Scaling container policy management with kernel features

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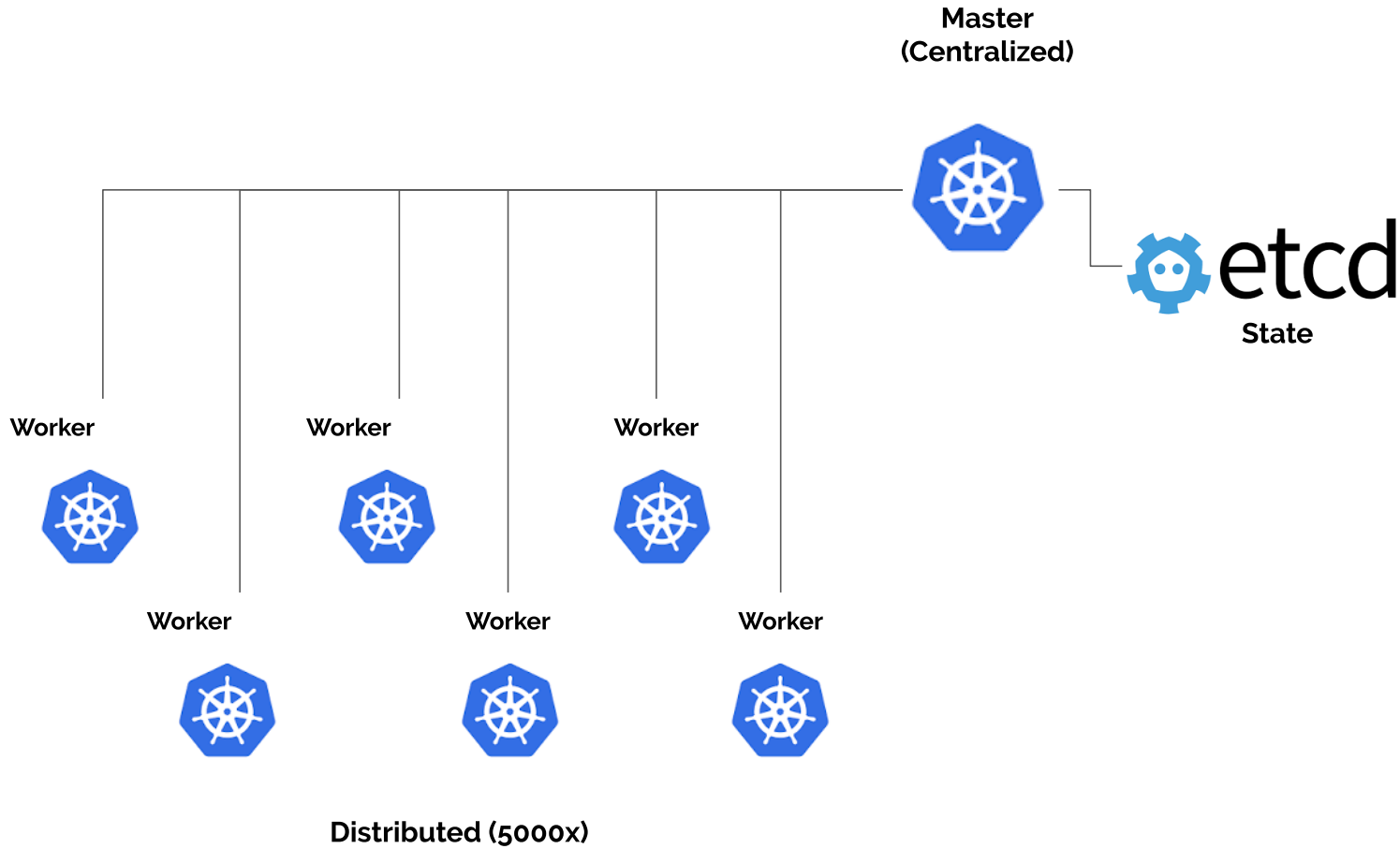
Cilium.io

Linux Plumbers 2019, Lisbon, Portugal

Overview

1. Background
2. Deploying fast datapaths fast
3. Identity-based security
4. Layer 7 security

Kubernetes Architecture 101



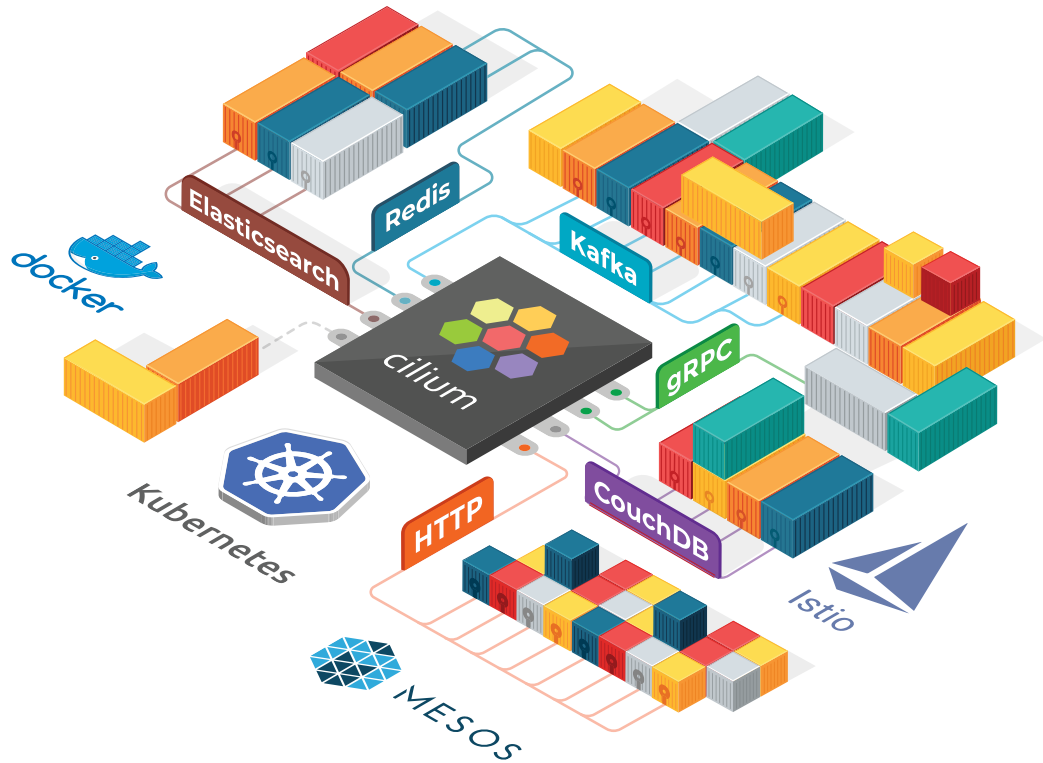
Kubernetes networking plugins

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

https://kubernetes.io/docs/concepts/extend-kubernetes/compute-storage-net/network-plugins/

Cilium

- Agent runs on each node
- 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

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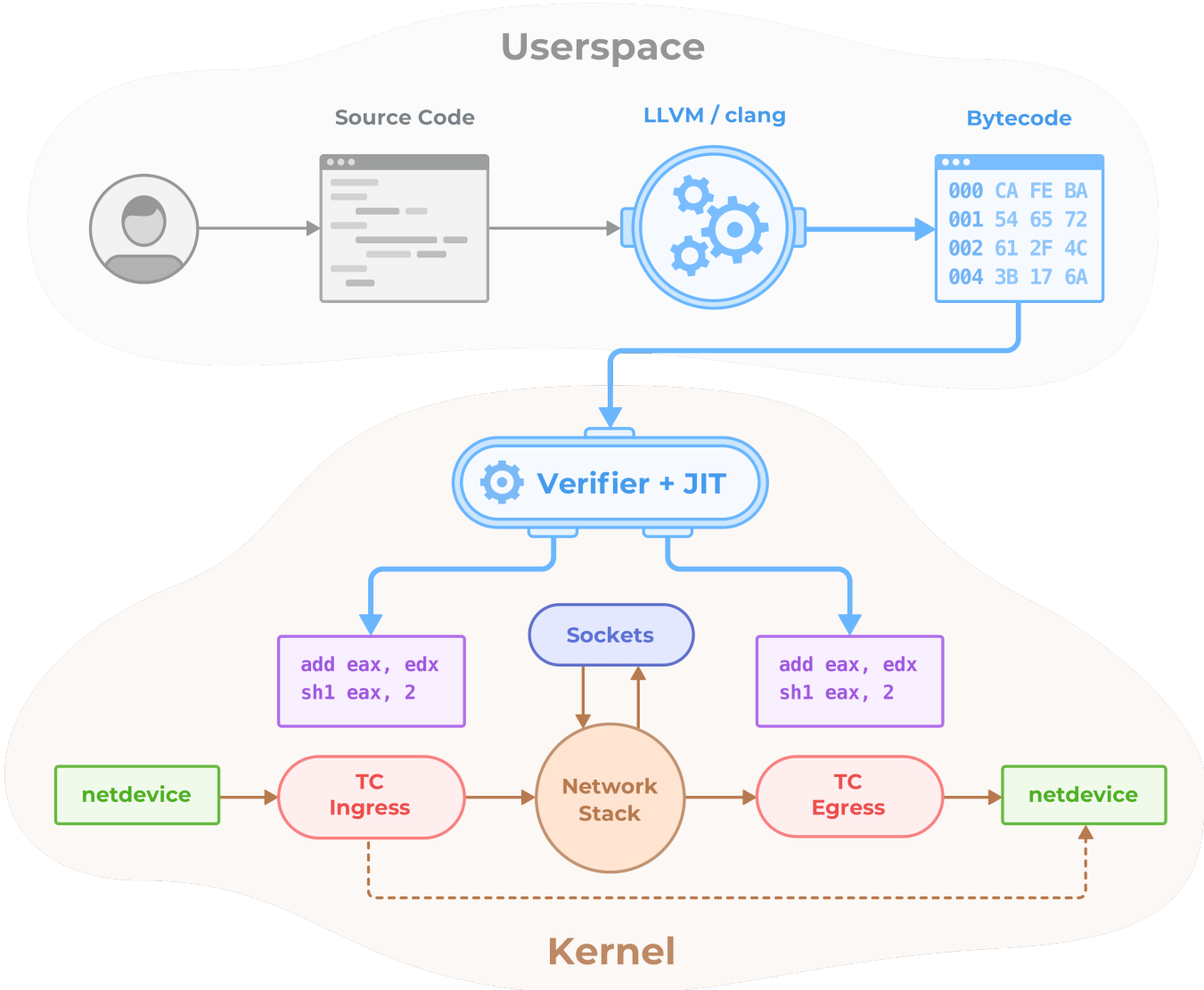
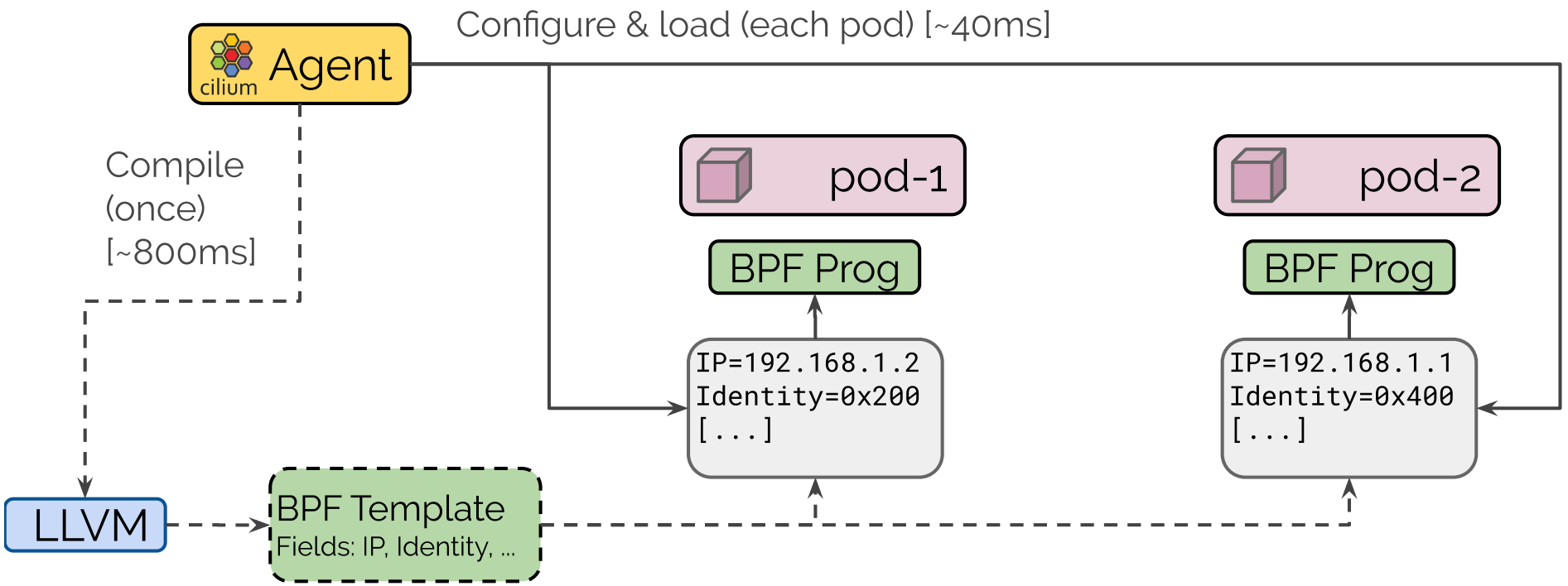
https://cilium.io/blog/2019/04/24/cilium-15

