peetch

an eBPF based networking tool

SSTIC 2023

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Quarkslab

Hello SSTIC!

https://github.com/secdev/scapy

Scapy co-maintainer

Python-based packet manipulation tool

Hobbyist reverser

I like to break things to understand them

Director of Security Research @Quarkslab

we bring our cutting edge researchers to customers

What is peetch?

collections of networking tools

using eBPF for the heavy lifting

two current uses

1. sniff packets and process metadata
2. dump OpenSSL secrets

`github.com/quarkslab/peetch`

Open-Source Contributions on github.com

secdev/scapy

- NSS Key Log support
- PCAPNg writing & comment option

iovisor/bcc

- CGROUP_SOCK_ADDR program type support

quarkslab/peetch

- the eBPF & TLS playground

eBPF 101

Quarkslab

eBPF

extended Berkeley Packet Filter

like cBPF but better

internally Linux convert cBPF to eBPF

cool features

designed to be JITed
function calls

attach an eBPF program to an event

packets, kernel functions…

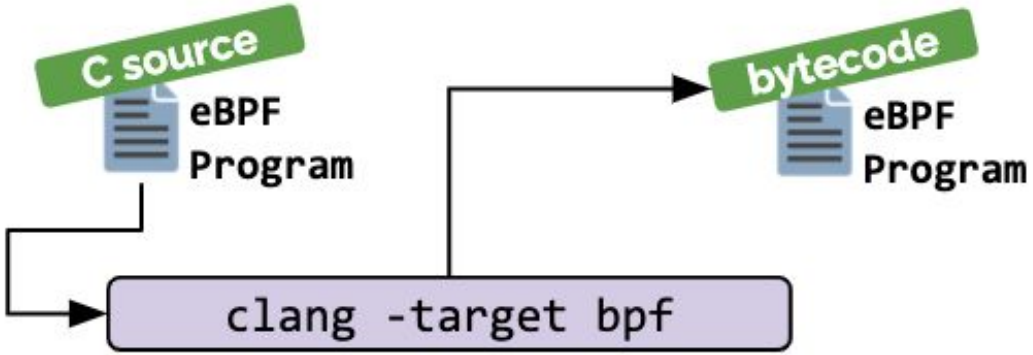
Using a kprobe Manually

```
00 # echo 'p:sstic23 do_sys_openat2 filename=+0($arg2):string' >
/sys/kernel/debug/tracing/kprobe_events
01 # echo 1 > /sys/kernel/debug/tracing/events/kprobes/sstic23/enable
02
03 # cat /sys/kernel/debug/tracing/trace_pipe
04 secret_binary-1603837 [000] d... 242641.480399: sstic23: (do_sys_openat2+0x0/0x164)
   filename="/etc/ld.so.cache"
05 secret_binary-1603837 [000] d... 242641.480470: sstic23: (do_sys_openat2+0x0/0x164)
   filename="/lib/aarch64-linux-gnu/libcurl.so.4"
06 secret_binary-1603837 [000] d... 242641.480594: sstic23: (do_sys_openat2+0x0/0x164)
   filename="/lib/aarch64-linux-gnu/libz.so.1"
07 secret_binary-1603837 [000] dn.. 242641.480695: sstic23: (do_sys_openat2+0x0/0x164)
   filename="/lib/aarch64-linux-gnu/libpthread.so.0"
```

three simple steps from a root shell

create the kprobe, enable it & enjoy

From C to eBPF bytecode



compiled to eBPF with clang

gcc can do it too

bytecode loaded with the bpf syscall

abstracted thanks to eBPF loaders

From https://ebpf.io

peetch dump

Packet process metadata with bpftrace

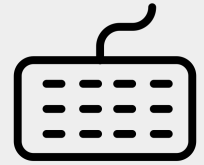
```
01 #include <net/flow.h>
02
03 kprobe:security_sk_classify_flow {
04   $flowi = (struct flowi*) arg1;
05   if ($flowi == 0) {
06     return;
07   }
08
09   $flowi4 = $flowi->u.ip4;
10   if ($flowi4.saddr == 0) {
11     return;
12   }
13
14   $sport = bswap($flowi4.uli.ports.sport);
15   $dport = bswap($flowi4.uli.ports.dport);
16
17   $saddr = ntop(AF_INET, $flowi4.saddr);
18   $daddr = ntop(AF_INET, $flowi4.daddr);
19
20   printf("%s/%d - %s:%d -> %s:%d\n", comm, pid, $saddr, $sport, $daddr, $dport);
21 }
```

https://t.m

bpftrace output

```
# bpftrace security_sk_classify_flow.bt
Attaching 1 probe...
secret_binary/11663 - 127.0.0.1:57338 -> 127.0.0.53:53
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 127.0.0.53:53 -> 127.0.0.1:57338
systemd-resolve/1152 - 127.0.0.53:53 -> 127.0.0.1:57338
secret_binary/11663 - 192.168.42.42:37890 -> 188.114.97.6:443
```

peetch Demo #1



Created by Sarah from Noun Project

store process information along packets

filter TLS and display results with Scapy

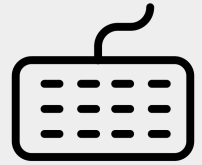
```
00 # peetch dump --write sstic23.pcapng
01 $ scapy
02 >>> rdpcap("sstic23.pcapng")
03 <sstic23.pcapng: TCP:37 UDP:0 ICMP:0 Other:0>
04 >>> l = _.filter(lambda p: TLS in p)
05 <filtered sstic23.pcapng: TCP:13 UDP:0 ICMP:0 Other:0>
06 >>> l[0].summary()
07 'Ether / IP / TCP / TLS 10.211.55.7:44154 > 208.97.177.124:443 / TLS / TLS Handshake
- Client Hello / Padding'
08 >>> l[0].comment
09 secret_binary/26380'
```

peetch tls

peetch Demo #2

dump plaintext

HTTP/1.1 works fine!



Created by Sarah from Noun Project

```
# peetch tls --content
<- curl (875531) 127.0.0.1/2807 TLS1.2

   0000  47 45 54 20 2F 3F 73 65 63 72 65 74 3D 31 37 38  GET /?secret=178
   0010  31 30 20 48 54 54 50 2F 31 2E 31 0D 0A 48 6F 73  10 HTTP/1.1..Hos
   0020  74 3A 20 6C 6F 63 61 6C 68 6F 73 74 3A 32 38 30  t: localhost:280
   0030  37 0D 0A 55 73 65 72 2D 41 67 65 6E 74 3A 20 63  7..User-Agent: c

-> curl (875531) 127.0.0.1/2807 TLS1.2

   0000  48 54 54 50 2F 31 2E 30 20 32 30 30 20 6F 6B 0D  HTTP/1.0 200 ok.
   0010  0A 43 6F 6E 74 65 6E 74 2D 74 79 70 65 3A 20 74  .Content-type: t
   0020  65 78 74 2F 68 74 6D 6C 0D 0A 0D 0A 3C 48 54 4D  ext/html....<HTM
   0030  4C 3E 3C 42 4F 44 59 20 42 47 43 4F 4C 4F 52 3D  L><BODY BGCOLOR=
```

