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Leveraging Kernel Tables with XDP

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Is XDP Really Different than DPDK?

XDP Overview

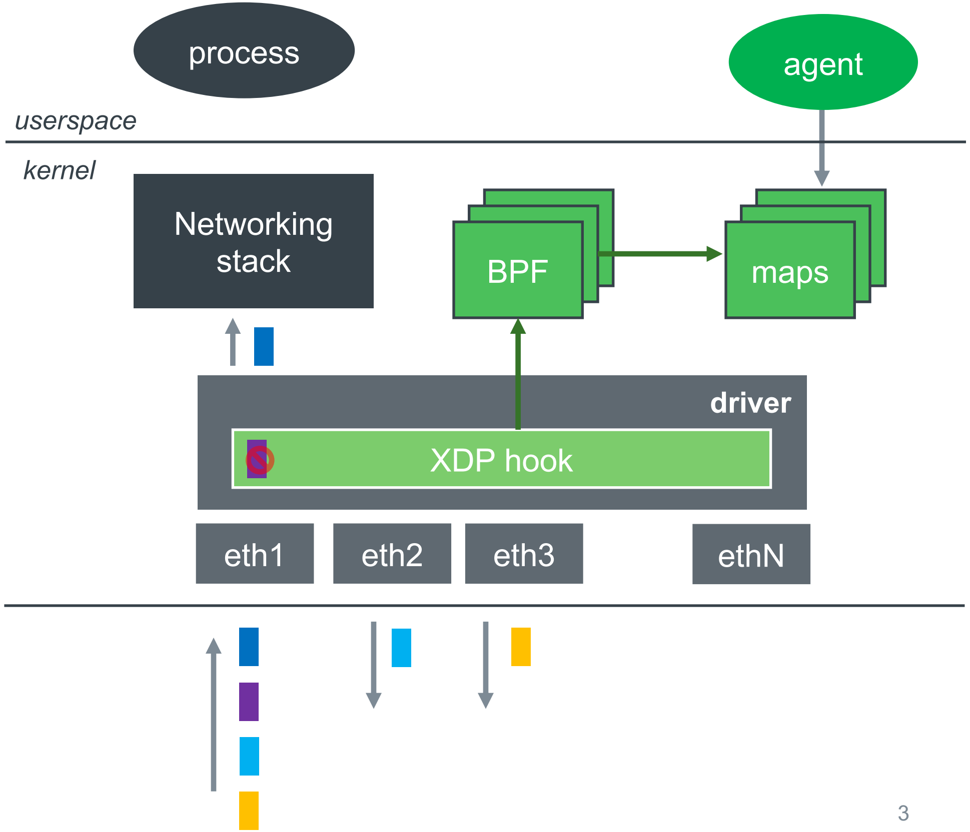
BPF programs are loaded, maps created

- Limited BPF helpers for XDP
- Maps provide data

Programs attached to device

- XDP hook in the driver runs programs for each packet
- Fast path packet processing

