Cilium Introduction and Improvement

Jiang Wang, System Technologies and Engineering, ByteDance

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ByteDance 字节跳动

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1. Introduction of eBPF
2. Introduction of Cilium
3. Cilium data path for DSR
4. Cilium DSR improvement
5. Q&A

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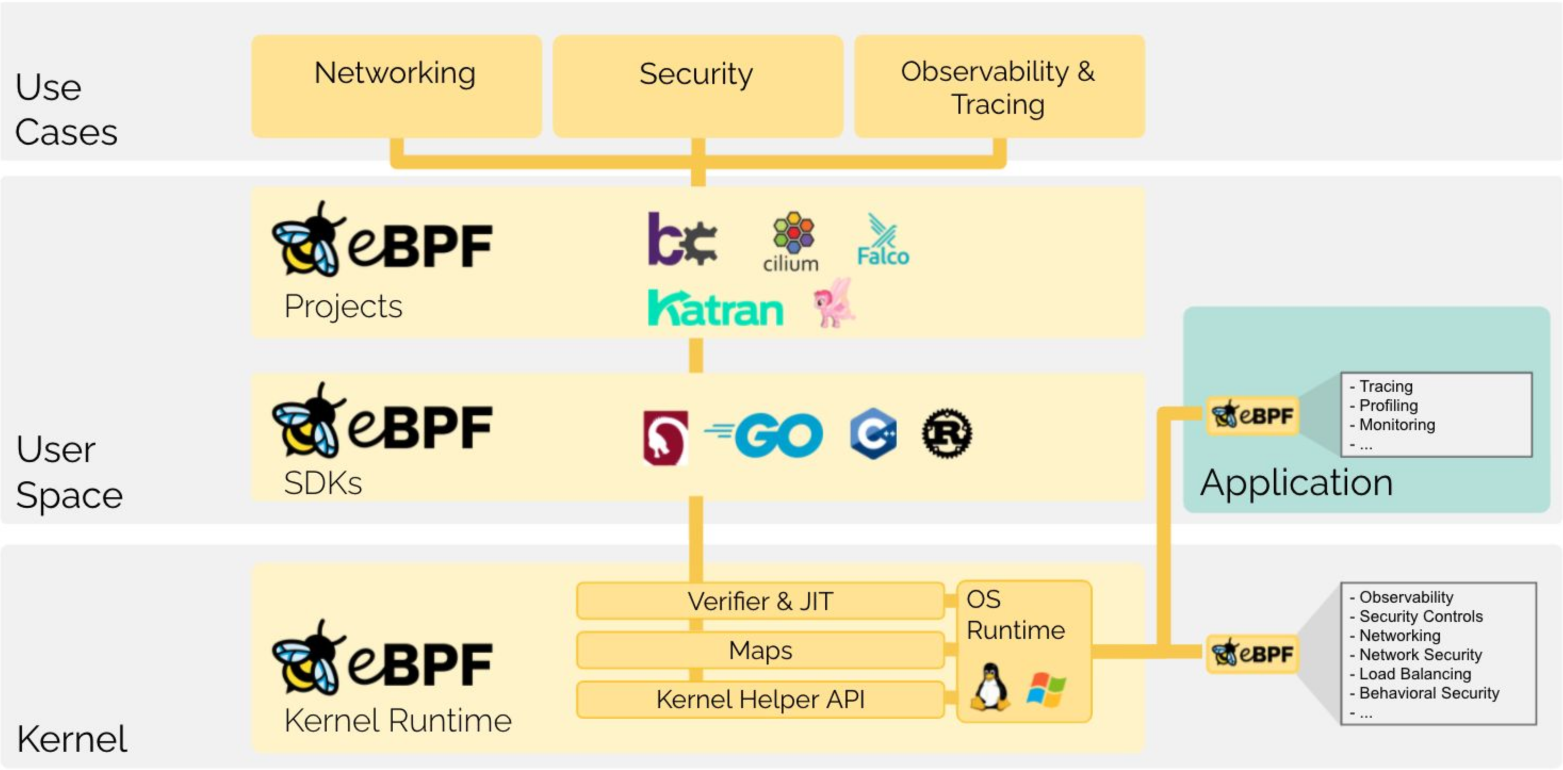
What is eBPF

- An instruction set based or
- RISC, JIT
- A sandboxed program in kerr
- Lightweight, safe, portable



