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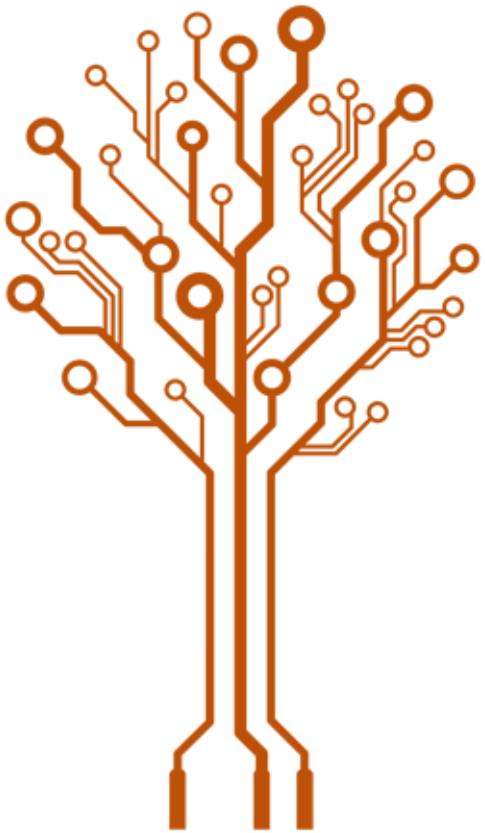
Offloading OVS Flow Processing using eBPF

What is eBPF?

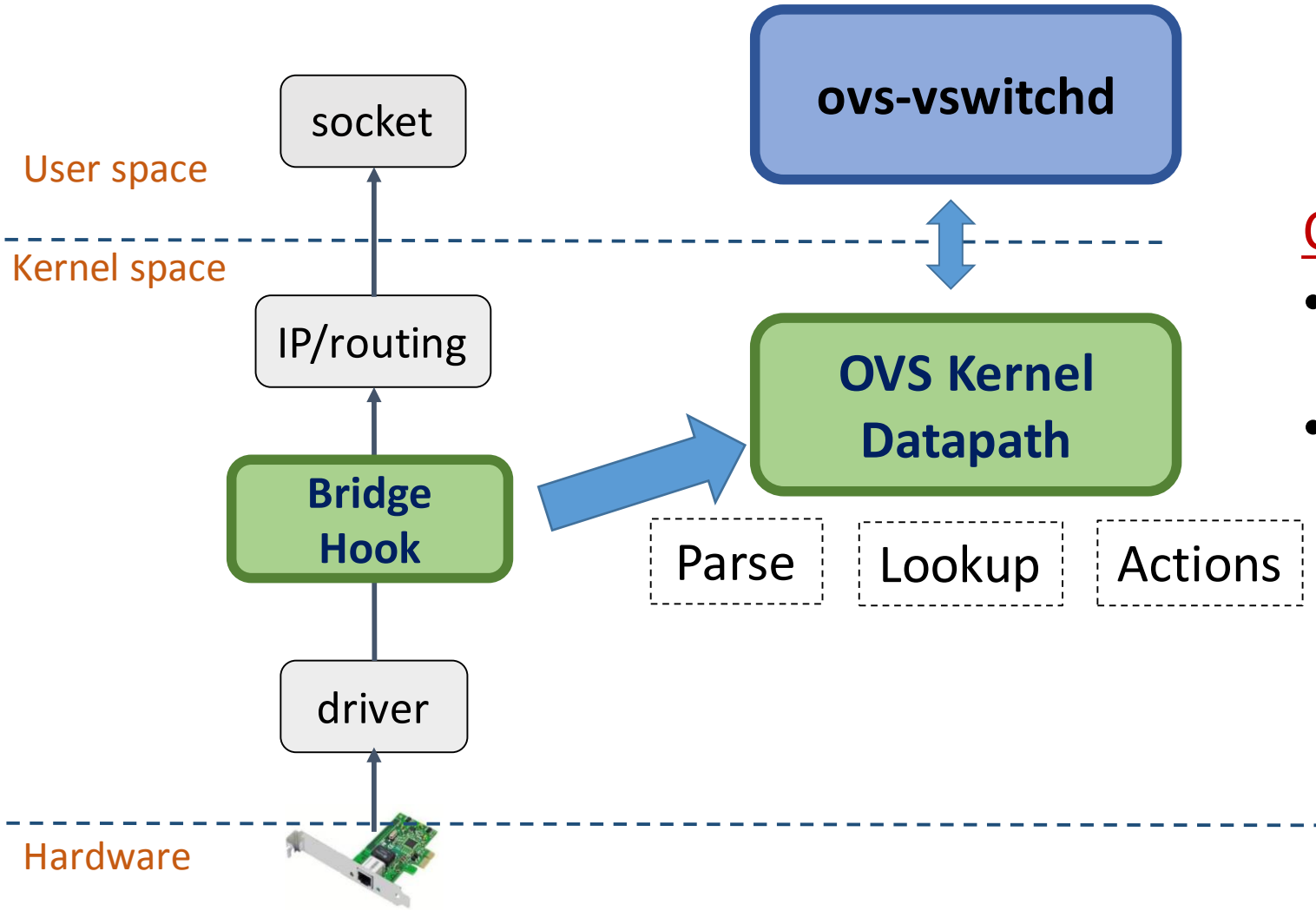
- A way to write a **restricted C** program and runs in **Linux kernel**
  - A new instruction set, but no corresponding HW
  - A virtual machine running in Linux kernel
  - Safety guaranteed by BPF verifier
- Maps
  - Efficient key/value store resides in kernel space
  - Can be shared between eBPF programs and user space applications
- Helper Functions
  - A core kernel defined set of functions for eBPF program to retrieve/push data from/to the kernel

