

Scaling container policy management with kernel features

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Cilium.io

Linux Plumbers 2019, Lisbon, Portugal



Overview

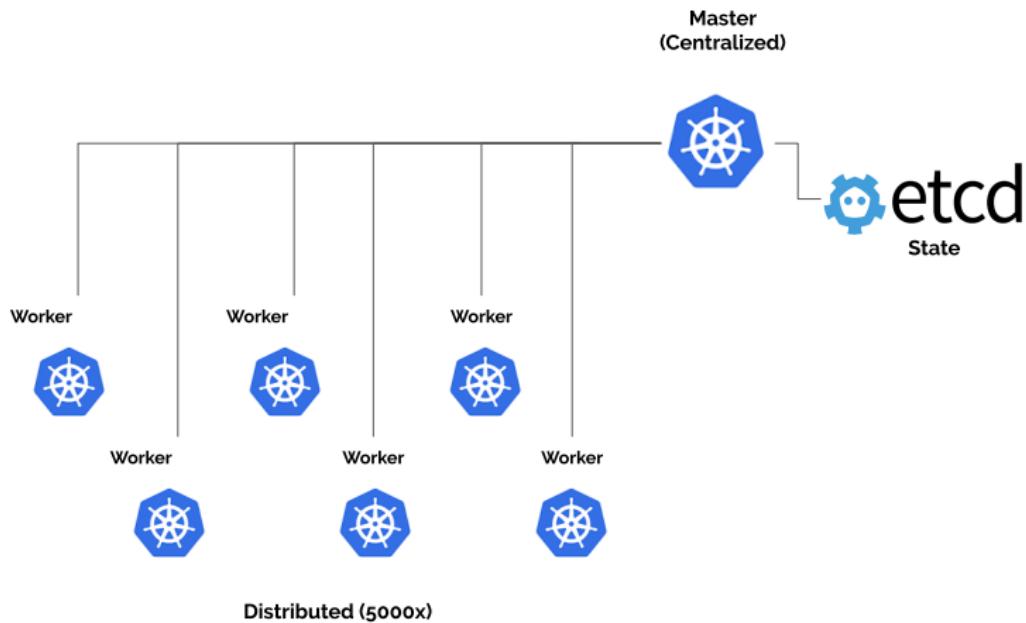
1 Background

2 Deploying fast datapaths fast

3 Identity-based security

4 Layer 7 security

Kubernetes Architecture 101



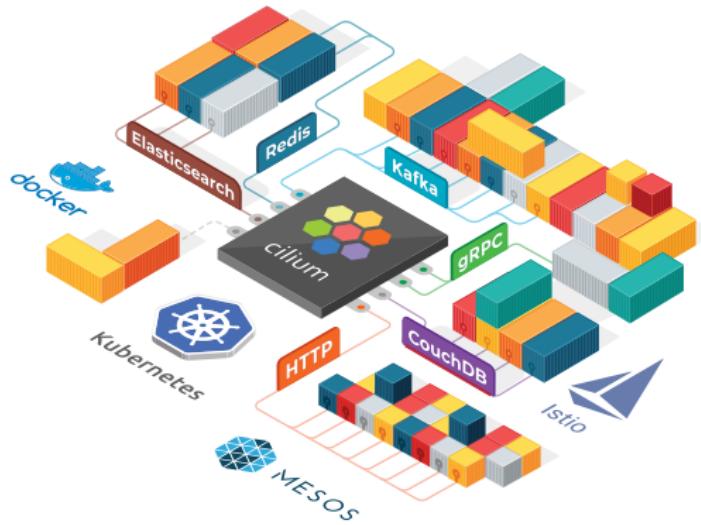
Kubernetes networking plugins

- Plumb local connectivity (CNI)
- Connect remote nodes
- Services / loadbalancing
- Network policy



Cilium

- Native eBPF dataplane
- Identity-based security
- Scalable

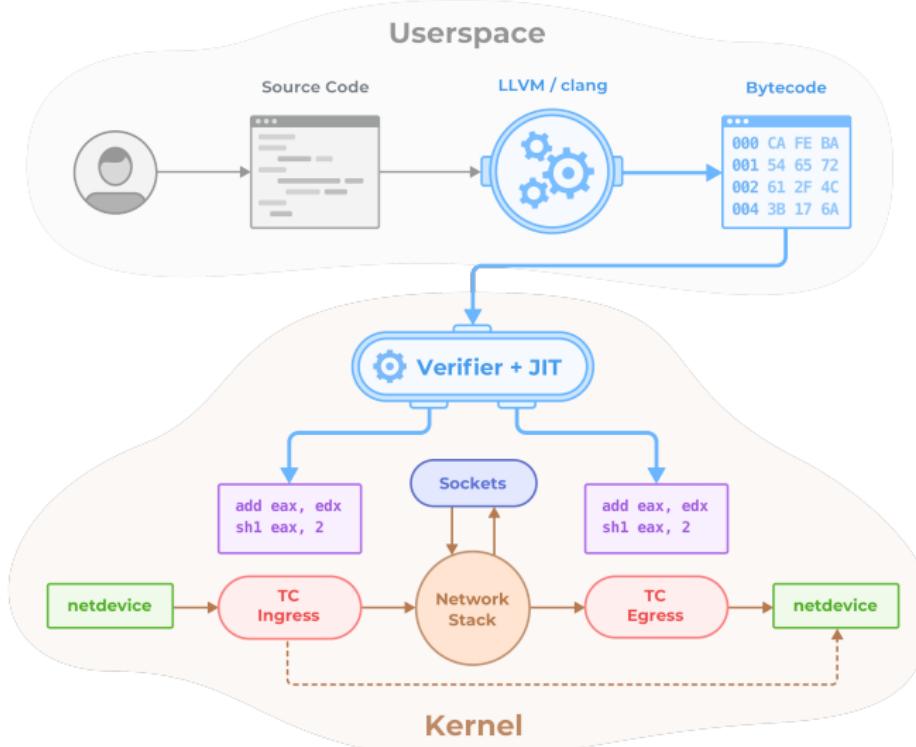


What does it mean to scale?

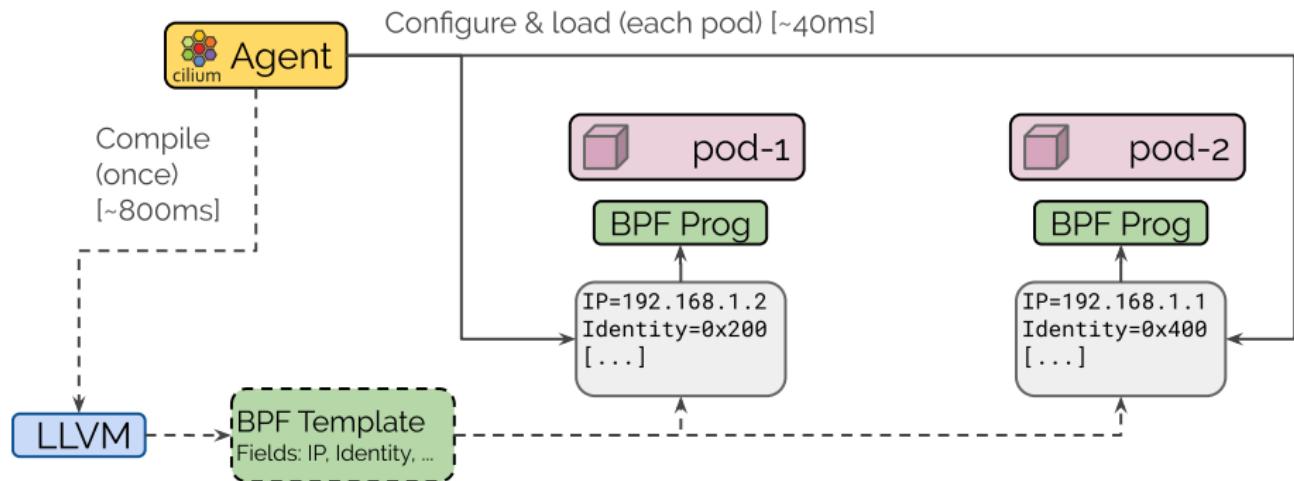
- Manage cluster interactions
 - Minimize unnecessary events
 - Reduce event sizes
 - ...
- Optimize work within the node
 - Apply datapath changes efficiently