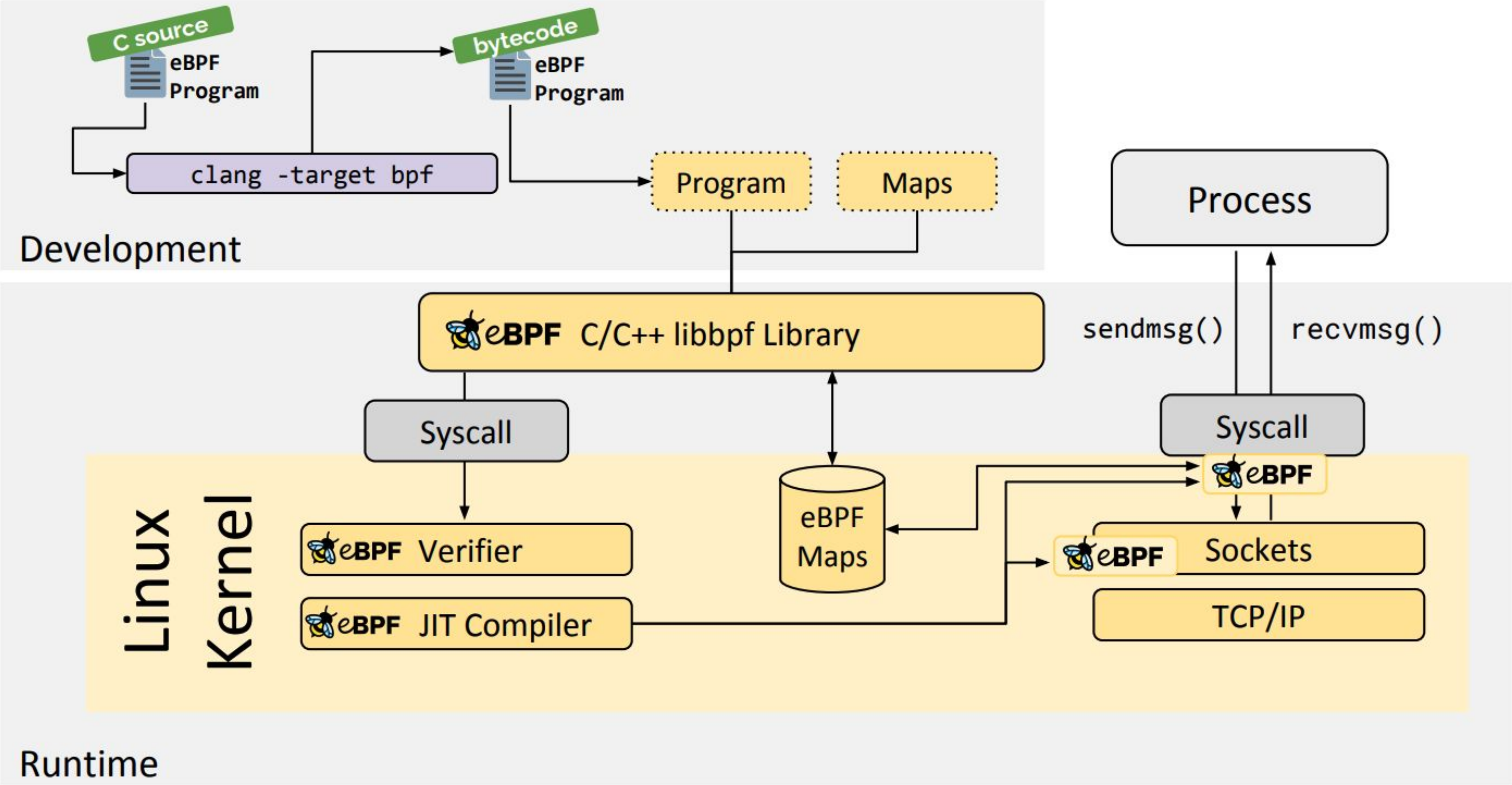
https://ebpf.io/

Why eBPF

- Hook pre-defined kernel functions
- A programmable interface, much more powerful than procfs/sysfs/syscall
- Safer, lighter and finer-granularity than kernel modules
- Compile-Once Run-Everywhere (?)

eBPF Architecture

- eBPF instruction set
- eBPF in-kernel verifier and JIT
- eBPF syscalls via bpf()
- Kernel components: programs, maps, helper functions, iterators, BTF, XDP etc.
- LLVM support
- Libbpf, bpftools


C source
eBPF Program
bytecode
eBPF Program
clang -target bpf
Program
Maps
Process
Development
eBPF C/C++ libbpf Library
sendmsg()
recvmsg()
Syscall
Syscall
eBPF
Linux Kernel
eBPF Verifier
eBPF Maps
eBPF Sockets
eBPF JIT Compiler
TCP/IP
Runtime

