SHADOWSERVER

Lighting the way to a more secure Internet

Internet Spelunking

IPv6 Scanning and Device Fingerprinting

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SHADOWSERVER.ORG

What is The Shadowserver Foundation

- A not-for-profit organisation (NPO) working to make the Internet more secure for everyone.
- **Unique sources**, a **global vantage point** and **proven partnerships** with:
  - *National Computer Security Incident Response Teams (nCSIRTs)*
  - *Law Enforcement*
  - *Industry and security researchers world-wide*
- **Shares information with Internet defenders at no cost** to mitigate vulnerabilities, detect malicious activity and counter emerging threats.
- An unparalleled combination of position, **trusted information** and **18 years of proven community partnerships** enables Shadowserver to **perform a critical role in Internet security** - **the world's largest provider of free cyber threat intelligence.**

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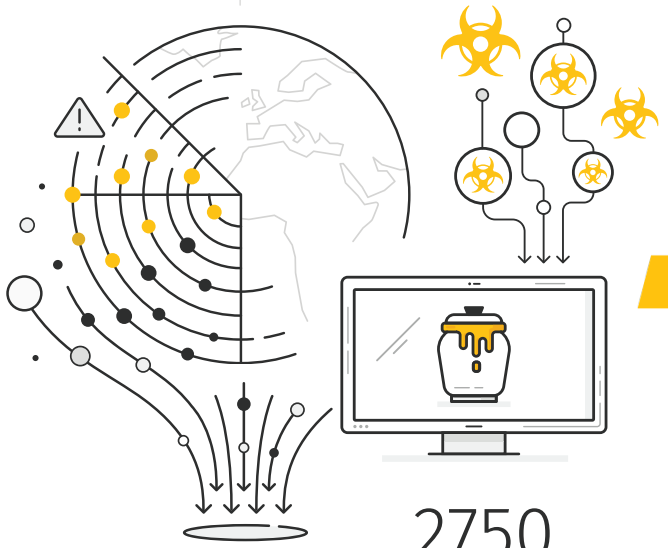
Shadowserver by (some of the) numbers

3.7 BILLION

IPv4 addresses scanned **103** times per day (**820 Million** IPv6 10 times per day). **381 Million** hosts respond



4-5 MILLION

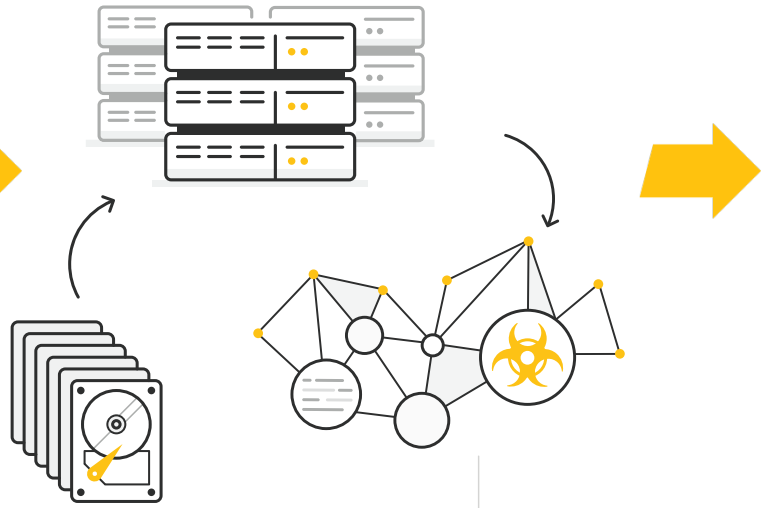
IP addresses per day sinkholed across **400** different malware variants

2750

Class C networks hosting honeypots & spampots

1,115,000

unique malware samples ingested & analyzed **every day** by our sandboxes. Over **1.7 billion samples** in our malware repository



12 PETABYTES

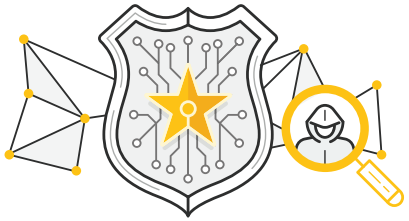
of malware & threat intel stored, **growing at 1+ PB/year**

40 BILLION

SSL certificates, indexed & searchable in our data & analysis clusters

7,000

network owners & **133 National CSIRTs in 175 countries and territories** rely on our **free** daily reports



Behind the scenes support for dozens of international Law Enforcement operations

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So, About Our Scanning …

Big numbers

149,281,685 Reported IPs

107,252,144,957 UDP Probes

225,577,728,428 TCP SYN

407,092,432 Full Handshakes

Ground Rules

Do no harm

Never exploit

Test, test, test, 1/250th test

Test some more

First, do no harm

- Scans will not compromise, harm, or degrade system performance
  - Use the smallest and most minimal packet possible to get the results
  - Test repeatedly before a full Internet scan occurs
  - 1/250th test
- Only scan what is necessary for remediation
  - Vulnerable or misconfigured systems
  - Specific ports used by criminal infrastructures
- Scans will not break any US laws

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How Did We Get Here?

No (good?) deed goes unpunished.

The Origin

You can all thank Christian Rossow for publishing:

"Amplification Hell: Revisiting Network Protocols for DDoS Abuse"

https://christian-rossow.de/publications/amplification-ndss2014.pdf

The Origin

- Started with DNS
  - It was easy
  - Miscreants were already abusing it
  - There were already two open DNS scanners available for us to confirm results against
    - Other data sets were deemed too polluted to be used easily for reporting purposes
    - Cleaning other data sets was difficult and the actual methodology of scanning was flawed by both other scanning entities
    - Better to build something new to meet our more narrow scope and mission

The Origin Story

- First scan took 91 hours to complete
- 16.9 million responses (53/udp only)
- 12.25 million openly recursive

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Fast Forward to curdate()

- The DNS scan now runs in 4 hours
  - 6 million total responses (53/udp only)
  - 1.8 million recursive resolvers

~10.4 million IPs that are no longer abusable

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Hey, It worked!

After discovering that the scanning worked, we:

- Acquired more hardware
- Acquired more bandwidth
- Wrote new scanning tools
- Proceeded to implement scans on the rest of the named UDP targets

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Something Different!

Smooth sailing until October 2014

- POODLE (SSLv3 Downgrade)
  - Padding Oracle On Downgraded Legacy Encryption

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Needed to learn some new tricks..

Discovered that scanning /0 for UDP is *much* easier than TCP

- UDP is just Spray'n'Pray (with some limits)
  - Self DDoS's can hurt if not controlled and rate limited
- TCP you have to track state and scan (at least) twice
  - And you have to talk x509!

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Success! (it took a bit)

- First reported POODLE data:
  - November 2014
  - 15,573,251 IPs vulnerable to a downgrade attack

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Fast Forward to curdate()

POODLE (SSLv3) now:

- 2,365,512

- Still a big number, but better

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Expansion of the beast

We couldn’t let all the lessons we learned sit idle, so we added in a *few* more scans..

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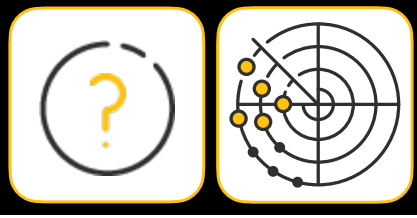
Over 100 Full Scans a Day (IPv4)