Motivation

- Extensibility, when introducing a new datapath feature:
  - Upstream process provides valuable feedbacks
  - Time to upstream could also be unpredictable
  - Maintain ABI compatibility between different kernel and OVS versions.
- Maintenance cost and compatibility effort
  - Keep up with new kernel API changes
  - Backport new features to older version
  - Bugs in compat code are easy to introduce and often non-obvious to fix
- **eBPF**: Implement datapath functionalities in eBPF and reduce dependencies on different kernel versions



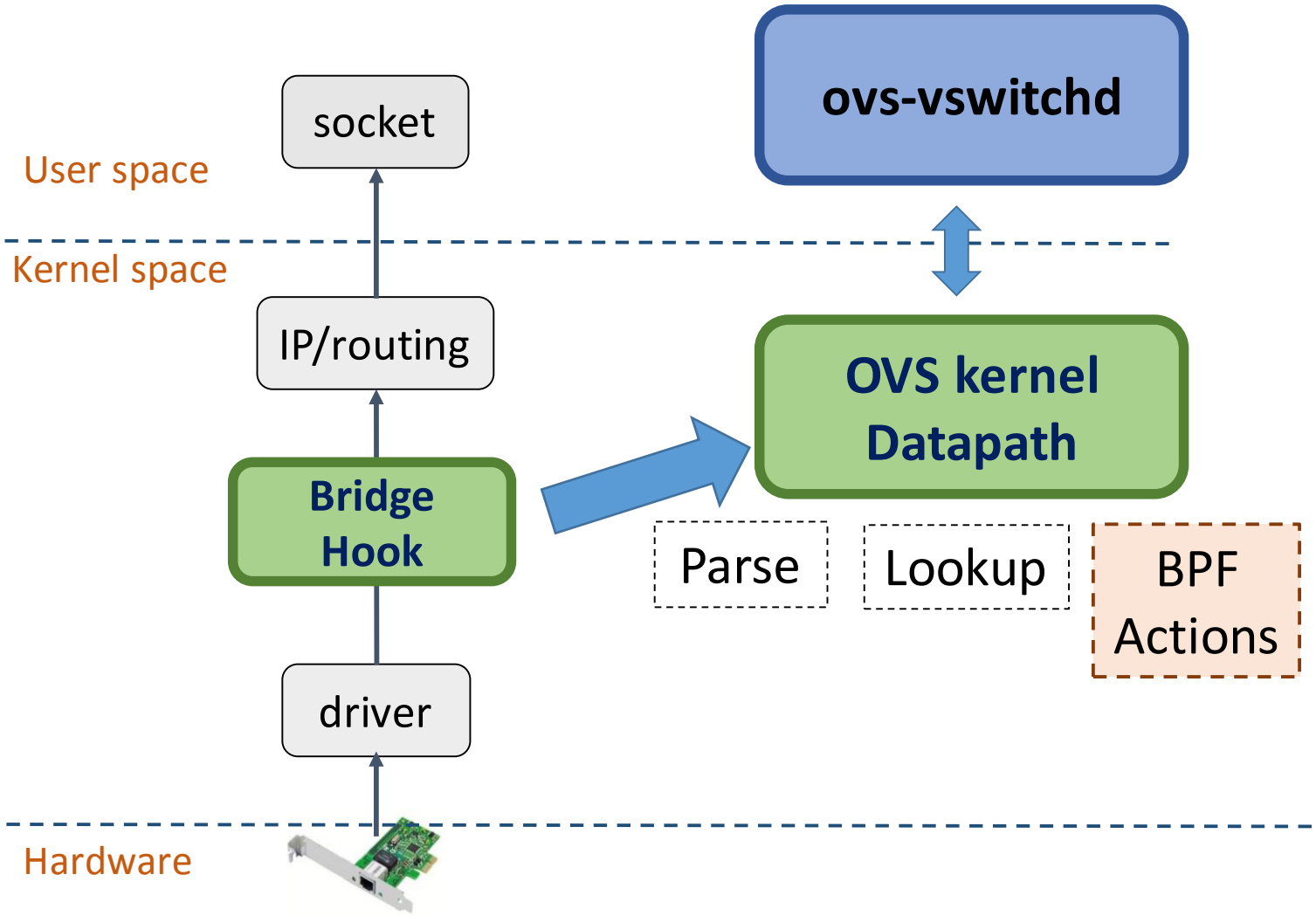
Review: Linux and OVS Datapath



Current OVS DP:

- Receive packets from bridge/device hook
- Parse -> Lookup -> Actions

Previous eBPF Proposal



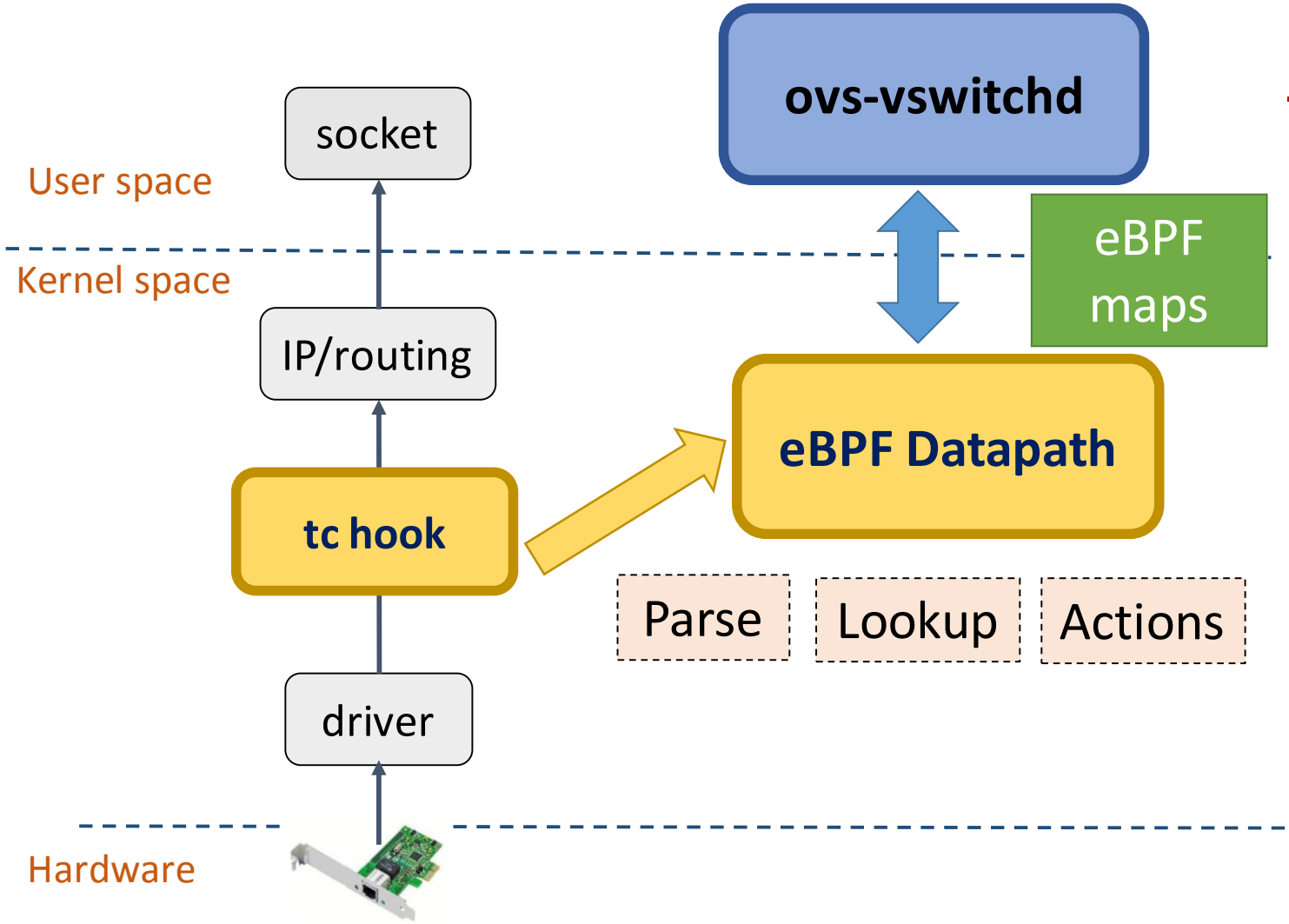
Introduce eBPF actions:

- Add BPF hook point in OVS kernel DP for actions
- New actions could be added without updating OVS kernel module

Limitations:

- Parsing new protocols
- Matching new fields

OVS eBPF Datapath



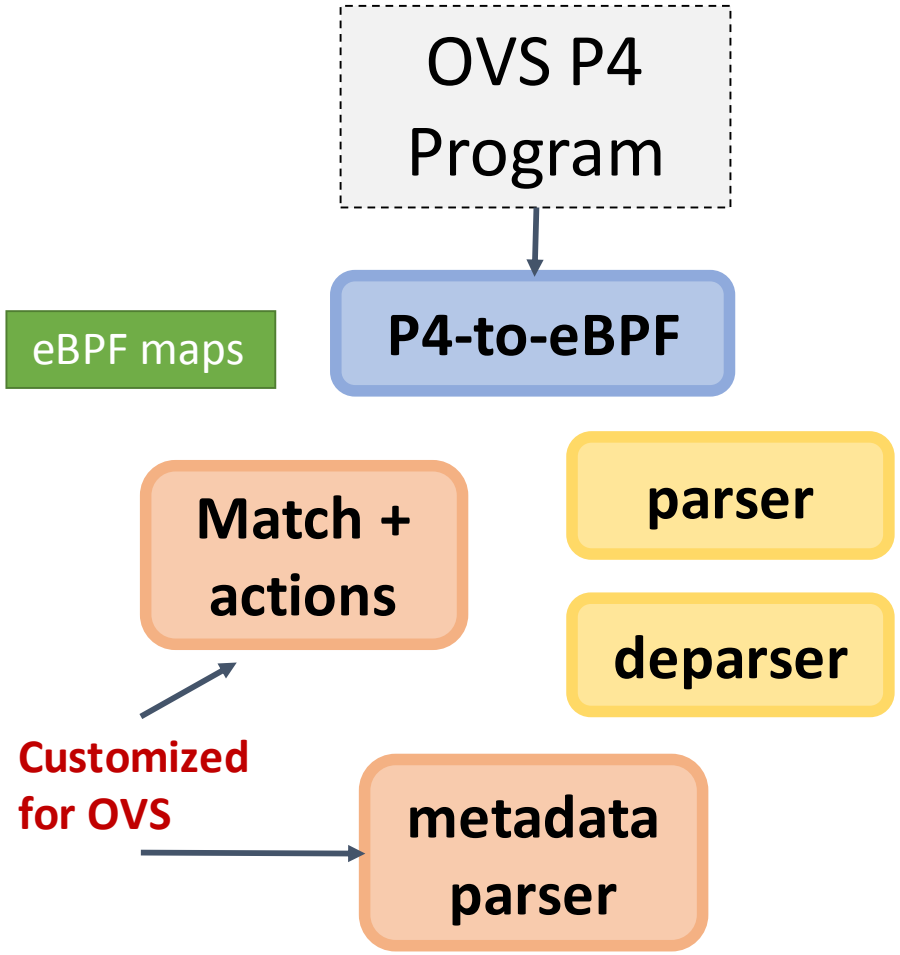
Goal

- Replace OVS kernel datapath **entirely** with eBPF
- ovs-vswitchd controls and manages the eBPF DP
- eBPF map as channels in between

