FAST PACKET PROCESSING IN LINUX WITH AF_XDP

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Motivation & Problem Statement

- Lots of good features
- AF_PACKET performance does not meet application requirement

Proprietary HW SDK

Netmap

PF_RING

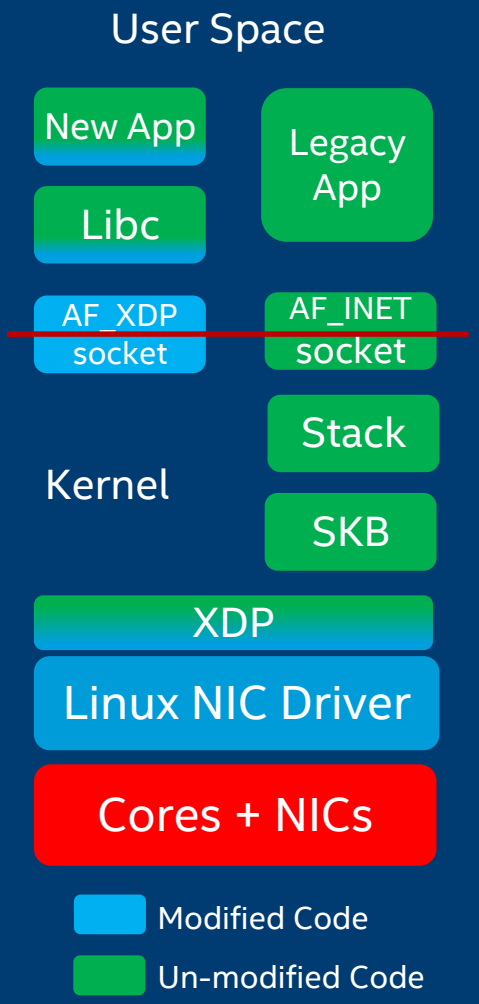
RDMA

- High networking performance
- Hard to use
- Might lack lots of features
- Might have little to no integration with Linux
- Not part of Linux net subsystem in kernel.org

How can we combine the functionality and ease-of-use of AF_PACKET sockets with the networking performance of these other solutions?

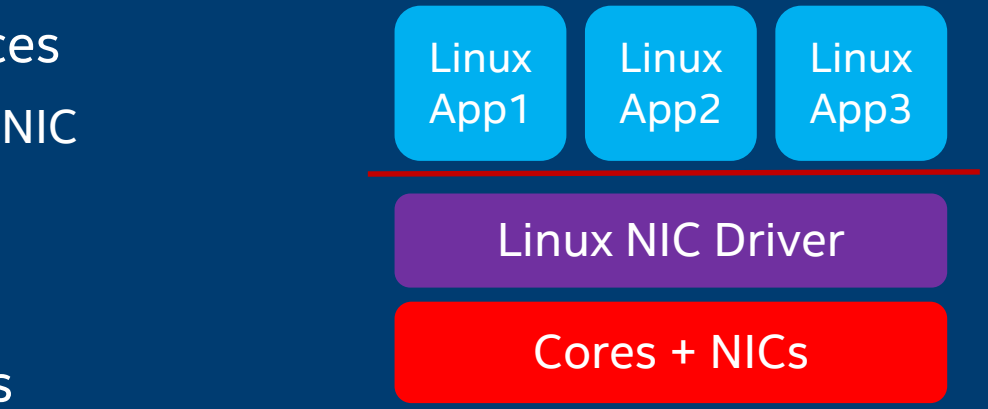
Proposed Solution

- New fast packet interfaces in Linux
  - AF_XDP: XDP's user-space interface
  - No system calls in data path
  - True zero-copy mode with new allocator, DMA packet buffers mapped to user space
  - Copy-mode for non-modified drivers
  - HW descriptors only mapped to kernel
- ZC mode requires HW steering support for untrusted applications
  - Copy required otherwise
- Goal is to hit 40 Gbit/s line rate on a single core for large packets and 25 Gbit/s for 64 byte packets



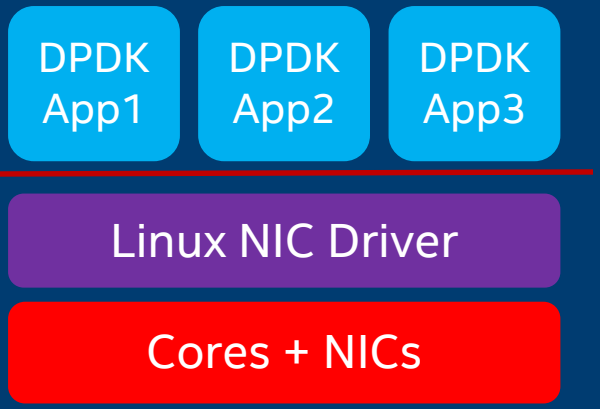
Benefits of Proposed Solution: Linux View

- Much faster standard libc based networking
  - Supports standard libc networking APIs
  - Goal: to be closer to DPDK performance
- Support all Linux network devices
  - E.g. virtio, veth, or your favorite NIC
  - Requires XDP support in driver
- Future work:
  - Speed up networking to VMs
    - Plug in virtio-net ring
    - No need for SR-IOV?
  - Extend it to other device types
    - Crypto and block devices?