ACLs, firewall, load balancer, fast-path forwarding, …



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Focus Discussion on

L2 / L3 Forwarding in XDP

Forwarding via Management by SDN Controller

Agent

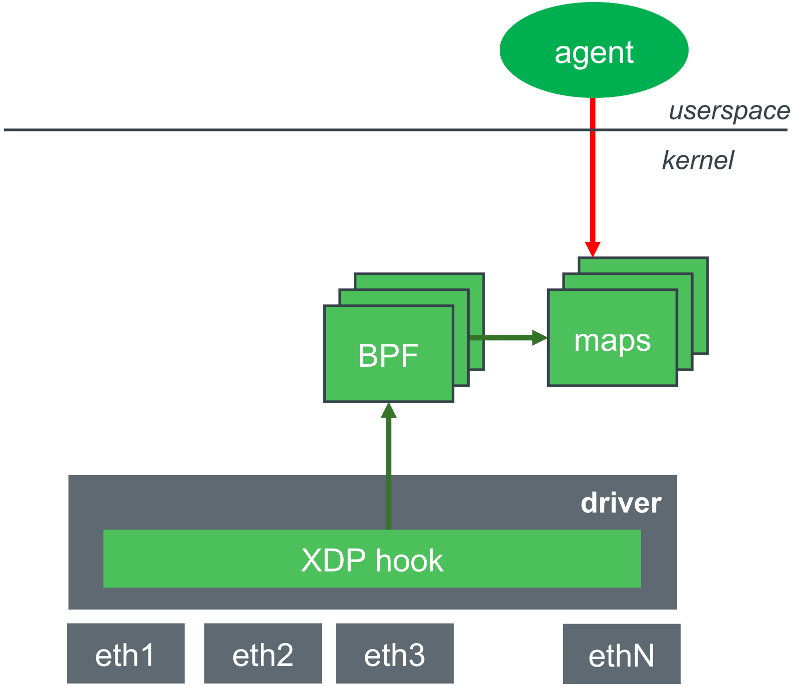
- Receives updates from controller
- Updates maps

Little / no updates based on local events

All packet parsing, processing, rewriting done in BPF

- Packet never sees the Linux stack

Linux is a boot OS



Is XDP with Maps Really Different than DPDK?

Both bypass Linux networking stack and its networking APIs

Custom implementations of standard protocols

- e.g., Bridging and aging fdb entries

Custom tools to manage solution

- Configuration, monitoring and debugging

…

Need better integration of XDP with Linux

- More complete and consistent Linux solution

More Linux: Snooping Notifications

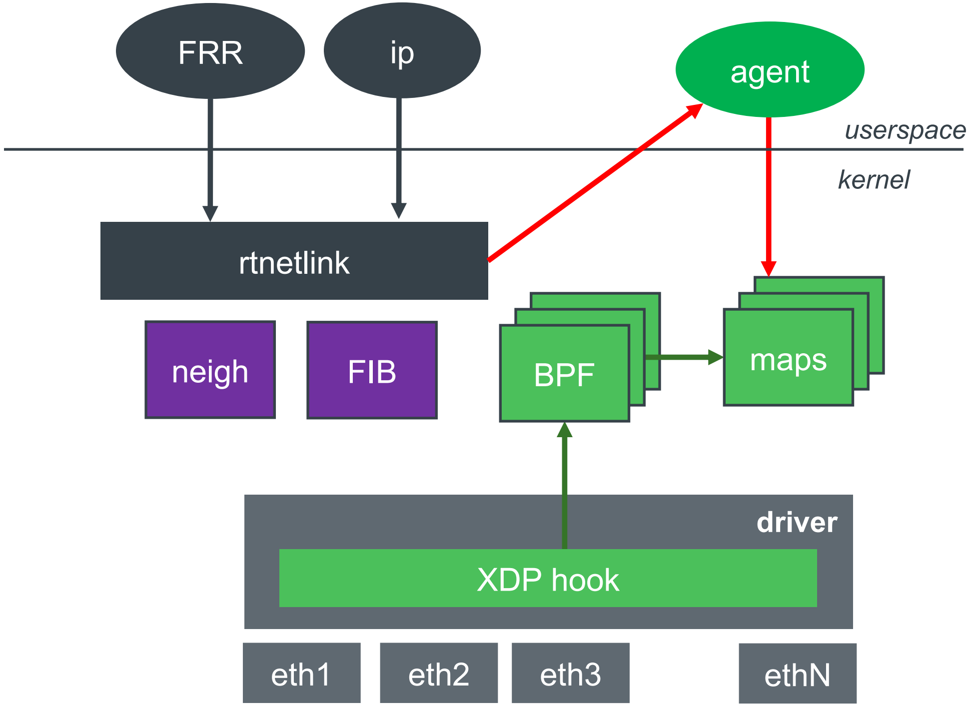
Agent

- snoops RTM_*ROUTE and RTM_*NEIGH entries
- Updates lpm and neigh maps based on rtnetlink notifications

For simple setups only

- VLANs and bonds?
- Scalability with number of routes & nexthops? Duplicate data
- Multipath or encaps (e.g,MPLS)?
- MTU and fragmentation, changes in link state, …?

