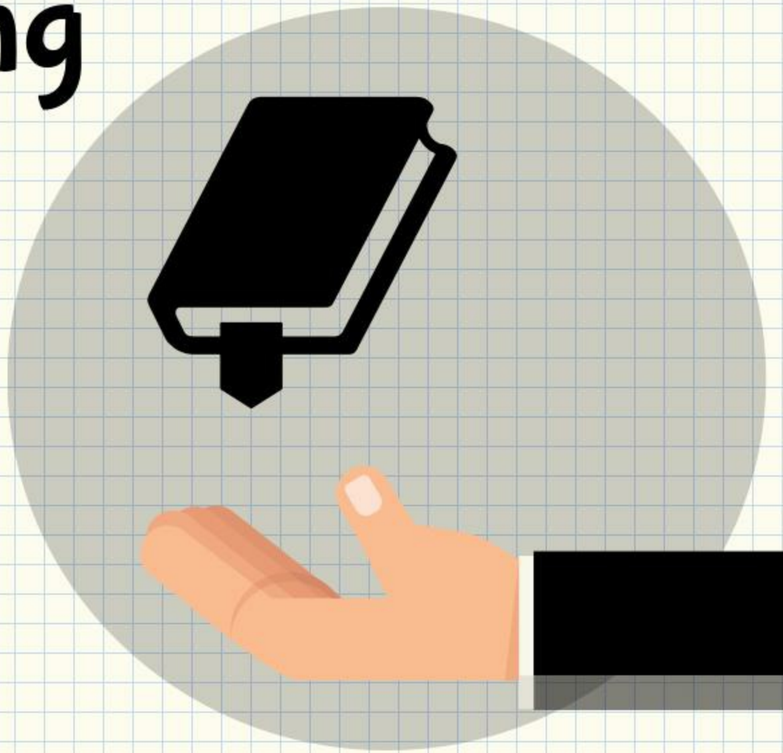
# Limon – Sandbox for Analyzing Linux Malwares

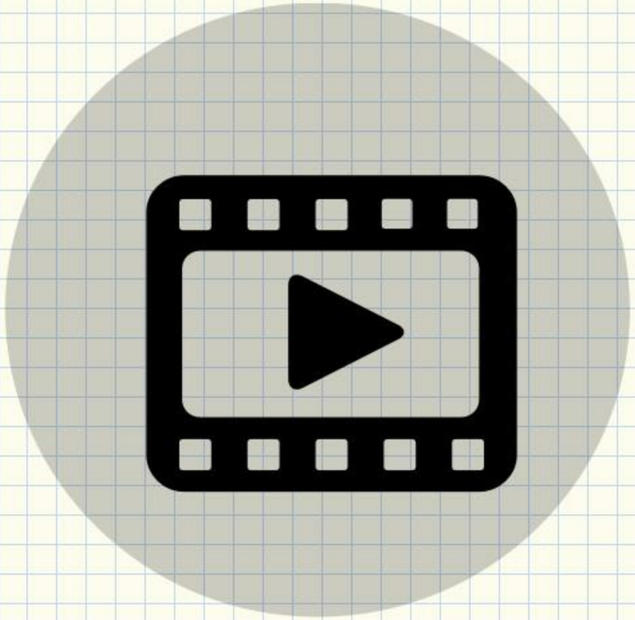
by Monnappa K A



# Who Am I

Monnappa K A

- Info Security Investigator – Cisco CSIRT
- Member of SecurityXploded
- Reverse Engineering, Malware Analysis, Memory Forensics
- Author of Limon Sandbox
- Conferences – Black Hat, FIRST, 4SICS etc
- Articles – EForensics, Hakin9, Hack Insight
- Email: monnappa22@gmail.com