Agenda

- Header Parsing
- Flow Table Lookup
- Action Execution
- Performance Evaluation

Parsing Headers/Metadata using P4



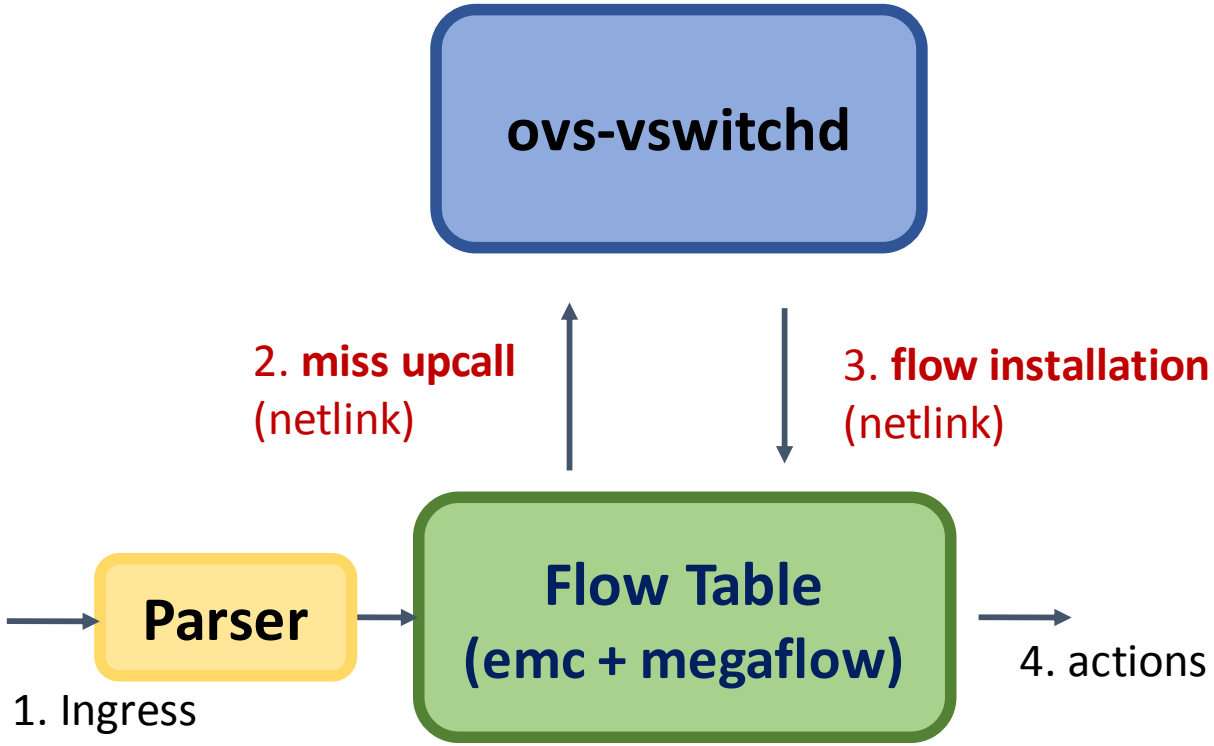
P4-to-eBPF

- Leverage P4-to-eBPF compiler from bcc
- Generate protocol/metadata headers
- Parser walks through the protocol parsing graph