Deploying fast datapaths fast

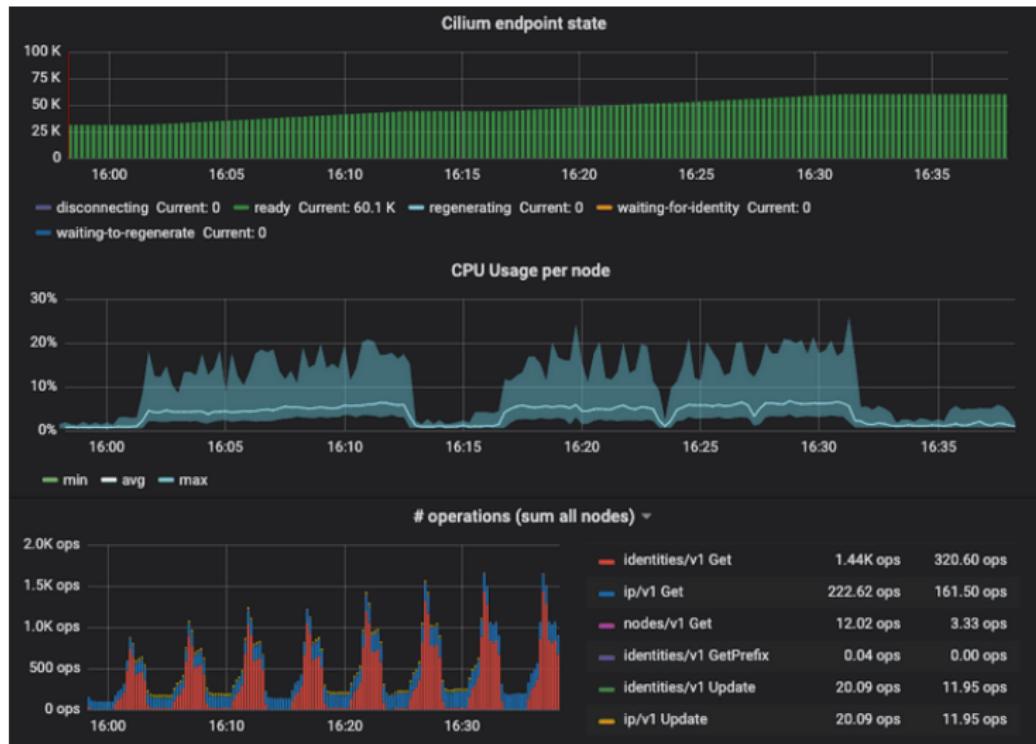
BPF plumbing



ELF Templating



1K nodes: Scaling to 60k pods



Initial implementation

- Treat ELF symbol table as a data table
- Declare symbols for all static data (constants)
- (hack) Cast desired static data symbol pointer to data
- Update loader to place data into global symbol table offset

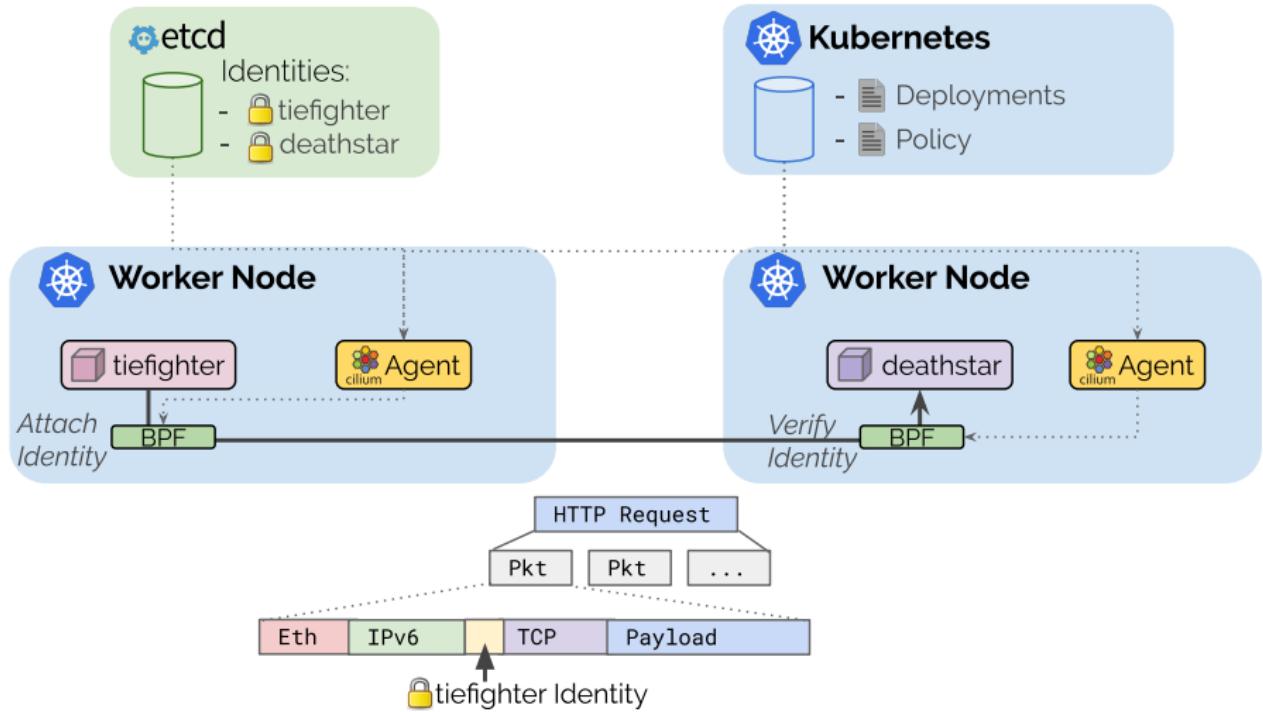
Upstream libbpf

- Create maps for .bss, .data, .rodata
- Relocate loads from static symbols to be map loads
- Kernel-side, fix up to be direct load

Future directions

- Load templates into the kernel
- Support code path manipulation

Identity-based security



Policy example

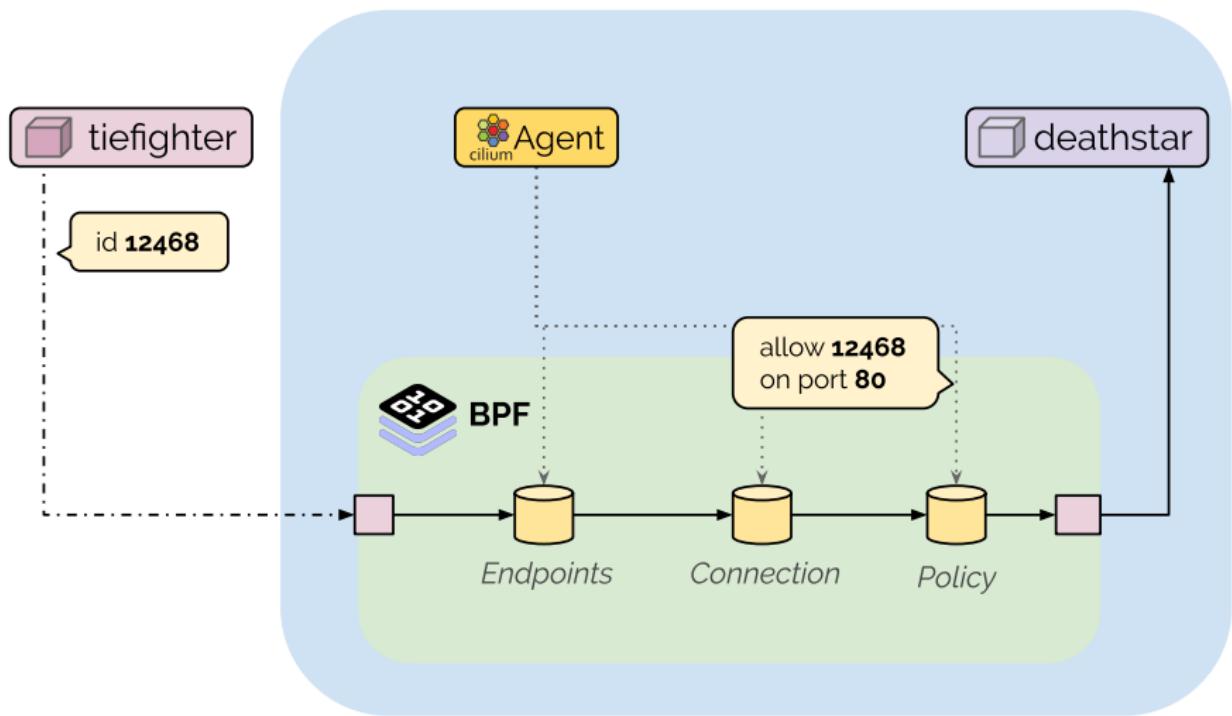
```
apiVersion: "cilium.io/v2"
kind: CiliumNetworkPolicy
description: "Restrict deathstar access to empire ships"
metadata:
  name: "deathstar-ingress"
spec:
  endpointSelector:
    matchLabels:
      org: empire
      class: deathstar
  ingress:
    - fromEndpoints:
        - matchLabels:
            org: empire
  toPorts:
    - ports:
        - port: "80"
          protocol: TCP
```