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eBPF Example for Tracing

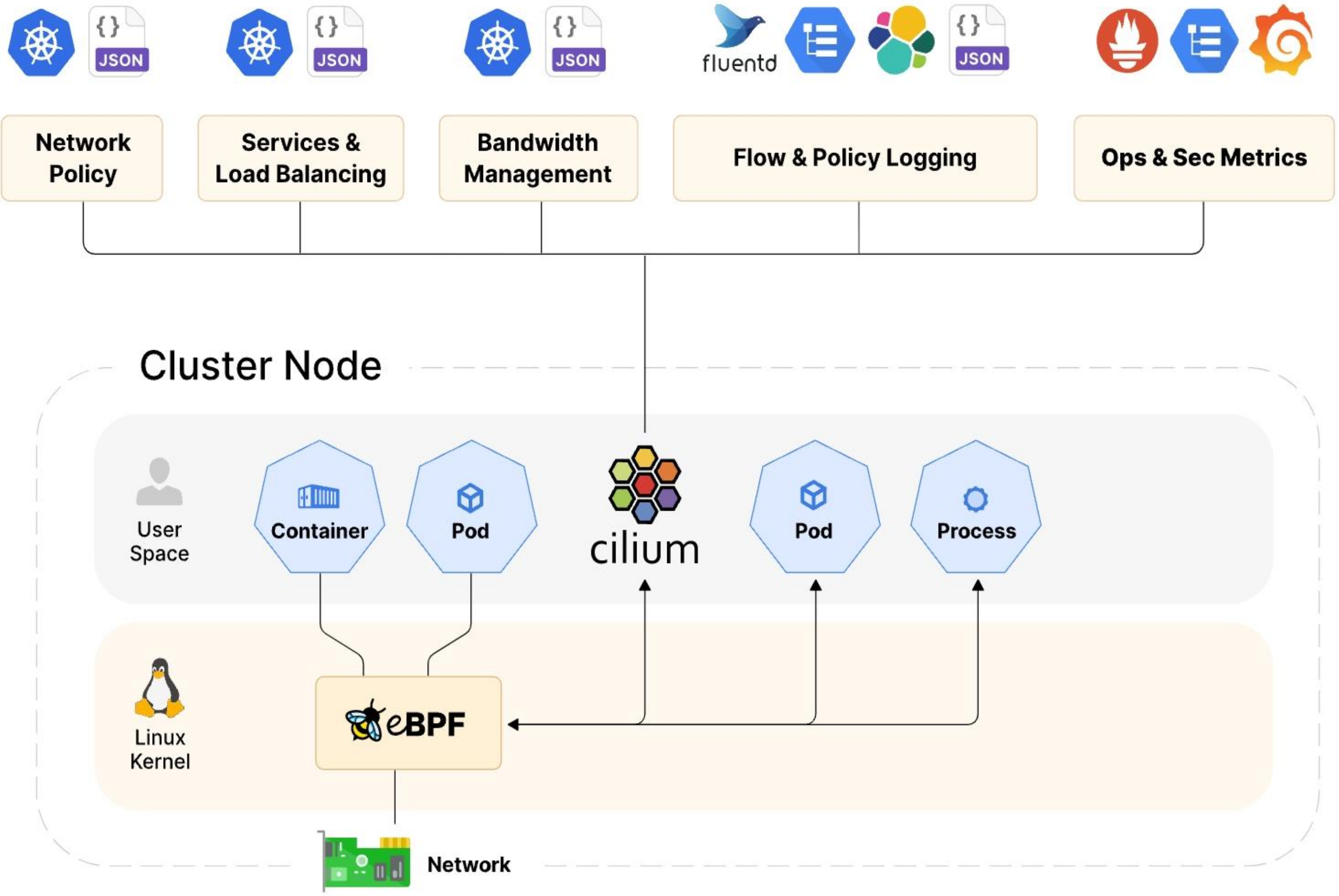
```
# ./tcpconnect -t
TIME(s)  PID    COMM         IP SADDR            DADDR            DPORT
31.871   2482   local_agent  4  10.103.219.236   10.251.148.38    7001
31.874   2482   local_agent  4  10.103.219.236   10.101.3.132     7001
31.878   2482   local_agent  4  10.103.219.236   10.171.133.98    7101
90.917   2482   local_agent  4  10.103.219.236   10.251.148.38    7001
90.928   2482   local_agent  4  10.103.219.236   10.102.64.230    7001
90.938   2482   local_agent  4  10.103.219.236   10.115.167.169   7101
```

https://github.com/iovisor/bcc/blob/master/tools/tcpconnect_example.txt

Cilium

- open source software providing, securing and observing network connectivity between container workloads
- High scale, low overhead

