Raw Packet Capture in the Cloud: PF_RING and Network Namespaces

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About ntop

- ntop develops high-performance network traffic monitoring technologies and applications, mostly open source, including:
  - Traffic monitoring (ntopng, nProbe)
  - High-speed packet capture (PF_RING)
  - Deep-packet inspection (nDPI)
  - Traffic recording (n2disk/disk2n)
  - DDoS mitigation (nScrub)
  - IDS/IPS acceleration (Suricata, Bro, Snort)

Packet Capture

- Network Monitoring tools need raw, high-speed, promiscuous packet capture

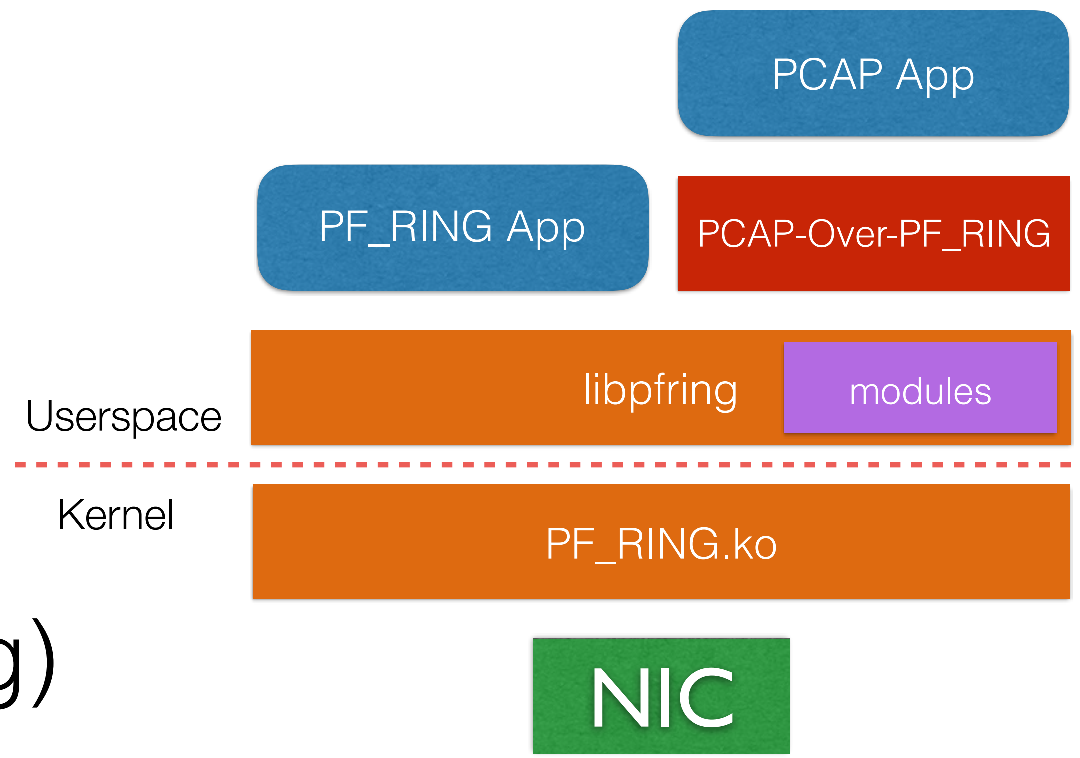
- Commodity network adapters and device drivers are designed for providing host connectivity

PF_RING

- Open source packet processing framework for Linux
- Originally (2003) designed to accelerate packet capture on commodity hardware, using a mmap approach, patched kernel drivers and in-kernel filtering
- Today it includes kernel-bypass zero-copy drivers (PF_RING ZC) for all Intel adapters and supports almost all FPGAs capture adapters on the market
- All ntop's applications leverage on PF_RING for packet capture acceleration, up to 100 Gbit/s

PF_RING Architecture

- PF_RING consists of:
  - Kernel module (pf_ring.ko)
  - Userspace library (libpfring)
  - Userspace modules implementing multi-vendor support
  - Patched libpcap for legacy applications



