Network Protocol Security Testing with the Packet Construction Set

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The Problem

- Writing network protocol code is hard
- Testing network protocols is as hard as writing the protocol in the first place
- Most current systems are incomplete
  - Only support a small number of packets
  - Not extensible
  - Written in write-once languages
- Proprietary systems are expensive and incomplete
  - ANVL
  - SmartBits

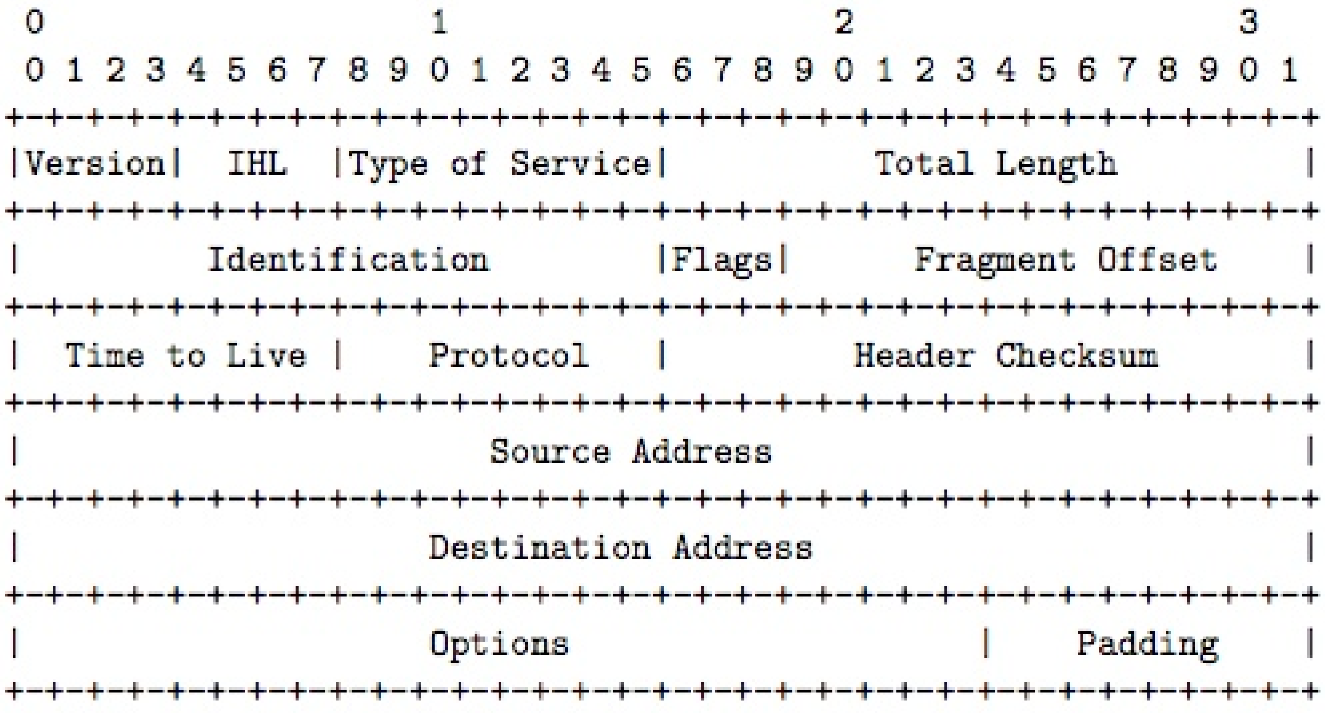
One Solution

- A packet programming language
- Programming languages are hard
- Most people don’t want to learn a special language
- Adoption rate might be low
- Maintenance is hard

Packet Construction Set

- A Python Library for creating new objects that represent packets
- Re-use a well known language
- Make it easy to create packet objects
- Most of the code in the scripts is pure Python
- Python is readable and easy to work with
- Python is not a write-once language

We need to get from this...



```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Identification        |Flags|      Fragment Offset    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time to Live |    Protocol   |         Header Checksum       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                    |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

...to this