Benefits of Proposed Solution: DPDK View

- DPDK AF_XDP based PMD
  - No change to DPDK apps
  - Cost goal: <10% performance decrease
  - Linux handles hardware
- Full isolation between processes/containers
- Linux features can now be used without having to reimplement some of them in DPDK
  - Power save, scheduling, etc.
- No need for bifurcated SR-IOV drivers
- Goal: Linux HW APIs can be used for setup
  - become as simple as "./my_app"
  - DPDK should just behave like a shared library

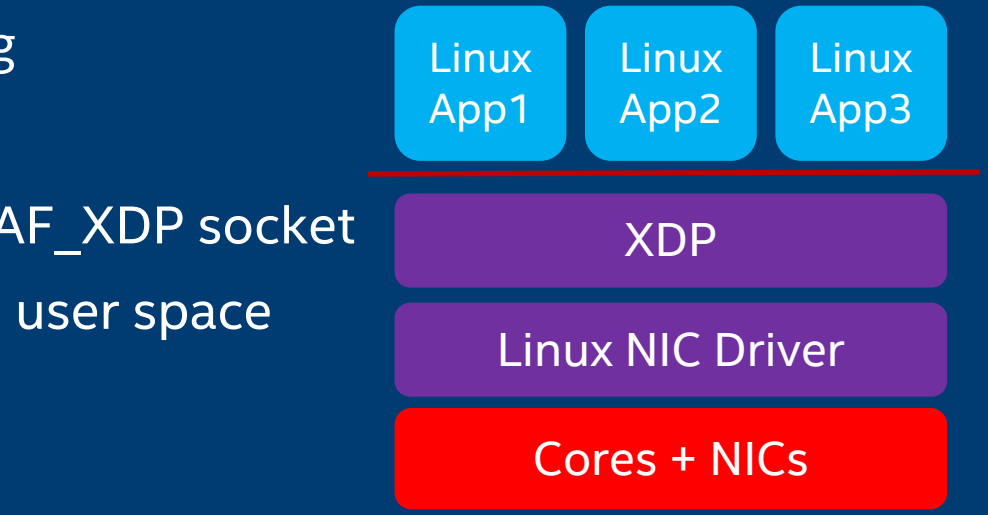


How to Use It?

```
sfd = socket(PF_XDP, SOCK_RAW, 0);
buffs = calloc(num_buffs, FRAME_SIZE);
setsockopt(sfd, SOL_XDP, XDP_MEM_REG, &mr_req, sizeof(mr_req));
setsockopt(sfd, SOL_XDP, XDP_RX_RING, &req, sizeof(req));
setsockopt(sfd, SOL_XDP, XDP_TX_RING, &req, sizeof(req));
mmap(..., sfd); /* map kernel Tx/Rx rings */
struct sockaddr_xdp addr = { PF_XDP, ifindex, queue_id };
bind(sfd, addr, sizeof(addr));
for (;;) {
        read_messages(sfd, msgs, ....);
        process_messages(msgs);
        send_messages(sfd, msgs, ....);
};
```

XDP with AF_XDP

- XDP = Small program injected into driver
- Actions: DROP, PASS, TX, and REDIRECT
  - Forwarding
  - Introspection and debugging
  - ACLs and DDos mitigation
- REDIRECT can now be done to AF_XDP socket
  - E.g., send specific packets to user space
- Future: descriptor rewriting
  - virtio-net support
  - Or any other format
- Future: load balancing, copy to socket + PASS (fast tcpdump)

