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Problem statement

How can we apply batching to XDP?
Performance results

<table>
<thead>
<tr>
<th>action</th>
<th>XDP_DROP</th>
<th>XDP_TX</th>
<th>XDP_REDIRECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perf boost</td>
<td>16%</td>
<td>70%</td>
<td>91%</td>
</tr>
</tbody>
</table>

Conducted on FVL 10G, i40e driver. No fancy performance settings, just 5.3 kernel with CONFIG_RETPOLINE=y
Agenda

- Source of performance improvements
- PoC contents
  - Driver changes
  - eBPF verifier changes
- Things to be solved/questions/thoughts
Source of performance improvements

- Bulking
- Less indirect calls
DRIVER CHANGES
Storing XDP program result per XDP buffer

- Extend `struct xdp_buff`

```c
struct xdp_buff {
    void *data;
    void *data_end;
    void *data_meta;
    void *data_hard_start;
    unsigned long handle;
    struct xdp_rxq_info *rxq;
    + unsigned int act;
};
```

- Pass array to be filled via argument to XDP program

```c
ret = (*prog)->bpf_func(ctx, (prog)->insn, results, size);
```
Storing XDP program result per XDP buffer

- Extend struct xdp_buff

```c
struct xdp_buff {
    void *data;
    void *data_end;
    void *data_meta;
    void *data_hard_start;
    unsigned long handle;
    struct xdp_rxq_info *rxq;
    + unsigned int act;
};
```

- Pass array to be filled via argument to XDP program

```c
ret = (*prog)->bpf_func(ctx, (prog)->insn, + results, size);
```
During ring alloc, for each ring:

```c
vsi->rx_rings[i]->xdp_buffs = (struct xdp_buff *)malloc(64, sizeof(struct xdp_buff), GFP_KERNEL);
```

<table>
<thead>
<tr>
<th>xdp_buff[0]</th>
<th>xdp_buff[1]</th>
<th>...</th>
<th>xdp_buff[n - 1]</th>
</tr>
</thead>
</table>

Act on each buffer:

- `act = XDP_DROP`
- `act = XDP_TX`
Bulking in driver – simplified pseudo code

Clean rx interrupt:

```c
struct xdp_buff *xdp;
total_rx_pkts = 0;

while (total_rx_pkts < budget) {
    get Rx descriptor from rx_ring
    xdp = &rx_ring->xdp_buffs[total_rx_pkts];
    setup xdp_buff;
    total_rx_pkts++;
}

(void)bpf_prog_run_xdp(xdp_prog, rx_ring->xdp_buffs);

for (i = 0; i < total_rx_pkts; i++) {
    xdp = &rx_ring->xdp_buffs[i];
    based on xdp->act, take appropriate action;
}
```
EBPF CHANGES
Trampoline patching flow

XDP prog in BPF asm

insn[0]
...
insn[prog->len - 1]

eBPF verifier

Prog safe?

gen trampoline

Little JIT change will be required

XDP prog in BPF asm

prologue
insn[0]
...
insn[prog->len - 2]
epilogue
insn[prog->len - 1]

JIT

XDP prog in x86 asm

push %rbp
mov %rsp, %rbp
...
leaveq
retq

attach to NIC

insn – a single BPF assembly instruction
eBPF calling convention

Before we dive into eBPF, a little reminder how calling convention is defined:

- R0 - return value from in-kernel function, and exit value for eBPF program
- R1 - R5 - arguments from eBPF program to in-kernel function
- R6 - R9 - callee saved registers that in-kernel function will preserve
- R10 - read-only frame pointer to access stack

Taken from https://www.kernel.org/doc/Documentation/networking/filter.txt
Prologue is executed once, whilst epilogue is executed on each loop iteration
eBPF trampoline prologue section

Simple as that:

<table>
<thead>
<tr>
<th>r2 = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>*(u32 *)(r10 - 4) = r2</td>
</tr>
<tr>
<td>*(u64 *)(r10 - 12) = r1</td>
</tr>
</tbody>
</table>

- Initialize the loop counter
- Store it on stack
- Store the xdp_buffs array on stack
- Beginning of initial BPF program

At the start of a program, R1 is of a PTR_TO_CTX register type. This means that, for XDP case, it is holding the xdp_buff pointer that was initialized by the network driver that is running the XDP program against that buffer.
Since we’re consuming 12 stack bytes, we need to refresh the instructions that are making use of stack in initial program.

There are two cases that need to be handled:

- store/load onto/from R10, e.g.:
  - BPF_LDX_MEM(BPF_DW, BPF_REG_2, BPF_REG_10, -12),

- ALU ops on PTR_TO_STACK register types, e.g.:
  - BPF_MOV64_REG(BPF_REG_1, BPF_REG_10),
  - BPF_ALU64_IMM(BPF_ADD, BPF_REG_1, -20),
eBPF trampoline prologue section, continued

In JIT generation, the additional 12 bytes needs to be taken into account when stack depth is looked up

0: push %rbp
1: mov %rsp,%rbp
4: sub $0x10,%rsp
b: push %rbx
c: push %r13
e: push %r14
10: push %r15

Otherwise, caller’s (driver’s) stack variables might get overwritten.
eBPF trampoline epilogue section

get the xdp_buff ptr that we pushed initially on the stack

get the counter that we pushed initially on the stack

move to next entry of xdp_buff array

increment counter

jump to the beginning of initial program (without prologue) if counter value is less than 64

insn[prog->len – 2]

r1 = *(u64*)(r10 - 12)

r2 = *(u32*)(r10 - 4)

*(u32*)(r1 + offsetof(struct xdp_buff, act)) = r0

r1 += sizeof(struct xdp_buff)

r2 += 1

*(u32*)(r10 - 4) = r2

*(u64*)(r10 - 12) = r1

if r2 < 64 goto insn[3]

insn[prog->len – 1]

Can be 'return bpf_redirect_map();'

store the retval before going to the next xdp_buff from array

store modified variables back to stack
Things to be solved/questions/thoughts

1. “prefetch” instruction in BPF assembly
2. Selftests
3. How to provide backward compatibility?
4. Sort actions?
5. How much AF_XDP would benefit from it?
6. Thought – driver changes ARE required
7. Thought – boost for Tx/Redirect speaks for itself
Q&A
eBPF program layout after generating trampoline putting it all together

```
#include <linux/bpf.h>
__section("prog")
int xdp_drop(struct xdp_md *ctx)
{
  return XDP_DROP;
}
```

Clang compiler

Generate trampoline

JIT

```
#include <linux/bpf.h>
__section("prog")
int xdp_drop(struct xdp_md *ctx)
{
  return XDP_DROP;
}
```