A Look at IPStorm - Cross-Platform Malware Written in Go

maldbg.com/ipstorm-golang-malware-windows

November 19, 2023

November 19, 2023 · 9 min read

Ian French
Malware Researcher

File Information
File name: `6558073e997da5ca440b5a4b.exe`
Size: 13 MB
Type: PE Windows Executable
Mime: application/x-dosexec
SHA256: 7f731d2502dd39cbc16193ca7e9d147fe158c10236e00c634bb0680e2bfc4bfa
Last VirusTotal Scan: 11/18/2023 00:20:37
Last Sandbox Report: 11/18/2023 00:22:13
Malware Family: IPStorm Label: Trojan:Win32/Fsysna

0x01 IPStorm

Note
This post is still a work in progress. I will update it as I make progress with this malware and will remove this comment when I am finished.

Earlier this week, several sites reported that the FBI dismantled the IPStorm botnet. The botnet was shut down on Tuesday, and Sergei Makinin has pleaded guilty to developing and deploying it.

What interested me about this article was learning that IPStorm was written in Go, allowing it to easily be compiled for different operating systems. Many sites have already written about the Linux variant of the malware, so I thought I'd take a look at a *Windows* sample.

The file details are listed above. All the Windows samples I could find were quite large for malware, over 13 MB. This will make analysis more difficult as the disassembled and decompiled code file will be full of spaghetti code.

0x02 Static Anaylsis

Go files, in general, are usually difficult to analyze as they are statically built and stripped. This results in very large files with hundreds or thousands of unlabeled functions. This sample was no different. Loading the sample in Ghidra revealed nothing but functions labeled as `FUN_00XXXX`, the default format Ghidra uses with unknown functions.

I installed the GolangAnalyzerExtension plugin to make analysis more manageable. This renamed all the random `FUN_00XXXX` functions to their proper names.

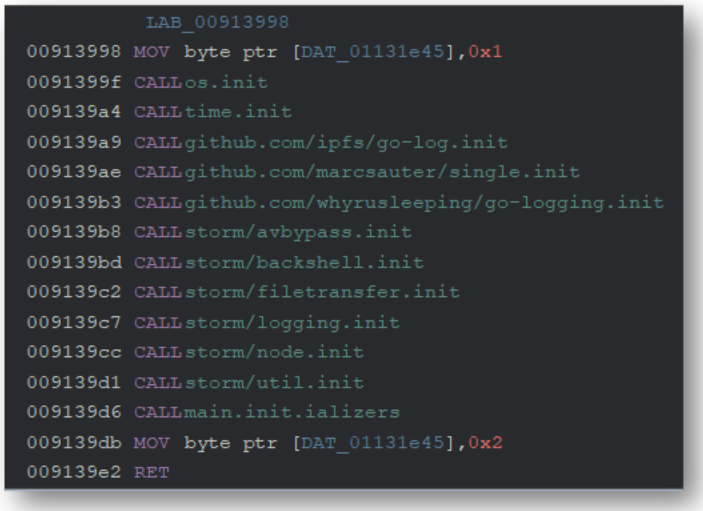
After loading the plugin, we can see the source path used by the malware author. The main file was saved at `/Users/brokleg/go/src/storm/storm.go` - here we can see why the malware was dubbed `IPStorm`, a combination of **ipfs** and **storm**.

Main Function

IPStorm implements its main logic in a package helpfully called `main`.

Upon execution, the `main.main` function starts its logging capability. It then begins calling functions from the `storm` package to bypass antivirus, set up file transfer, collect system runtime information, and add a new firewall rule using Powershell. The function also calls the `single` package to ensure that no other IPStorm processes are running.

Looking at function `main.init`, we can see a list of the packages called.



```
             LAB_00913998
00913998 MOV  byte ptr [DAT_01131e45],0x1
0091399f CALL os.init
009139a4 CALL time.init
009139a9 CALL github.com/ipfs/go-log.init
009139ae CALL github.com/marcsauter/single.init
009139b3 CALL github.com/whyrusleeping/go-logging.init
009139b8 CALL storm/avbypass.init
009139bd CALL storm/backshell.init
009139c2 CALL storm/filetransfer.init
009139c7 CALL storm/logging.init
009139cc CALL storm/node.init
009139d1 CALL storm/util.init
009139d6 CALL main.init.ializers
009139db MOV  byte ptr [DAT_01131e45],0x2
009139e2 RET
```

The main package of the malware is helpfully labeled as `storm`:

Antivirus Evasion

The Windows variant contains several functions to bypass any antivirus engines running on the host.

