Userspace networking: beyond the kernel bypass with RDMA!

Using the RDMA infrastructure for performance while retaining kernel integration

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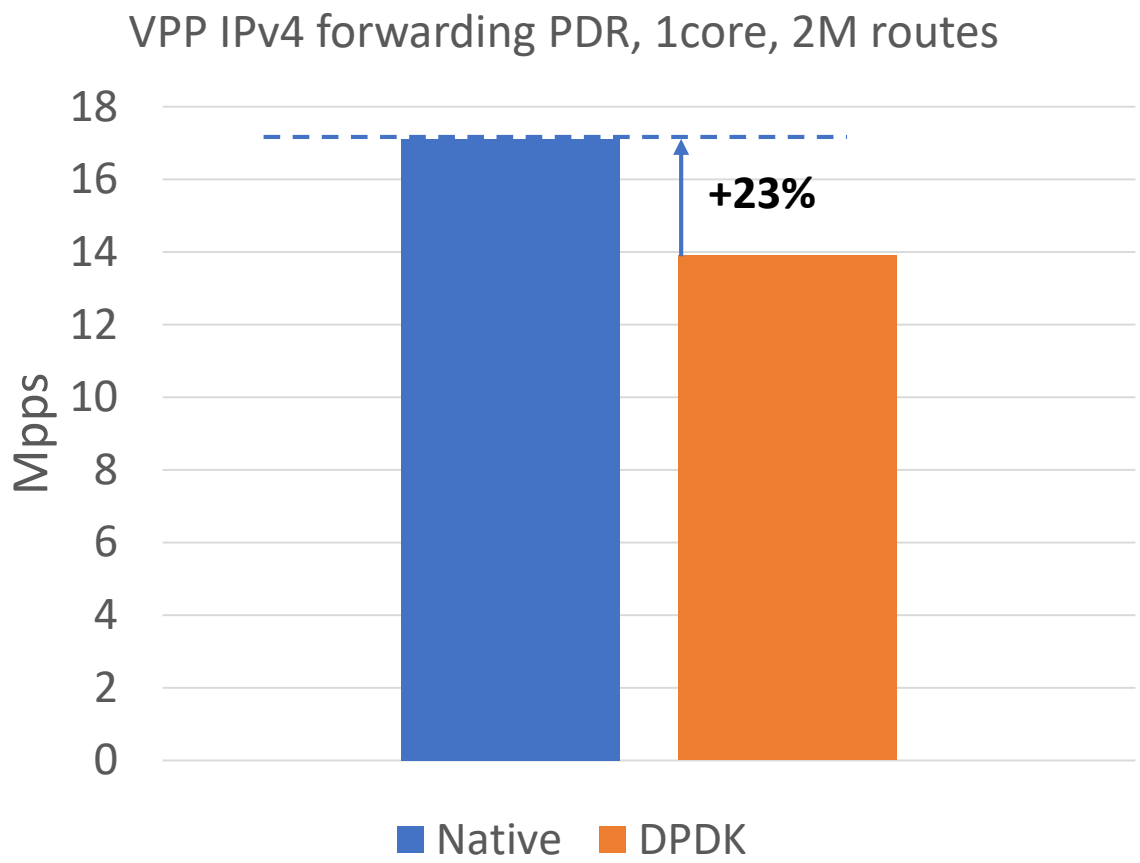
Why a native network driver?

- Why userspace networking?
  - **Performance** (avoid kernel overhead)
  - Update network functions seamlessly (no reboot required, containerization)
- Why your own network driver?
  - **Performance** (metadata translation tax, feature tax)
  - Ease-of-use (no reliance on hugepages, etc.)
- Why you should think twice?
  - No integration with kernel (interface fully owned by userspace)
  - You care about rx/tx packets but device initialization & setup is 95% of the work
  - *Hardware is hard* (more on that later)