Protocol	Port	Protocol	Port	Protocol	Port	Protocol	Port	Protocol	Port	Protocol	Port
AMQP	5672/tcp	DVR DHCPDiscover	37810/udp	HTTPS	10443/tcp	LDAP	389/tcp	NTP (Monitor)	123/udp	SMB	445/tcp
Android Debug Bridge	5555/tcp	ElasticSearch	9200/tcp	HTTPS	8010/tcp	mDNS	5353/udp	NTP (Version)	123/udp	SMTP	25/tcp
Apple File Protocol	548/tcp	EPMD	4369/tcp	HTTPS	5001/tcp	MELSEC-Q	5007/tcp	Omron FINS	9600/udp	SMTP (IPv6)	25/tcp
Apple Remote Management	3283/udp	EtherCAT	34980/udp	HTTPS	4433/tcp	MemCacheD	11211/udp	OPC-UA	4840/tcp	SNMPv2	161/udp
BACnet	47808/tcp	EtherNet/IP	44818/tcp	HTTPS	6443/tcp	MemCacheD	11211/tcp	PCWORX	1962/tcp	SOCKS4/5	1080/tcp
CharGEN	19/udp	FTP	21/tcp	HTTPS	447/tcp	Microsoft Exchange	443/tcp	PLEX SSDP	32414/udp	SSDP	1900/udp
cLDAP	389/udp	GE-SRTP	18245/tcp	HTTPS	4117/tcp	Middlebox	80/tcp	Portmapper	111/udp	SSH	22/tcp
CoAP (v1)	5683/udp	Hadoop (DataNode)	50075/tcp	HTTPS	8080/tcp	Mikrotik (Speed Test)	2000/tcp	PostgreSQL	5432/tcp	SSH (IPv6)	22/tcp
CoAP (v2)	5683/udp	Hadoop (NameNode)	50070/tcp	HTTPS	5443/tcp	Mitel	10074/udp	PostgreSQL (IPv6)	5432/tcp	SYNful Knock	80/tcp
CODESYS IEC 61131-3	2455/tcp	HART	5094/tcp	HTTPS	7443/tcp	MODBUS	502/tcp	ProConOS	20547/tcp	Telnet	23/tcp
CODESYS IEC 61131-3	1200/tcp	HTTP	80/tcp	HTTPS (IPv6)	443/tcp	MongoDB	27017/tcp	QOTD	17/udp	Telnet	2323/tcp
CouchDB	5984/tcp	HTTP (IPv6)	80/tcp	HTTPS	443/tcp	MQTT	1883/tcp	QUIC	443/udp	Telnet (IPv6)	23/tcp
Crimson (Red Lion)	789/tcp	HTTP	8080/tcp	ICCP	102/tcp	MQTT SSL	8883/tcp	Radmin	4899/tcp	TFTP	69/udp
CWMP	7547/tcp	HTTP (IPv6)	8080/tcp	IEC 60870-5-104	2404/tcp	MS-SQL	1434/udp	RDP	3389/tcp	Tridium Niagra	1911/tcp
CWMP	30005/tcp	HTTP	8000/tcp	IPMI	623/udp	MySQL	3306/tcp	RDPEUDP	3389/udp	Ubiquiti Discovery Service	10001/udp
DB2	523/udp	HTTPS	8443/tcp	IPP	631/tcp	MySQL (IPv6)	3306/tcp	Redis	6379/tcp	VNC	5900/tcp
DNP3	20000/tcp	HTTPS (IPv6)	8443/tcp	ISAMKP	500/udp	NAT-PMP	5351/udp	rsync	873/tcp	VNC	5901/tcp
DNS	53/udp	HTTPS	9000/tcp	Kubernetes	6443/tcp	NetBIOS	137/udp	S7	102/tcp	XDMCP	177/udp
Docker	2375/tcp	HTTPS	449/tcp	Kubernetes	443/tcp	Netis	53413/udp	SmartInstall	4786/tcp		

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How and Why are the next targets chosen

- Topical – new blog comes out with a vulnerability that can be remotely tested
  - Netis, Synfulknock, ISAKMP, etc
- Looking at legacy protocols that really should not be exposed
  - Telnet, rsh, etc
- Current protocols that really should not be exposed
  - MongoDB, Kubernetes, etc
- Someone asked us to look for it

Fun Facts

We have sent (with daily repeats):

- 209,724,213,326,259 UDP Probes
  - 209.7 Trillion UDP Probes
- 221,639,352,853,200 TCP SYNs
  - 221.6 Trillion TCP Syns
- 508,013,815,018 Full Protocol Connections
  - 508 Billion Connections
- 287,916,573,658 Services for remediation
  - 287.9 Billion Reported

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Sorry for the noise…

The Gear

How the work gets done – Grab the hearing protection

Stack o’ Boxes in a Colo

Just a pile of leftover gear

- 37 x servers
- 2 x 10 Gb/s lines
- 5 x /26 IPv4 blocks (and 1 /24)
- 1 x /64 IPv6 block

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Dirtiest CIDRs on the net?

- We scan from 558 IPv4 addresses:

  [redacted]

- And 1221 IPv6 addresses:

  [redacted]

- Nodes are each assigned 15 IPv4 and 33 IPv6 addrs
- Evenly split across 2x 10 gb lines

Scanning Methodology

- TCP and UDP scans are handled differently
  - TCP Scans are:
    - Broken into shards
      - Shard is 1/250th of the IP space to be scanned
      - IPs in a shard are algorithmically determined by a random seed that is supplied to every shard.
    - Will use the entire cluster to scan
    - Performed using commodity software
  - UDP Scans are:
    - Monolithic
    - Run from a single node
    - Performed using custom software

UDP Scans

- Meet “**railgun**”
  - Designed to send a single UDP packet as randomly as possible and as fast as possible to all 3.4B IPs
  - Tuned for sending small packets
  - Will send packets using all available IPs
  - Has very few safety measures

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UDP Scans

- Railgun can usually scan the internet for one service in around four hours.
  - Highly dependent on the number of responding devices.

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TCP Scans

- Commodity tools
  - Assignment of jobs:
    - HTCondor
  - Actual scanning:
    - Zmap performs the initial sweep
    - Zgrab (mostly) performs the connection
    - Other tools for doing custom things

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TCP Scans

Each service takes between ten minutes and three hours

- Dependent on the complexity of the scan
  - Things with no crypto (Telnet) are fast
    - 8 minutes in human time
    - 3 hours and 57 minutes in machine time
  - Things with crypto (HTTPS) are much slower
    - 2 hours and 29 minutes in human time
    - 82 hours in machine time

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Same From Here

- The raw data is:
  - Parsed (protocol specific)
  - Sanity checked (bad data?)
  - Standardized
  - Shipped off to the Datacenter to get turned into reports

IPv6

You want to scan what?

Surprisingly Familiar

- Like IPv4, just a LOT more of it
- Not feasible to scan it all, so curated lists
  - IPv6 addresses sourced from SSL certificates, IPv6 Hitlist, other.
- Currently scanning 814,675,045 IPv6 addresses

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Blindly Scanning is Infeasible

IPv6 space is 3.48x10^38 unique addresses

Time to scan ~6.33x10^32 seconds

Roughly 2x10^25 years

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Blindly Scanning is Infeasible

- Use curated lists from:
  - DNS AAAA records (passive DNS)
  - IPv6 Hitlist: https://ipv6hitlist.github.io/
  - Certificate transparency streams
  - Sinkholes
  - Partners

Yet Different…

Fewer options for scanning tools

- zmap6: https://github.com/tumi8/zmap
- zgrab/zgrab2 have native IPv6 support
- Other tools.. Not so much

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And Slower…

IPv6 requires more gentle timings than IPv4

- IPv4: Potential packet loss at > 500,000 pps
- IPv6: Potential packet loss at > 100,000 pps

And Slower…

IPv6 requires more gentle timings than IPv4

- IPv4: Packet loss at > 3500 concurrent senders
- IPv6: Packet loss at > 1500 concurrent senders

And Slower…

Average number of IPs/second that can be processed

- IPv4: 243,116 IPs/second
- IPv6: 58,542 IPs/second

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And Doesn’t Like to Share…

IPv4 and IPv6 scans don’t like running at the same time on the same interface

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IPv6 Scans

- SSL (443/tcp, 8443/tcp)
- SMTP (25/tcp)
- TELNET (23/tcp)
- SSH (22/tcp)
- HTTP (80/tcp, 8080/tcp)
- MySQL (3306/tcp)
- FTP (21/tcp)
- PostgreSQL (5432/tcp)

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IPv6 Scan Stats

Scan	Port	Responses
SSL	443/tcp	8 192 360
SSL	8443/tcp	75 432
SMTP	25/tcp	407 521
Telnet	23/tcp	25 267
SSH	22/tcp	839 575
HTTP	80/tcp	109 845 303
HTTP	8080/tcp	415 989
MySQL	3306/tcp	1 424 136
FTP	21/tcp	2 622 208
PostgreSQL	5432/tcp	34 795

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IPv6 Scans (Observations)

SSL

- Fewer hosts with really old ciphers (SSLv3, TLSv1.0, TLSv1.1)
- 3.86% IPv4 vs 0.04% IPv6

