CLOUDFLARE

Speedrun through SOCKMAP

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Cloudflare

SREcon23
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$ whoami

Linux (kernel) Team @ Cloudflare

🌽 roll out fresh kernels

🐞 squash bugs

🕵️ troubleshoot stuff

✨ prototype features

DISCLAIMER: This is not my mug

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- 🌽 roll out fresh kernels
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- ✨ prototype features

SOCKMAP co-maintainer @ Linux upstream

- 🤏 small-time (= feature) maintainer
- 🪲 fix bugs
- 🧐 review patches
- 🤔 answer questions

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About this talk

Will be helpful if you know a bit about:

- ❏ network programming (`socket`, `connect`, `sendmsg`, `recvmsg`)
- ❏ basics of eBPF (what are BPF maps, programs, hooks, `bpftool`)
- ❏ building blocks of containers (cgroups, namespaces)

Goals:

- ❏ know that SOCKMAP exists
- ❏ have idea how / when / what for use it
- ❏ feel ready to dive deeper

Agenda

1 What is SOCKMAP? What can SOCKMAP do?

2 Evolution of SOCKMAP

3 How to set up SOCKMAP?

4 How to get sockets into a SOCKMAP?

5 Supported configurations

6 Real life use cases

Section

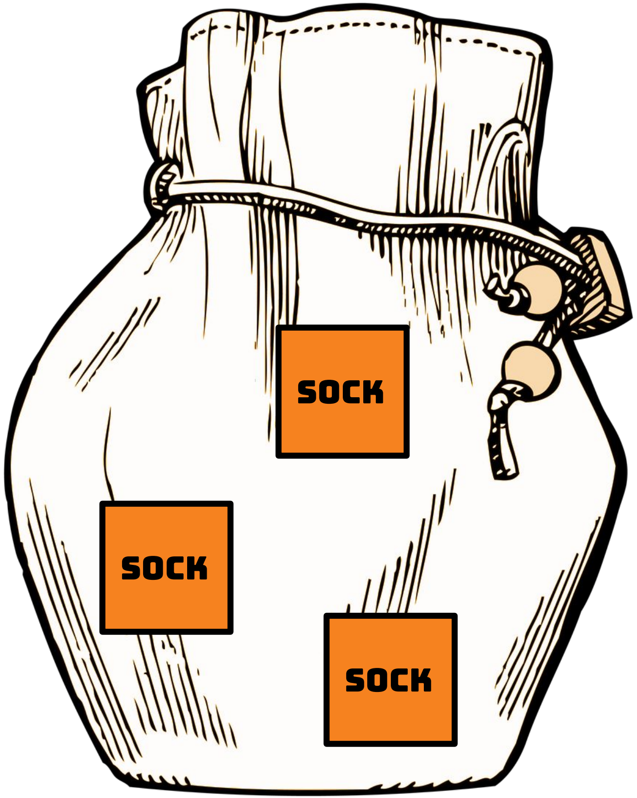
What is SOCKMAP?
&
What can SOCKMAP do?

What is SOCKMAP?

Two things

What is SOCKMAP?

Collection / container
for socket references
in Linux kernel



Rawpixel, CC0

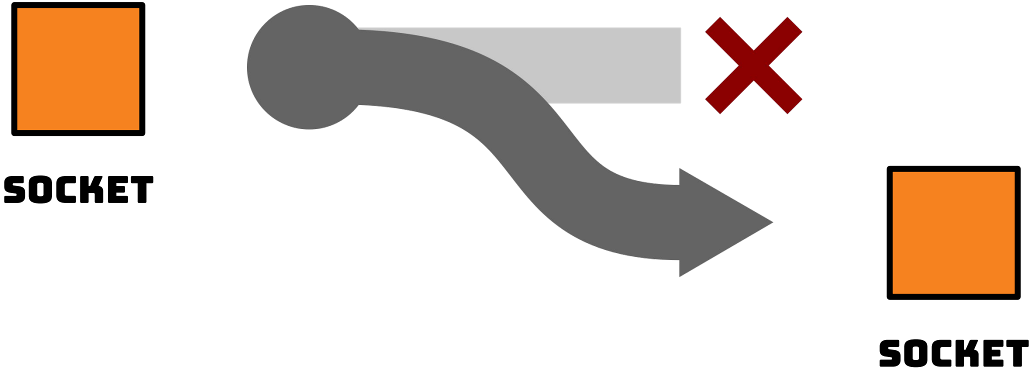
What is SOCKMAP?

SOCKMAP
API

1. **container for sockets**

- BPF map (K/V store)
- holds weak refs to sockets

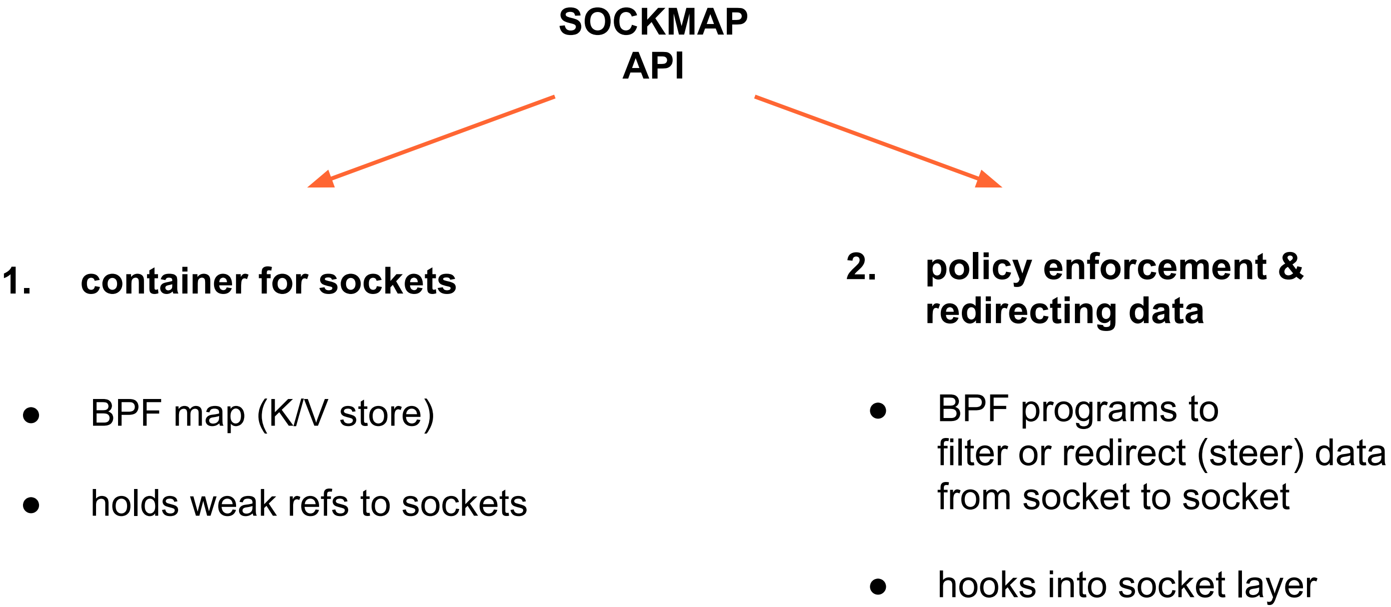
What is SOCKMAP?



Linux API for enforcing policy
and
redirecting data between sockets

Wikimedia Commons, CC BY 3.0 DEED

What is SOCKMAP?



SOCKMAP API

1. **container for sockets**

- BPF map (K/V store)
- holds weak refs to sockets

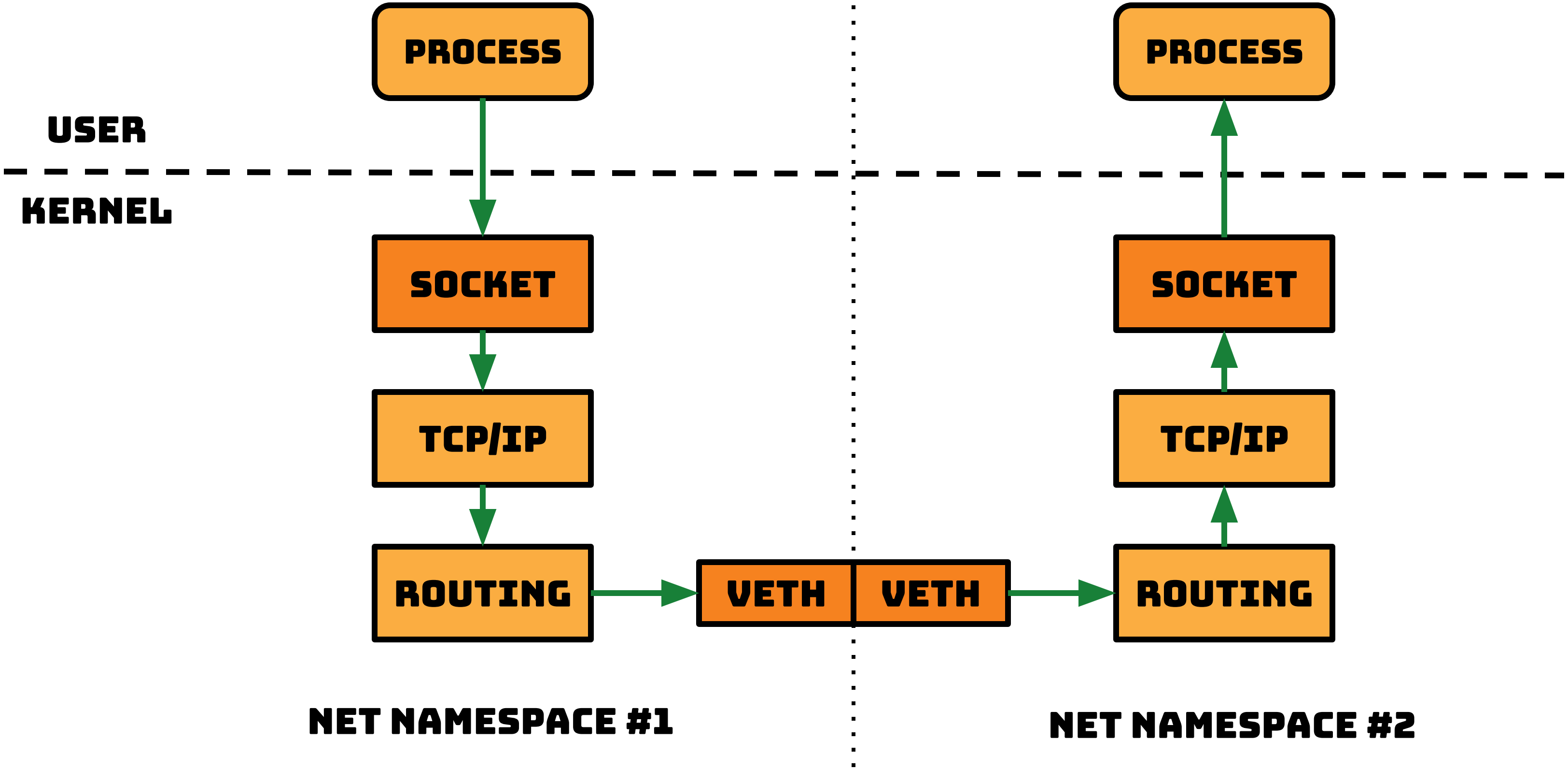
2. **policy enforcement & redirecting data**

- BPF programs to filter or redirect (steer) data from socket to socket
- hooks into socket layer

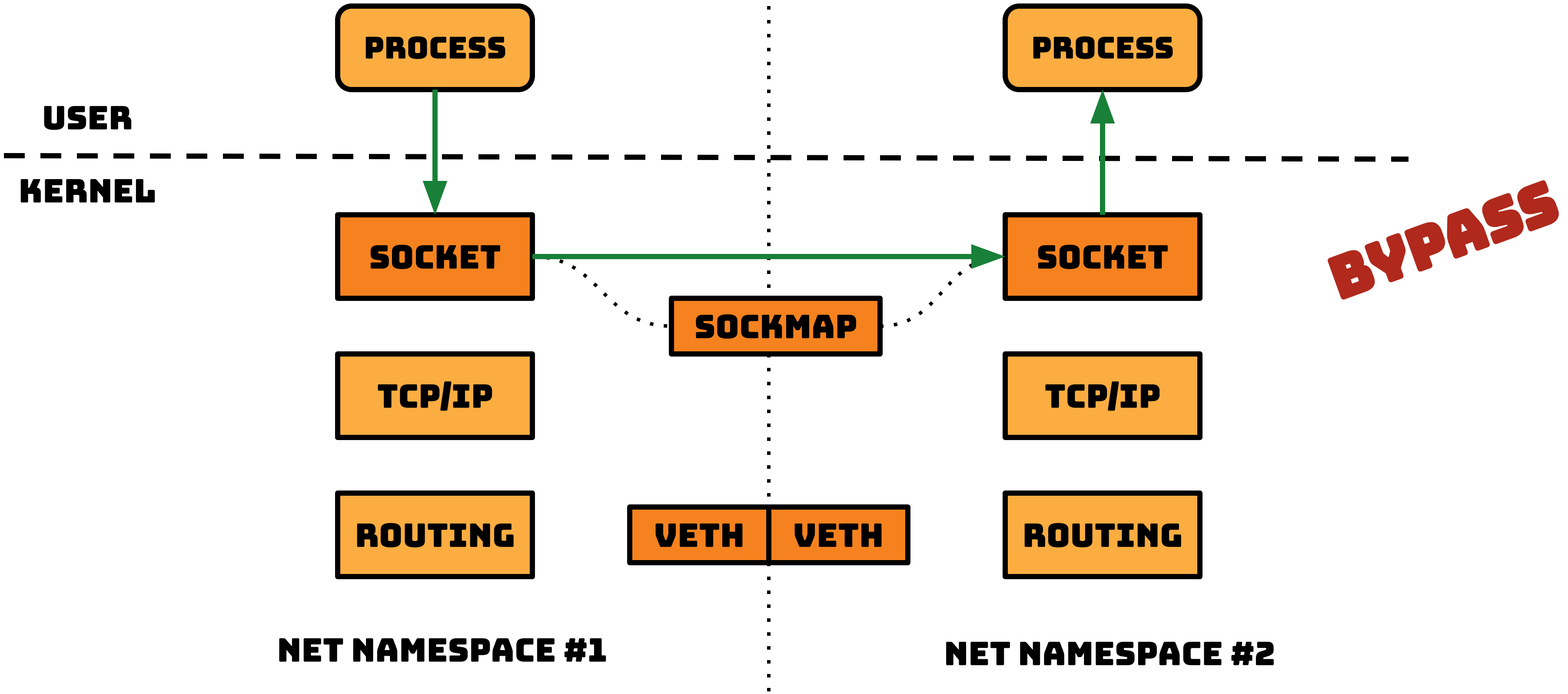
What can SOCKMAP do for you?

publicdomainpictures.net, CC0

What can SOCKMAP do for … container networking



What can SOCKMAP do for … container networking



Test it → Setup a pair of network namespaces

Create network namespaces

```
# ip netns add A
# ip netns add B
```

Link network namespaces with a veth pair

```
# ip -n A link add name veth0 type veth peer name veth0 netns B
```

Bring up the links inside network namespaces

```
# ip -n A link set dev lo up
# ip -n B link set dev lo up
# ip -n A link set dev veth0 up
# ip -n B link set dev veth0 up
```

Assign addresses to links inside network namespaces

```
# ip -n A addr add 10.0.0.1/24 dev veth0
# ip -n B addr add 10.0.0.2/24 dev veth0
```

Test it → Run TCP request-response benchmark

Run TCP server

```
# ip netns exec A \
  sockperf server -i 10.0.0.1 --tcp --daemonize
```

Run TCP client

```
# ip netns exec B \
  sockperf ping-pong -i 10.0.0.1 --tcp --time 30
…
sockperf: [Total Run] RunTime=30.000 sec; Warm up time=400 msec; SentMessages=2599753;
ReceivedMessages=2599752
…
sockperf: ====> avg-latency=5.748 (std-dev=2.010, mean-ad=0.322, median-ad=0.220,
siqr=0.239, cv=0.350, std-error=0.001, 99.0% ci=[5.745, 5.751])
sockperf: # dropped messages = 0; # duplicated messages = 0; # out-of-order messages = 0
sockperf: Summary: Latency is 5.748 usec
```

5.748 ± 2.010 usec

Test it → Configure SOCKMAP bypass

Load BPF programs and create BPF maps

```
# bpftool prog loadall redir_bypass.bpf.o /sys/fs/bpf pinmaps /sys/fs/bpf
```

Attach BPF program to BPF map

```
# bpftool prog attach \
  pinned /sys/fs/bpf/sk_msg_prog sk_msg_verdict \
  pinned /sys/fs/bpf/sock_map
```

Create a test cgroup

```
# mkdir /sys/fs/cgroup/unified/test.slice
```

Attach BPF program to cgroup

```
# bpftool cgroup attach \
  /sys/fs/cgroup/unified/test.slice \
  cgroup_sock_ops pinned /sys/fs/bpf/sockops_prog
```

Test it → Repeat the test with SOCKMAP bypass

```
Spawn client and server inside the test cgroup
# echo $$ > /sys/fs/cgroup/unified/test.slice/cgroup.procs

Run TCP server
# ip netns exec A \
  sockperf server -i 10.0.0.1 --tcp --daemonize

Run TCP client
# ip netns exec B \
   sockperf ping-pong -i 10.0.0.1 --tcp --time 30
sockperf: [Total Run] RunTime=30.000 sec; Warm up time=400 msec; SentMessages=3189584;
ReceivedMessages=3189583
…
sockperf: ====> avg-latency=4.686 (std-dev=2.862, mean-ad=0.250, median-ad=0.216,
siqr=0.173, cv=0.611, std-error=0.002, 99.0% ci=[4.682, 4.690])
sockperf: # dropped messages = 0; # duplicated messages = 0; # out-of-order messages = 0
sockperf: Summary: Latency is 4.686 usec
```

4.686 ± 2.862 usec

Test it → Compare without and with SOCKMAP bypass

before: 5.748 ± 2.010 usec

↓ - 18.5%

after: 4.686 ± 2.862 usec

Run the benchmark yourself:
https://github.com/jsitnicki/srecon-2023-sockmap/blob/main/examples/redir-bypass/test_redir_bypass.sh

Section

Evolution of SOCKMAP

How did we get here?

Kernel Connection Multiplexor

Added infrastructure later reused by SOCKMAP - Psock and stream parser program.

2016

v4.6

```
+------------+   +------------+   +------------+   +------------+
| KCM socket |   | KCM socket |   | KCM socket |   | KCM socket |
+------------+   +------------+   +------------+   +------------+
      |                 |               |                |
      +-----------+     |               |     +----------+
                  |     |               |     |
               +----------------------------------+
               |           Multiplexor            |
               +----------------------------------+
                 |   |           |           |  |
       +---------+   |           |           |  ------------+
       |             |           |           |              |
+----------+  +----------+  +----------+  +----------+ +----------+
|  Psock   |  |  Psock   |  |  Psock   |  |  Psock   | |  Psock   |
+----------+  +----------+  +----------+  +----------+ +----------+
      |              |           |            |             |
+----------+  +----------+  +----------+  +----------+ +----------+
| TCP sock |  | TCP sock |  | TCP sock |  | TCP sock | | TCP sock |
+----------+  +----------+  +----------+  +----------+ +----------+
```

[PATCH v2 net-next 00/13] kcm: Kernel Connection Multiplexor (KCM)

How did we get here?

Kernel Connection Multiplexor

Added infrastructure later reused by SOCKMAP - Psock and stream parser program.

2016

v4.6

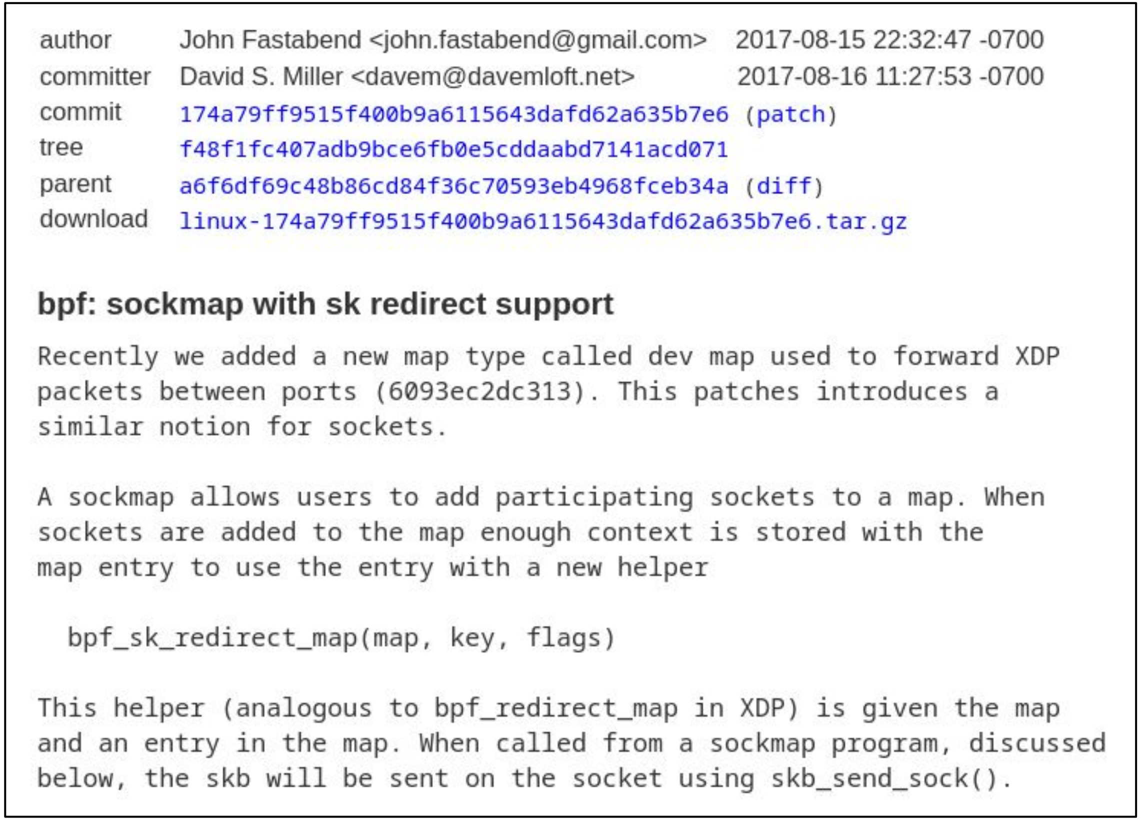
2017

v4.14

SOCKMAP initial version

Filtering and redirect on ingress to socket layer.