Label selectors

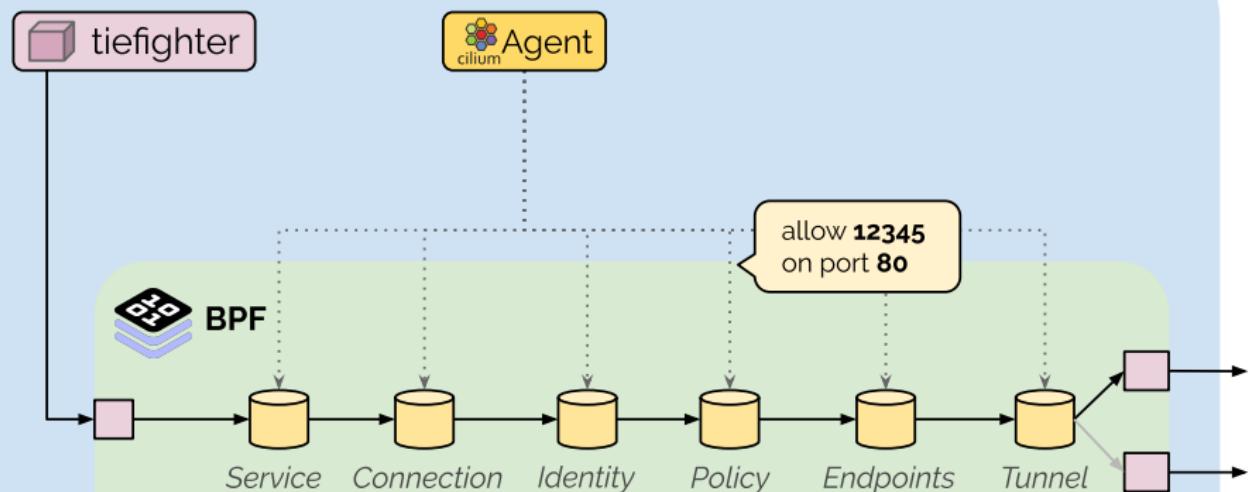
- 12345 {org:empire, class:deathstar}
- 12468 {org:empire, class:tiefighter}
- 12465 {org:alliance, class:xwing}

matchLabels: org: empire	12345 {org:empire, class:deathstar} 12468 {org:empire, class:tiefighter}
matchLabels: org: empire class: deathstar	12345 {org:empire, class:deathstar}