- Deparser writes back the packet changes
- Maps for flow lookup and counters

Limitations for OVS:

- OVS requires Linux-specific metadata fields
- OVS implements its own match + action eBPF program

Review: Flow Lookup in kernel Datapath



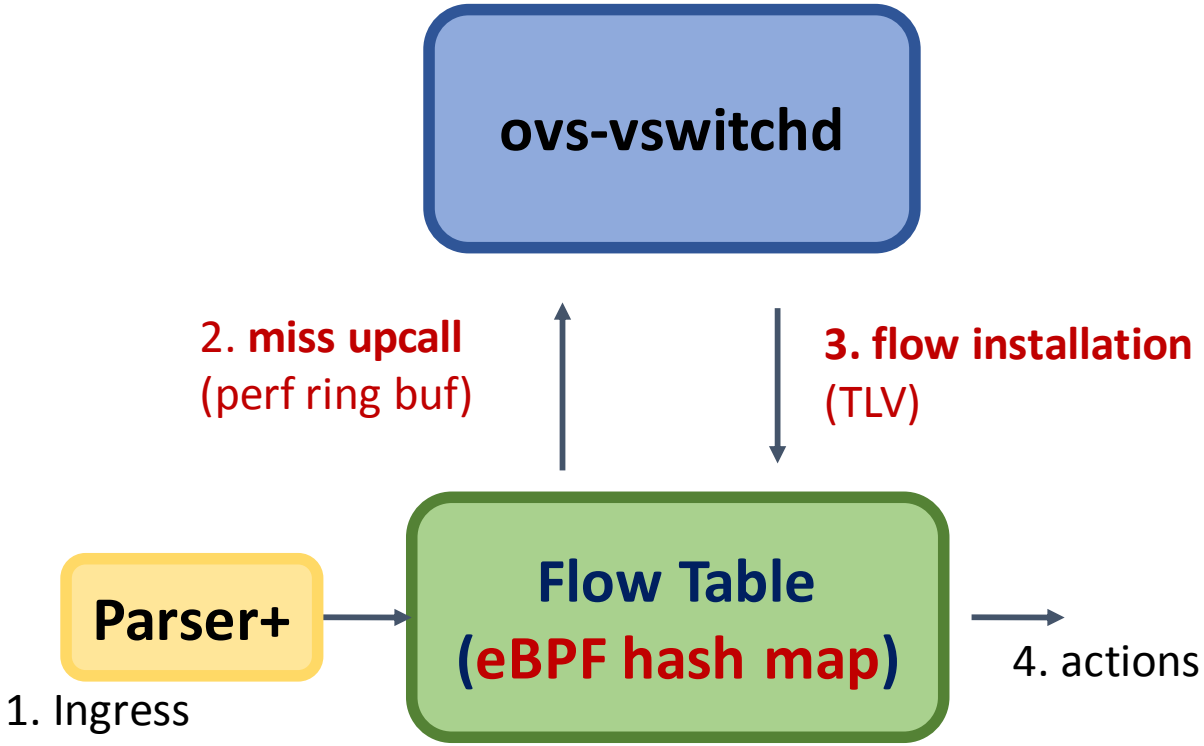
Slow Path:

- Ingress: lookup miss and upcall
- ovs-vswitchd receives, does flow translation, and programs flow entry into flow table in OVS kernel module
- OVS kernel DP installs the flow entry
- OVS kernel DP receives and executes actions on the packet

Fast Path:

- Subsequent packets hit the flow cache

Flow Lookup in eBPF Datapath



Limitation at flow installation:
TLV format currently not supported in BPF verifier
Solution: Convert TLV into fixed length array

Slow Path:

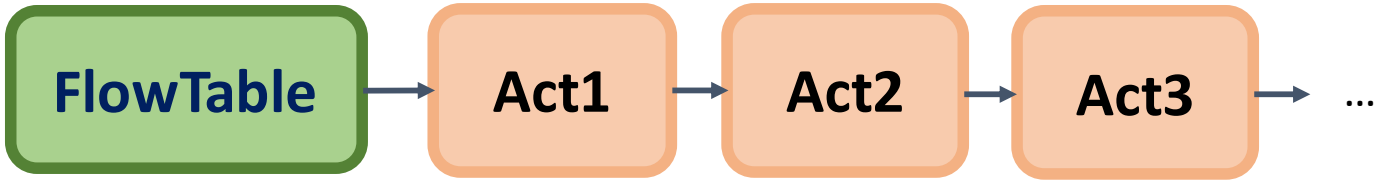
- Ingress: lookup miss and upcall
- Perf ring buffer carries packet and its metadata to ovs-vswitchd
- ovs-vswitchd receives, does flow translation, and programs flow entry into **eBPF map**
- ovs-vswitchd sends the packet down to trigger lookup again

Benefits:

- Use any fixed binary format between userspace and kernel eBPF program.

Review: OVS Kernel Datapath Actions

A list of actions to execute on the packet

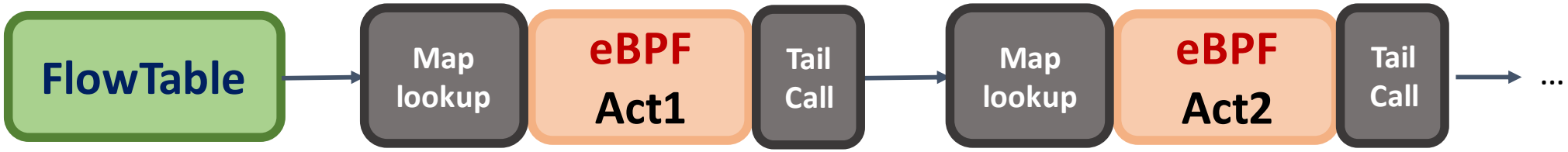


Example cases of DP actions

- Flooding:
  - Datapath actions: 9,55,10,55,66,11,77,88,9,1
- Mirror and push vlan:
  - Datapath actions: 3,push_vlan(vid=17,pcp=0),2
- Tunnel:
  - Datapath actions: set(tunnel(tun_id=0x5,src=2.2.2.2,dst=1.1.1.1,ttl=64,flags(df|key))),1