HTTP/2

```
<- curl (904765) 208.97.177.124/443 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  50 52 49 20 2A 20 48 54 54 50 2F 32 2E 30 0D 0A  PRI * HTTP/2.0..
   0010  0D 0A 53 4D 0D 0A 0D 0A                          ..SM....

<- curl (904765) 208.97.177.124/443 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  00 00 12 04 00 00 00 00 00 00 03 00 00 00 64 00  ..............d.
   0010  04 40 00 00 00 00 02 00 00 00 00                .@.........

<- curl (904765) 208.97.177.124/443 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  00 00 04 08 00 00 00 00 00 3F FF 00 01           .........?...
```

content is much more difficult to get

must support HTTP/2 in peetch

Extracting and Exporting Keys

```
[0xffffb0325c70]> pd 2 @ sym.SSL_get_session
            ;-- sym.SSL_get_session:
            0xffffb032d518      008842f9       ldr x0, [x0, 0x510]     ; [0x510:4]=-1 ; 1296
            0xffffb032d51c      c0035fd6       ret
```

extract keys from the ssl_session_st structure

- offsets could be guessed at runtime

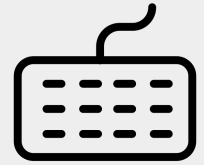
export keys in a NSS Key Log

- simple plaintext format
- supports TLS1.2 & TLS 1.3
- tools support: Firefox, curl, Wireshark, Scapy…

https://firefox-source-docs.mozilla.org/security/nss/legacy/key_log_format/index.html

peetch Demo #3

decrypting secret_binary TLS traffic



Created by Sarah
from Noun Project

```
01 $ (sleep 5; secret_binary) &
02 # peetch tls --write &
secret_binary (930462) 188.114.96.6/443 TLS1.2 ECDHE-ECDSA-CHACHA20-POLY1305
03 # peetch dump --write traffic.pcapng
04 ^C
05
06 $ editcap --inject-secrets tls,930462-master_secret.log traffic.pcapng traffic-ms.pcapng
07
08 $ scapy
09 >>> load_layer("tls")
10 >>> conf.tls_session_enable = True
11 >>> l = rdpcap("traffic-ms.pcapng")
12 >>> l[13][TLS].msg
[<TLSApplicationData  data='GET /?name=highly%20secret%20information HTTP/1.1\r\nHost:
hello.guedou.workers.dev\r\nUser-Agent: curl/7.68.0\r\nAccept: */*\r\n\r\n' |>]
```

WIP - Transparent TLS Proxy

```
01 # peetch proxy
02 [!] Proxying OpenSSL traffic
03 [+] Decrypting traffic to 208.97.177.124/443 via 127.0.0.1/33305
04     <-- 10.211.55.10 > 208.97.177.124 tcp
05     --> 208.97.177.124 > 127.0.0.1 tcp
06     --> 208.97.177.124 > 127.0.0.1 tcp
07     --> 208.97.177.124 > 127.0.0.1 tcp
08     <-- 10.211.55.10 > 208.97.177.124 tcp
09     --> 208.97.177.124 > 127.0.0.1 tcp
10     <-- 10.211.55.10 > 208.97.177.124 tcp
11     --> 208.97.177.124 > 127.0.0.1 tcp
12     <-- 10.211.55.10 > 208.97.177.124 tcp
13
14 ###[ TLS Application Data ]###
15   data      = 'GET /?name=highly%20secret%20information HTTP/1.1\r\nHost: www.perdu.com\r\nUser-Agent:
curl/7.68.0\r\nAccept: */*\r\n\r\n'
```

Questions?
Issues?
PR?

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Today Goals

experiment with eBPF as a security tool

try it yourself back home

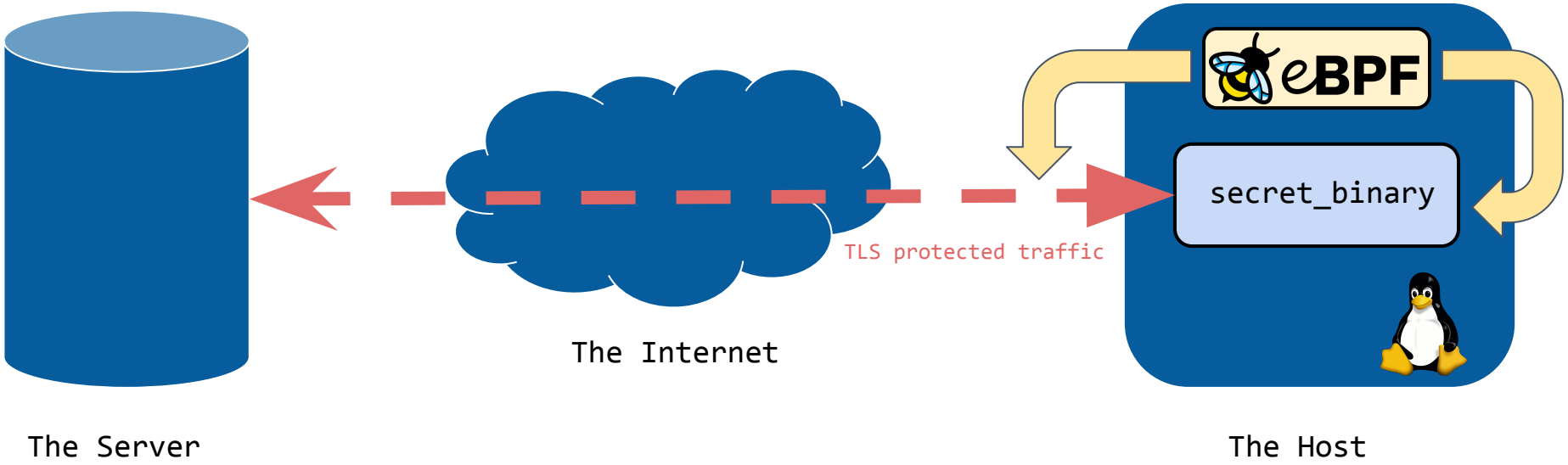
discuss uses-cases with examples

focus on TLS analysis

snoop on a local process

network traffic, function calls…

Today Setup



eBPF used to snoop on the secret_binary process

it runs on the host as root

Objective #1

identify a local process network activity on Linux

Why?

save a network capture and associated processes

capture now and analyze later

discard traffic associated with a noisy process

SSH and Firefox are usually not interesting

focus attention on a specific process

malware only traffic

Linux Possible Options

alternatives yet missing process information

two candidate solutions

1. sniff a specific user traffic
   using iptables NFLOG feature

2. sniff a specific process traffic
   using a dedicated network namespace

Objective #3

get cryptographic keys from memory and decrypt traffic

Why?

defeat certificate pinning

no need to patch the binary

decrypt with networking tools

like Wireshark, Scapy

TLS 101

succession of unauthenticated messages

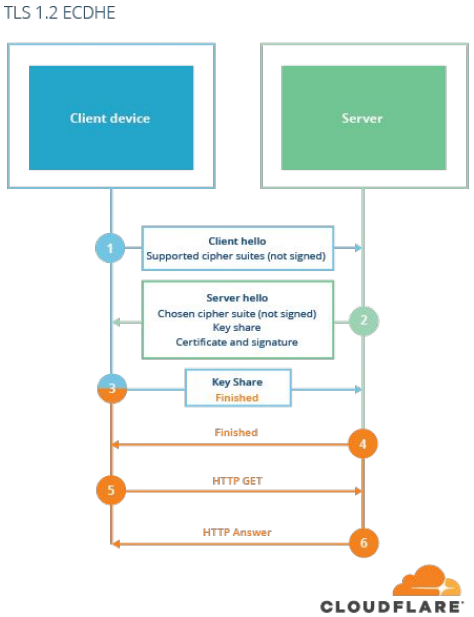
ClientHello, ServerHello, Certificate…

trusting the server is enough

must validate its certificate

resulting shared cryptographic session keys

used to protect traffic



From https://blog.cloudflare.com/rfc-8446-aka-tls-1-3/

Decrypting TLS Traffic

steal server RSA private key

- nowadays not pertinent
- does not defeat Perfect Forward Secrecy

access TLS session keys

- get the master secret

Tool #3 Blueprint

1 . explore OpenSSL structures
not designed to be accessed externally

2 . get a pointer to the master secret
from SSL_get_session()

3 . get the TLS ciphersuite
enhance the output

See https://github.com/openssl/openssl/blob/master/ssl/ssl_local.h

struct ssl_session_st pointer

```
[0xffffb0325c70]> pd 2 @ sym.SSL_get_session
            ;-- sym.SSL_get_session:
            0xffffb032d518      008842f9       ldr x0, [x0, 0x510]     ; [0x510:4]=-1 ; 1296
            0xffffb032d51c      c0035fd6       ret
```

offset to the ssl_session_st structure

could be emulated with miasm, or radare2 ESIL

Exporting & Importing Keys

NSS Key Log

- simple plaintext format
- supports TLS1.2 & TLS 1.3

many tools supports it

- exporters: Firefox, curl…
- importers: Wireshark, Scapy…

https://firefox-source-docs.mozilla.org/security/nss/legacy/key_log_format/index.html