https://cilium.io/



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Cilium at ByteDance

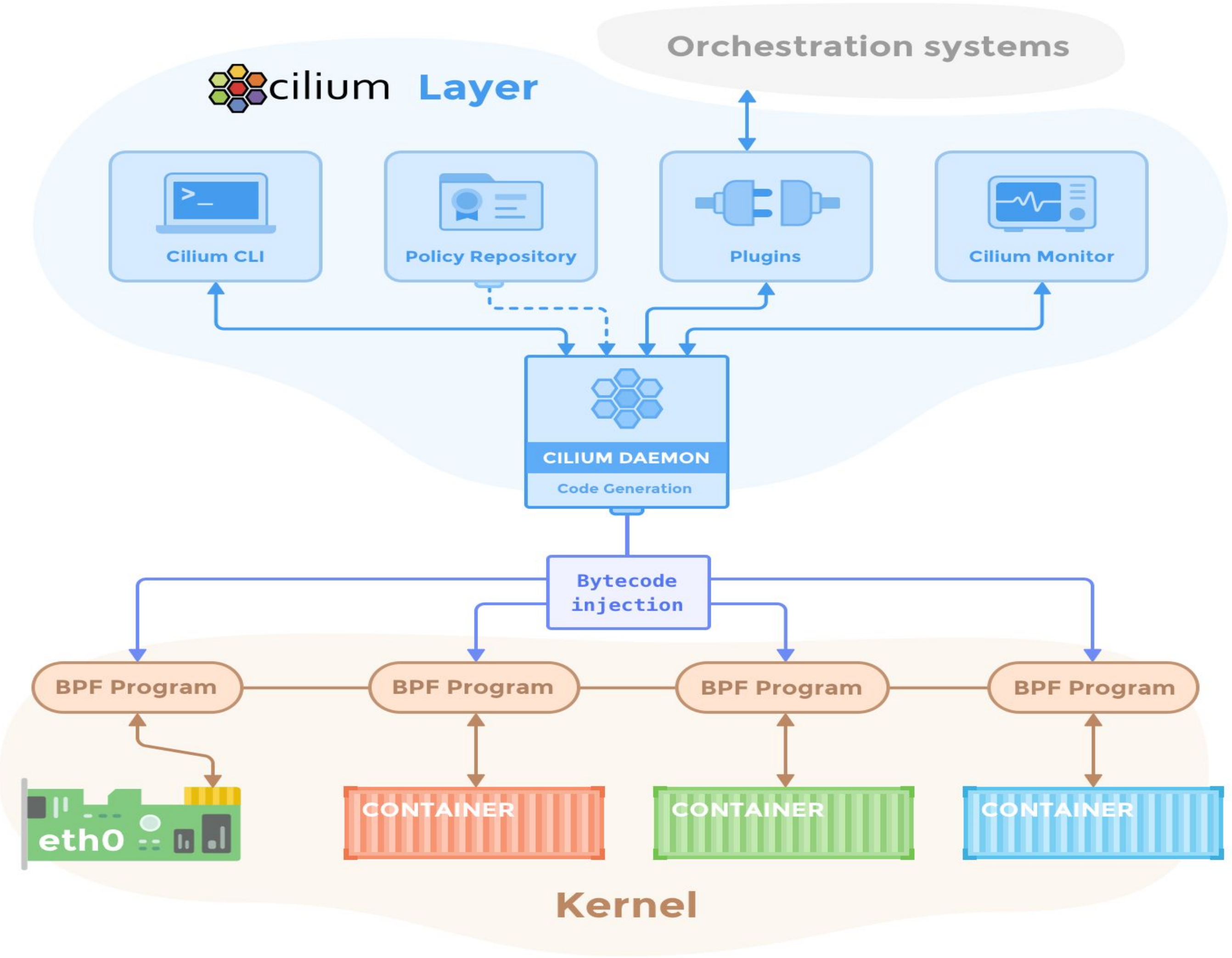
- Use Cilium as CNI for Kubernetes to replace kube-proxy
- Better performance, less cpu usage
- Deployed on a few edge networks.

Hubble

- Hubble is a fully distributed networking and security observability platform
- built on top of Cilium and eBPF to enable deep visibility
- Can answer the following questions:
  - Service dependencies & communication map
  - Network monitoring & alerting
  - Application monitoring
  - Security observability

Cilium Components

- Agent (Daemon)
- Client (CLI)
- Operator
- CNI Plugin



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Cilium Terminologies

- Labels
  - E.g io.cilium.mykey=myvalue
  - Label Source: Kubernetes or container
- Endpoint
  - Unique IP
  - By default, assign both IPv4 and IPv6
- Identification
  - Uint32 value

```
0x00000001 - 0x000000FF (1           to 2^8  - 1)        => reserved identities
0x00000100 - 0x0000FFFF (2^8         to 2^16 - 1)        => cluster-local identities
0x00010000 - 0x00FFFFFF (2^16        to 2^24 - 1)        => identities for remote clusters
0x01000000 - 0x0100FFFF (2^24        to 2^24 + 2^16 - 1) => identities for CIDRs (node-local)
0x01010000 - 0xFFFFFFFF (2^24 + 2^16 to 2^32 - 1)        => reserved for future use
```