Counterpart of XDP DEVMAP.



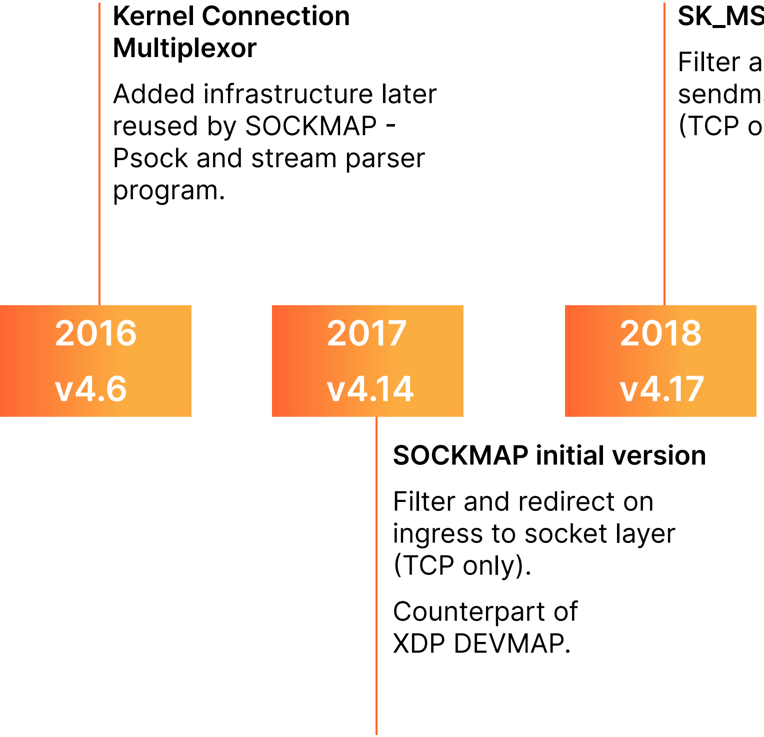
author	John Fastabend <john.fastabend@gmail.com>	2017-08-15 22:32:47 -0700
committer	David S. Miller <davem@davemloft.net>	2017-08-16 11:27:53 -0700
commit	174a79ff9515f400b9a6115643dafd62a635b7e6 (patch)	
tree	f48f1fc407adb9bce6fb0e5cddaabd7141acd071	
parent	a6f6df69c48b86cd84f36c70593eb4968fceb34a (diff)	
download	linux-174a79ff9515f400b9a6115643dafd62a635b7e6.tar.gz	

bpf: sockmap with sk redirect support

```
Recently we added a new map type called dev map used to forward XDP
packets between ports (6093ec2dc313). This patches introduces a
similar notion for sockets.

A sockmap allows users to add participating sockets to a map. When
sockets are added to the map enough context is stored with the
map entry to use the entry with a new helper

  bpf_sk_redirect_map(map, key, flags)

This helper (analogous to bpf_redirect_map in XDP) is given the map
and an entry in the map. When called from a sockmap program, discussed
below, the skb will be sent on the socket using skb_send_sock().
```

commit 174a79ff9515 ("bpf: sockmap with sk redirect support")

How did we get here?



Kernel Connection Multiplexor

Added infrastructure later reused by SOCKMAP - Psock and stream parser program.

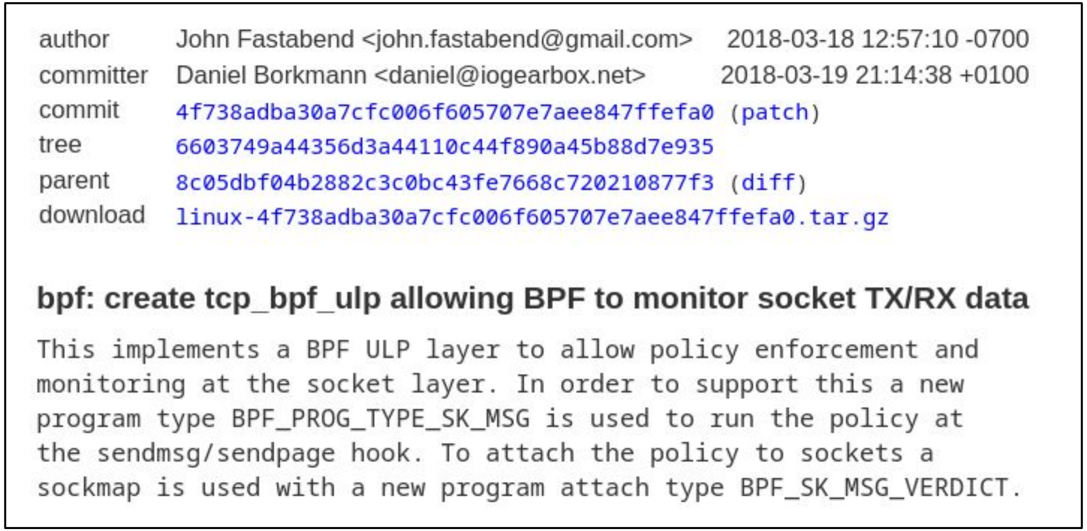
SOCKMAP initial version

Filter and redirect on ingress to socket layer (TCP only).

Counterpart of XDP DEVMAP.

SK_MSG program

Filter and redirect at sendmsg() time (TCP only).



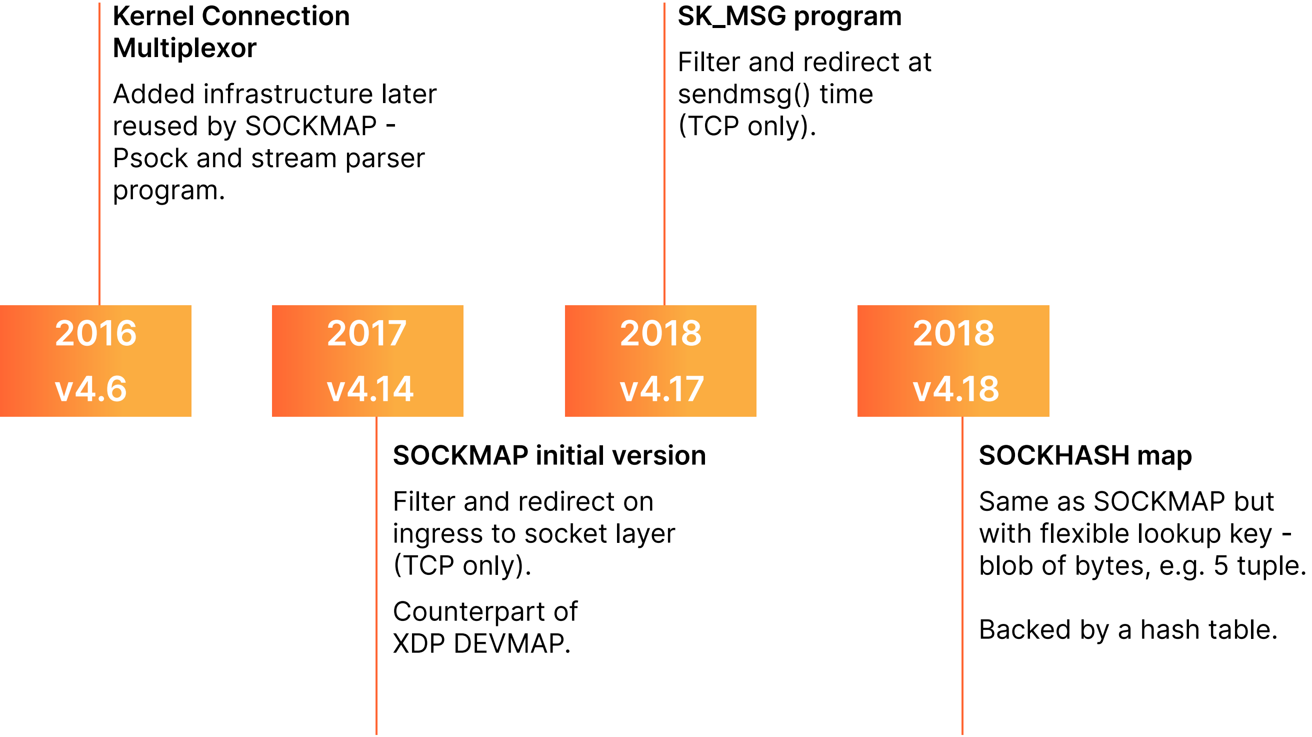
author	John Fastabend <john.fastabend@gmail.com>	2018-03-18 12:57:10 -0700
committer	Daniel Borkmann <daniel@iogearbox.net>	2018-03-19 21:14:38 +0100
commit	4f738adba30a7cfc006f605707e7aee847ffefa0 (patch)	
tree	6603749a44356d3a44110c44f890a45b88d7e935	
parent	8c05dbf04b2882c3c0bc43fe7668c720210877f3 (diff)	
download	linux-4f738adba30a7cfc006f605707e7aee847ffefa0.tar.gz	

bpf: create tcp_bpf_ulp allowing BPF to monitor socket TX/RX data

```
This implements a BPF ULP layer to allow policy enforcement and
monitoring at the socket layer. In order to support this a new
program type BPF_PROG_TYPE_SK_MSG is used to run the policy at
the sendmsg/sendpage hook. To attach the policy to sockets a
sockmap is used with a new program attach type BPF_SK_MSG_VERDICT.
```

commit 4f738adba30a ("bpf: create tcp_bpf_ulp allowing BPF to monitor socket TX/RX data")

How did we get here?



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v4.6

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2018
v4.17

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Filter and redirect at sendmsg() time (TCP only).

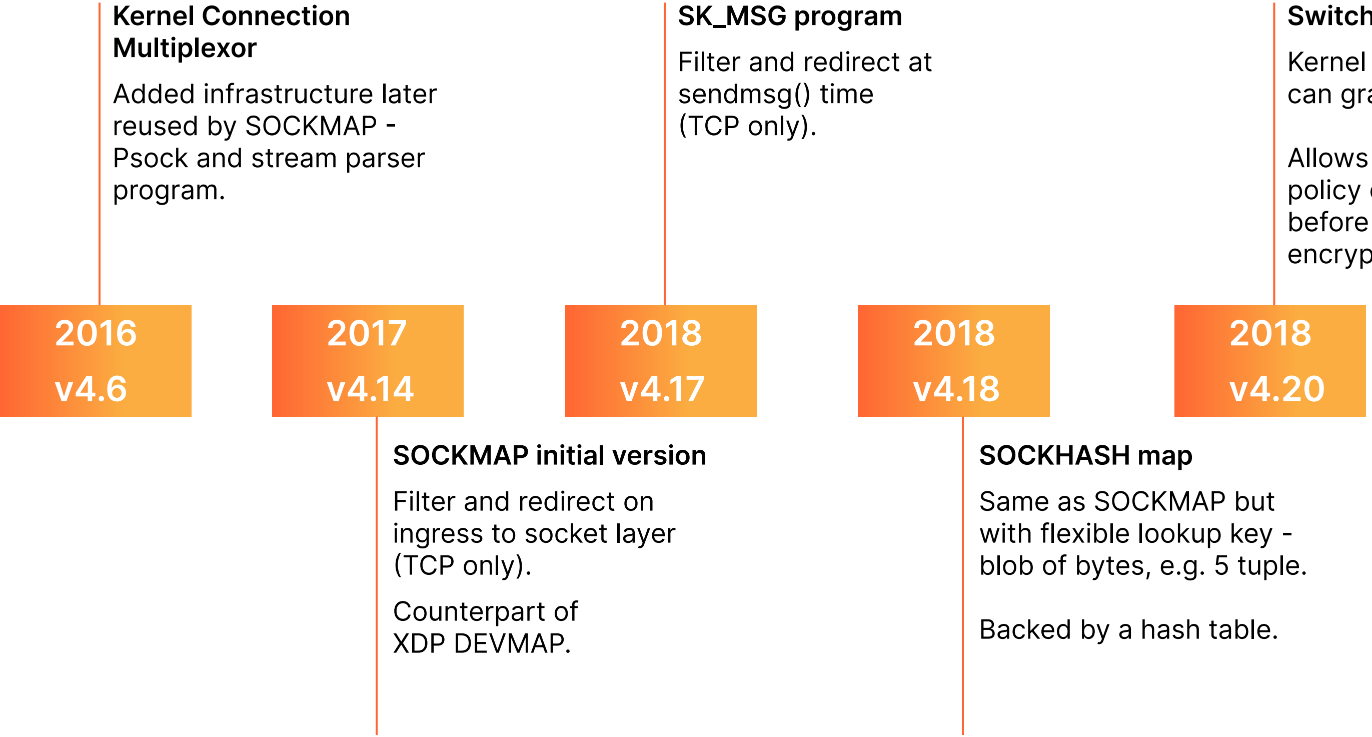
2018
v4.18

SOCKHASH map

Same as SOCKMAP but with flexible lookup key - blob of bytes, e.g. 5 tuple.

Backed by a hash table.

How did we get here?



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v4.18

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Backed by a hash table.

2018

v4.20

Switch to sk_msg API

Kernel TLS and SK_MSG can gracefully coexist.

Allows introspection / policy enforcement before in-kernel encryption.

commit 4f738adba30a ("bpf: create tcp_bpf_ulp allowing BPF to monitor socket TX/RX data")

How did we get here?

Store TCP or UDP sockets

SOCKMAP becomes a generic BPF map for sockets.

It can hold both connected and listening TCP sockets, and any bound UDP socket.

2020

v5.7

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2020

v5.7

2020

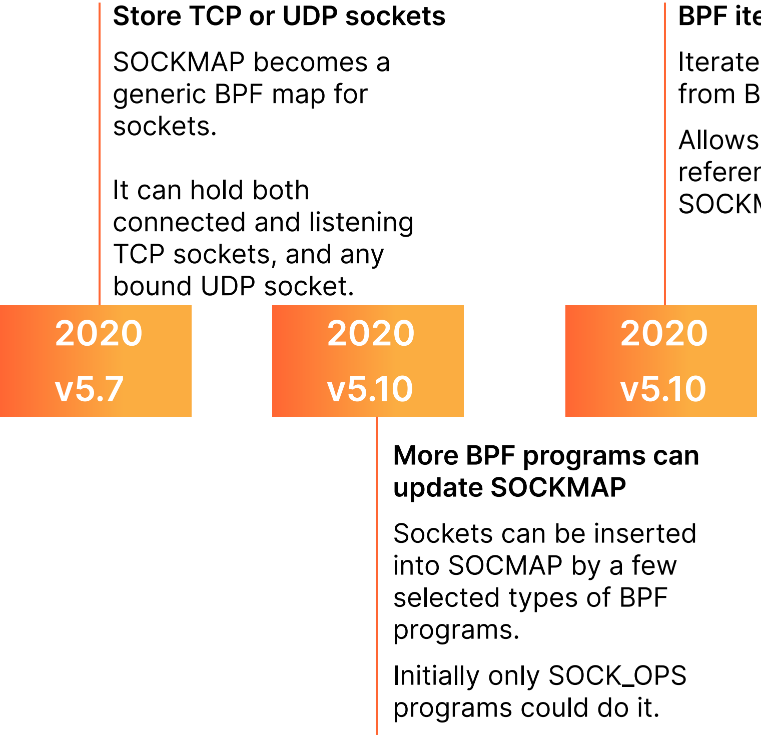
v5.10

More BPF programs can update SOCKMAP

Sockets can be inserted into SOCMAP by a few selected types of BPF programs.

Initially only SOCK_OPS programs could do it.

How did we get here?



2020

v5.7

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2020

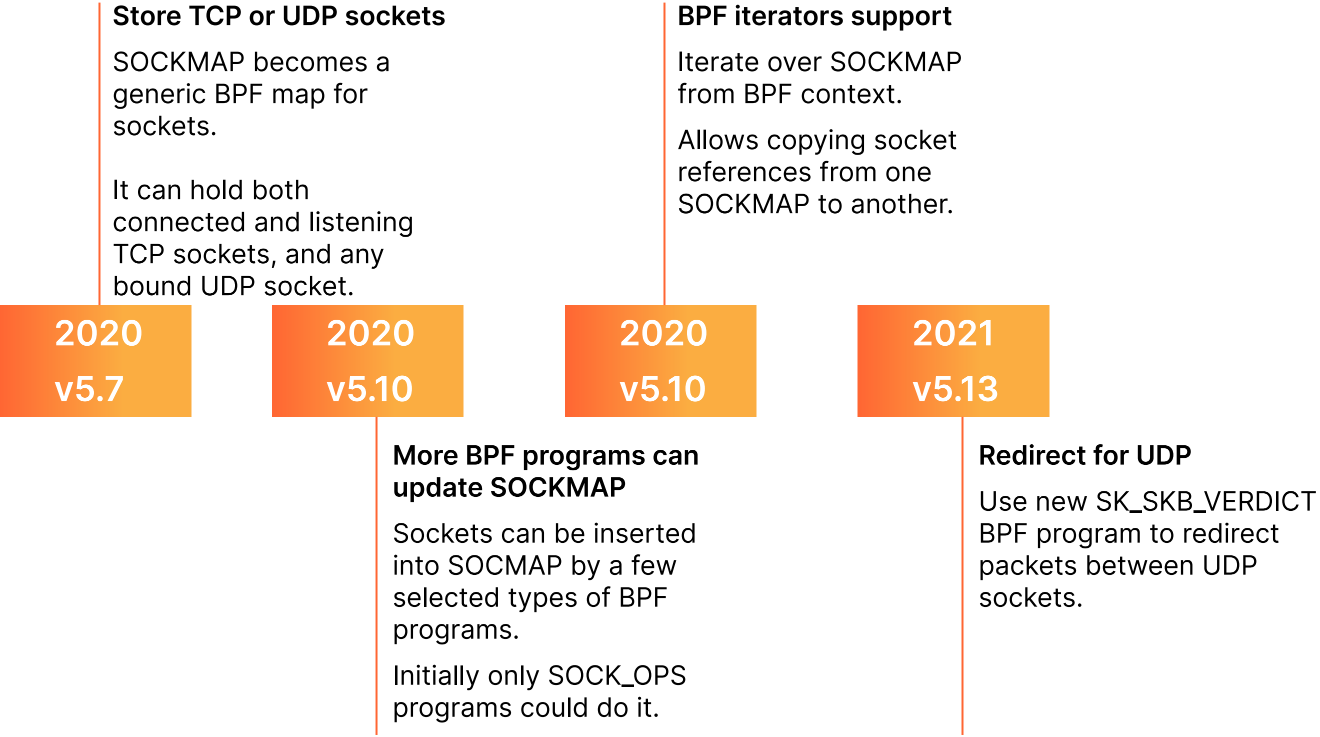
v5.10

BPF iterators support

Iterate over SOCKMAP from BPF context.

Allows copying socket references from one SOCKMAP to another.

How did we get here?



2020

v5.7

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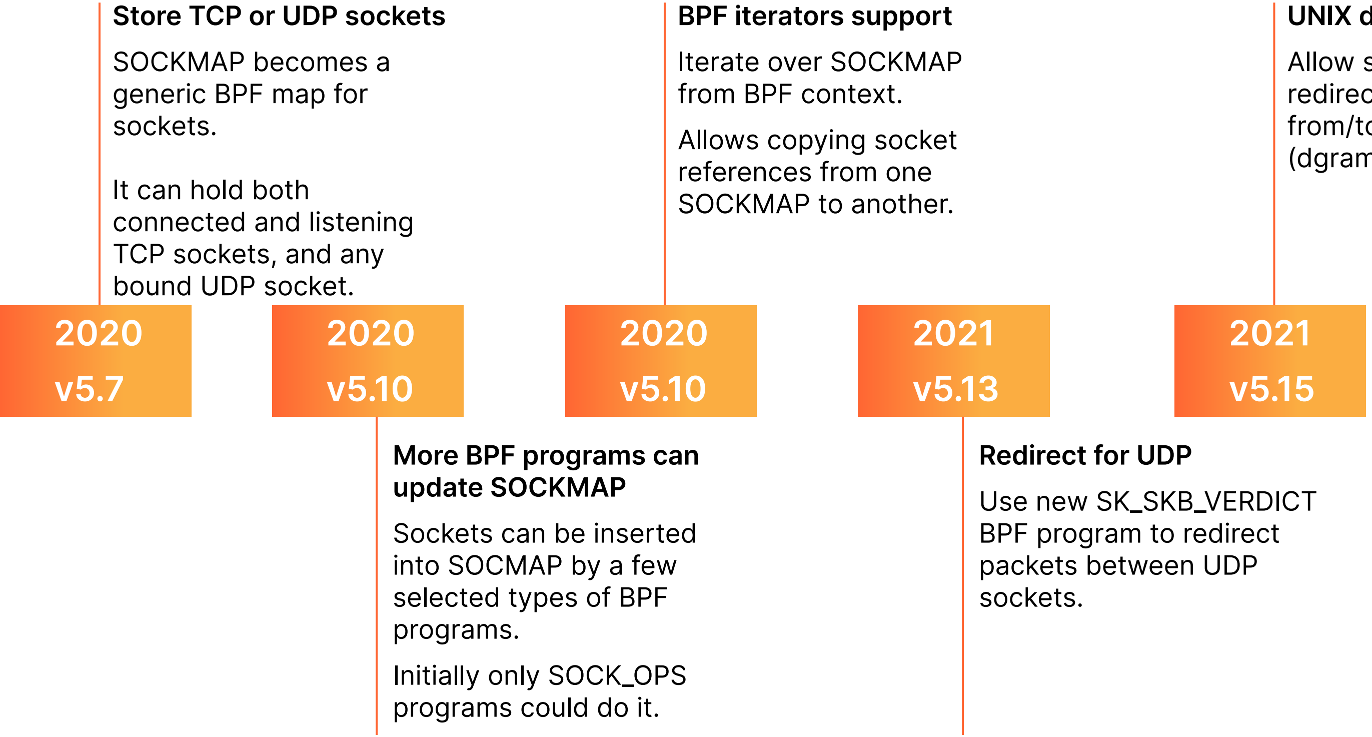
2021

v5.13

Redirect for UDP

Use new SK_SKB_VERDICT BPF program to redirect packets between UDP sockets.