Extract Master Secret from ssl_session_st

```
# peetch tls --secrets
<- secret_binary (907675) 188.114.97.6/2807 TLS1.2 ECDHE-RSA-AES256-GCM-SHA384

   CLIENT_RANDOM 28071980 c3266a14409a49fc482a0d9074 .. 2830fccce7325b1e69e73dd4a28ee79a3eceb
```

unsigned char master_key[TLS13_MAX_RESUMPTION_PSK_LENGTH];

it is 48 bytes for TLS1.2

Decrypting secret_binary TLS Traffic

```
01 $ (sleep 5; secret_binary) &
02 # peetch tls --write &
secret_binary (930462) 188.114.96.6/443 TLS1.2 ECDHE-ECDSA-CHACHA20-POLY1305
03 # peetch dump --write traffic.pcapng
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12 >>> l[13][TLS].msg
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hello.guedou.workers.dev\r\nUser-Agent: curl/7.68.0\r\nAccept: */*\r\n\r\n' |>]
```

Open-Source Contributions on github.com

secdev/scapy

- NSS Key Log support
- PCAPNg writing & comment option

iovisor/bcc

- CGROUP_SOCK_ADDR program type support

quarkslab/peetch

- the eBPF & TLS playground

Get the slides at

Quarkslab

eBPF 101

Quarkslab

cBPF

classical Berkeley Packet Filter

See https://www.tcpdump.org/papers/bpf-usenix93.pdf

define network packets filters

commonly used with tcpdump

filter expressions compiled to BPF bytecode

host 1.1.1.1 and tcp and port 443

attached to a RAW socket and processed by the kernel

SO_ATTACH_FILTER or SO_ATTACH_BPF

Convert a Filter to Bytecode

```
# tcpdump -i eth0 -d 'host 1.1.1.1 and tcp and port 443'
(000) ldh      [12]
(001) jeq      #0x800           jt 2    jf 16
(002) ld       [26]
(003) jeq      #0x1010101       jt 6    jf 4
(004) ld       [30]
(005) jeq      #0x1010101       jt 6    jf 16
(006) ldb      [23]
(007) jeq      #0x6             jt 8    jf 16
(008) ldh      [20]
(009) jset     #0x1fff          jt 16   jf 10
(010) ldxb     4*([14]&0xf)
(011) ldh      [x + 14]
(012) jeq      #0x1bb           jt 15   jf 13
(013) ldh      [x + 16]
(014) jeq      #0x1bb           jt 15   jf 16
(015) ret      #262144
(016) ret      #0
```

Using a filter

```
# tcpdump -ni eth0 -X 'host 1.1.1.1 and tcp and port 443'
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 262144 bytes
17:34:44.647471 IP 10.211.55.4.39712 > 1.1.1.1.443: Flags [S], seq 649388654, win 64240,
options [mss 1460,sackOK,TS val 951387719 ecr 0,nop,wscale 7], length 0
     0x0000:  4500 003c 360c 4000 4006 c0d7 0ad3 3704  E..<6.@.@.....7.
     0x0010:  0101 0101 9b20 01bb 26b4 e26e 0000 0000  ........&..n....
     0x0020:  a002 faf0 4407 0000 0204 05b4 0402 080a  ....D...........
     0x0030:  38b5 0647 0000 0000 0103 0307            8..G........
17:34:44.676148 IP 1.1.1.1.443 > 10.211.55.4.39712: Flags [S.], seq 1336932985, ack 649388655,
win 32768, options [mss 1460,wscale 1,nop], length 0
     0x0000:  4500 0030 ed3c 0000 8006 09b3 0101 0101  E..0.<..........
     0x0010:  0ad3 3704 01bb 9b20 4faf fa79 26b4 e26f  ..7.....O..y&..o
     0x0020:  7012 8000 d00c 0000 0204 05b4 0303 0101  p...............
```

eBPF

extended Berkeley Packet Filter

like cBPF but better

internally Linux convert cBPF to eBPF

cool features

designed to be JITed
function calls

attach an eBPF program to an event

packets, kernel functions…

eBPF Programs

eBPF programs types

XDP, TRACEPOINT, UPROBE, KPROBE...

eBPF maps

share data between kernel and userspace

eBPF verifier

ensure programs safety
your worst best friend

Focus on Kernel Probes

break into any kernel function

- INT3 on i386 and x86_64

collect information

- can't modify functions behavior

two types

- kprobe - anywhere
- kretprobe - when a function returns

Using a kprobe Manually

```
00 # echo 'p:sstic23 do_sys_openat2 filename=+0($arg2):string' >
/sys/kernel/debug/tracing/kprobe_events
01 # echo 1 > /sys/kernel/debug/tracing/events/kprobes/sstic23/enable
02
03 # cat /sys/kernel/debug/tracing/trace_pipe
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   filename="/lib/aarch64-linux-gnu/libz.so.1"
07 secret_binary-1603837 [000] dn.. 242641.480695: sstic23: (do_sys_openat2+0x0/0x164)
   filename="/lib/aarch64-linux-gnu/libpthread.so.0"
```
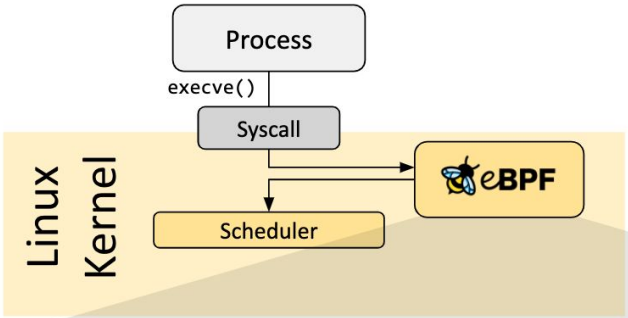

three simple steps from a root shell

create the kprobe, enable it & enjoy

Process Execution Example

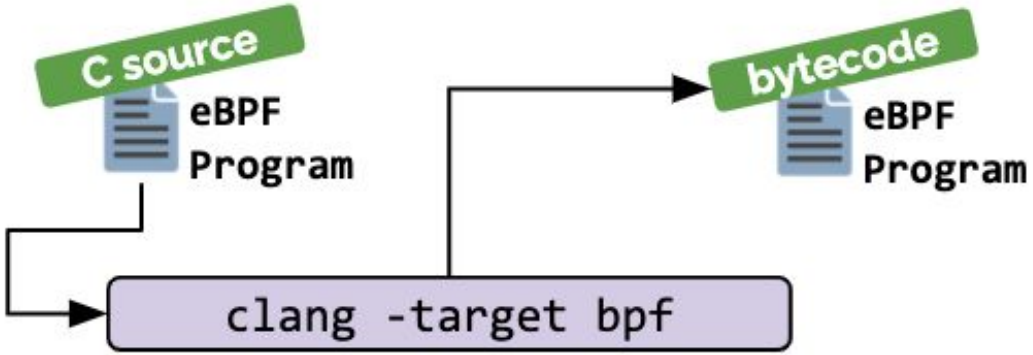



```c
int syscall__ret_execve(struct pt_regs *ctx)
{
        struct comm_event event = {
                .pid = bpf_get_current_pid_tgid() >> 32,
                .type = TYPE_RETURN,
        };

        bpf_get_current_comm(&event.comm, sizeof(event.comm));
        comm_events.perf_submit(ctx, &event, sizeof(event));

        return 0;
}
```