The malware makes several passes at evasion. In each pass, it calls the `util.RandomInt` and `time.Sleep` functions to pause for a random amount of time.

Installation and Persistence

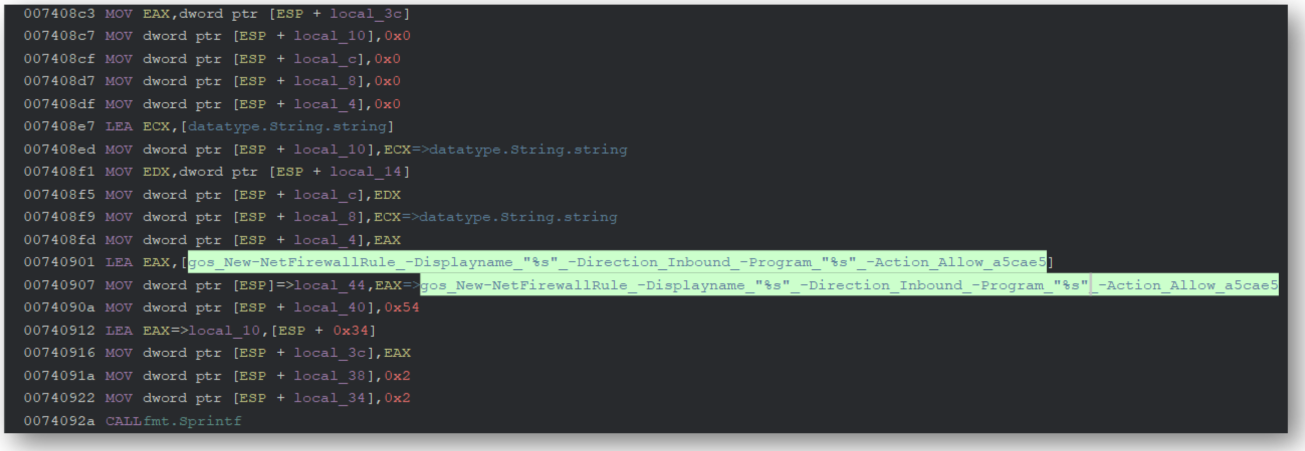
The `storm/util` package is responsible for installing the malware and gaining a persistent foothold on the host OS. The malware uses several functions to achieve this goal.

The util package contains code to generate random folder and file names. It also references `Microsoft.AAD.BrokerPlugin`, which is part of Microsoft OneDrive.

The malware then uses Powershell to access the Windows registry. The code contains logic to access registry keys at `HKCU:\Software\Microsoft\FixDrive\Registration` and `HKCU:\Software\Microsoft\Windows\CurrentVersion\Run`. The `CurrentVersion\Run` key is used by programs to ensure that their executable starts every time the user logs in to Windows.

It later confirms it has been added to the registry keys by calling the `storm.util.IsPersisted` function.

Using Powershell, it creates a new **firewall rule** for itself to ensure it can communicate with its C2.



```
007408c3 MOV EAX,dword ptr [ESP + local_3c]
007408c7 MOV dword ptr [ESP + local_10],0x0
007408cf MOV dword ptr [ESP + local_c],0x0
007408d7 MOV dword ptr [ESP + local_8],0x0
007408df MOV dword ptr [ESP + local_4],0x0
007408e7 LEA ECX,[datatype.String.string]
007408ed MOV dword ptr [ESP + local_10],ECX=>datatype.String.string
007408f1 MOV EDX,dword ptr [ESP + local_14]
007408f5 MOV dword ptr [ESP + local_c],EDX
007408f9 MOV dword ptr [ESP + local_8],ECX=>datatype.String.string
007408fd MOV dword ptr [ESP + local_4],EAX
00740901 LEA EAX,[gos_New-NetFirewallRule_-Displayname_"%s"_-Direction_Inbound_-Program_"%s"_-Action_Allow_a5cae5]
00740907 MOV dword ptr [ESP]=>local_44,EAX=>gos_New-NetFirewallRule_-Displayname_"%s"_-Direction_Inbound_-Program_"%s"_-Action_Allow_a5cae5
0074090a MOV dword ptr [ESP + local_40],0x54
00740912 LEA EAX=>local_10,[ESP + 0x34]
00740916 MOV dword ptr [ESP + local_3c],EAX
0074091a MOV dword ptr [ESP + local_38],0x2
00740922 MOV dword ptr [ESP + local_34],0x2
0074092a CALLfmt.Sprintf
```