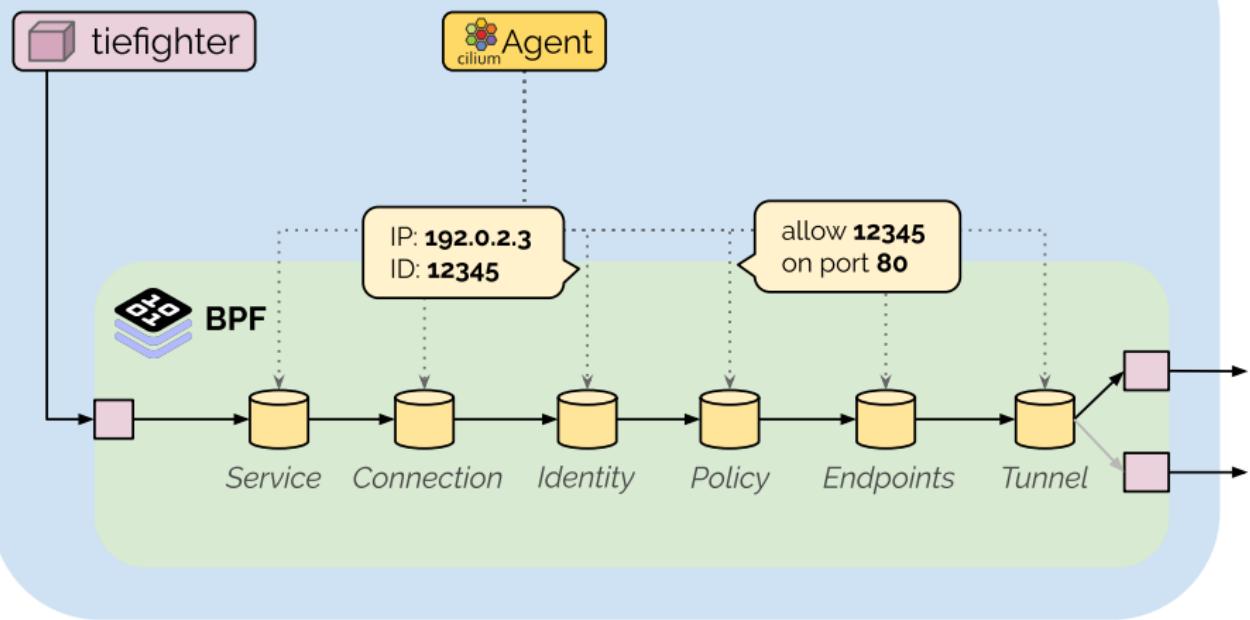
Datapath Configuration: Ingress



Datapath Configuration: Egress

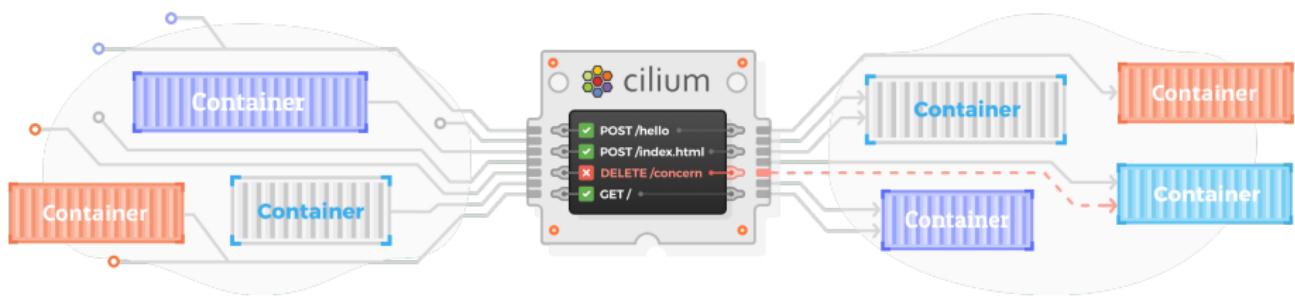


Datapath Configuration: Egress

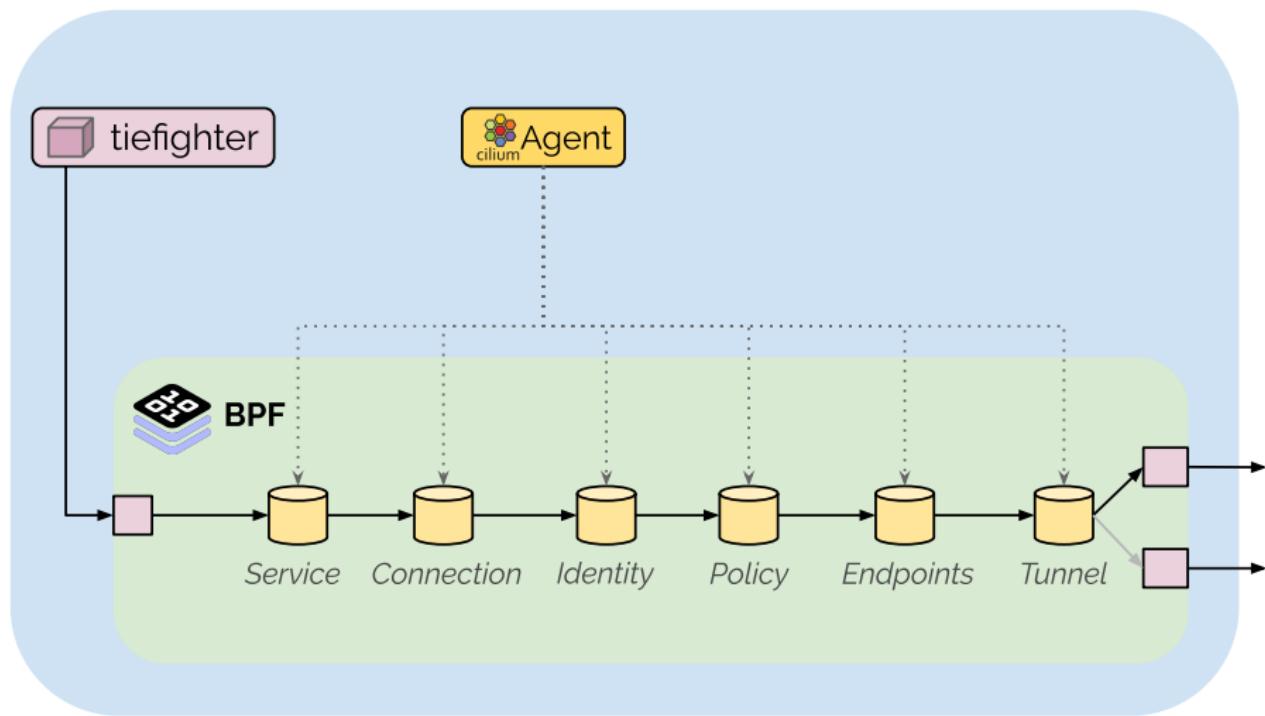


Layer 7 security

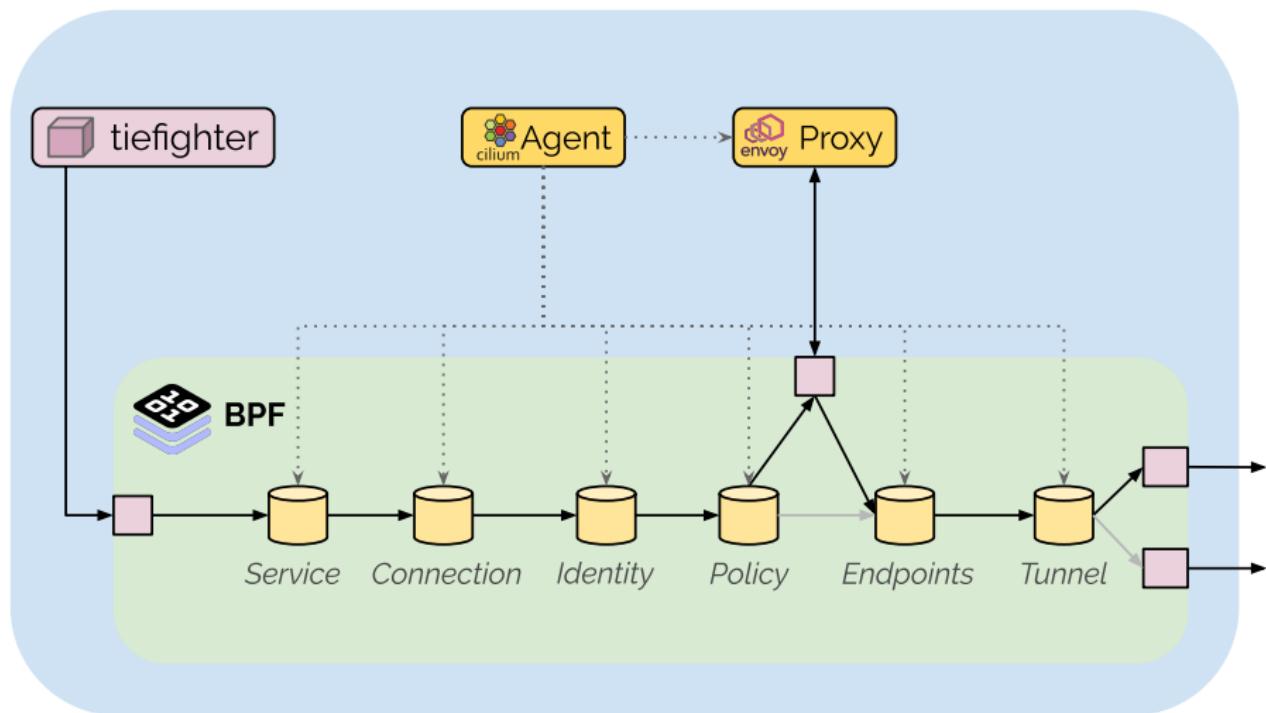
L7 is the new L4



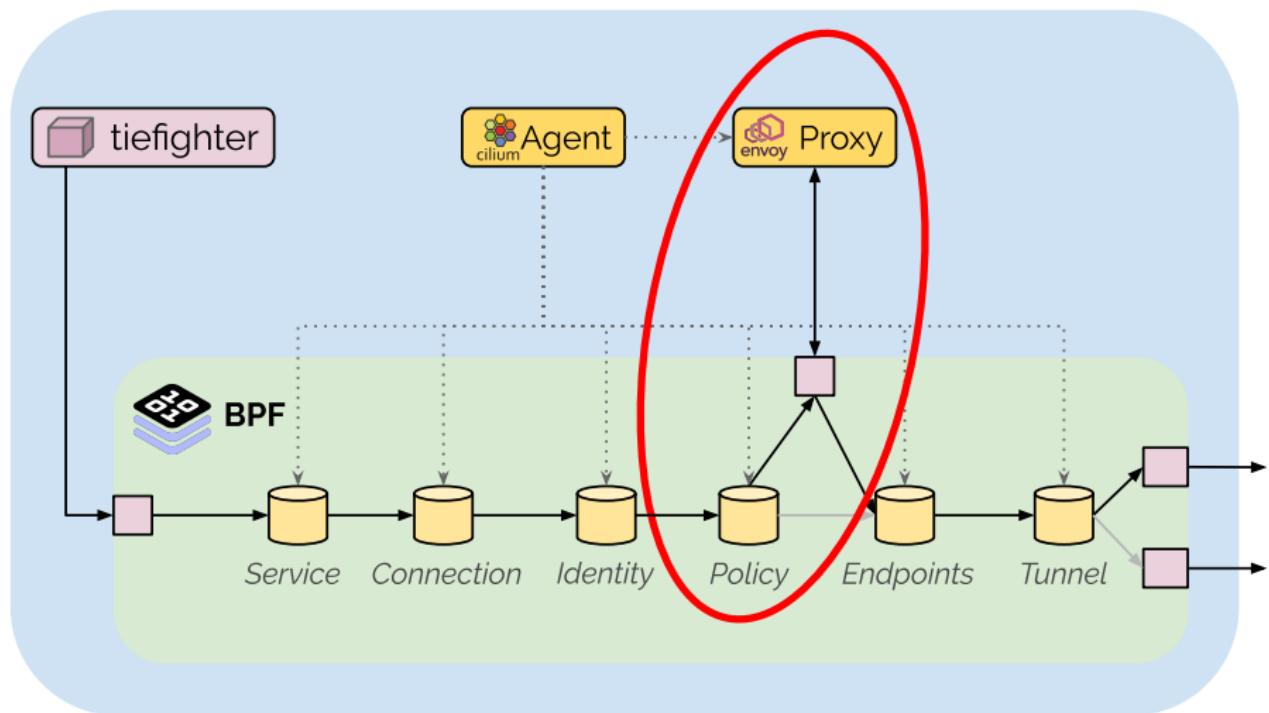
Datapath Configuration: L3 flow



Datapath Configuration: L7 flow

