PATHspider II: The Tutorial

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Active Measurement of Path Transparency

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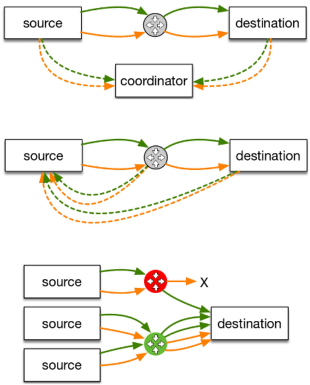

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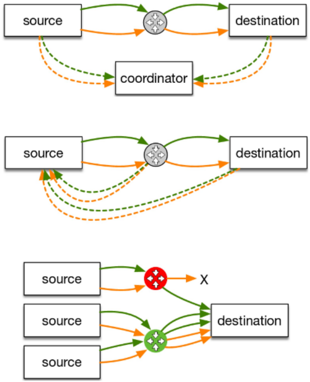

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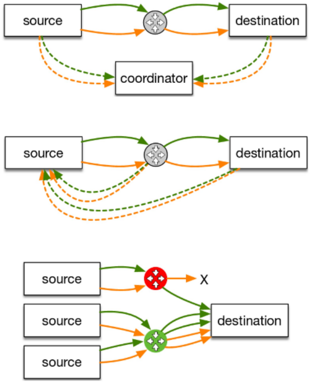

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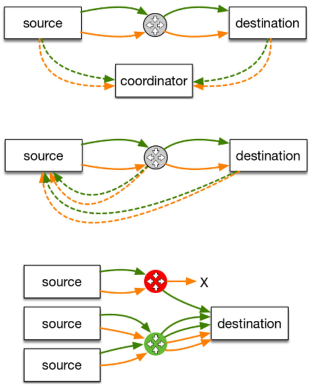

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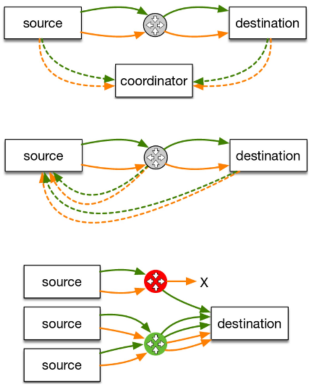

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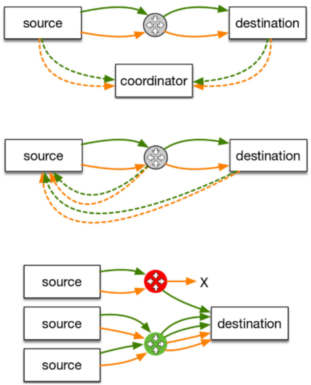

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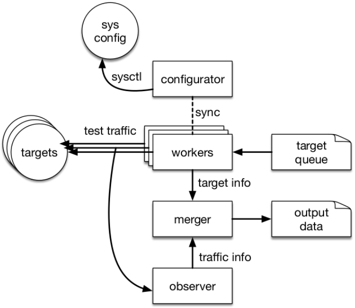

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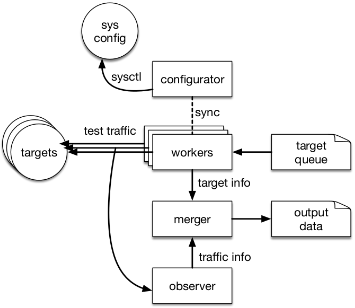

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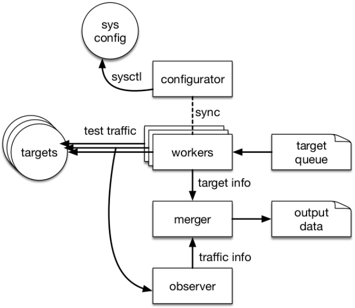

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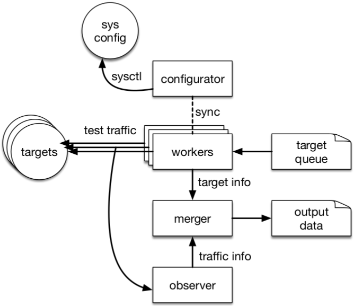