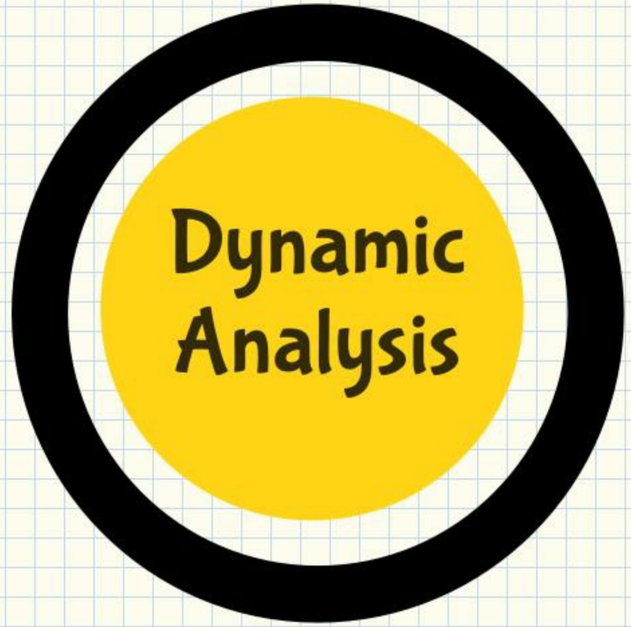


# What is Limon?

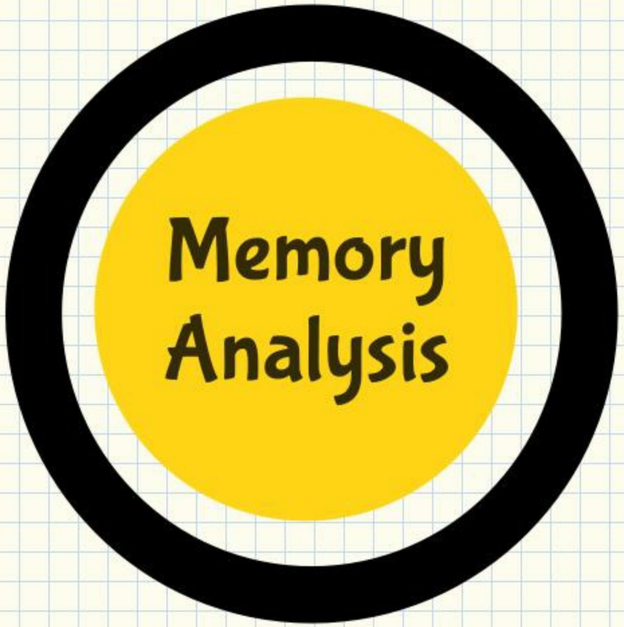
- Sandbox for analyzing Linux malwares
- Developed as a research project
- For learning Linux malware analysis
- Written in Python
- Performs static,dynamic and memory analysis
- Uses various open source tools

# Types of Analysis


Analysis without Executing the malware

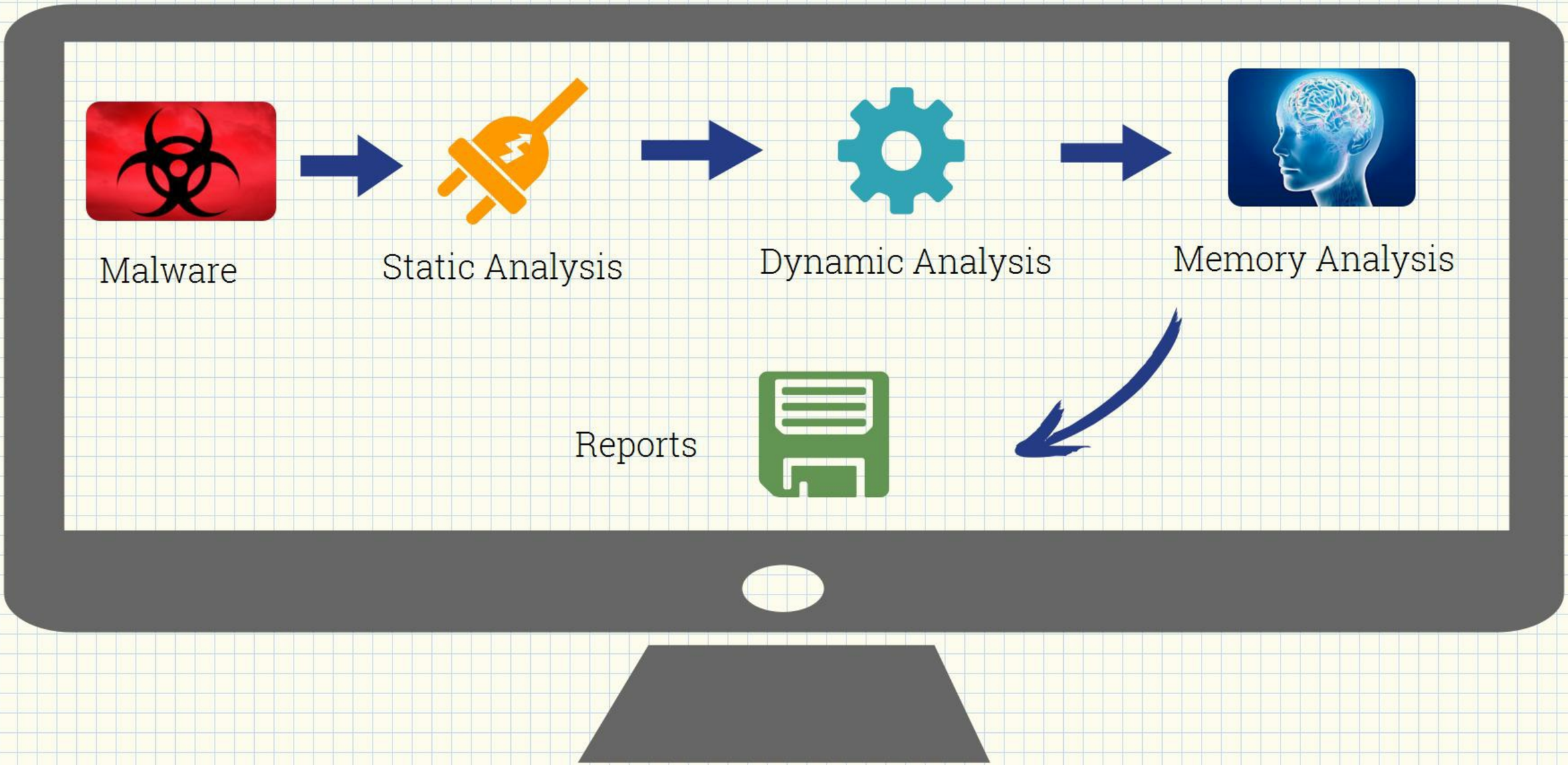



Analysis by executing the malware




Analysis of RAM (main memory) after executing the malware

# Working of Limon

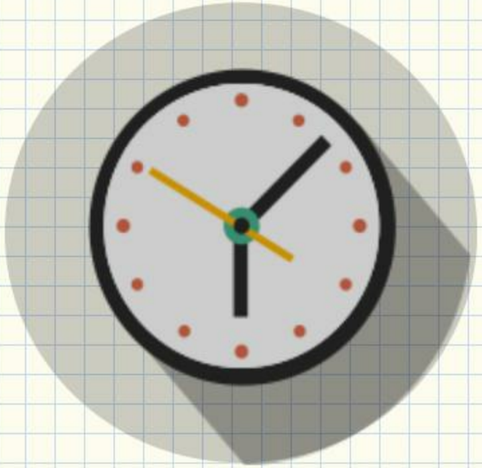


# General Features

- Can run in sandbox mode (does not allow to connect to c2)
- Can run in internet mode (connects to c2)
- Simulates all services (like dns, http and other protocols) when run in sandbox mode
- Option to run malware for specified time (default is 60 seconds)
- Captures desktop screenshot
- Reports on the malware behaviour