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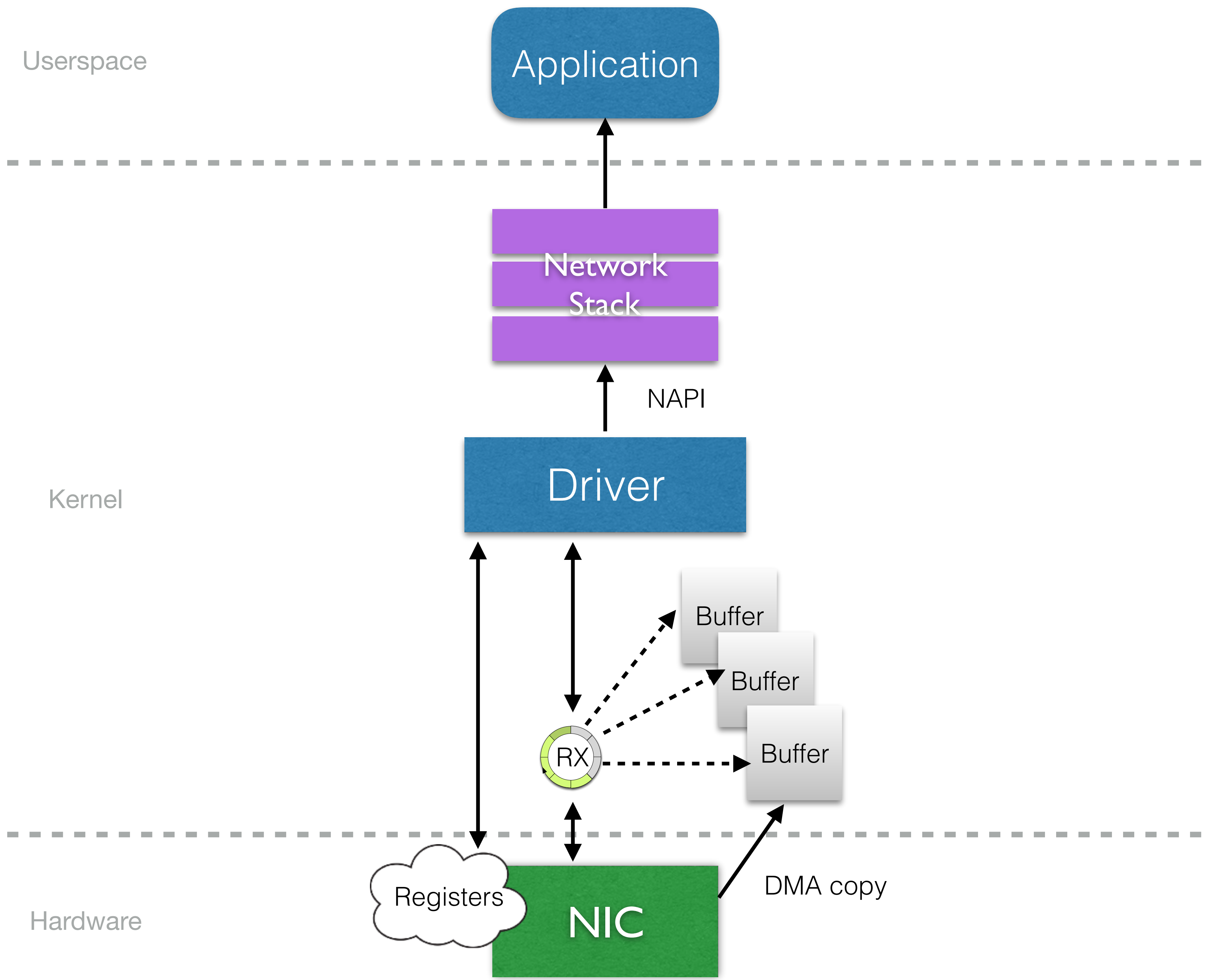
Network Drivers



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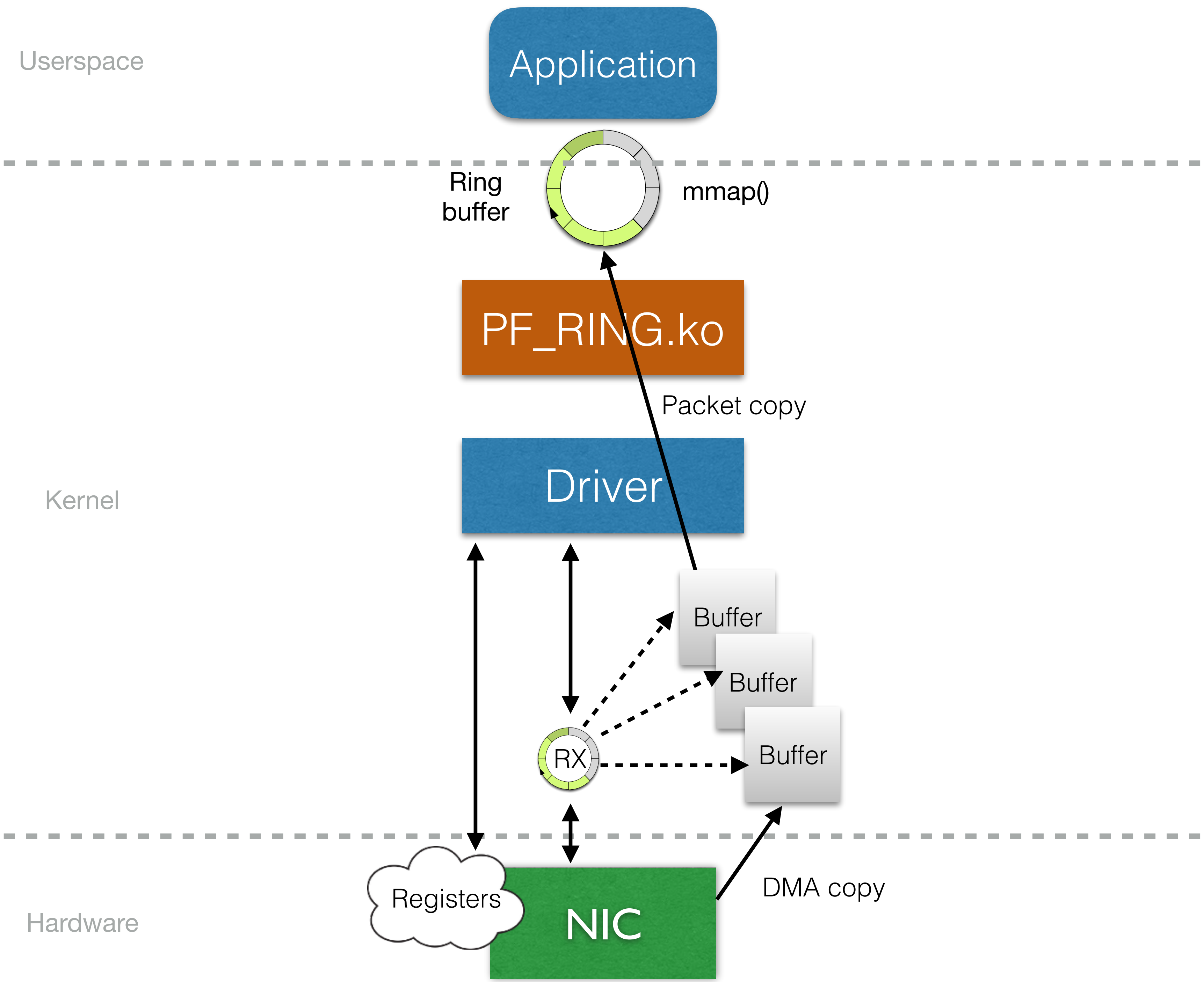
PF_RING - Standard Drivers