FTP

- Far higher ratio of FTP+SSL
- 55% IPv4 vs 91% IPv6

MySQL

- Far fewer hosts with deny rules
- 42% IPv4 vs 4% IPv6

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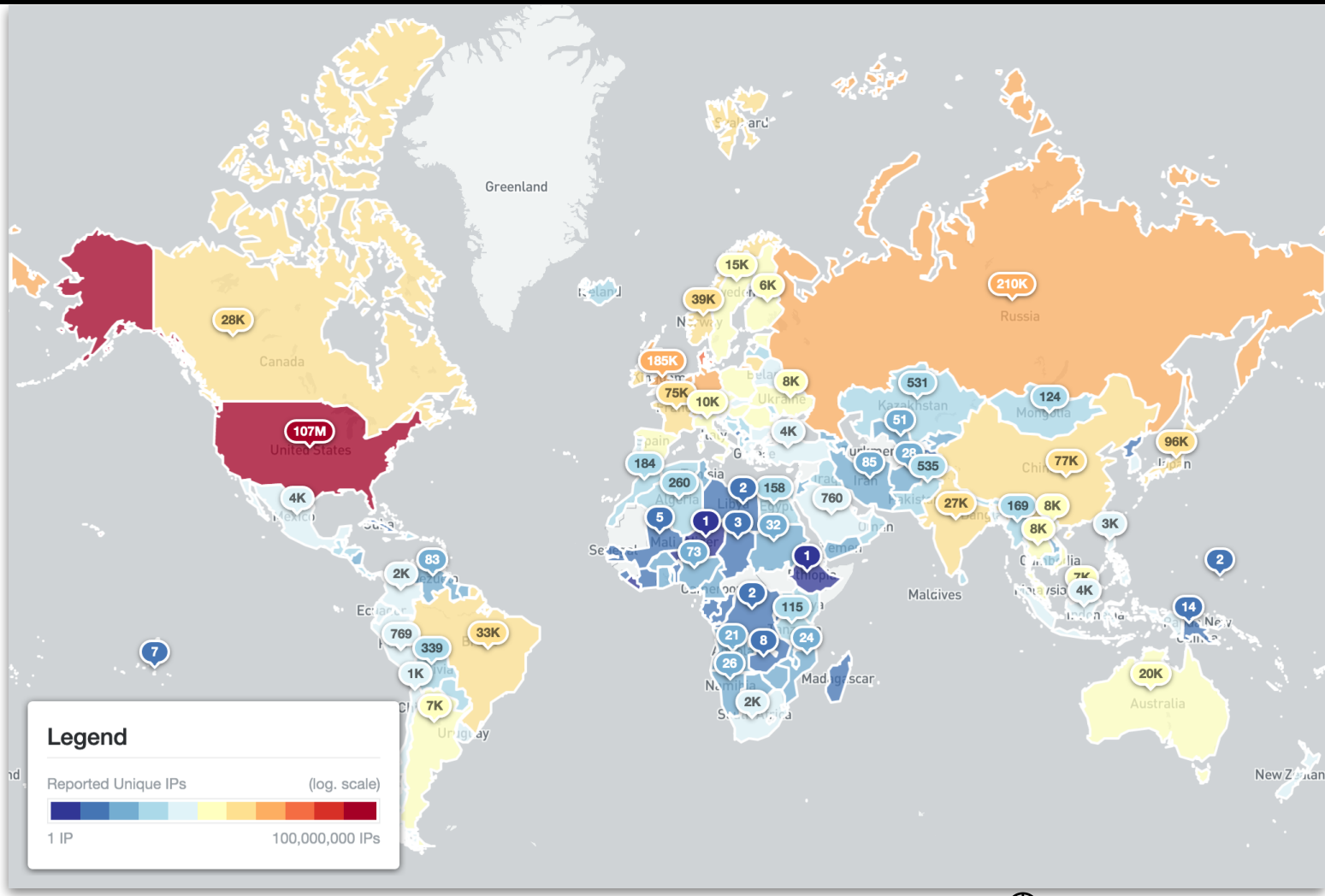
IPv6 Scans (Population)

Bulk of the “in use” IPv6 is in the United States

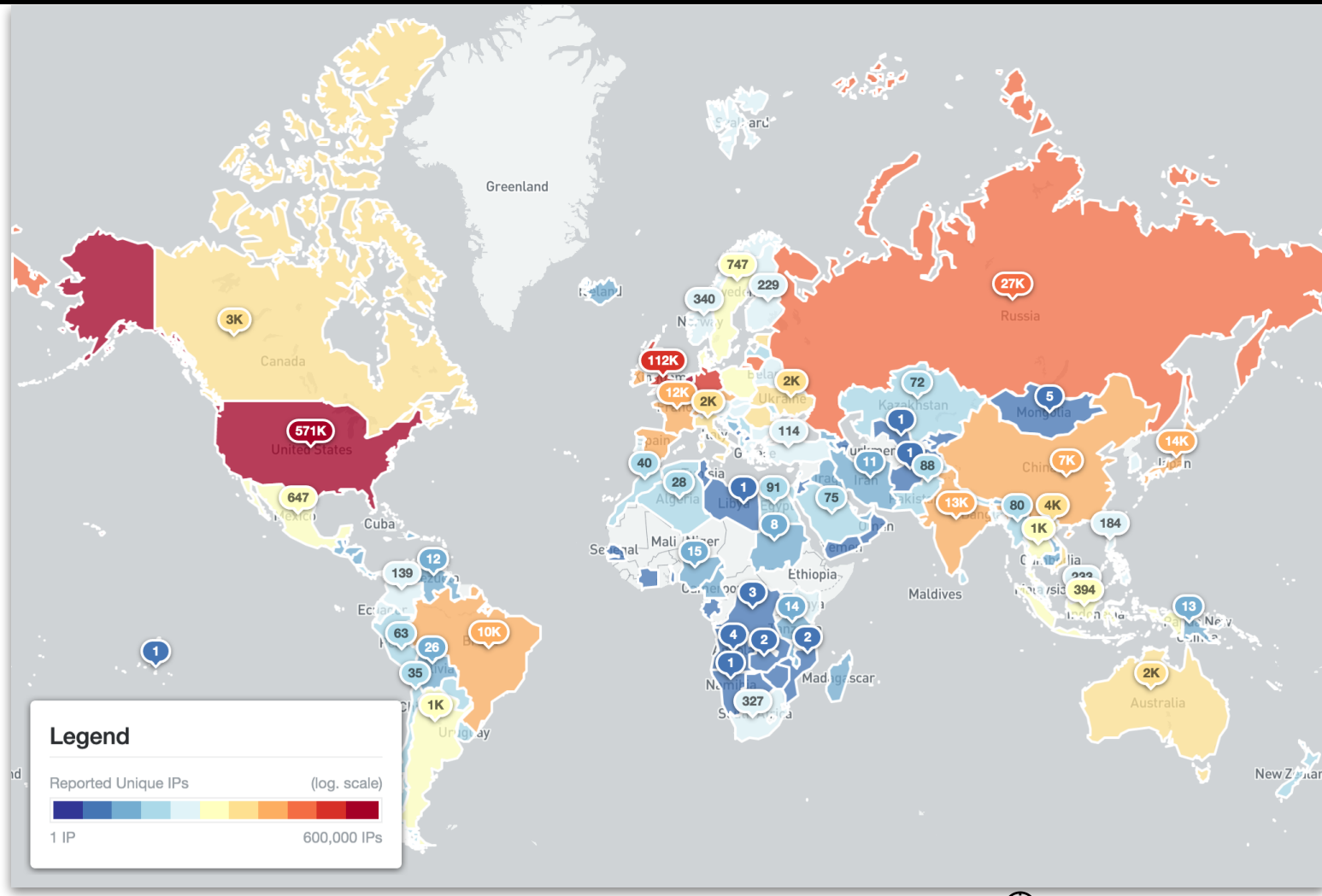
Followed by Denmark, Germany, and Netherlands



IPv6 Scans (Exposed/Vulnerable)

Leader is still the United States.

Followed by Netherlands, Germany, and Singapore.



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IPv6 Scans

Always Looking for More Sources of IPv6 Targets

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Device Identification

Fingerprinting all things!

Device Identification

- Take all data we collect in all our daily scans
  - match fields, banners and responses to identify device make-and-model
- Classify all IPs by:
  - device_type
  - device_vendor
  - device_model
  - device_version
  - device_sector

Device Identification

- Scan rule engine implemented
- Classifies scan data as it is submitted to the Shadowserver backend API
- Currently ~1200 scan rules implemented
- Support for detection of devices from 173 vendors
- Daily successfully classifies over 28M devices (excluding desktops/ servers, web servers etc)
- Findings shared daily with all subscribers in Device Identification Report: https://www.shadowserver.org/what-we-do/network-reporting/device-identification-report/
- More to come!