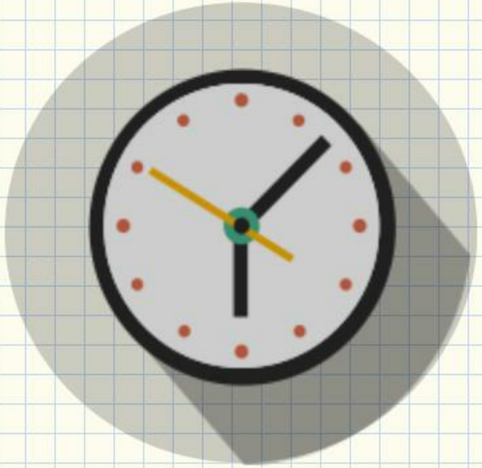
# Static Analysis Features

- Determine File Type
- Determine File Size
- Determines md5 hash
- Determines fuzzy hash(ssdeep hash)
- Comparison of fuzzy hash with previously submitted samples to determine similar variants
- Display ELF header Structure
- Dumps ASCII and UNICODE strings
- Determines packers using YARA rules



# Static Analysis Features

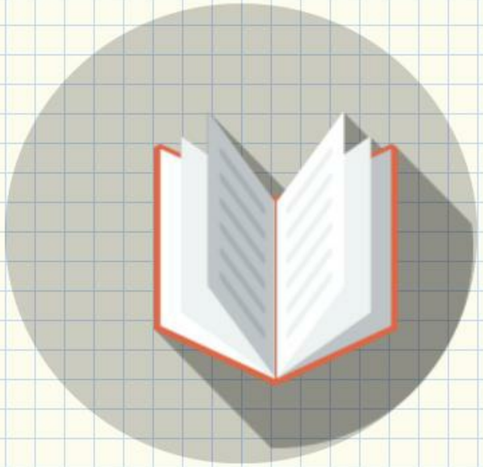
- Determines malware capability using YARA rules (ability to run custom YARA rules will be added soon)
- Performs md5 search on VirusTotal(does not submit samples)
- Displays dependencies of the malware (shared objects)
- Displays program header structures
- Displays section header information
- Displays symbol table (both static and dynamic symbols)



# Dynamic Analysis Features

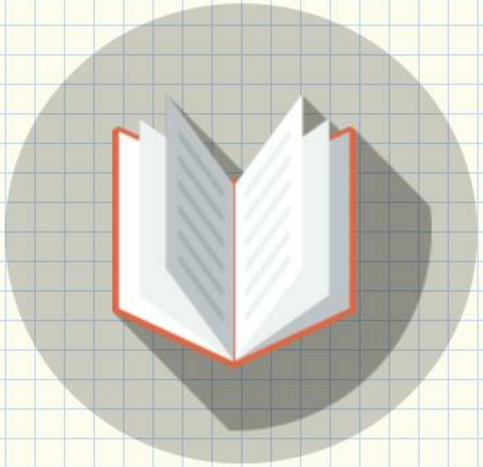
Limon gives different options for performing dynamic analysis to track activity of the malware(during execution), below are the different options

- Filtered call trace for tracing system calls related to file, process, network activity
- Unfiltered call trace – traces all system calls (more noisy)
- Filtered system event montioring to track file, process, network activity (less noisy)
- Unfiltered system even monitoring to track file, process, network, memory allocations/unallocations, signals etc (more noisy)



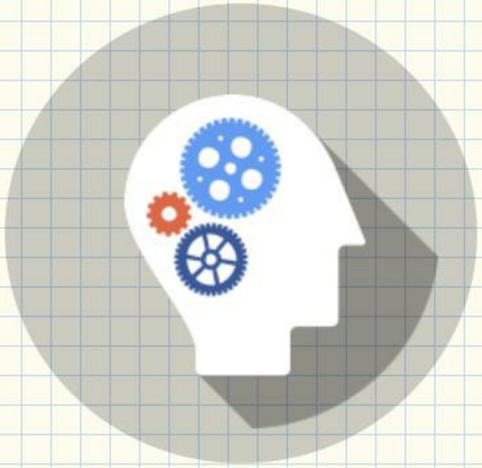
# Dynamic Analysis Features

- Shows DNS summary
- Shows TCP conversations
- Stores packet captures
- Stores event trace dump



# Memory Analysis Features

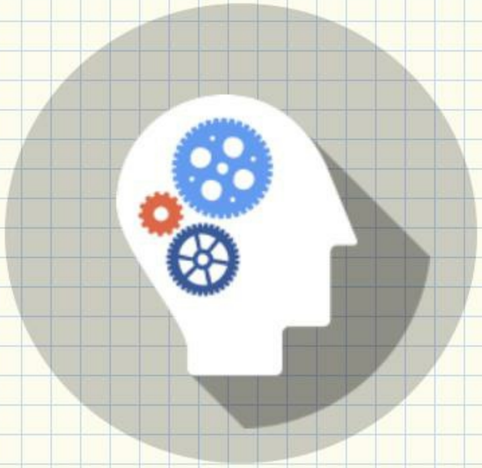
Limon performs post-mortem analysis by performing memory analysis using Volatility framework. This feature should help in detecting stealthy rootkits and malwares peforming Anti-Forensic tricks. Below are the memory analysis features:



- Option to perform verbose memory forensics (slow)
- Process Listing (using different methods)
- Process tree listing
- Process listing with process arguments
- Displays thread associated with each process
- Dispays Network connections (TCP and UDP)

# Memory Analysis Features

- Displays Interface Information
- Displays processes running with RAW sockets
- Displays shared libaries associated with the processes (using different methods)
- Displays kernel modules
- Dislays kernel modules hidden from module list but present in SYSFS
- Displays Kernel modules hidden from both module list and SYSFS
- Displays files opened within kernel
- Displays processes sharing credential structures
- Checks for keyboard notifier hooks
- Checks for TTY hooks



# Memory Analysis Features

- Checks for system call table modification
- Displays BASH history
- Checks for modified file operation structures
- Checks hooked network operation function structures
- Checks netfilter hooks
- Check inline kernel hooks
- Displays BASH history
- Checks for code or binary injection
- Check for PLT/GOT hooks (only in verbose mode)
- Checks for userland api hooks (only in verbose mode)

# Tools used by Limon

Limon relies on below tools to perform static, dynamic and memory analysis

- YARA-python
  https://github.com/plusvic/yara

- VirusTotal Public api
  https://www.virustotal.com/en/documentation/public-api/

- ssdeep
  http://ssdeep.sourceforge.net/

- strings utility
  http://linux.die.net/man/1/strings

- ldd
  http://linux.die.net/man/1/ldd

# Tools used by Limon

- readelf
  https://sourceware.org/binutils/docs/binutils/readelf.html
- Inetsim
  http://www.inetsim.org/downloads.html
- Tcpdump
  http://www.tcpdump.org/
- Volatility memory forensics framework
  http://www.volatilityfoundation.org/#!releases/component_71401
- strace
  http://linux.die.net/man/1/strace
- Sysdig
  http://www.sysdig.org/

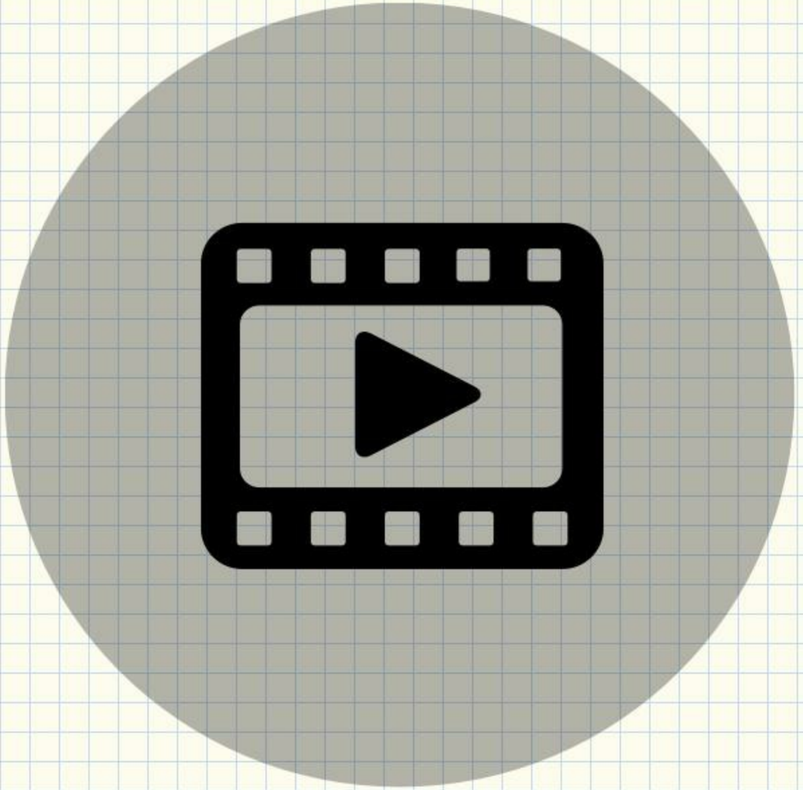
# Supported File Types:

Limon can analyse below file types (both with and without parameters)