How did we get here?



2020

v5.7

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2020

v5.10

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2020

v5.10

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2021

v5.13

Redirect for UDP

Use new SK_SKB_VERDICT BPF program to redirect packets between UDP sockets.

2021

v5.15

UNIX domain sockets

Allow storing and redirecting packets from/to UNIX sockets (dgram and stream).

How did we get here?

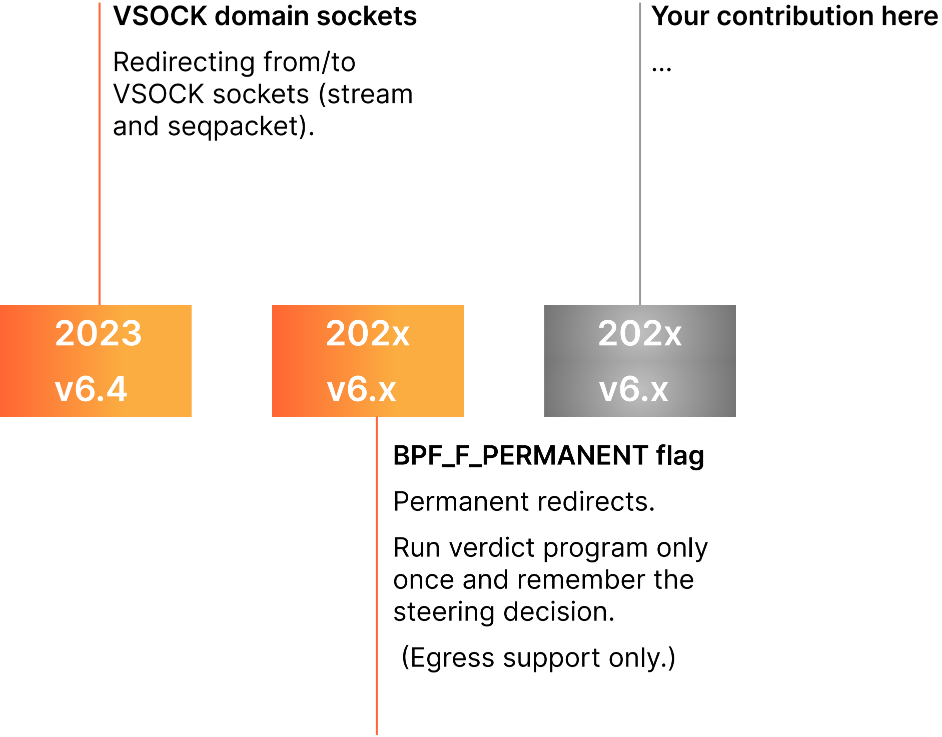
VSOCK domain sockets

Redirecting from/to VSOCK sockets (stream and seqpacket).

2023

v6.4

How did we get here?



VSOCK domain sockets

Redirecting from/to VSOCK sockets (stream and seqpacket).

Your contribution here

…

2023
v6.4

202x
v6.x

202x
v6.x

BPF_F_PERMANENT flag

Permanent redirects.

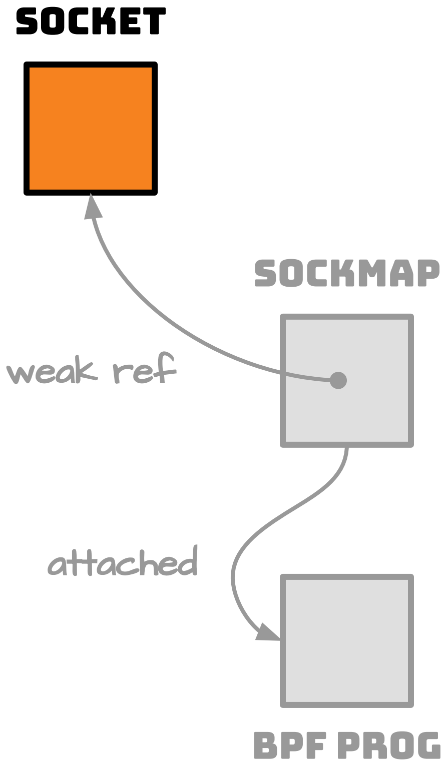
Run verdict program only once and remember the steering decision.

(Egress support only.)

Section

How to set up SOCKMAP?

① Open a connected (established) socket



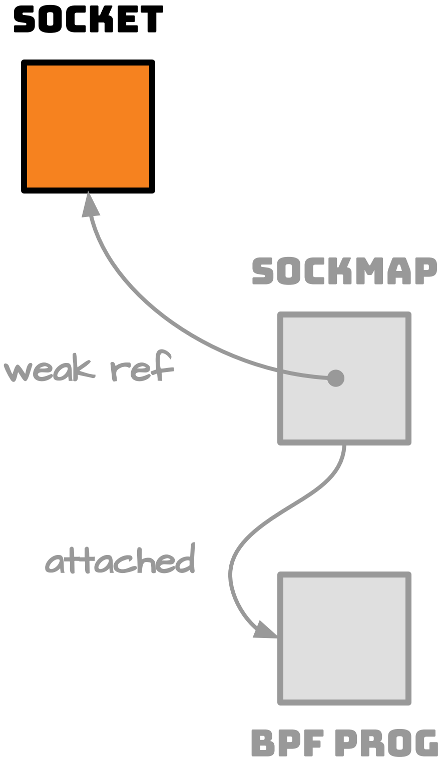
active open

```
socket(AF_INET, SOCK_STREAM, IPPROTO_IP) = 8
connect(8, {sa_family=AF_INET,
            sin_port=htons(41895),
            sin_addr=inet_addr("127.0.0.1")}, 16) = 0
```

passive open

```
socket(AF_INET, SOCK_STREAM, IPPROTO_IP) = 7
bind(7, {sa_family=AF_INET,
         sin_port=htons(41895),
         sin_addr=inet_addr("127.0.0.1")}, 16) = 0
listen(7, 4096)                               = 0
accept(7, NULL, NULL)                         = 9
```

What sockets can you use?



connected (established) socket:

❏ TCP

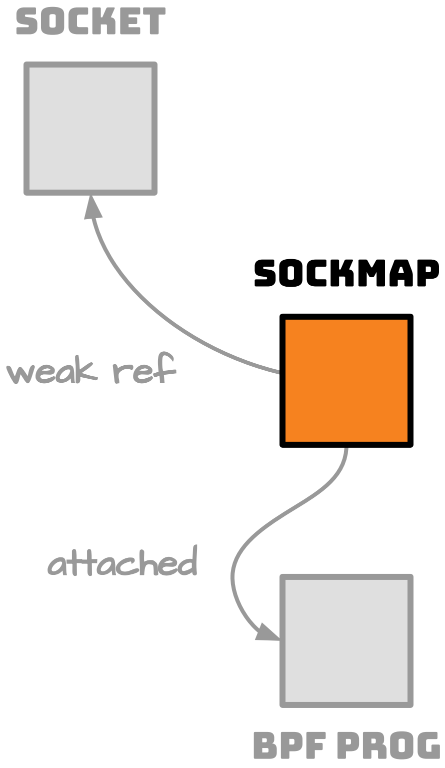
❏ UDP

❏ UNIX (STREAM, DGRAM)

❏ VSOCK (STREAM, SEQPACKET)

`man 7 {tcp,udp,unix,vsock}`

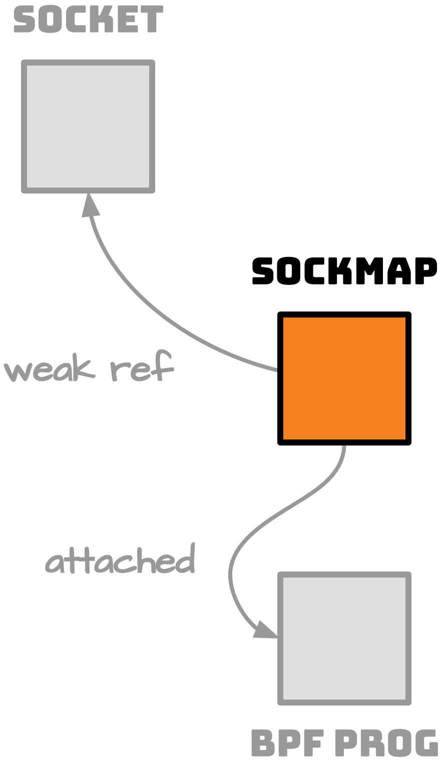
② Create a BPF map - SOCKMAP or SOCKHASH



from a program using the `bpf()` syscall
or a library wrapper (`libbpf`)

```
bpf(BPF_MAP_CREATE, {map_type=BPF_MAP_TYPE_SOCKMAP,
                     key_size=4,
                     value_size=8,
                     max_entries=1,
                     map_flags=0,
                     …}, 72) = 5
```

What BPF maps can you use?



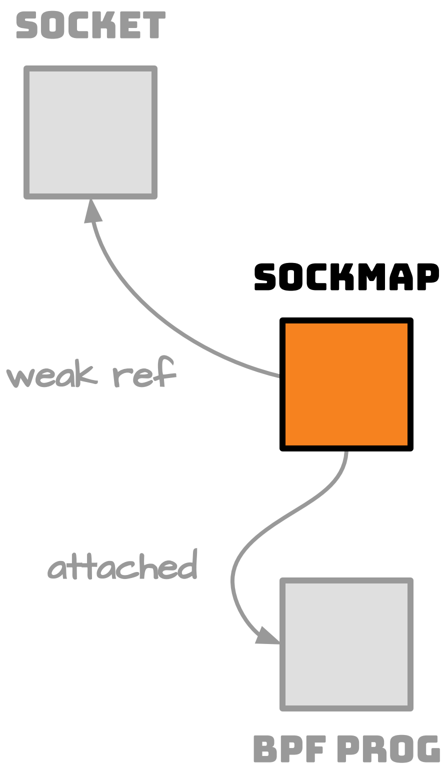
Map types:

- ❏ **BPF_MAP_TYPE_SOCKMAP**
  - ❏ **key size always 4B**
- ❏ **BPF_MAP_TYPE_SOCKHASH**
  - ❏ **arbitrary key size**

Not to be confused with
BPF_MAP_TYPE_REUSEPORT_SOCKARRAY

https://docs.kernel.org/bpf/map_sockmap.html

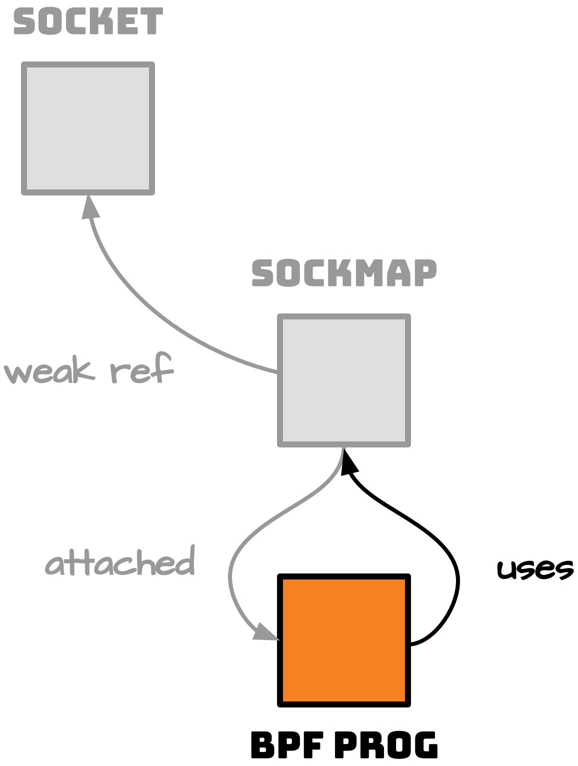
② Create a BPF map - From command line



using `bpftool map create`

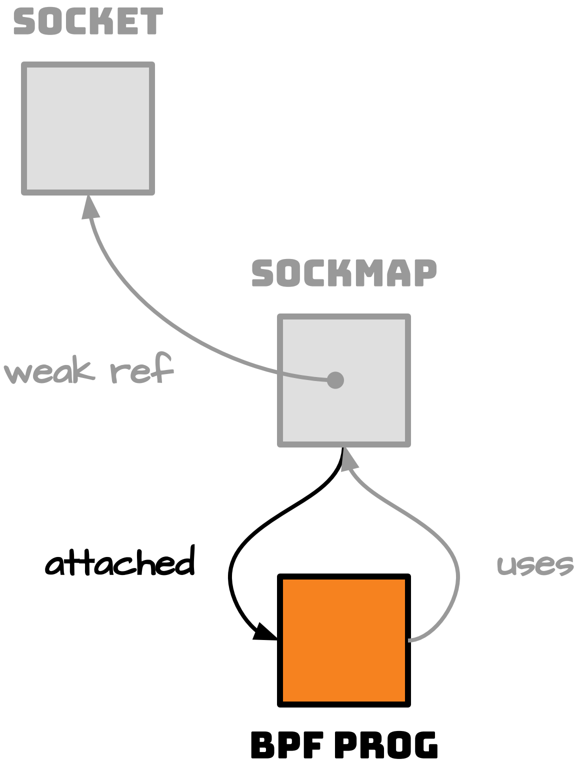
```
# bpftool map create                                          \
    /sys/fs/bpf/sockmap `# path on bpffs`                     \
    type sockmap        `# sockmap or sockhash`               \
    key 4               `# always 4 bytes for sockmap`        \
    value 8             `# use 8 bytes for dump to work`      \
    entries 1                                                 \
    name sockmap
#
# bpftool map show pinned /sys/fs/bpf/sockmap
3: sockmap  name sockmap  flags 0x0
        key 4B  value 8B  max_entries 1  memlock 328B
```

③ Load a BPF program - SK_MSG or SK_SKB type



```
bpf(BPF_PROG_LOAD, {prog_type=BPF_PROG_TYPE_SK_MSG,
                    insn_cnt=6,
                    insns=0xcf2a70,
                    expected_attach_type=BPF_SK_MSG_VERDICT,
                    …}, 128) = 6
```

What BPF programs can you use?

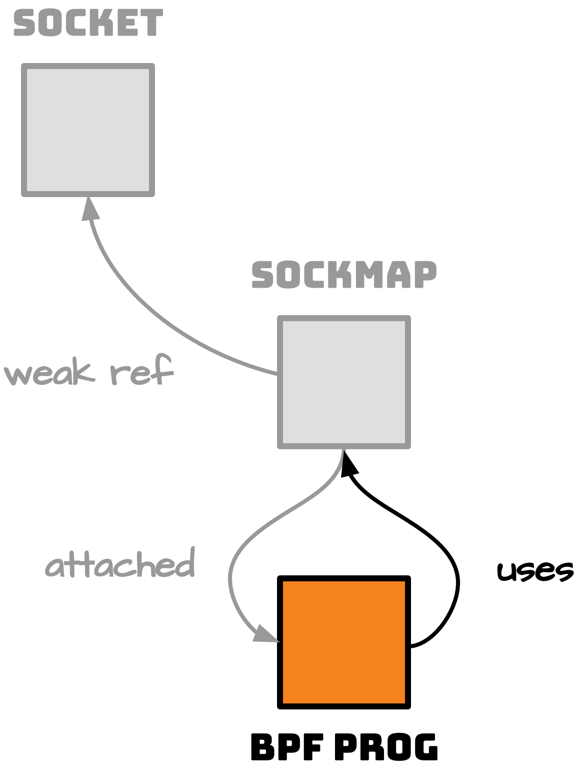


Program types:

- ❏ BPF_PROG_TYPE_SK_MSG
- ❏ BPF_PROG_TYPE_SK_SKB

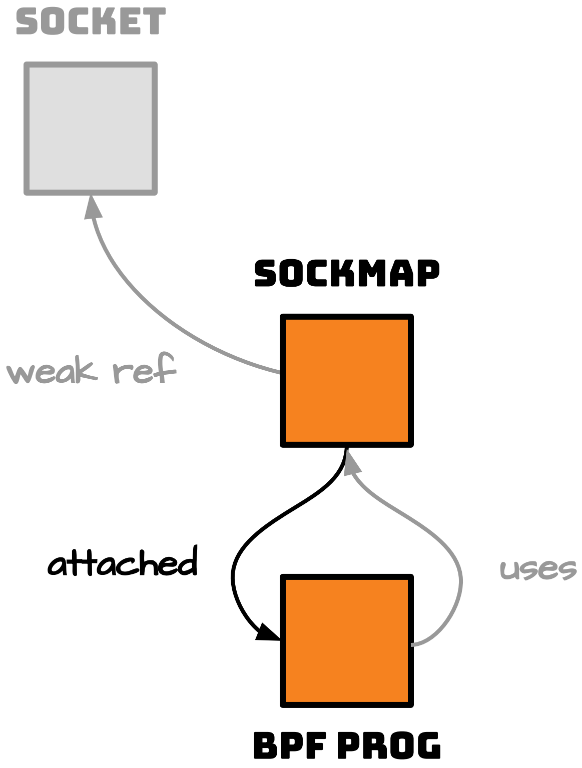
https://docs.kernel.org/bpf/map_sockmap.html

③ Load a BPF program - SK_MSG or SK_SKB type



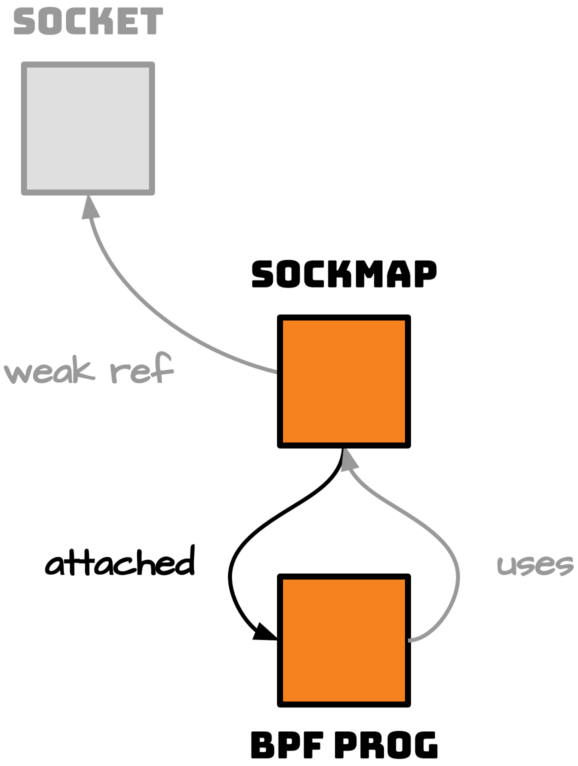
```
# bpftool prog dump xlated id 42
int prog_msg_redir_ingress(struct sk_msg_md * msg):
   0: (18) r2 = map[id:17]
   …
   5: (95) exit
# bpftool map show id 17
17: sockmap  name output  flags 0x0
        key 4B  value 8B  max_entries 1  memlock 328B
        pids sockmap-redir-m(331)
```

④ Attach BPF program to SOCKMAP



```
bpf(BPF_PROG_ATTACH, {target_fd=5,
                      attach_bpf_fd=6,
                      attach_type=BPF_SK_MSG_VERDICT,
                      attach_flags=0,
                      replace_bpf_fd=0}, 20) = 0
```

What BPF programs can you use?



