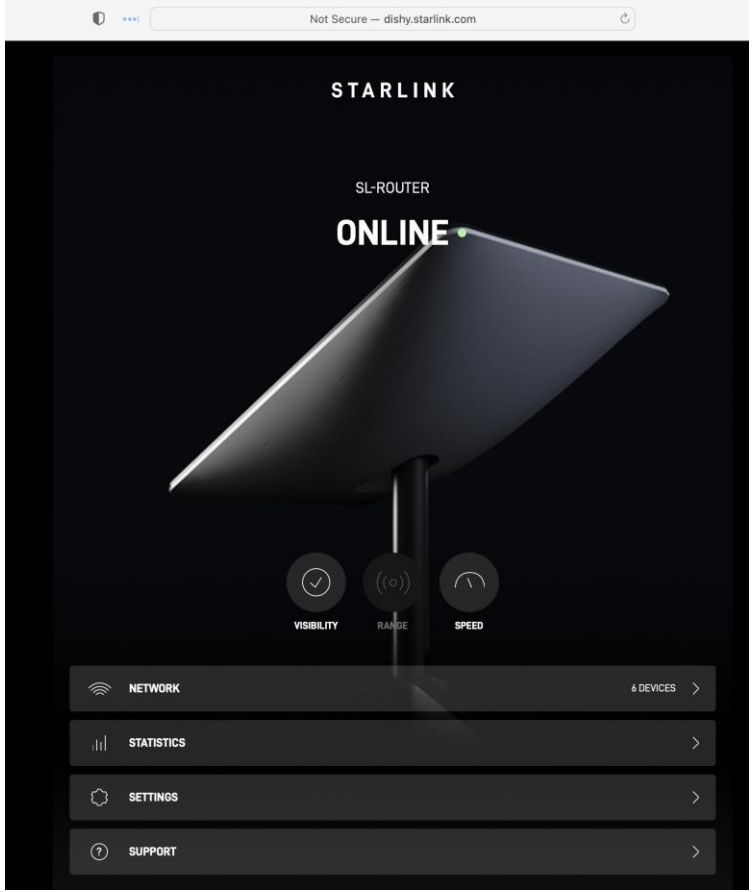
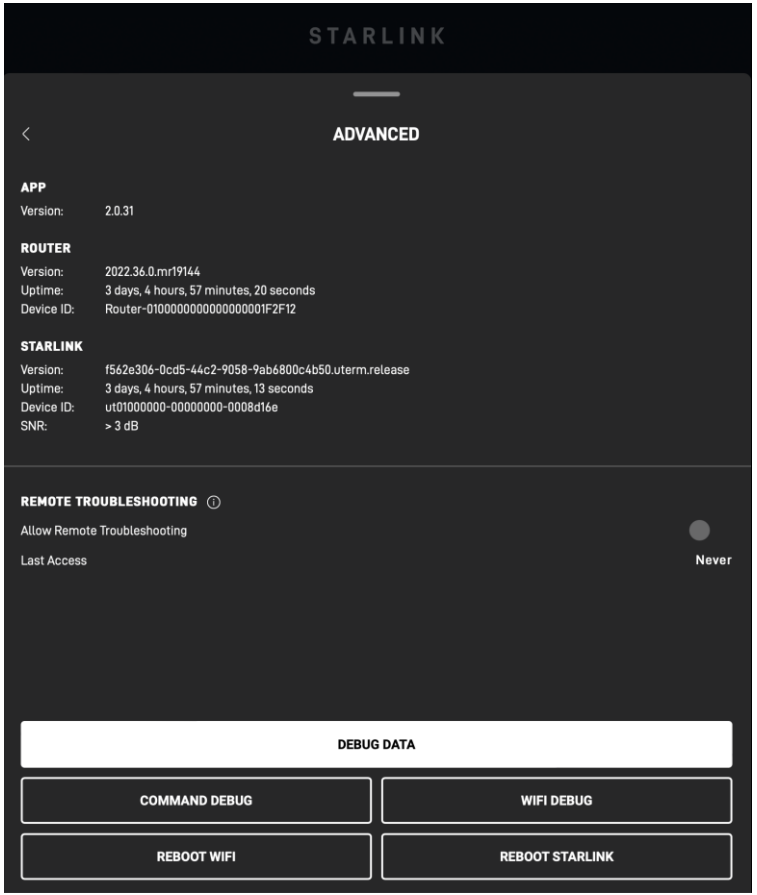
http://dishy.starlink.com





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Starlink Debug


```
"dish": {
  "reachable": true,
  "service": "dish",
  "cloud": false,
  "features": {
    "stowRequested": true,
    "unstow": true
  },
  "timestamp": 1666895243,
  "deviceInfo": {
    "id": "ut01000000-00000000-0008d16e",
```

```
"auth": {
    "accessToken": "<len=848>",
    "refreshToken": "<len=66>",
    "accessTokenExpirationDate": "2022-10-27T18:39:21Z",
    "idToken": "<len=723>",
    "tokenType": "Bearer"
```

```
    "isDev": false,
    "bootcount": 129,
    "antiRollbackVersion": 0,
    "isHitl": false
  },
```

```
    "installPending": false,
    "isHeating": false,
    "powerSupplyThermalThrottle": false
  },
  "gpsStats": {
```

```
"gpsStats": {
  "gpsValid": true,
  "gpsSats": 16,
```


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Should you leave your SL Router WIFI Enabled?

- The short answer is yes – primarily for local debug reasons
- Just don't use it for actual production users
  - It is not secured
  - It is not configurable
  - It is not a Firewall
  - It is a very poor performing Access Point

BYOS – Bring Your Own Security

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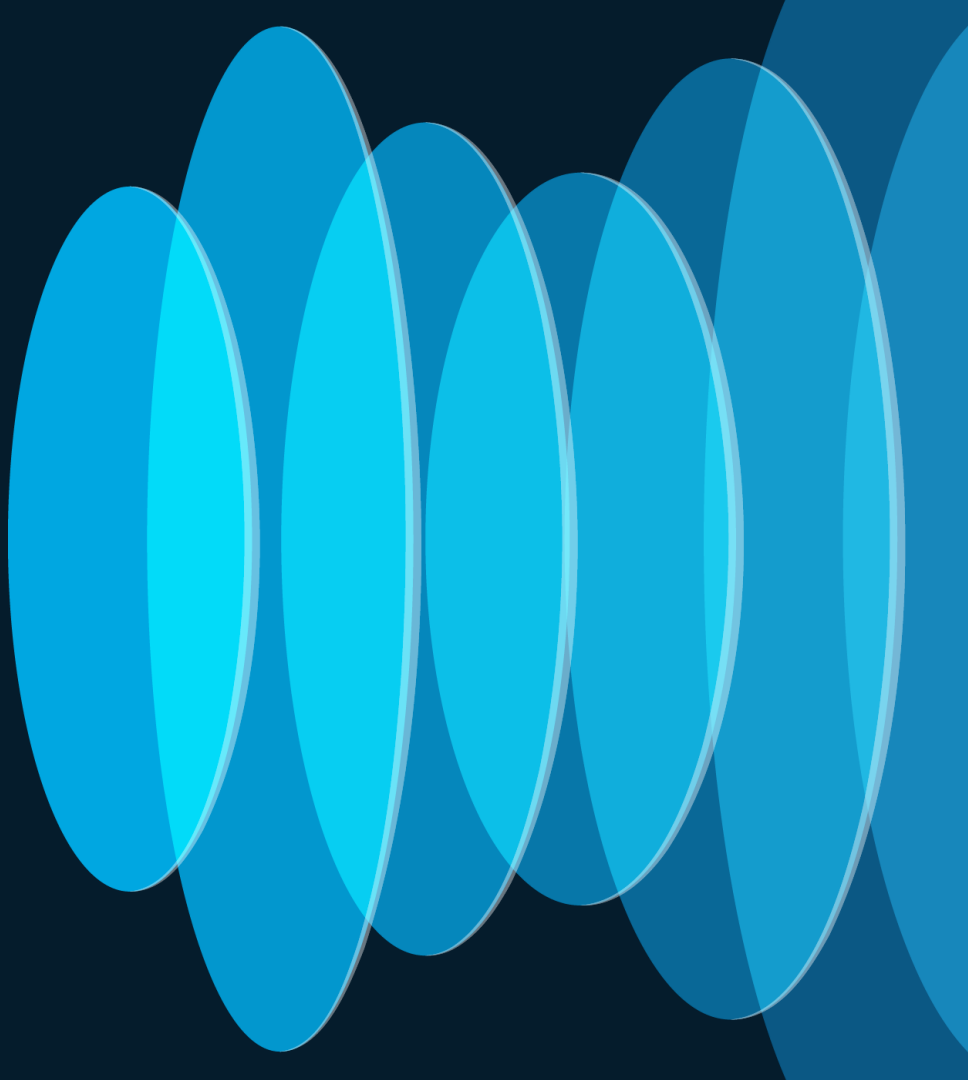
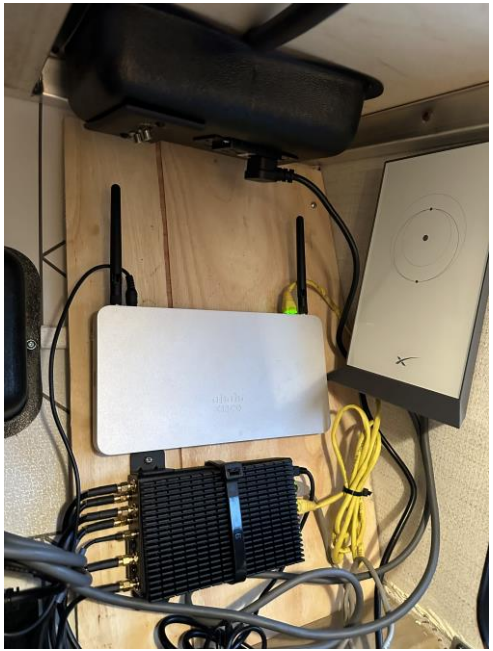
What do you have running?





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What is running now?

- Meraki MX95 (IPv4 and IPv6)
- Meraki MX65 (IPv4 and IPv6)
- Peplink MAX Transit Duo Pro (IPv4)

- Cisco

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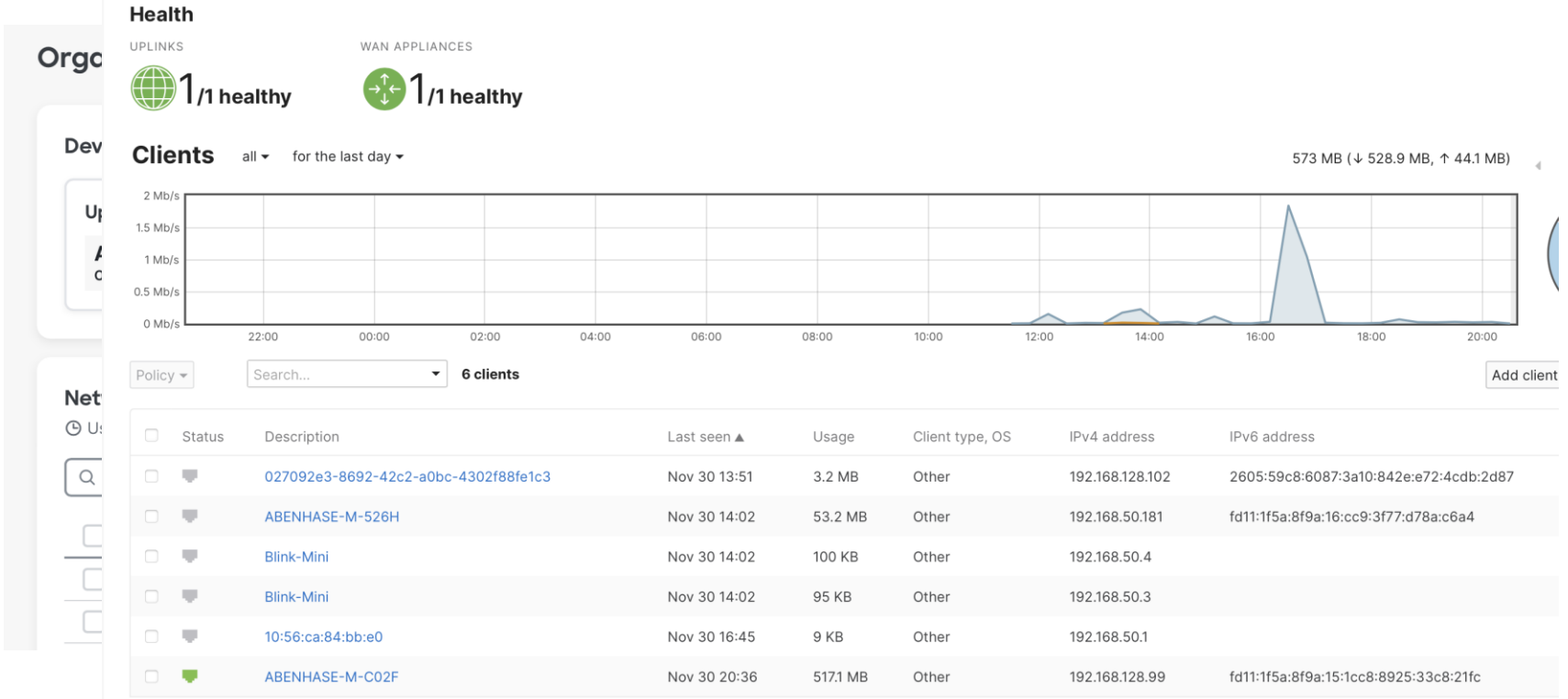
Meraki Starlink