Deploying fast datapaths fast

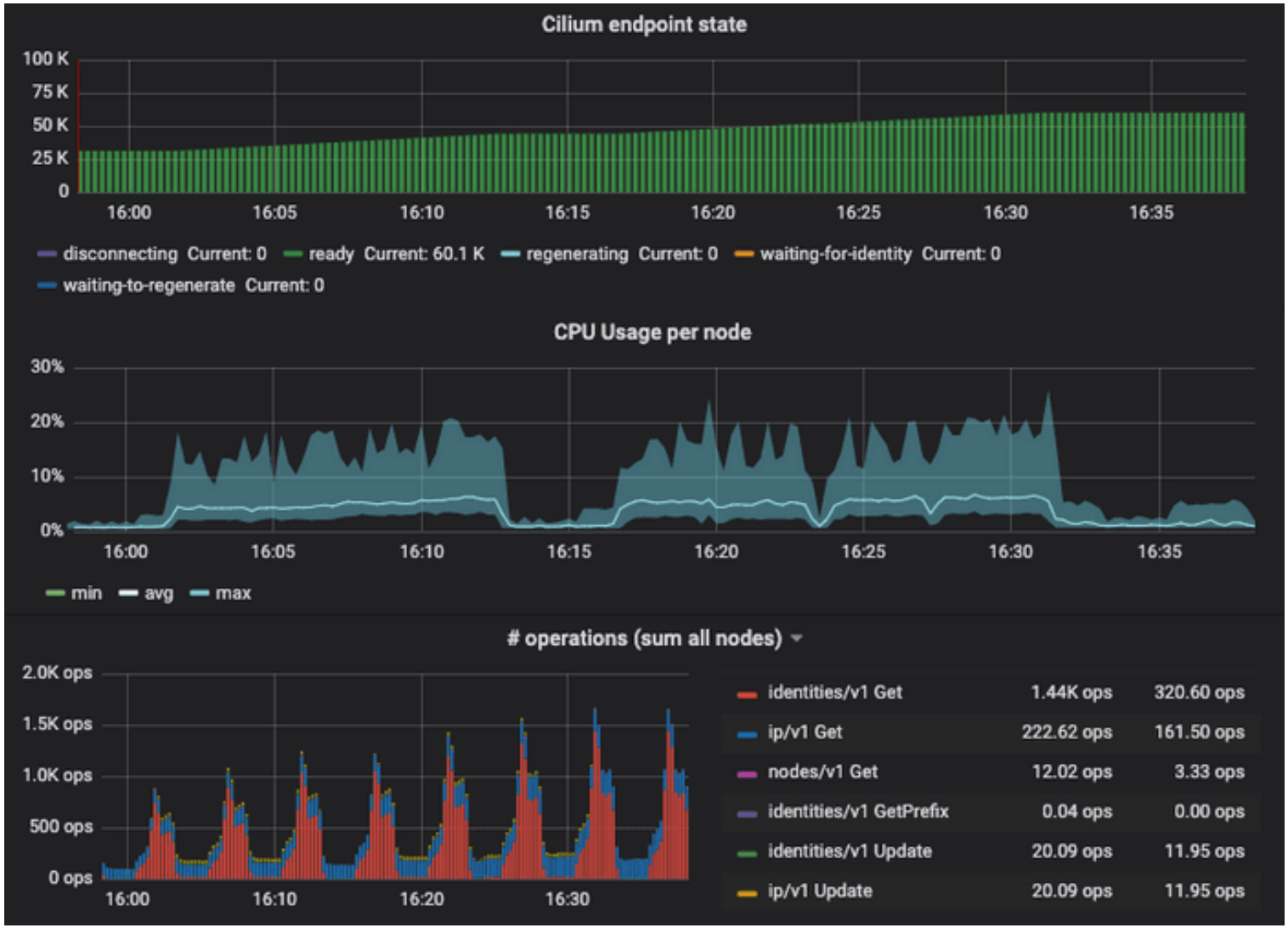
BPF plumbing



ELF Templating



1K nodes: Scaling to 60k pods

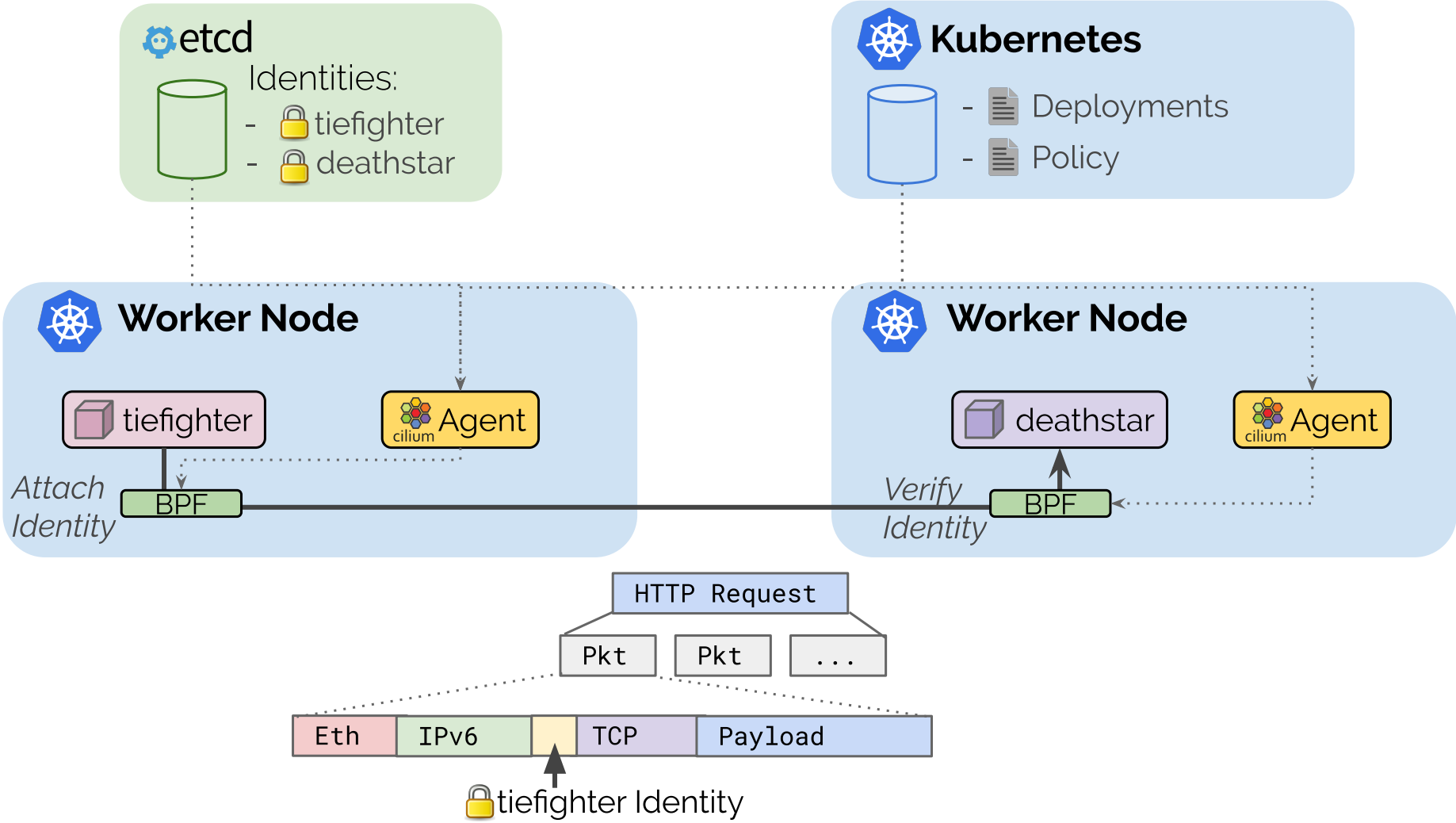


Future directions

- Optimize verifier execution: $O(n) \rightarrow O(1)$
- Support code path templatization