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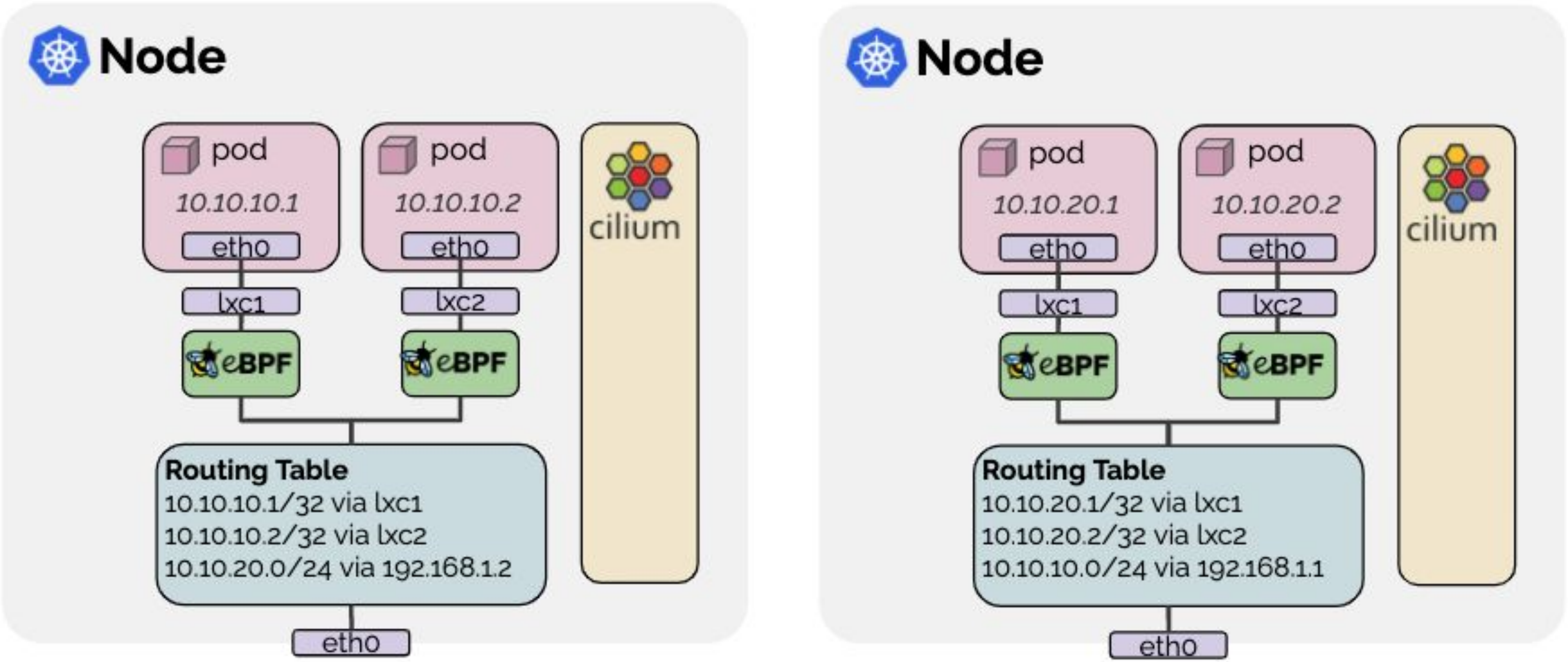
Networking mode 1: Encapsulation/tunneling

- Encapsulation (or tunneling mode)
- Vxlan or Geneve
- Requirement:
  - the underlying network and firewalls must allow encapsulated packets
- Advantage:
  - Simplicity
  - Addressing space
  - Auto-configuration
  - Identity context in the pkt
- Disadvantage:
  - MTU Overhead

Networking mode 2: native routing



Node

pod
10.10.10.1
eth0
lxc1
eBPF

pod
10.10.10.2
eth0
lxc2
eBPF

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Routing Table
10.10.10.1/32 via lxc1
10.10.10.2/32 via lxc2
10.10.20.0/24 via 192.168.1.2

eth0

Node

pod
10.10.20.1
eth0
lxc1
eBPF

pod
10.10.20.2
eth0
lxc2
eBPF

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Routing Table
10.10.20.1/32 via lxc1
10.10.20.2/32 via lxc2
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eth0