eBPF Datapath Actions

A list of actions to execute on the packet



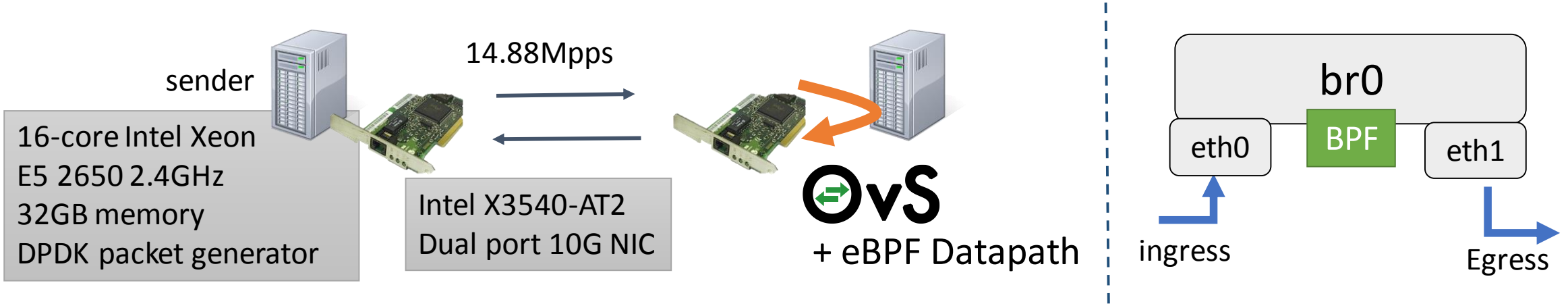
Challenges

- Limited eBPF program size (maximum 4K instructions)
- Variable number of actions: BPF disallows loops to ensure program termination

Solution:

- Make each action type an eBPF program, and tail call the next action
- Side effects: tail call has **limited context** and **does not return**
- Solution: keep **action metadata** and **action list** in a map

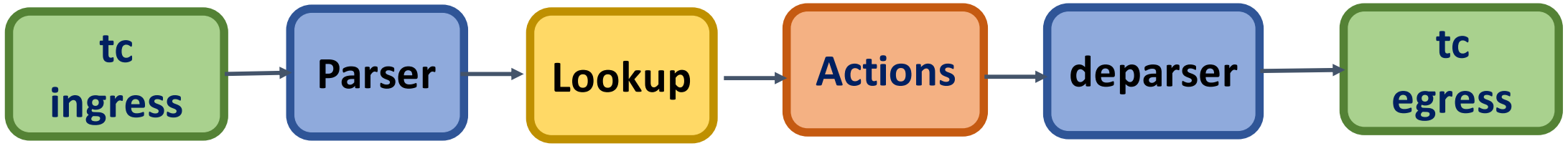
Performance Evaluation



- Sender sends 64Byte, 14.88Mpps to one port, measure the receiving packet rate at the other port
- OVS receives packets from one port, forwards to the other port
- Compare OVS kernel datapath and eBPF datapath
- Measure single flow, single core performance with Linux kernel 4.9-rc3 on OVS server

OVS Kernel and eBPF Datapath Performance

Recap: eBPF DataPath



eBPF DP Actions	Mpps
Redirect(no parser, lookup, actions, deparser)	1.90
Hash	1.12
Push vlan	1.11
Set dst_mac	0.84
Set dst_mac <no deparser>	1.14
Set GRE tunnel	0.48

All measurements are based on single flow, single core.

OVS Kernel DP Actions	Mpps
Output	1.34
Set dst_mac	1.23
Set GRE tunnel	0.57

Opportunity for improving parser and deparser

Conclusion and Future Work

Conclusion

- Feasibility of implementing OVS Datapath entirely using eBPF
- Decouple OVS datapath functionality from kernel versions
- Limitation of eBPF might incur performance overhead

Future work

- Complete all the datapath actions, ex: connection tracking
- Megaflow lookup using eBPF map

Question?

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Thank You