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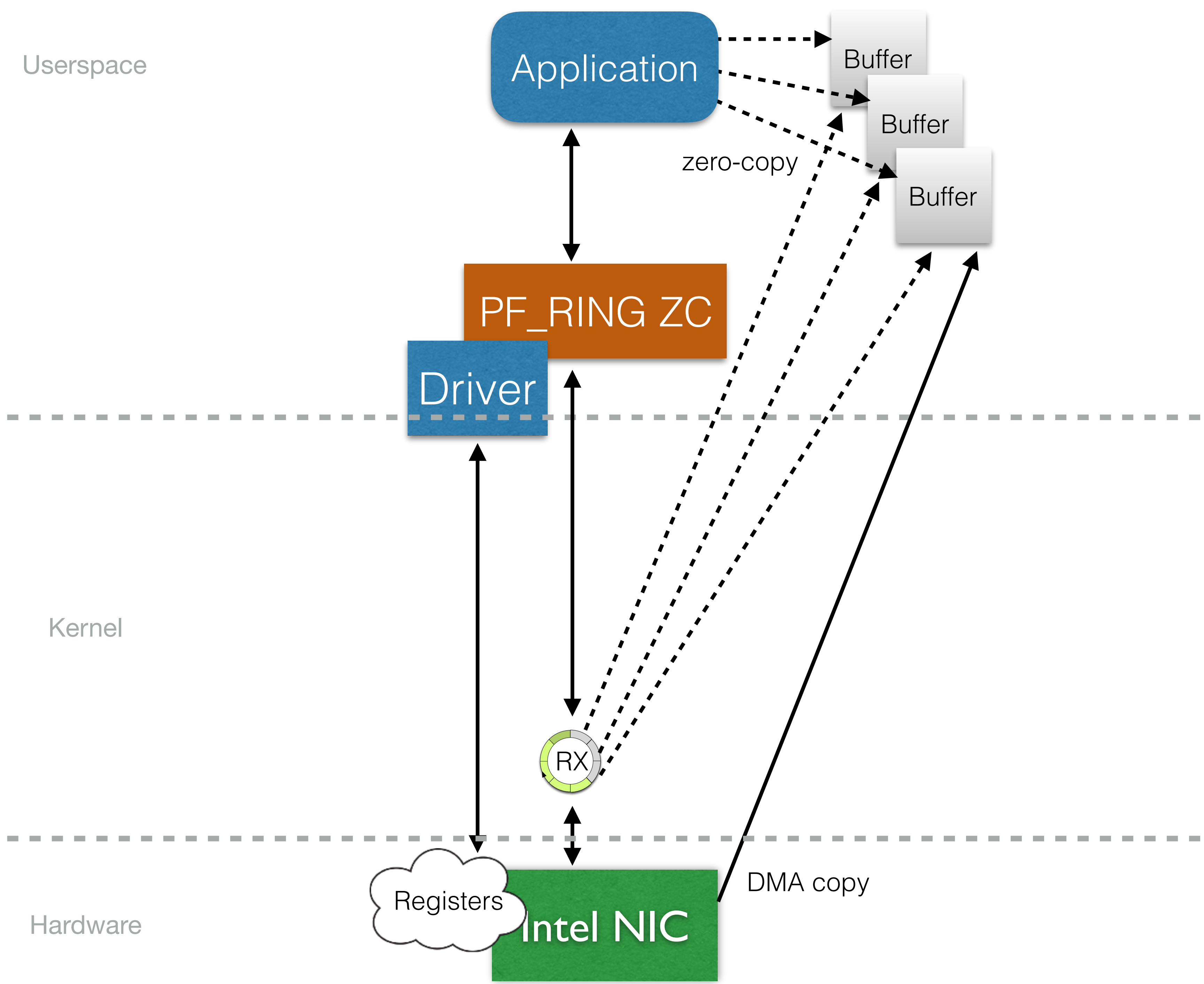
PF_RING - ZC Drivers