1. attach to execve syscall
2. get PID and name
3. submit them to a map

From https://ebpf.io

From C to eBPF bytecode



compiled to eBPF with clang

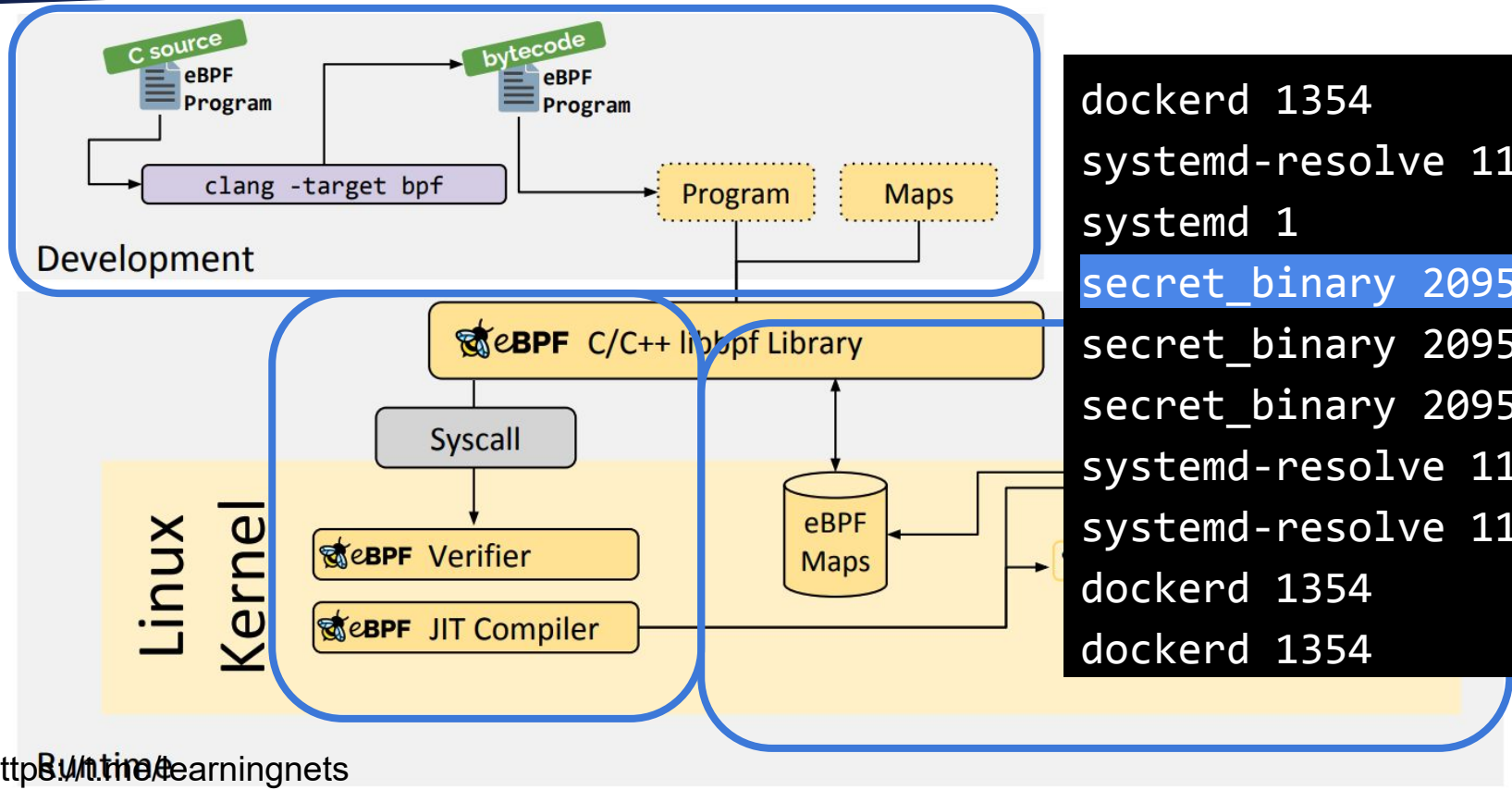
gcc can do it too

bytecode loaded with the bpf syscall

abstracted thanks to eBPF loaders

From https://ebpf.io

The High-Level Overview




```
dockerd 1354
systemd-resolve 1152
systemd 1
secret_binary 20958
secret_binary 20958
secret_binary 20958
systemd-resolve 1152
systemd-resolve 1152
dockerd 1354
dockerd 1354
```

https://t.me/learningnets

eBPF Tools

Check https://ebpf.io/projects

limited languages options

C, Rust, awk-like

many loaders

Go, Rust, Python, bpftrace

beloved security tools works!

Ghidra, objdump, readelf...

eBPF & Networking

Quarkslab

Objective #1

identify a local process network activity on Linux

Why?

save a network capture and associated processes

capture now and analyze later

discard traffic associated with a noisy process

SSH and Firefox are usually not interesting

focus attention on a specific process

malware only traffic

Linux Possible Options

alternatives yet missing process information

two candidate solutions

1. sniff a specific user traffic
   using iptables NFLOG feature

2. sniff a specific process traffic
   using a dedicated network namespace

Existing Tools on macOS

```
# tcpdump -i pktap,en0 host 1.1.1.1 -w out.pcapng
tcpdump: data link type PKTAP
tcpdump: listening on pktap,en0, link-type PKTAP (Apple DLT_PKTAP), capture
size 262144 bytes
2 packets captured
78 packets received by filter
0 packets dropped by kernel
```

macOS tcpdump do it natively

specify pktap as the interface name

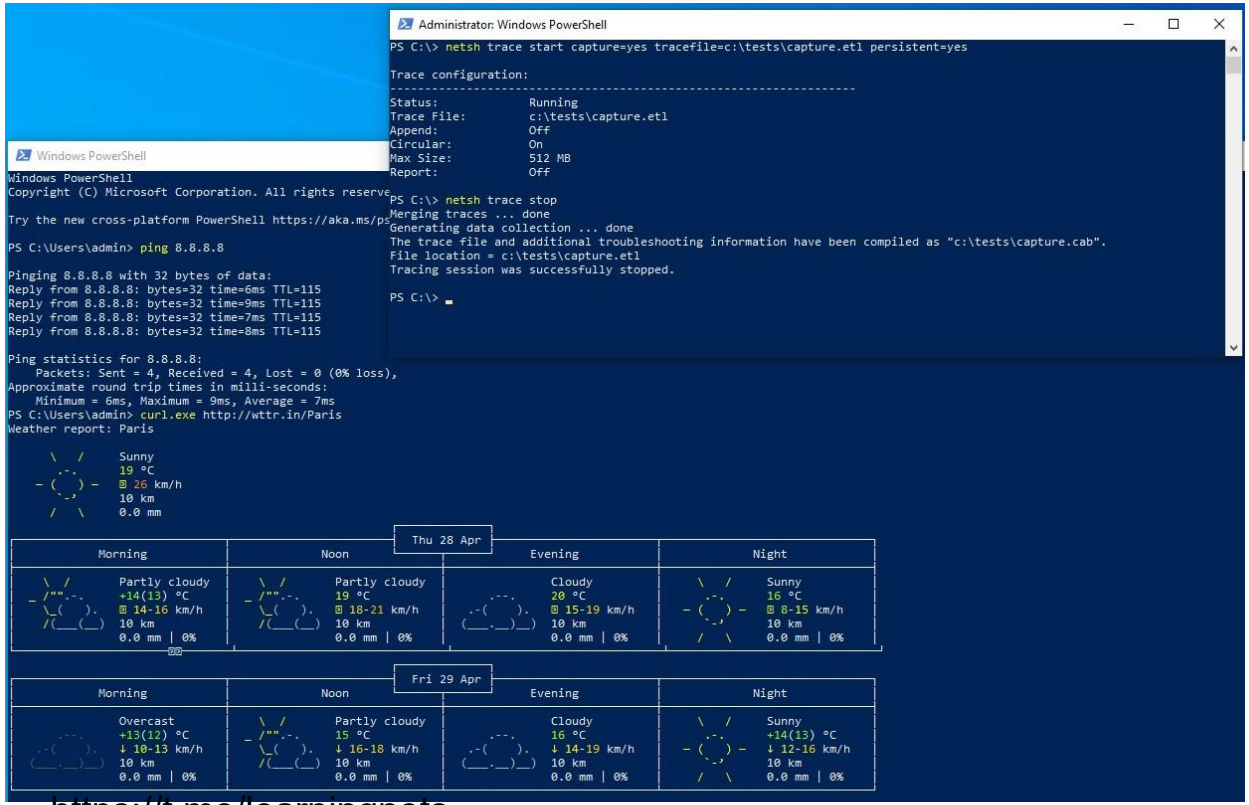
Existing Tools on macOS

```
$ tcpdump -k -r out.pcapng
reading from PCAP-NG file out.pcapng
14:31:36.627265 (en0, proc dig:10855, svc BE, out, so) IP 10.0.3.61.57044 >
one.one.one.one.domain: 26562+ [1au] A? www.example.org. (44)
14:31:36.640010 (en0, proc dig:10855, svc BE, in, so) IP
one.one.one.one.domain > 10.0.3.61.57044: 26562$ 1/0/1 A 93.184.216.34 (60)
```