Full solution duplicates Linux!

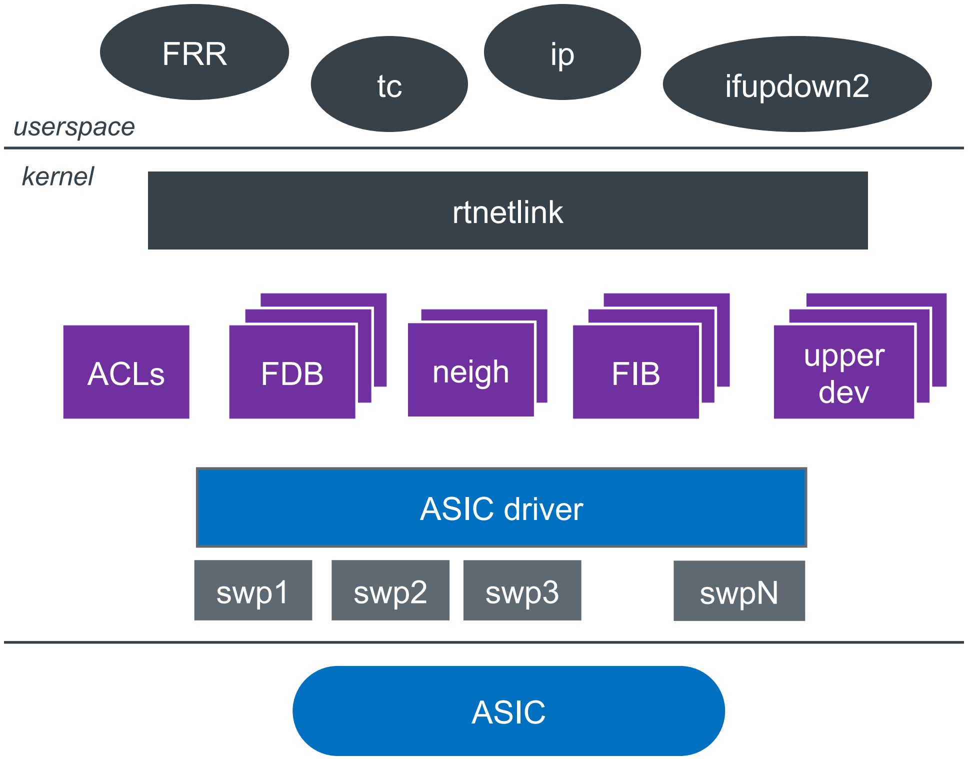


Linux and Hardware Offload

Standard Linux APIs configure networking

Kernel modified so that ASIC driver gets necessary information

ASIC driver handles notifications and programs hardware



XDP as a Software "Offload"