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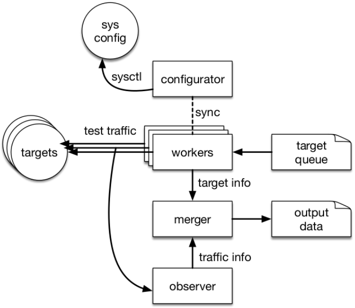

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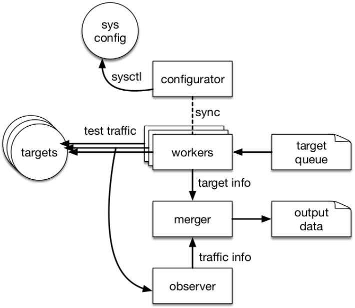

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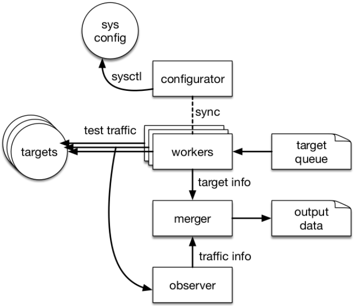

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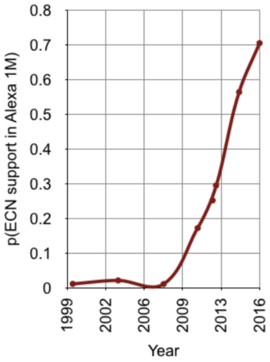

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ecnspider Results

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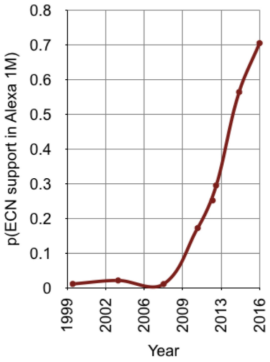
- This continues a trend ETH started observing with *ecnspider* in 2013 [3]



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- Published at 2016 Applied Networking Research Workshop [4]

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  - Checksum recalculations

PATHspider 1.0 Results

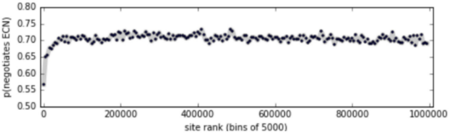
We presented some initial findings along with the publication of PATHspider 1.0 [4]:

Explicit Congestion Notification (ECN)

State of ECN server-side deployment, as measured from a Digital Ocean vantage point in Amsterdam on 13th June 2016:

	IPv4	IPv6	all
No ECN connectivity issues	99.5%	99.9%	99.5%
ECN successfully negotiated	70.0%	82.8%	70.5%

ECN negotiation by Alexa rank bin:



DiffServ Code Points (DSCP)

Initial study: 10,006 of 96,978 (10.31%) of Alexa Top 100k websites had unexpected, non-zero DSCP values. More measurement was needed to better characterize these anomalies.

TCP Fast Open (TFO)

Initial study: 330 IPv4 and 32 IPv6 addresses of Alexa Top 1M are TFO-capable (of which 278 and 28 respectively are Google properties). DDoS prevention services, enterprise firewalls, and CPE tend to interfere with TFO. More measurement was necessary to analyze impairments.

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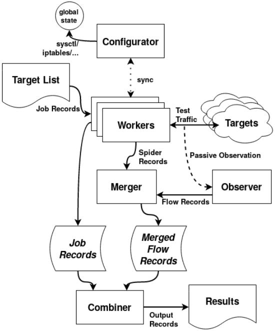

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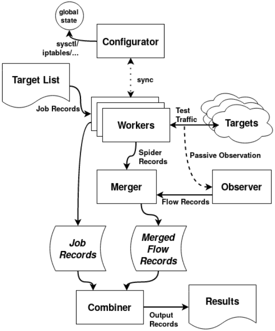

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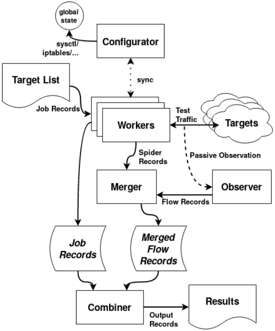

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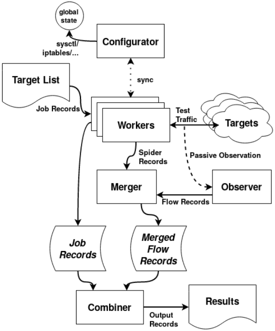