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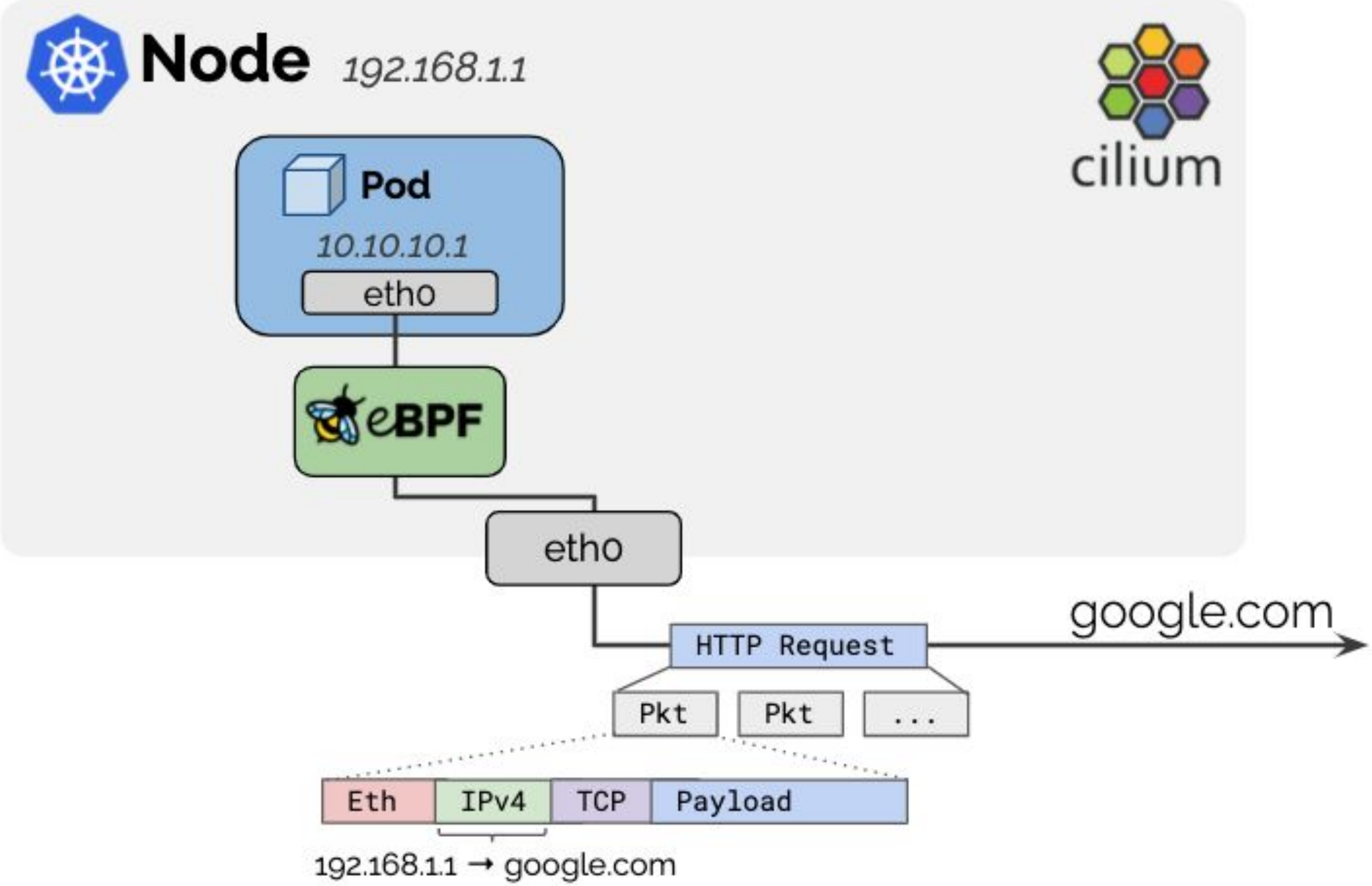
Masquerading