process information stored in PCAPng

Apple specific option understood by Wireshark

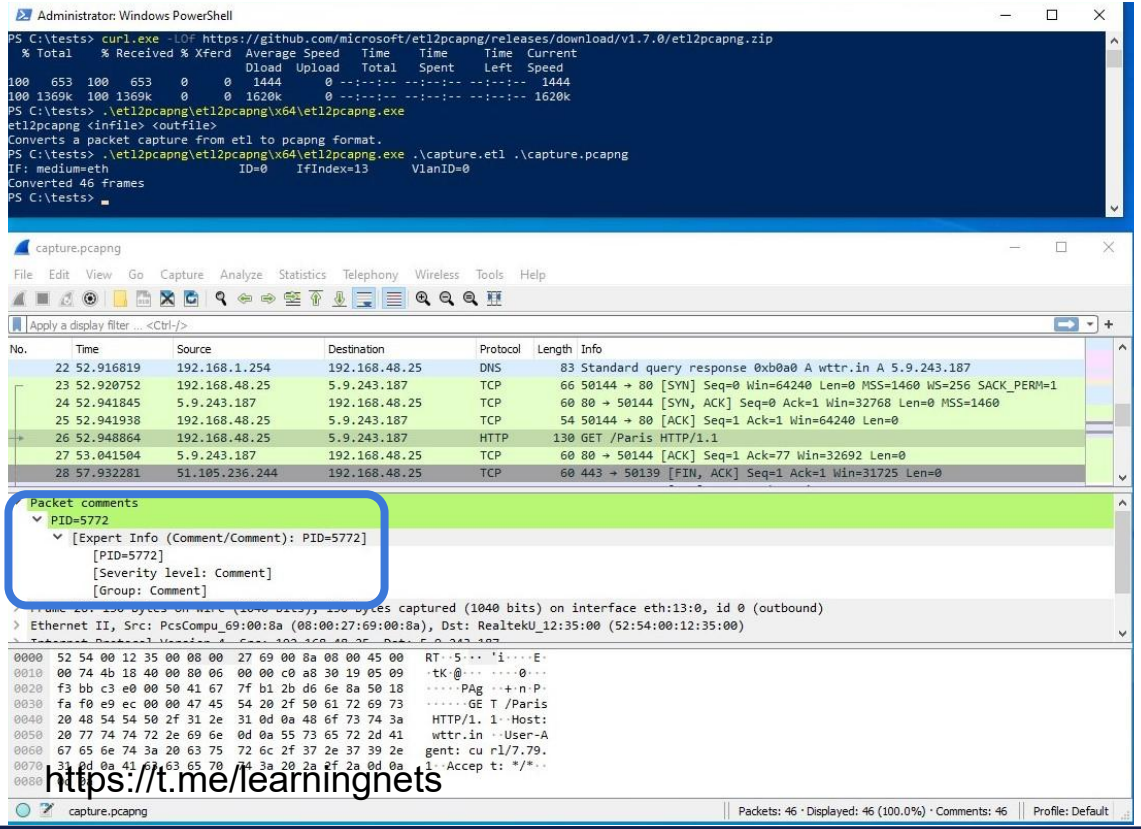
Existing Tools on Windows



netsh trace
capture=yes

trace saved in ETL

Existing Tools on Windows



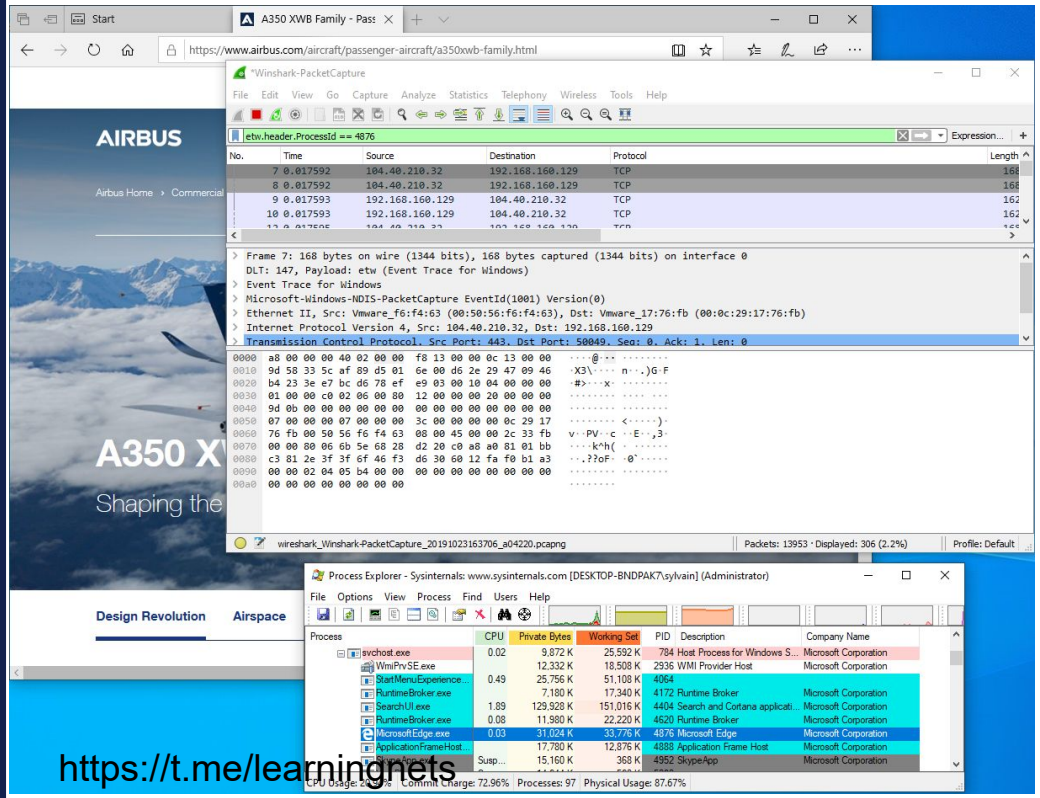
etl2pcapng tool

convert ETL to pcapng

visualize in Wireshark

info in PCAPng comments

Existing Tools - Windows



Winshark captures ETW

mix system and network information

https://github.com/airbus-cert/winshark

Tool #1 Blueprint

1 . sniff packets
with eBPF

2 . get per packet process information
process name and ID

3 . identify TLS messages
with Scapy

Sniff Packets with eBPF

custom Traffic Control (TC)

an eBPF program can alter traffic

two custom programs exist

custom classifier CLS BPF_PROG_TYPE_SCHED_CLS

custom actions ACT BPF_PROG_TYPE_SCHED_ACT

how?