Powershell Feature

The Windows version of IPStorm uses **Powershell** to perform various tasks, including creating a **reverse shell**.

Reverse Shell

The `backshell` package uses Powershell to create a reverse shell on the system.

The reverse shell capability is the main threat posed by this malware, allowing the attacker to execute system commands on the infected system.

Other Interesting Functions

The malware checks if it is running in Wine, a compatibility layer that lets users run Windows programs on Linux.

0x03 Dynamic Analysis

Execution

To simplify the analysis, I renamed my malware sample `ipstorm.exe`. After running VMWare Cloak, I took a snapshot and detonated the malware. Immediately upon execution, the process creates a lock file at `C:\<USER>\AppData\Local\Temp\n3R1PYfY.lock`.

If the malware is started with elevated privileges, it drops the file at `C:\Windows\Temp\n3R1PYfY.lock`.

The process then launches `cmd.exe`, which launches `powershell.exe -NoExit -Command -`. Using Powershell, IPStorm creates a firewall rule and writes data to a file named `StartupProfileData-Interactve`.

The malware opens several TCP sockets and communicates with several hosts.

Network Calls

The sample attempts to connect to several different IPs and domains. Examining the strings in the process memory can give us more insight into what network activity is happening.

We can see some of the IPFS requests being made as well:

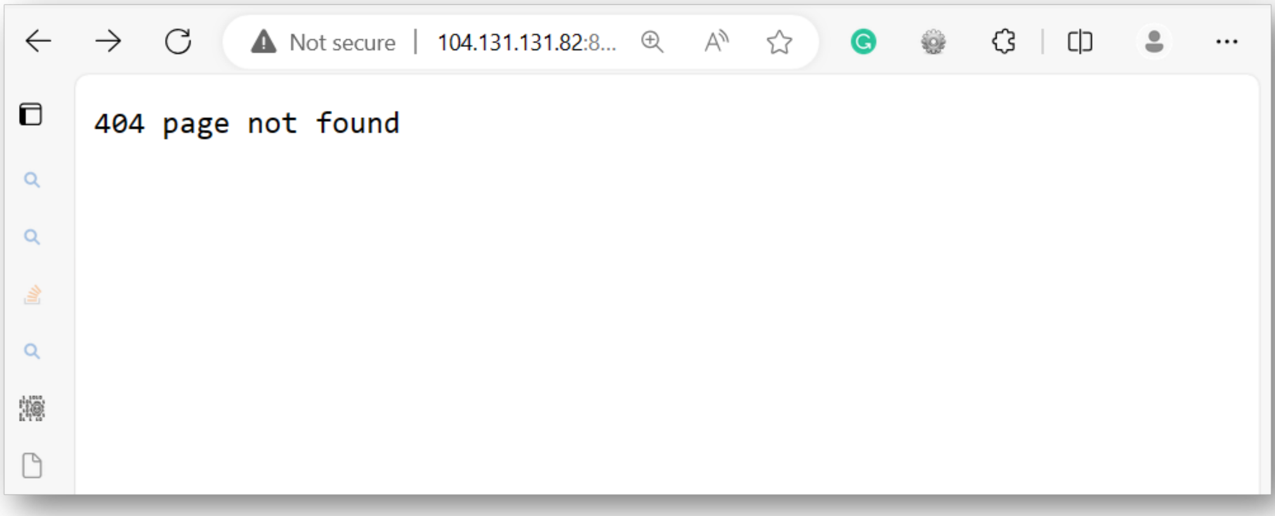
I've resolved a few of the domains to their IPs below:

- `104.131.131.82:4001 (mars.i.ipfs.io)` **Possible C2**
- `178.62.158.247:4001`
- `128.199.219.111:4001`
- `104.236.76.40:4001`
- `104.236.179.241:4001`
- `_dnsaddr.sv15.bootstrap.libp2p.io (139.178.91.71)`

All hosts except `104.131.131.82` and `139.178.91.71` are down. We can see some preliminary evidence that an IPFS service is running on at least one of the hosts:

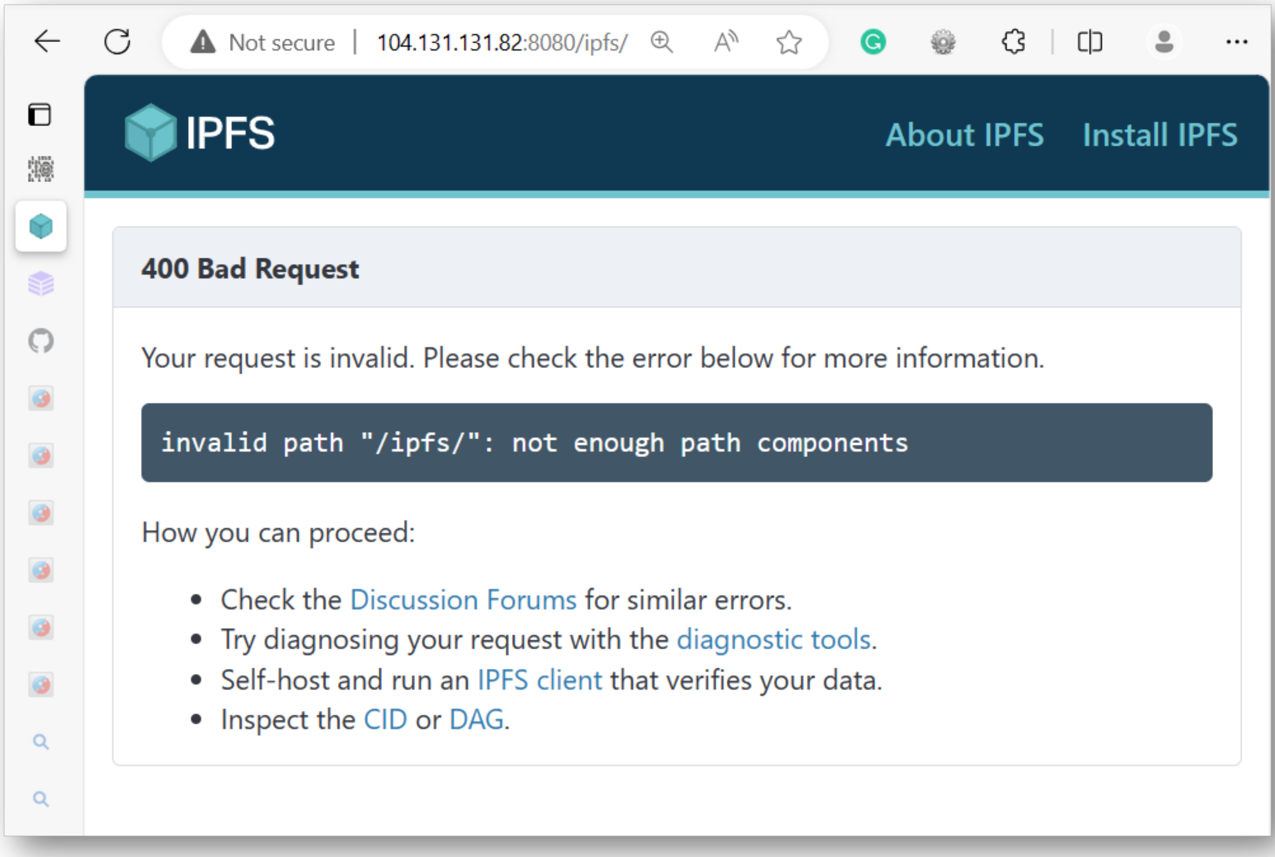
```
sudo nmap -sV 104.131.131.82  -p 8080,4001

Starting Nmap 7.94 ( https://nmap.org ) at 2023-11-18 08:49 PST
Nmap scan report for mars.i.ipfs.io (104.131.131.82)
Host is up (0.020s latency).

PORT     STATE SERVICE            VERSION
4001/tcp open  libp2p-multistream libp2p multistream protocol 1.0.0
8080/tcp open  http               Golang net/http server (Go-IPFS json-rpc or InfluxDB API)
```

Trying to navigate to port `8080` in a browser gives a very non-descript 404:



```
404 page not found
```

By playing with the URL path a bit, we can see a descriptive error message clearly showing IPFS:



400 Bad Request

Your request is invalid. Please check the error below for more information.