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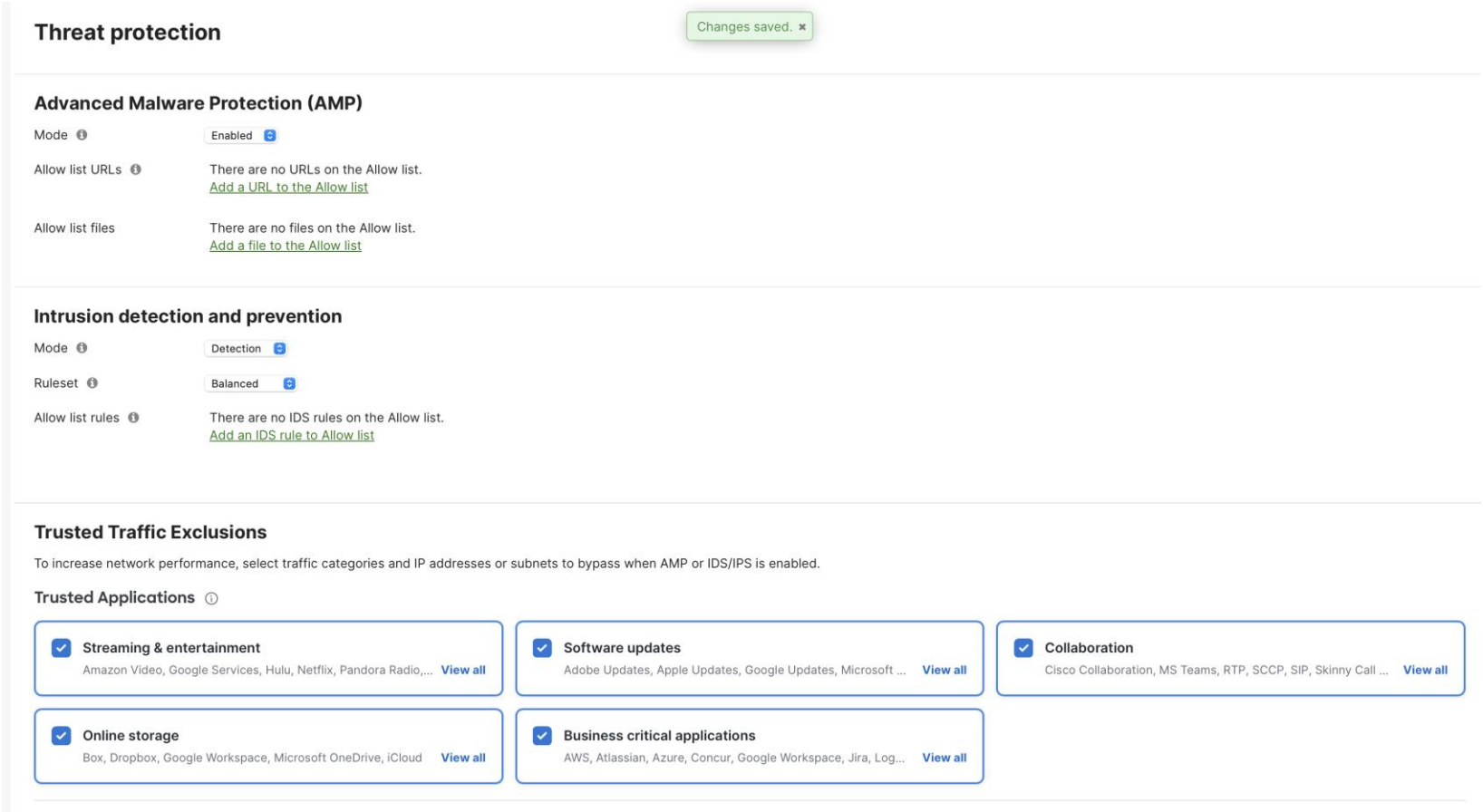

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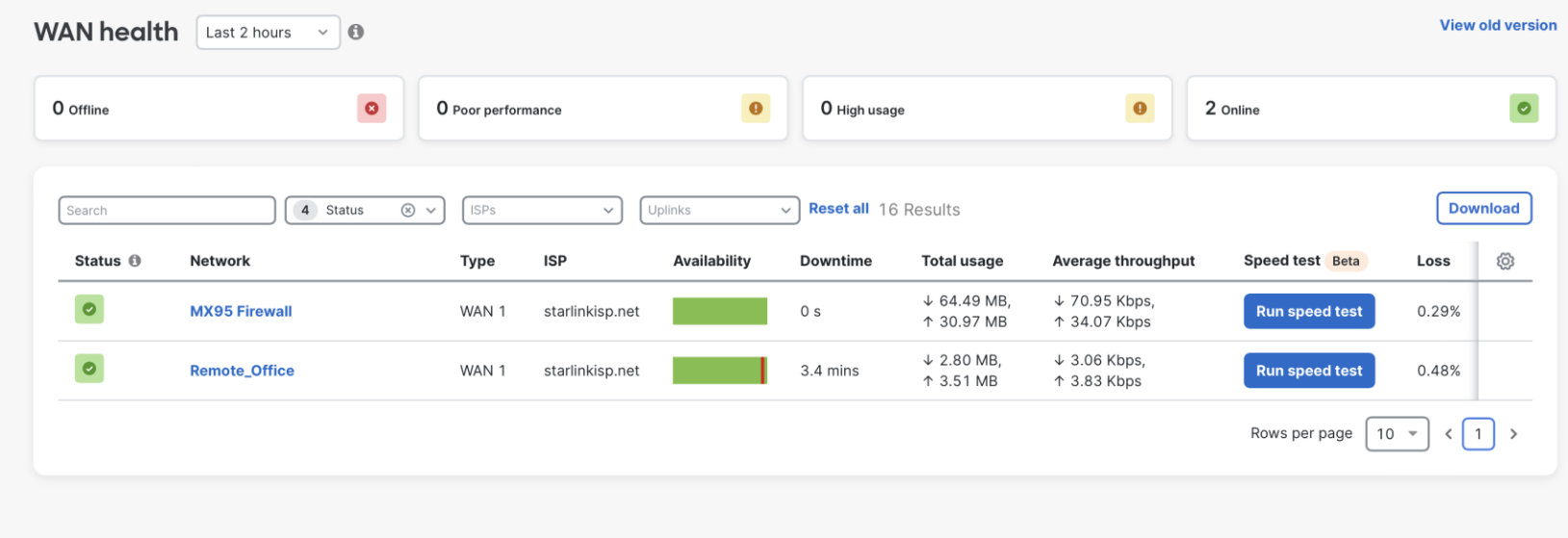
WAN Health using 1keye



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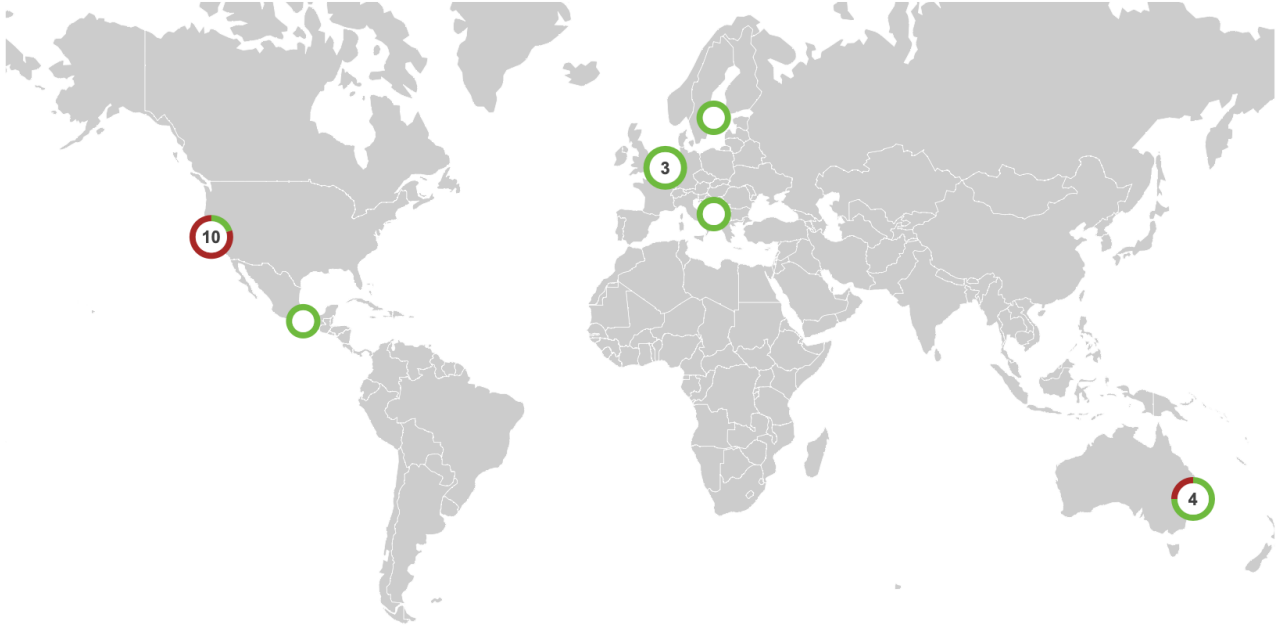

Agent based Reporting for Thousand Eyes running Starlink across the Globe

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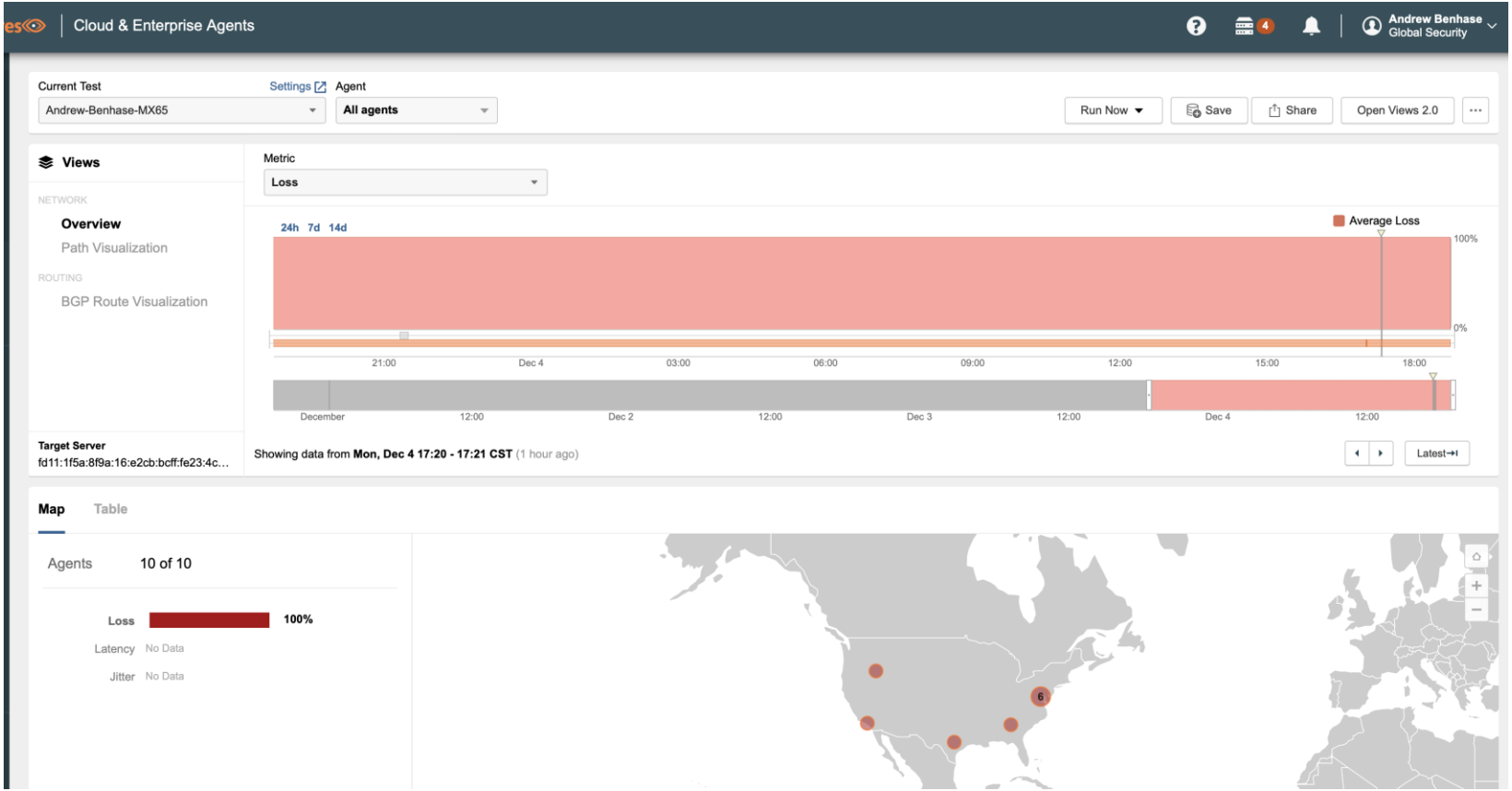
Agent to ICMP IPv6 not working