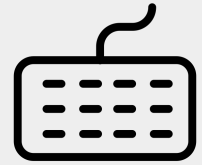
access packets in a TC classifier

send them to userland using an eBPF map

Simple eBPF TC Classifier in C

```
01 int process_frame(struct __sk_buff *skb)
02 {
03   // Data accessors
04   unsigned char *data = (void *)(long)skb->data;
05   unsigned char *data_end = (void *)(long)skb->data_end;
06
07   // Mapping data to the Ethernet and IP headers
08   struct ethhdr *eth = (struct ethhdr *)data;
09   struct iphdr *iph = (struct iphdr*) (data + sizeof(struct ethhdr));
10
11   // Simple length check
12   if ((data + sizeof(struct ethhdr) + sizeof(struct iphdr)) > data_end)
13     return TC_ACT_OK;
14
15   // Discard everything but IPv4 and TCP
16   if (ntohs(eth->h_proto) != ETH_P_IP && iph->protocol != IPPROTO_TCP)
17     return TC_ACT_OK;
18
19   bool _unused = true;
20   skb_events.perf_submit_skb(skb, skb->len, &_unused, sizeof(_unused));
21
22   return TC_ACT_OK;
23 }
```

Peetch Demo #1



Created by Sarah
from Noun Project

sniff packets with eBPF

parsed and displayed with Scapy

```
# peetch dump --raw
Ether / IP / TCP 10.211.55.7:43908 > 208.97.177.124:https S / Padding
Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43908 SA / Padding
Ether / IP / TCP 10.211.55.7:43908 > 208.97.177.124:https A / Padding
Ether / IP / TCP 10.211.55.7:43908 > 208.97.177.124:https PA / Raw / Padding
Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43908 A / Padding
Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43908 PA / Raw / Padding
Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43908 PA / Raw / Padding
Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43908 PA / Raw / Padding
Ether / IP / TCP 10.211.55.7:43908 > 208.97.177.124:https A / Padding
```

Get Per Packet PID

`bpf_get_current_pid_tgid()` helper not available

- cannot use it in BPF_PROG_TYPE_SCHED_ACT programs

`struct flowi` describes packets parameters

- used for IPsec SA lookups
- accessible in stable LSM hooks

Per Packet PID Lookup Strategy

1 . find a hook point

for example `security_sk_classify_flow()`

2 . access the PID

using the eBPF helper function

3 . write the PID into an eBPF map

use IP & ports as indexes

security_sk_classify_flow() kprobe with bpftrace

```
01 #include <net/flow.h>
02
03 kprobe:security_sk_classify_flow {
04   $flowi = (struct flowi*) arg1;
05   if ($flowi == 0) {
06     return;
07   }
08
09   $flowi4 = $flowi->u.ip4;
10   if ($flowi4.saddr == 0) {
11     return;
12   }
13
14   $sport = bswap($flowi4.uli.ports.sport);
15   $dport = bswap($flowi4.uli.ports.dport);
16
17   $saddr = ntop(AF_INET, $flowi4.saddr);
18   $daddr = ntop(AF_INET, $flowi4.daddr);
19
20   printf("%s/%d - %s:%d -> %s:%d\n", comm, pid, $saddr, $sport, $daddr, $dport);
21 }
```

security_sk_classify_flow() kprobe Output

```
# bpftrace security_sk_classify_flow.bt
Attaching 1 probe...
secret_binary/11663 - 127.0.0.1:57338 -> 127.0.0.53:53
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 42.1.203.8:27903 -> 12.51.197.0:47654
systemd-resolve/1152 - 127.0.0.53:53 -> 127.0.0.1:57338
systemd-resolve/1152 - 127.0.0.53:53 -> 127.0.0.1:57338
secret_binary/11663 - 192.168.42.42:37890 -> 188.114.97.6:443
```

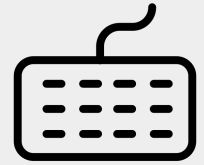
Shake Well!

1 . compute a packet hash
    from IP & ports

2 . use hash to lookup PID information
    match PID & packets

3 . display everything
    relax

Peetch Demo #2



display process information along packets

retrieved using an eBPF map

```
# peetch dump
curl/24102 - Ether / IP / TCP 10.211.55.7:43912 > 208.97.177.124:https S / Padding
curl/24102 - Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43912 SA / Padding
curl/24102 - Ether / IP / TCP 10.211.55.7:43912 > 208.97.177.124:https A / Padding
curl/24102 - Ether / IP / TCP 10.211.55.7:43912 > 208.97.177.124:https PA / Raw / Padding
curl/24102 - Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43912 A / Padding
curl/24102 - Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43912 PA / Raw / Padding
curl/24102 - Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43912 PA / Raw / Padding
curl/24102 - Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43912 PA / Raw / Padding
curl/24102 - Ether / IP / TCP 208.97.177.124:https > 10.211.55.7:43912 PA / Raw / Padding
curl/24102 - Ether / IP / TCP 10.211.55.7:43912 > 208.97.177.124:https A / Padding
```

Storing Process Information

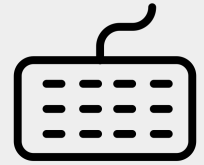
PCAPng is a good candidate

- extensible packet capture format
- options can be added to packet

comment option

- can store any text
- supported by Wireshark, tcpdump, Scapy…

Peetch Demo #3



Created by Sarah
from Noun Project

store process information along packets

filter TLS and display results with Scapy

```
00 # peetch dump --write csw22.pcapng
01 $ scapy
02 >>> rdpcap("csw22.pcapng")
03 <csw22.pcapng: TCP:37 UDP:0 ICMP:0 Other:0>
04 >>> l = _.filter(lambda p: TLS in p)
05 <filtered test.pcapng: TCP:13 UDP:0 ICMP:0 Other:0>
06 >>> l[0].summary()
07 'Ether / IP / TCP / TLS 10.211.55.7:44154 > 208.97.177.124:443 / TLS / TLS Handshake
- Client Hello / Padding'
08 >>> l[0].comment
09 'secret_binary/26380'
```

eBPF & Userspace

Quarkslab

Objective #2

identify when a process uses OpenSSL functions

Why?

observe a process behavior

hook functions and execute eBPF program

access data manipulated by OpenSSL

plaintext is nearby!

Setting an OpenSSL uprobe Manually

```
# echo "p:SSL_read /lib/aarch64-linux-gnu/libssl.so.1.1:0x34990" >
/sys/kernel/debug/tracing/uprobe_events

# echo 1 > /sys/kernel/debug/tracing/events/uprobes/SSL_read/enable

# cat /sys/kernel/debug/tracing/trace_pipe
     secret_binary-72453   [000] .... 33213.115372: SSL_read: (0xffffab025990)
     secret_binary-72453   [000] .... 33213.116449: SSL_read: (0xffffab025990)
     secret_binary-72453   [000] .... 33213.126230: SSL_read: (0xffffab025990)
     secret_binary-72453   [000] .... 33213.126467: SSL_read: (0xffffab025990)
```

three simple steps from a root shell

create the uprobe, enable it & enjoy

Setting an OpenSSL uprobe with bpftrace

```
# bpftrace -e 'uprobe:/lib/aarch64-linux-gnu/libssl.so:SSL_read
{ printf("SSL_read() from %s (%d)\n", comm, pid); }'
Attaching 1 probe...
SSL_read() from secret_binary (306772)
SSL_read() from secret_binary (306772)
SSL_read() from secret_binary (306796)
```

hook and display information with a one-liner

perfect way to experiment with eBPF

Tool #2 Blueprint

1 . hook connect()

send destination IP and port to an eBPF map

2 . hook TLS libraries functions

like SSL_read, or gnutls_record_recv

3 . mix information inside TLS hooks

retrieve data from connect()

send an event to userland

connect() tracepoint with bpftrace

```
01 #include <linux/in.h>
02
03 tracepoint:syscalls:sys_enter_connect {
04   $addr_in = (struct sockaddr_in *)args->uservaddr;
05
06   if ($addr_in->sin_family == 2) { // AF_INET
07     $addr = ntop($addr_in->sin_family, $addr_in->sin_addr.s_addr);
08
09     if ($addr_in->sin_port > 0) {
10       printf("%s/%d\n", $addr, bswap($addr_in->sin_port));
11     }
12   }
13 }
```

access sockaddr_in structure

check values and print information

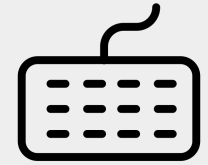
connect() tracepoint Output

```
# bpftrace sys_enter_connect.bt
Attaching 1 probe...
127.0.0.53/53
188.114.97.6/443
```