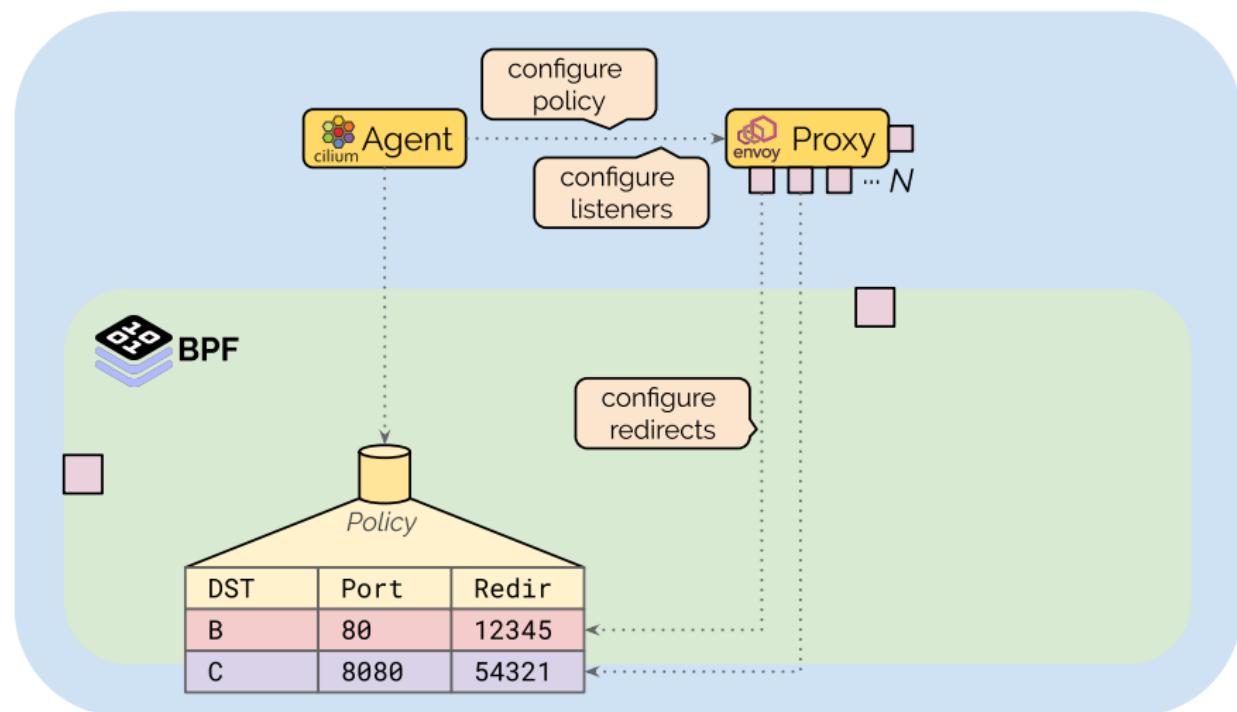


Datapath Configuration: L7 flow



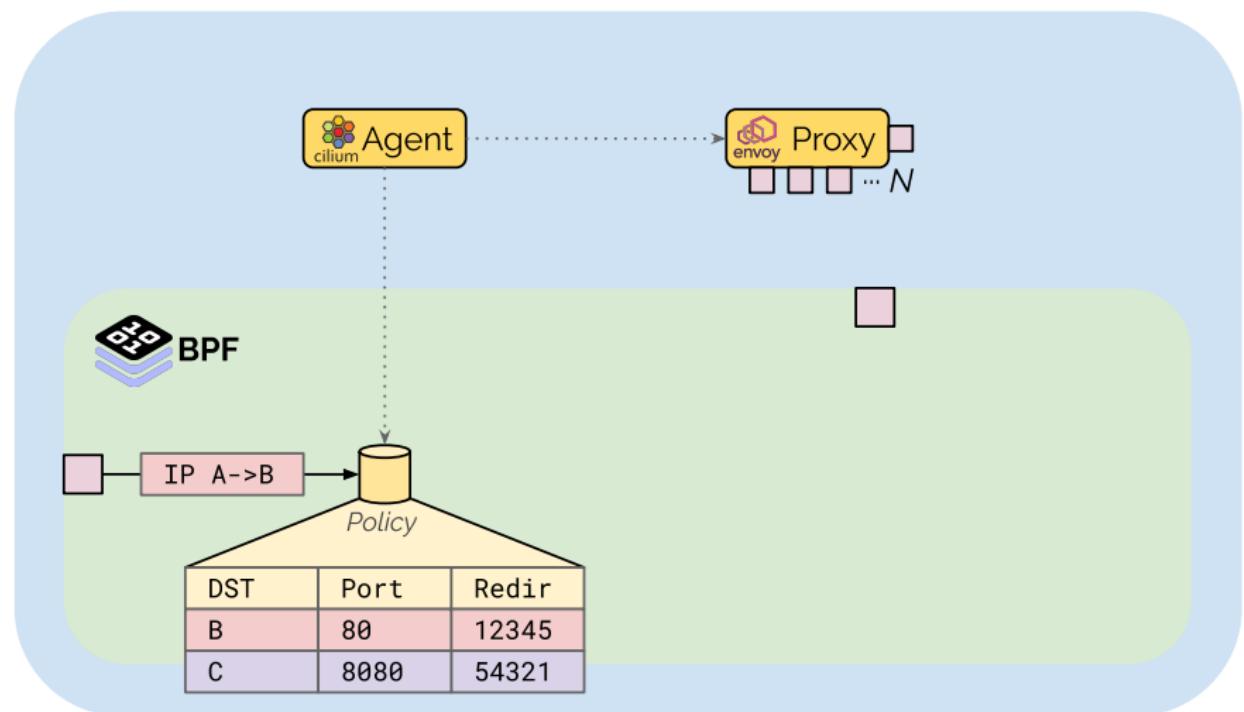
L7 Configuration: Past

Per-endpoint configuration



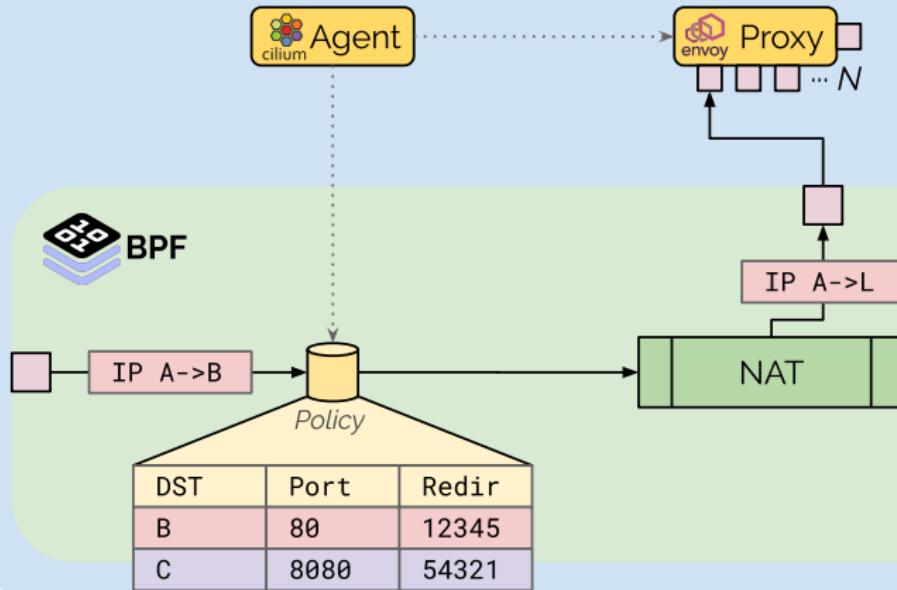
A: 192.0.2.3:33333 ; B: 192.0.2.4:80 ; L: 192.0.2.1:12345

L7 Configuration: Past



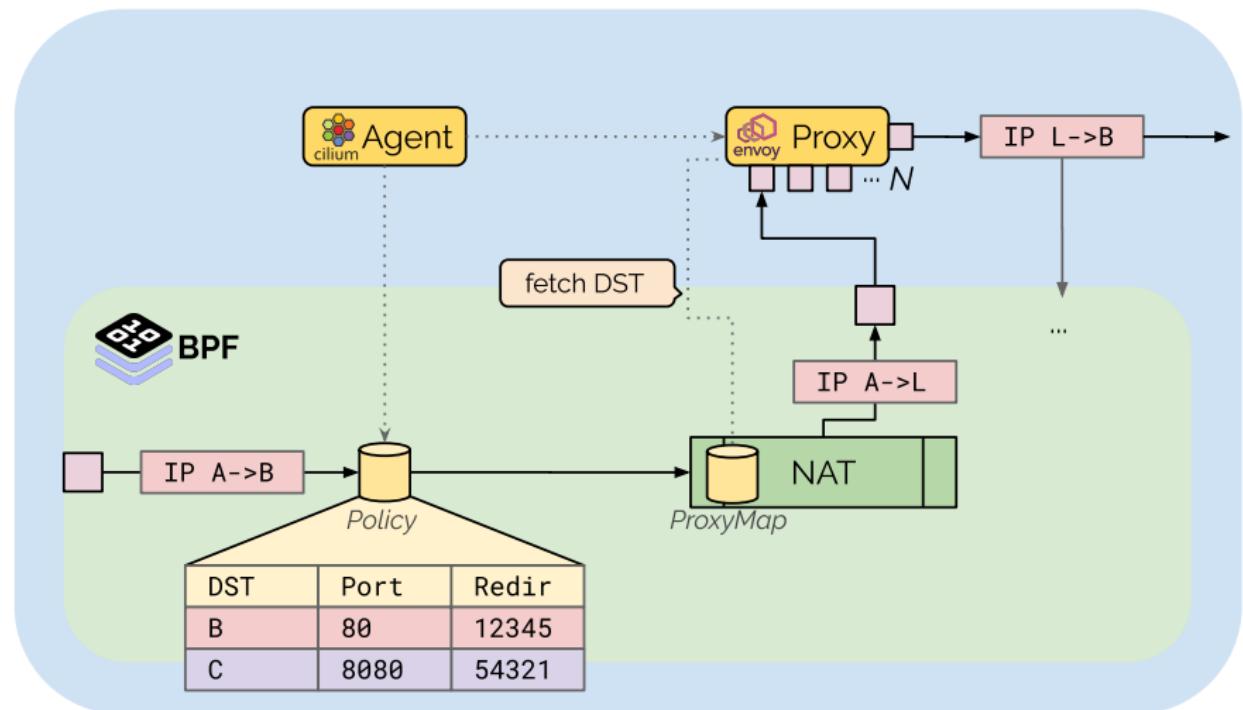
A: 192.0.2.3:33333 ; B: 192.0.2.4:80 ; L: 192.0.2.1:12345