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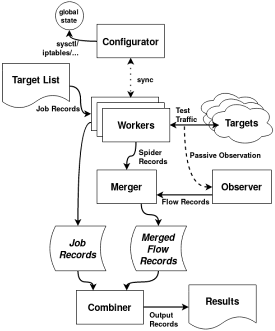

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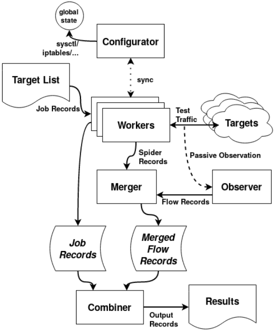

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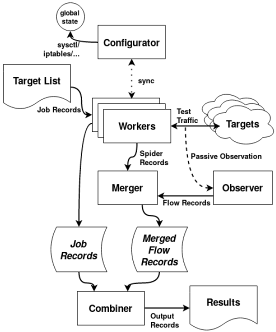

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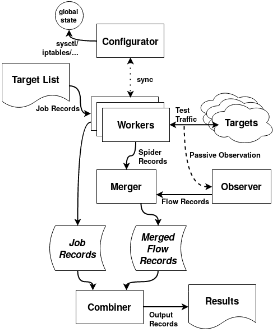

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- For desycnhronised plugins, the helpers are customisable, e.g. cURL helpers accept arbitrary CURLOPTs

Synchronized Plugin

- SynchronizedSpider plugins use **built-in connection methods** along with **global system configuration** to change the behaviour of the connections
- Configuration functions are at the heart of a SynchronizedSpider plugin
- Configuration functions may make calls to sysctl or iptables to make changes to the way that traffic is generated.
- One function should be written for each of the configurations and PATHspider will ensure that the configurations are set before the corresponding traffic is generated. It is the responsibility of plugin authors to ensure that any configuration is reset by the next configuration function if that is required

Synchronized Plugin

```python
class ECN(SynchronizedSpider, PluggableSpider):
    def config_no_ecn(self): # pylint: disable=no-self-use
        """
        Disables ECN negotiation via sysctl.
        """

        logger = logging.getLogger('ecn')
        subprocess.check_call(
            ['/sbin/sysctl', '-w', 'net.ipv4.tcp_ecn=2'],
            stdout=subprocess.DEVNULL,
            stderr=subprocess.DEVNULL)
        logger.debug("Configurator disabled ECN")

    def config_ecn(self): # pylint: disable=no-self-use
        """
        Enables ECN negotiation via sysctl.
        """

        logger = logging.getLogger('ecn')
        subprocess.check_call(
            ['/sbin/sysctl', '-w', 'net.ipv4.tcp_ecn=1'],
            stdout=subprocess.DEVNULL,
            stderr=subprocess.DEVNULL)
        logger.debug("Configurator enabled ECN")

    configurations = [config_no_ecn, config_ecn]
```

Listing 1: Configuration Functions for the ECN Plugin

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- DesynchronizedSpider plugins modify the connection logic in order to change the behaviour of the connections. There is no global state synchronisation and so a DesynchronizedSpider can be more efficient than a SynchronizedSpider

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- One function should be written for each connection to be made, usually with at least two functions to provide a baseline followed by an experimental connection

Desynchronized Plugin

```
class H2(DesynchronizedSpider, PluggableSpider):
    def conn_no_h2(self, job, config):  # pylint: disable=unused-argument
        curlopts = {}
        curlinfos = [pycurl.INFO_HTTP_VERSION]
        if self.args.connect == "http":
            return connect_http(self.source, job, self.args.timeout, curlopts, curlinfos)
        if self.args.connect == "https":
            return connect_https(self.source, job, self.args.timeout, curlopts, curlinfos
    )
        else:
            raise RuntimeError("Unknown connection mode specified")

    def conn_h2(self, job, config): # pylint: disable=unused-argument
        curlopts = {pycurl.HTTP_VERSION: pycurl.CURL_HTTP_VERSION_2_0}
        curlinfos = [pycurl.INFO_HTTP_VERSION]
        if self.args.connect == "http":
            return connect_http(self.source, job, self.args.timeout, curlopts, curlinfos)
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    connections = [conn_no_h2, conn_h2]
```