Attach types (hooks):

❏ BPF_SK_MSG_VERDICT

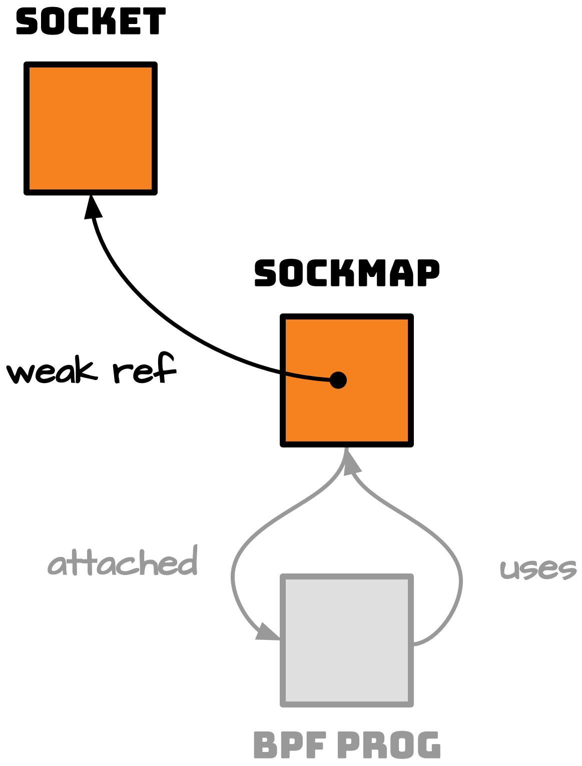
❏ BPF_SK_SKB_VERDICT

❏ BPF_SK_SKB_STREAM_PARSER

❏ BPF_SK_SKB_STREAM_VERDICT

https://docs.kernel.org/bpf/map_sockmap.html

⑤ Insert socket into SOCKMAP



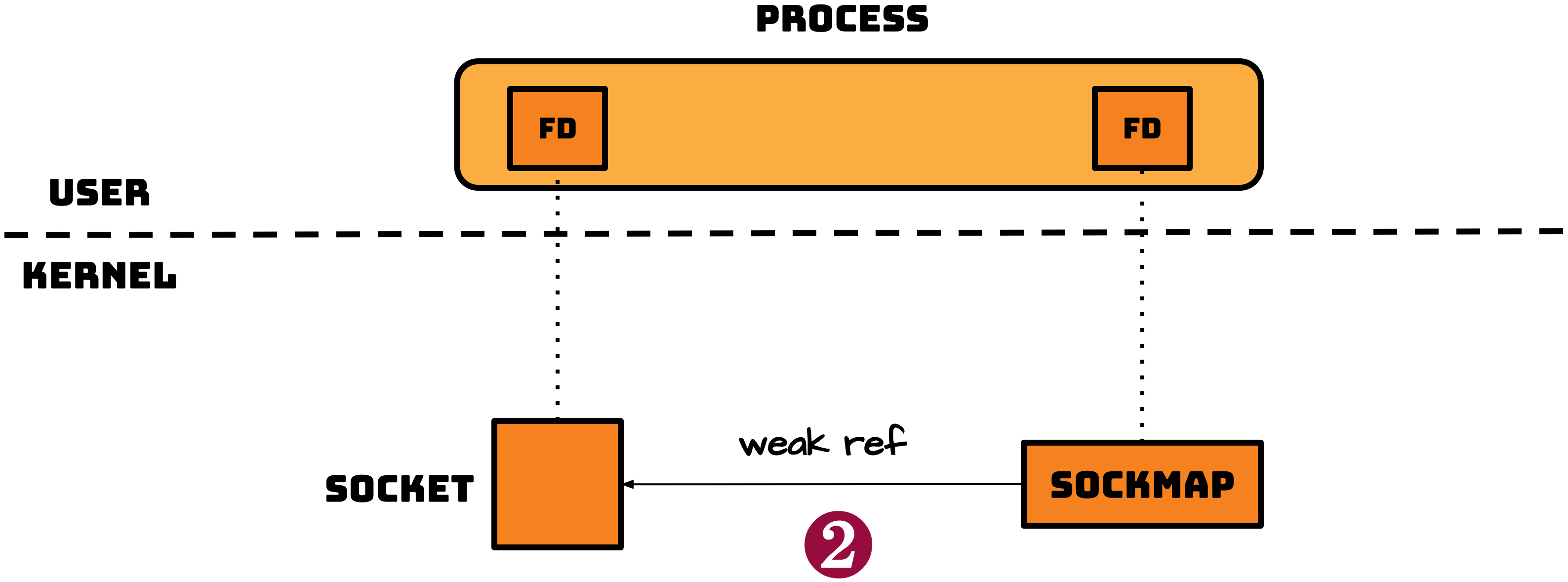
```
bpf(BPF_MAP_UPDATE_ELEM, {map_fd=5,
                          key=0x7ffeb3803870,
                          value=0x7ffeb3803868,
                          flags=BPF_NOEXIST}, 32) = 0
```

⚠ must be done after attaching the program

Section

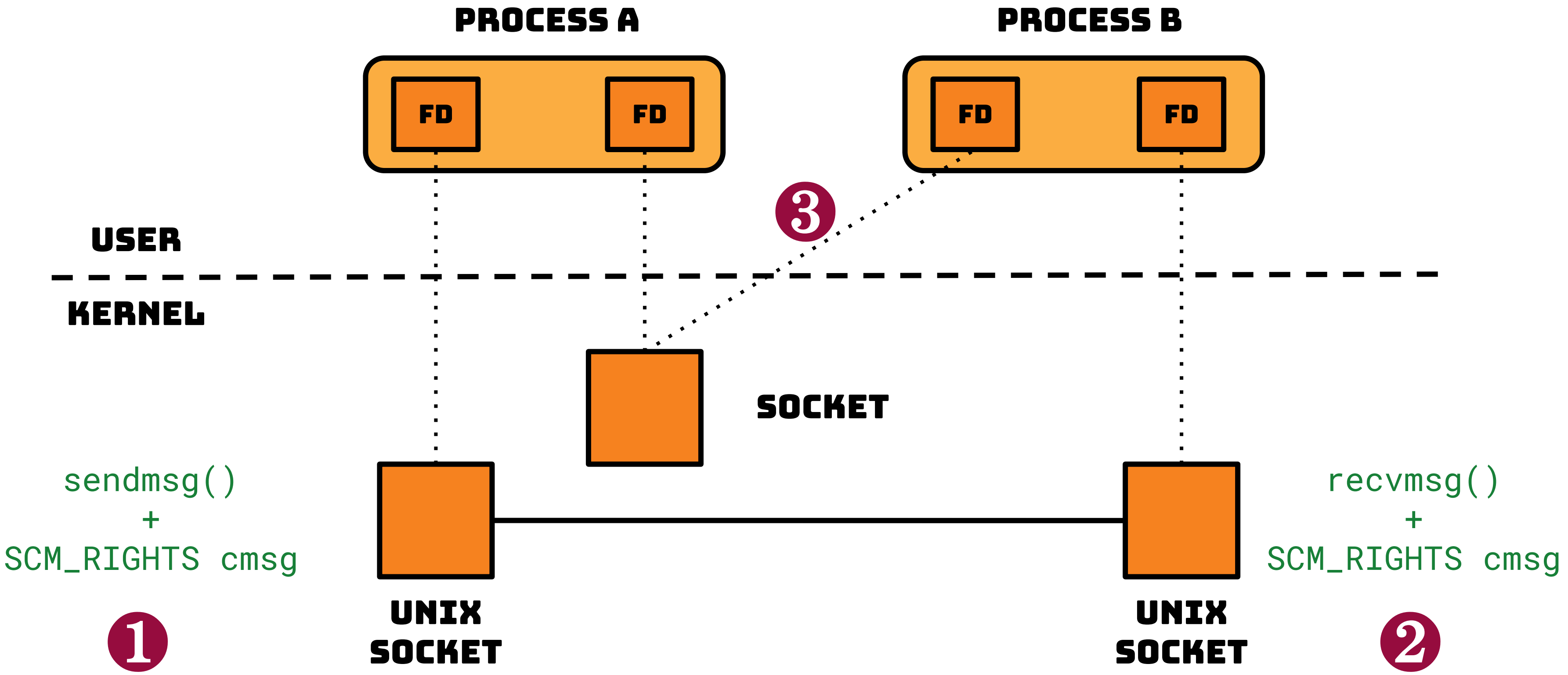
How to get sockets into a SOCKMAP?

Easy case



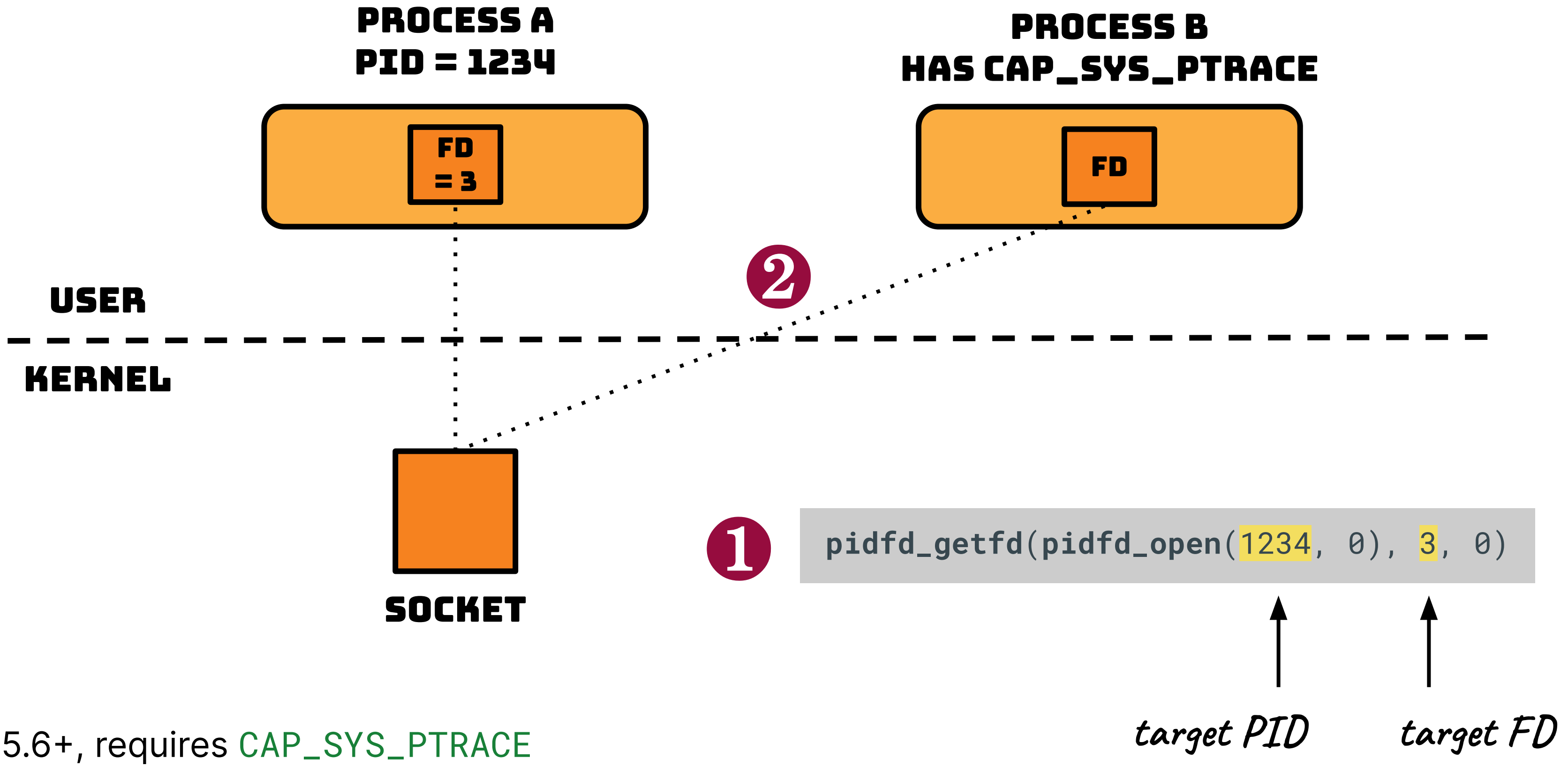
❶ `bpf(BPF_MAP_UPDATE_ELEM, …)`

Socket FD handover with SCM_RIGHTS



https://manpages.debian.org/unstable/manpages/unix.7.en.html#SCM_RIGHTS
https://blog.cloudflare.com/know-your-scm_rights/

“Steal” a socket FD



PROCESS A
PID = 1234

FD
= 3

PROCESS B
HAS CAP_SYS_PTRACE

FD

USER

KERNEL

SOCKET

❷

❶

```
pidfd_getfd(pidfd_open(1234, 0), 3, 0)
```

target PID

target FD

Linux 5.6+, requires `CAP_SYS_PTRACE`

https://manpages.debian.org/unstable/manpages-dev/pidfd_getfd.2.en.html

Use BPF sock_ops program attached to cgroup (TCP only)

```
SEC("sockops")
int sockops_prog(struct bpf_sock_ops *ctx)
{
     if (!ctx->sk)
          return SK_PASS;

     switch (ctx->op) {
     case BPF_SOCK_OPS_ACTIVE_ESTABLISHED_CB:
          bpf_sock_map_update(ctx, &sock_map, &(__u32){ 0 }, BPF_ANY);
          break;
     case BPF_SOCK_OPS_PASSIVE_ESTABLISHED_CB:
          bpf_sock_map_update(ctx, &sock_map, &(__u32){ 1 }, BPF_ANY);
          break;
     }

     return SK_PASS;
}
```

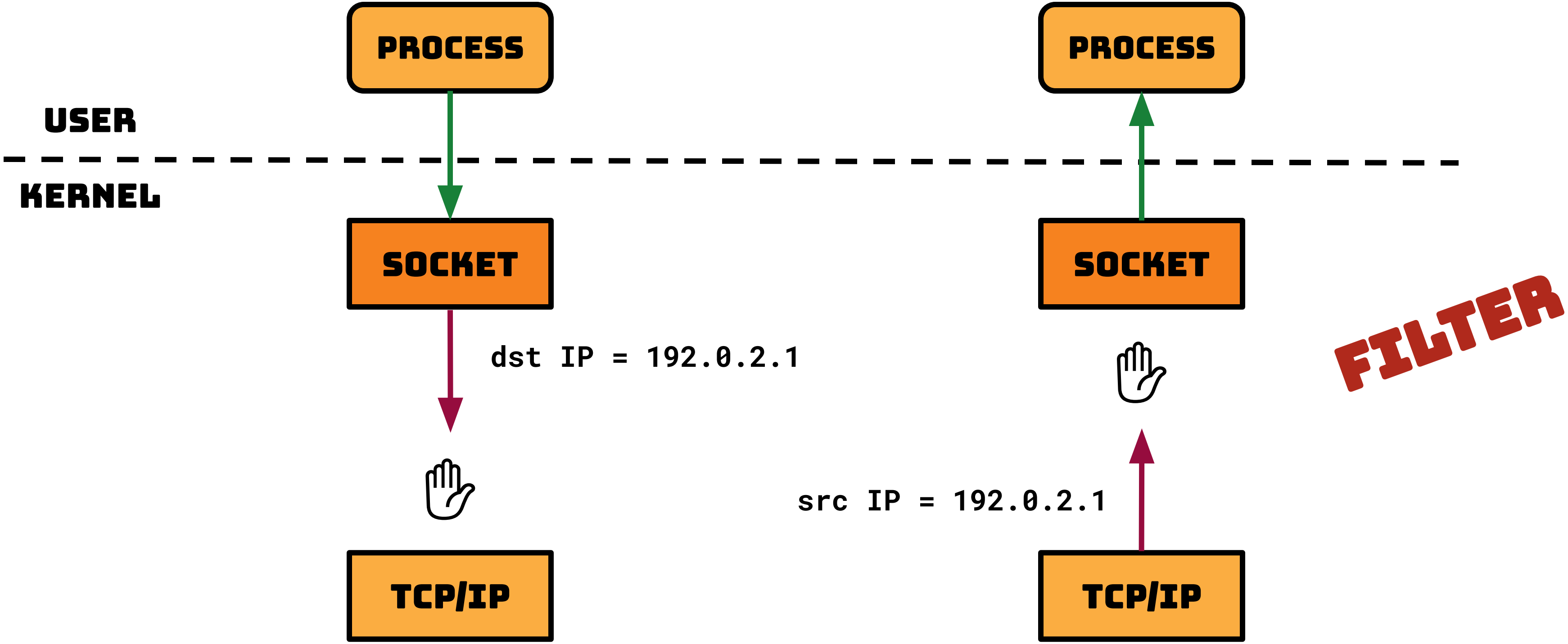
Section

Supported configurations

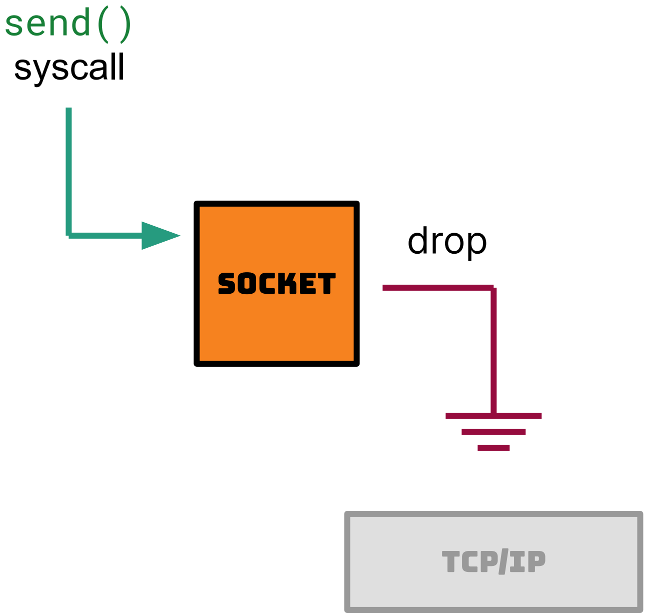
POLICY

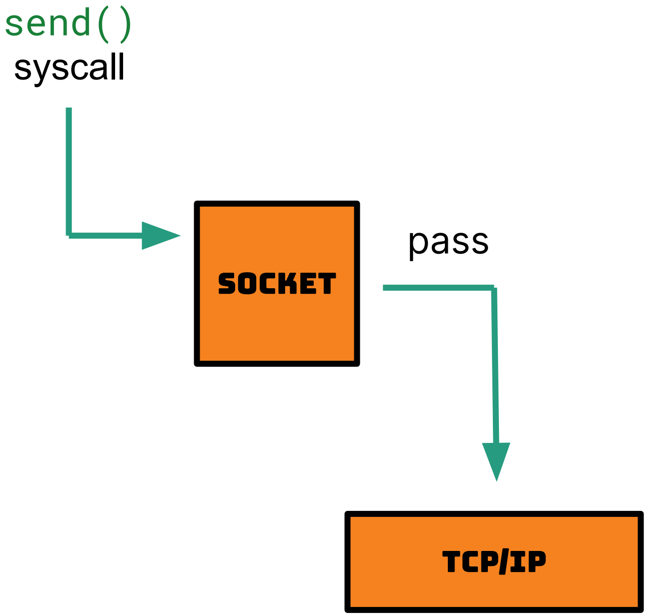
Rawpixel, CC0

Policy use case → API endpoints

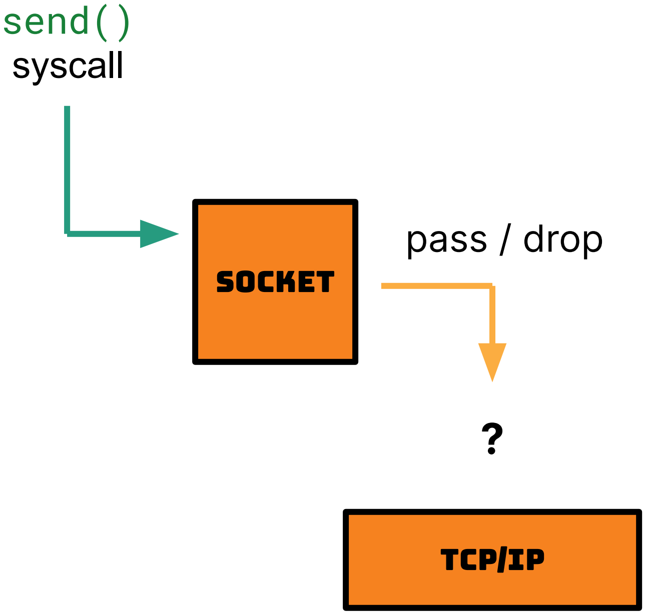


Policy on egress - pass or drop





Policy on egress → How?