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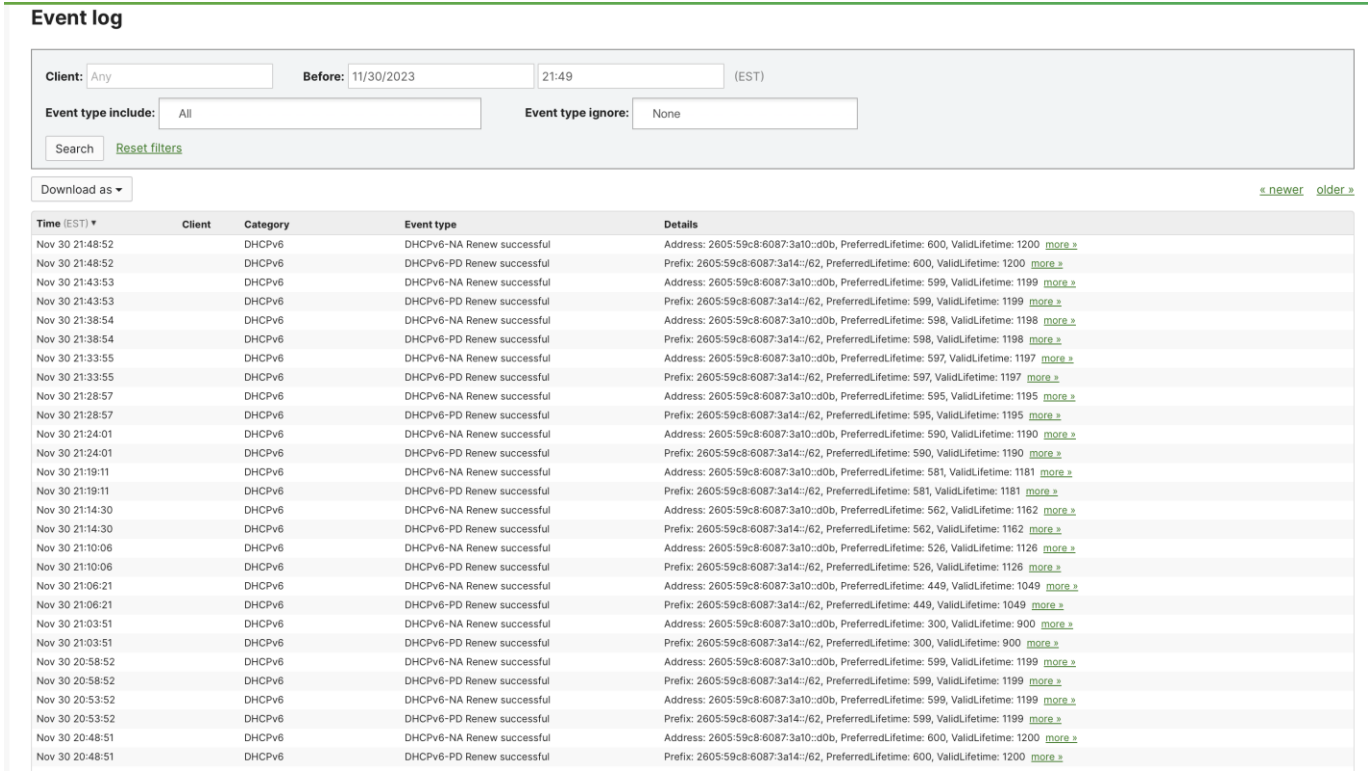
IPv6 PD Renew Every 5 Minutes



Event log

Client: Any Before: 11/30/2023 21:49 (EST)

Event type include: All Event type ignore: None

Search Reset filters

Download as ▾ « newer older »

Time (EST) ▾	Client	Category	Event type	Details
Nov 30 21:48:52		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 600, ValidLifetime: 1200 more »
Nov 30 21:48:52		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 600, ValidLifetime: 1200 more »
Nov 30 21:43:53		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 599, ValidLifetime: 1199 more »
Nov 30 21:43:53		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 599, ValidLifetime: 1199 more »
Nov 30 21:38:54		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 598, ValidLifetime: 1198 more »
Nov 30 21:38:54		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 598, ValidLifetime: 1198 more »
Nov 30 21:33:55		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 597, ValidLifetime: 1197 more »
Nov 30 21:33:55		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 597, ValidLifetime: 1197 more »
Nov 30 21:28:57		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 595, ValidLifetime: 1195 more »
Nov 30 21:28:57		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 595, ValidLifetime: 1195 more »
Nov 30 21:24:01		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 590, ValidLifetime: 1190 more »
Nov 30 21:24:01		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 590, ValidLifetime: 1190 more »
Nov 30 21:19:11		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 581, ValidLifetime: 1181 more »
Nov 30 21:19:11		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 581, ValidLifetime: 1181 more »
Nov 30 21:14:30		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 562, ValidLifetime: 1162 more »
Nov 30 21:14:30		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 562, ValidLifetime: 1162 more »
Nov 30 21:10:06		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 526, ValidLifetime: 1126 more »
Nov 30 21:10:06		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 526, ValidLifetime: 1126 more »
Nov 30 21:06:21		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 449, ValidLifetime: 1049 more »
Nov 30 21:06:21		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 449, ValidLifetime: 1049 more »
Nov 30 21:03:51		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 300, ValidLifetime: 900 more »
Nov 30 21:03:51		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 300, ValidLifetime: 900 more »
Nov 30 20:58:52		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 599, ValidLifetime: 1199 more »
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Nov 30 20:53:52		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 599, ValidLifetime: 1199 more »
Nov 30 20:53:52		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 599, ValidLifetime: 1199 more »
Nov 30 20:48:51		DHCPv6	DHCPv6-NA Renew successful	Address: 2605:59c8:6087:3a10::d0b, PreferredLifetime: 600, ValidLifetime: 1200 more »
Nov 30 20:48:51		DHCPv6	DHCPv6-PD Renew successful	Prefix: 2605:59c8:6087:3a14::/62, PreferredLifetime: 600, ValidLifetime: 1200 more »

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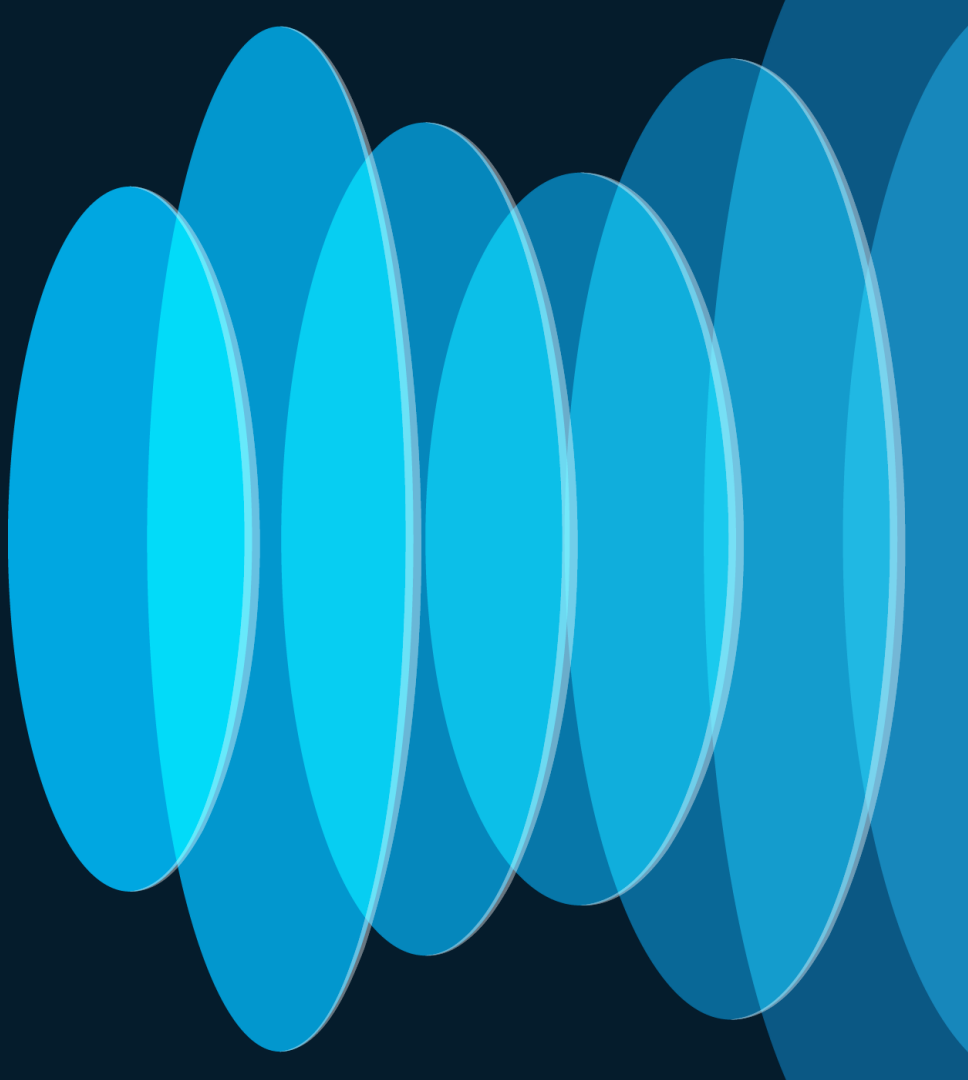
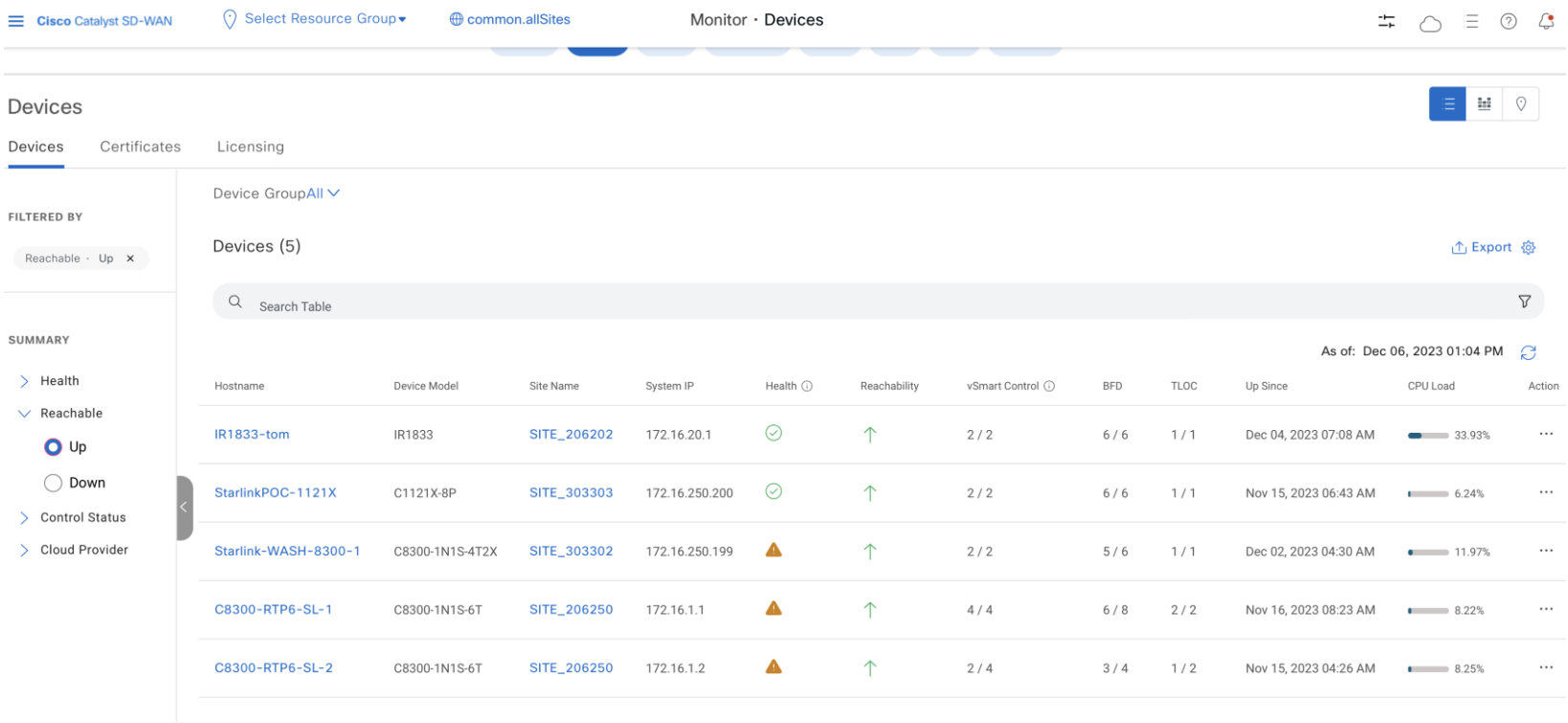
SDWAN





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Things we know

- CG-NAT is a reality for all Residential and Mobile Plans
- High Performance Array is allocated a public IP address
- This is NOT a static IP address!
  - DHCP 5 minute renewal