Listing 2: Connection Functions for the H2 Plugin

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- This function takes two arguments, the job containing the target information and the sequence number
- This function will be called the number of times set in the packets metadata variable and seq will be set to the number of times the function has been called for this job

Single Plugin

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- SingleSpider uses the built-in connection helpers to make a single connection to the target which is optionally observed by Observer chains
- This is the simplest model and only requires a `combine_flows()` function to generate conditions from the connection helper output and flow record output from the Observer

Observer Modules

- While these used to be part of plugins in PATHspider 1.0, they are now independent and so can be reused across multiple plugins:
  - BasicChain, DNSChain, DSCPChain, ECNChain, EvilChain, ICMPChain, TCPChain, TFOChain
- These can also be used together, limiting each chain to just a single layer and letting the combiner produce conditions
- Chains can produce information to be consumed by other chains later in the list
- These can be used independently of a PATHspider measurement:

```
irl@z~$ pspdr observe tcp ecn
```

Listing 3: Running the PATHspider Observer independently

Target List Resolution

- Hellfire is a parallelised DNS resolver. It is written in Go and for the purpose of generating input lists to PATHspider, though may be useful for other applications
- Can use many sources for inputs:
  - Alexa Top 1 Million Global Sites
  - Cisco Umbrella 1 Million
  - Citizen Lab Test Lists
  - OpenDNS Public Domain Lists
  - Comma-Seperated Values Files
  - Plain Text Domain Lists
- More on this later

Packet Forging

- PATHspider uses the Scapy library for Python for packet forging
- This is the most flexible method of creating new measurement plugins for PATHspider

Make a Packet

- Scapy packets are constructed layer by layer
- While you can specify raw bytes, Scapy provides a number of useful classes for common protocols, which makes things a lot easier

Make a Packet

- Scapy must be launched with sudo as we will need to use “raw” sockets to emit forged packets.
- Note also the command is scapy*3*, to ensure we are running the Python 3 version.

```
irl@z:~$ sudo scapy3

                     aSPY//YASa
             apyyyyCY//////////YCa       |
            sY//////YSpcs  scpCY//Pp     | Welcome to Scapy
 ayp ayyyyyyySCP//Pp           syY//C    | Version 2.4.0
 AYAsAYYYYYYYY///Ps              cY//S   |
         pCCCCY//p          cSSps y//Y   | https://github.com/secdev/scapy
         SPPPP///a          pP///AC//Y   |
              A//A            cyP////C   | Have fun!
              p///Ac            sC///a   |
              P////YCpc           A//A   | We are in France, we say Skappee.
       scccccp///pSP///p          p//Y   | OK? Merci.
      sY/////////y  caa           S//P   |             -- Sebastien Chabal
       cayCyayP//Ya              pY/Ya   |
        sY/PsY////YCc          aC//Yp
         sc  sccaCY//PCypaapyCP//YSs
                  spCPY//////YPSps
                       ccaacs
                                       using IPython 5.5.0
>>>
```

Listing 4: Launching Scapy

Make a Packet

IPv4 Header - Create and Dissect

```
>>> IP()
<IP  |>
>>> i = IP()
>>> i.summary()
'127.0.0.1 > 127.0.0.1 hopopt'
>>> i.display()
###[ IP ]###
  version= 4
  ihl= None
  tos= 0x0
  len= None
  id= 1
  flags=
  frag= 0
  ttl= 64
  proto= hopopt
  chksum= None
  src= 127.0.0.1
  dst= 127.0.0.1
  \options\
```

Listing 5: Creating and Dissecting an IPv4 Header

Make a Packet

IPv4 Header - Customize

```
>>> i = IP(src="192.0.2.1",dst="198.51.100.1", ttl=10)
>>> i
<IP  ttl=10 src=192.0.2.1 dst=198.51.100.1 |>
>>> i.summary()
'192.0.2.1 > 198.51.100.1 hopopt'
>>> i.display()
###[ IP ]###
  version= 4
  ihl= None
  tos= 0x0
  len= None
  id= 1
  flags=
  frag= 0
  ttl= 10
  proto= hopopt
  chksum= None
  src= 192.0.2.1
  dst= 198.51.100.1
  \options\
```

Listing 6: Customizing an IPv4 Header[1]