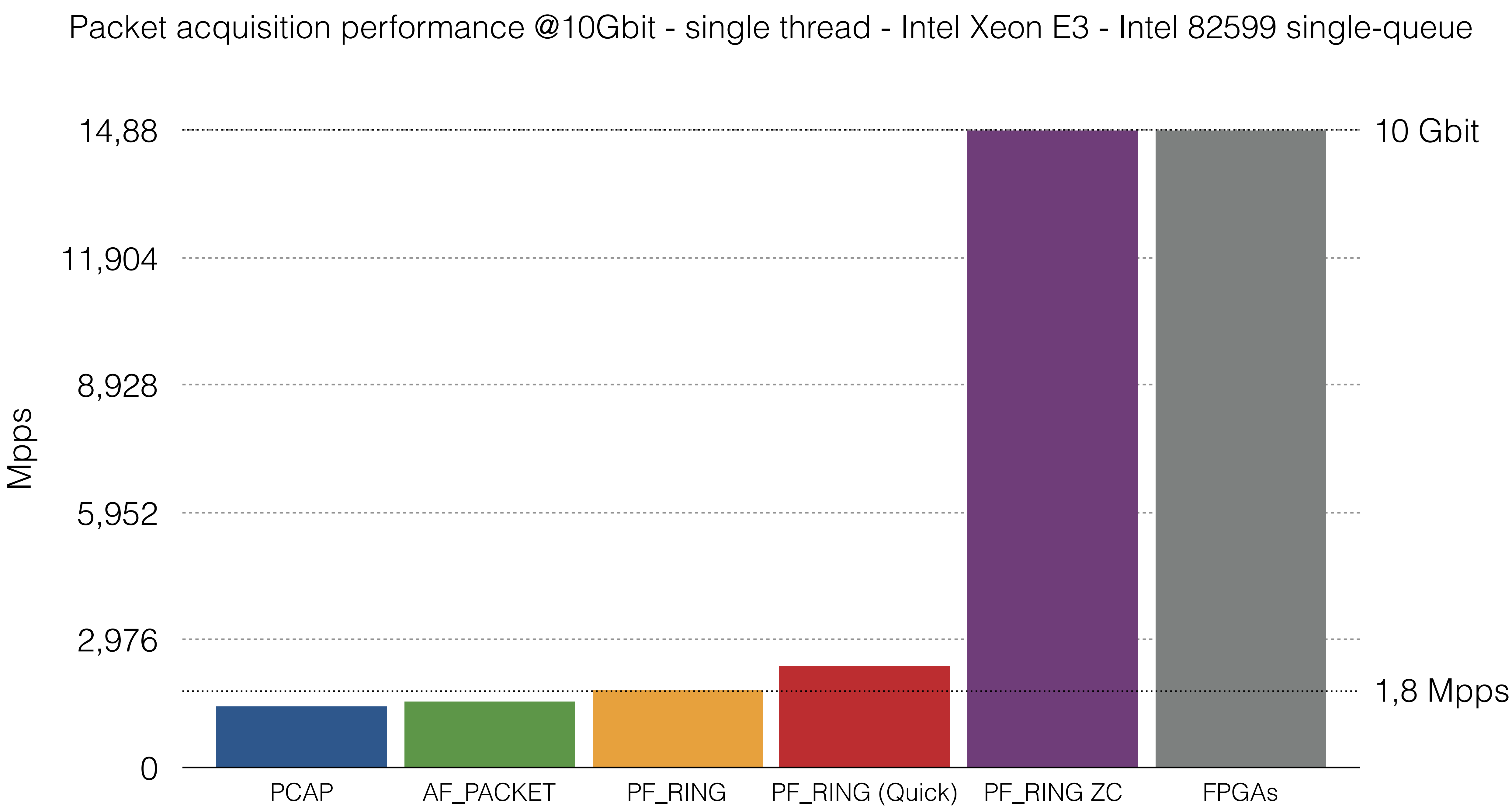
PF_RING - FPGA Adapters

- PF_RING natively supports the following vendors (1/10/40/100 Gbit)

- PF_RING or (our) libpcap based applications transparently select the module by means of the interface name:

  - `tcpdump -i eth1        [Linux drivers]`
  - `tcpdump -i zc:eth1     [ZC drivers]`
  - `tcpdump -i anic:1      [Accolade]`
  - `tcpdump -i nt:1        [Napatech]`

Performance



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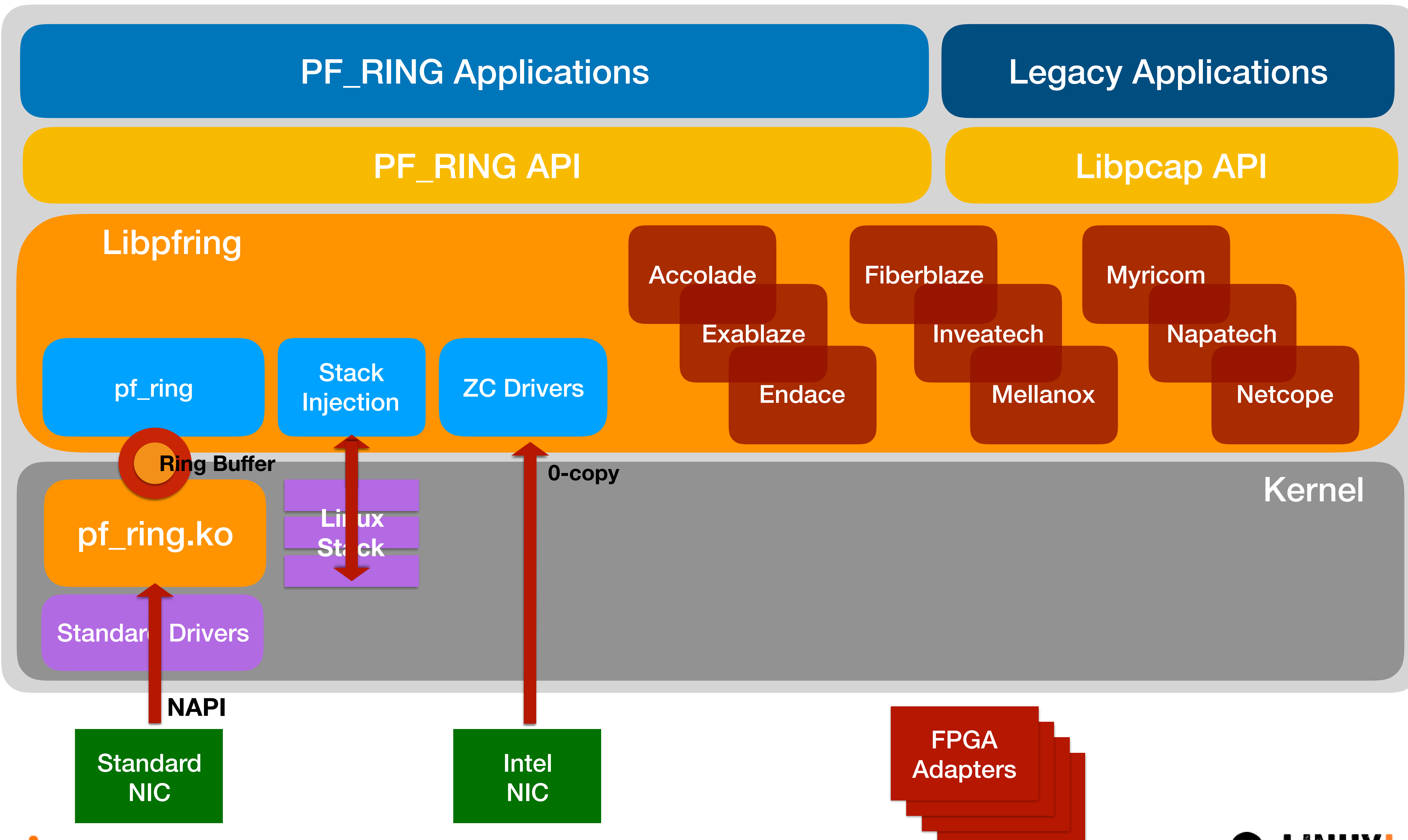
Many Other Features..