```
struct ip {
#if BYTE_ORDER == LITTLE_ENDIAN
 u_int ip_hl:4,          /* header length */
       ip_v:4;                    /* version */
#endif
#if BYTE_ORDER == BIG_ENDIAN
 u_int ip_v:4,                    /* version */
       ip_hl:4;          /* header length */
#endif
 u_char         ip_tos;                     /* type of service */
 u_short        ip_len;                     /* total length */
 u_short        ip_id;                      /* identification */
 u_short        ip_off;                     /* fragment offset field */
#define         IP_RF 0x8000                         /* reserved fragment
flag */
#define         IP_DF 0x4000                         /* dont fragment flag */
#define         IP_MF 0x2000                         /* more fragments flag
*/
#define         IP_OFFMASK 0x1fff           /* mask for fragmenting bits */
 u_char         ip_ttl;                     /* time to live */
 u_char         ip_p;                       /* protocol */
 u_short        ip_sum;                     /* checksum */
 struct         in_addr ip_src,ip_dst;      /* source and dest address */
} __packed;
```

…er I mean this

```
version = pcs.Field("version", 4,
                    default = 4)
hlen = pcs.Field("hlen", 4)
tos = pcs.Field("tos", 8)
length = pcs.Field("length", 16)
id = pcs.Field("id", 16)
flags = pcs.Field("flags", 3)
offset = pcs.Field("offset", 13)
ttl = pcs.Field("ttl", 8, default = 64)
protocol = pcs.Field("protocol", 8)
checksum = pcs.Field("checksum", 16)
src = pcs.Field("src", 32)
dst = pcs.Field("dst", 32)
```

What does PCS provide?

- A simple system for laying out packets
- A way to access packet fields programmatically
- A special set of classes called `Connectors` which provide easy access to
  - TCP
  - UDP
  - IP
  - PCAP
- Access to pcap and bpf interfaces by an extended version of py-pcap
  - Thanks Doug Song!

A Simple Example

```
from pcs.packets.arp import *
from pcs.packets.ethernet import *

arppkt = arp()
arppkt.op = 1
arppkt.sha = ether_atob(ether_source)
arppkt.spa = inet_atol(ip_source)
arppkt.tha = "\x00\x00\x00\00\x00\x00"
arppkt.tpa = inet_atol(target)
```

A Simple Example continued

```
ether = ethernet()
ether.src = ether_atob(ether_source)
ether.dst = "\xff\xff\xff\xff\xff\xff"
ether.type = 0x806

packet = Chain([ether, arppkt])

output = PcapConnector(interface)

out = output.write(packet.bytes, len
(packet.bytes))
```

What just happened?

- We hand crafted an ARP packet
- We hand crafted an Ethernet packet
- We chained two packets together
- We transmitted them
- We did this in 15 lines of code

A quick on line demo

Why do I care?

- You now have programmatic access to any field in any packet
- It is now trivial to write
  - Protocol conformance tests
  - Fuzzers
  - Experimental protocols

What about security?

- Triggering kernel panics
- Attempting to get servers to give up their data
- Interactively interrogate a server
  - Using PCS in python’s command line interpreter
- Using the Python unittest module to generate repeatable tests for known security issues

Google Summer of Code Project

- Clement Lecigne took PCS and created IPv6 specific protocol fuzzers
- Several issues were found
- All were fixed (of course)
- Validates our approach

Too Big Packet Generator

- Try to trigger a kernel panic with PCS
- Send a “packet too big” message to the system
- The entire program including options parsing, is 125 lines

Making the packet

```
def makepkt(sip, smac, dmac, dip, len = 8):
    ip = ipv6.ipv6()
    ip.traffic_class = 0
    ip.flow = 0
    ip.next_header = IPPROTO_ICMPV6
    ip.length = len + 8
    ip.hop = 64
    ip.src = inet_pton(AF_INET6, dip)
    ip.dst = inet_pton(AF_INET6, sip)
    # icmp6 header
    icmp6 = icmpv6(ICMP6_ECHO_REPLY)
    icmp6.type = ICMP6_ECHO_REPLY
    icmp6.code = 0
    icmp6.id = os.getpid()
    data = "A" * len
        icmp6.checksum = icmp6.cksum(ip, data) + 1
        chain = pcs.Chain([ip, icmp6])
        return chain.bytes
```

Putting on the headers