Make a Packet

TCP Header: Create and Dissect

```
>>> TCP()
<TCP  |>
>>> t = TCP()
>>> t.summary()
'TCP ftp_data > http S'
>>> t.display()
###[ TCP ]###
  sport= ftp_data
  dport= http
  seq= 0
  ack= 0
  dataofs= None
  reserved= 0
  flags= S
  window= 8192
  chksum= None
  urgptr= 0
  options= []
```

Listing 7: Creating and Dissecting a TCP Header

Make a Packet

TCP Header: Customizing

```
>>> t = TCP(dport=443)
>>> t
<TCP  dport=https |>
>>> t.summary()
'TCP ftp_data > https S'
>>> t.display()
###[ TCP ]###
  sport= ftp_data
  dport= https
  seq= 0
  ack= 0
  dataofs= None
  reserved= 0
  flags= S
  window= 8192
  chksum= None
  urgptr= 0
  options= []
```

Listing 8: Customizing a TCP Header

Make a Packet

Sticking the Pieces Together

- The / operator is used to join layers together.
- Scapy will automatically set fields, such as the IP Protocol field, when you do this.
- When dissecting, Scapy will automatically choose the dissector to use based on fields such as the IP Protocol field.

```
>>> p=i/t
>>> p.summary()
'IP / TCP 192.0.2.1:ftp_data > 198.51.100.1:https S'
>>> p.display()
    [... output snipped ...]
```

Listing 9: Sticking the IP and TCP Headers Together

Make a Packet

View in Wireshark

```
>>> wrpcap("/tmp/scapy.pcap", [p])
```

Listing 10: Exporting a PCAP File from Scapy

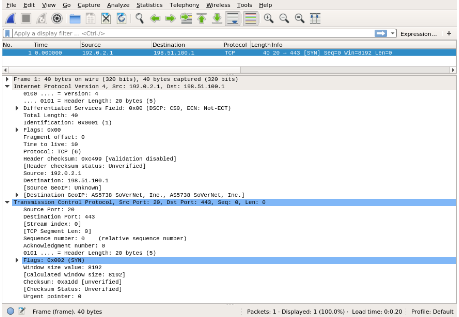

Figure: Dissection of the packet created in Scapy, in Wireshark

Send a Packet

- The `sr1()` function sends a single packet, and returns a single packet if a reply is received.
- Start Wireshark capturing before executing the `sr1()` function.

```
>>> p=IP(dst="139.133.210.32")/TCP()
>>> a=sr1(p)
Begin emission:
.Finished sending 1 packets.
*
Received 2 packets, got 1 answers, remaining 0 packets
>>> a
<IP  version=4 ihl=5 tos=0x0 len=44 id=0 flags=DF frag=0 ttl=47 proto=tcp chksum=0xa98d
     src=139.133.210.32 dst=172.22.152.130 options=[] |<TCP  sport=http dport=ftp_data
     seq=3081101820 ack=1 dataofs=6 reserved=0 flags=SA window=29200 chksum=0xe9c7 urgptr
     =0 options=[('MSS', 1452)] |<Padding  load=':v' |>>>
>>> a.summary()
'IP / TCP 139.133.210.32:http > 172.22.152.130:ftp_data SA / Padding'
```

Listing 11: Create and Send an IP/TCP Packet

Evil Bit

The evil bit is a fictional **IPv4 packet header field** *proposed in RFC 3514 [2], a humorous April Fools' Day RFC from 2003 authored by Steve Bellovin. The RFC recommended that the last remaining unused bit, the "Reserved Bit," in the IPv4 packet header be used to indicate whether a packet had been sent with malicious intent, thus making computer security engineering an easy problem — simply ignore any messages with the evil bit set and trust the rest.*

– Wikipedia

- The flags in the IP header are just an attribute you can modify:

```
>>> i = IP()
>>> i.flags = 'evil'
```

Listing 12: Setting the Evil Bit on an IPv4 Header with Scapy

PATHspider Plugins

Download the Evil Bit Demonstration Plugin

```
git clone https://github.com/mami-project/pathspider-evilbit.git
```

Listing 13: Download the Evil Bit Demonstration Plugin

PATHspider Plugins

Directory Layout

- To get started you will need the required directory layout for PATHspider plugins, in this case for the EvilBit plugin:

```
pathspider-evilbit
+-- pathspider
    +-- __init__.py
    +-- plugins
        +-- __init__.py
        +-- evilbit.py
```