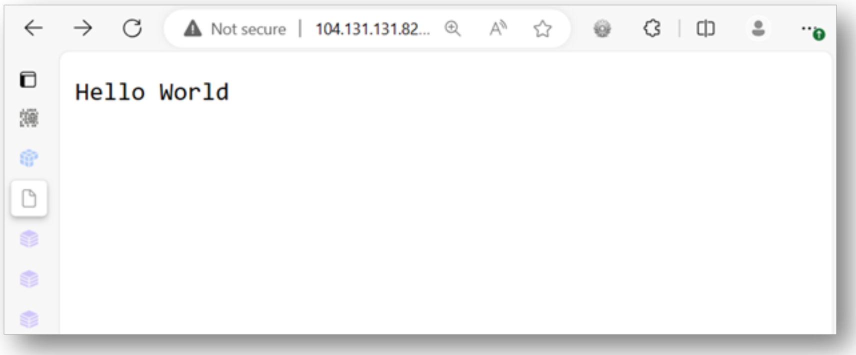
```
invalid path "/ipfs/": not enough path components
```

How you can proceed:

- Check the Discussion Forums for similar errors.
- Try diagnosing your request with the diagnostic tools.
- Self-host and run an IPFS client that verifies your data.
- Inspect the CID or DAG.

Thus far, every sample of IPStorm I've looked at contacts this host and the one below (sv15.bootstrap.libp2p.io).

This application needs an IPFS content identifier or **CID**. This can be a string or a file. IPFS encodes all content into a **base58** encoded hash called a **multihash**. As an example, we can have the application display back a message by navigating to `http://104.131.131.82:8080/ipfs/QmWATWQ7fVPP2EFGu71UkfnqhYXDYH566qy47CnJDgvs8u`:



Hello World

The last address - `_dnsaddr.bootstrap.libp2p.io` - is interesting as it appears to be using multiaddr. Here is an excerpt from their github

Without multiaddr support, the domain is unreachable as-is, possibly another built-in defense mechanism to evade analysis in a sandbox.

```
nslookup _dnsaddr.sv15.bootstrap.libp2p.io
Server:         172.31.80.1
Address:        172.31.80.1#53

Non-authoritative answer:
*** Can't find _dnsaddr.sv15.bootstrap.libp2p.io: No answer
```

Removing the `_dnsaddr` gives a little more info:

```
nslookup sv15.bootstrap.libp2p.io
Server:         172.31.80.1
Address:        172.31.80.1#53

Non-authoritative answer:
Name:   sv15.bootstrap.libp2p.io
Address: 139.178.91.71
Name:   sv15.bootstrap.libp2p.io
Address: 2604:1380:45e3:6e00::1
```

Running a `whois 139.178.91.71` reveals that the IP is assigned to Equinix Services, a network provider and data center based in New York.

Nmap reveals a little more information about the application running on port `4001`:

```
sudo nmap -sV  139.178.91.71 -p 443,4001
Starting Nmap 7.94 ( https://nmap.org ) at 2023-11-18 08:42 PST
Nmap scan report for sv15 (139.178.91.71)

Host is up (0.032s latency).

PORT     STATE SERVICE            VERSION
443/tcp  open  ssl/http           nginx 1.16.1
4001/tcp open  libp2p-multistream libp2p multistream protocol 1.0.0

Service detection performed. Please report any incorrect results at https://nmap.org/submit/ .
Nmap done: 1 IP address (1 host up) scanned in 19.68 seconds

 nc -v  139.178.91.71 4001

Warning: forward host lookup failed for sv15: Unknown host
sv15 [139.178.91.71] 4001 (?) open

/multistream/1.0.0
```

The web server is a wrapper for the multistream service on port `4001`:

```
curl https://sv15.bootstrap.libp2p.io/

WebSocket protocol violation: Connection header "keep-alive" does not contain Upgrade
```