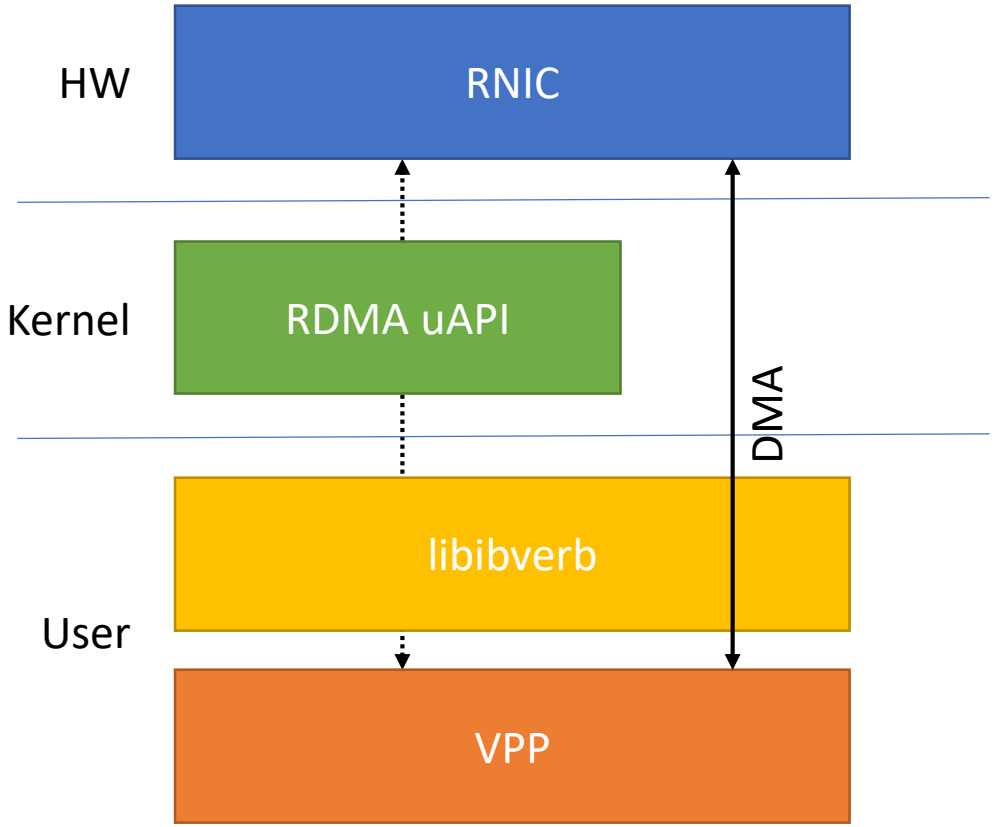
Source: https://docs.fd.io/csit/master/report/vpp_performance_tests/packet_throughput_graphs/ip4-2n-skx-xxv710.html

RDMA

- « Remote Direct Memory Access »
  - Designed for message passing and data transfer
  - Has evolved to use Ethernet transport (iWARP, RoCE)

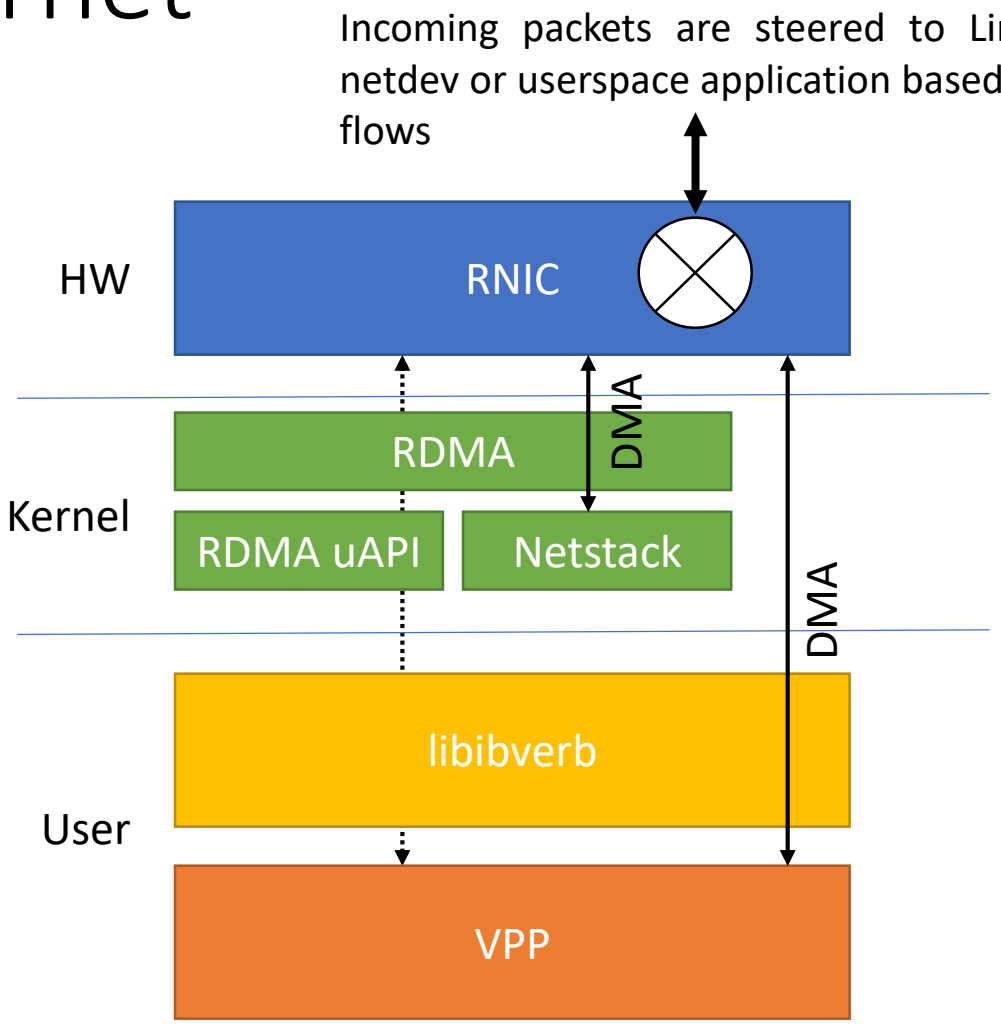
- Key properties
  - Hardware offload
  - Kernel bypass
  - Zero Copy data transfer
  - High network bandwidth