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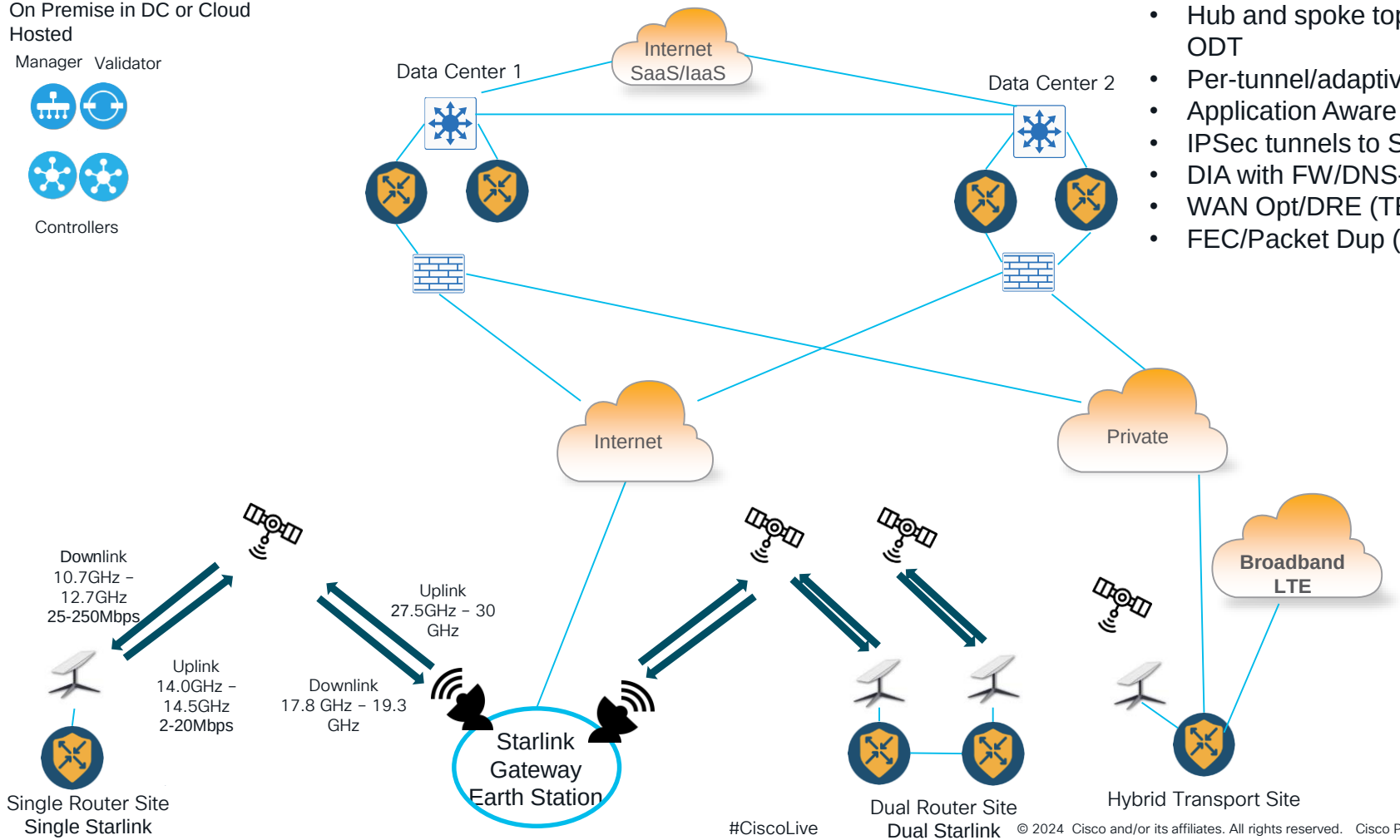
Starlink Reference Architecture

Catalyst SD-WAN Controllers
On Premise in DC or Cloud
Hosted

Manager Validator

Controllers

- SD-WAN version 17.x
- Hub and spoke topology with ODT
- Per-tunnel/adaptive QoS
- Application Aware Routing
- IPSec tunnels to SIG
- DIA with FW/DNS-Sec
- WAN Opt/DRE (TBD)
- FEC/Packet Dup (TBD)



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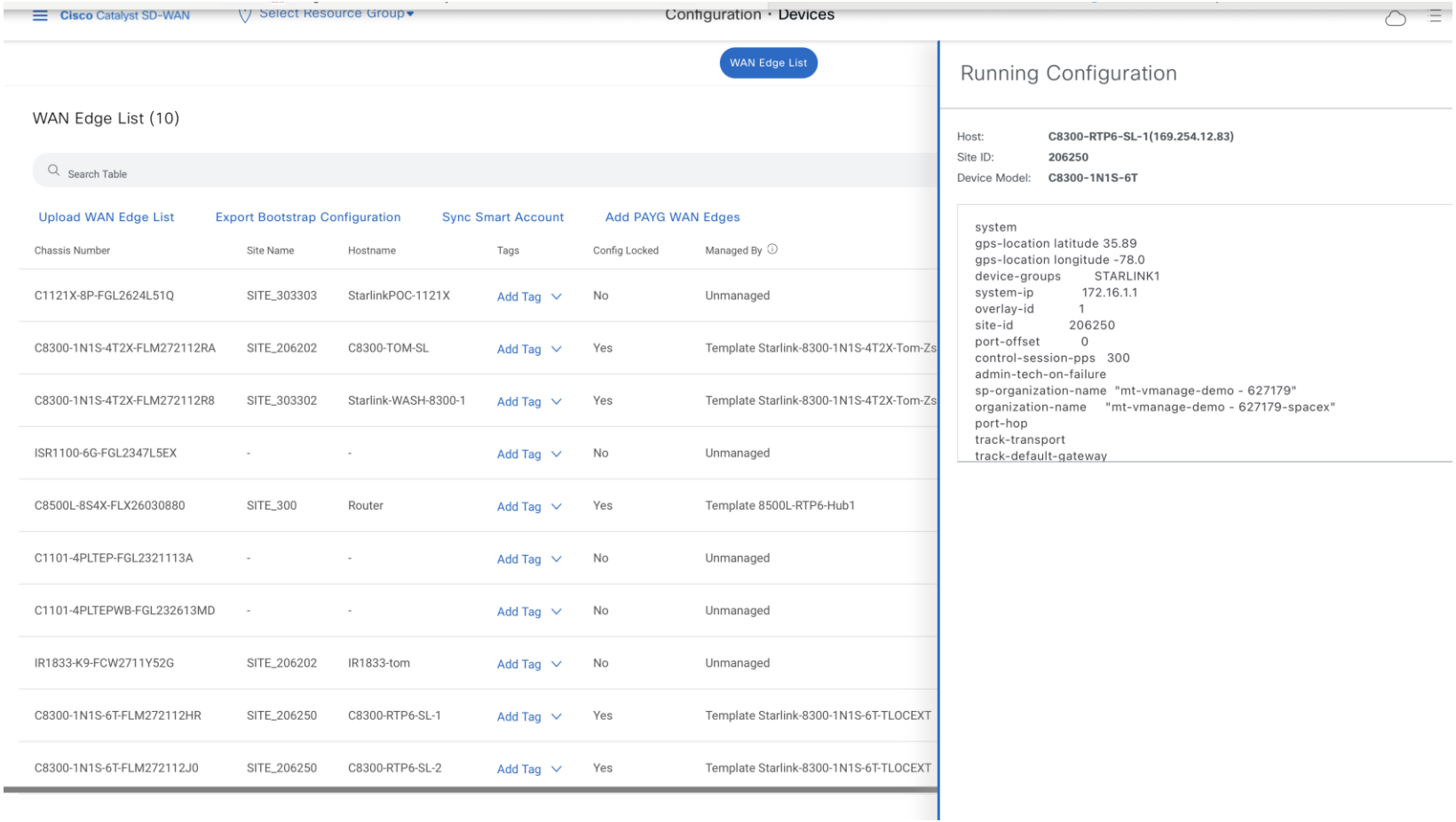

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SD WAN Configuration

```
interface GigabitEthernet0/0/0
 description   Ethernet to Starlink LEO satellite
 no shutdown
 arp timeout 1200
 ip address dhcp client-id GigabitEthernet0/0/0
 no ip redirects
 ip tcp adjust-mss 1360
 ip dhcp client default-router distance 1
 ip mtu    1500
 ip nat outside
 load-interval 30
 mtu          1500
 negotiation auto
```

```
interface Tunnel100201
 no shutdown
 ip unnumbered       GigabitEthernet0/0/0
 no ip clear-dont-fragment
 ip mtu              1400
 tunnel source GigabitEthernet0/0/0
 tunnel destination dynamic
 tunnel mode ipsec ipv4
 tunnel protection ipsec profile if-ipsec201-ipsec-profile
 tunnel vrf multiplexing
 tunnel route-via GigabitEthernet0/0/0 mandatory
exit
interface Tunnel100202
 no shutdown
 ip unnumbered       GigabitEthernet0/0/0
 no ip clear-dont-fragment
 ip mtu              1400
 tunnel source GigabitEthernet0/0/0
 tunnel destination dynamic
 tunnel mode ipsec ipv4
 tunnel protection ipsec profile if-ipsec202-ipsec-profile
 tunnel vrf multiplexing
 tunnel route-via GigabitEthernet0/0/0 mandatory
exit
```


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Crypto Configuration

```
crypto ikev2 policy policy1-global
 proposal p1-global
!
crypto ikev2 profile if-ipsec201-ikev2-profile
 no config-exchange request
 dpd 60 10 on-demand
 dynamic
 lifetime 14400
!
crypto ikev2 profile if-ipsec202-ikev2-profile
 no config-exchange request
 dpd 60 10 on-demand
 dynamic
 lifetime 14400
!
crypto ikev2 proposal p1-global
 encryption aes-cbc-128 aes-cbc-256
 group 14 15 16 19 20 21
 integrity sha1 sha256 sha384 sha512
```

```
crypto ipsec transform-set if-ipsec201-ikev2-transform esp-null esp-sha-hmac
 mode tunnel
!
crypto ipsec transform-set if-ipsec202-ikev2-transform esp-null esp-sha-hmac
 mode tunnel
!
crypto ipsec profile if-ipsec201-ipsec-profile
 set ikev2-profile if-ipsec201-ikev2-profile
 set transform-set if-ipsec201-ikev2-transform
 set security-association lifetime kilobytes disable
 set security-association lifetime seconds 3600
 set security-association replay window-size 1024
!
crypto ipsec profile if-ipsec202-ipsec-profile
 set ikev2-profile if-ipsec202-ikev2-profile
 set transform-set if-ipsec202-ikev2-transform
 set security-association lifetime kilobytes disable
 set security-association lifetime seconds 3600
 set security-association replay window-size 1024
```


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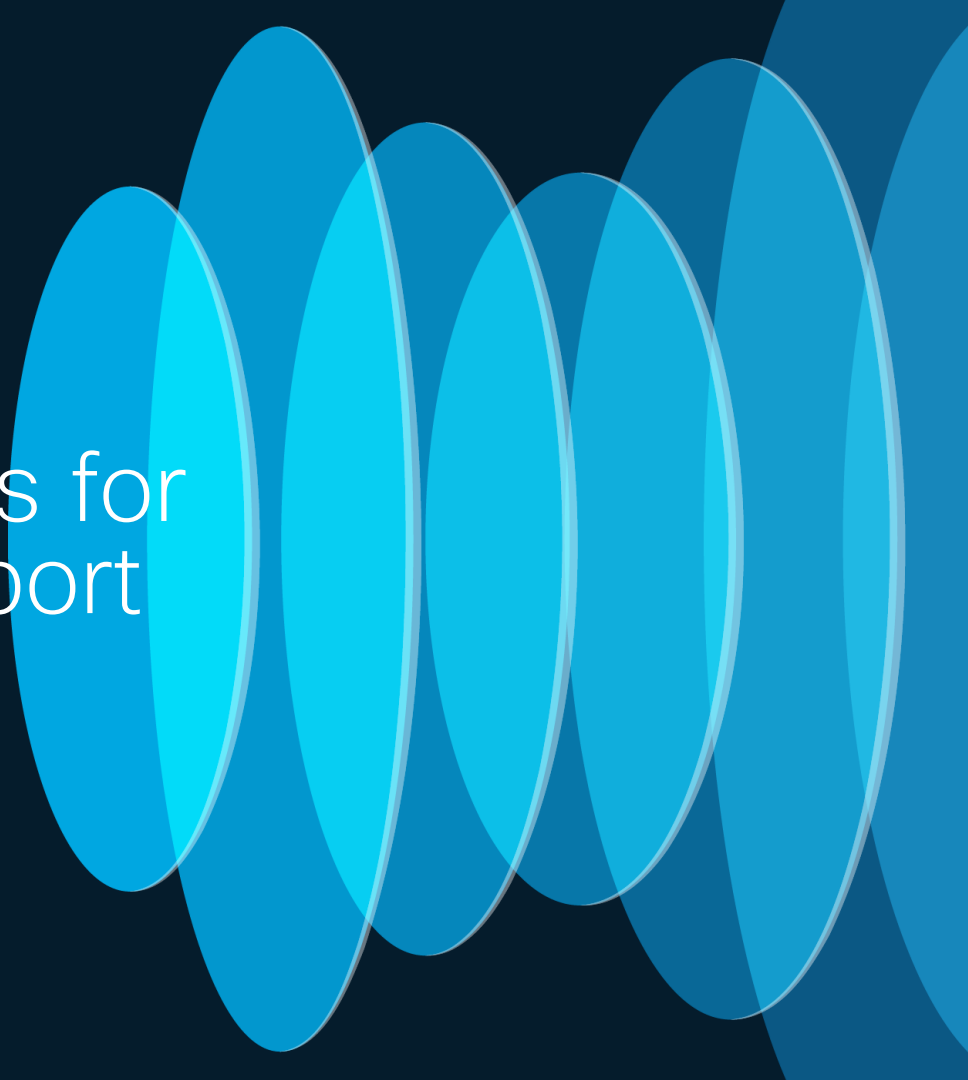
Design optimizations for LEO Satellite Transport



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Reducing SD-WAN control plane traffic on Satellite links

Problems

LEO satellite have low transmit speeds (2-20 Mbps up) relative to download speeds of 25-220 Mbps down). SD-WAN control traffic can consume a high proportion of this bandwidth in heavily meshed topologies with default timers. This includes:

- BFD probes over each IPSec tunnel (2.2 Kbps per SD-WAN tunnel)
- OMP hellos and updates to/from Catalyst controllers (up to 80 Kbps)
- Statistics upload to the Catalyst Manager (up to 1.2 Mbps)

Control traffic is automatically mapped to Q0 on the WAN edge, which can contend with user realtime traffic also in Q0 resulting in drops and instability

Solutions

- Dynamic OnDemand tunnel design (reduces # of BFD sessions)
- BFD low bandwidth link
- Last-resort-circuit in cases where Starlink is for backup
- vManage connection preference 1
- Administration Settings for Statistics – disable some, all or vAnalytics only?
- QoS design with Adaptive QoS and 2-level policer / Split LLQ

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Tunnel Optimizations for low bandwidth links

Low bandwidth link: Reduces BFD overhead by 50% per tunnel

Last-Resort-Circuit: No tunnel or traffic unless all other transports down

vManage connection preference 1: Prefer terrestrial (if available) over Satellite for vManage control connections to reduce overhead of statistics publishing.