Identity-based security

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
```

---

https://docs.cilium.io/en/stable/gettingstarted/http/

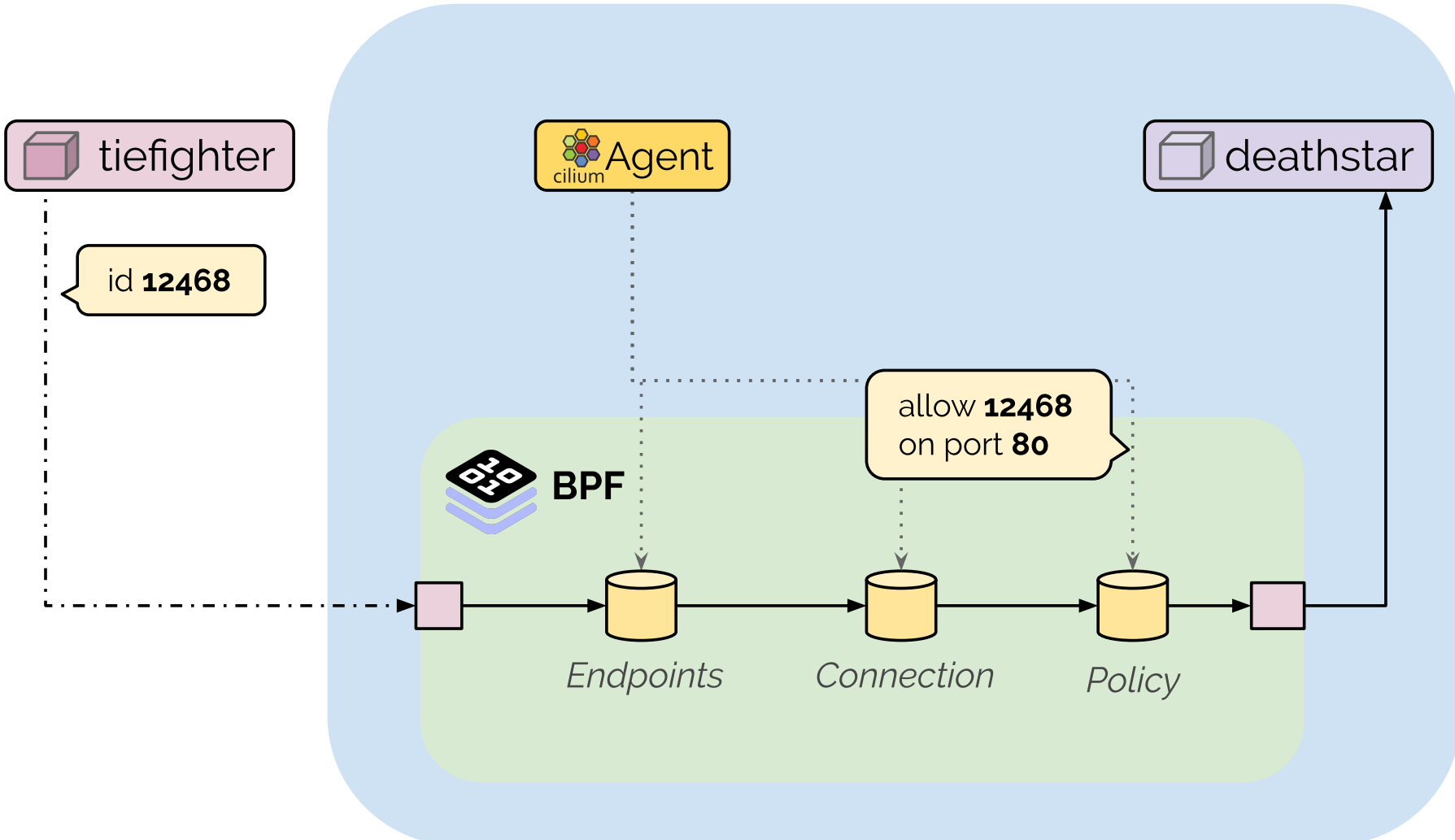
Label selectors

- 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}

https://cilium.io/blog/2019/08/20/cilium-16

Datapath Configuration: Ingress



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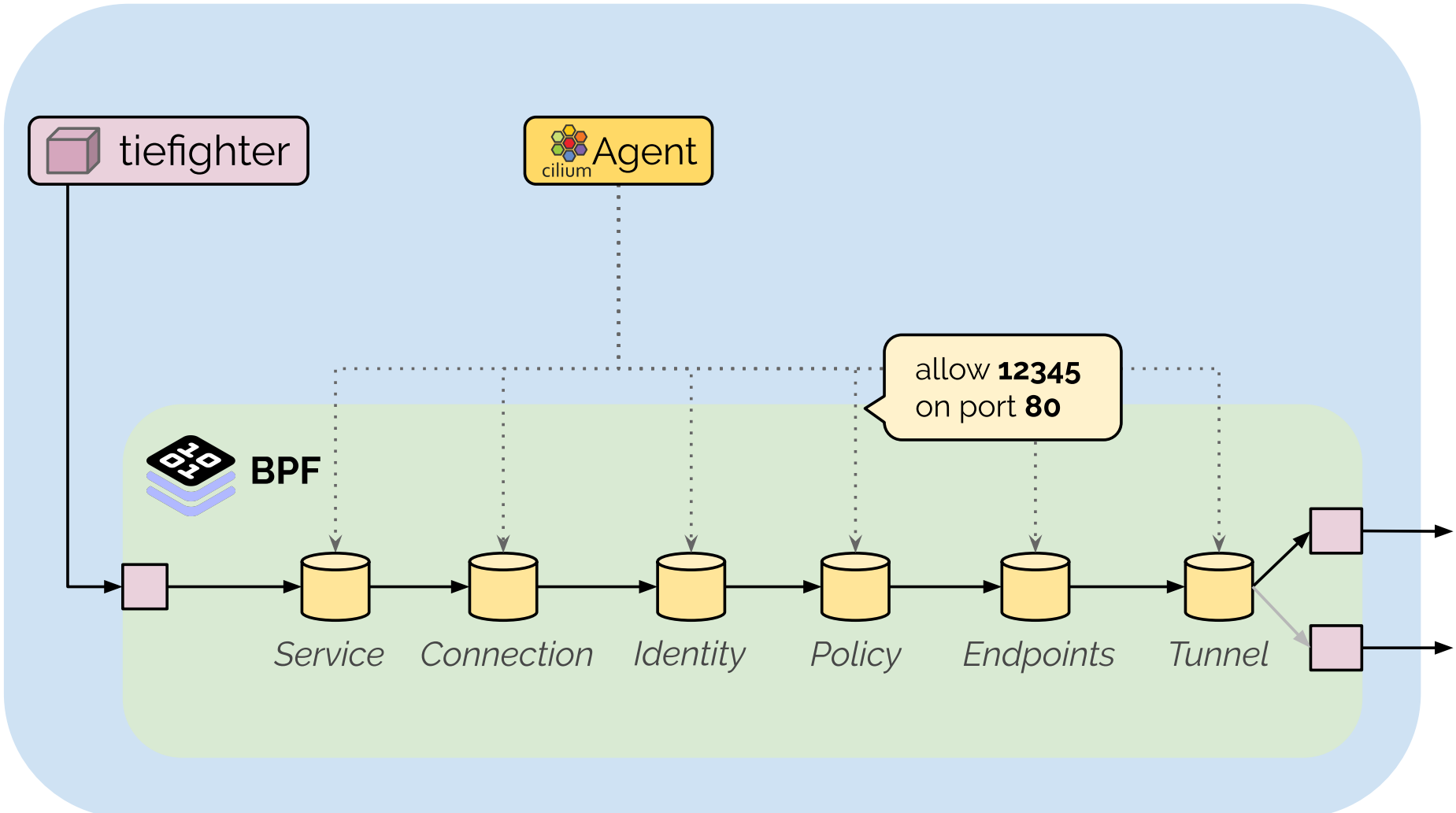