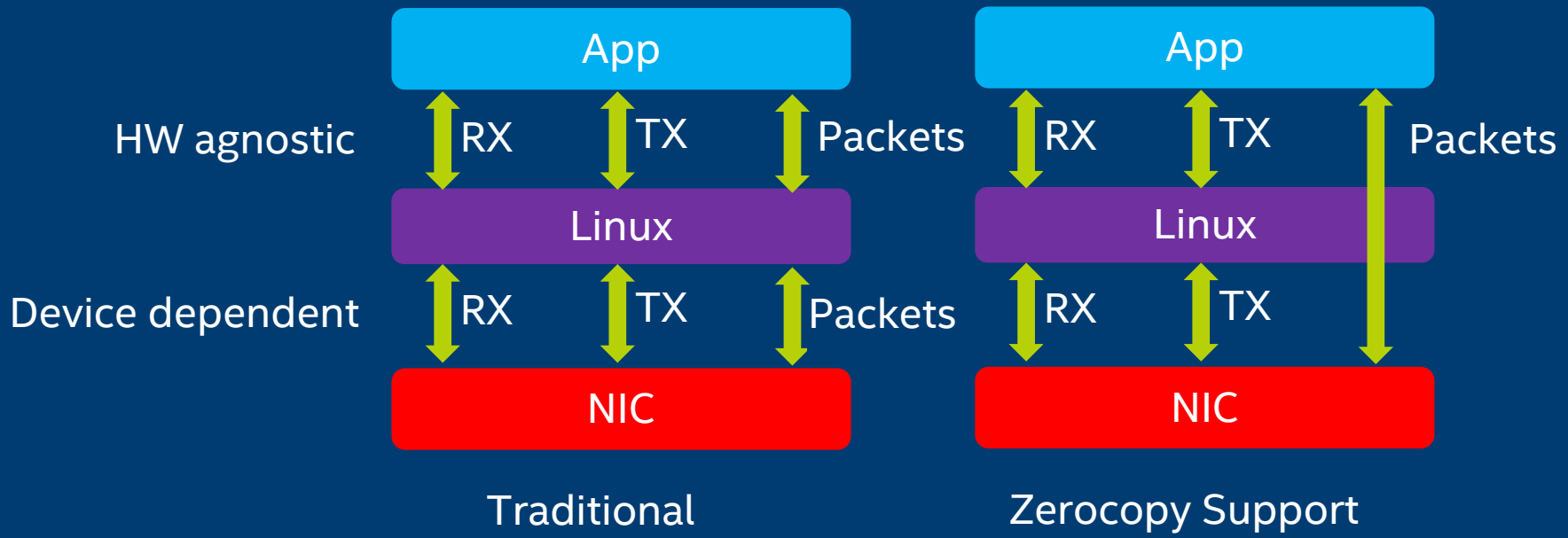


Operation Modes

From slower -> faster

- XDP_SKB:
  - Works on any netdevice using sockets and generic XDP path
- XDP_DRV:
  - Works on any device with XDP support (all three NDOs)
- XDP_DRV + ZC:
  - Need buffer allocator support in driver + a new NDO for TX

Zerocopy Support: Basic Principle



- Application still HW agnostic with ZC
- Each application gets its own packet buffer and TX/RX descriptor rings
  - Packet buffers can be shared if desired
  - TX/RX descriptor rings always private to process

Security and Isolation Requirements for XDP_DRV + ZC

- Important properties:
  - User space cannot crash kernel or other processes
  - User space cannot read or write any kernel data
  - User-space cannot read or write any packets from other processes unless packet buffer is explicitly shared
- Requirement for untrusted applications:
  - HW packet steering, when there are packets with multiple destinations arriving on the same interface
  - If not available => XDP_SKB or XDP_DRV mode need to be used

Experimental Setup

- RFC V1 of AF_XDP published on Januray 31, 2018
- Broadwell E5-2699 v4 @ 2.10GHz
- 2 cores used for benchmarks
- Rx is a softirq (thread)
- Tx is driven from application via syscall
  - TX and RX is currently in same NAPI context
  - Item in backlog to make this a thread on third core
- One VSI / queue pair used on I40E. 40Gbit/s interface
- Ixia load generator blasting at full 40 Gbit/s

Performance I40E 64-Byte Packets

	AF_PACKET V3	XDP_SKB	XDP_DRV	XDP_DRV + ZC
rxdrop	0.73 Mpps	3.3 Mpps	11.6 Mpps	16.9 Mpps
txpush	0.98 Mpps	2.2 Mpps	-	21.8 Mpps
l2fwd	0.71 Mpps	1.7 Mpps	-	10.3 Mpps

- XDP_SKB mode up to 5x faster than previous best on Linux
- XDP_DRV ~16x faster
- XDP_DRV + ZC up to ~22x faster
  - Not optimized at all at this point!
  - Rxdrop for AF_PACKET V4 in zero-copy mode was at 33.7 Mpps after some optimizations. We have more work to do.

Future Work

- More performance optimization work
- Try it out on real workloads
- Make send syscall optional and get TX off RX core
- Packet steering using XDP
- Metadata support, using XDP data_meta
- Queue pairs w/o HW support gets emulated
- XDP redirect to other netdevices RX path
- 1 XDP program per queue pair
- XDP support on TX
- Multi produce single consumer queues for AF_XDP
- Clone pkt configuration

Conclusions

- Introduced AF_XDP
- Integrated with XDP
- AF_XDP with zero-copy provides up to 20x performance improvements compared to AF_PACKET V2 and V3 in our experiments on I40E NIC
- RFC on the netdev mailing list
- Still lots of performance optimization and design work to be performed
- Lots of exciting XDP extensions possibile in conjunction with AF_XDP

Check out the RFC:

https://patchwork.ozlabs.org/cover/867937/

Acknowledgements

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Packets from Kernel to Process