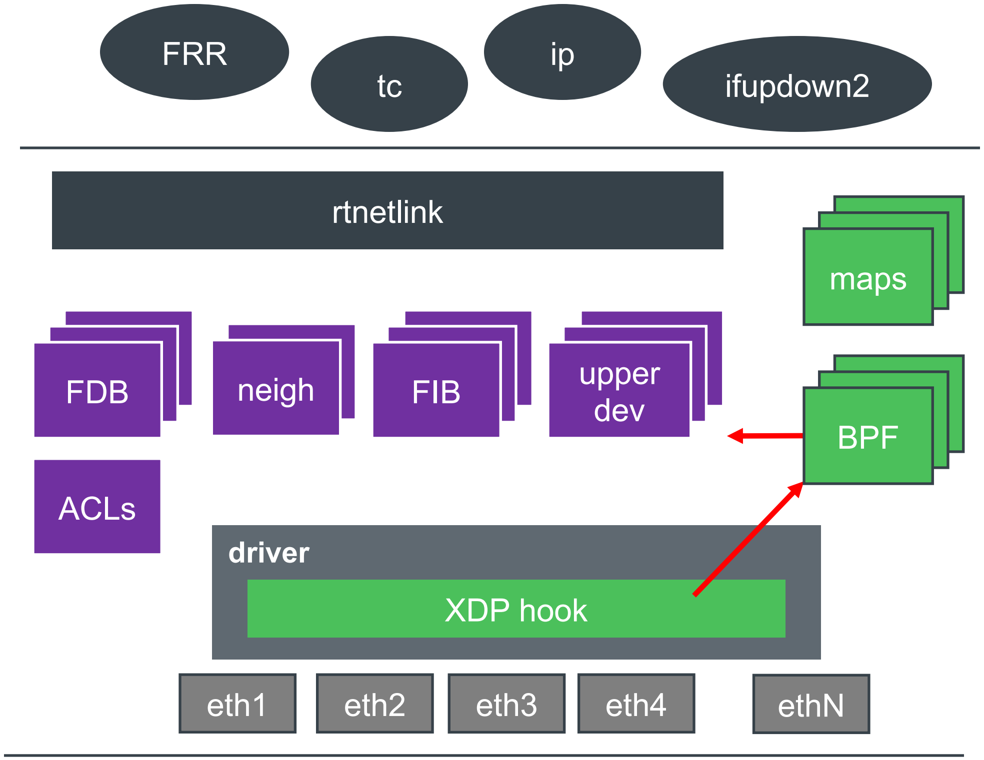
Consider XDP as an offload rather than new framework

- Do not want to reinvent implementations of networking features

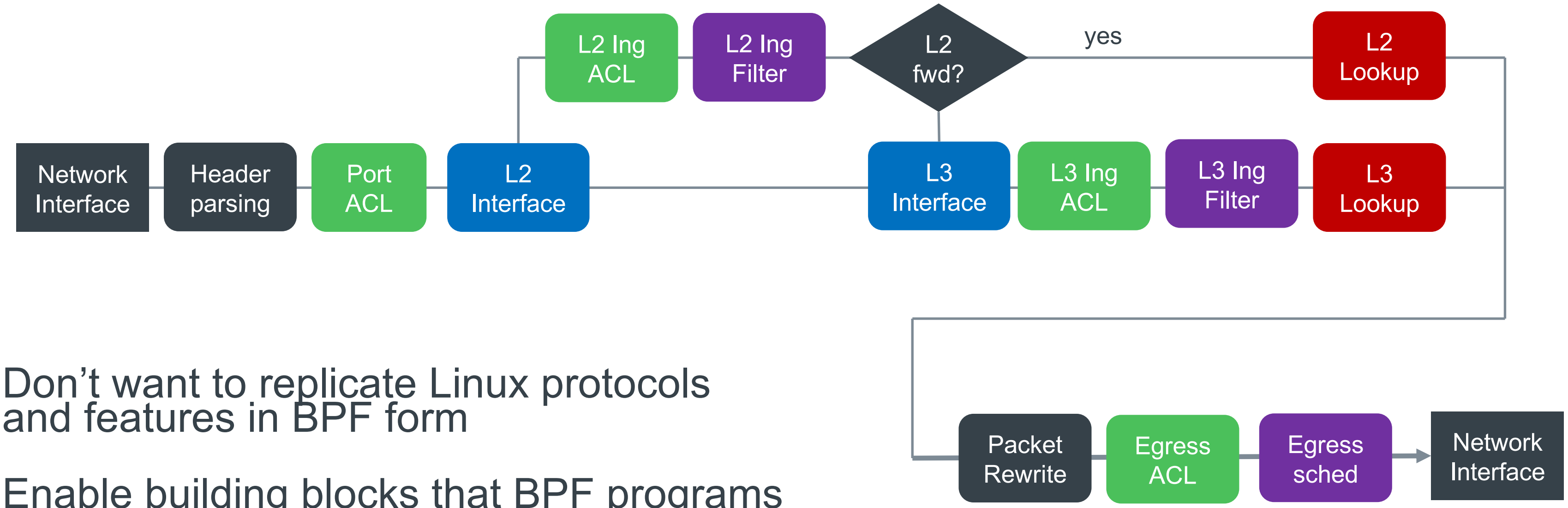
Allow BPF programs to access kernel tables