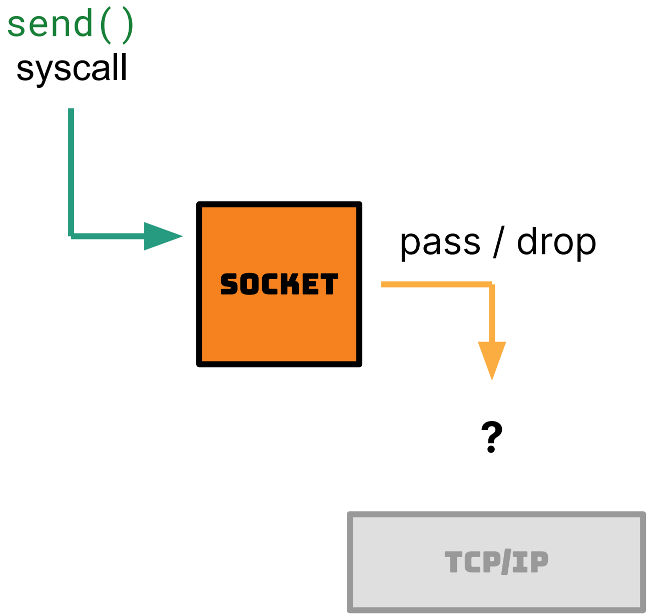


BPF_PROG_TYPE_**SK_MSG** prog

→ attached BPF_**SK_MSG_VERDICT** hook

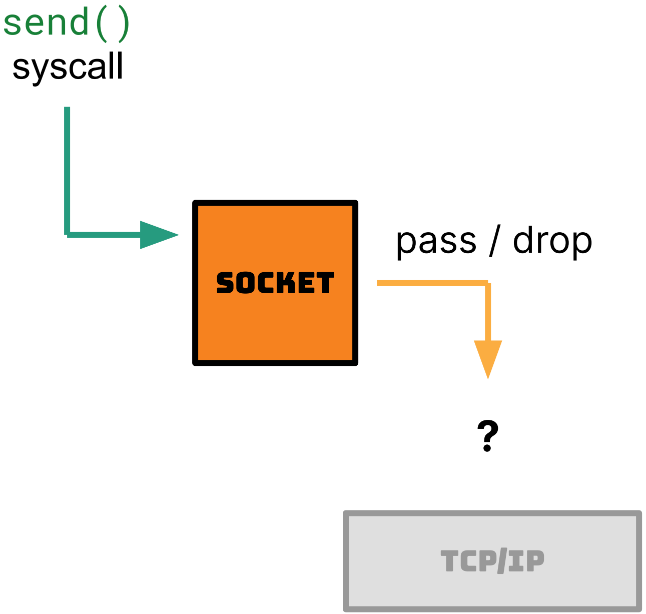
→ returns SK_**PASS** or SK_**DROP** verdict

Policy on egress → Program input



```
struct sk_msg_md {
        __bpf_md_ptr(void *, data);
        __bpf_md_ptr(void *, data_end);

        __u32 family;
        __u32 remote_ip4;
        __u32 local_ip4;
        __u32 remote_ip6[4];
        __u32 local_ip6[4];
        __u32 remote_port;
        __u32 local_port;
        __u32 size;

        __bpf_md_ptr(struct bpf_sock *, sk);
};
```

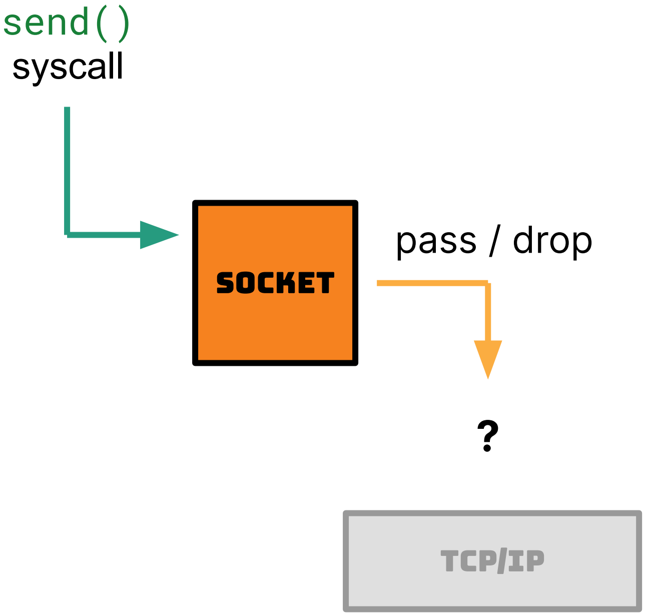
Policy on egress → Program input



```
struct sk_msg_md {
        __bpf_md_ptr(void *, data);
        __bpf_md_ptr(void *, data_end);

        __u32 family;
        __u32 remote_ip4;
        __u32 local_ip4;
        __u32 remote_ip6[4];
        __u32 local_ip6[4];
        __u32 remote_port;
        __u32 local_port;
        __u32 size;

        __bpf_md_ptr(struct bpf_sock *, sk);
};
```

message data

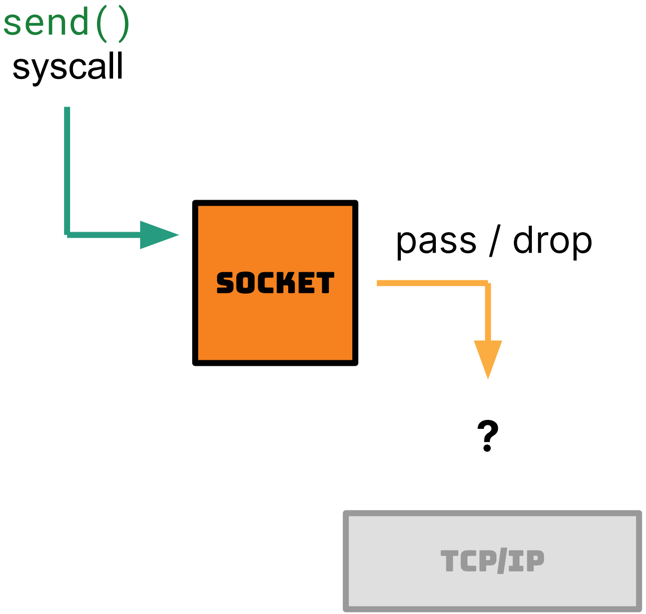
Policy on egress → Program input



```
struct sk_msg_md {
        __bpf_md_ptr(void *, data);
        __bpf_md_ptr(void *, data_end);

        __u32 family;
        __u32 remote_ip4;
        __u32 local_ip4;
        __u32 remote_ip6[4];
        __u32 local_ip6[4];
        __u32 remote_port;
        __u32 local_port;
        __u32 size;

        __bpf_md_ptr(struct bpf_sock *, sk);
};
```

src & dst info

Policy on egress → Program input



send()
syscall

SOCKET

pass / drop

?

TCP/IP

```
struct sk_msg_md {
        __bpf_md_ptr(void *, data);
        __bpf_md_ptr(void *, data_end);

        __u32 family;
        __u32 remote_ip4;
        __u32 local_ip4;
        __u32 remote_ip6[4];
        __u32 local_ip6[4];
        __u32 remote_port;
        __u32 local_port;
        __u32 size;

        __bpf_md_ptr(struct bpf_sock *, sk);
};
```

other socket info

Policy on egress → Example

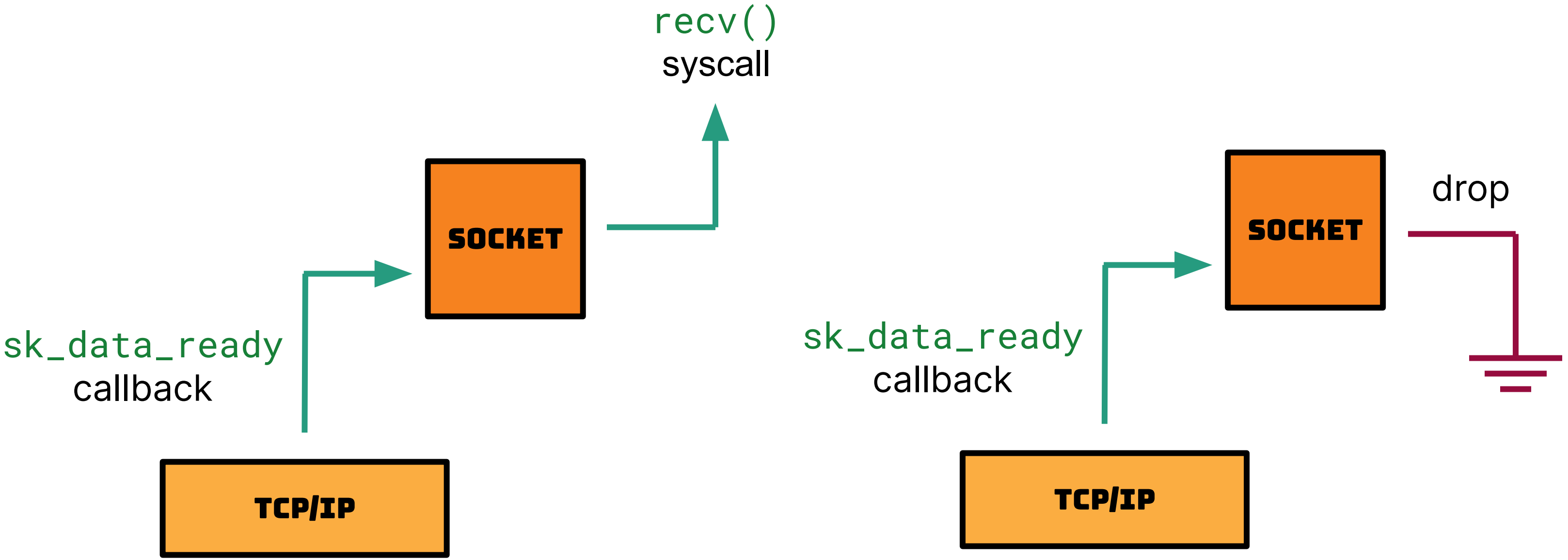
```
#define TEST_NET_1_ADDR IP4(192,   0,   2, 0)
#define TEST_NET_1_MASK IP4(255, 255, 255, 0)

SEC("sk_msg")
int sk_msg_prog(struct sk_msg_md *msg)
{
     if (msg->family != AF_INET)
          return SK_PASS;
     if ((msg->remote_ip4 & TEST_NET_1_MASK) != TEST_NET_1_ADDR)
          return SK_PASS;

     /* Drop anything destined to 192.0.2.0/24 documentation range */
     return SK_DROP;
}
```

Policy on egress → Test run

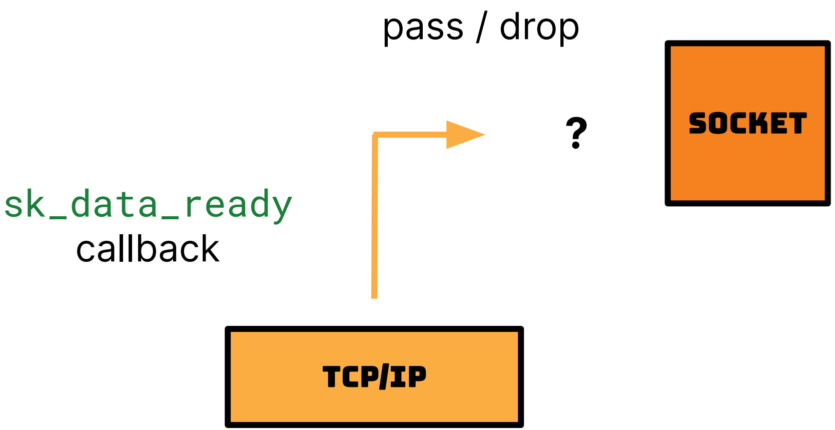
```
# nc -lke /bin/true 1234 &
#
# echo -n a | strace -e sendto nc 127.0.0.1 1234
sendto(3, "a", 1, 0, NULL, 0)           = 1
+++ exited with 0 +++
#
# echo -n b | strace -e sendto nc 192.0.2.1 1234
sendto(3, "b", 1, 0, NULL, 0)           = -1 EACCES (Permission denied)
Ncat: Permission denied.
+++ exited with 1 +++
```

https://github.com/jsitnicki/srecon-2023-sockmap/tree/main/examples/policy-egress

Policy on ingress



Policy on ingress → How?

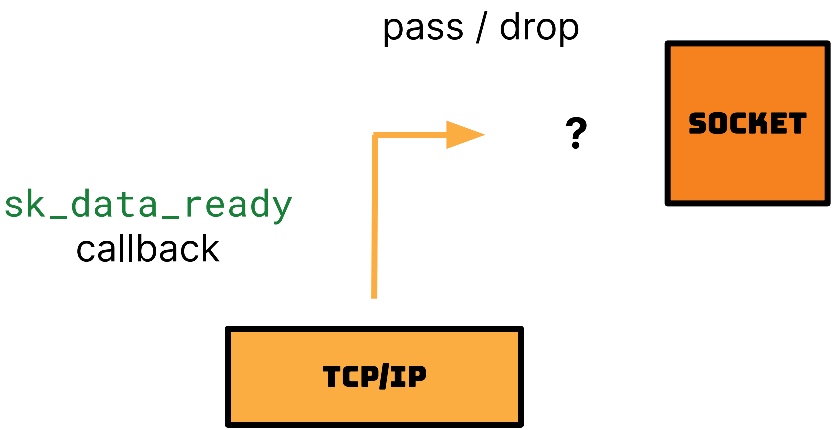


BPF_PROG_TYPE_**SK_SKB** prog

→ attached to BPF_**SK_SKB_VERDICT** hook

→ returns SK_**DROP** or SK_**PASS** verdict

Policy on ingress → Program input

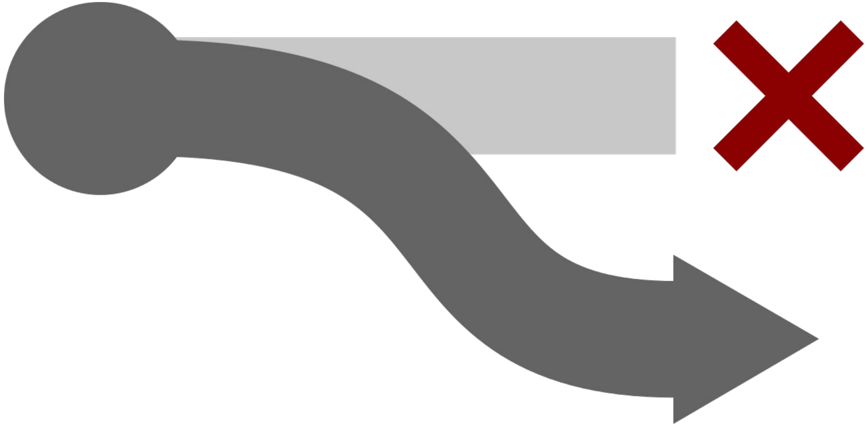


packet payload &
metadata from network stack

```
struct __sk_buff {
        …
        // too many fields to include here
        // see the link at the bottom
        …
};
```

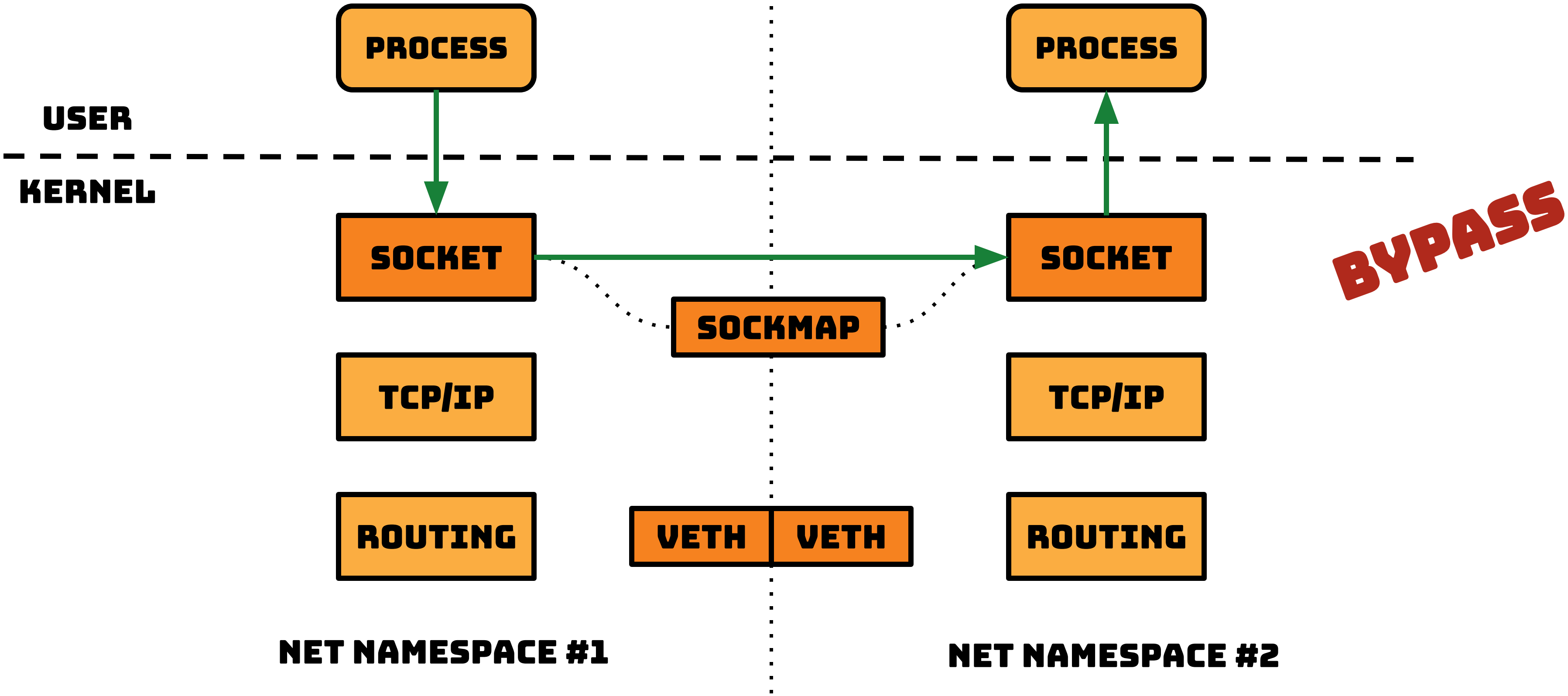
https://elixir.bootlin.com/linux/v6.5/source/include/uapi/linux/bpf.h#L6005

REDIRECT

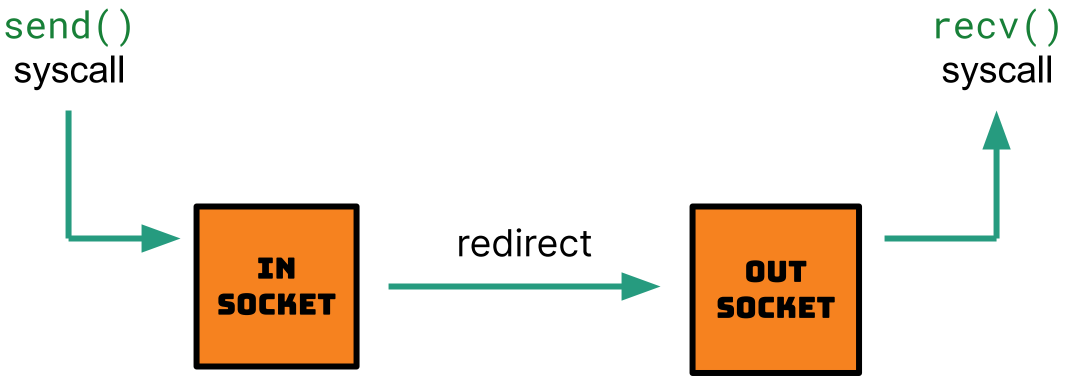


Wikimedia Commons, CC BY 3.0 DEED

Redirect use case → Bypass for containers



Redirect → send to local



send() syscall

IN SOCKET

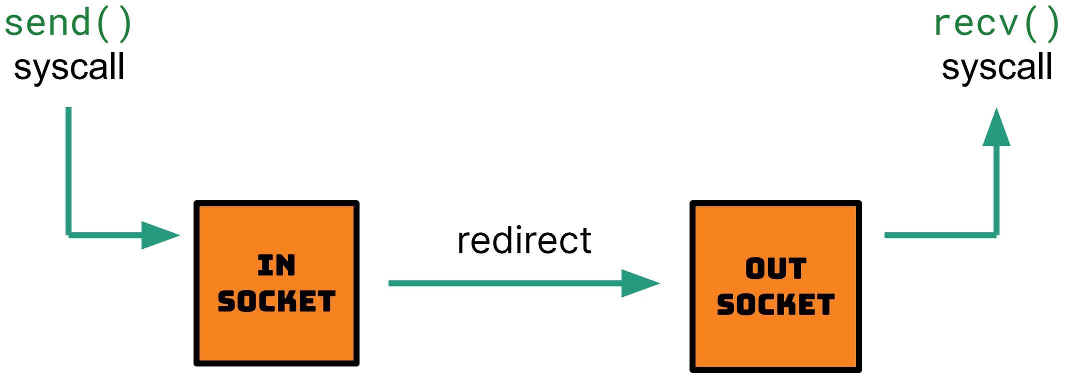
redirect

OUT SOCKET

recv() syscall

Like socketpair() or pipe()

Redirect → send to local → How?