L7 Configuration: Past



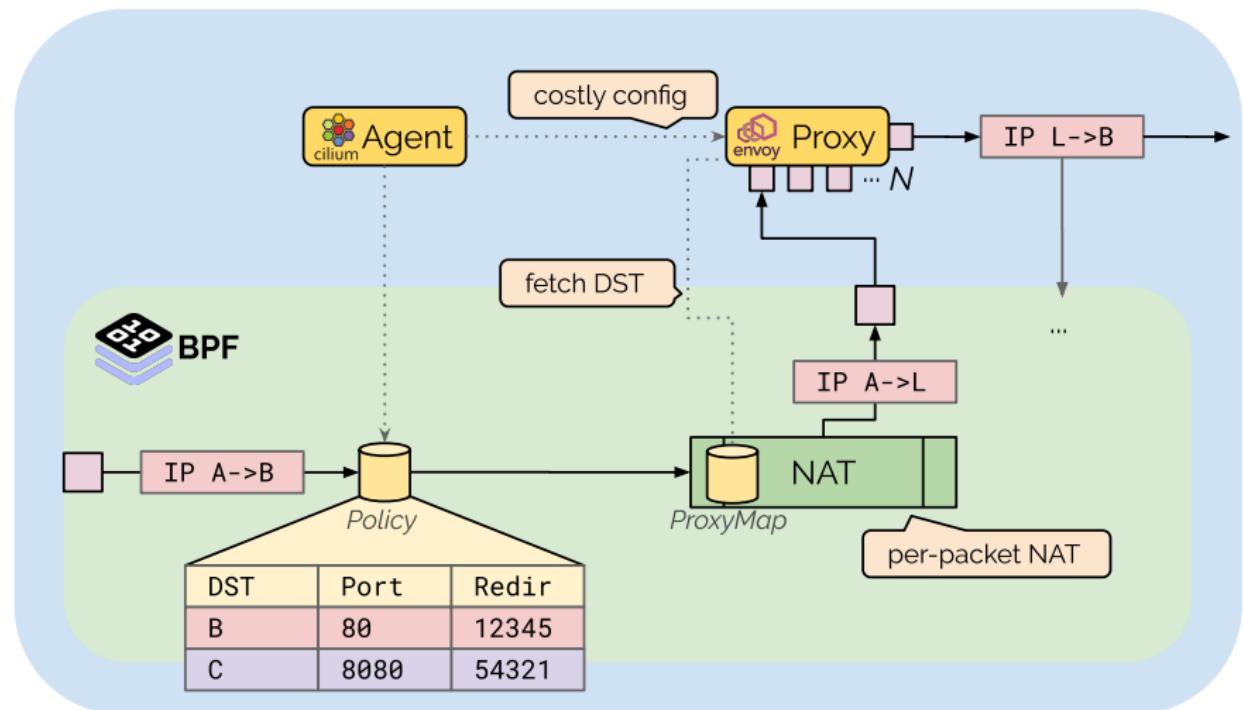
A: 192.0.2.3:33333 ; B: 192.0.2.4:80 ; L: 192.0.2.1:12345

L7 Configuration: Past



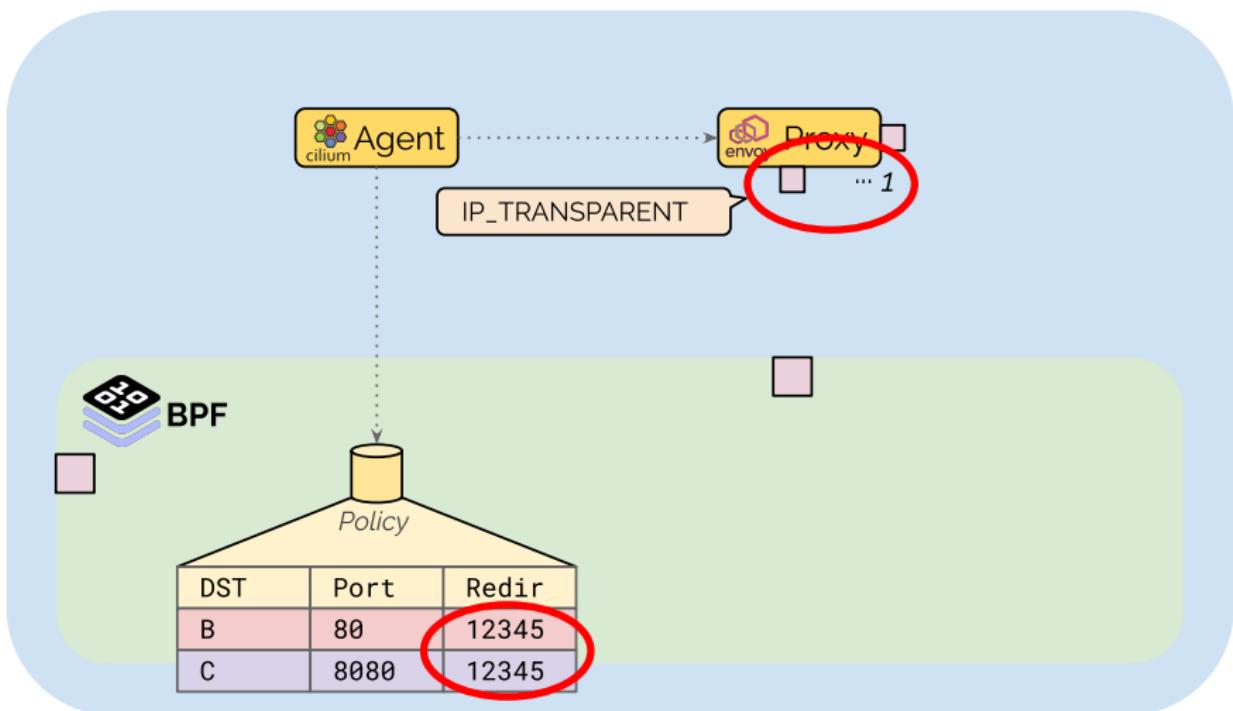
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L7 Configuration: Past