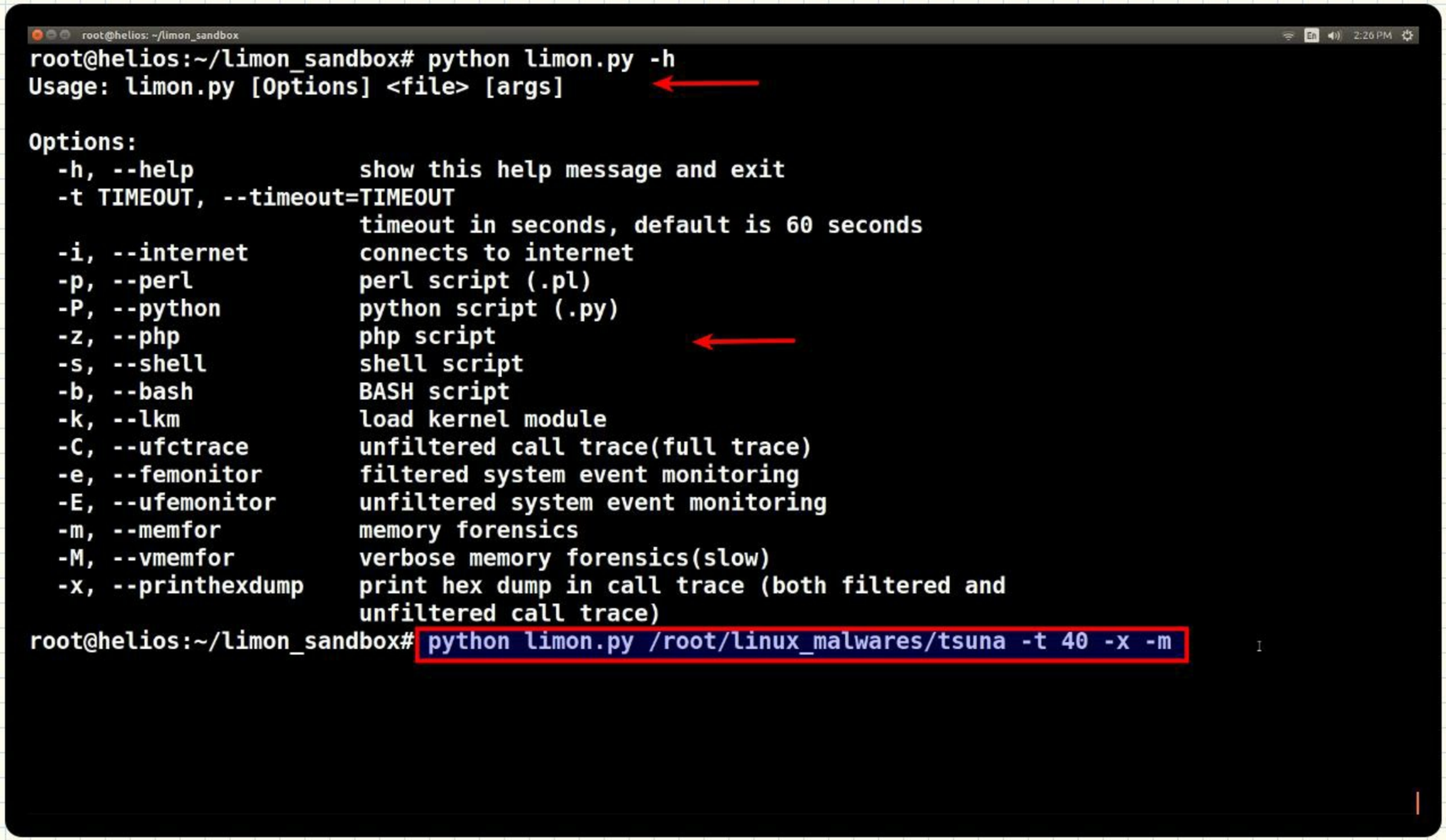
- ✔ ELF Executable(both x86 and x86_64)
- ✔ Perl Script
- ✔ Python script
- ✔ Shell script
- ✔ Bash script
- ✔ PHP script
- ✔ Loadable kernel module(LKM)

# Demo

## Analysis of Tsunami Using Limon



# Running Tsunami malware



# Tsunami – Static Analysis Results

## Malware file is 32 bit ELF executable and the symbols are not stripped

```
==========================[STATIC ANALYSIS RESULTS]==========================

Filetype: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), dynamically linked (uses shared libs), for
GNU/Linux 2.6.8, not stripped
File Size: 28.63 KB (29318 bytes)
md5sum: 1610768b1524e24d840ae25964d02c8e
ssdeep: 384:fJp2sVqQvqRFP514VWPE898bTyJGb0GnfknfXI0yIUQhLxJs+C3POCtZ8ax0h/49:BpRkQiVHAbTyJGb01fXI+9w9f5+R4wC
ELF Header:
  Magic:   7f 45 4c 46 01 01 01 00 00 00 00 00 00 00 00 00
  Class:                             ELF32
  Data:                              2's complement, little endian
  Version:                           1 (current)
  OS/ABI:                            UNIX - System V
  ABI Version:                       0
  Type:                              EXEC (Executable file)
  Machine:                           Intel 80386
  Version:                           0x1
  Entry point address:               0x8048e10
  Start of program headers:          52 (bytes into file)
  Start of section headers:          23172 (bytes into file)
  Flags:                             0x0
  Size of this header:               52 (bytes)
  Size of program headers:           32 (bytes)
  Number of program headers:         7
  Size of section headers:           40 (bytes)
  Number of section headers:         36
  Section header string table index: 33
```

# Tsunami –Static Analysis Results

Fuzzy hash comparsion shows 100% match with previously submitted sample and YARA rule match shows IRC capability.

```
----------------------------------------
ssdeep comparison:
/root/linux_malwares/tsuna matches /root/linux_reports/ssdeep_master.txt:/root/lin_test/tsuna (100)

----------------------------------------
Strings:
    Ascii strings written to /root/linux_reports/tsuna/strings_ascii.txt
    Unicode strings written to /root/linux_reports/tsuna/strings_unicode.txt
----------------------------------------
Packers:
    []
----------------------------------------
Malware Capabilities and classification using YARA rules:
    [irc, bankers]
----------------------------------------
```