Using websocat, we can connect to the server using a websocket:

```
./websocat_max.x86_64-unknown-linux-musl  wss://sv15.bootstrap.libp2p.io//multistream/1.0.0

/multistream/1.0.0
```

Multistream Requests

I captured and extracted the following multisteam DNS requests:

Request	Response
_dnsaddr.bootstrap.libp2p.io	dnsaddr=/dnsaddr/sv15.bootstrap.libp2p.io/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBMjTezGAJ
_dnsaddr.bootstrap.libp2p.io	dnsaddr=/dnsaddr/sg1.bootstrap.libp2p.io/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZcYW3dwt
_dnsaddr.bootstrap.libp2p.io	dnsaddr=/dnsaddr/am6.bootstrap.libp2p.io/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbUcqanj75N
_dnsaddr.bootstrap.libp2p.io	dnsaddr=/dnsaddr/ny5.bootstrap.libp2p.io/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ16u19uLTa
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/dns4/sv15.bootstrap.libp2p.io/tcp/443/wss/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBM
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/ip4/139.178.91.71/udp/4001/quic-v1/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBMjTezG
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/dns6/sv15.bootstrap.libp2p.io/tcp/443/wss/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBM
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/ip4/139.178.91.71/tcp/4001/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBMjTezGAJN
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:45e3:6e00::1/udp/4001/quic-v1/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBMjTezGAJN
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:45e3:6e00::1/udp/4001/quic/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gB
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/ip4/139.178.91.71/udp/4001/quic/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBMjTezGAJ
_dnsaddr.sv15.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:45e3:6e00::1/tcp/4001/p2p/QmNnooDu7bfjPFoTZYxMNLWUQJyrVwtbZg5gBMjTez
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/dns6/ny5.bootstrap.libp2p.io/tcp/443/wss/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ1
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/ip4/136.144.51.25/udp/4001/quic-v1/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ16u19
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/ip4/136.144.51.25/tcp/4001/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ16u19uLTa
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/dns4/ny5.bootstrap.libp2p.io/tcp/443/wss/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ1
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:45d2:8100::1/udp/4001/quic-v1/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ16u19uLTa
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:45d2:8100::1/tcp/4001/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ16u1
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/ip4/139.178.65.157/udp/4001/quic/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJJ16u19u
_dnsaddr.ny5.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:45d2:8100::1/udp/4001/quic/p2p/QmQCU2EcMqAqQPR2i9bChDtGNJchTbq5TbXJ
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/dns6/sg1.bootstrap.libp2p.io/tcp/443/wss/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZc
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/ip4/145.40.118.135/udp/4001/quic-v1/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZcYW
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/dns4/sg1.bootstrap.libp2p.io/tcp/443/wss/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZc
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/ip4/145.40.118.135/tcp/4001/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZcYW3dwt
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:40e1:9c00::1/udp/4001/quic/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjY
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:40e1:9c00::1/tcp/4001/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZcYW
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:40e1:9c00::1/udp/4001/quic-v1/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZcYW3dwt
_dnsaddr.sg1.bootstrap.libp2p.io	dnsaddr=/ip4/145.40.118.135/udp/4001/quic/p2p/QmcZf59bWwK5XFi76CZX8cbJ4BhTzzA3gU1ZjYZcYW3d
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/ip4/147.75.87.27/tcp/4001/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbUcqanj75Nb
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/dns4/am6.bootstrap.libp2p.io/tcp/443/wss/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbU
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/dns6/am6.bootstrap.libp2p.io/tcp/443/wss/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbU
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/ip4/147.75.87.27/udp/4001/quic-v1/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbUcqanj75

Request	Response
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:4602:5c00::3/udp/4001/quic/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbU
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:4602:5c00::3/udp/4001/quic-v1/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbUcqanj75Nb
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/ip6/2604:1380:4602:5c00::3/tcp/4001/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbUcqanj
_dnsaddr.am6.bootstrap.libp2p.io	dnsaddr=/ip4/147.75.87.27/udp/4001/quic/p2p/QmbLHAnMoJPWSCR5Zhtx6BHJX9KiKNN6tpvbUcqanj75Nb

Contacted Countries