OMP Hello tuning: Reduce Hello-interval to further optimize bandwidth

```
sdwan

 interface GigabitEthernet 0/1/0
Description connected to Starlink
  tunnel-interface
   encapsulation ipsec weight 1
   no border
   color
   no last-resort-circuit
   low-bandwidth-link
   hello-interval              6000
   hello-tolerance              600
   vmanage-connection-preference 1
```


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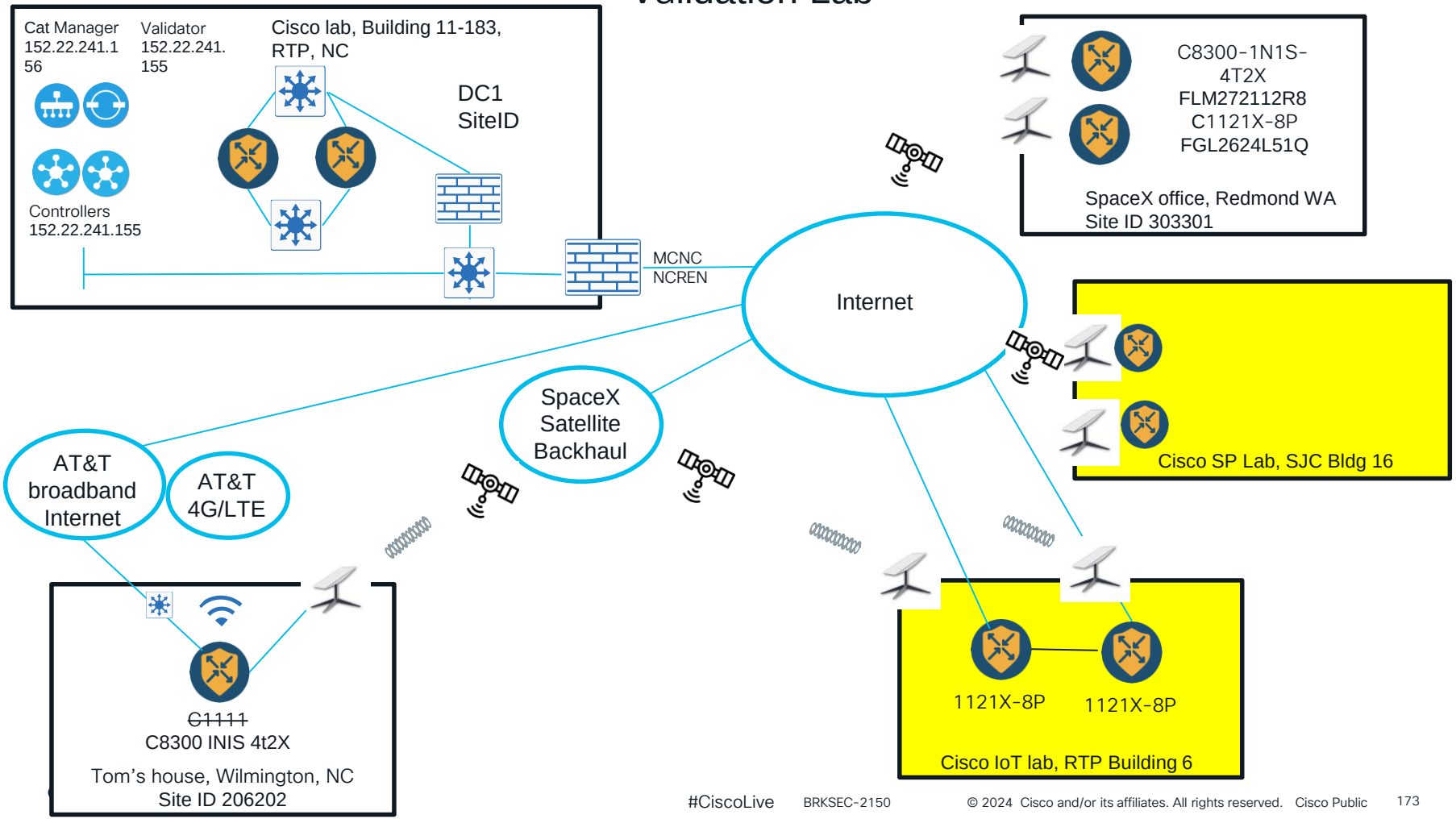
Validation Lab



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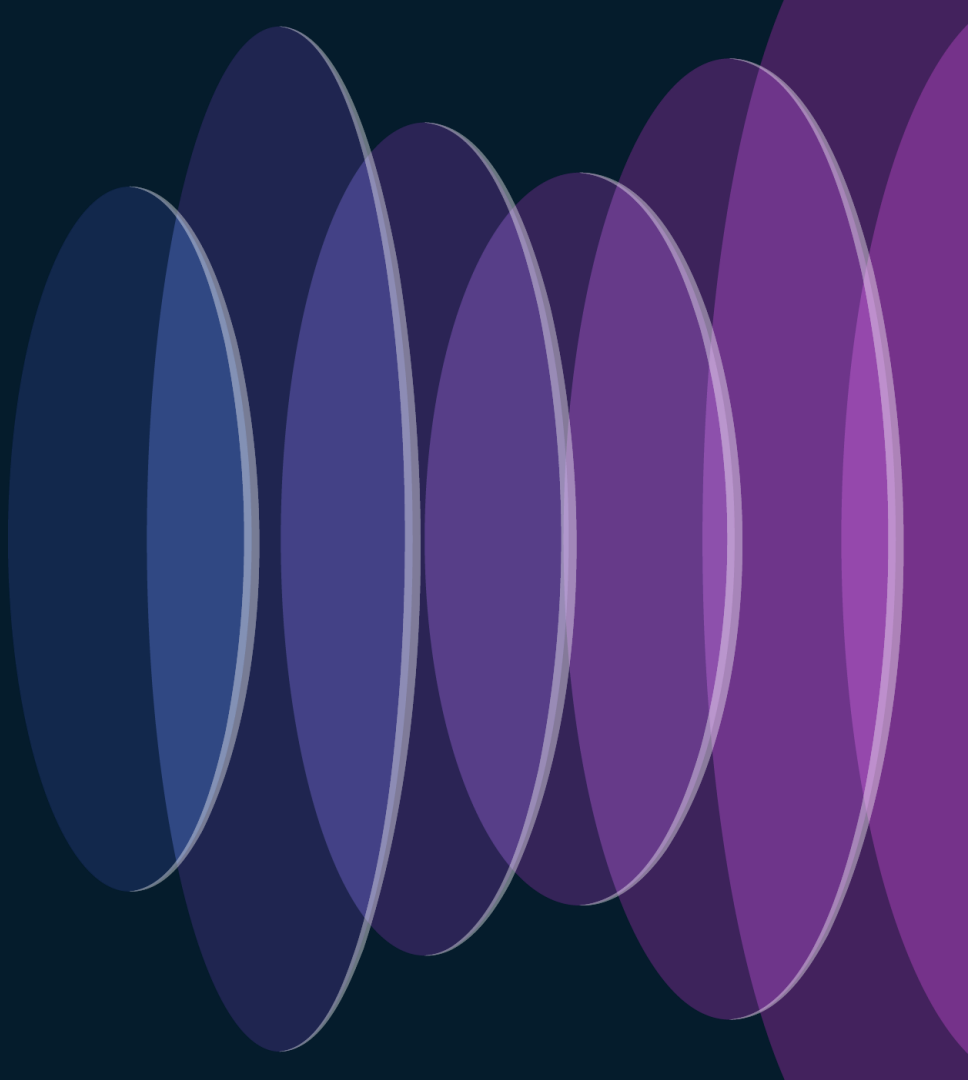
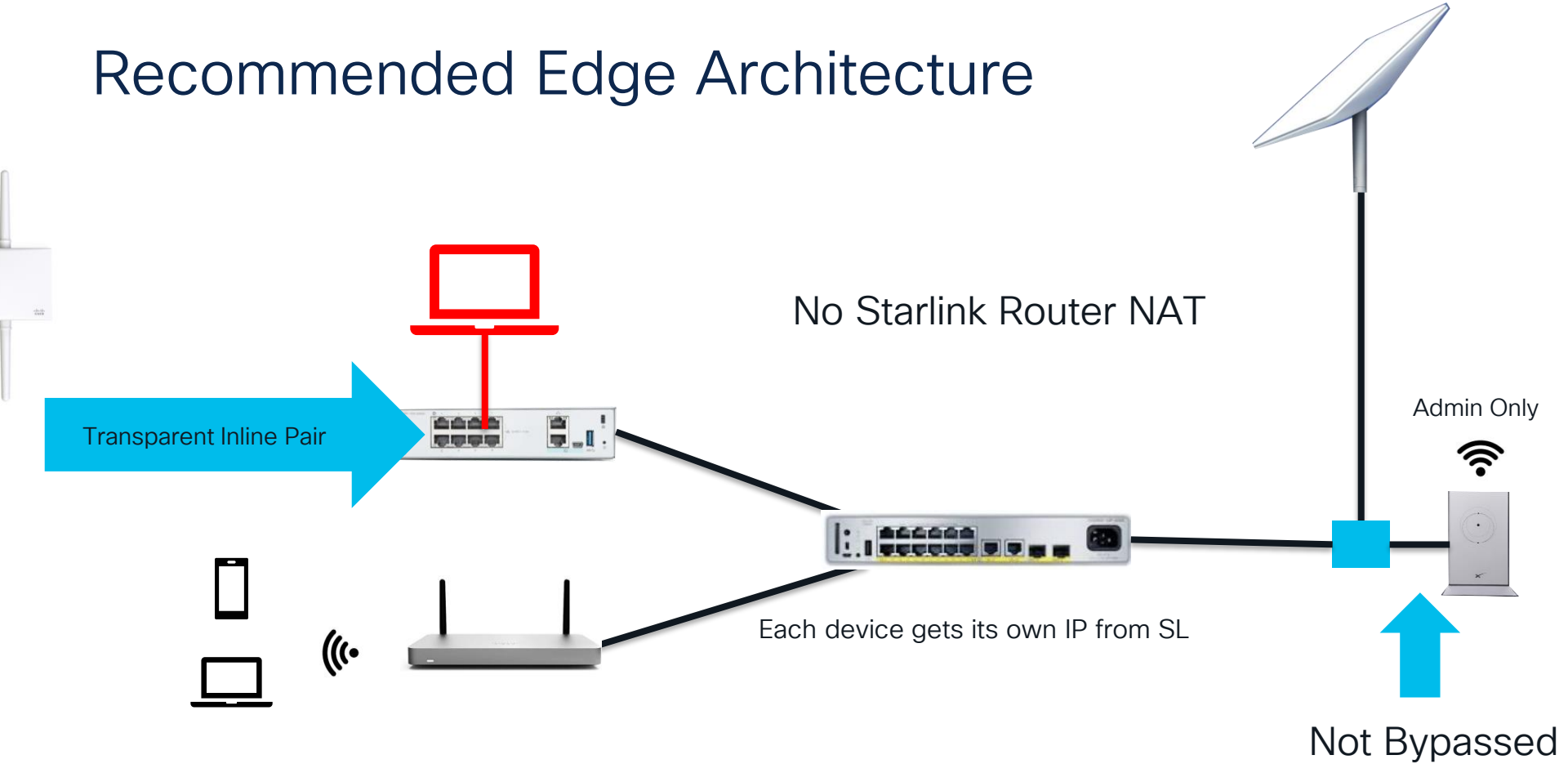
Ground/Space Architectures