- Inside both `__init__.py` files, you will need to add the following (and only the following):

```python
from pkgutil import extend_path
__path__ = extend_path(__path__, __name__)
```

- Your plugin will be written in `example.py` and this plugin will be discovered automatically when you run PATHspider

PATHspider Plugins

ForgeSpider

```python
class EvilBit(ForgeSpider, PluggableSpider):

    name = "evilbit"
    description = "Evil bit connectivity testing"
    version = '0.0.0'
    chains = [BasicChain, TCPChain, EvilChain]
    connect_supported = ["tcpsyn"]
    packets = 2

    def forge(self, job, seq):
        ...
```

Listing 14: Outline for Evil Bit plugin using ForgeSpider

PATHspider Plugins

Forging the Packets

```
def forge(self, job, seq):
    sport = 0
    while sport < 1024:
        sport = int(RandShort())
    l4 = (TCP(sport=sport, dport=job['dp']))
    if ':' in job['dip']:
        ip = IPv6(src=self.source[1], dst=job['dip'])
    else:
        ip = IP(src=self.source[0], dst=job['dip'])
    if seq == 1:
        ip.flags = 'evil'
    return ip/l4
```

Listing 15: Creating Packets With and Without the Evil Bit

```
./run.sh
```

Listing 16: Running the Evil Bit Plugin

Target Lists

Types of Targets

- Popular - Cisco Umbrella, Alexa Topsites
- Curated Lists - CitizenLab
- Random - massscan

Target Lists

Using *hellfire*

```
irl@z:~$ hellfire
Usage:
  hellfire --topsites [--file=<filename>] [--output=<individual|array|oneeach>] [--type=<host|ns|mx>] [--canid=<canid address>]
  hellfire --cisco [--file=<filename>] [--output=<individual|array|oneeach>] [--type=<host|ns|mx>] [--canid=<canid address>]
  hellfire --citizenlab [--country=<cc>|--file=<filename>] [--output=<individual|array|oneeach>] [--type=<host|ns|mx>] [--canid=<canid address>]
  hellfire --opendns [--list=<name>|--file=<filename>] [--output=<individual|array|oneeach>] [--type=<host|ns|mx>] [--canid=<canid address>]
  hellfire --csv --file=<filename> [--output=<individual|array|oneeach>] [--type=<host|ns|mx>] [--canid=<canid address>]
  hellfire --txt --file=<filename> [--output=<individual|array|oneeach>] [--type=<host|ns|mx>] [--canid=<canid address>]
```

Listing 17: *hellfire*'s Usage Help

```
irl@z~$ hellfire --cisco
```

Listing 18: Start Resolving the Cisco Umbrella List

Explicit Congestion Notification

Using the Built-In Plugin

```
irl@z~$ pspdr measure -i enp0s3 ecn \
        < ~/pathspider-evilbit/targets.ndjson \
        > ~/ecn-results.ndjson
```

Listing 19: Start Resolving the Cisco Umbrella List

Up next:
Path Transparency Observatory (PTO)

Don't delete your PATHspider results, you'll need them in the next session.

References I

[1] J. Arkko, M. Cotton, and L. Vegoda.
IPv4 Address Blocks Reserved for Documentation.
RFC 5737 (Informational), January 2010.

[2] S. Bellovin.
The Security Flag in the IPv4 Header.
RFC 3514 (Informational), April 2003.

[3] Mirja Kühlewind, Sebastian Neuner, and Brian Trammell.
On the state of ECN and TCP options on the Internet.
In *Proceedings of the Passive and Active Measurement Conference*, pages 135–144, Hong Kong, China, 2013.

References II

[4] Iain R. Learmonth, Brian Trammell, Mirja Kühlewind, and Gorry Fairhurst.
PATHspider: A tool for active measurement of path transparency.
In *Proceedings of the 2016 Applied Networking Research Workshop*, pages 62–64, July 2016.

[5] Brian Trammell, Mirja Kühlewind, Damiano Boppart, Iain Learmonth, Gorry Fairhurst, and Richard Scheffenegger.
Enabling internet-wide deployment of explicit congestion notification.
In *Proceedings of the Passive and Active Measurement Conference*, pages 193–205, New York, USA, 2015.