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Device Identification

Scan rules

Import scan rules | Export scan rules | Advanced filters | Create new | Create in bulk

Action: Go 0 of 20 selected

Contact	Name	Device model	Device type	Device vendor	Group	Order	Test count	Usage	Enabled	State	Created	Actions
Piotr Kije...	Allegro_Software_RomPag...	RomPager	embedded-sys...	Allegro Software	Allegro Software	100			✔		2021-11-14	View | Edit | Delete | Clone
Piotr Kije...	Allegro_Software_RomPag...	RomPager	embedded-sys...	Allegro Software	Allegro Software	200			✔		2021-11-14	View | Edit | Delete | Clone
Piotr Kije...	Realtron_Embedded_Syst...		embedded-sys...	Realtron	Realtron	100			✔		2022-04-24	View | Edit | Delete | Clone
Piotr Kije...	ASUS_httpd_server_http_...		router	ASUS	ASUS	90			✔		2021-01-29	View | Edit | Delete | Clone
Piotr Kije...	ASUS_by_AiCloud_html_title		router	ASUS	ASUS	90			✔		2022-04-13	View | Edit | Delete | Clone
Piotr Kije...	ASUS_catchall_FTP_Banner		router	ASUS	ASUS	95			✔		2021-02-05	View | Edit | Delete | Clone
Piotr Kije...	ASUS_router.asus.com		router	ASUS	ASUS	100			✔		2020-11-13	View | Edit | Delete | Clone
Piotr Kije...	ASUS_by_ASUSTek_cert		router	ASUS	ASUS	100			✔		2022-04-14	View | Edit | Delete | Clone
Piotr Kije...	ASUS_asuscomm_issuer_...		router	ASUS	ASUS	101			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_asuscomm_lets_en...		router	ASUS	ASUS	102			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_asuscomm_lets_en...		router	ASUS	ASUS	105			✔		2021-02-01	View | Edit | Delete | Clone
Piotr Kije...	ASUS_ASUSWRT_issuer_...		router	ASUS	ASUS	120			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_ASUSWRT_HGG_is...		router	ASUS	ASUS	200			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_Merlin_Koolshare_i...		router	ASUS	ASUS	202			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_ASUSWRT_Merlin_i...		router	ASUS	ASUS	203			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_Merlin_Koolshare_r...		router	ASUS	ASUS	204			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_ASUSWRT_Merlin_...		router	ASUS	ASUS	205			✔		2020-11-23	View | Edit | Delete | Clone
Piotr Kije...	ASUS_Merlin_Koolshare_r...	RT-AX88U	router	ASUS	ASUS	206			✔		2020-11-23	View | Edit | Delete | Clone

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Device Identification - Popular matched responses

- SSL Common Names & Organization Names
- HTML body content
- HTTP server names
- HTTP cookies
- SNMP sysdesc, sysname
- FTP, TELNET, SSH banners
- … many more!

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Device Identification - Scan rules

- Rule syntax

```
( boolean expression ) -> statement(s)
```

- Rule operators

Name	Operation
and	boolean and
or	boolean or
=	case sensitive string equality
!=	case sensitive string inequality
=~	regex match
!~	regex difference
:=	assignment

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Example fingerprinting rule - iRobot Roomba

```
(issuer_common_name =~ /^Roomba/ and
issuer_organization_name = "iRobot")
-> tag := "iot", device_type :=
"home-appliance", device_vendor :=
"iRobot", device_model := "Roomba",
device_sector := "consumer"
```

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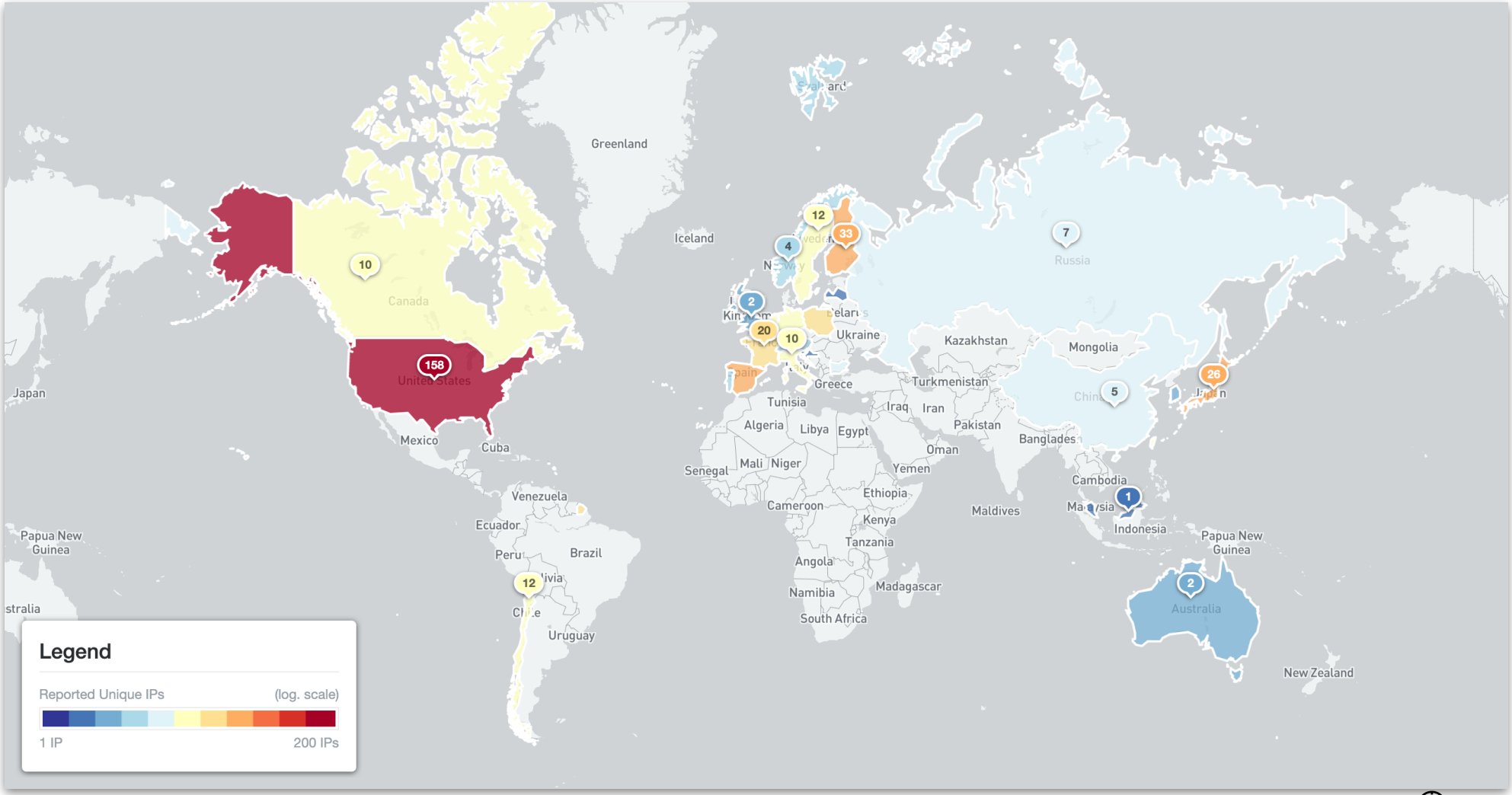
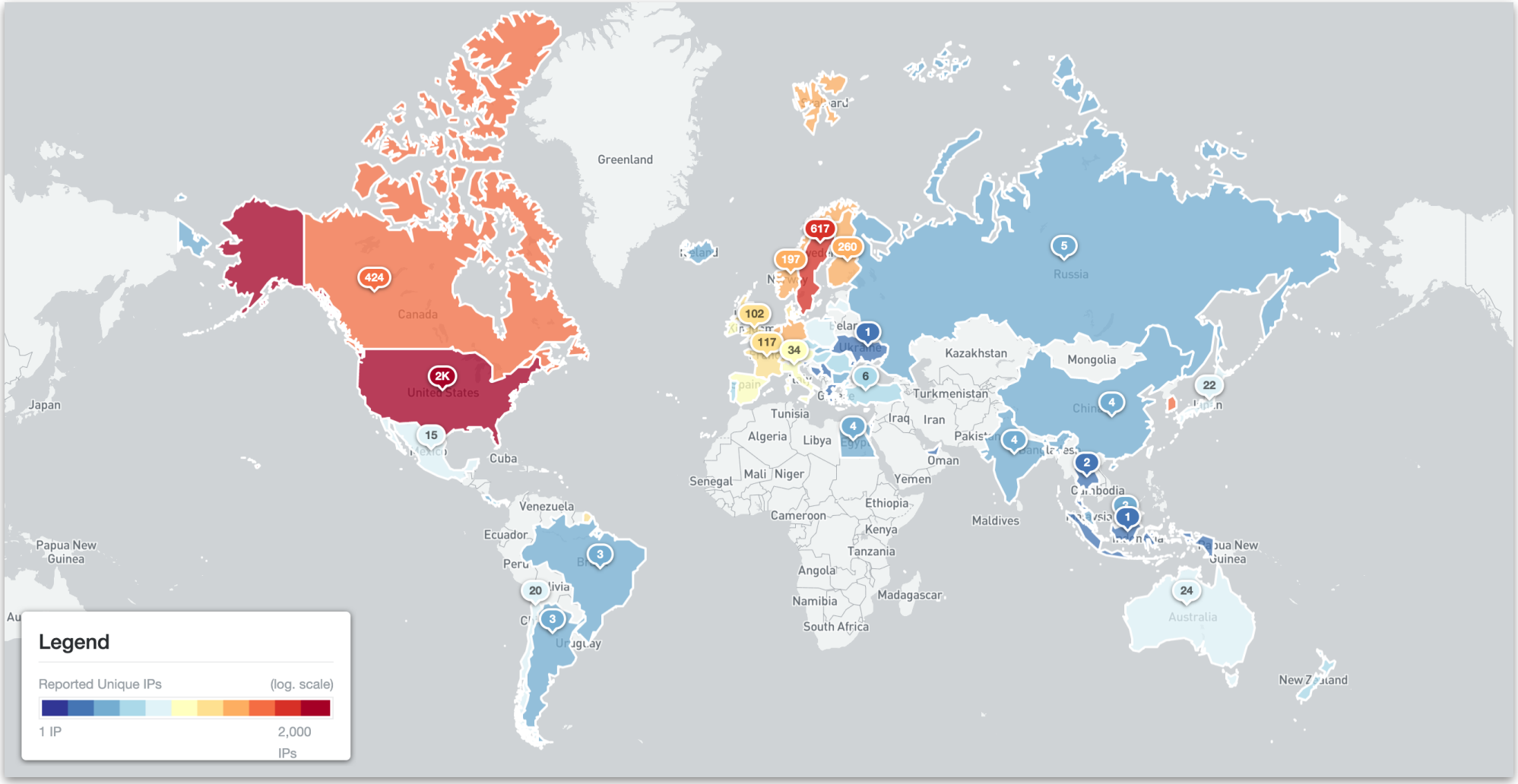
Device Identification - iRobot Roomba (2022-06-21)