```
def toobig(iface, mtu, dstip, dstmac, srcip, srcmac,
pkt):
    """send fake icmp TOO BIG packet"""
    # ethernet header
    eth = ethernet()
    eth.dst = eth.name2eth(dstmac)
    eth.src = eth.name2eth(srcmac)
    eth.type = ETHERTYPE_IPV6
    # ipv6 header
    ip = ipv6.ipv6()
    ip.traffic_class = 0
    ip.flow = 0
    ip.next_header = IPPROTO_ICMPV6
    ip.hop = 255
    ip.length = 8 + len(pkt)
    ip.src = inet_pton(AF_INET6, srcip)
    ip.dst = inet_pton(AF_INET6, dstip)
```

```
# icmp6 header
icmp6 = icmpv6(ICMP6_PACKET_TOO_BIG)
icmp6.type = ICMP6_PACKET_TOO_BIG
icmp6.code = 0
icmp6.mtu = mtu
icmp6.checksum = icmp6.cksum(ip, pkt)
chain = pcs.Chain([eth, ip, icmp6])
c = pcs.Connector("IPV6", iface)
c.write(chain.bytes + pkt)
c.close()
```

Results

- Code did not cause a panic
- In some cases it caused the system to be unable to communicate using IPv6
- More tests are necessary

Access to PCAP

- Most tools that work with PCAP files are one offs
- Some tools are too graphical
- What is needed is a library for working with PCAP on which to build more tools
- PCS provides extensions to pypcap for better integration with scripting

DDOS Analyzer

- Sometimes a site DDOSs itself
- How can we detect a real DDOS from a mistake?
- Look at the source addresses and see if they are clustered
- ddos_analyze.py is 67 lines including options parsing
- 5000 packet pcap file
- Test data retrieved from a public server
- Snaplen of 9000 bytes

Analysis Output

```
? ddos_analyze.py -f pcaptestfile -s 255.255.255.0 -n
10.0.0.0 -m 5

5001 packets in dumpfile
5 unique source IPs
0 packets in specified network
Top 5 source addresses were
Address 204.152.184.203 Count 2473 Percentage 49.450110
Address 64.13.135.16    Count 2    Percentage 0.039992
Address 64.13.134.241   Count 1    Percentage 0.019996
Address 195.137.95.246  Count 1    Percentage 0.019996
Address 64.13.134.241   Count 1    Percentage 0.019996
Address 195.137.95.246  Count 1    Percentage 0.019996
1.898u 0.214s 0:02.12 99.0%     0+0k 0+7io 0pf+0w
```

Analyzing the packets

```
while not done:
    try:
       packet = file.read()
    except:
       done = True
    packets += 1
    ip = ipv4(packet[file.dloff:len(packet)])
    if (ip.src & mask) != network:
        if ip.src in srcmap:
           srcmap[ip.src] += 1
        else:
           srcmap[ip.src] = 1
    else:
        in_network +=1
```

Doing the analysis

```
hit_list = sorted(srcmap.itervalues(), reverse = True)
for i in range(1,max):
    for addr in srcmap.items():
        if addr[1] == hit_list[i]:
            print "Address %s\t Count %s\t Percentage %
f" % (inet_ntop(AF_INET, struct.pack('!L', addr[0])),
addr[1], (float(addr[1]) / float(packets)) * float
(100))
```

Current Status

- Alpha 0.3 currently available
  - But most people would call it Beta
- Packets
  - Link Layer: Localhost, Ethernet
  - Network Layer: ARP, IPv4, ICMPv4, IPv6, ICMPv6, ND6
  - Transport Layer: UDP, TCP
  - Application Protocols: DNS, DHCPv4
  - **Every protocol has a test suite!**

Scripts

- arpwhohas.py
  - Generate a fake ARP
- ddos_analyze.py
  - Determine majority source addresses in a pcap file
- dns_query.py
  - Generate a fake DNS query
- http_get.py
  - Grab a web page
- pcap_info.py
  - Print out various bits of info about a pcap file

Scripts Con't

- ping.py
  - A simple ICMPv4 packet generator
- snarf.py
  - A trivial packet sniffer
- pcap_slice.py
  - Carve up pcap files analogous to tcpslice
- udp_echo.py
  - Generate a fake UDP packet

Future Work

- Add more packets
  - Attempt to cover 80% of all known protocols
- Add more scripts
- Integrate into a protocol conformance test framework
  - NetTest is another project
- More documentation
  - Manual exists but is incomplete

More Information

- Project hosted on Source Forge
- BSD License
- http://pcs.sf.net
- More scripts and packets welcome!

Questions?