Consistency all the way around

- Existing protocols, APIs and processes to configure networking
- Slow path and fast path driven by same data



Options for Packet Pipeline in XDP



Don't want to replicate Linux protocols and features in BPF form

Enable building blocks that BPF programs can invoke as desired

Networking management still done with standard tools

Key Elements for Packet Forwarding in XDP

Support for essential networking features

- vlans, bonds, bridges, macvlan

ACL and filters - ingress and egress

- Several attach points

Forwarding lookup

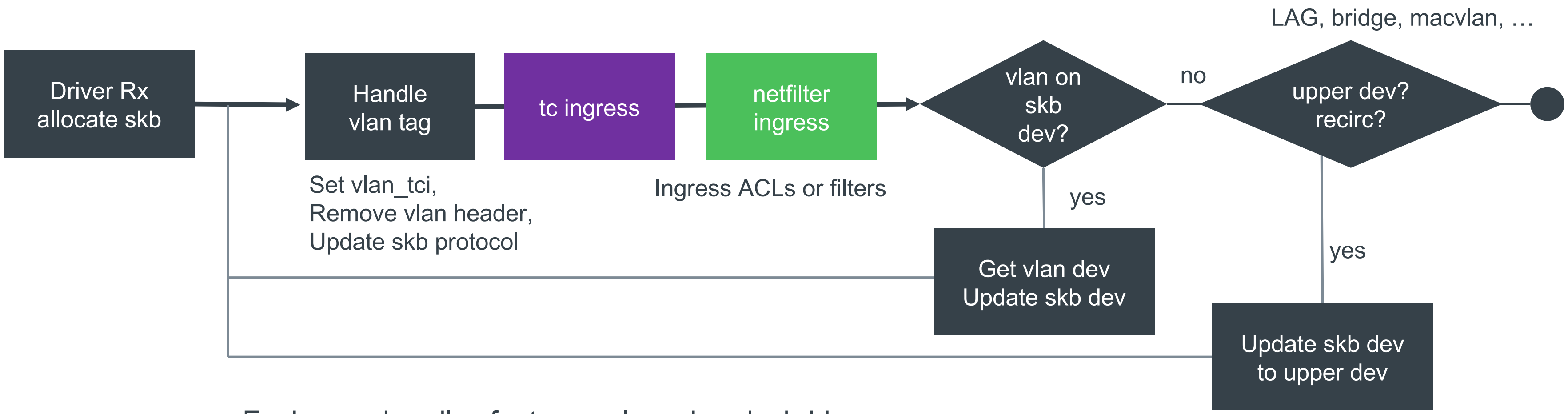
- FDB Lookup - L2 forwarding
- FIB Lookup - L3 forwarding

Packet Scheduling

- Crossing bandwidths, traffic shaping and priority

Linux Packet Processing (simplified)