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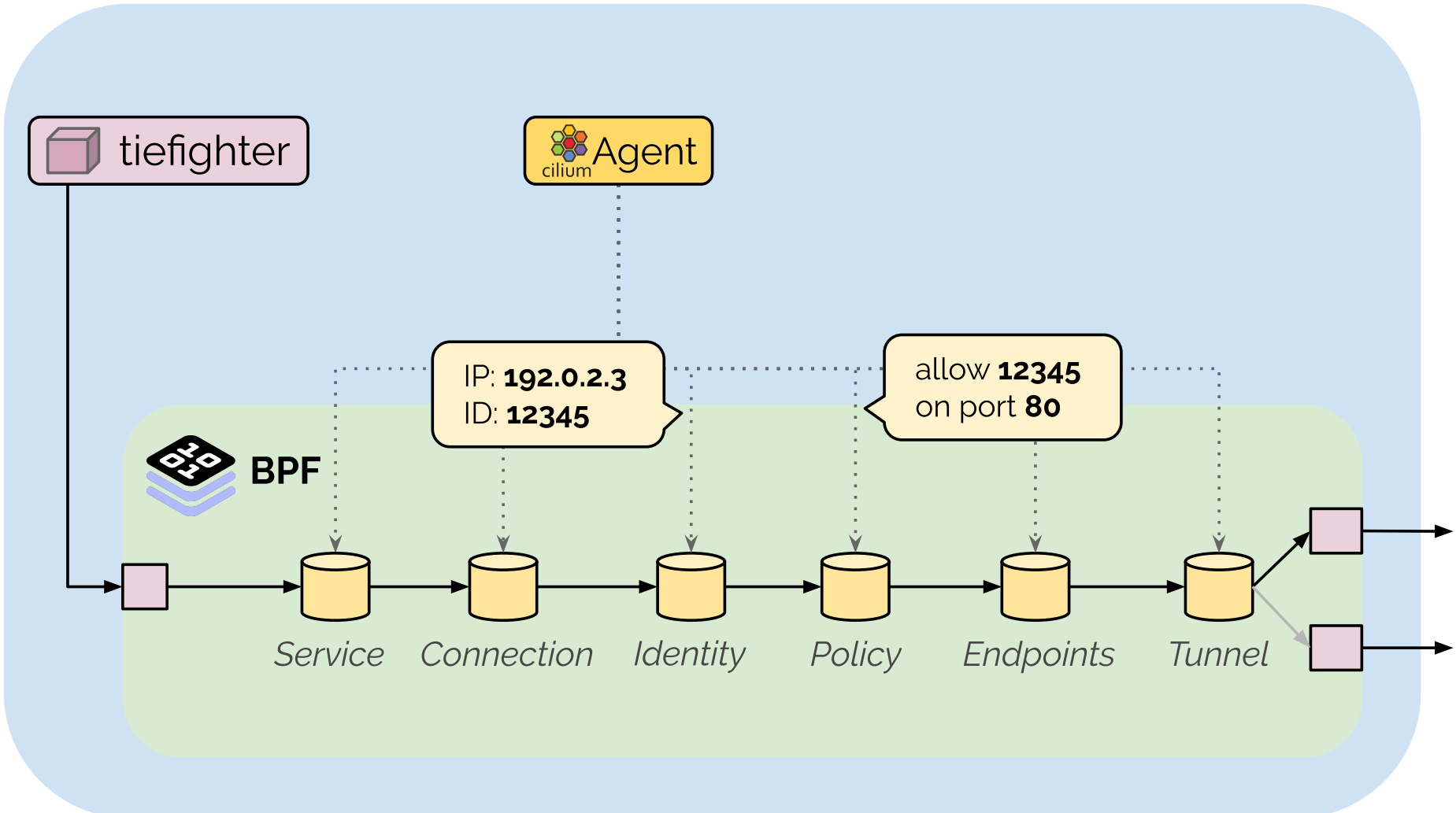
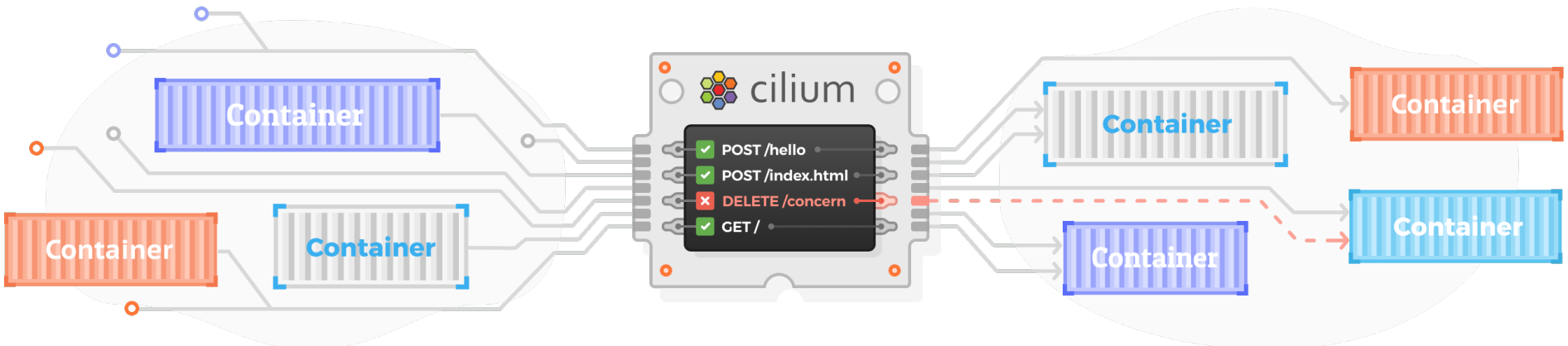
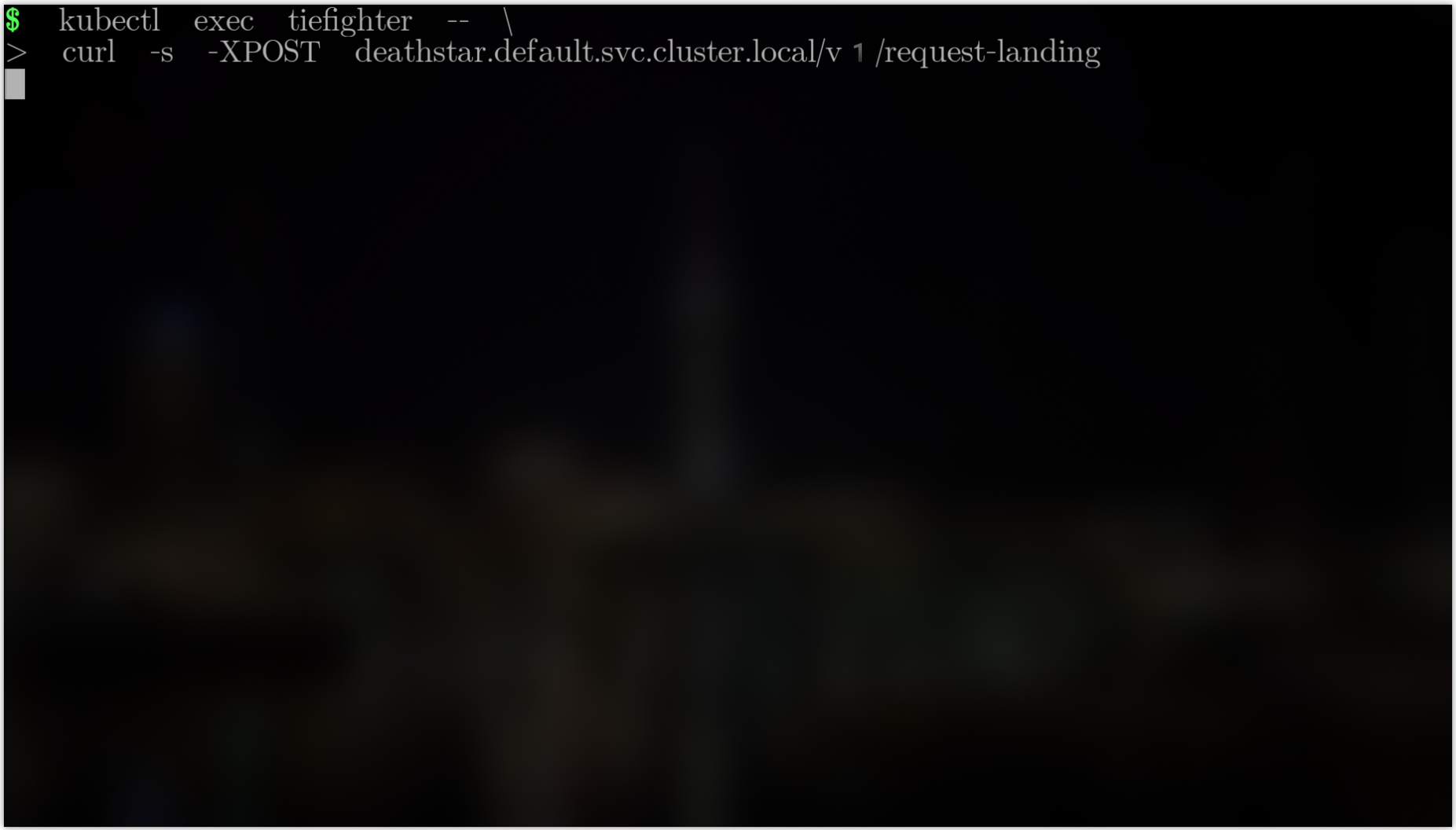


Layer 7 security

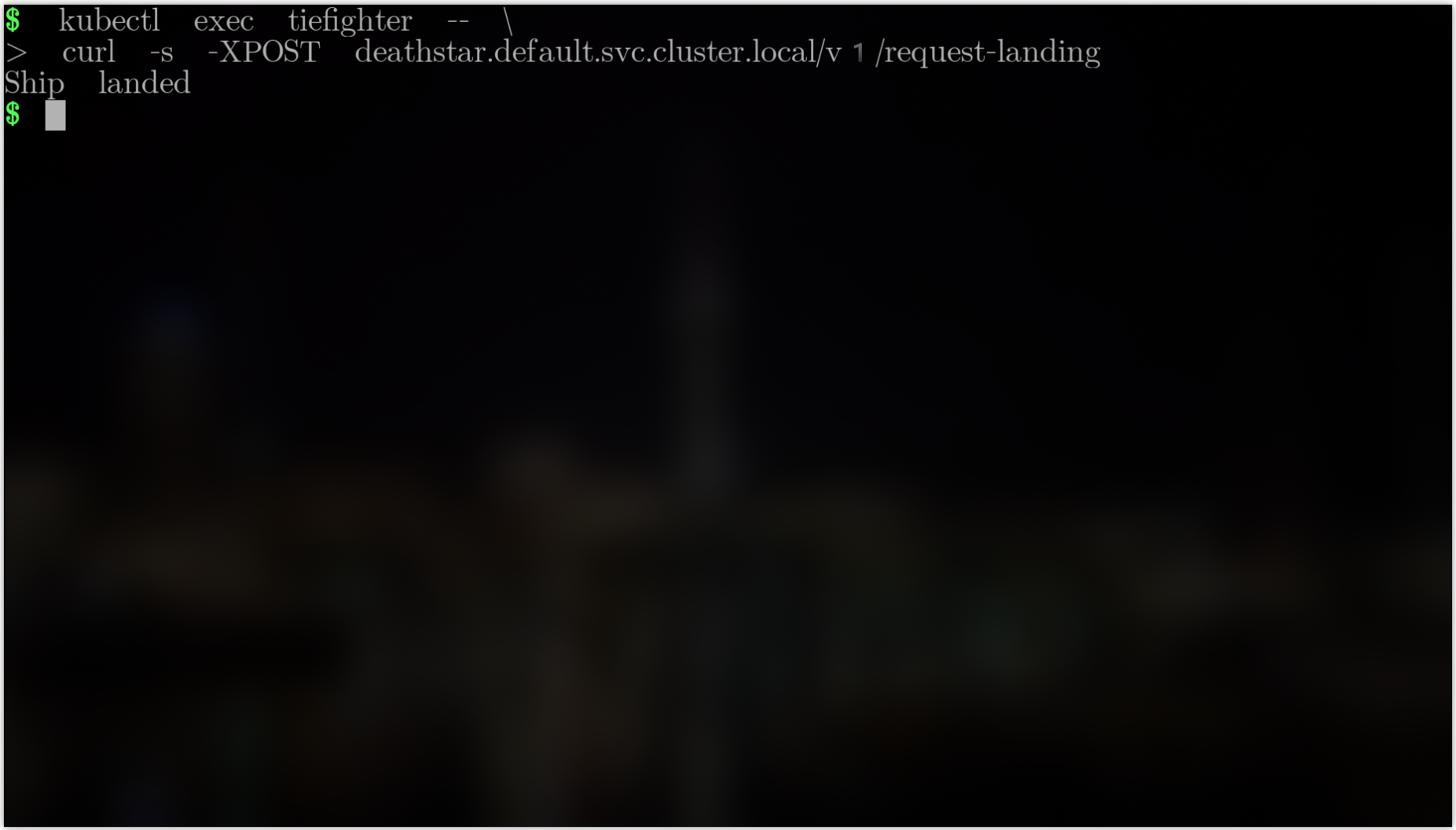
L7 is the new L4



Rejecting traffic in a protocol-aware manner



Rejecting traffic in a protocol-aware manner