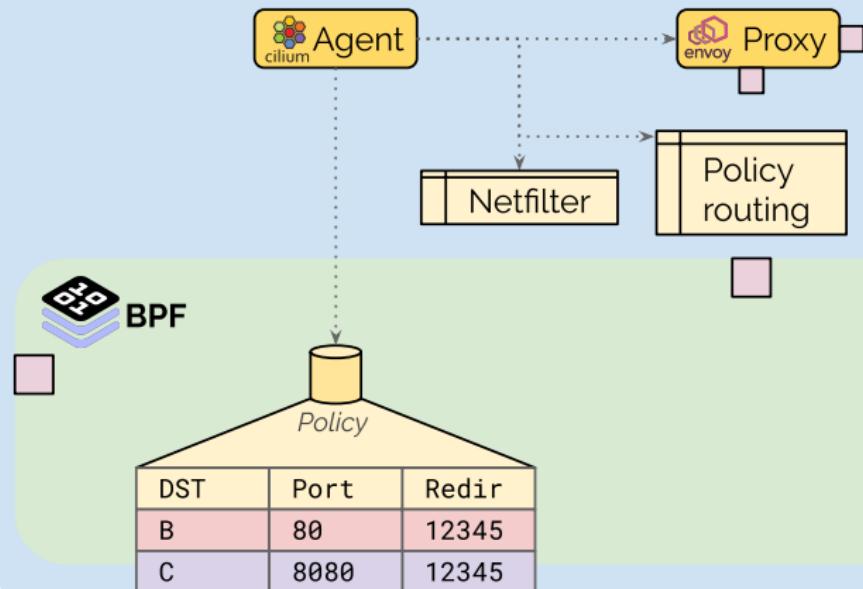


A: 192.0.2.3:33333 ; B: 192.0.2.4:80 ; L: 192.0.2.1:12345

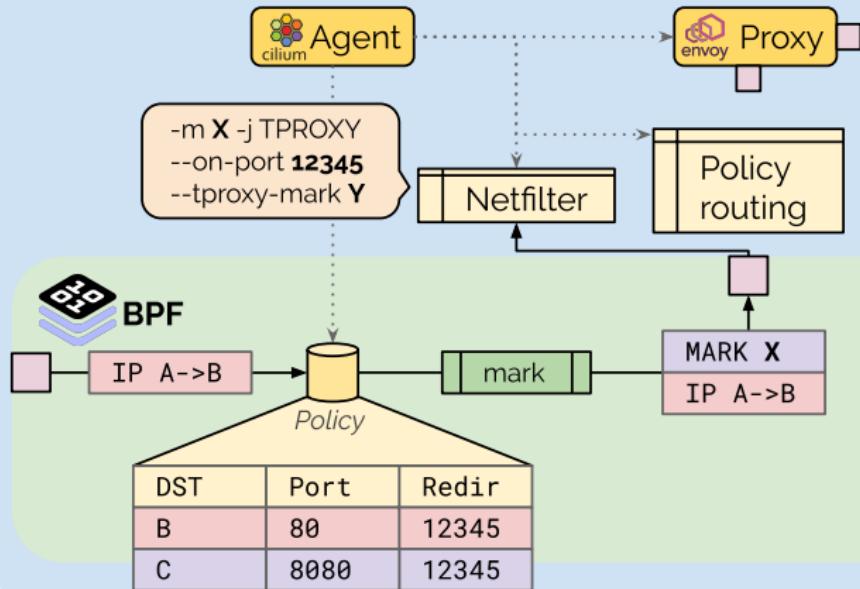
L7 Configuration: Present



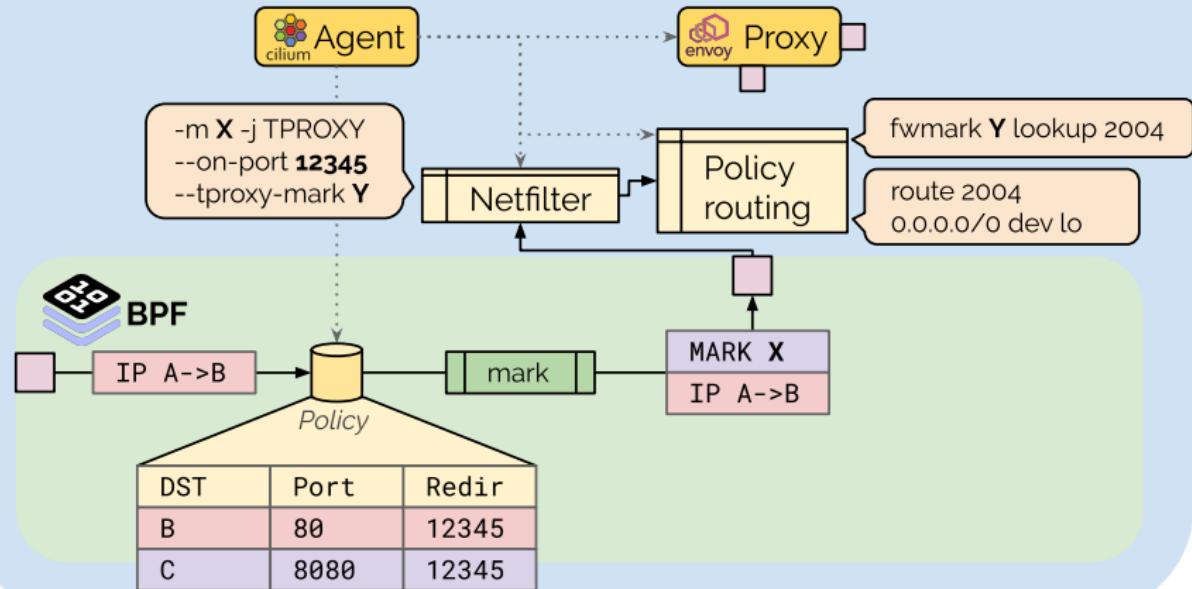
L7 Configuration: Present



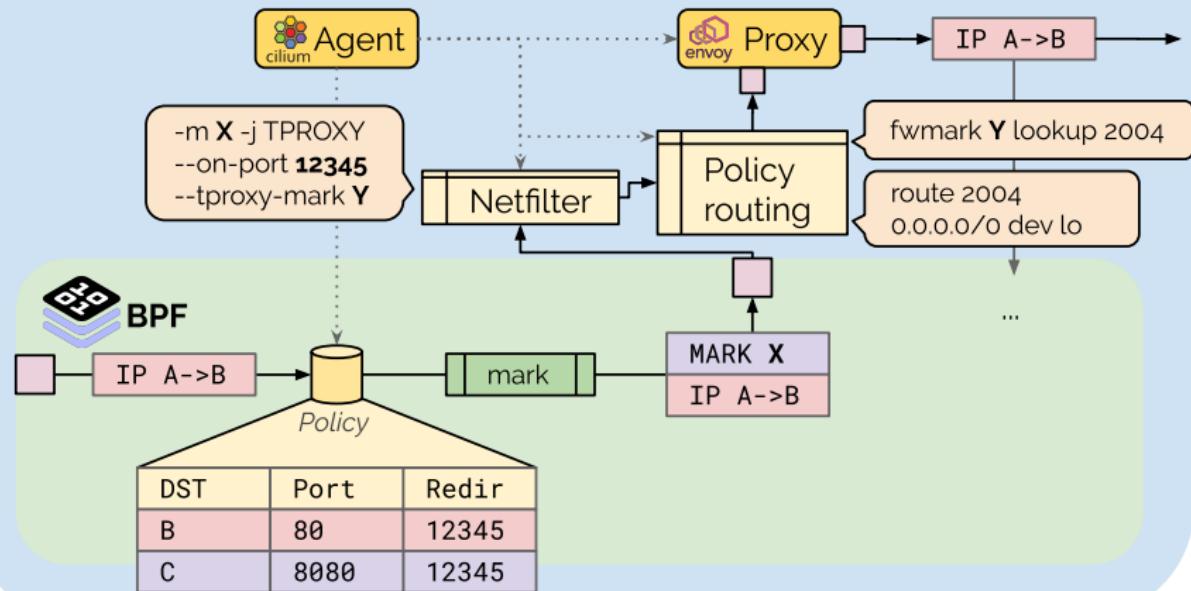
L7 Configuration: Present



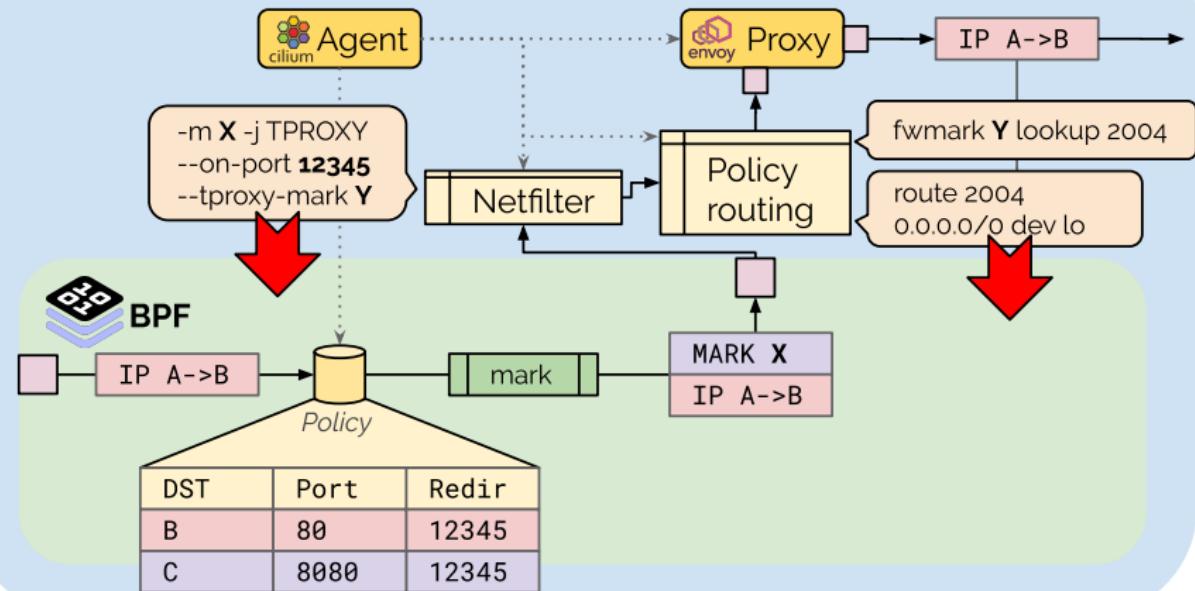
L7 Configuration: Present



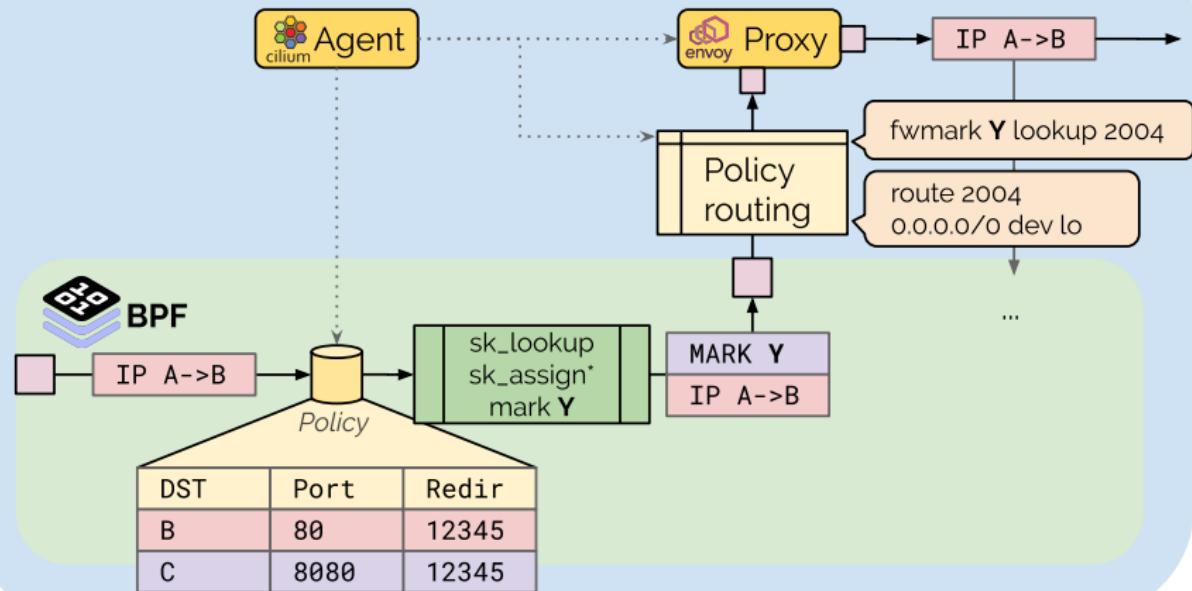
L7 Configuration: Present



L7 Configuration: Proposal



L7 Configuration: Proposal



Socket assign: RFC

```
/* int bpf_sk_assign(struct sk_buff *skb, struct bpf_sock *sk,
 *                     u64 flags)
 *   Description
 *     Assign the *sk* to the *skb*.
 *
 *   This operation is only valid from TC ingress path.
 *
 *   The *flags* argument must be zero.
 *
 * Return
 *   0 on success, or a negative errno in case of failure.
 *
 *   * **-EINVAL**: Unsupported flags specified.
 *   * **-EOPNOTSUPP**: Unsupported operation, for example
 *     a call from outside of TC ingress.
 *   * **-ENOENT**: The socket cannot be assigned.
 */
```