# Tsunami – VirusTotal Results

```
Virustotal:

      AVG ==>
      AhnLab-V3 ==>
      AntiVir ==> BDS/Katien.R
      Antiy-AVL ==>
      Avast ==> ELF:Tsunami-B
      Avast5 ==> ELF:Tsunami-B
      BitDefender ==> Generic.Malware.G!IFg.2C2A4AA5
      CAT-QuickHeal ==>
      ClamAV ==> Trojan.Tsunami.B
      Commtouch ==>
      Comodo ==>
      DrWeb ==>
      Emsisoft ==> Backdoor.Linux.Tsunami!IK
      F-Prot ==>
      F-Secure ==> Generic.Malware.G!IFg.2C2A4AA5
      Fortinet ==>
      GData ==> Generic.Malware.G!IFg.2C2A4AA5
      Ikarus ==> Backdoor.Linux.Tsunami
      Jiangmin ==>
      K7AntiVirus ==>
      Kaspersky ==> Backdoor.Linux.Tsunami.gen
      McAfee ==> Linux/DDoS-Kaiten
      McAfee-GW-Edition ==> Linux/DDoS-Kaiten
      Microsoft ==>
      NOD32 ==>
      Norman ==>
      PCTools ==> Malware.Linux-Backdoor
```

# Tsunami – Symbol Information

shows references to network related system calls, indicating network capability of the malware

```
Symbol table '.dynsym' contains 56 entries:
   Num:    Value  Size Type    Bind   Vis      Ndx Name
     0: 00000000     0 NOTYPE  LOCAL  DEFAULT  UND
     1: 00000000    29 FUNC    GLOBAL DEFAULT  UND __errno_location@GLIBC_2.0 (2)
     2: 00000000    49 FUNC    GLOBAL DEFAULT  UND sprintf@GLIBC_2.0 (2)
     3: 00000000   141 FUNC    GLOBAL DEFAULT  UND popen@GLIBC_2.1 (3)
     4: 00000000    96 FUNC    GLOBAL DEFAULT  UND srand@GLIBC_2.0 (2)
     5: 00000000   108 FUNC    GLOBAL DEFAULT  UND connect@GLIBC_2.0 (2)
     6: 00000000    49 FUNC    GLOBAL DEFAULT  UND getpid@GLIBC_2.0 (2)
     7: 00000000     0 NOTYPE  WEAK   DEFAULT  UND __gmon_start__
     8: 00000000   192 FUNC    GLOBAL DEFAULT  UND vsprintf@GLIBC_2.0 (2)
     9: 00000000   555 FUNC    GLOBAL DEFAULT  UND inet_network@GLIBC_2.0 (2)
    10: 00000000   108 FUNC    GLOBAL DEFAULT  UND recv@GLIBC_2.0 (2)
    11: 00000000    34 FUNC    GLOBAL DEFAULT  UND inet_addr@GLIBC_2.0 (2)
    12: 00000000   198 FUNC    GLOBAL DEFAULT  UND strncpy@GLIBC_2.0 (2)
    13: 00000000   112 FUNC    GLOBAL DEFAULT  UND write@GLIBC_2.0 (2)
    14: 00000000   108 FUNC    GLOBAL DEFAULT  UND sendto@GLIBC_2.0 (2)
    15: 00000000    55 FUNC    GLOBAL DEFAULT  UND listen@GLIBC_2.0 (2)
    16: 00000000    50 FUNC    GLOBAL DEFAULT  UND toupper@GLIBC_2.0 (2)
    17: 00000000   369 FUNC    GLOBAL DEFAULT  UND fgets@GLIBC_2.0 (2)
    18: 00000000    88 FUNC    GLOBAL DEFAULT  UND memset@GLIBC_2.0 (2)
    19: 00000000   441 FUNC    GLOBAL DEFAULT  UND __libc_start_main@GLIBC_2.0 (2)
    20: 00000000     7 FUNC    GLOBAL DEFAULT  UND ntohl@GLIBC_2.0 (2)
    21: 00000000    14 FUNC    GLOBAL DEFAULT  UND htons@GLIBC_2.0 (2)
    22: 00000000   251 FUNC    GLOBAL DEFAULT  UND free@GLIBC_2.0 (2)
    23: 00000000   108 FUNC    GLOBAL DEFAULT  UND accept@GLIBC_2.0 (2)
    24: 00000000    58 FUNC    GLOBAL DEFAULT  UND ioctl@GLIBC_2.0 (2)
    25: 00000000    55 FUNC    GLOBAL DEFAULT  UND socket@GLIBC_2.0 (2)
    26: 00000000   539 FUNC    GLOBAL DEFAULT  UND fclose@GLIBC_2.1 (3)
```

# Tsunami – Strings

## Strings show reference to C2 ip, http and IRC commands

```
80.243.54.131
NOTICE %s :Unable to comply.
/usr/dict/words
%s : USERID : UNIX : %s
NOTICE %s :GET <host> <save as>
NOTICE %s :Unable to create socket.
http://
NOTICE %s :Unable to resolve address.
NOTICE %s :Unable to connect to http.
GET /%s HTTP/1.0
Connection: Keep-Alive
User-Agent: Mozilla/4.75 [en] (X11; U; Linux 2.2.16-3 i686)
Host: %s:80
Accept: image/gif, image/x-xbitmap, image/jpeg, image/pjpeg, image/png, */*
Accept-Encoding: gzip
Accept-Language: en
Accept-Charset: iso-8859-1,*,utf-8
NOTICE %s :Receiving file.
NOTICE %s :Saved as %s
NOTICE %s :Spoofs: %d.%d.%d.%d
NOTICE %s :Spoofs: %d.%d.%d.%d - %d.%d.%d.%d
NOTICE %s :Kaiten wa goraku
NOTICE %s :NICK <nick>
NOTICE %s :Nick cannot be larger than 9 characters.
```