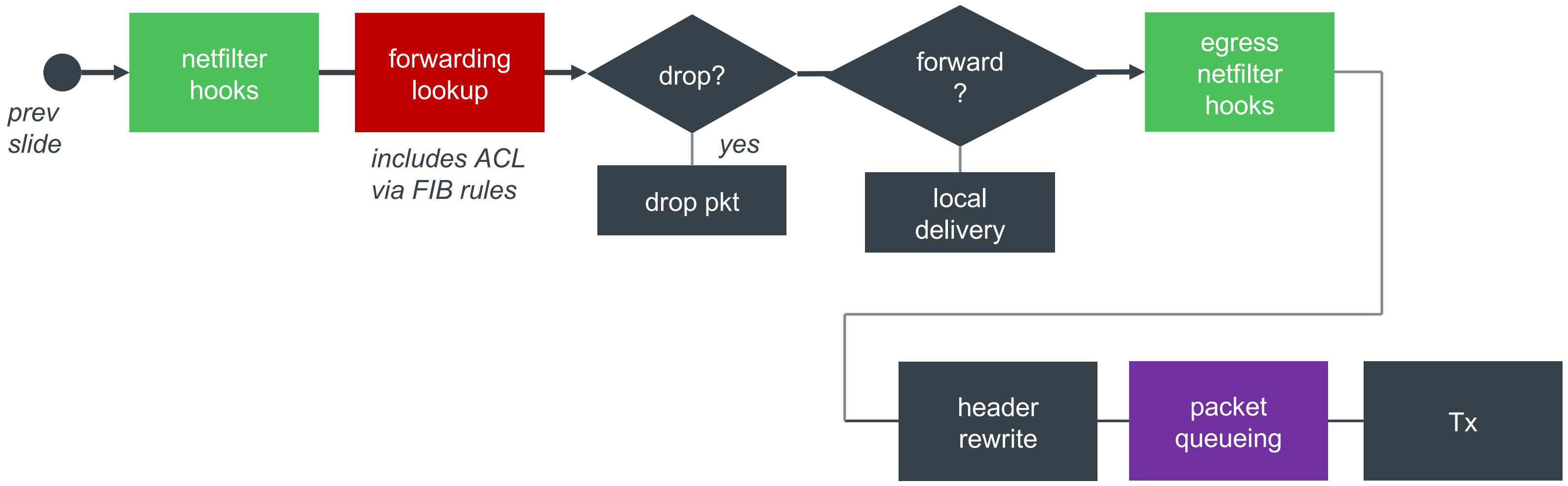
per packet loop in __netif_receive_skb_core



Each pass handles features: vlans, bonds, bridges

Pass 1: skb->dev = net_dev for port
Pass 2: skb->dev could be net_dev for {port.vlan}
Pass 3: skb->dev could be upper dev (e.g., bond)
Pass 4: skb->dev could be net_dev for {upper_dev.vlan}

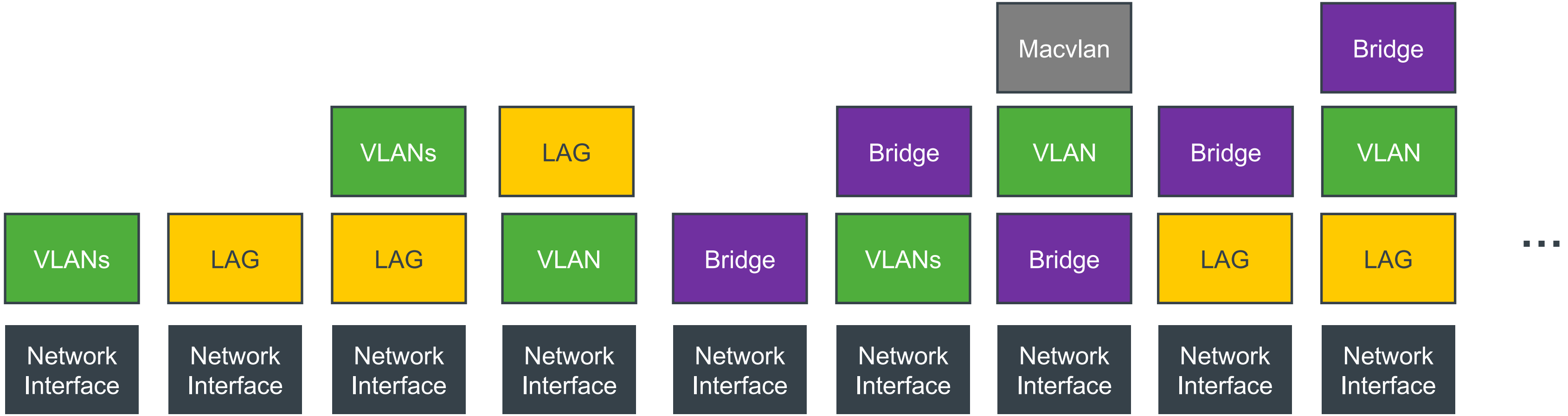
Linux Packet Processing (simplified)