Socket assign: Hiccup

- BPF progs are attached at TC ingress
- `skb_orphan()` invoked directly before PREROUTING

¹ <https://www.mail-archive.com/netdev@vger.kernel.org/msg303851.html>

² <https://www.mail-archive.com/netdev@vger.kernel.org/msg304057.html>

Socket assign: Hiccup

- BPF progs are attached at TC ingress
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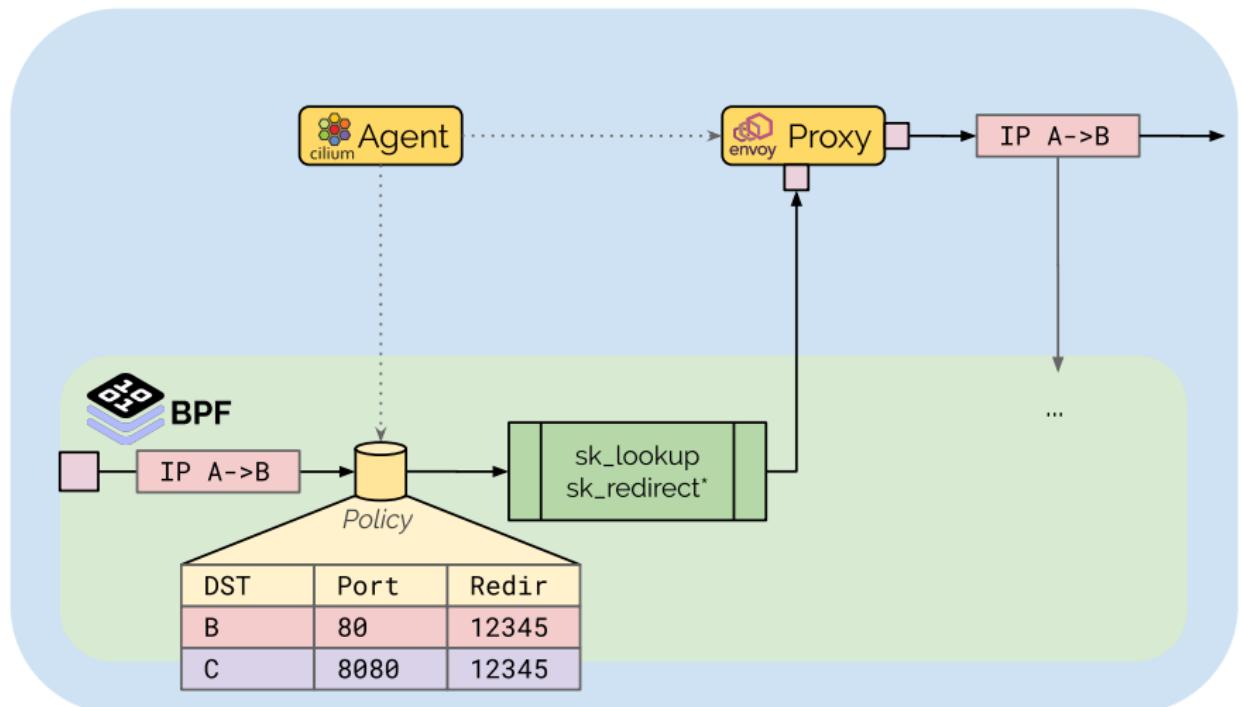
Socket assign: Hiccup

- BPF progs are attached at TC ingress
- `skb_orphan()` invoked directly before PREROUTING
- TC folks are already carrying hacks for this¹
- Just move to `__dev_forward_skb()`²?

¹ <https://www.mail-archive.com/netdev@vger.kernel.org/msg303851.html>

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L7 Configuration: Socket redirect



Early demux

```
int tcp_v4_early_demux(struct sk_buff *skb) {
    // ... snipped: validate packet type, tcphdr offsets

    struct sock *sk = __inet_lookup_established(dev_net(skb->dev),
                                                &tcp_hashinfo, iph->saddr, th->source,
                                                iph->daddr, ntohs(th->dest),
                                                skb->skb_iif, inet_sdif(skb));

    if (sk) {
        skb->sk = sk;
        skb->destructor = sock_edemux;
        if (sk_fullsock(sk)) {
            struct dst_entry *dst = READ_ONCE(sk->sk_rx_dst);

            if (dst)
                dst = dst_check(dst, 0);
            if (dst &&
                inet_sk(sk)->rx_dst_ifindex == skb->skb_iif)
                skb_dst_set_noref(skb, dst);
        }
    }
    return 0;
}
```

Summary

- Minimize processing cost
 - Number of events
 - Cost for each event
- Separate concerns: Policy vs addressing
- Frontload expensive operations
- ... while keeping runtime costs low

Thank you

More information

- [!\[\]\(f3eee9e16642d048ba929a1333876158_img.jpg\) https://cilium.io](https://cilium.io)
- [!\[\]\(2d8391a96f4a2402e5626b0c323b0e2d_img.jpg\) https://cilium.io/slack](https://cilium.io/slack)
- [!\[\]\(20c6dd23ef91e03388ad4a148cece2f9_img.jpg\) https://github.com/cilium/cilium](https://github.com/cilium/cilium)
- [!\[\]\(44bf1d2b3eff40f23cafdd1e6317af59_img.jpg\) https://twitter.com/ciliumproject](https://twitter.com/ciliumproject)



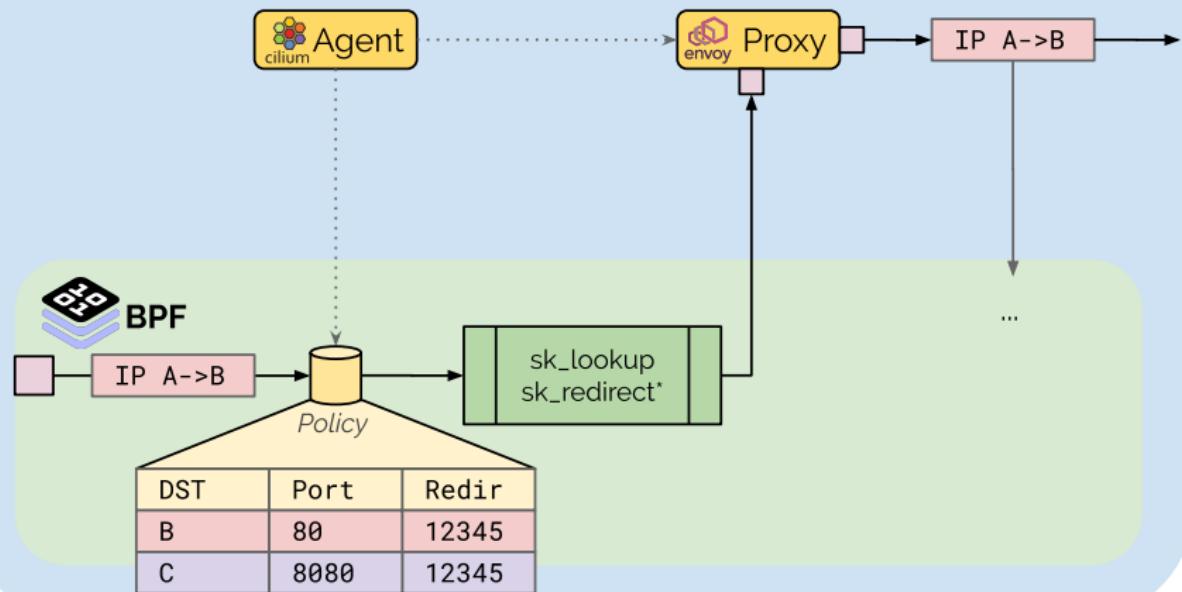
Thank you

More information

- [🌐 https://cilium.io](https://cilium.io)
- [📢 https://cilium.io/slack](https://cilium.io/slack)
- [🔗 https://github.com/cilium/cilium](https://github.com/cilium/cilium)
- [🐦 https://twitter.com/ciliumproject](https://twitter.com/ciliumproject)



Socket redirect



Socket assign: API quirks

- Nit: Need to use `sock_common` socket lookups
- Add `bpf_skc_lookup_udp()`
- Optimization: Add lookup flags to `bpf_sk*_lookup_*`()