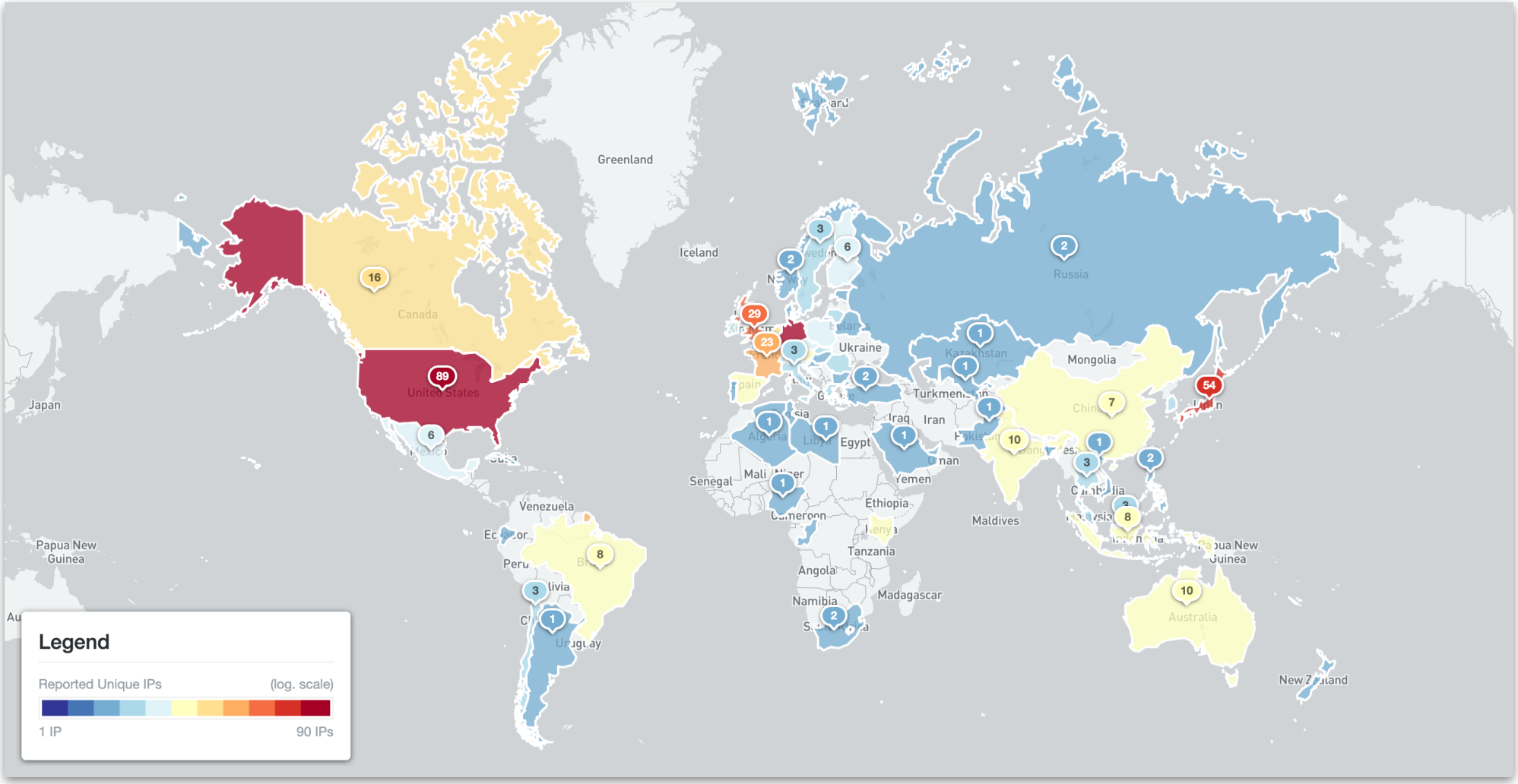
~ 400 devices

Device Identification - Philips HUE (2022-06-21)