Rejecting traffic in a protocol-aware manner

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cilium-agent –http-403-msg="..."

Rejecting traffic in a protocol-aware manner

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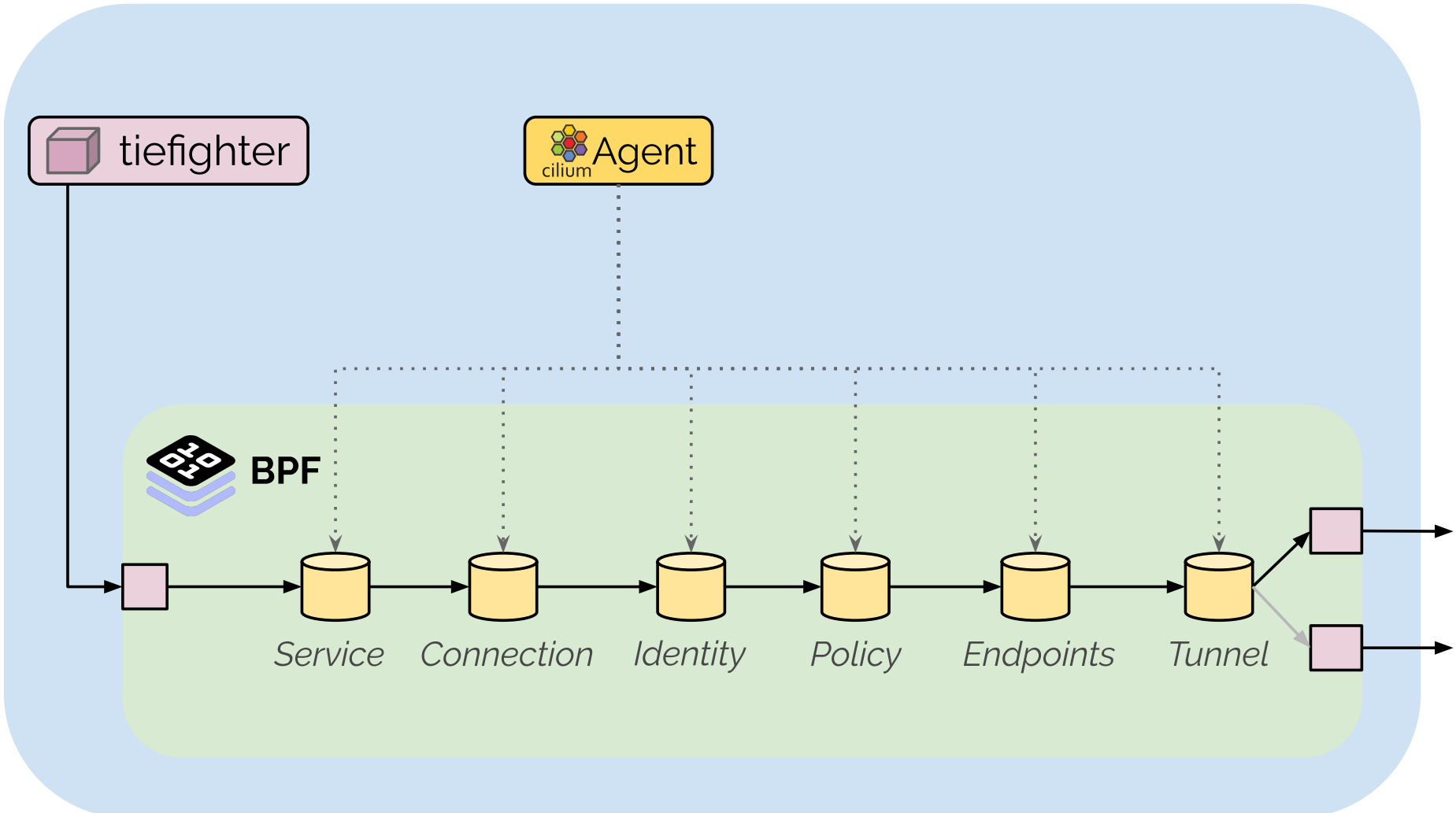
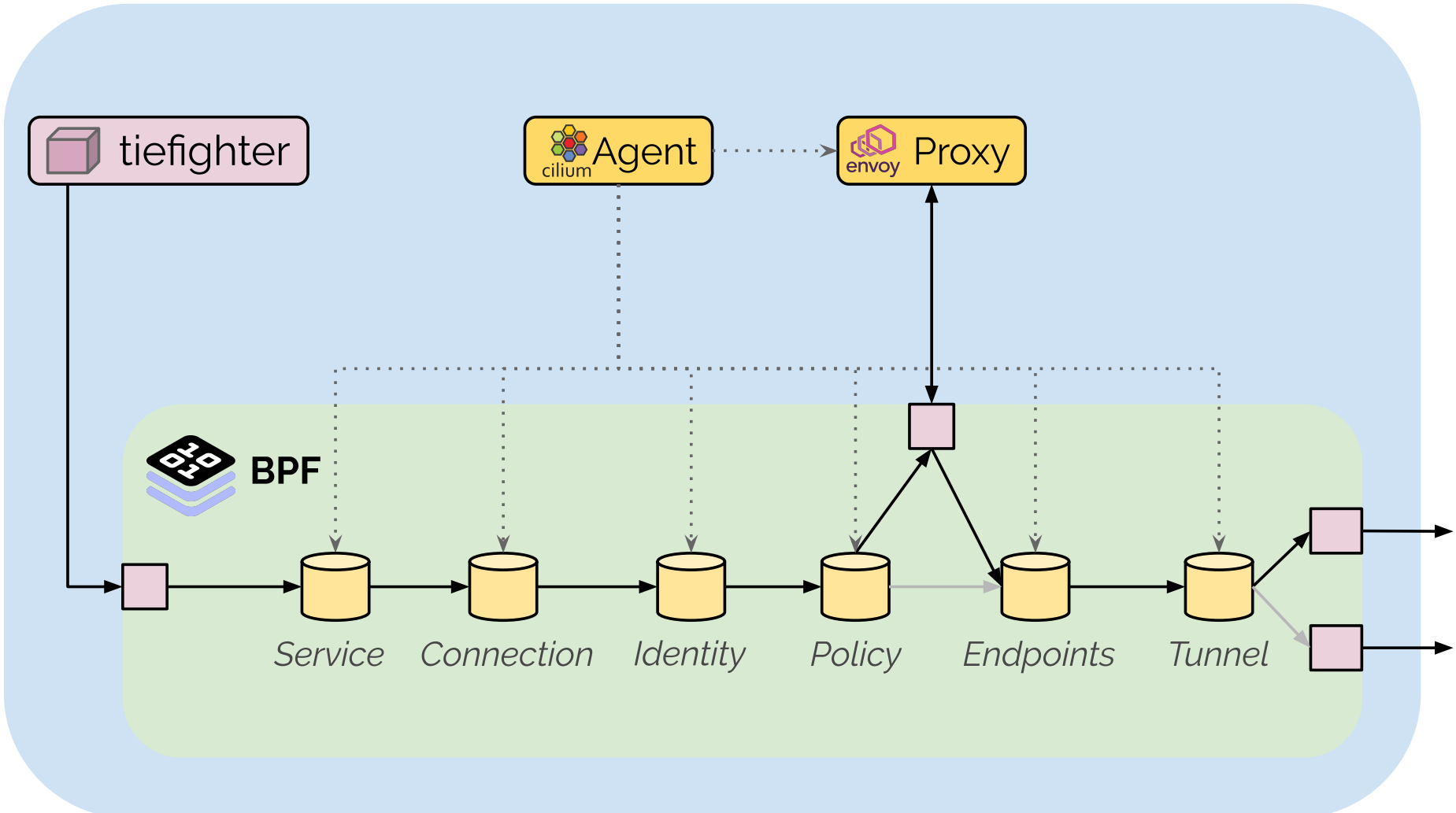
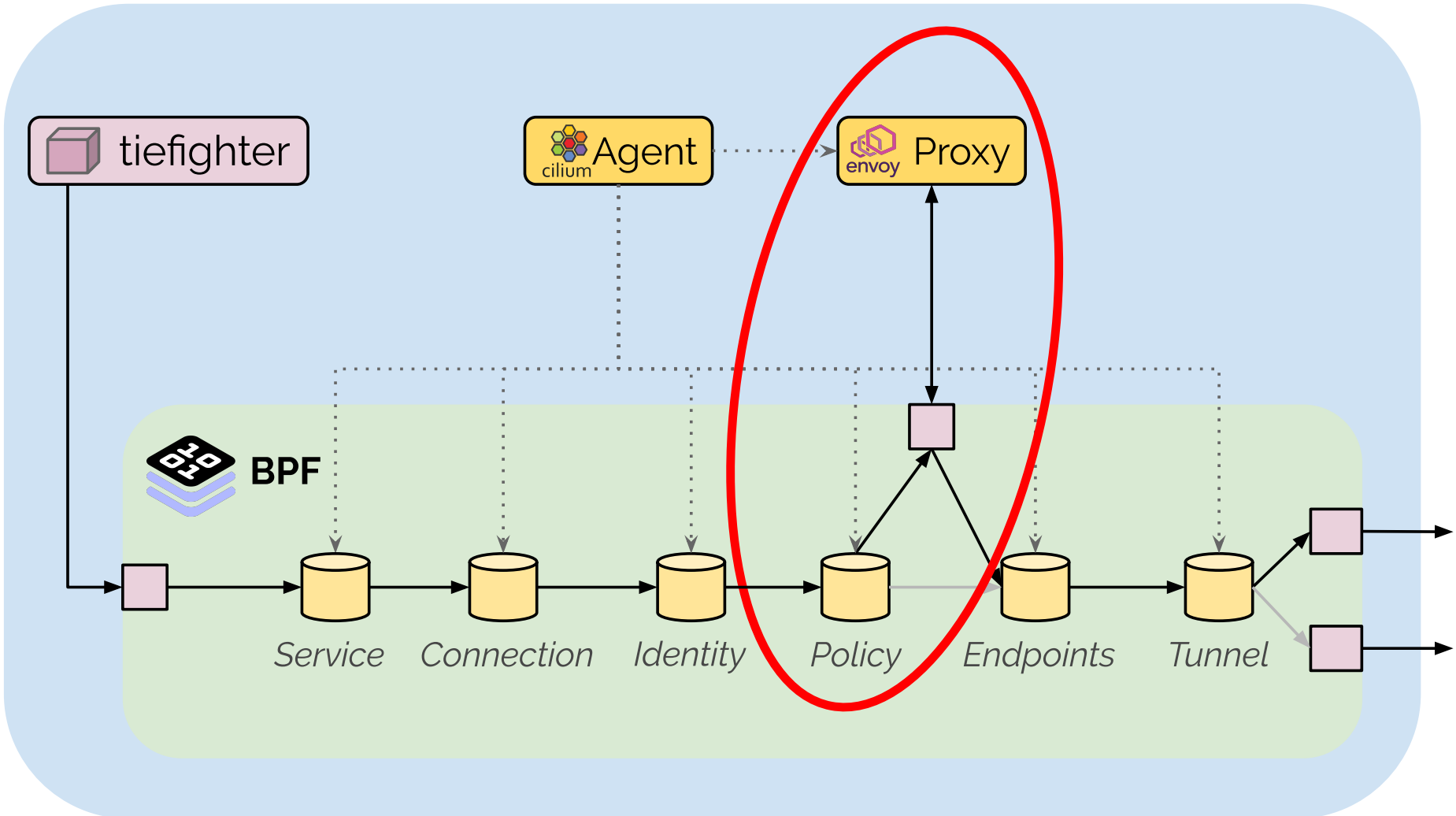
Datapath Configuration: L3 flow



Datapath Configuration: L7 flow