# Tsunami – Strings

## Strings show reference to attack commands, show DOS/DDOS capabilities

```
NOTICE %s :Tsunami heading for %s.
NOTICE %s :UNKNOWN <target> <secs>
NOTICE %s :Unknowning %s.
NOTICE %s :MOVE <server>
NOTICE %s :TSUNAMI <target> <secs>                          = Special packeter that wont be blocked by
most firewalls
NOTICE %s :PAN <target> <port> <secs>                       = An advanced syn flooder that will kill
most network drivers
NOTICE %s :UDP <target> <port> <secs>                       = A udp flooder
NOTICE %s :UNKNOWN <target> <secs>                          = Another non-spoof udp flooder
NOTICE %s :NICK <nick>                                      = Changes the nick of the client
NOTICE %s :SERVER <server>                                  = Changes servers
NOTICE %s :GETSPOOFS                                        = Gets the current spoofing
NOTICE %s :SPOOFS <subnet>                                  = Changes spoofing to a subnet
NOTICE %s :DISABLE                                          = Disables all packeting from this client
NOTICE %s :ENABLE                                           = Enables all packeting from this client
NOTICE %s :KILL                                             = Kills the client
NOTICE %s :GET <http address> <save as>                     = Downloads a file off the web and saves
it onto the hd
NOTICE %s :VERSION                                          = Requests version of client
NOTICE %s :KILLALL                                          = Kills all current packeting
NOTICE %s :HELP                                             = Displays this
NOTICE %s :IRC <command>                                    = Sends this command to the server
NOTICE %s :SH <command>                                     = Executes a command
NOTICE %s :Killing pid %d.
```

# Dynamic Analysis Results

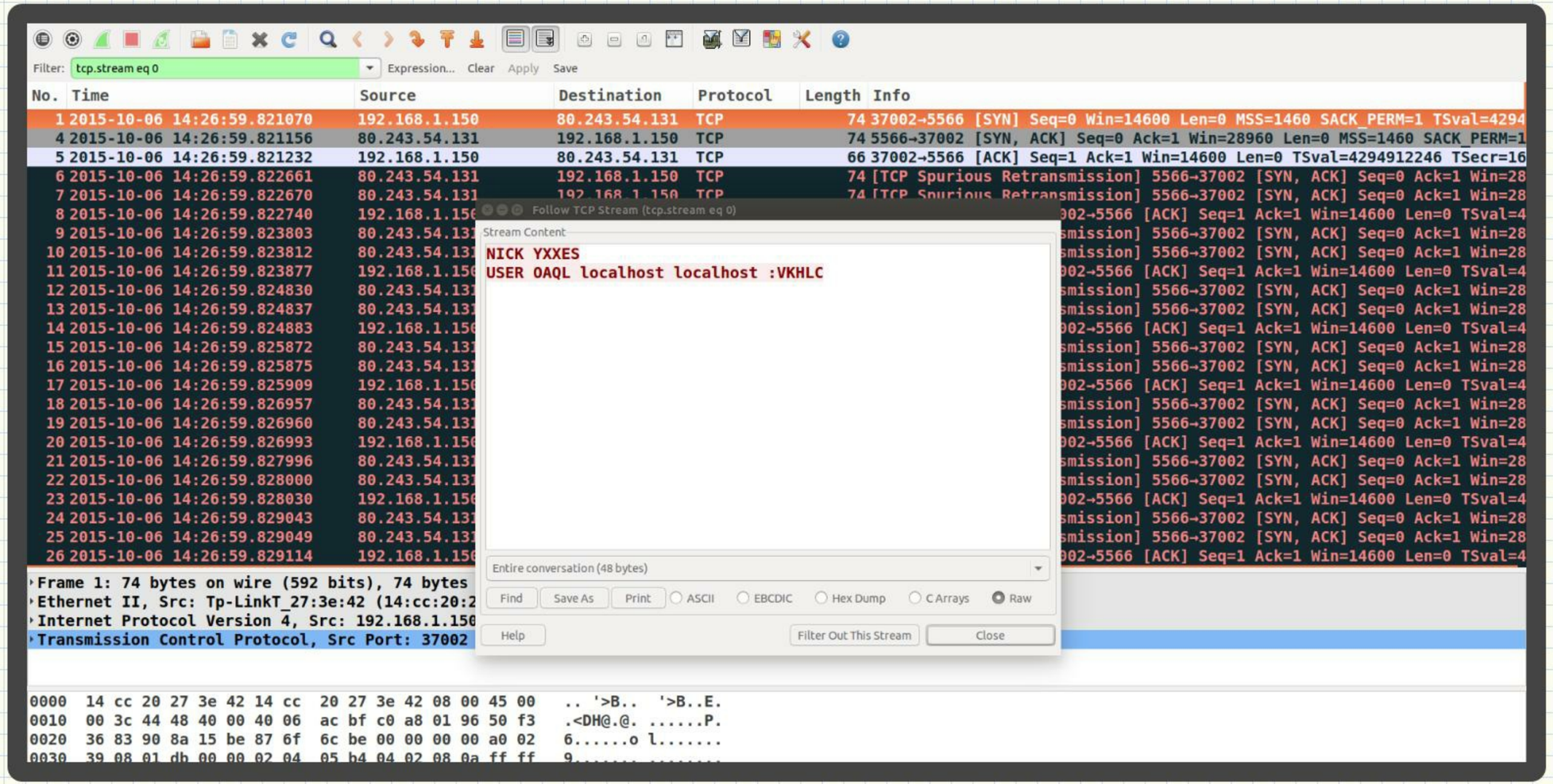
```
=========================[DYNAMIC ANALYSIS RESULTS]=========================

CALL TRACE ACTIVITIES
=====================================
2673  execve("/root/malware_analysis/tsuna", ["/root/malware_analysis/tsuna"], [/* 50 vars */]) = 0
2673  open("/usr/lib/vmware-tools/libconf/lib/tls/i686/sse2/cmov/libc.so.6", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
2673  open("/usr/lib/vmware-tools/libconf/lib/tls/i686/sse2/libc.so.6", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
2673  open("/usr/lib/vmware-tools/libconf/lib/tls/i686/cmov/libc.so.6", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
2673  open("/usr/lib/vmware-tools/libconf/lib/tls/i686/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
2673  open("/usr/lib/vmware-tools/libconf/lib/tls/sse2/cmov/libc.so.6", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
2673  open("/usr/lib/vmware-tools/libconf/lib/tls/sse2/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
```

```
2673  clone(child_stack=0, flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_SETTID|SIGCHLD, child_tidptr=0) =
2674
2674  open("/usr/dict/words", O_RDONLY) = -1 ENOENT (No such file or directory)
2674  open("/usr/dict/words", O_RDONLY) = -1 ENOENT (No such file or directory)
2674  open("/usr/dict/words", O_RDONLY) = -1 ENOENT (No such file or directory)
2674  socket(PF_INET, SOCK_STREAM, IPPROTO_TCP) = 3
2674  connect(3, {sa_family=AF_INET, sin_port=htons(5566), sin_addr=inet_addr("80.243.54.131")}, 16)
= -1 EINPROGRESS (Operation now in progress)
2674  connect(3, {sa_family=AF_INET, sin_port=htons(5566), sin_addr=inet_addr("80.243.54.131")}, 16)
= 0
2674  write(3, "NICK YXXES\nUSER OAQL localhost localhost :VKHLC\n", 48) = 48
 | 00000  4e 49 43 4b 20 59 58 58  45 53 0a 55 53 45 52 20  NICK YXX ES.USER  |
 | 00010  4f 41 51 4c 20 6c 6f 63  61 6c 68 6f 73 74 20 6c  OAQL loc alhost l |
 | 00020  6f 63 61 6c 68 6f 73 74  20 3a 56 4b 48 4c 43 0a  ocalhost  :VKHLC. |
```