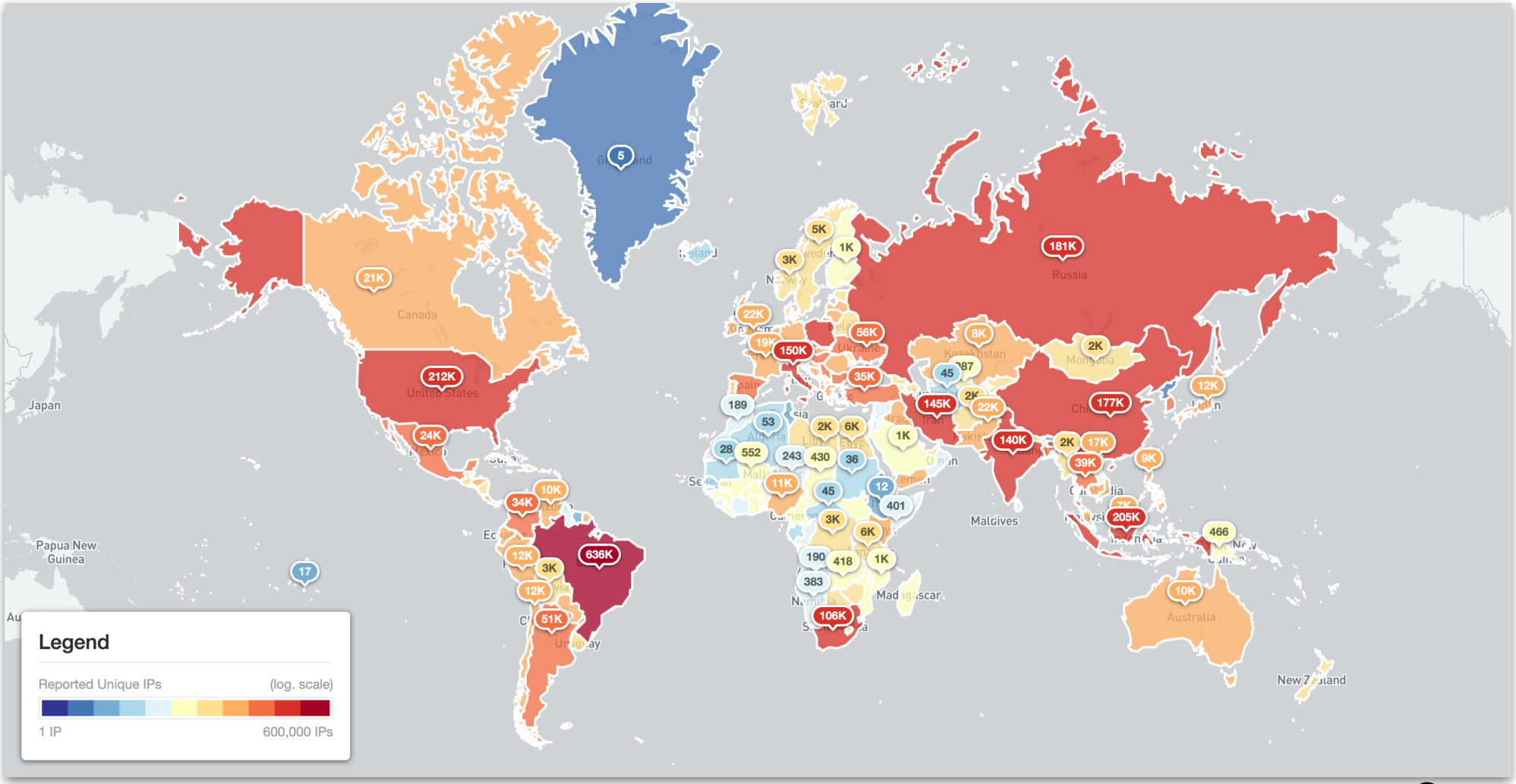
~ 5300 devices

Device Identification - Siemens SIMATIC S7-300 (2022-06-21)



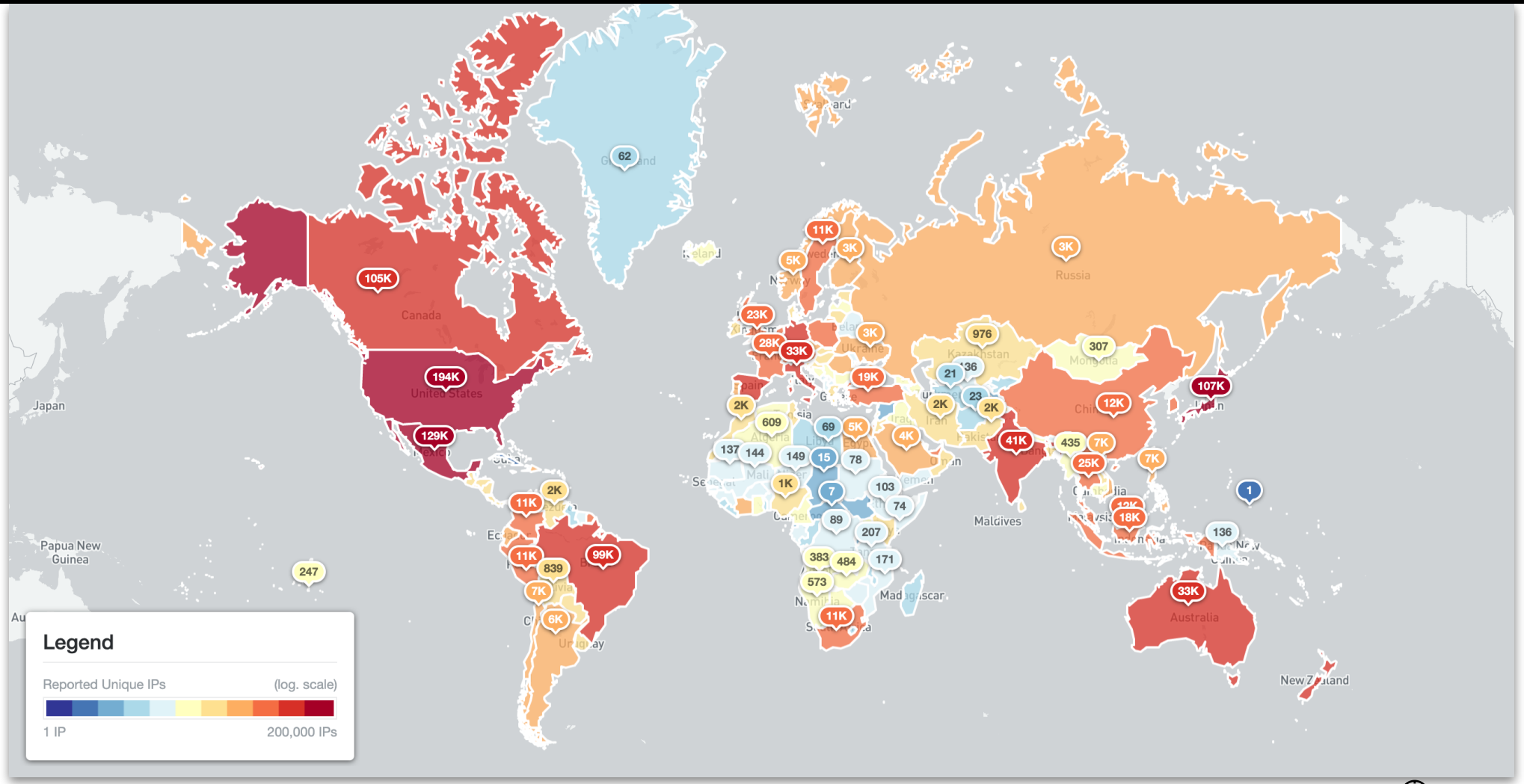
~ 500 devices (based only on non-native ICS scans)

Device Identification - Mikrotik (2022-06-21)



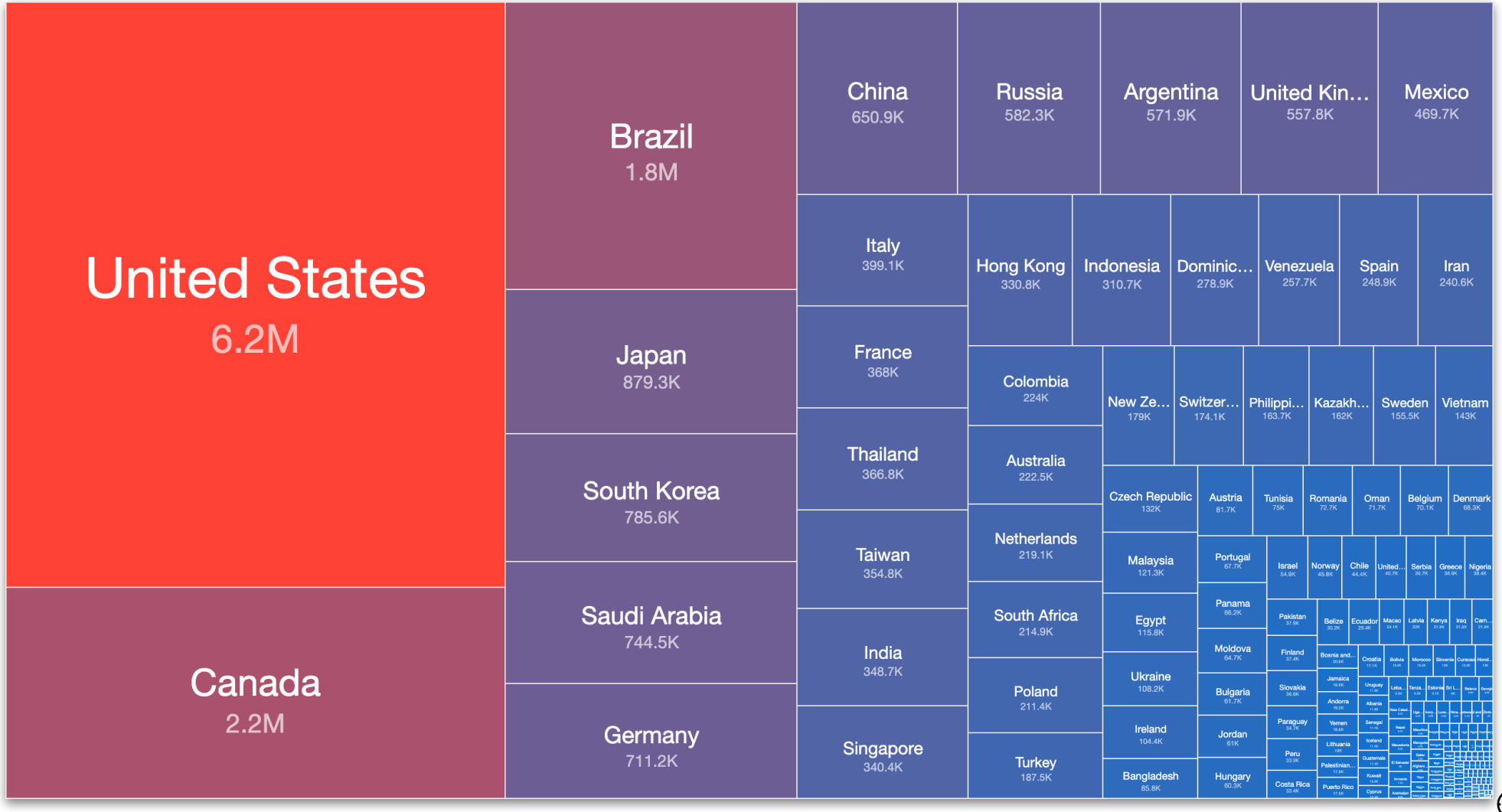
~ 3 200 000 devices

Device Identification - Fortinet (2022-06-21)