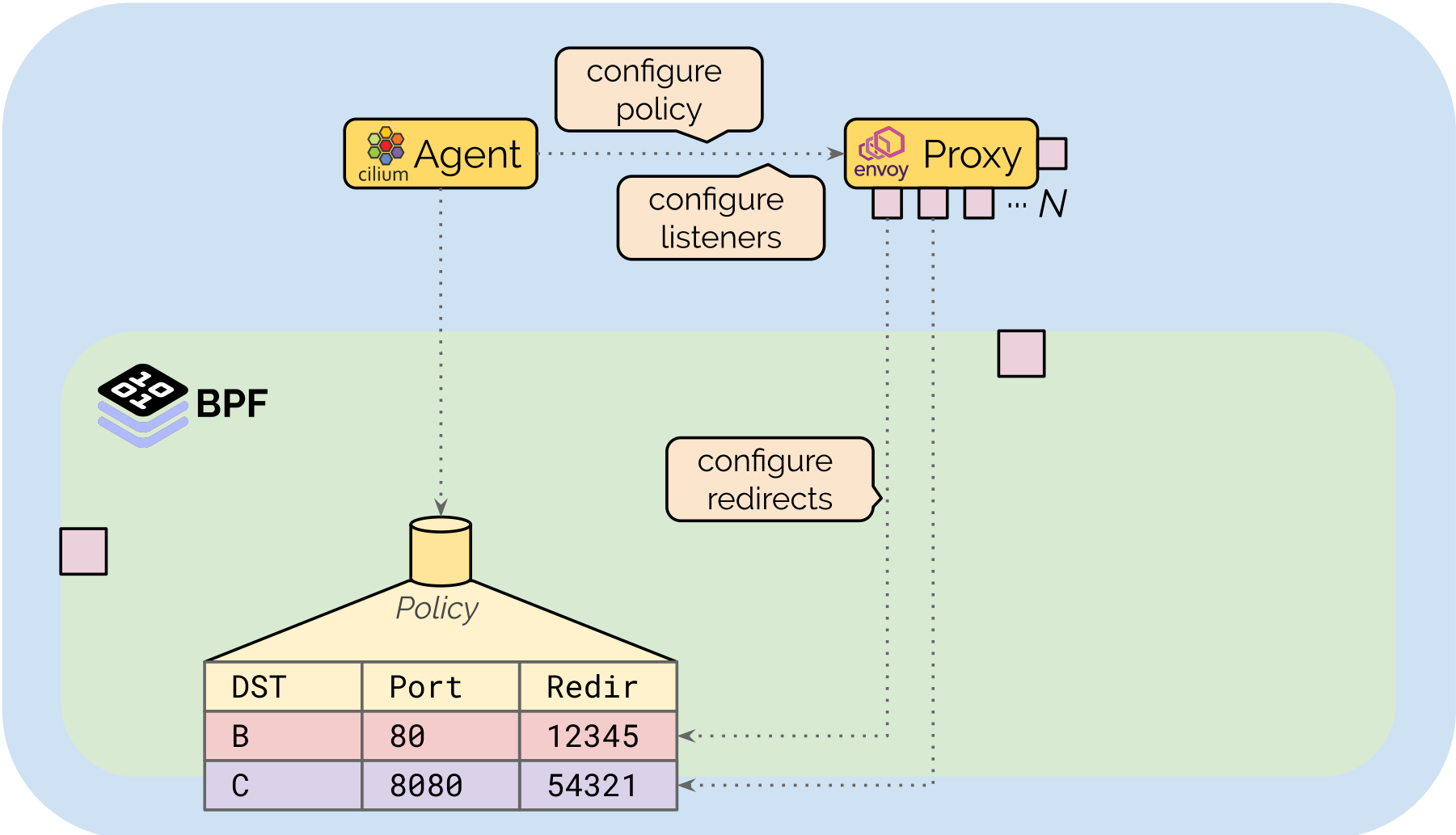


Datapath Configuration: L7 flow



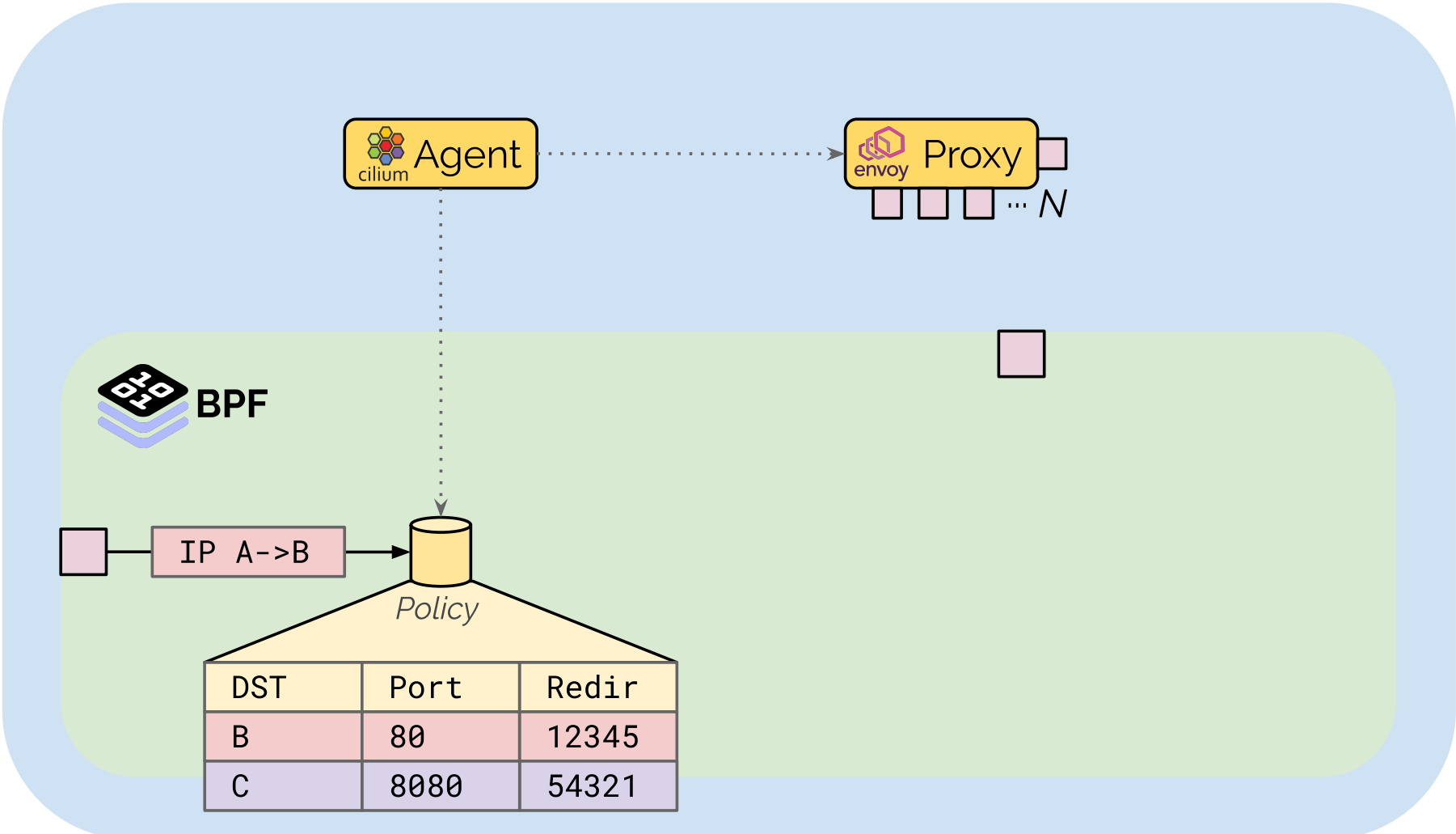
L7 Configuration: Past

Per-endpoint configuration



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

L7 Configuration: Past



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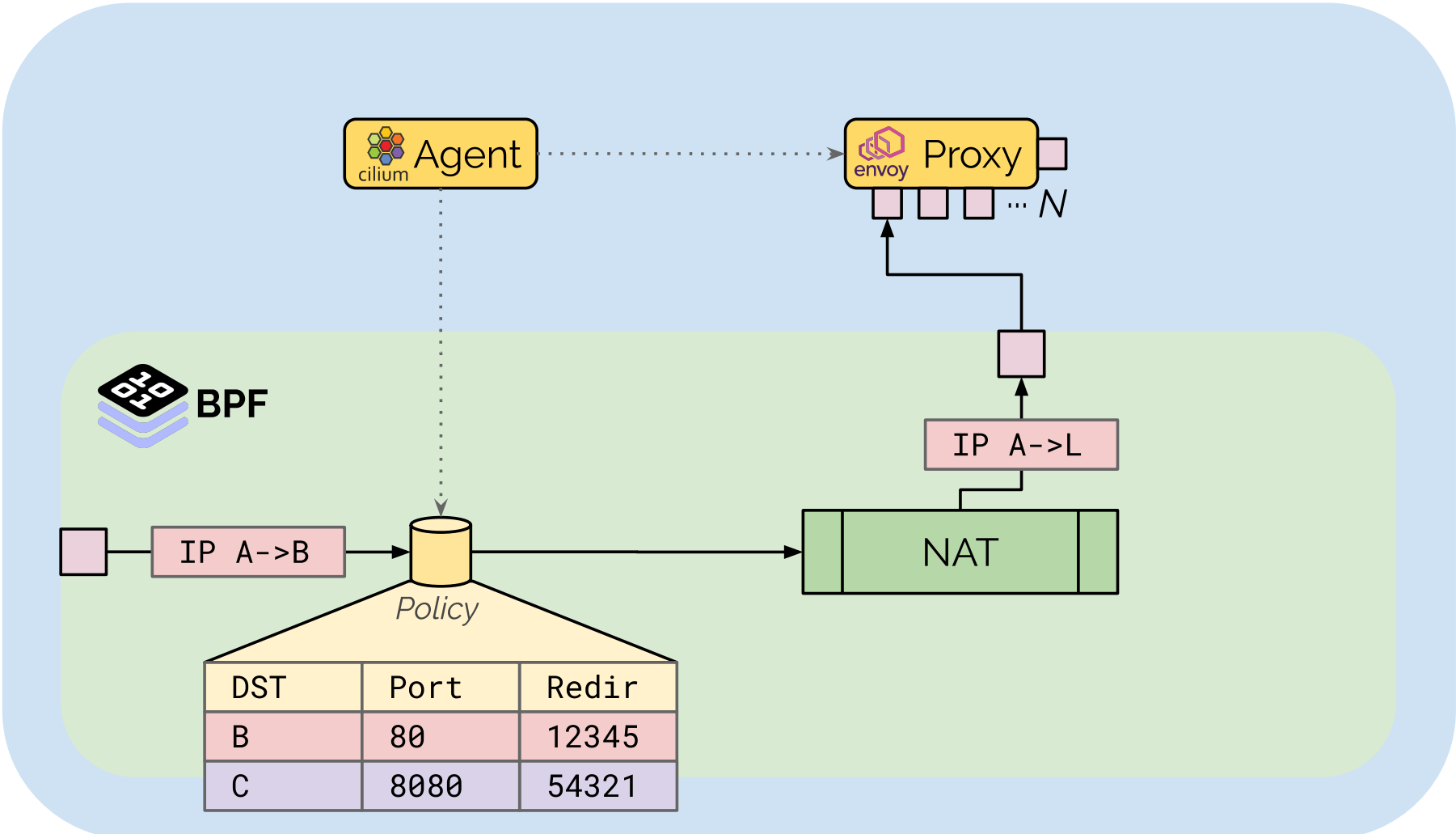