Recommended Edge Architecture



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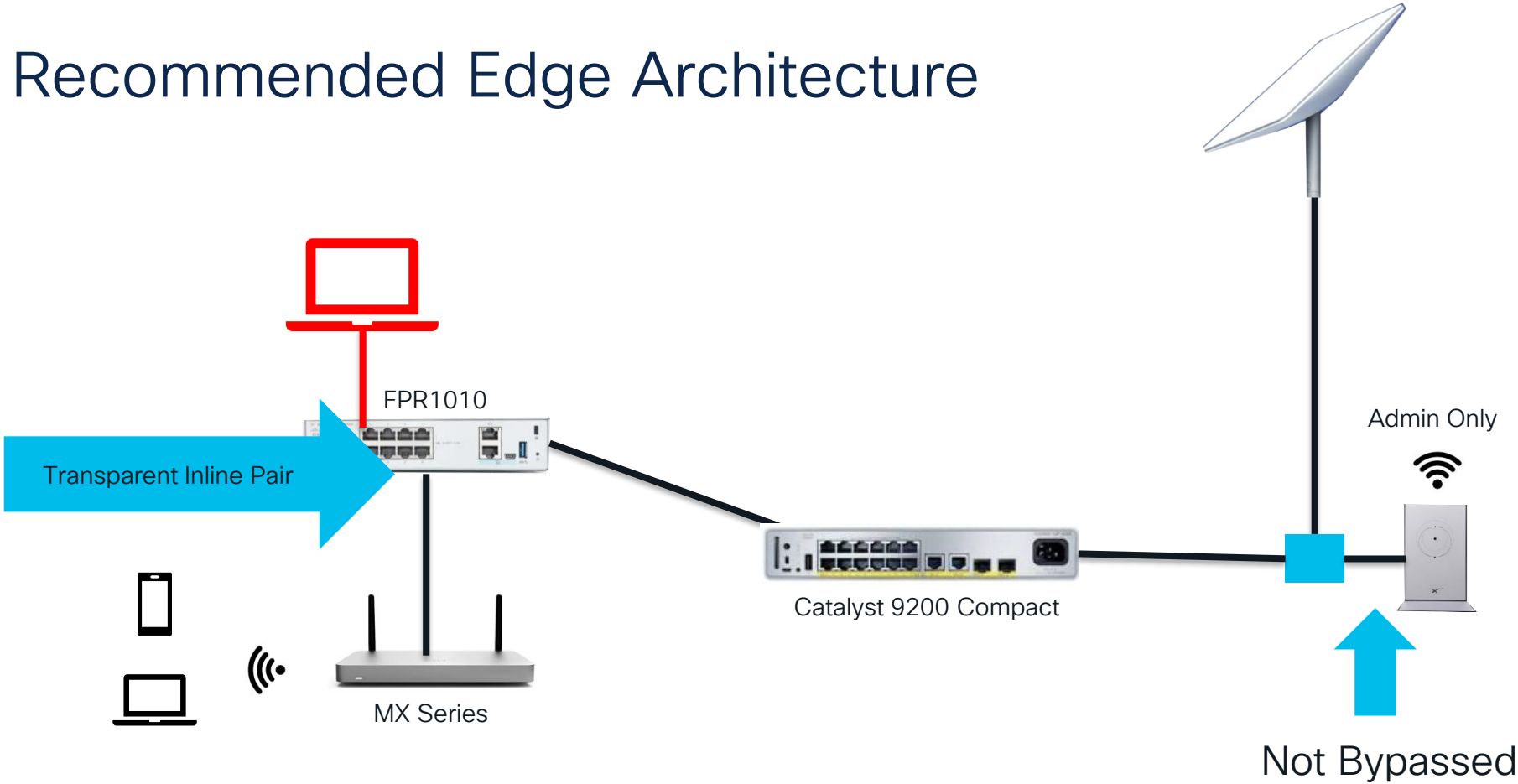
Recommended Edge Architecture



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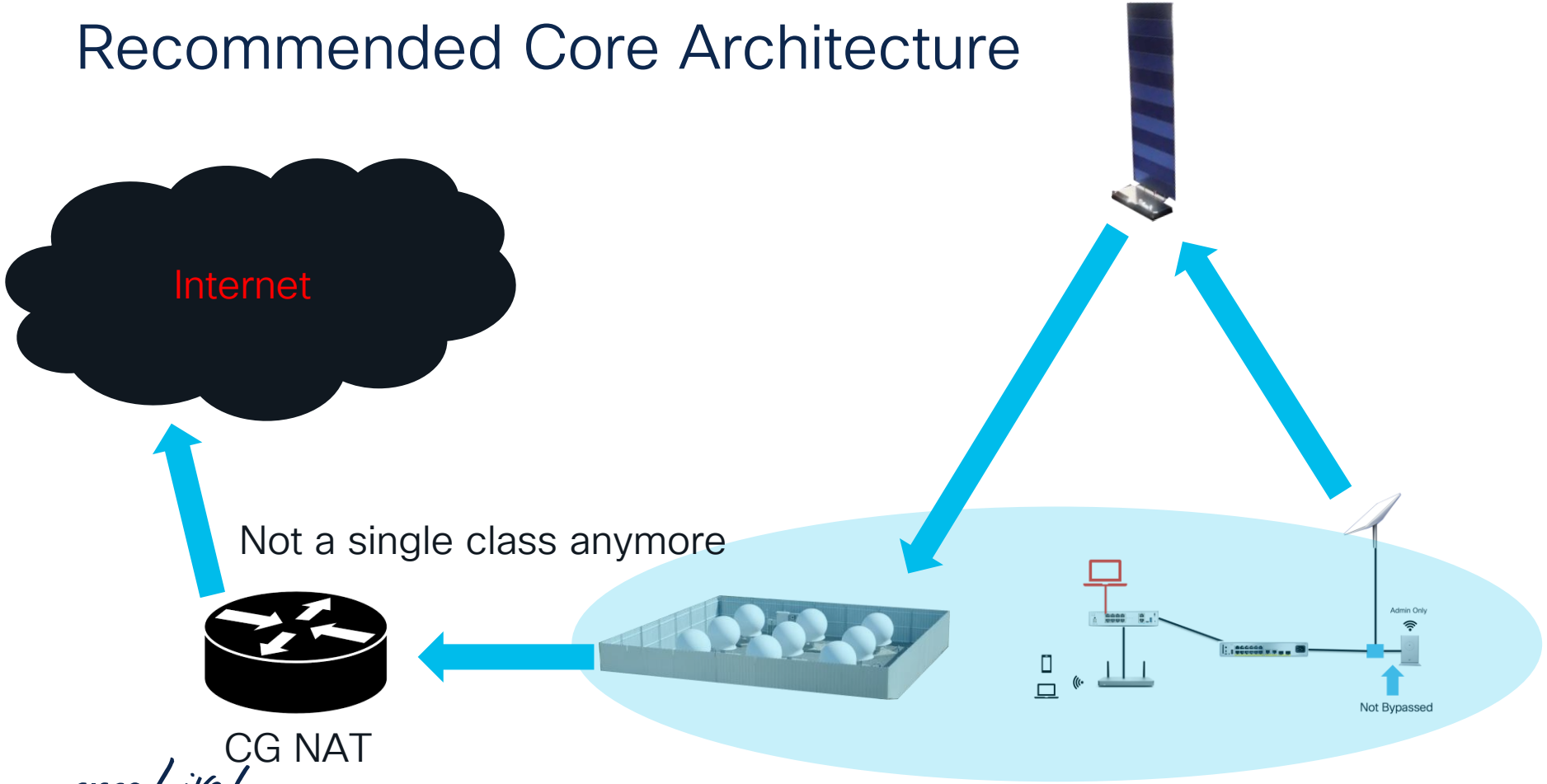
Recommended Core Architecture



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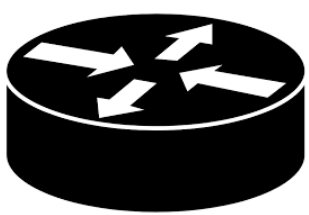
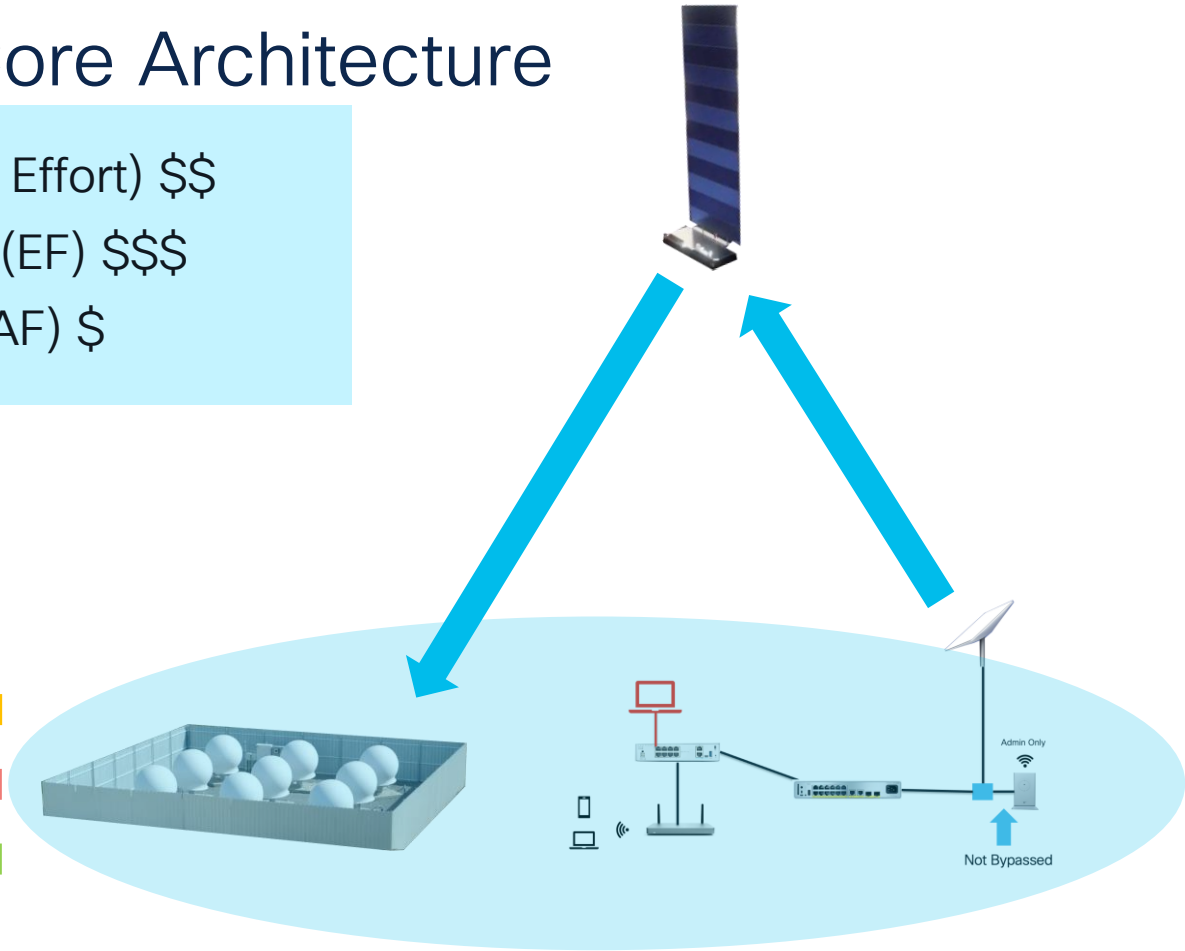
Recommended Core Architecture

Mobile (Best Effort) $$

Priority Data (EF) $$$

Residential (AF) $





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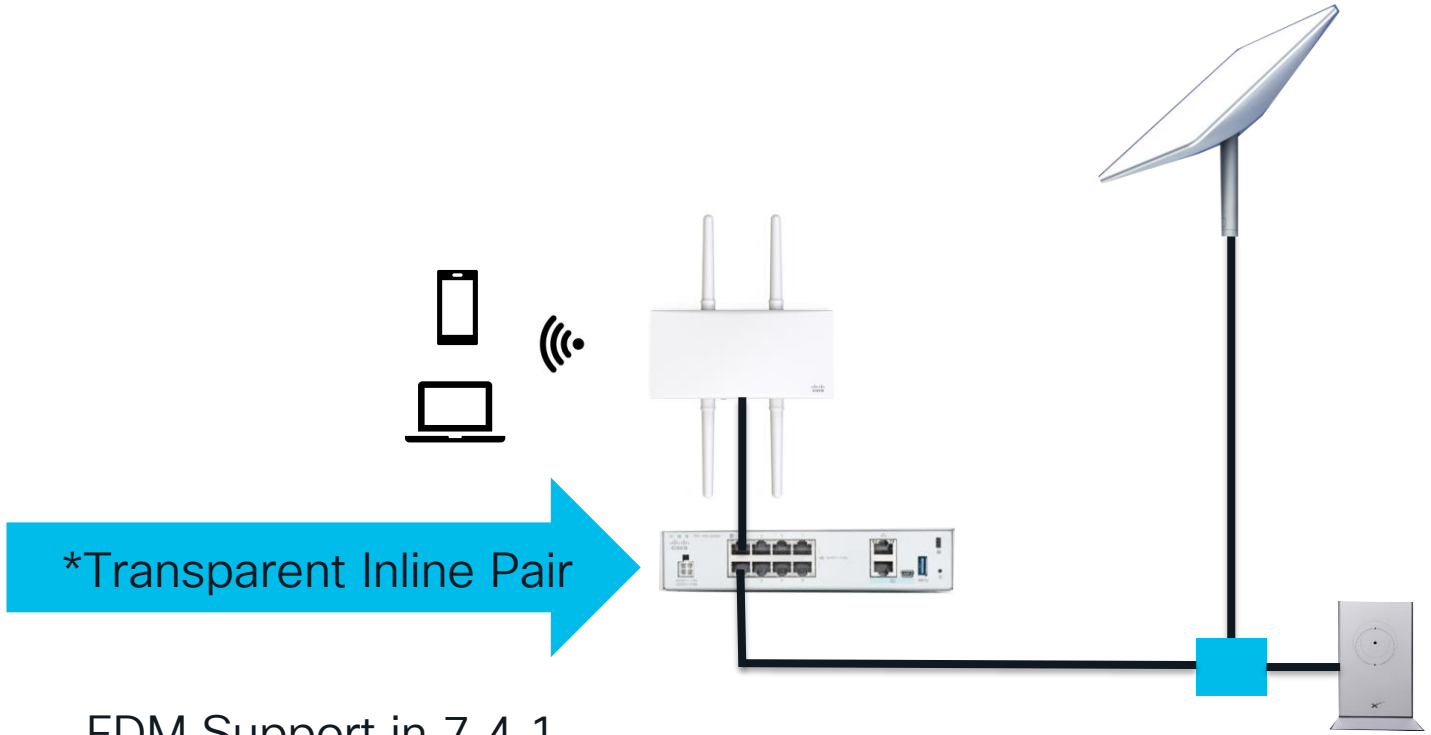
Recommended Architecture