Device “Table” and Feature Stacking on NIC Port

Base is NIC Port

- Number of combinations of features stacked on top of port



Example: Port with multiple VLANs

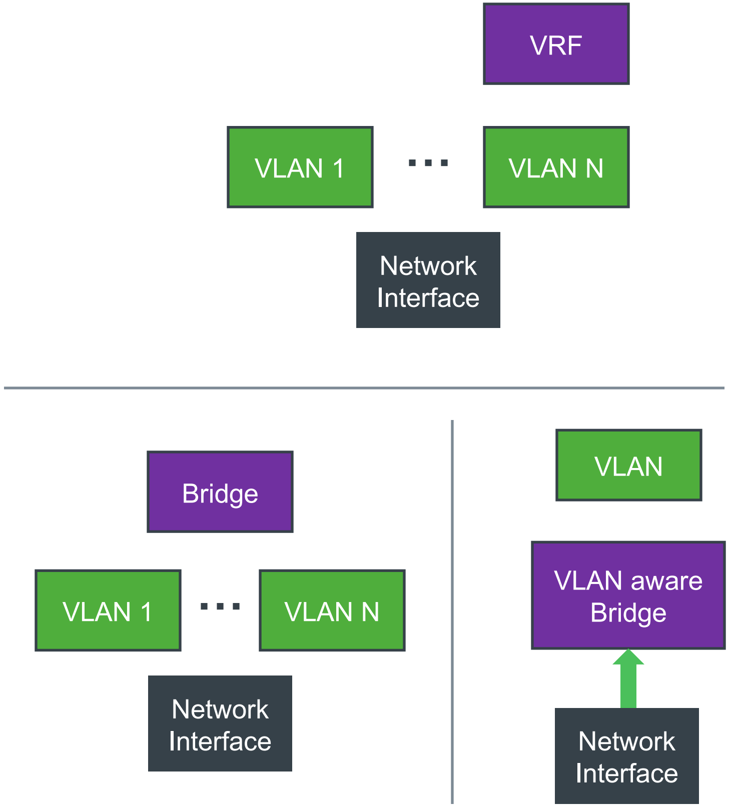
NIC port as a trunk for multiple VLANs

VLAN subinterfaces exist and match destination mac

- "Router interfaces," L3 Forwarding, potentially based on VRF
- Look up needs the subinterface index

VLANs directed at bridge?

- L2 forwarding … maybe
- VLAN aware bridge means no explicit subinterface devices
- Could be a VLAN on the bridge (SVI)!



Example: Port with Bonding

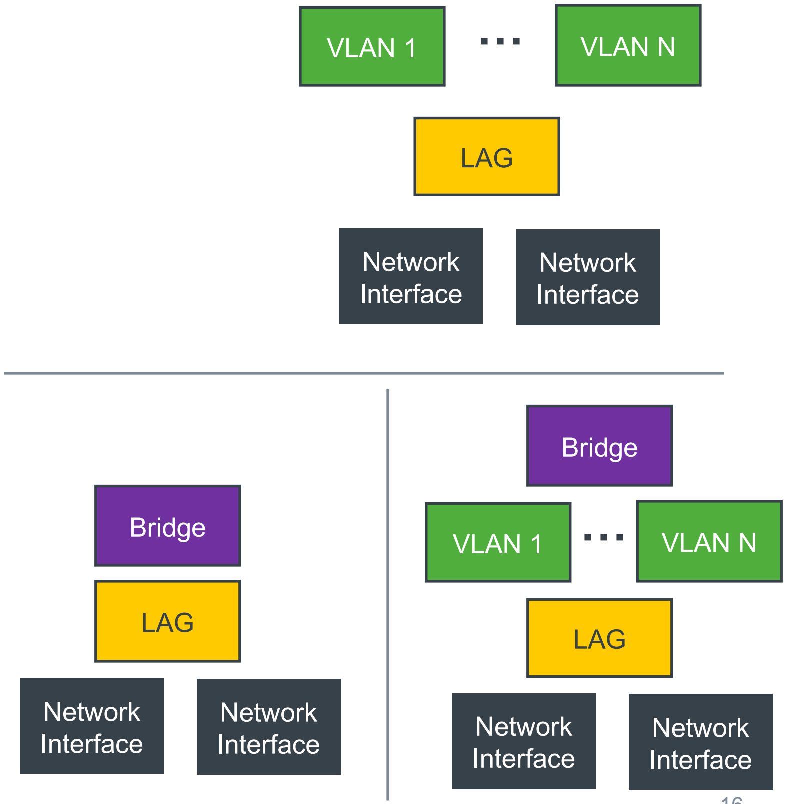
NIC ports are part of a LAG (bond)