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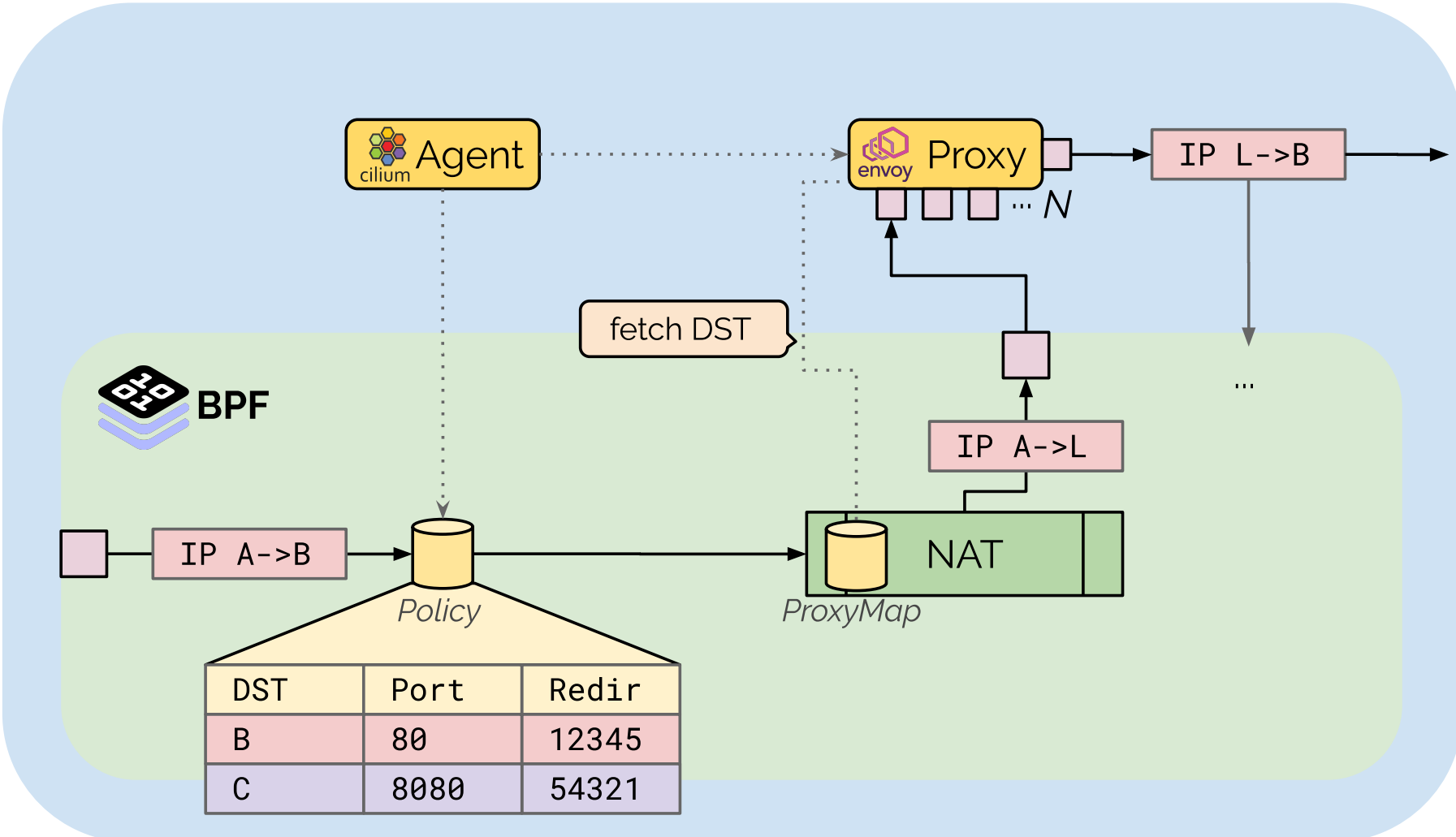

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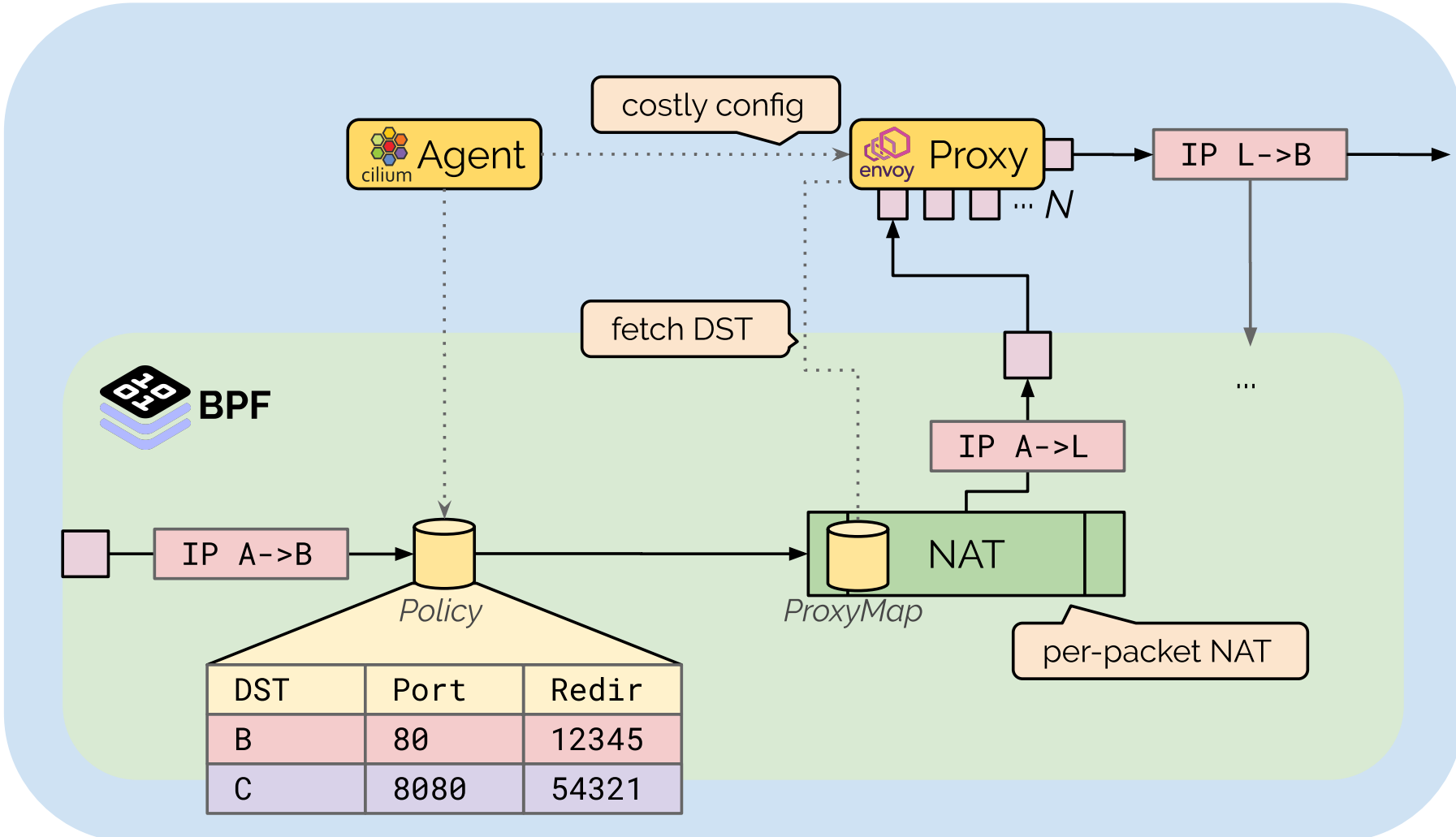

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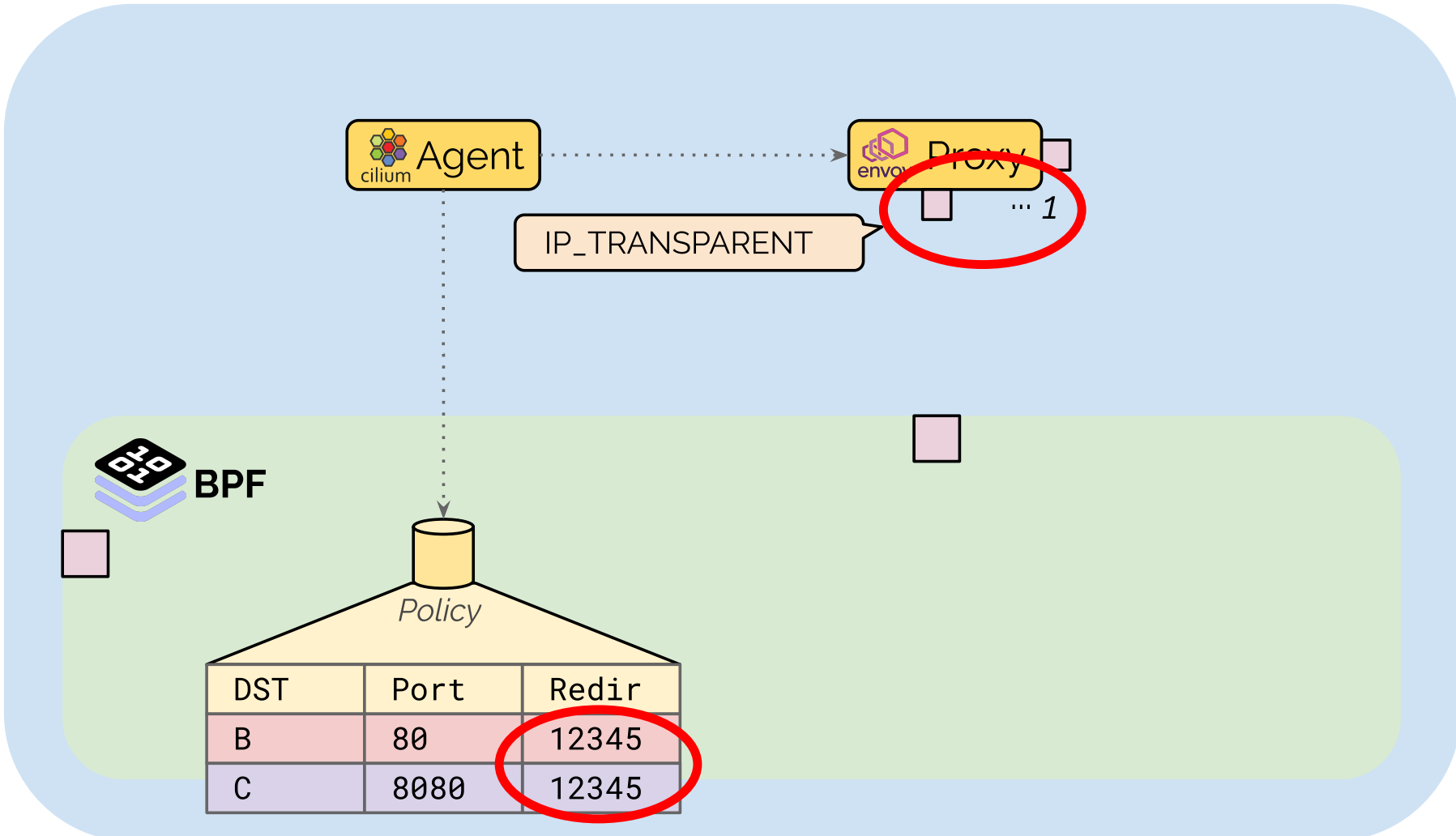
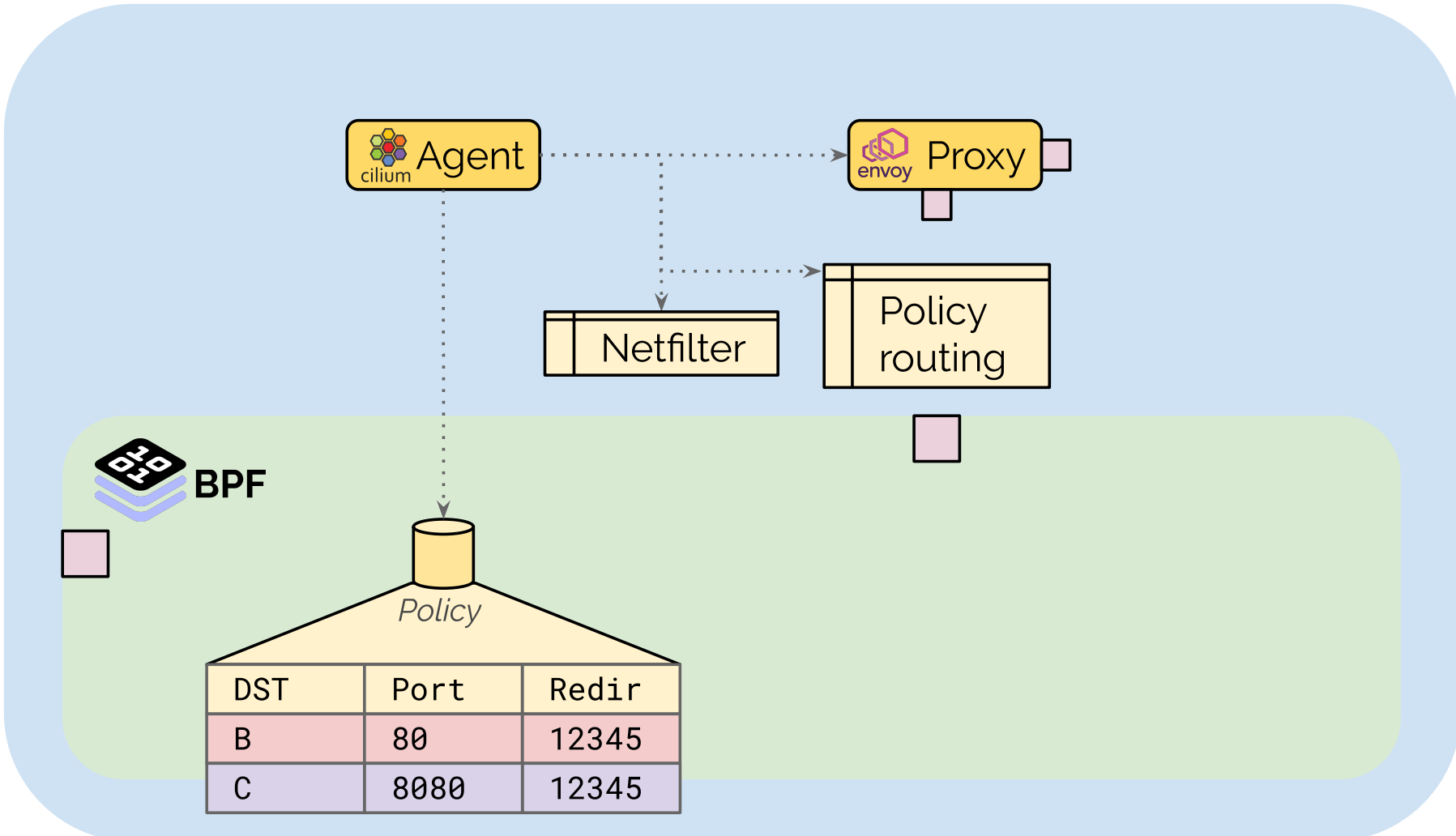
L7 Configuration: Present



L7 Configuration: Present



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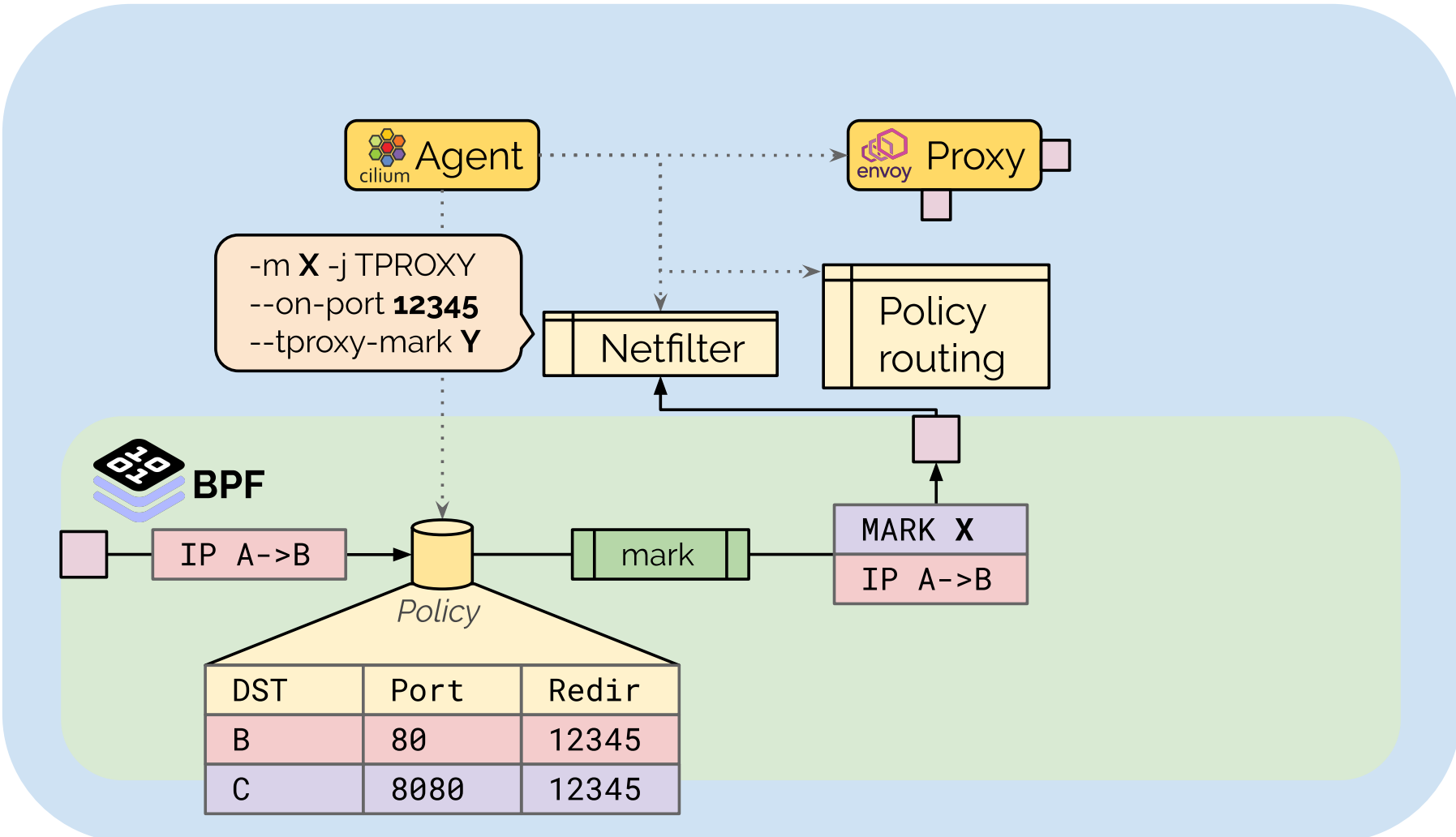