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SNAT mode

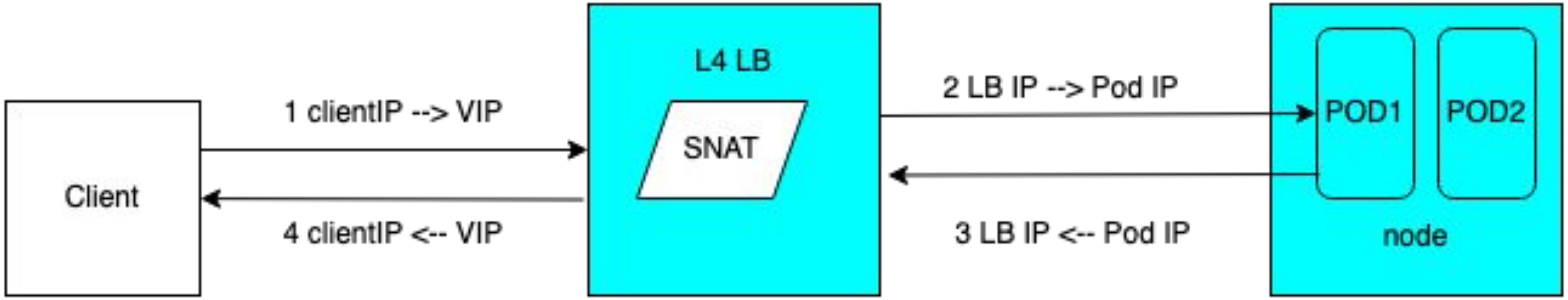


Figure1: SNAT packet flow

Direct Server Return (DSR) mode

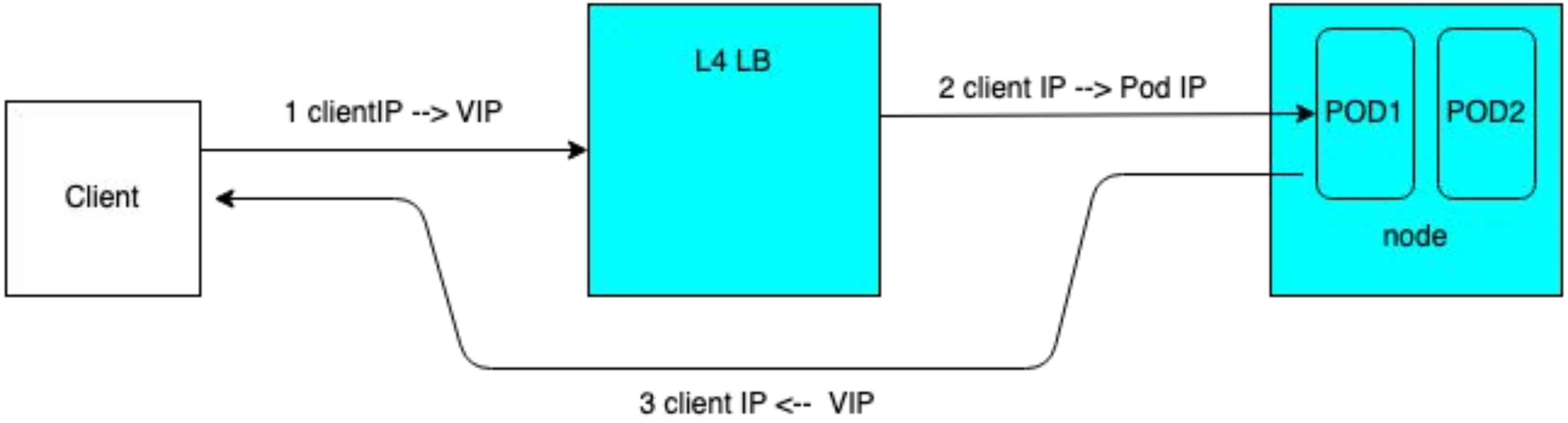
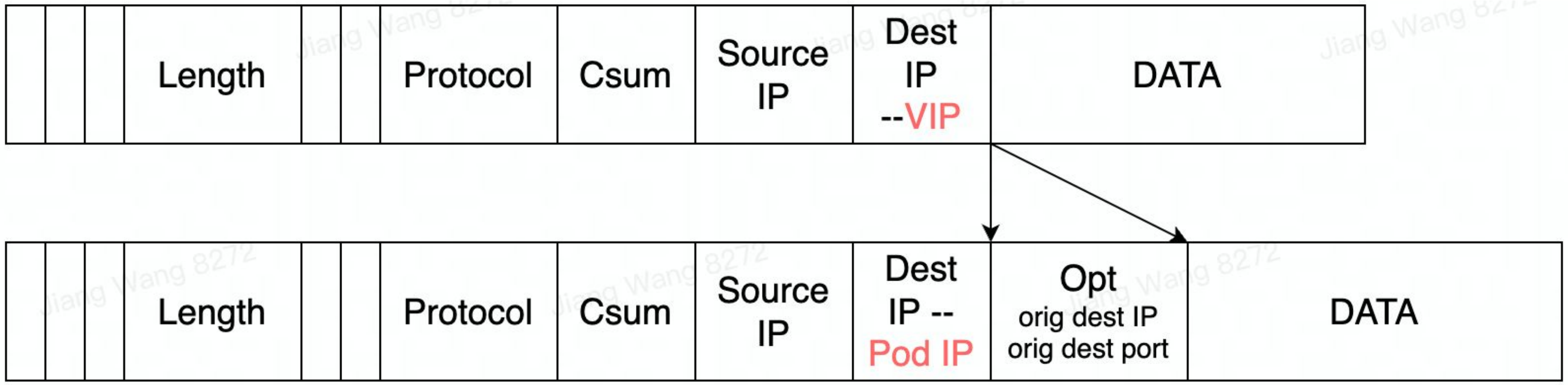


Figure1: DSR packet flow

- Benefit: less processing on LB.
- Where to store VIP?

Current Cilium DSR Support for IPv4

- Use IPv4 options



Length | Protocol | Csum | Source IP | Dest IP --VIP | DATA

Length | Protocol | Csum | Source IP | Dest IP -- Pod IP | Opt orig dest IP orig dest port | DATA

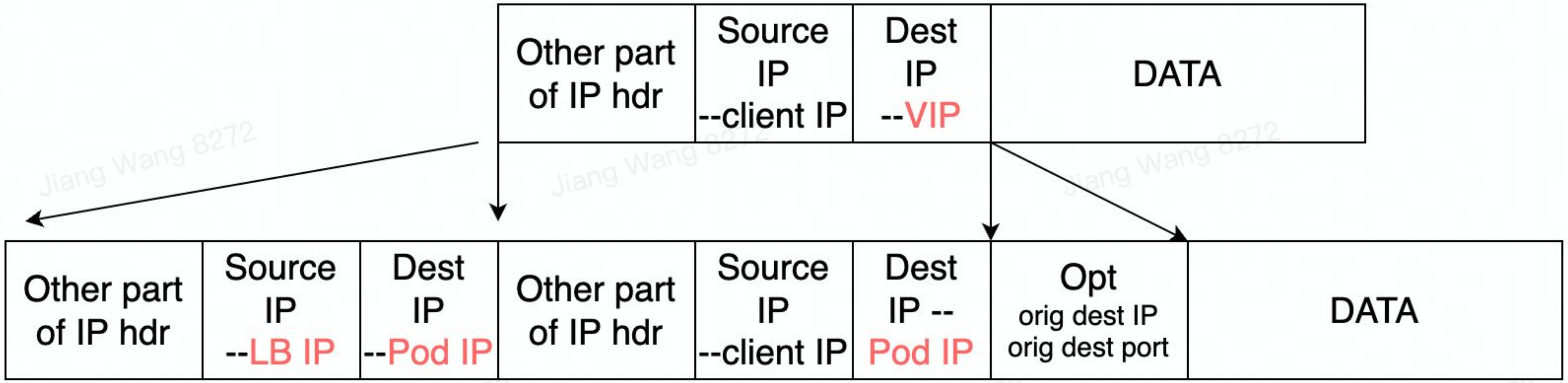
Figure 2: IP packet format in DSR with IP option