FDM Support in 7.4.1

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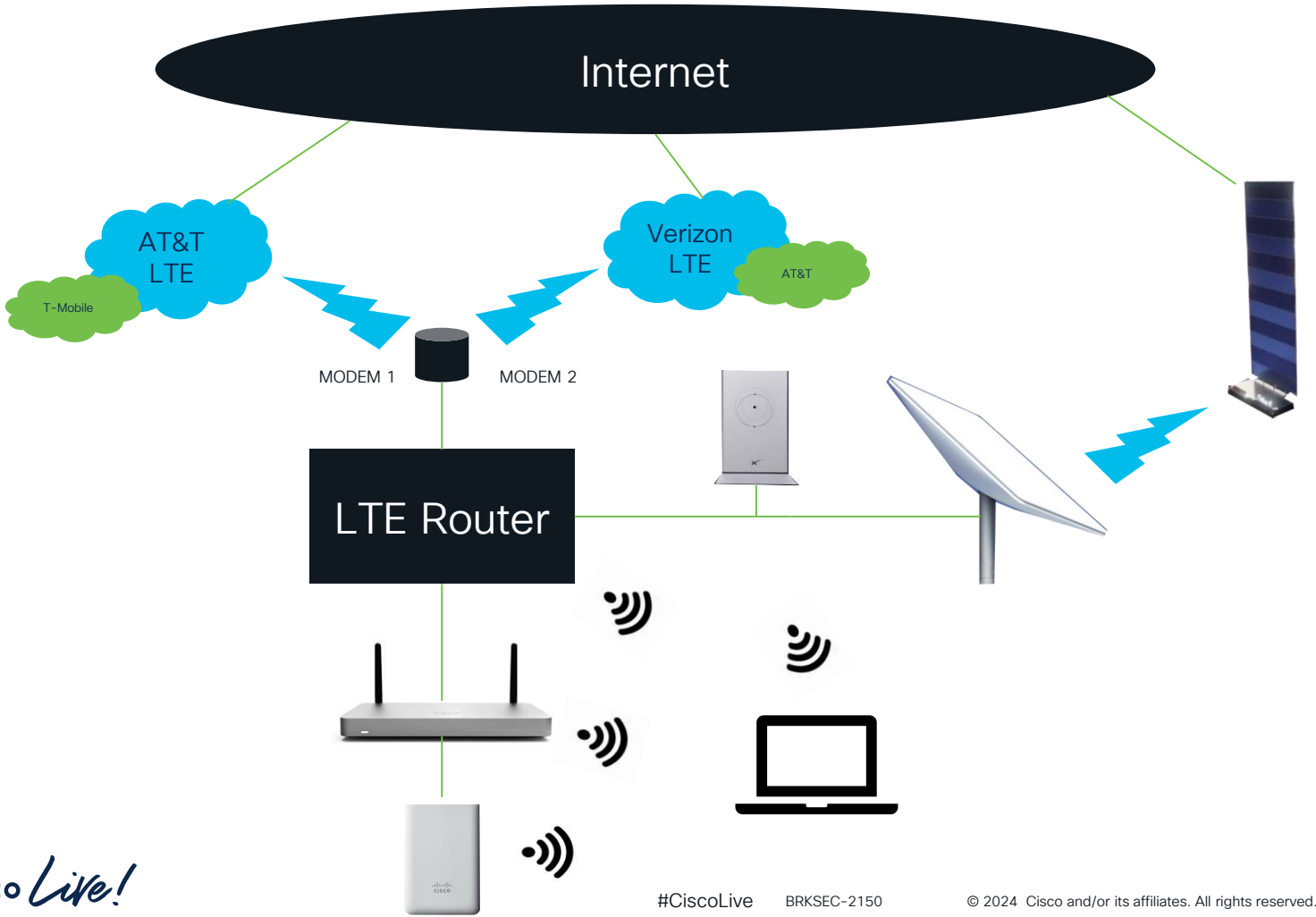

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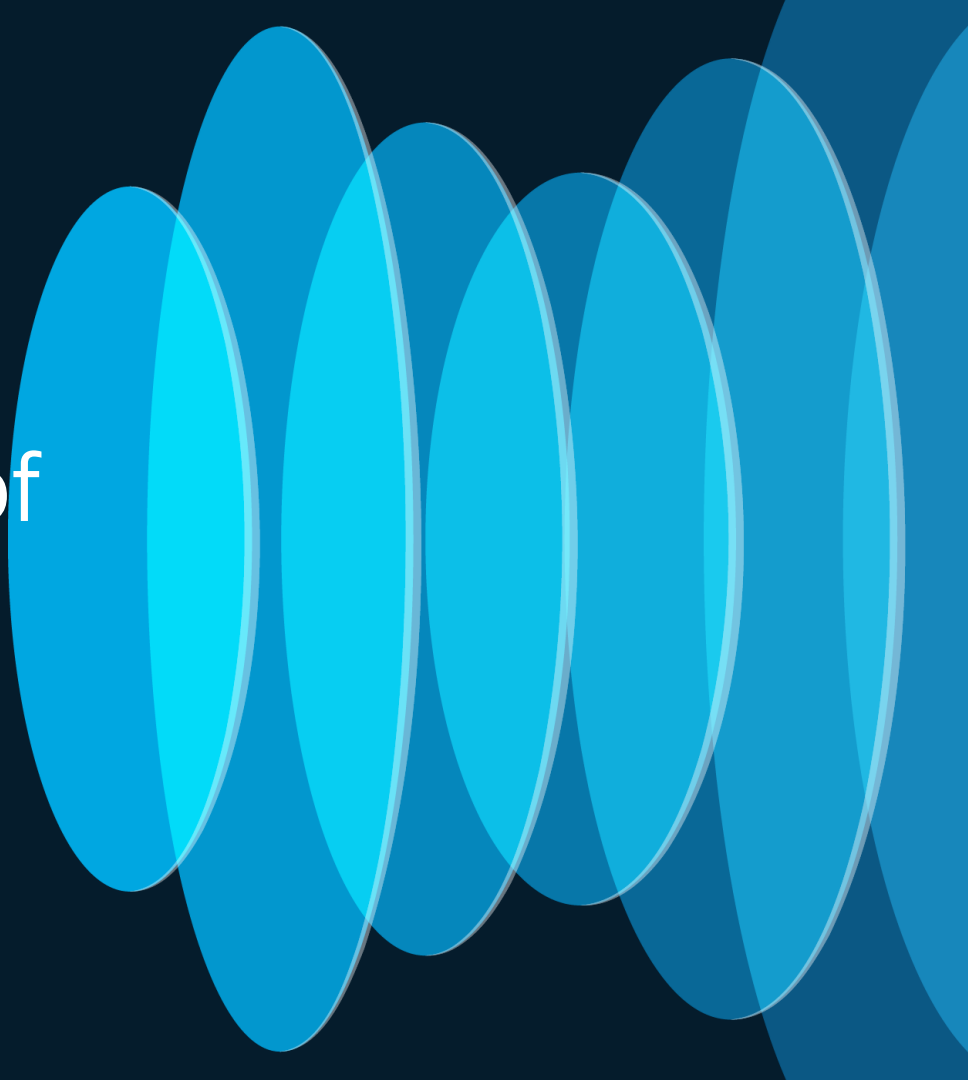
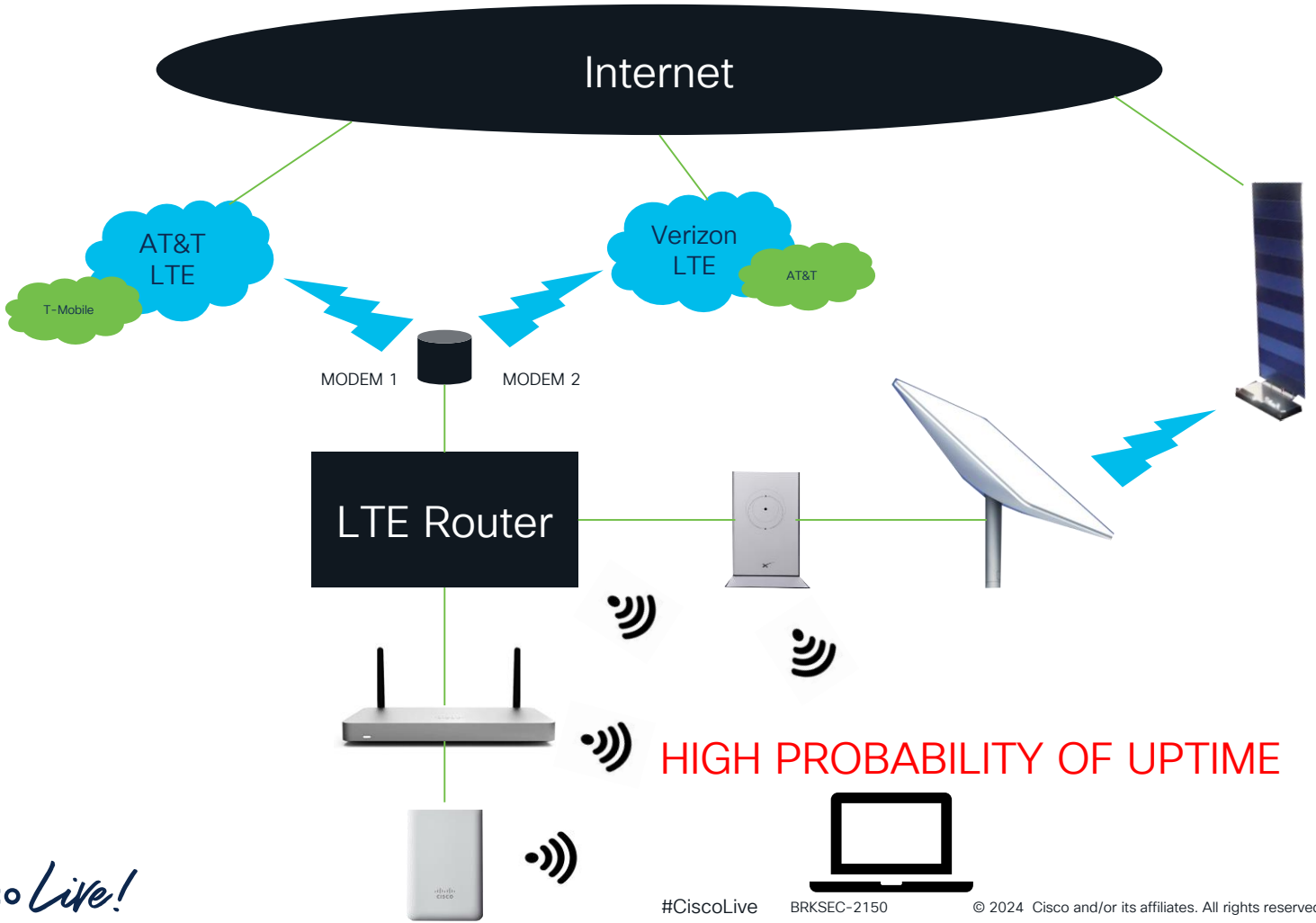
Highest Probability of Network Uptime