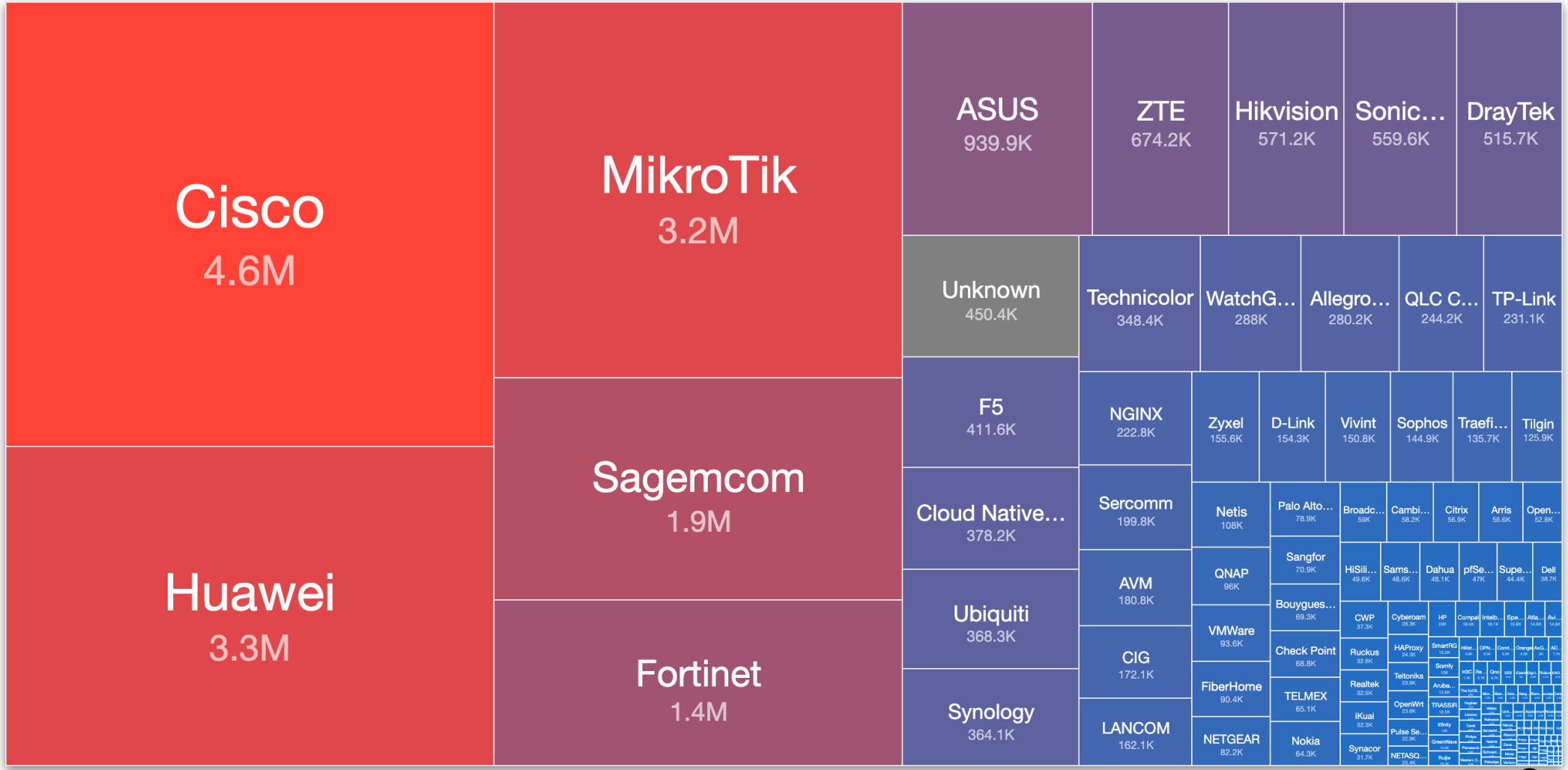
~ 1 400 000 devices

Devices identified by Country (2022-06-21)



(Excluding desktop/servers & web servers)

Device Identification - Vendors (2022-06-21)



(Excluding desktop/servers & web servers)

HaDEA CEF - VARIoT Project

- July 2019 - Oct 2022
- Shadowserver role is focused on improving:
  - scanning of IoT devices
  - observations of IoT attacks
  - collection & analysis of IoT malware
  - sharing of statistics as open data (in the European Data Portal - EDP)

https://variot.eu

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Co-financed by the Connecting Europe Facility of the European Union

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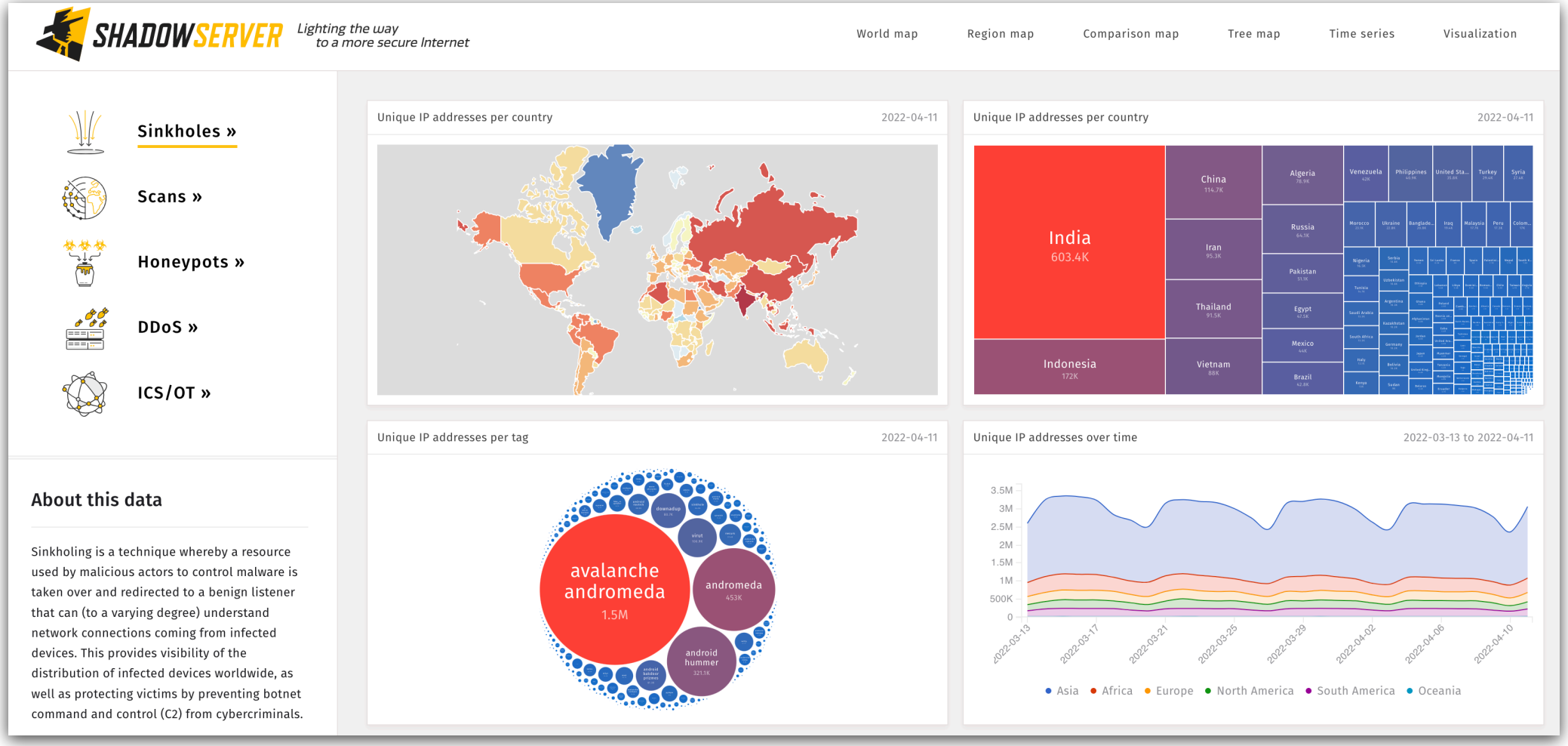
Shadowserver Public Dashboard (New)



https://dashboard.shadowserver.org

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Preview: Username: **alliance** Password: **SaferInternet**