Bond can:

- have a network address (L3 forwarding)
- be enslaved to a bridge (L2 forwarding)
- Bond can have multiple VLANS – previous slide

Egress port selection

- Forwarding lookup shows bond as the egress. Which port to use to Tx packet?
- Logic within the bond to select egress



Device Stacking on NIC Port

Networking features typically implemented in modules and instantiated as virtual net_devices

- VLANs, LAG, bridging, VRF
- Manages upper/lower relationships
- Could be manipulating the packet (adding/removing vlan header) or dropping it (ingress on inactive slave)
- Could be implementing a protocol (bond and 802.3ad; bridge and stp)
- Selecting an egress device (bond, team)
- Influencing a lookup (bridge, vrf) or learning (bridge)

Do not want to have to reimplement networking features for XDP

Allow standard Linux interface managers to configure/manage networking features

- VLANs, bonds, macvlans, vlan-aware bridge, SVIs

Access to Device Table

Need bpf helpers to convert {port index, vlan, dmac} to:

- LAG id
- L2 device index – device enslaved to a bridge; L2 forwarding lookup
- L3 / RIF device index – input to L3 forwarding lookup
- Other intermediary devices? Features as a device is a Linux'ism

Device (or index) is key to other features

- ACL, filtering, scheduling, forwarding

Egress port index

- L2/L3 forwarding returns upper device
- Need egress port index for redirect

Prototype

One option is to use existing upper/lower list_heads

- Reduces code refactoring and APIs
- Does not scale (e.g., number of VLANs)

Better solution is to mimic logic of __netif_receive_skb_core

- Heavy refactoring, exporting APIs or creating new ones to move from one device type (feature) to another
  - Ingress port
  - If vlan tag, search for vlan device on port
  - Is net_device a LAG, bridge or macvlan slave?

Tested with VLANs and bonds – ingress and egress

Challenges

Core kernel code vs modules

- BPF helpers in filter.c – compiled into kernel
- Driver functionality often loaded as modules
- Common problem: vlan, bond, bridge, mpls, …

Code refactoring needed to not duplicate code

- Functions need to be invoked from 2 different contexts – XDP and skb

Number of use cases to cover to converge device lookup API

ACL, Filters and Packet Scheduling

ACL

- FIB rules supported via FIB lookup helper – L3 ACL
- tc vs netfilter

Packet Scheduling

- tc and qdiscs

Start point

- Converting tc code to handle frames from XDP context is the bigger ROI

L2 / L3 Forwarding

FIB lookup helper exists for L3 Forwarding

- Needs more work – e.g., handle lwtunnel encaps
- MPLS support (started)

Bridges and L2 forwarding

- FDB access per bridge
- MAC learning
- Flooding

Summary

Need better integration of XDP with Linux

- More complete and consistent Linux solution

Do not need BPF programs reinventing / re-implementing Linux

- Established APIs for configuring, monitoring, troubleshooting
- Established implementations of protocols with notifications and cleanups (e.g., aging entries)

Enables Linux to be a slow-path assist

- Same data for full-stack and fast-path in XDP

Thank you!

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