- Load balancing with Clustering or RSS
- PF_RING ZC API for Zero-Copy traffic distribution
- nBPF filtering engine supporting hw filtering
- Wireshark local and remote capture modules
- Acceleration modules for Bro, Snort, Suricata
- Stack Injection support
- KVM support (Host-to-VM datapath)
- Containers support..

The Big Picture



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Containers, why?

- Docker, LXC, are “Virtual Environments”, with much less overhead compared to Virtual Machines as there is no Guest OS
- Containers applications in Network monitoring:
  - Easy deployment of traffic monitoring applications (e.g. ntopng-docker)
  - NFV (Network Functions Virtualization, e.g. Firewalls, IDSs)
  - Network traffic monitoring as a service

Cgroups and Namespaces

- Containers are built on the following components:
  - cgroups (Control Groups), limit and account resource usage of a collection of processes including CPU/cores, memory, block I/O, network (tc, iptables).
  - Namespaces, isolate and virtualize system resources of a collection of processes, including PIDs, hostnames, user IDs, network, filesystems.

Network Namespaces

- Network namespaces virtualize the network stack: a network namespace is (logically) another copy of the network stack with its own network interfaces, iptables rules, routing tables, sockets
- On creation a network namespace only contains the loopback device, then you can create virtual interfaces or move physical interfaces to the namespace
- A network interface belongs to exactly one network namespace
- Containers usually use virtual interface pairs (*veth* driver), *eth0* in the container namespace is paired (logically cross-connected) with *vethXXX* in the host namespace

Under The Hood

Code is worth a thousand words..

struct net

- A network namespace is represented by a *struct net* in the Linux kernel
- The default initial network namespace is *init_net* (instance of *struct net*), it includes all the host interfaces
- For any namespace, *struct net* includes a loopback device, SNMP stats, network tables (routing, neighboring), sockets, procfs/sysfs

pf_ring.ko

- The PF_RING kernel module is namespaces-aware
- It cannot be otherwise:
  - Even when you are not running containers, you are in a namespace (*init_net*)
  - Most of the methods in the stack have *struct net* as a parameter

pf_ring.ko - init

- In the init function of the pf_ring kernel module, we register with register_pernet_subsys to be notified when network namespaces are created or deleted:

```
static struct pernet_operations ring_net_ops = {
  .init = ring_net_init,
  .exit = ring_net_exit,
};

static int __init ring_init(void)
{
  …
  register_pernet_subsys(&ring_net_ops);
```

- When a new network namespace is created, the *ring_net_init* callback is called, and we keep track of all active network namespaces:

```
static int __net_init ring_net_init(struct net *net)
{
  printk("[PF_RING] New network namespace\n");
  netns_add(net);
```

pf_ring.ko - ring_create

- Opening a new socket the *struct net_proto_family.create* callback is called, this is where we determine if the current task has the capability for opening a raw socket:

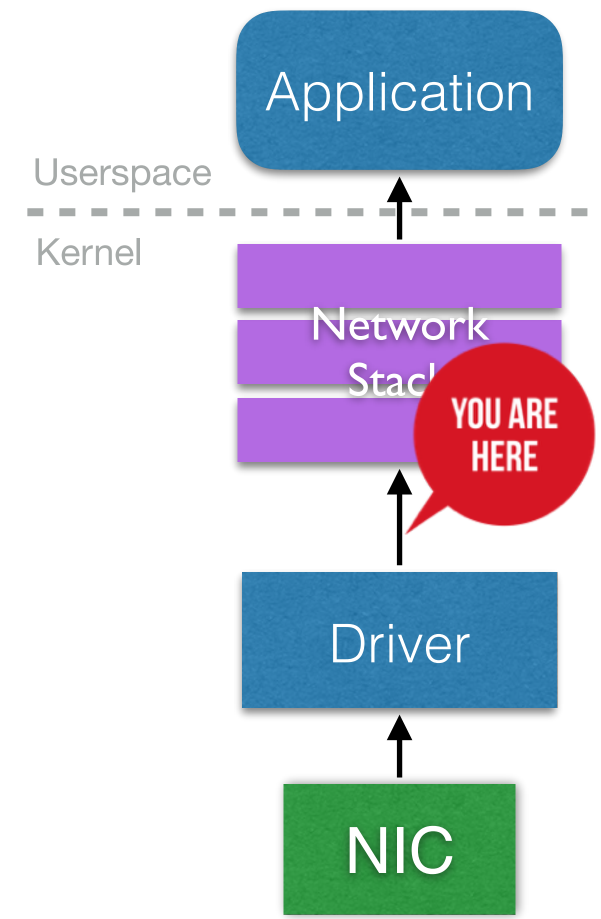
```
static int ring_create(struct net *net,
 struct socket *sock, int protocol, int kern)
{
  if(!ns_capable(net->user_ns, CAP_NET_RAW))
    return -EPERM;
```