monitor on-going TCP connections

create the uprobe, enable it & enjoy

Peetch Demo #3

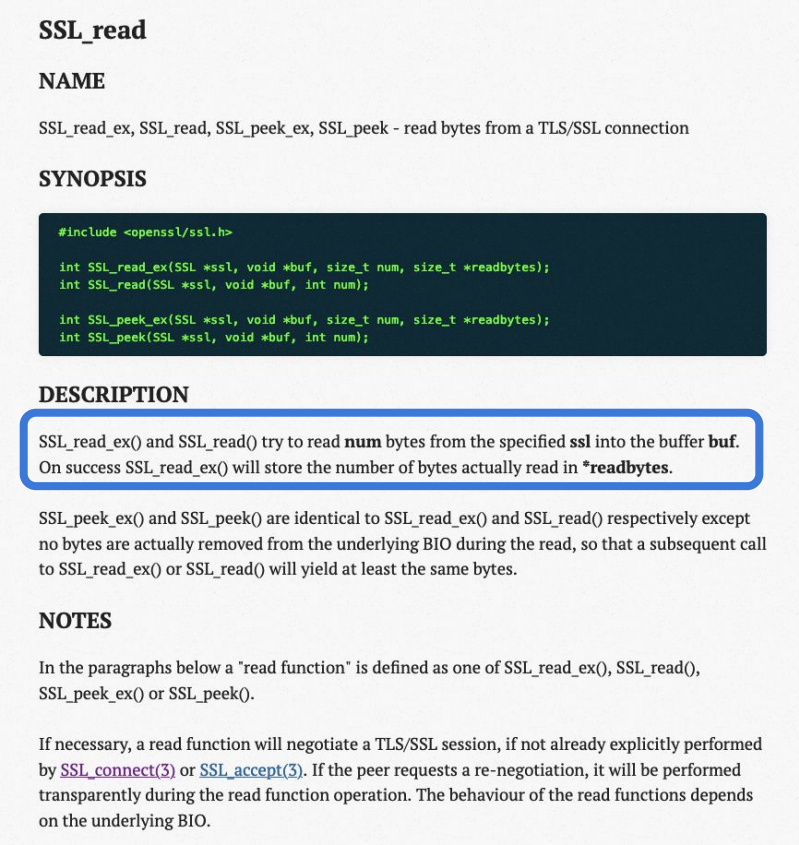


show processes using OpenSSL

get IP and ports from connect()

```
# peetch tls --directions
<- secret_binary (61673) 188.114.97.6/443
-> secret_binary (61673) 188.114.97.6/443
-> secret_binary (61673) 188.114.97.6/443
<- mutt (16453) 85.65.32.2/993
-> mutt (16453) 85.65.32.2/993
-> mutt (16453) 85.65.32.2/993
```

Accessing Unencrypted Data



SSL_read

NAME

SSL_read_ex, SSL_read, SSL_peek_ex, SSL_peek - read bytes from a TLS/SSL connection

SYNOPSIS

```
#include <openssl/ssl.h>

int SSL_read_ex(SSL *ssl, void *buf, size_t num, size_t *readbytes);
int SSL_read(SSL *ssl, void *buf, int num);

int SSL_peek_ex(SSL *ssl, void *buf, size_t num, size_t *readbytes);
int SSL_peek(SSL *ssl, void *buf, int num);
```

DESCRIPTION

SSL_read_ex() and SSL_read() try to read **num** bytes from the specified **ssl** into the buffer **buf**. On success SSL_read_ex() will store the number of bytes actually read in ***readbytes**.

SSL_peek_ex() and SSL_peek() are identical to SSL_read_ex() and SSL_read() respectively except no bytes are actually removed from the underlying BIO during the read, so that a subsequent call to SSL_read_ex() or SSL_read() will yield at least the same bytes.

NOTES

In the paragraphs below a "read function" is defined as one of SSL_read_ex(), SSL_read(), SSL_peek_ex() or SSL_peek().

If necessary, a read function will negotiate a TLS/SSL session, if not already explicitly performed by SSL_connect(3) or SSL_accept(3). If the peer requests a re-negotiation, it will be performed transparently during the read function operation. The behaviour of the read functions depends on the underlying BIO.

OpenSSL manipulates plaintext

eBPF programs can access it

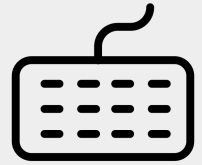
a uretprobe is needed for SSL_read

data is only available after its call

Peetch Demo #4

dump plaintext

HTTP/1.1 works fine!



Created by Sarah from Noun Project

```
# peetch tls --content
<- curl (875531) 127.0.0.1/2807 TLS1.2

   0000  47 45 54 20 2F 3F 73 65 63 72 65 74 3D 31 37 38  GET /?secret=178
   0010  31 30 20 48 54 54 50 2F 31 2E 31 0D 0A 48 6F 73  10 HTTP/1.1..Hos
   0020  74 3A 20 6C 6F 63 61 6C 68 6F 73 74 3A 32 38 30  t: localhost:280
   0030  37 0D 0A 55 73 65 72 2D 41 67 65 6E 74 3A 20 63  7..User-Agent: c

-> curl (875531) 127.0.0.1/2807 TLS1.2

   0000  48 54 54 50 2F 31 2E 30 20 32 30 30 20 6F 6B 0D  HTTP/1.0 200 ok.
   0010  0A 43 6F 6E 74 65 6E 74 2D 74 79 70 65 3A 20 74  .Content-type: t
   0020  65 78 74 2F 68 74 6D 6C 0D 0A 0D 0A 3C 48 54 4D  ext/html....<HTM
   0030  4C 3E 3C 42 4F 44 59 20 42 47 43 4F 4C 4F 52 3D  L><BODY BGCOLOR=
```

Several Issues with Unencrypted Data

HTTP/2 is now common

- it is a binary protocol

HTTP/1.1 answers are usually compressed

HTTP/2

```
<- curl (904765) 208.97.177.124/443 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  50 52 49 20 2A 20 48 54 54 50 2F 32 2E 30 0D 0A  PRI * HTTP/2.0..
   0010  0D 0A 53 4D 0D 0A 0D 0A                          ..SM....

<- curl (904765) 208.97.177.124/443 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  00 00 12 04 00 00 00 00 00 00 03 00 00 00 64 00  ..............d.
   0010  04 40 00 00 00 00 02 00 00 00 00                 .@.........

<- curl (904765) 208.97.177.124/443 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  00 00 04 08 00 00 00 00 00 3F FF 00 01           .........?...
```

content is much more difficult to get

must support HTTP/2 in peetch

Dump TLS Keys and Decrypt Traffic

Quarkslab

Objective #3

get cryptographic keys from memory and decrypt traffic

Why?

defeat certificate pinning

no need to patch the binary

decrypt with networking tools

like Wireshark, Scapy

TLS 101

succession of unauthenticated messages

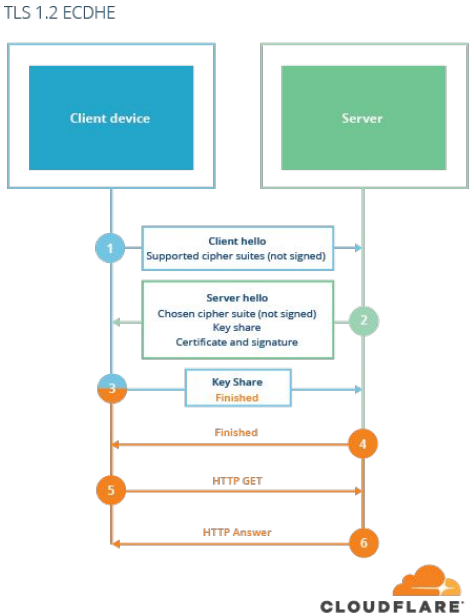
ClientHello, ServerHello, Certificate…

trusting the server is enough

must validate its certificate

resulting shared cryptographic session keys

used to protect traffic



From https://blog.cloudflare.com/rfc-8446-aka-tls-1-3/

Decrypting TLS Traffic

steal server RSA private key

- nowadays not pertinent
- does not defeat Perfect Forward Secrecy

access TLS session keys

- get the master secret

Tool #3 Blueprint

1 . explore OpenSSL structures
not designed to be accessed externally

2 . get a pointer to the master secret
from SSL_get_session()