BPF_PROG_TYPE_**SK_MSG** prog

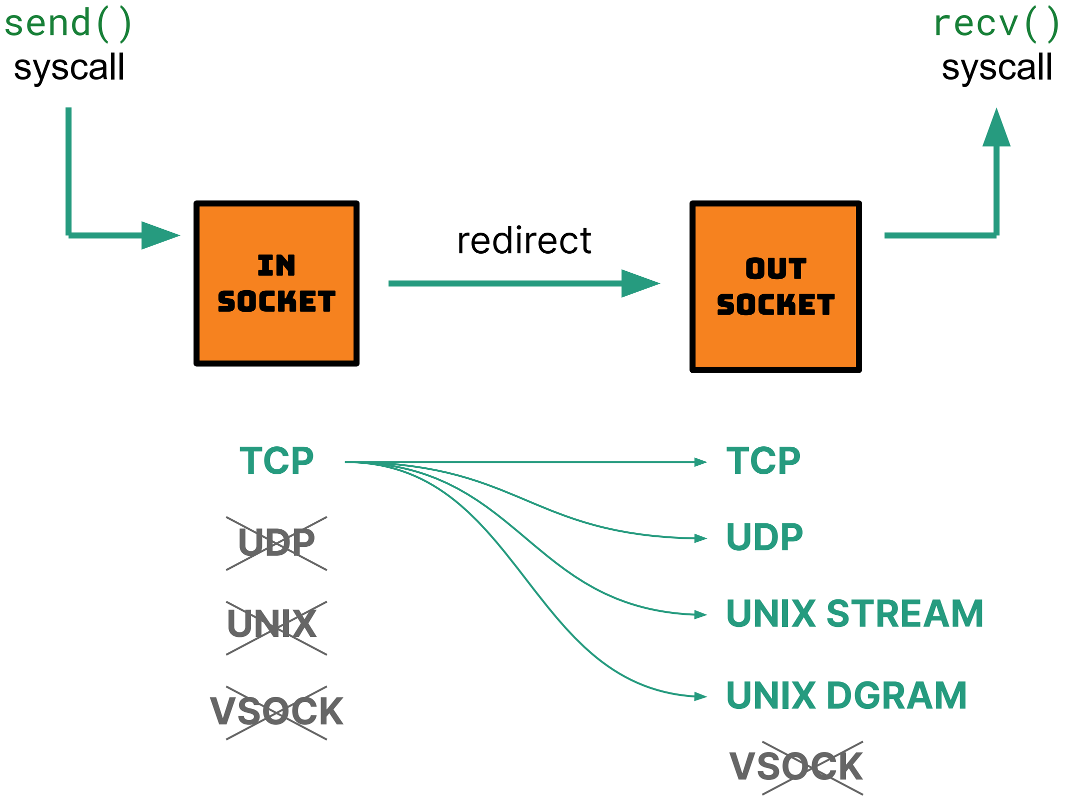
→ attached to BPF_**SK_MSG_VERDICT** hook

→ calls bpf_**msg**_redirect_hash/map() with BPF_F_**INGRESS** flag

→ returns SK_**PASS**

selects target socket

Redirect → send to local → What?



send()
syscall

IN SOCKET

redirect

OUT SOCKET

recv()
syscall

TCP

~~UDP~~

~~UNIX~~

~~VSOCK~~

TCP

UDP

UNIX STREAM

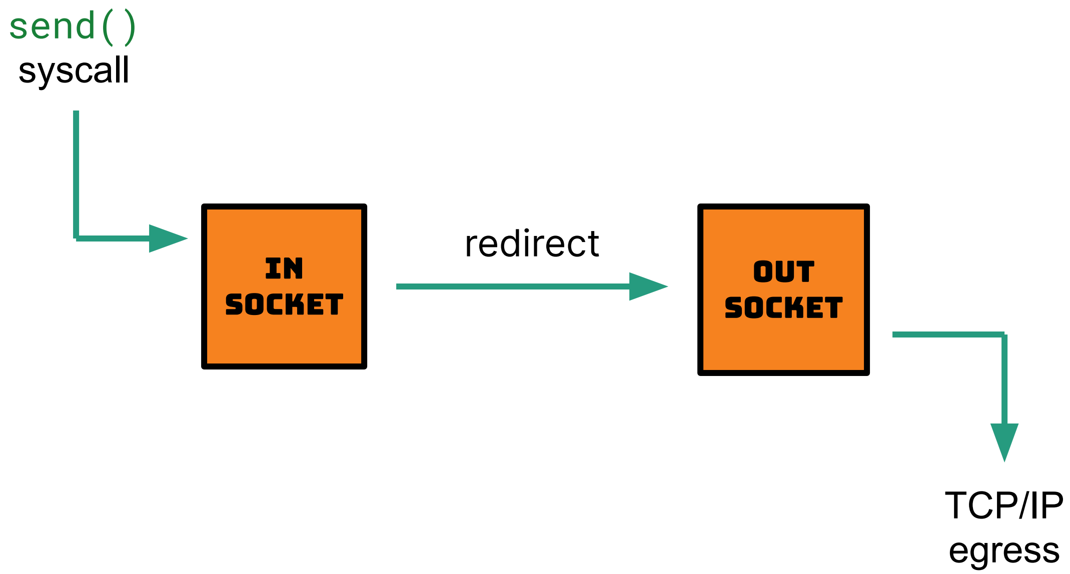
UNIX DGRAM

~~VSOCK~~

Redirect → send to local → Example

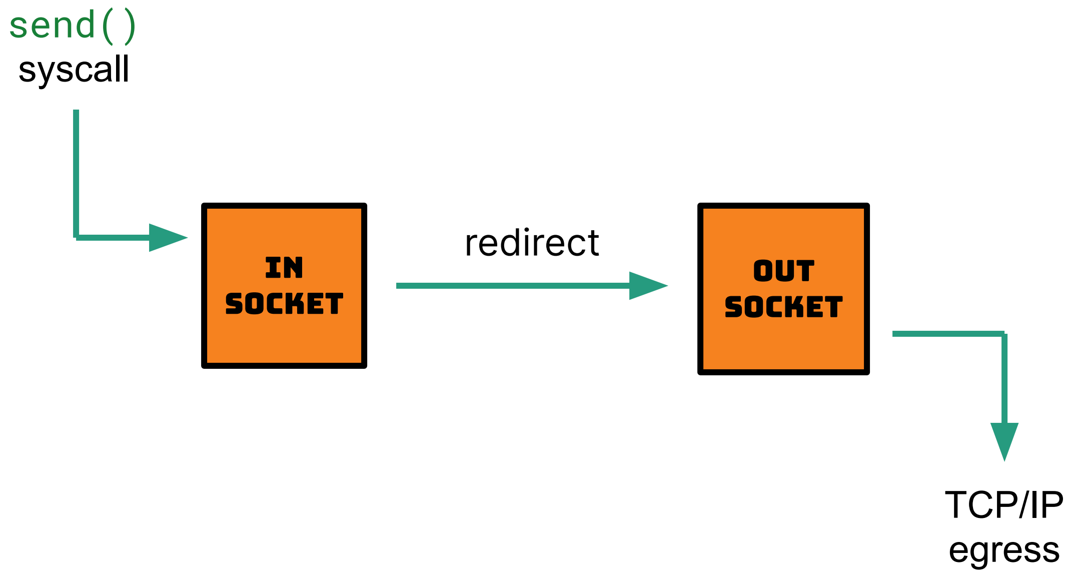
```
SEC("sk_msg")
int sk_msg_redir_ingress(struct sk_msg_md *msg)
{
    __u32 key = 0;

    if (msg->remote_port == bpf_htonl(53))
        key = 1;

     return bpf_msg_redirect_map(msg, &sockmap, key, BPF_F_INGRESS);
}
```

Redirect → send to egress



Sort of like splice()
(pipe → socket)

Redirect → send to egress → How?



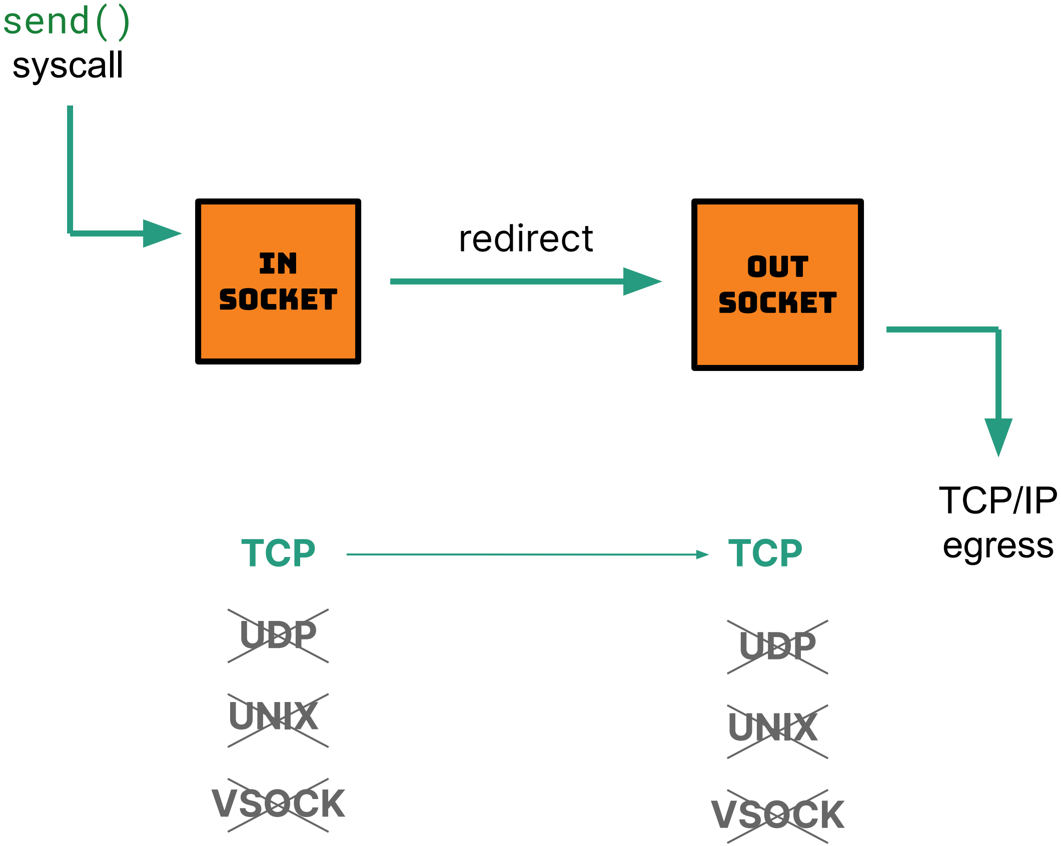
BPF_PROG_TYPE_**SK_MSG** prog

→ attached to BPF_**SK_MSG_VERDICT** hook

→ calls bpf_**msg**_redirect_hash/map() without any flags

→ returns SK_**PASS**

Redirect → send to egress → What?



send()
syscall

IN SOCKET

redirect

OUT SOCKET

TCP/IP
egress

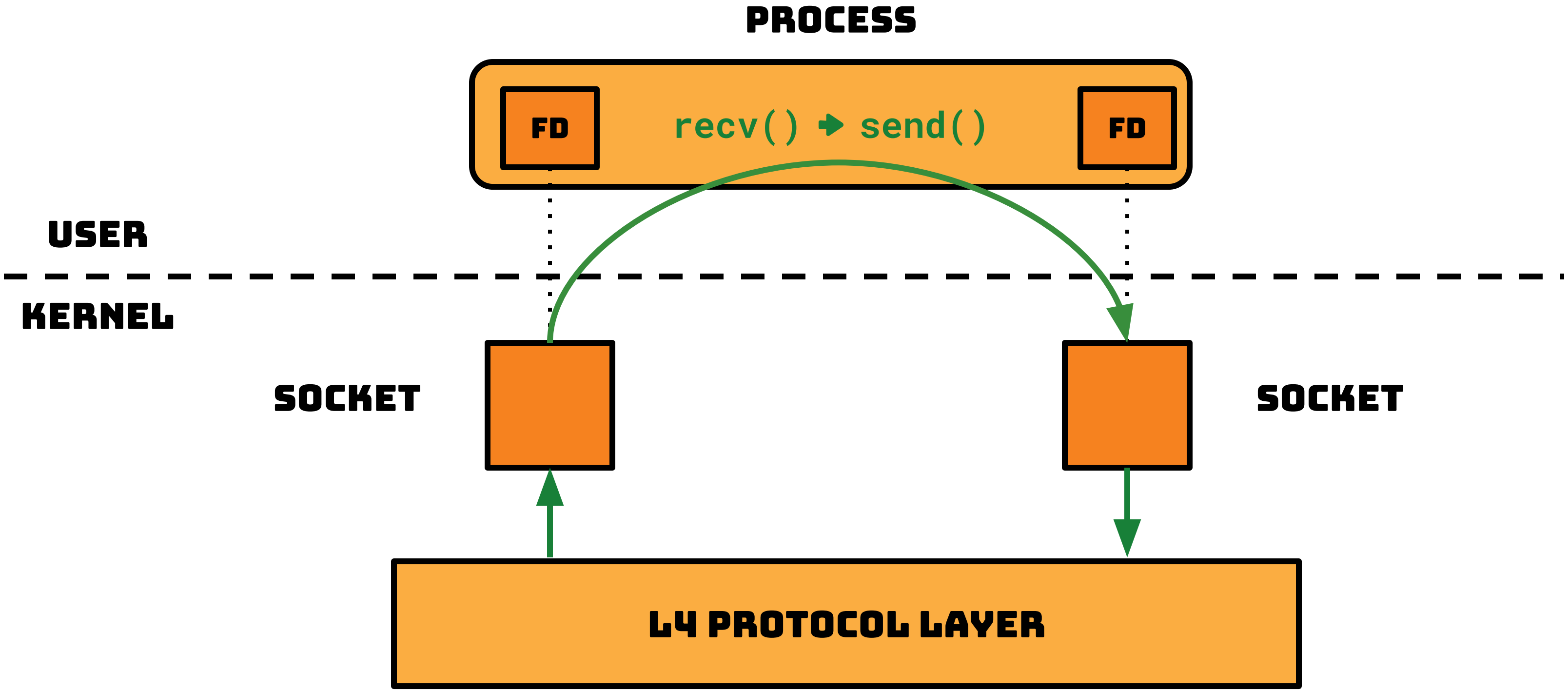
TCP → TCP

~~UDP~~ ~~UDP~~

~~UNIX~~ ~~UNIX~~

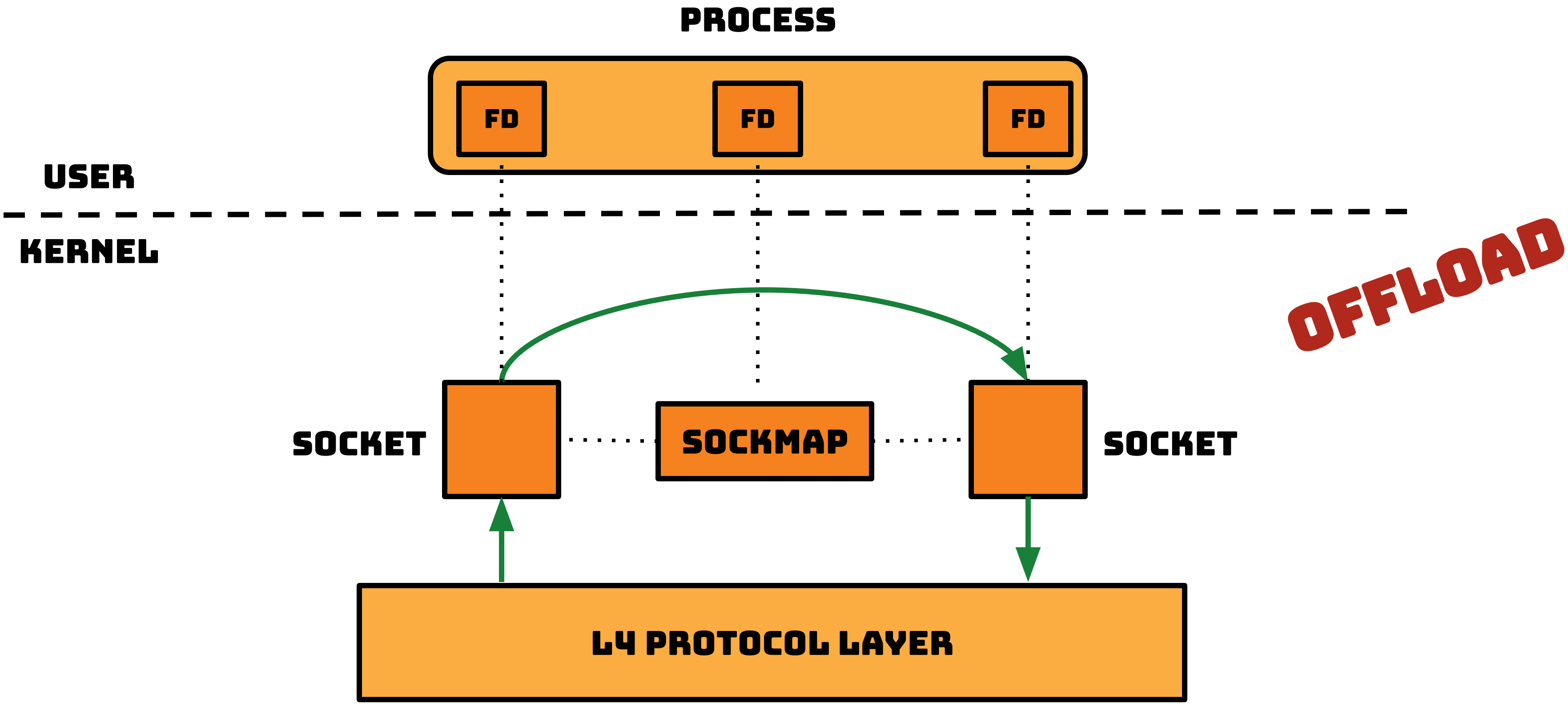
~~VSOCK~~ ~~VSOCK~~

Redirect use case → L7 network proxy

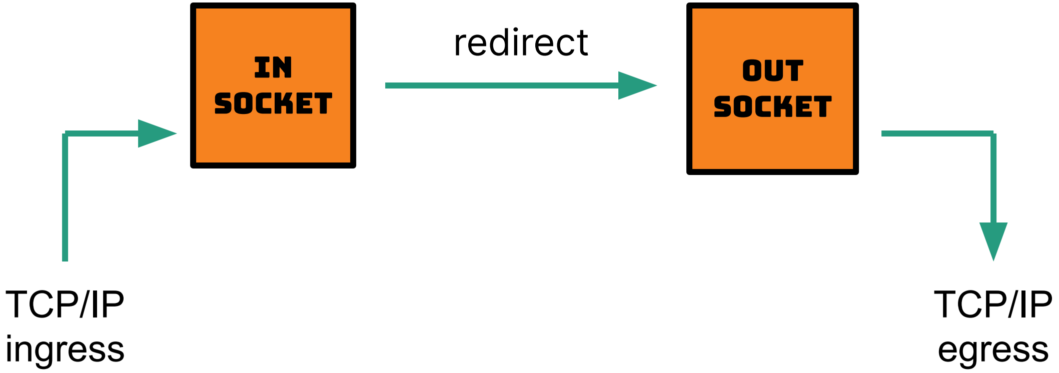


Examples: `socat`, `systemd-socket-proxyd`

Redirect use case → L7 network proxy

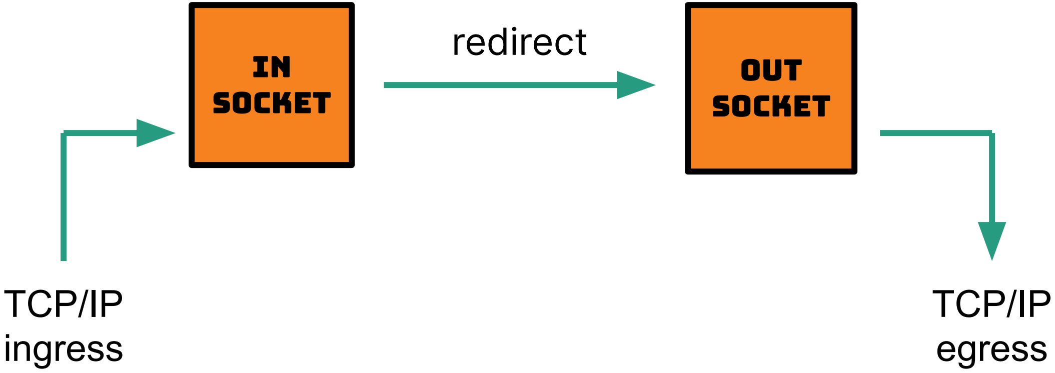


Redirect → ingress to egress



Like double `splice()`
(socket → pipe → socket)

Redirect → ingress to egress → How?