pf_ring.ko - init (2)

- In the init function of the pf_ring kernel module, we also set the callback to receive all raw packets from the kernel.

```
static struct packet_type prot_hook;

static int __init ring_init(void)
{
   …
   prot_hook.func = packet_rcv;
   prot_hook.type = htons(ETH_P_ALL);
   dev_add_pack(&prot_hook);
```



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pf_ring.ko - packet_rcv

- For every packet received from / transmitted to the network interfaces, *packet_rcv* is called, that's where we match the device namespace vs the socket namespace:

```
static int packet_rcv(struct sk_buff *skb,
 struct net_device *dev, struct packet_type *pt,
 struct net_device *orig_dev){
  …
  while(sk != NULL){/* foreach pf_ring socket */
    if (net_eq(dev_net(skb->dev), sock_net(sk)))
      /* deliver the packet to the application*/
      …
```

pf_ring.ko - /proc

- PF_RING exports sockets informations under /proc/net/pf_ring/
- There is a */proc/net/pf_ring/* view for each namespace
- */proc/net/pf_ring/* is created when a new network namespace is registered in *ring_net_init(struct net *net)*
- *proc_mkdir()* has *struct net.proc_net* as parameter, which is the proc root for the actual network namespace

```
static pf_ring_net *netns_add(struct net *net) {
  …
  netns->proc_dir = proc_mkdir("pf_ring", net-
>proc_net);
```

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Examples

- *ip netns* can be used to play with network namespaces
- Create a network namespace *ns0*:

```
ip netns add ns0
```

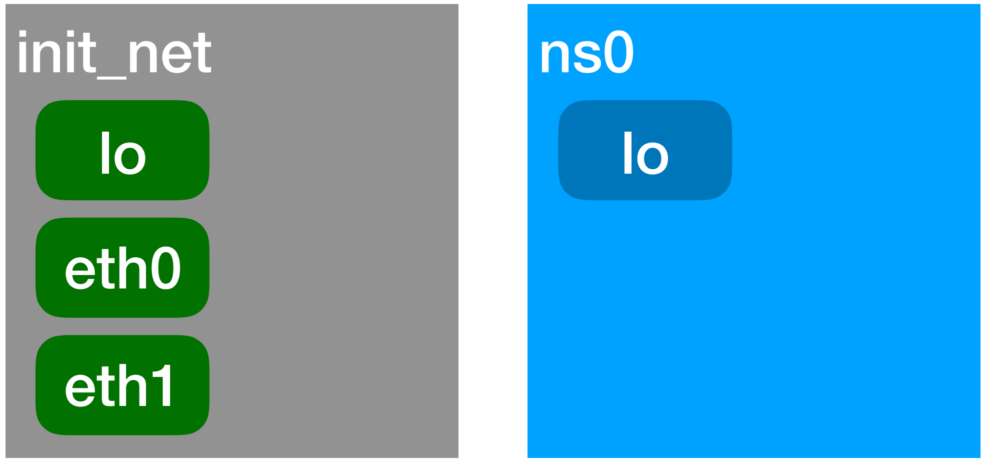
This creates an object at /var/run/netns/ns0

- Delete a network namespace *ns1*:

```
ip netns del ns1
```

- List all network namespaces:

```
ip netns list
ns0
```



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Examples

- List all interfaces registered with pf_ring in the host:

```
ls /proc/net/pf_ring/dev/
eth0  eth1  lo
```

- List all interfaces registered with pf_ring in the namespace *ns0*:

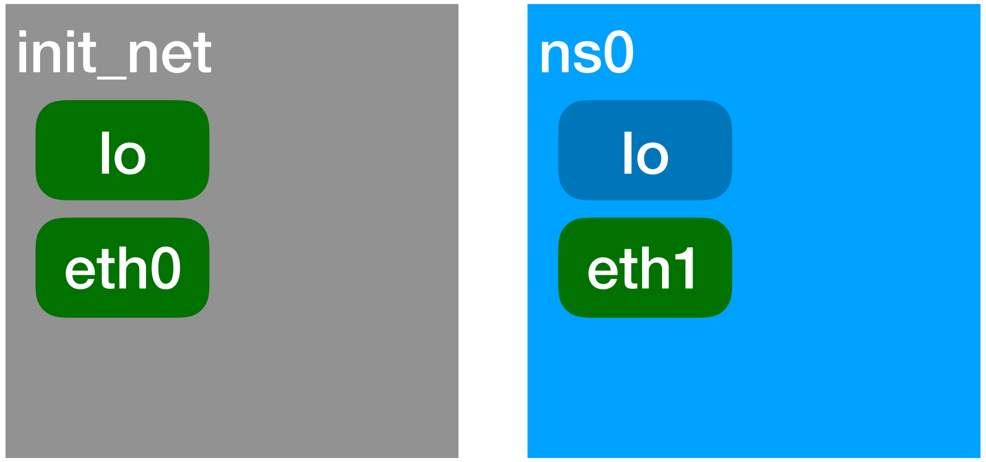
```
ip netns exec ns0 bash
ls /proc/net/pf_ring/dev/
lo
```