➔ Great for kernel networking!



Extending RDMA for Ethernet

- Not designed for efficient Ethernet communication – but!
  - Ethernet-capable HW (initially for transport)
  - High performance (200Gbps today)
  - Kernel bypass with well established API and native Linux kernel support
- Why not extend it to support userspace networking?
  - Introduce new IBV_QPT_RAW_PACKET queue pair type
  - Support for bifurcation with flow steering
    - **Keep your Linux netdev**
    - Support MACVLAN, IPVLAN model…



Using RDMA for Ethernet

How to send 20 Mpps with 1 CPU

1. Get a handle to the device you want to use
2. Initialize queues
   - Queue Pair (QP) = Submission Queue (SQ) + Completion Queue (CQ)
   - Protection Domain (PD) = where the NIC is allowed to read/write data (packets)
3. Send packets
   - Put Work Queue Elements (WQE – kind of IOV) in SQ
   - Notify new packets to send
   - Poll CQ for completion

```
/* step 1: get device handle */
dev = ibv_get_device_list(&dev_nb);
ctx = ibv_open_device(dev[i]);
/* step 2: initialize queues for RX/TX */
cq = ibv_create_cq(ctx, TXNB, 0, 0, 0);
pd = ibv_alloc_pd(ctx);
qp = ibv_create_qp(pd, type=IBV_QPT_RAW_PACKET);
ibv_modify_qp (qp, state=IBV_QPS_INIT, IBV_QP_STATE | IBV_QP_PORT);
ibv_modify_qp (qp, state=IBV_QPS_RTR, IBV_QP_STATE);
ibv_modify_qp (qp, state=IBV_QPS_RTS, IBV_QP_STATE);
mr = ibv_reg_mr(pd, addr, len, 0);
/* step 3: RX/TX in a busy loop */
while (1) {
    ibv_poll_cq (cq, TXNB, wc);
    ibv_post_send(qp, wr[wc[i].wr_id], 0);
}
```

Full example at https://github.com/bganne/rdma-pktgen

Going deeper with Direct Verbs

- RDMA user API is ibverb
  - Simple enough, mostly standard, open-source
  - Not full performance (metadata translation tax, feature tax)
- Direct Verbs
  - ibverb extension to access DMA ring-buffers directly
  - Hardware-dependent!
  - Setup done through ibverb, then get DMA rings addresses

```
/* convert ibverb SQ/CQ to DV SQ/CQ */
struct mlx5dv_obj obj = {
    .qp = { .in = ibv_qp, .out = dv_qp },
    .cq = { .in = ibv_cq, .out = dv_cq },
};
mlx5dv_init_obj (&obj, MLX5DV_OBJ_CQ | MLX5DV_OBJ_QP);

/* get SQ and doorbell addresses */
sq_base = dv_qp->sq.buf;
sq_dbrec = dv_qp->dbrec;
sq_db = dv_qp->bf.reg;
sq_sz = dv_qp->sq.wqe_cnt;

/* get CQ and doorbell addresses */
cq_cqes = dv_cq->buf;
cq_dbrec = dv_cq->dbrec;
cq_sz = dv_cq->cqe_cnt;
```

VPP native RDMA driver

- ibverb version
  - Available since 19.04
  - ~ 20 Mpps L2-xconnect per core
- Direct Verb
  - Development underway
  - *Hardware is hard*: while trying to debug my driver I almost bricked my NIC
- Next
  - Add support for hardware offloads (checksum offload, TSO)

A call to action

- We love this model
  - No need to write code boilerplate to initialize the NIC: we can focus on what matters (rx/tx packets)
  - Seamless integration with Linux kernel
  - Great performance
- But is has limitations
  - Need RDMA-capable NIC: must support Hardware security model, etc.
  - Only supported on Mellanox for now
- Could other technologies enable this approach?
  - Disclaimer: a bit outside of my domain knowledge here…
  - vfio-mdev?
  - AF_XDP?