Problem with Current DSR Support for IPv4

- Problem: will go to slow path on switches
  - Network switch has a fast path and slow path
  - IP packets with option will go via slow path on many switches
  - Switches CPU usage arrived 100% for some cores. Bottleneck!
- Could we do better?

Proposal: Use IP-in-IP for DSR on IPv4

- Use IP-in-IP



Other part of IP hdr | Source IP --client IP | Dest IP --VIP | DATA

Other part of IP hdr | Source IP --LB IP | Dest IP --Pod IP | Other part of IP hdr | Source IP --client IP | Dest IP -- Pod IP | Opt orig dest IP orig dest port | DATA

Figure 3: IP packet format in DSR with IP-in-IP

- Will go to fast path on switches
- Drawbacks: smaller MTU for UDP and TCP Syn packets

Cilium eBPF DSR Data Path Changes

- On the LB:

```
nodeport_lb4
    |- tail_nodeport_ipv4_dsr
        |- dsr_set_ipip4
```

- On real node:

```
handle_to_container
 |-tail_ipv4_to_endpoint
    |-ipv4_policy
      |- handle_dsr_v4
        |- snat_v4_create_dsr
```

Cilium eBPF DSR Data Path

- When sending a reply to the client
  - bpf_lxc finds out that the "dsr" bit was set
  - does a lookup in the NAT table to find the mapping
  - rewrites the source addr and port to the svc addr and port.
- No changes here

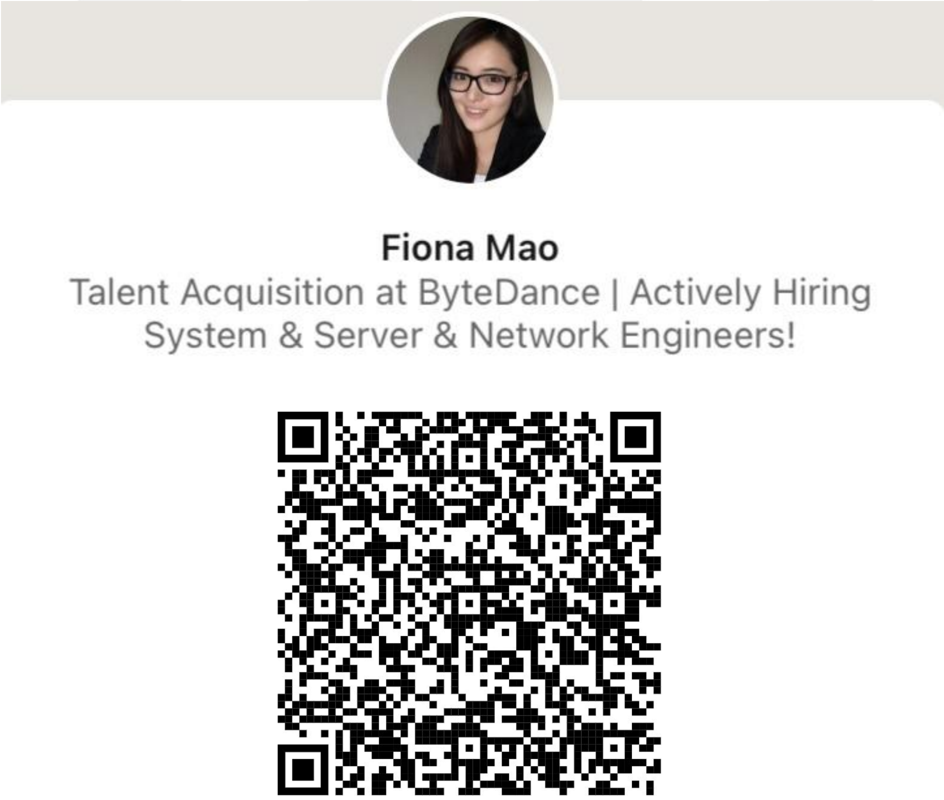
Future Work

- IPv6 support? We may not need that.

PR link:

https://github.com/cilium/cilium/pull/18449

We Are Hiring!



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Thank you!

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