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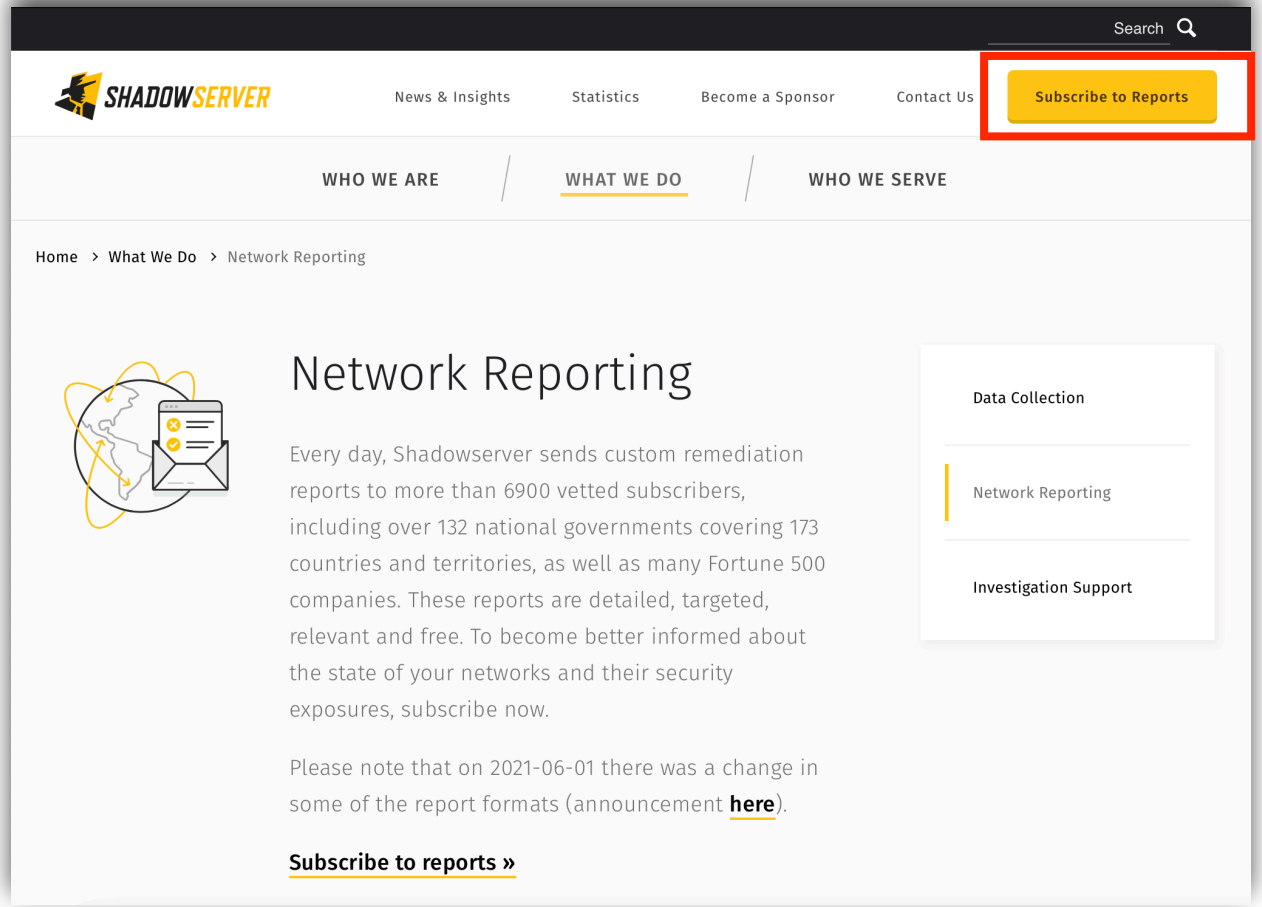

https://www.shadowserver.org

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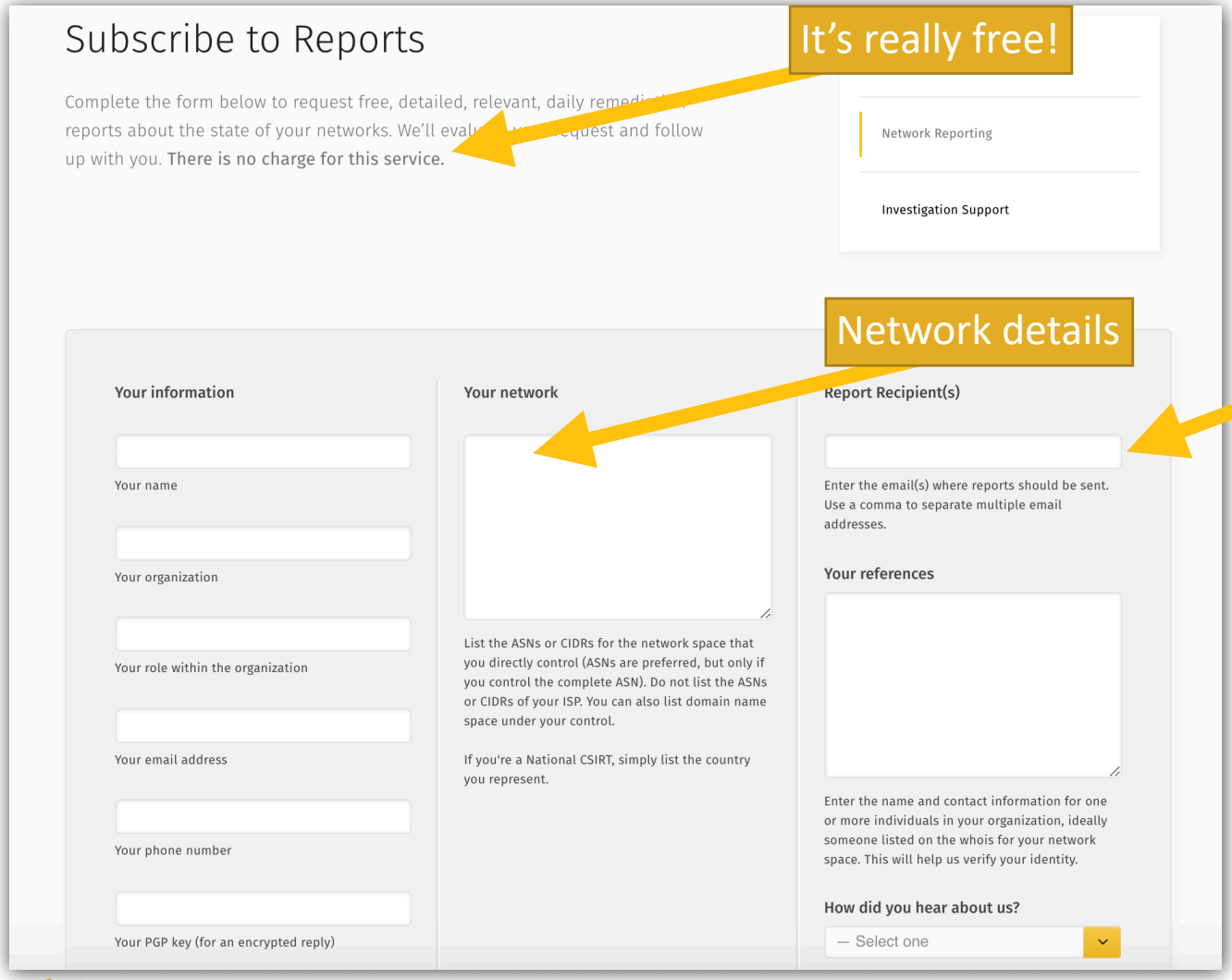

It's really free!

Network details

Email address where reports or download links will be sent

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https://www.shadowserver.org/what-we-do/network-reporting/get-reports/

Questions?

SHADOWSERVER

Lighting the way to a more secure Internet

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