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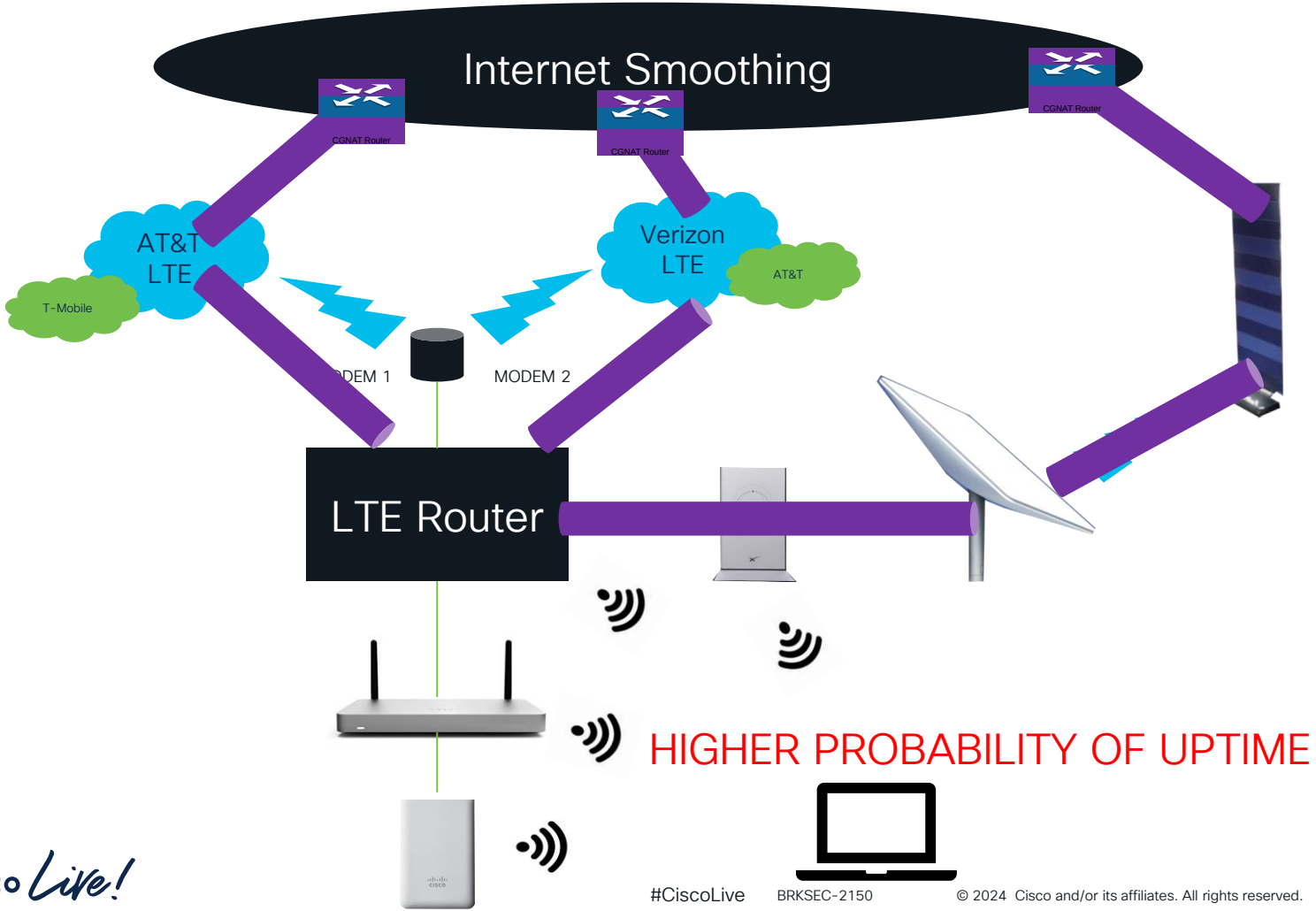

HIGHER PROBABILITY OF UPTIME

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LTE Cat 7/14 or 5G Cat 20 Modem?

- Great question – do you think y
  consistent basis?
- If not, I would opt for LTE based
- With WAN Smoothing technolo
  impacts are largely minimized

Downlink			Uplink			
DL UE Gategor	Max data rate in Mbps	DL MIMO	DL UE Gategor	Max data rate in Mbps	64QAM Support	256QAM Support
M1	~1 Mbps	1	M1	~3 Mbps		
M2	~ 4 Mbps		M2	~7 Mbps		
0	~1 Mbps		0	~0 Mbps	No	
1bits	~10 Mbps		1bits	~5 Mbps		
4	~150 Mbps	2	3	~50 Mbps		
6	~300 Mbps		5	~75 Mbps	Yes	No
7	~300 Mbps		7	~100 Mbps		
9	~450 Mbps		8	~1500 Mbps		
10	~450 Mbps	2 or 4	13	~150 Mbps		
11	~600 Mbps		14	~9500 Mbps		
12	~600 Mbps		15	~220 Mbps		
13	~390 Mbps		16	~100 Mbps	No	
14	~3900 Mbps	8	17	~2100 Mbps		
15	~800 Mbps	2 or 4	18	~210 Mbps		Yes
16	~1050 Mbps		19	~13500 Mbps		
17	~25000 Mbps	8	20	~315 Mbps		
18	~1200 Mbps		21	~300 Mbps		
19	~1600 Mbps	2,4 or 8				
20	~2000 Mbps					
21	~1400 Mbps	2 or 4				

315Mbp

2Gbps

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When Starlink goes down for 20 minutes

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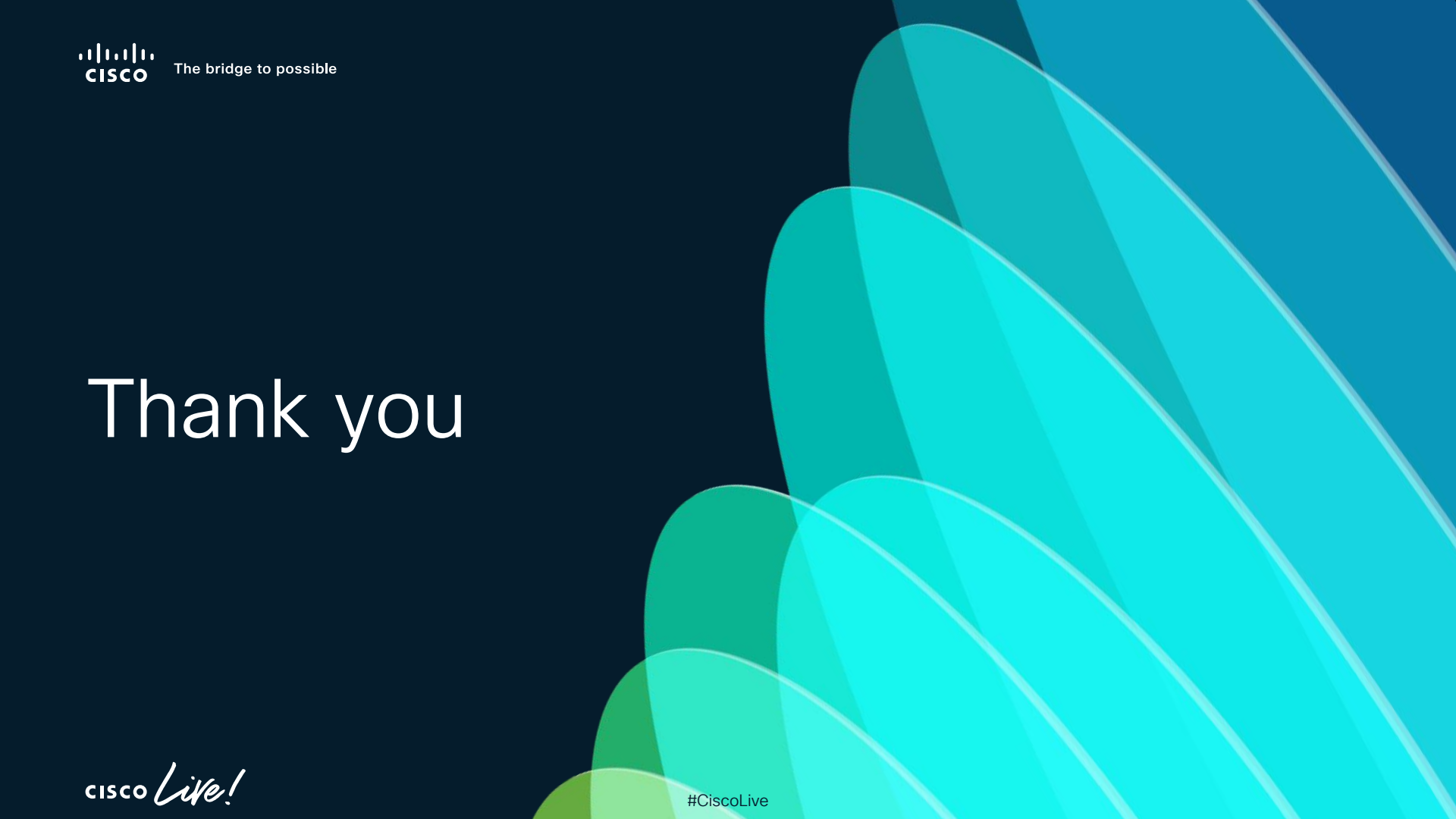
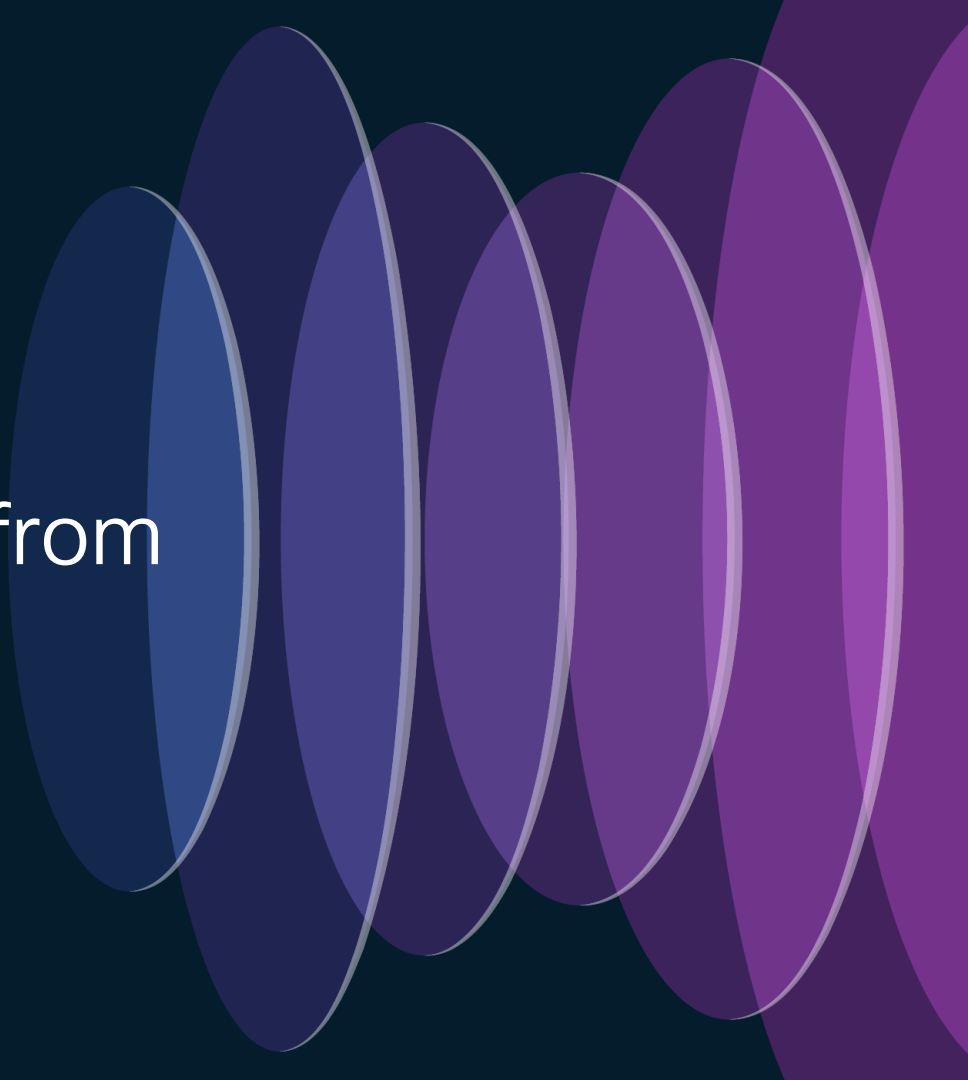

The bridge to possible
Thank you
cisco Live!
#CiscoLive

Bonus Material: Local Launch Pictures from Melbourne (Florida)



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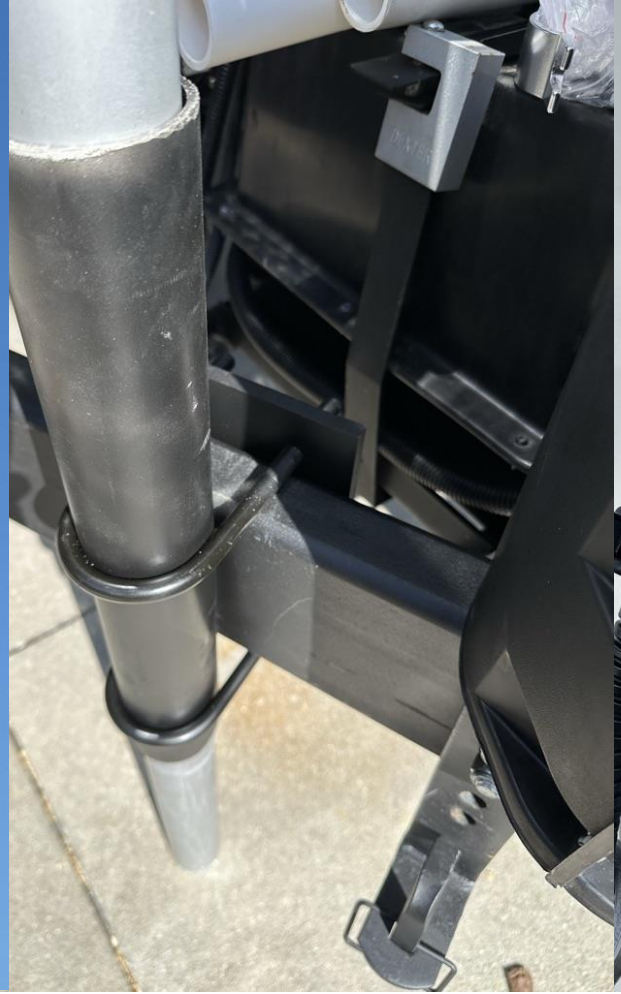

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