- Move a network interface to the network namespace *ns0*:

```
ip link set eth1 netns ns0
```

- List all interfaces in *ns0* again:

```
ip netns exec ns0 bash
ls /proc/net/pf_ring/dev/
eth1  lo
```



Running Docker with PF_RING

- Build the Docker image:

```
docker build -t ubuntu16 -f Dockerfile .
```

- Dockerfile

```
FROM ubuntu:16.04
MAINTAINER ntop.org

RUN apt-get update && \
    apt-get -y -q install wget lsb-release && \
    wget -q http://apt.ntop.org/16.04/all/apt-ntop.deb && \
    dpkg -i apt-ntop.deb
RUN apt-get update && \
    apt-get -y install pfring

ENTRYPOINT ["/bin/bash", "-c"]
```

Running Docker with PF_RING

- Run docker passing the command to execute (in this case *pfcount*, it prints traffic statistics using pf_ring):

```
docker run ubuntu16 pfcount -i eth0
```

- Or run docker with an interactive bash prompt:

```
sudo docker run -i -t --entrypoint /bin/bash
ubuntu16
root@60d98f7e92ba:/#
```

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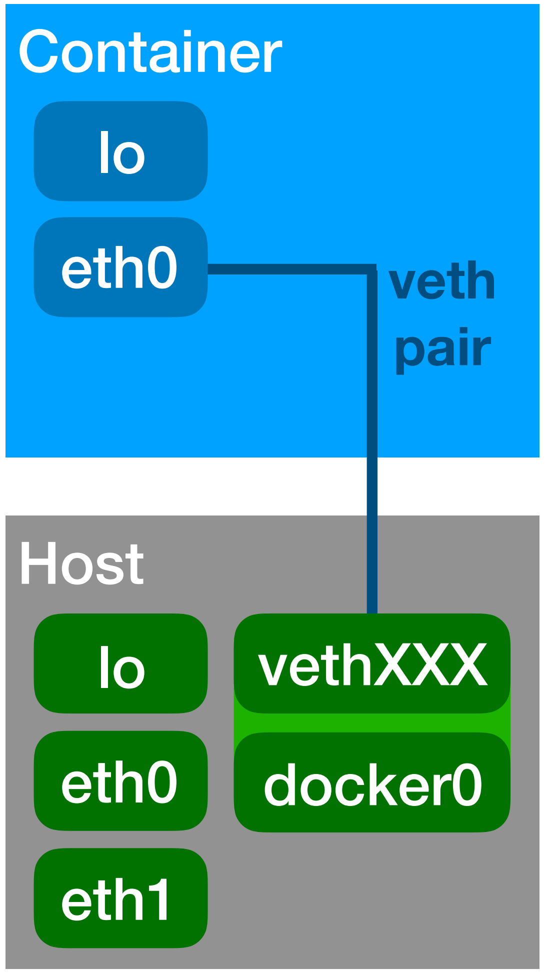
Docker - Standard Conf

- Run the container in a new namespace, this will capture traffic received by the container:

```
docker run ubuntu16 pfcount -i eth0
```

- If you are in the host and want to monitor traffic generated by the container, you can sniff from *vethXXX*

- Find the right *vethXXX*:




```
root@964868fc9380:/# cat /sys/class/net/eth0/iflink
99
root@host:/# grep -l 99 /sys/class/net/veth*/ifindex
/sys/class/net/vetha7819c4/ifindex
```

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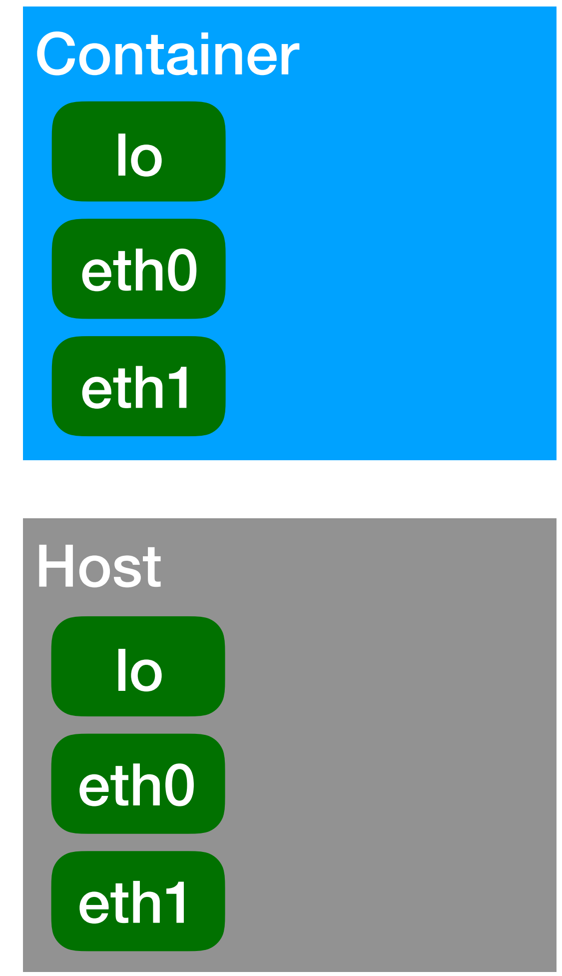
Docker - Host Network