3 . get the TLS ciphersuite
enhance the output

See https://github.com/openssl/openssl/blob/master/ssl/ssl_local.h

struct ssl_session_st pointer

```
[0xffffb0325c70]> pd 2 @ sym.SSL_get_session
            ;-- sym.SSL_get_session:
            0xffffb032d518      008842f9       ldr x0, [x0, 0x510]     ; [0x510:4]=-1 ; 1296
            0xffffb032d51c      c0035fd6       ret
```

offset to the ssl_session_st structure

could be emulated with miasm, or radare2 ESIL

Extract the TLS Cipher Suite

```
# peetch tls --content
<- curl (894762) 127.0.0.1/2807 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  47 45 54 20 2F 3F 73 65 63 72 65 74 3D 31 35 34  GET /?secret=154
   0010  33 20 48 54 54 50 2F 31 2E 31 0D 0A 48 6F 73 74  3 HTTP/1.1..Host
   0020  3A 20 6C 6F 63 61 6C 68 6F 73 74 3A 32 38 30 37  : localhost:2807
   0030  0D 0A 55 73 65 72 2D 41 67 65 6E 74 3A 20 63 75  ..User-Agent: cu

-> curl (894762) 127.0.0.1/2807 TLS1.3 TLS_AES_256_GCM_SHA384

   0000  48 54 54 50 2F 31 2E 30 20 32 30 30 20 6F 6B 0D  HTTP/1.0 200 ok.
   0010  0A 43 6F 6E 74 65 6E 74 2D 74 79 70 65 3A 20 74  .Content-type: t
   0020  65 78 74 2F 70 6C 61 69 6E 0D 0A 0D 0A 45 72 72  ext/plain....Err
   0030  6F 72 20 6F 70 65 6E 69 6E 67 20 27 3F 73 65 63  or opening '?sec
```

```
struct ssl_cipher_t *cipher;
```

that's a string!

Exporting & Importing Keys

NSS Key Log

- simple plaintext format
- supports TLS1.2 & TLS 1.3

many tools supports it

- exporters: Firefox, curl…
- importers: Wireshark, Scapy…

https://firefox-source-docs.mozilla.org/security/nss/legacy/key_log_format/index.html

Extract Master Secret from ssl_session_st

```
# peetch tls --secrets
<- secret_binary (907675) 188.114.97.6/2807 TLS1.2 ECDHE-RSA-AES256-GCM-SHA384

   CLIENT_RANDOM 28071980 c3266a14409a49fc482a0d9074 .. 2830fccce7325b1e69e73dd4a28ee79a3eceb
```

unsigned char master_key[TLS13_MAX_RESUMPTION_PSK_LENGTH];

it is 48 bytes for TLS1.2

Decrypting secret_binary TLS Traffic

```
01 $ (sleep 5; secret_binary) &
02 # peetch tls --write &
secret_binary (930462) 188.114.96.6/443 TLS1.2 ECDHE-ECDSA-CHACHA20-POLY1305
03 # peetch dump --write traffic.pcapng
04 ^C
05
06 $ editcap --inject-secrets tls,930462-master_secret.log traffic.pcapng traffic-ms.pcapng
07
08 $ scapy
09 >>> load_layer("tls")
10 >>> conf.tls_session_enable = True
11 >>> l = rdpcap("traffic-ms.pcapng")
12 >>> l[13][TLS].msg
[<TLSApplicationData  data='GET /?name=highly%20secret%20information HTTP/1.1\r\nHost:
hello.guedou.workers.dev\r\nUser-Agent: curl/7.68.0\r\nAccept: */*\r\n\r\n' |>]
```

Transparent Traffic Interception

Objective #4

intercept OpenSSL traffic transparently and decrypt it on the fly

Why?

demonstrate elaborated eBPF usage

many programs and maps interacting

simplify TLS traffic manipulation

plug it to burp, mitmproxy...

CGROUP_SOCK_ADDR eBPF Programs

alter socket behaviors

connect(), bind()...

change connect() destination IP & port

could also change source IP & port

Modify connect() Behavior with eBPF

```
00 int connect_v4_prog(struct bpf_sock_addr *ctx)
01 {
02   if (bpf_ntohs(ctx->user_port) == 53) {
03     bpf_trace_printk("connect_v4_prog() - %d\\n", bpf_ntohs(ctx->user_port));
04     ctx->user_ip4 = bpf_htonl(0x01010101); // 1.1.1.1
05   }
06   return 1;
07 }
```

redirect all TCP DNS traffic

to 1.1.1.1

Boring dig Output

```
00 $ dig @8.8.8.8 +tcp +nsid www.perdu.com
01
02 ; <<>> DiG 9.16.8-Ubuntu <<>> @8.8.8.8 +tcp +nsid www.perdu.com
03 ;; global options: +cmd
04 ;; Got answer:
05 ;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 24528
06 ;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1
07
08 ;; OPT PSEUDOSECTION:
09 ; EDNS: version: 0, flags:; udp: 1232
10 ; NSID: 31 39 6d 34 32 39 ("19m429")
11 ;; QUESTION SECTION:
12 ;www.perdu.com.                 IN      A
13
14 ;; ANSWER SECTION:
15 www.perdu.com.          4198    IN      A       208.97.177.124
16
17 ;; Query time: 11 msec
18 ;; SERVER: 8.8.8.8#53(8.8.8.8)
19 ;; WHEN: Wed May 18 12:15:10 PDT 2022
20 ;; MSG SIZE  rcvd: 68
```

8.8.8.8 does not support NSID

1.1.1.1 is answering

Tool #4 Blueprint

1 . interception machinery

identify process loading libssl.so

retrieve TLS master secrets

2 . transparent proxy

connect to the real destination

decrypt TLS traffic

Interception Machinery

1 . detect when libssl.so is opened

check the filename and write PID to a map

2 . redirect to a custom proxy

get PID candidates from the map

rewrite source port with the PID

store real destination in a map

3 . get the TLS master secret

send it to a map indexed by PID

Transparent Proxy

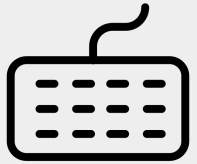
1 . connect to the real destination
retrieve the destination IP using the source port

2 . retrieve the master secret
decrypt traffic!

3 . dissect TLS messages
using Scapy

Peetch Demo #5

Transparent OpenSSL Traffic Interception & Decryption



Created by Sarah from Noun Project

Work In Progress

```
01 # peetch proxy
02 [!] Proxying OpenSSL trafic
03 [+] Decrypting traffic to 208.97.177.124/443 via 127.0.0.1/33305
04     <-- 10.211.55.10 > 208.97.177.124 tcp
05     --> 208.97.177.124 > 127.0.0.1 tcp
06     --> 208.97.177.124 > 127.0.0.1 tcp
07     --> 208.97.177.124 > 127.0.0.1 tcp
08     <-- 10.211.55.10 > 208.97.177.124 tcp
09     --> 208.97.177.124 > 127.0.0.1 tcp
10     <-- 10.211.55.10 > 208.97.177.124 tcp
11     --> 208.97.177.124 > 127.0.0.1 tcp
12     <-- 10.211.55.10 > 208.97.177.124 tcp
13
14 ###[ TLS Application Data ]###
15   data      = 'GET /?name=highly%20secret%20information HTTP/1.1\r\nHost: www.perdu.com\r\nUser-Agent:
curl/7.68.0\r\nAccept: */*\r\n\r\n'
```

Looking Ahead

eBPF is Fun!

powerful kernel and userspace hooks

available in most Linux versions

rich ecosystem

bcc, bpftrace…

new security tools ahead

eBPF simplifies putting ideas into code

Open-Source Contributions on github.com

secdev/scapy

- NSS Key Log support
- PCAPNg writing & comment option

iovisor/bcc

- CGROUP_SOCK_ADDR program type support

quarkslab/peetch

- the eBPF & TLS playground

Questions?

Quarkslab