# Tsunami – Network Communication

## Shows IRC communication to the C2 ip on port 5566



# Tsunami – Memory Process Listing

shows malicious process "tsuna" running on the system

```
2015-10-06 08:56:06 UTC+0000
0xffff88001c332de0 goa-daemon        2603   0      0      0x0000000006cb8000
2015-10-06 08:56:06 UTC+0000
0xffff88001a250000 gnome-screensav   2608   0      0      0x0000000009126000
2015-10-06 08:56:11 UTC+0000
0xffff88001a35dbc0 aptd              2662   0      0      0x000000000c8cf000
2015-10-06 08:56:52 UTC+0000
0xffff8800020b8000 vmtoolsd          2671   0      0      0x000000001a5c7000
2015-10-06 08:56:59 UTC+0000
0xffff88001a35ade0 strace            2672   0      0      0x000000001a3d8000
2015-10-06 08:56:59 UTC+0000
0xffff88001b992de0 tsuna             2674   0      0      0x00000000005aa000
2015-10-06 08:56:59 UTC+0000
0xffff88001a555bc0 dnsmasq           2691   65534  30     0x000000001a1a8000
2015-10-06 08:57:44 UTC+0000
0xffff88001efedbc0 dbus-daemon       2698   102    105    0x000000001cc07000
2015-10-06 08:57:44 UTC+0000
0xffff88001a5544d0 dbus-daemon-lau   2700   0      0      0x00000000178b3000
2015-10-06 08:57:44 UTC+0000
```

# Tsunami – Memory Network Communication

Network listing from memory analysis shows process "tsuna" establishing network connection with C2 ip

```
NETWORK CONNECTIONS
====================================

UDP      0.0.0.0          : 5353 0.0.0.0          :    0                    avahi-daemon/677
UDP      ::               : 5353 ::               :    0                    avahi-daemon/677
UDP      0.0.0.0          :38766 0.0.0.0          :    0                    avahi-daemon/677
UDP      ::               :43148 ::               :    0                    avahi-daemon/677
TCP      127.0.0.1        :  631 0.0.0.0          :    0 LISTEN                      cupsd/752
TCP      192.168.1.150    :39549 91.189.89.144    :   80 CLOSE WAIT        ubuntu-geoip-pr/2455
TCP      192.168.1.150    :37002 80.243.54.131    : 5566 ESTABLISHED             tsuna/2674
UDP      127.0.0.1        :   53 0.0.0.0          :    0                  dnsmasq/2691
TCP      127.0.0.1        :   53 0.0.0.0          :    0 LISTEN           dnsmasq/2691
```

# Getting Started with Limon?

## Donwload Link

https://github.com/monnappa22/Limon

## Setting Up Limon Sandbox

http://malware-unplugged.blogspot.in/2015/11/setting-up-limon-sandbox-for-analyzing.html

## Limon Sandbox for analyzing Linux Malwares

http://malware-unplugged.blogspot.in/2015/11/limon-sandbox-for-analyzing-linux.html

## Black Hat Europe 2015 presentation

https://youtu.be/fSCKyF--tRs

# THANK YOU

@monnappa22

http://malware-unplugged.blogspot.in

monnappa22@gmail.com