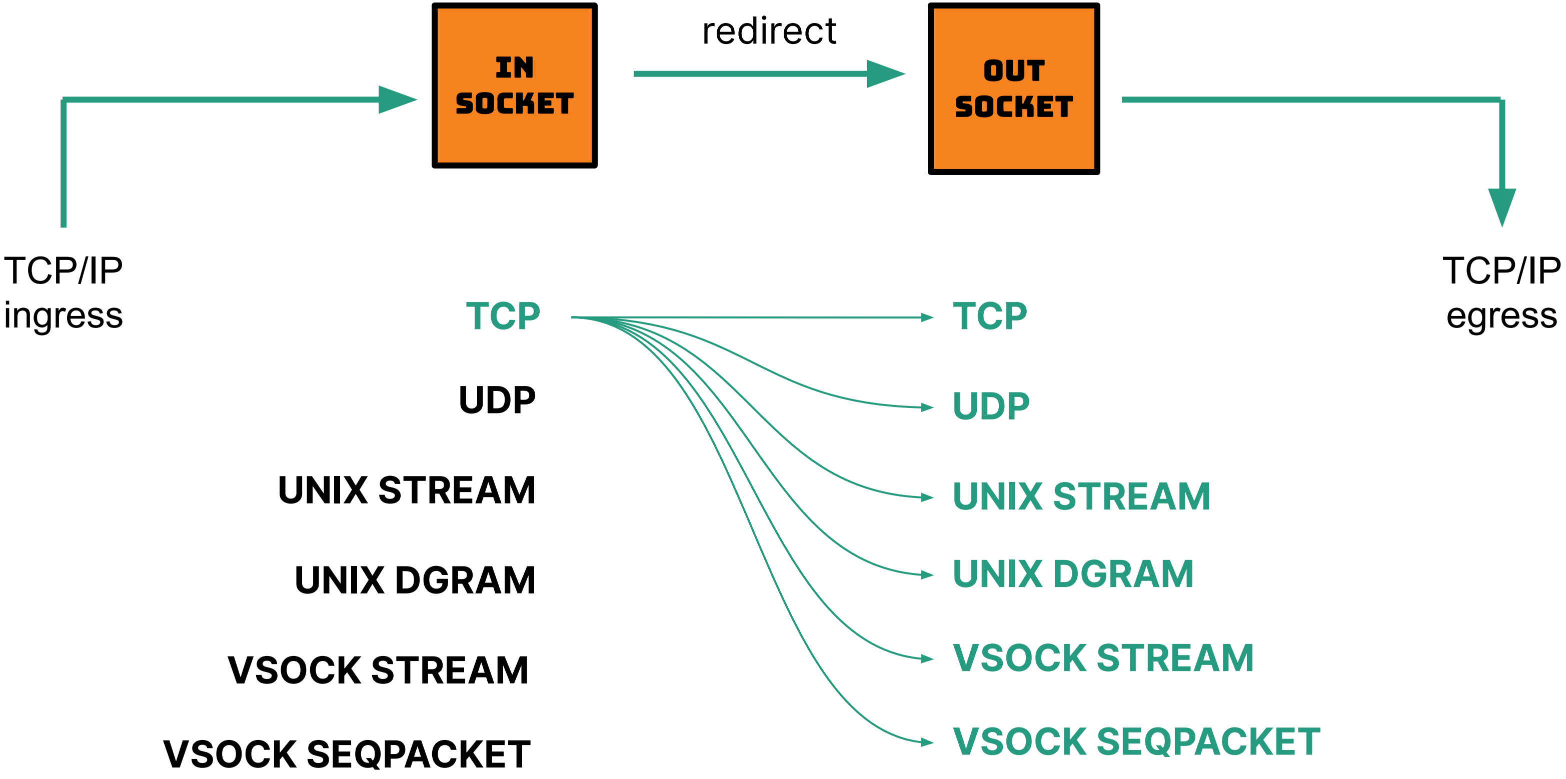
BPF_PROG_TYPE_**SK_SKB** prog

→ attached to BPF_**SK_SKB_VERDICT** hook

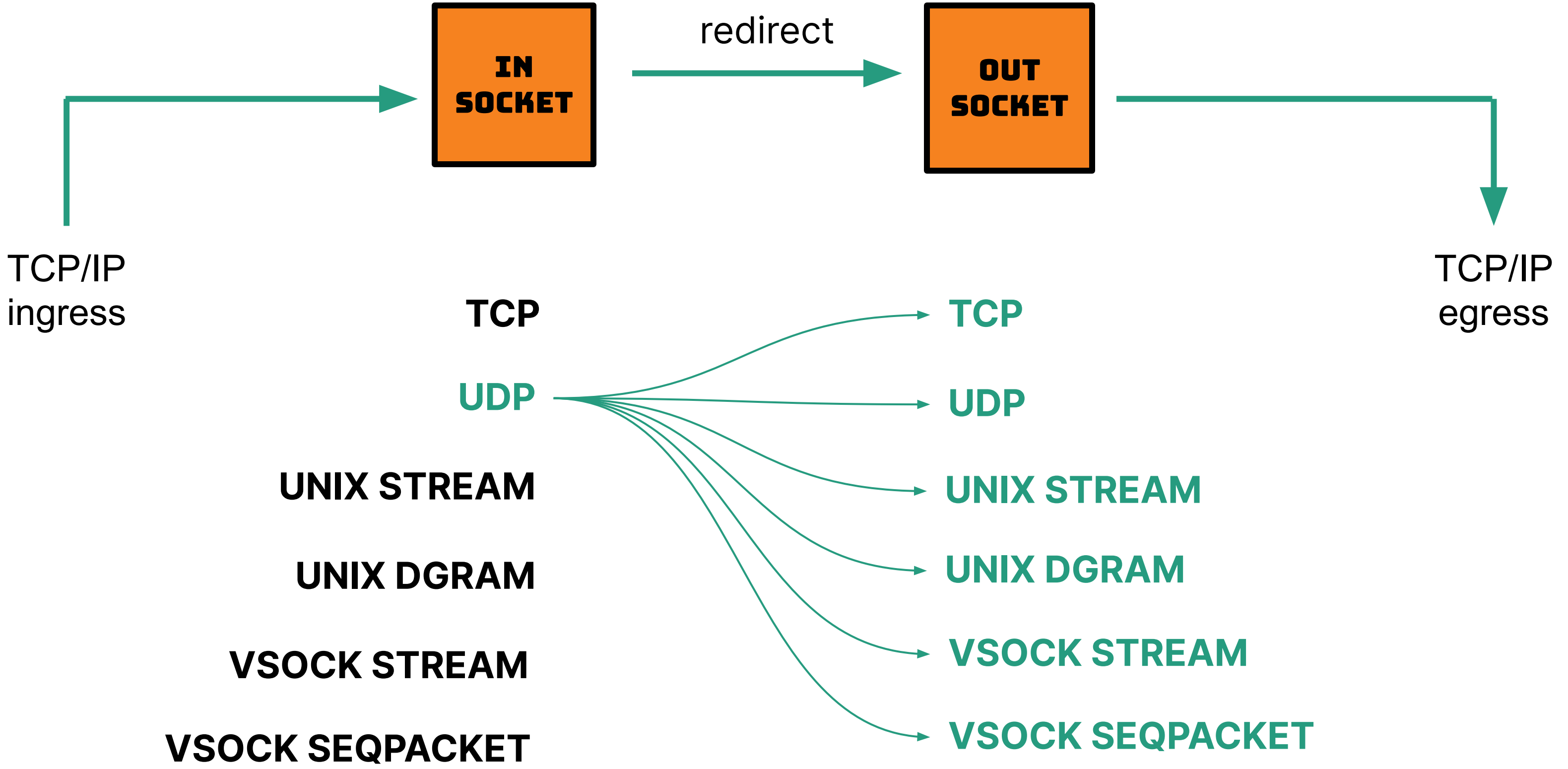
→ calls bpf_sk_redirect_hash/map() without any flags

→ returns SK_**PASS**

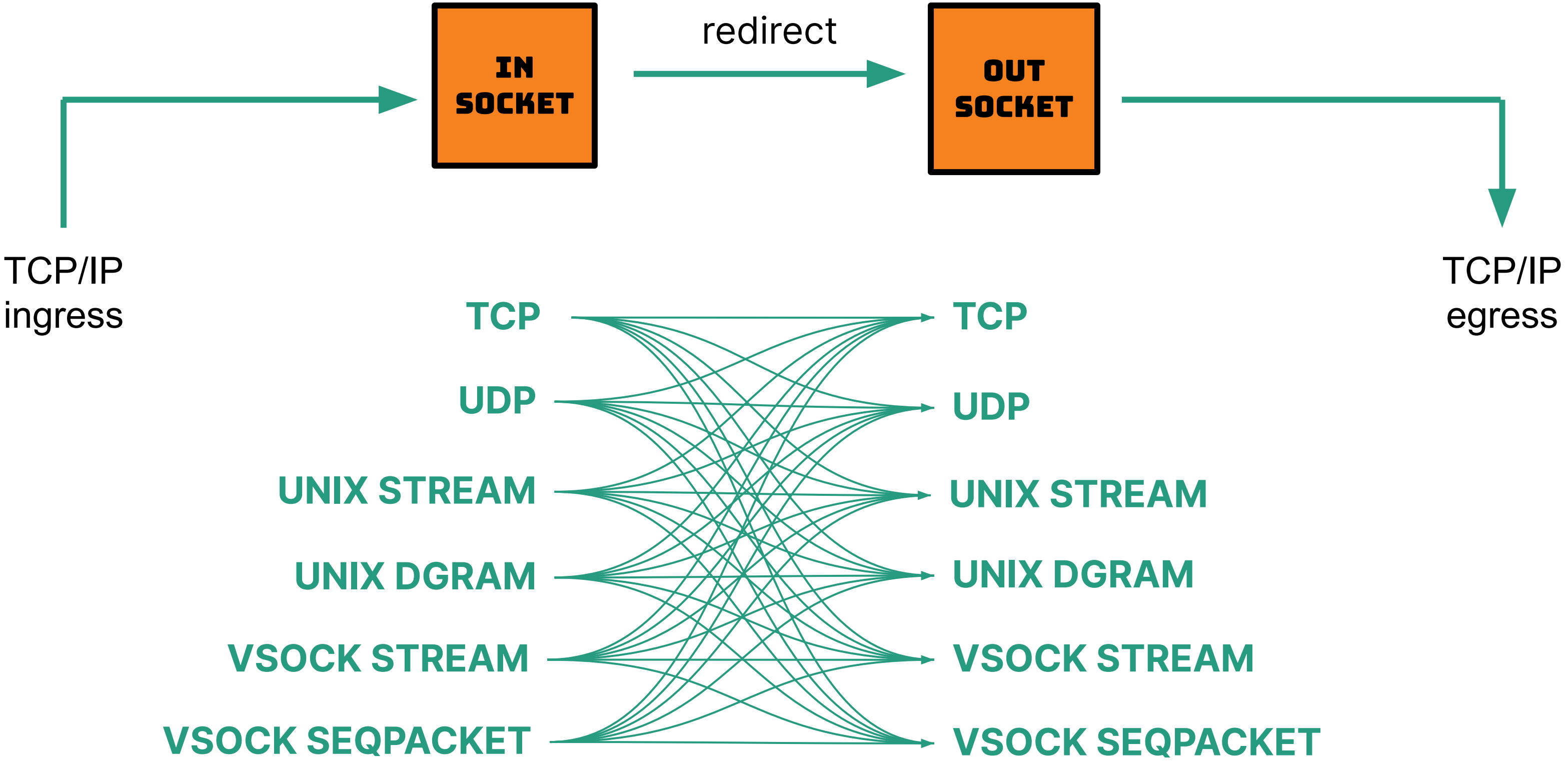
Redirect → ingress to egress → What?



Redirect → ingress to egress → What?

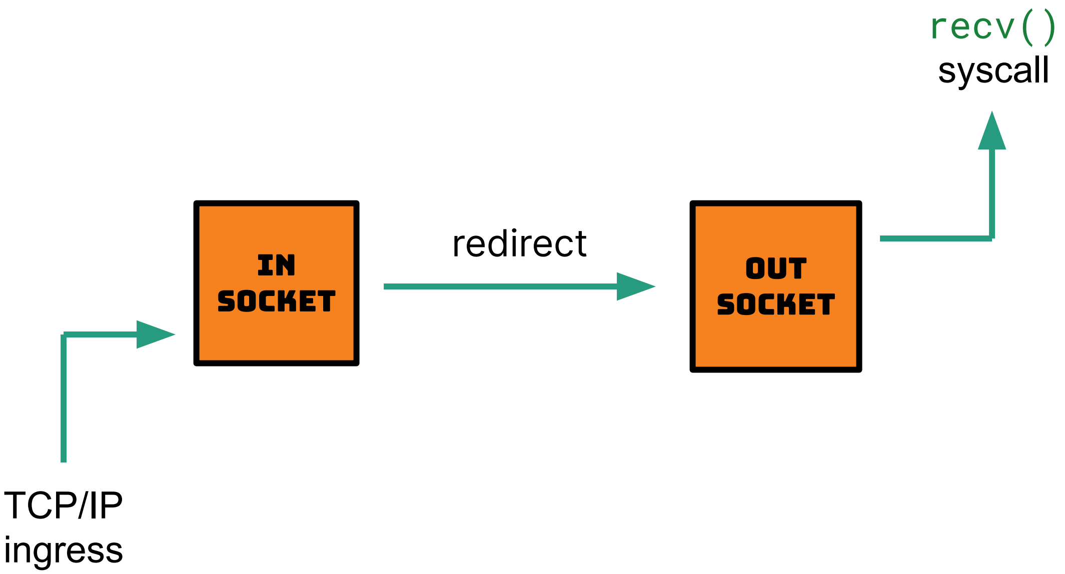


Redirect → ingress to egress → What?



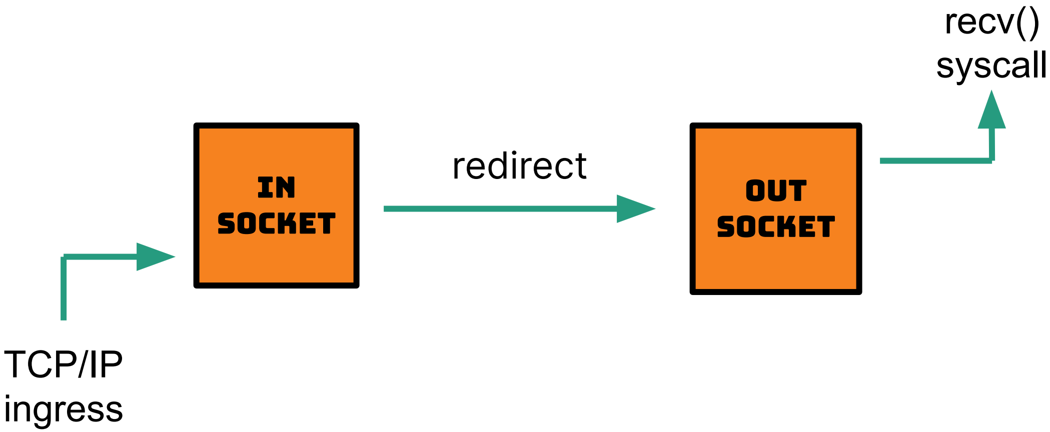
any to any

Redirect → ingress to local



Also sort of like `splice()`
(socket → pipe)

Redirect → ingress to local → How?



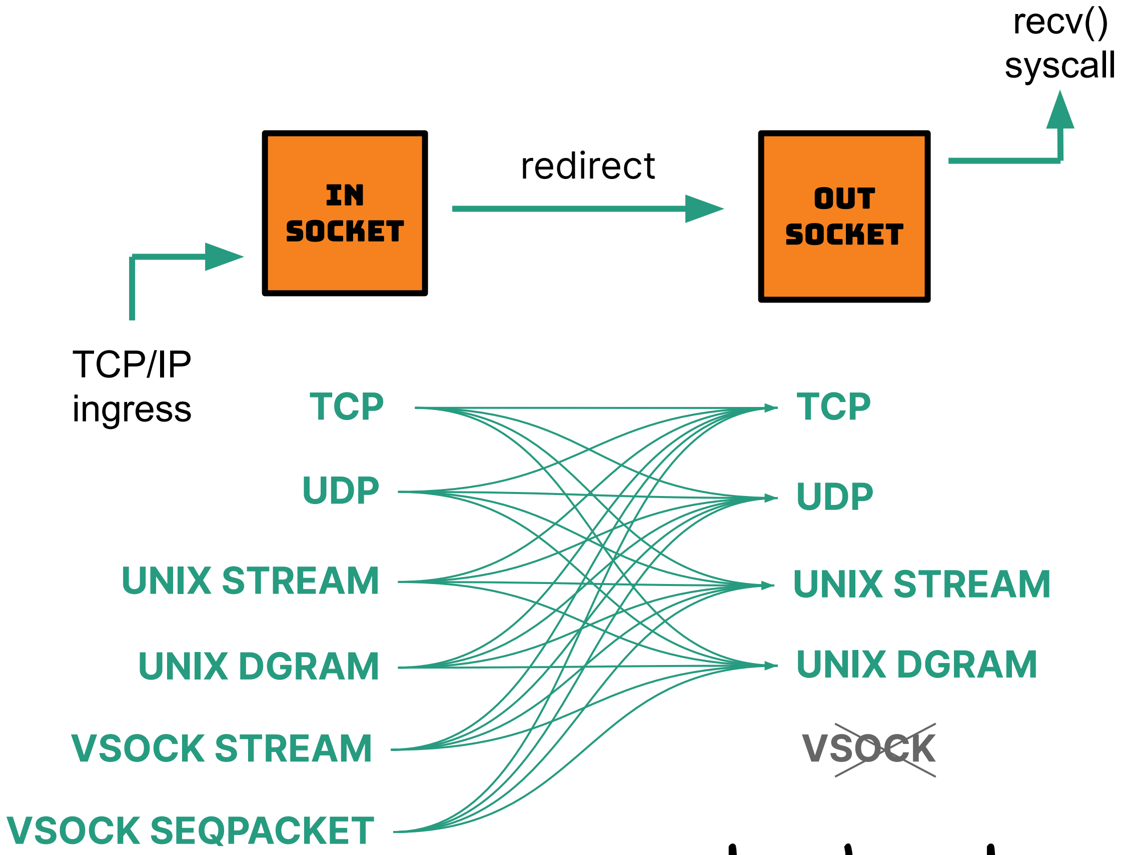
BPF_PROG_TYPE_**SK_SKB** prog

→ attached to BPF_**SK_SKB_VERDICT** hook

→ calls bpf_**sk**_redirect_hash/map() with BPF_F_**INGRESS** flag

→ returns SK_**PASS**

Redirect → ingress to local → What?



recv()
syscall

IN SOCKET

redirect

OUT SOCKET

TCP/IP
ingress

TCP

UDP

UNIX STREAM

UNIX DGRAM

VSOCK STREAM

VSOCK SEQPACKET

TCP

UDP

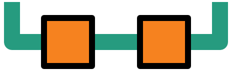
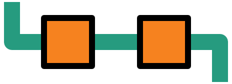
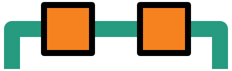
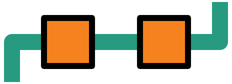
UNIX STREAM

UNIX DGRAM

~~VSOCK~~

any to almost any

Cheatsheet - Redirect with SOCKMAP

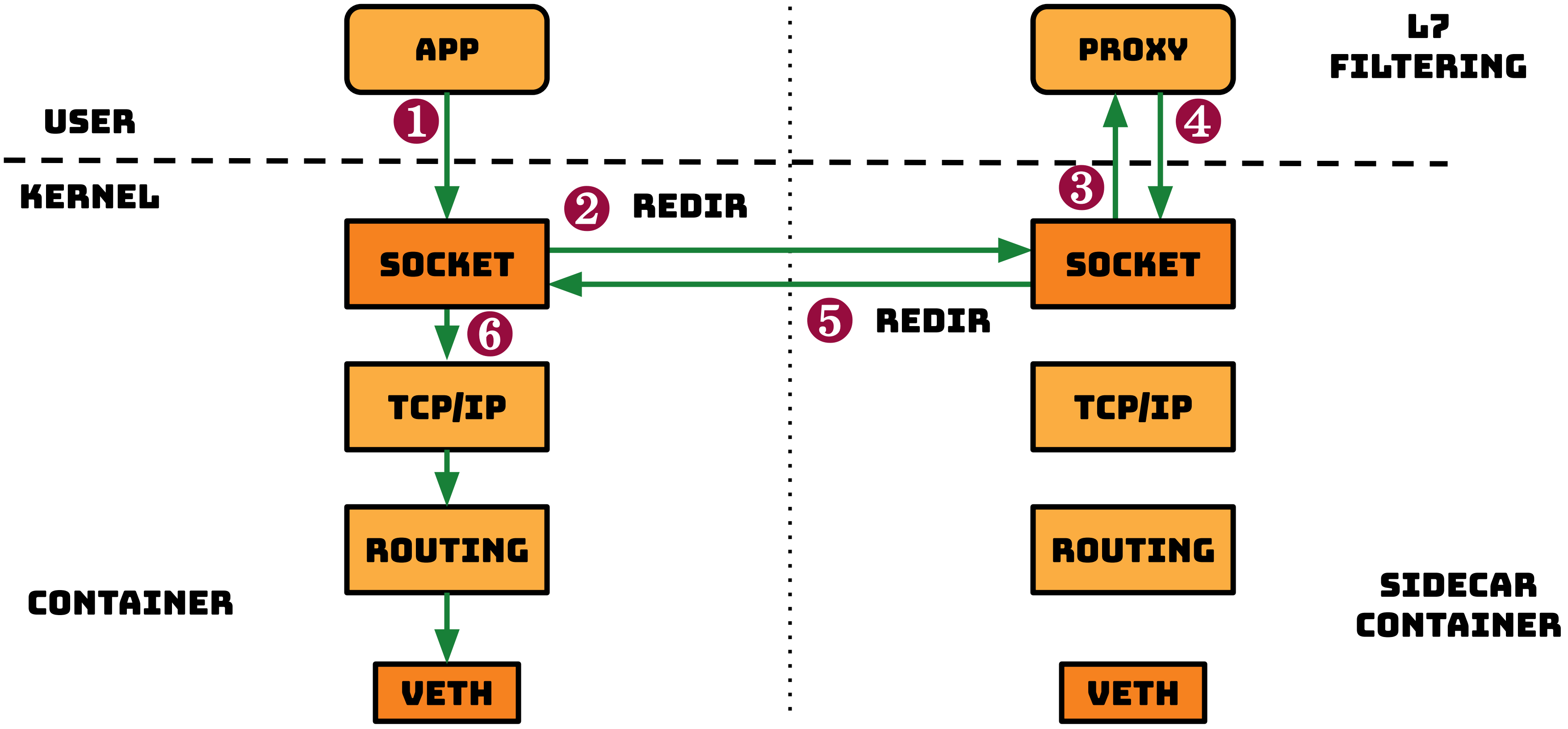
redirect scenario	program type BPF_PROG_TYPE_*	attach type BPF_*	redirect function	redirect flag	in socket type	out socket type
send to local 	SK_MSG	SK_MSG_VERDICT	bpf_msg_redirect_*()	BPF_F_INGRESS	TCP	any but VSOCK
send to egress 	SK_MSG	SK_MSG_VERDICT	bpf_msg_redirect_*()	none	TCP	TCP
ingress to egress 	SK_SKB	SK_SKB_VERDICT	bpf_sk_redirect_*()	none	any	any
ingress to local 	SK_SKB	SK_SKB_VERDICT	bpf_sk_redirect_*()	BPF_F_INGRESS	any	any but VSOCK

Section

CLOUDFLARE

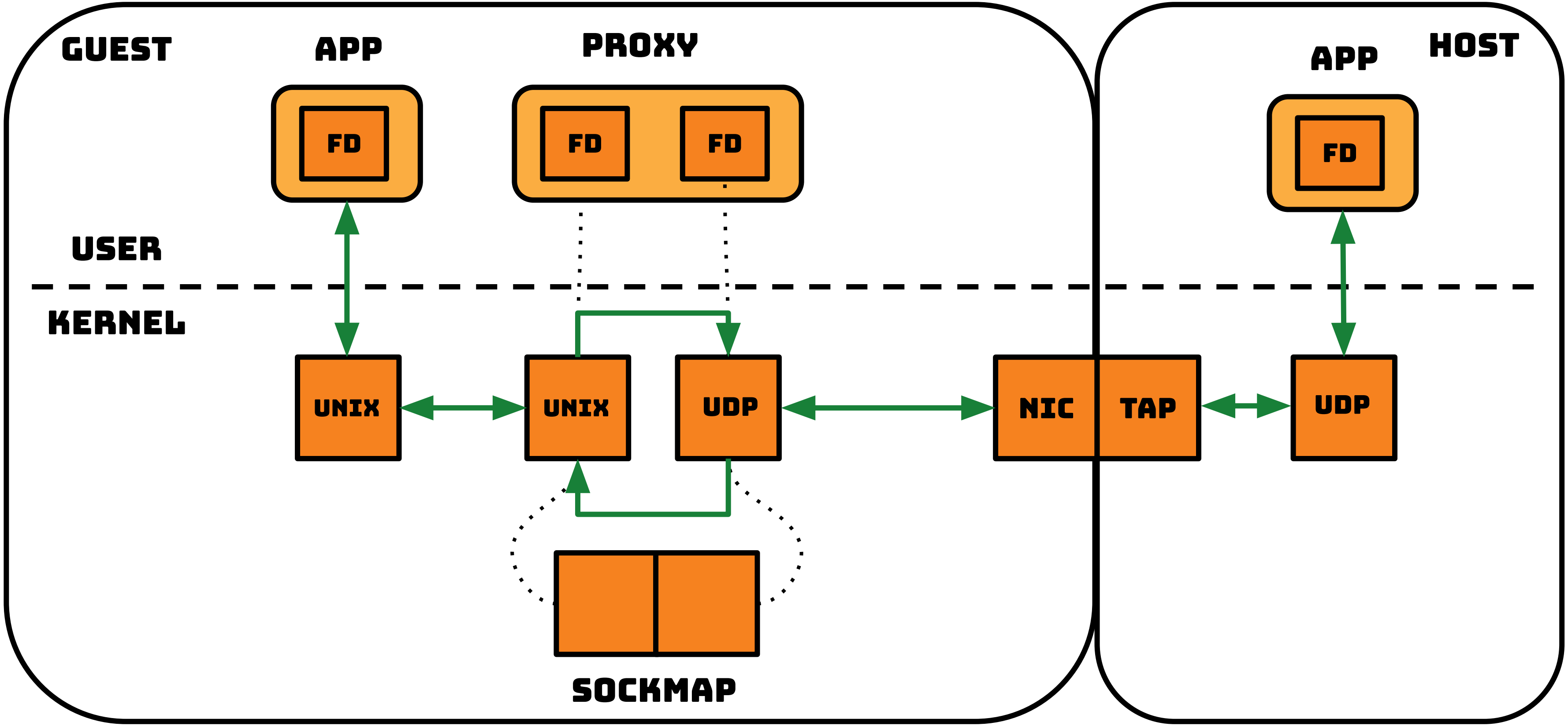
Real life use-cases

Cilium project (CNI for K8S)