- Run the container in the host network namespace with *—network=host*, this will capture traffic received by the host:

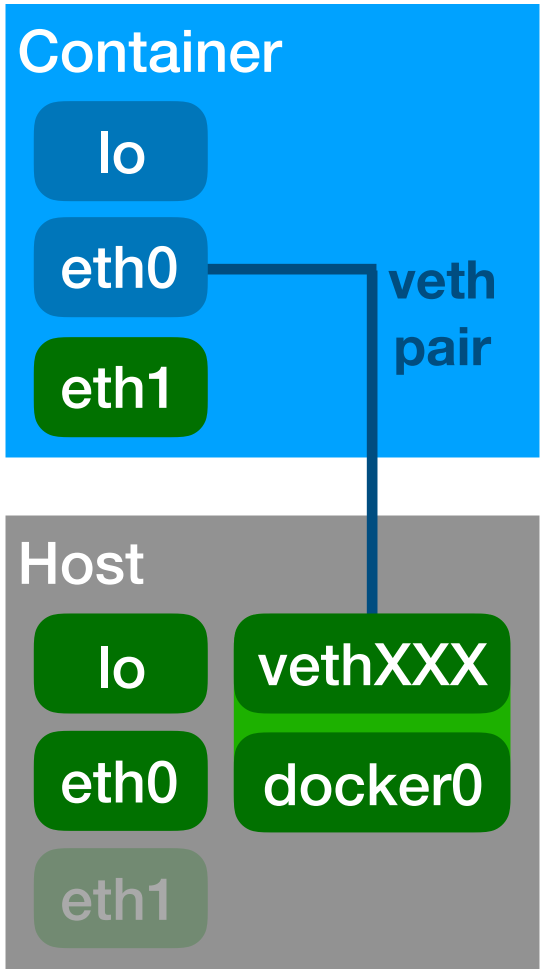
```
docker run —network=host ubuntu16
pfcount -i eth0
```

Docker - “Passthrough”

- Run the container in a new namespace, and assign a host interface to the container.
- By default docker does not add network namespaces to /var/run/netns as *ip netns* does, we need to create a symlink and then use *ip netns:*

```
docker ps
98d96967bc1f ubuntu16
docker inspect -f '{{ .State.Pid }}' 98d96967bc1f
9318
ln -s /proc/9318/ns/net /var/run/netns/ubuntu16
ip link set eth1 netns ubuntu16
ip netns exec ubuntu16 ifconfig eth1 up
```

- Now it’s possible to run *pfcount -i eth1* inside the container



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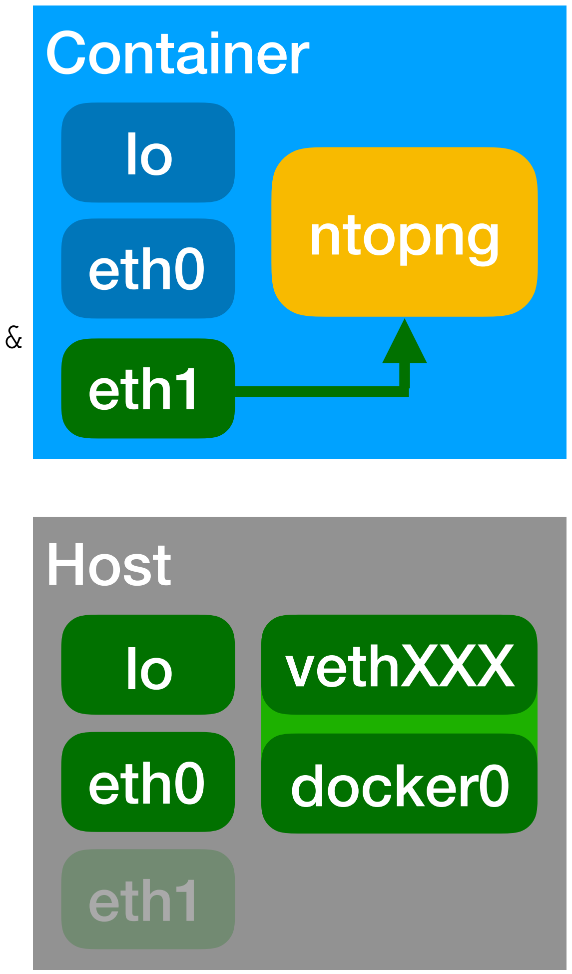
Example - ntopng

- Dockerfile.ntopng

```
FROM ubuntu:16.04
MAINTAINER ntop.org

RUN apt-get update && apt-get -y -q install net-tools wget lsb-release &&
    wget -q http://apt.ntop.org/16.04/all/apt-ntop.deb && \
    dpkg -i apt-ntop.deb
RUN apt-get update && apt-get -y install pfring ntopng
```



- docker-run-ntopng.sh

```
#!/bin/bash

IMAGE=$1
IFNAME=$2

ID=$(docker run -d -i -t --entrypoint /bin/bash $IMAGE)

mkdir -p /var/run/netns
PID=$(docker inspect -f '{{ .State.Pid }}' $ID)
ln -sf /proc/$PID/ns/net /var/run/netns/$ID
ip link set $IFNAME netns $ID
ip netns exec $ID ifconfig $IFNAME up

docker exec -it $ID /etc/init.d/redis-server start
docker exec -it $ID ntopng -i $IFNAME
```

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Get Started

Source Code (GitHub)

- git clone https://github.com/ntop/PF_RING.git

Packages

- http://packages.ntop.org

Thank you