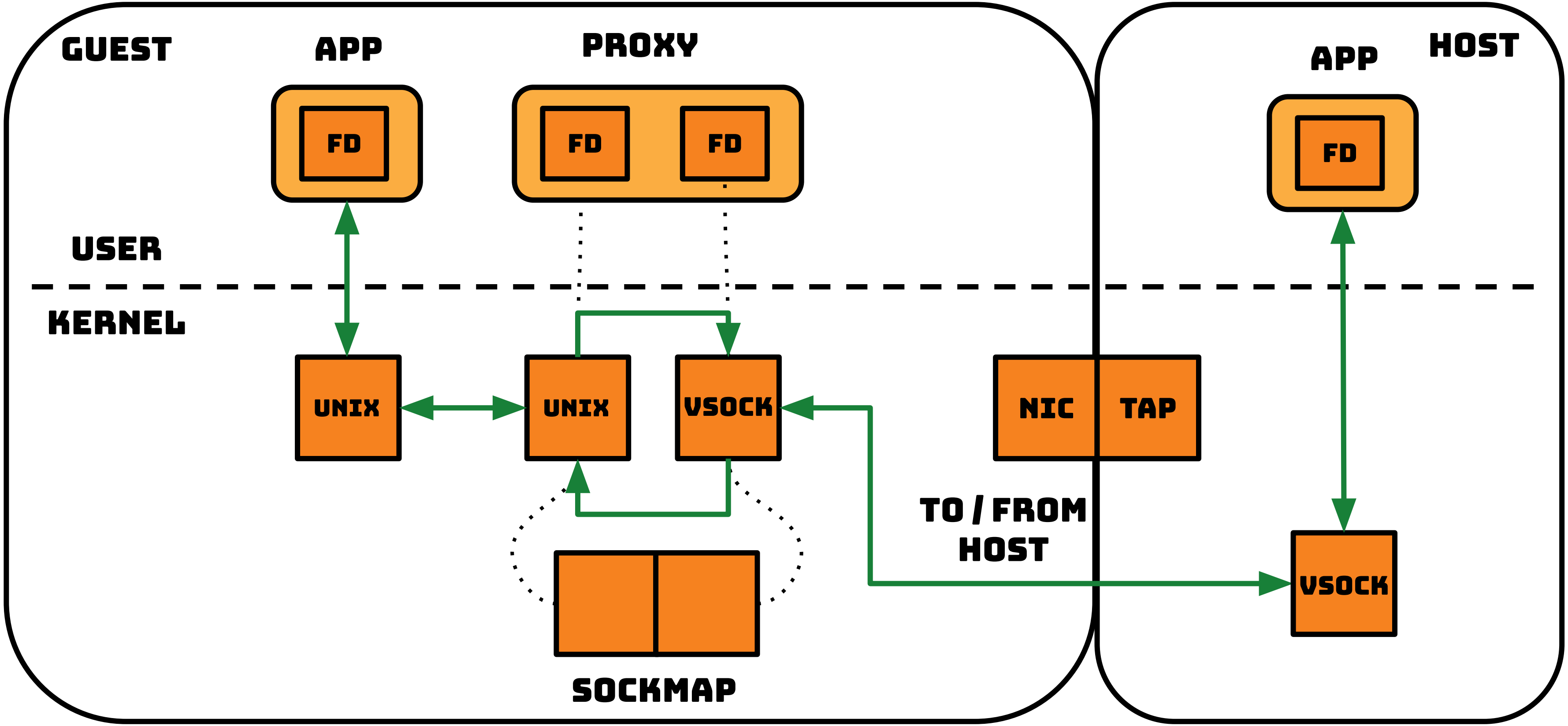
https://cilium.io/blog/2019/02/12/cilium-14/

Bytedance (TikTok)



https://lore.kernel.org/bpf/20210331023237.41094-1-xiyou.wangcong@gmail.com/

Bytedance (TikTok) → Improved



https://lore.kernel.org/all/20230327-vsock-sockmap-v4-0-c62b7cd92a85@bytedance.com/

Section

Where to learn more?

Documentation & Resources

1) Linux Kernel → BPF Documentation → SOCKMAP and SOCKHASH map

   Includes links to unit tests with API usage examples

2) LPC 2018: Combining kTLS and BPF for Introspection and Policy Enforcement

   See Daniel & John talk about Cilium SOCKMAP + kTLS use case (video, slides, paper)

3) Cloudflare Blog: SOCKMAP - TCP splicing of the future

   Read Marek review SOCKMAP from L7 proxy perspective

4) eBPF Summit 2020: Steering connections to sockets with BPF socket lookup hook

   Another use case for SOCKMAP as a container (video, slides, code)

Documentation & Resources

Code + Slides

https://github.com/jsitnicki/srecon-2023-sockmap

```
$ logout
```

Thank you

`jakub@cloudflare.com`

`@jkbs0` @ ~~Twitter~~ X

Mailing lists:

`bpf@vger.kernel.org`

`netdev@vger.kernel.org`

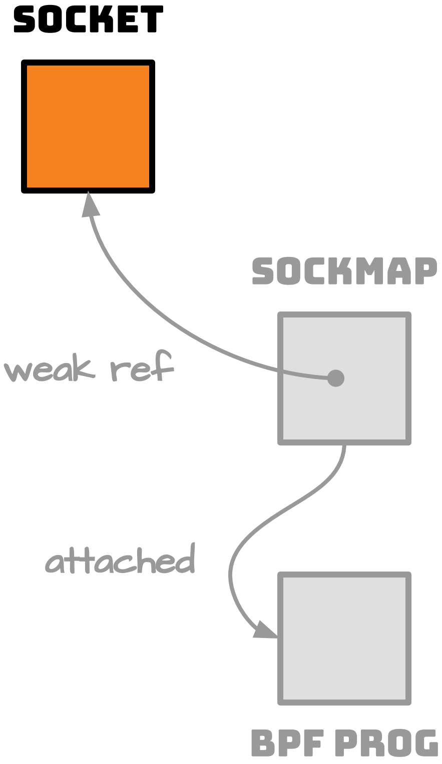
`#ebpf-kernel-dev` @ `cilium.slack.com`

code & slides repo

CLOUDFLARE

Overflow slides

What sockets you can't use



connected (established) socket:

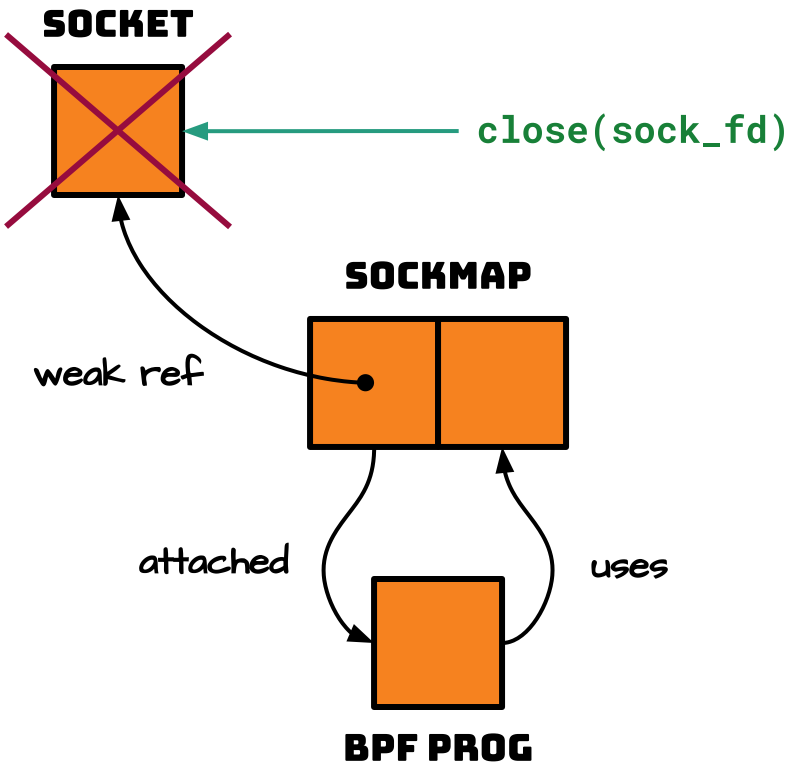
- ❏ UNIX SEQPACKET
- ❏ VSOCK DGRAM

`man 7 {tcp,udp,unix,vsock}`

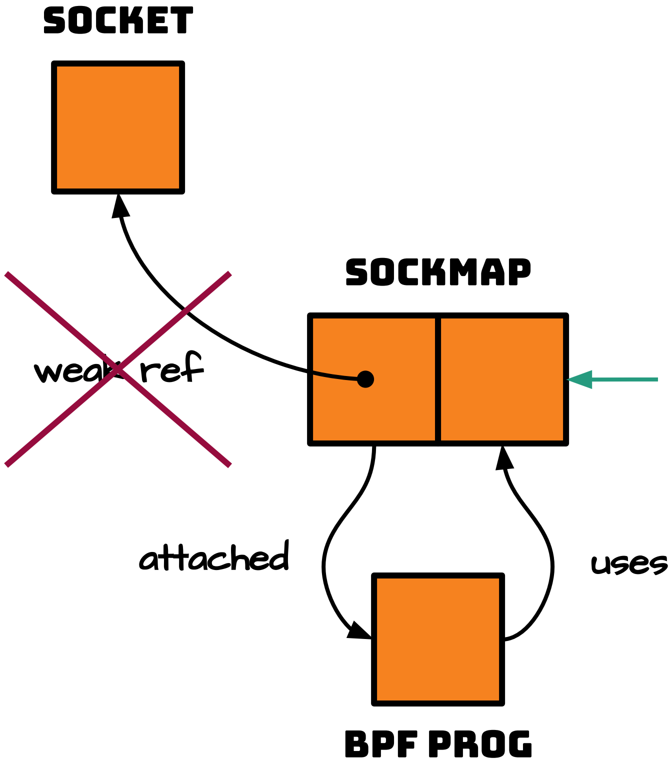
How to tear it down?

[pxhere.com, CC0](https://pxhere.com)

(A) destroy the socket



(B) remove socket from sockmap



SOCKET

SOCKMAP

~~weak ref~~

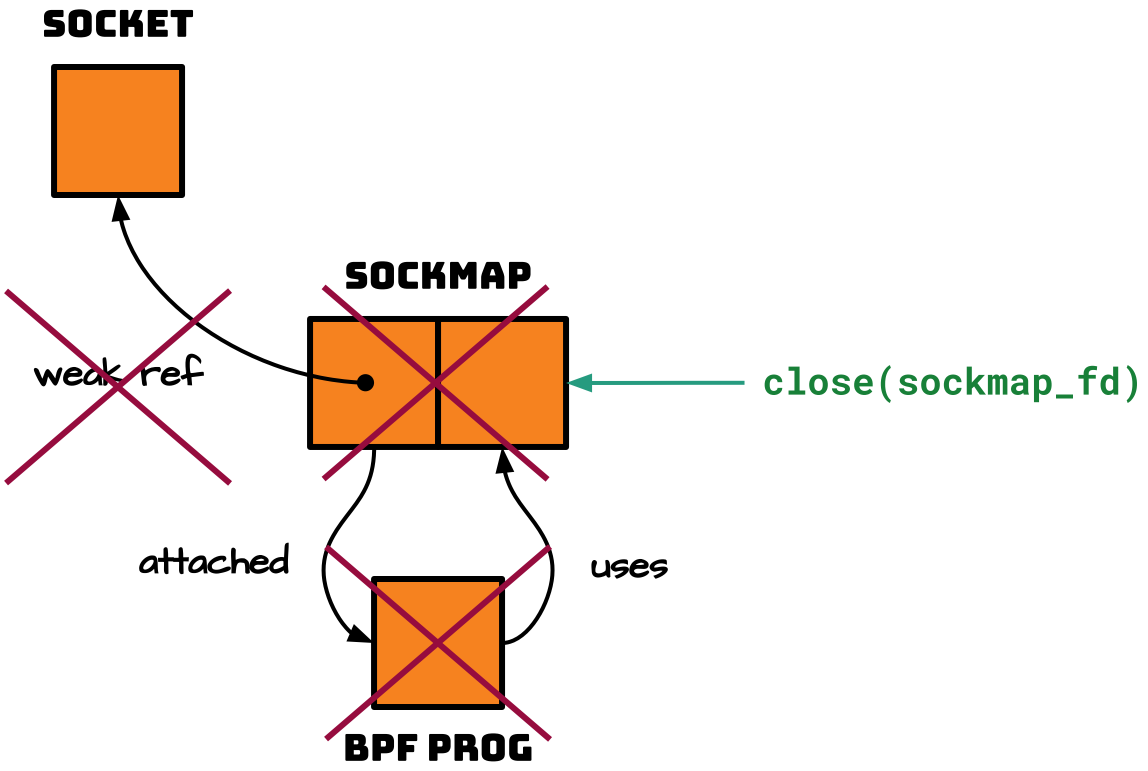
attached

uses

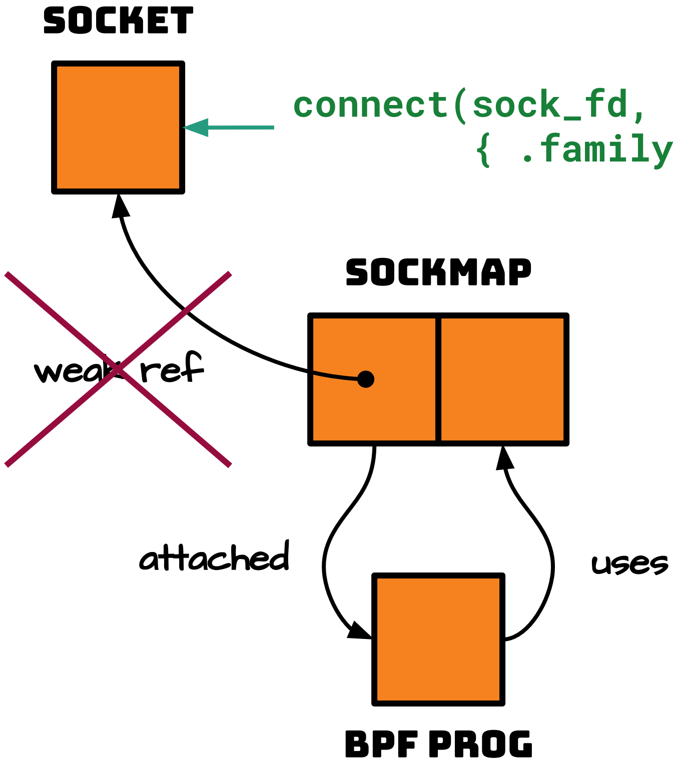
BPF PROG

`bpf(BPF_MAP_DELETE_ELEM, …)`

(C) destroy the sockmap



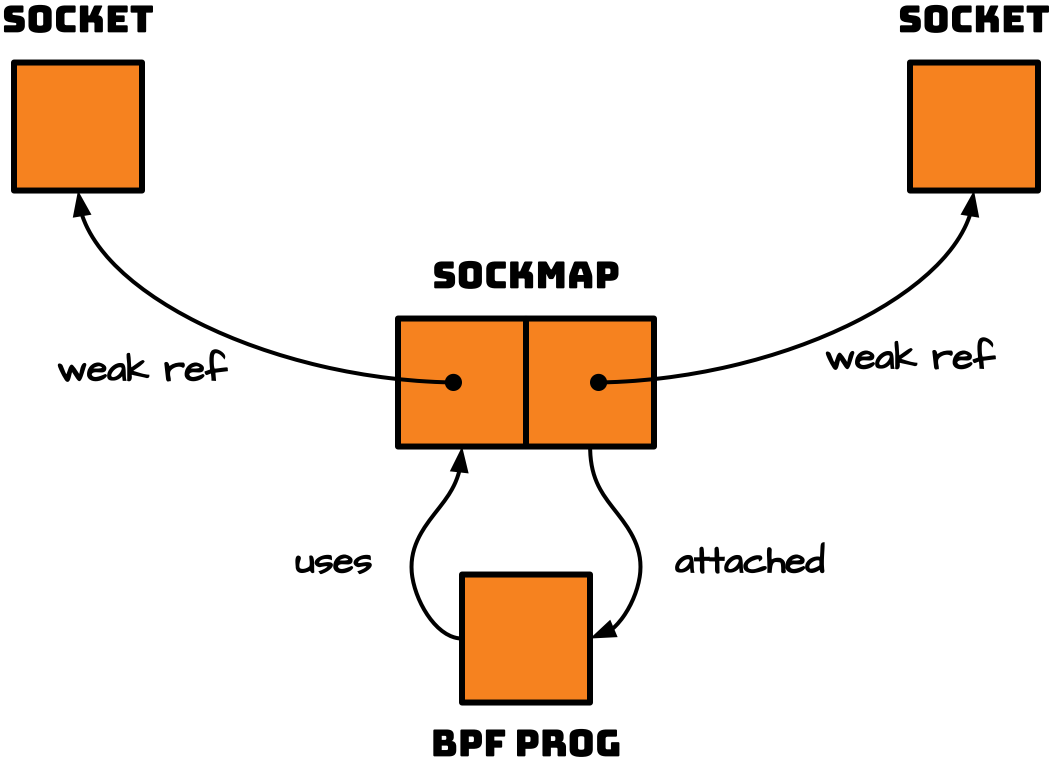
(D) disconnect the socket (rare)



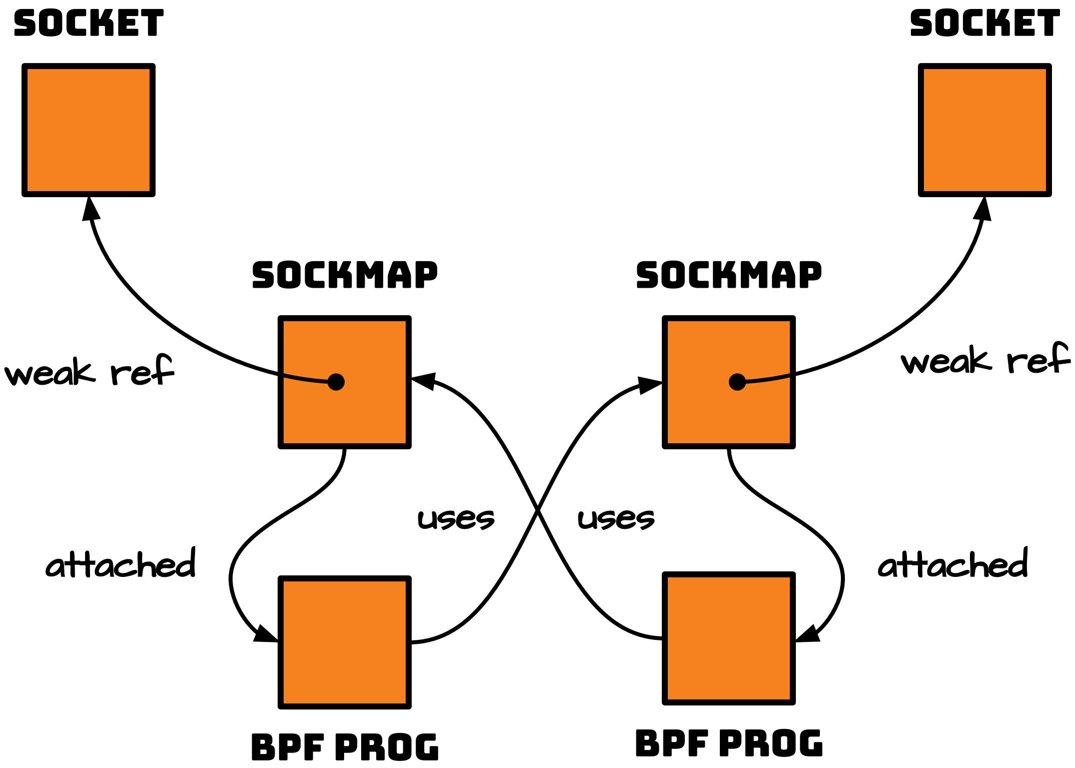
```
connect(sock_fd,
        { .family = AF_UNSPEC }, …)
```

💡 See `connect(2)` man page

Two sockets in one sockmap



Two sockets in two sockmaps


SOCKET
SOCKET
SOCKMAP
SOCKMAP
weak ref
weak ref
uses
uses
attached
attached
BPF PROG
BPF PROG