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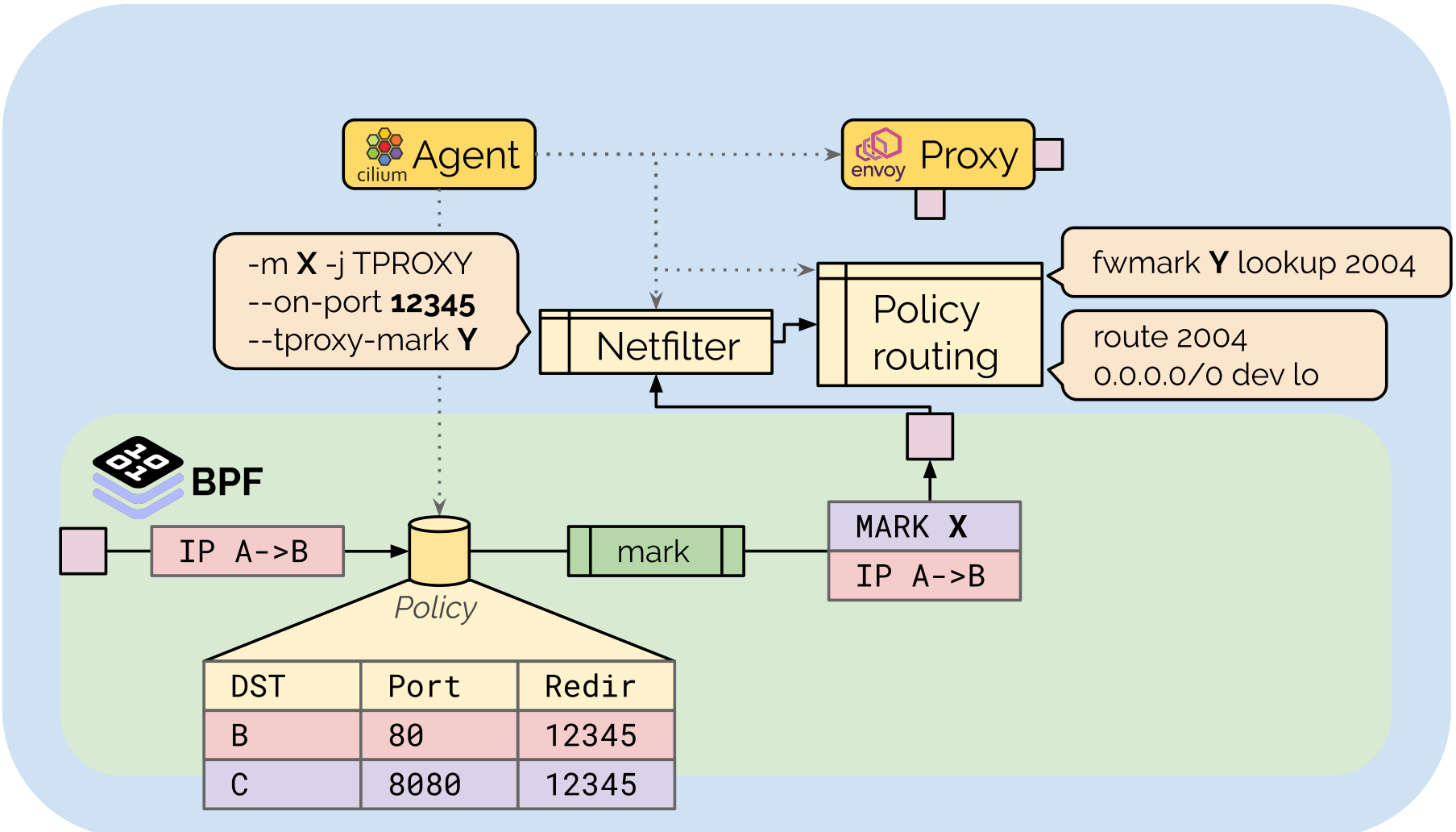

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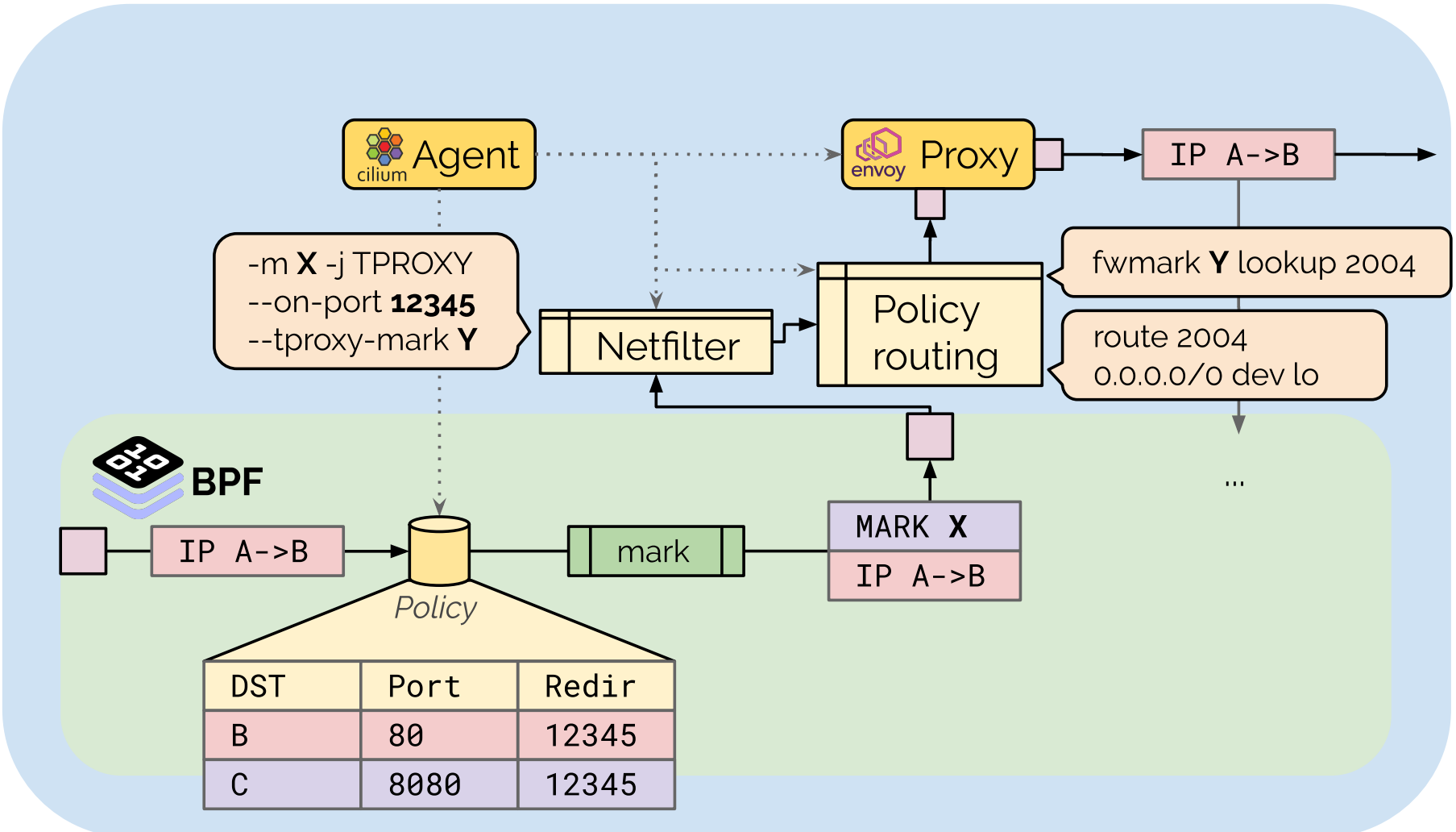
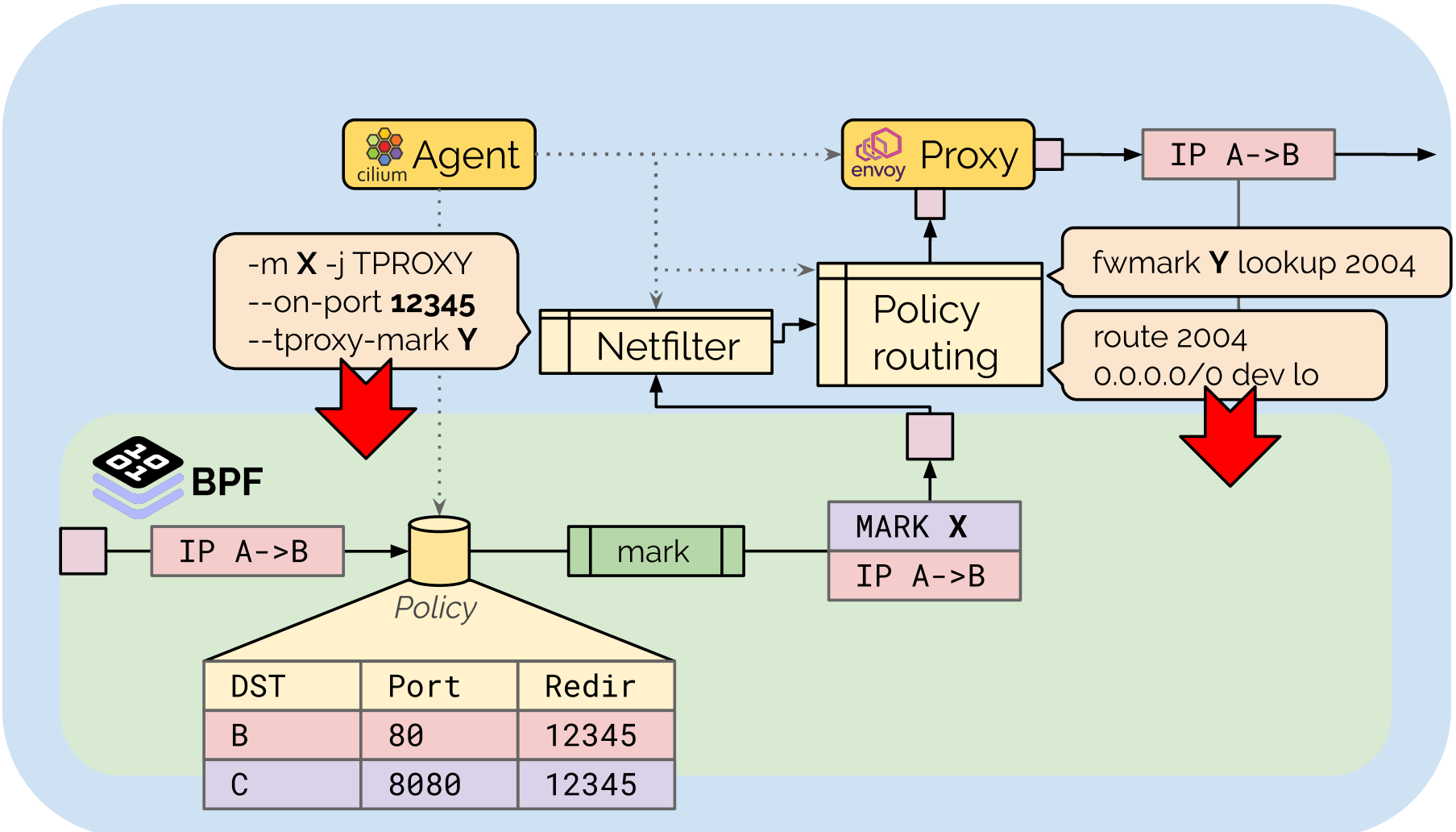


L7 Configuration: Proposal



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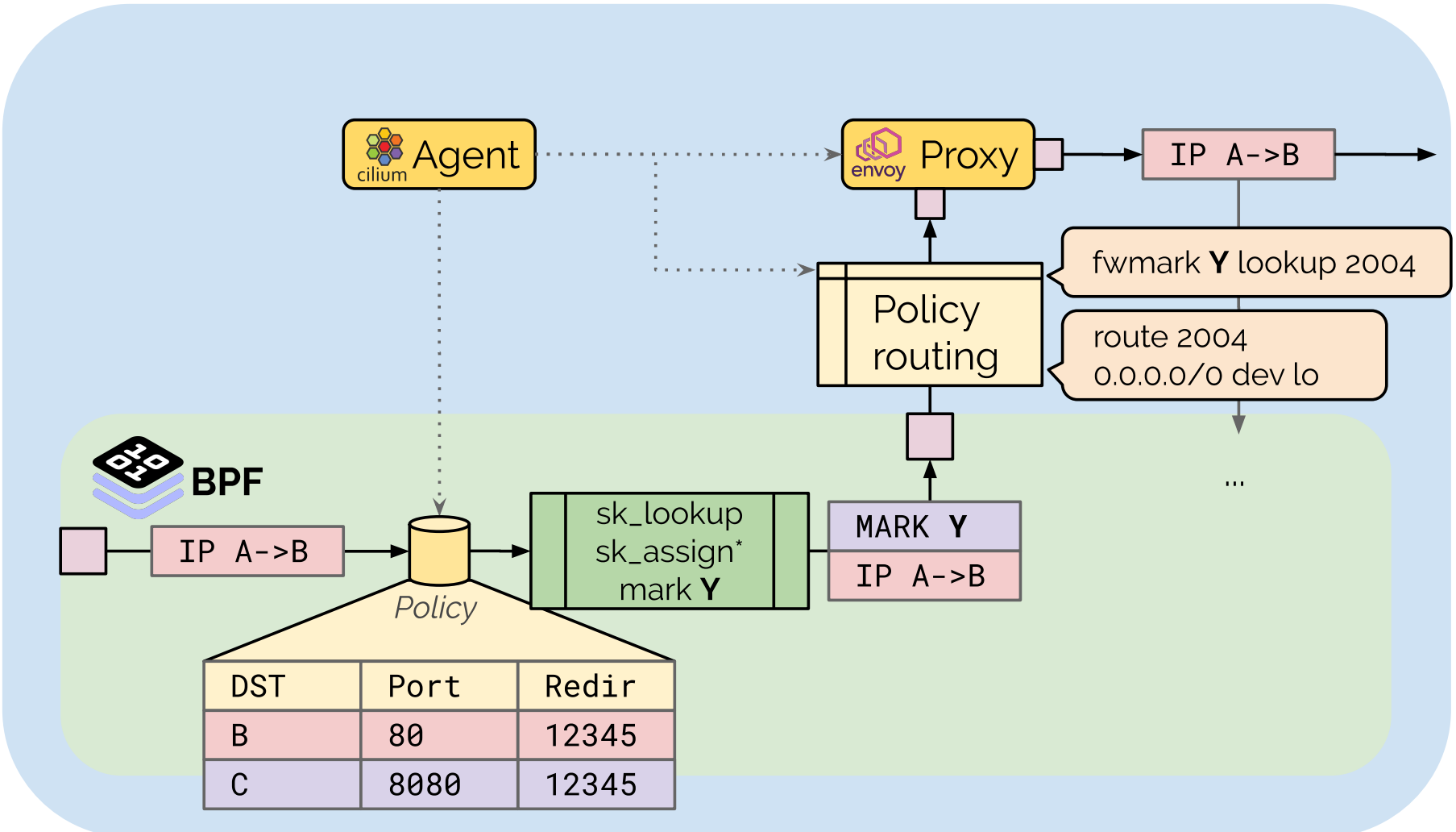
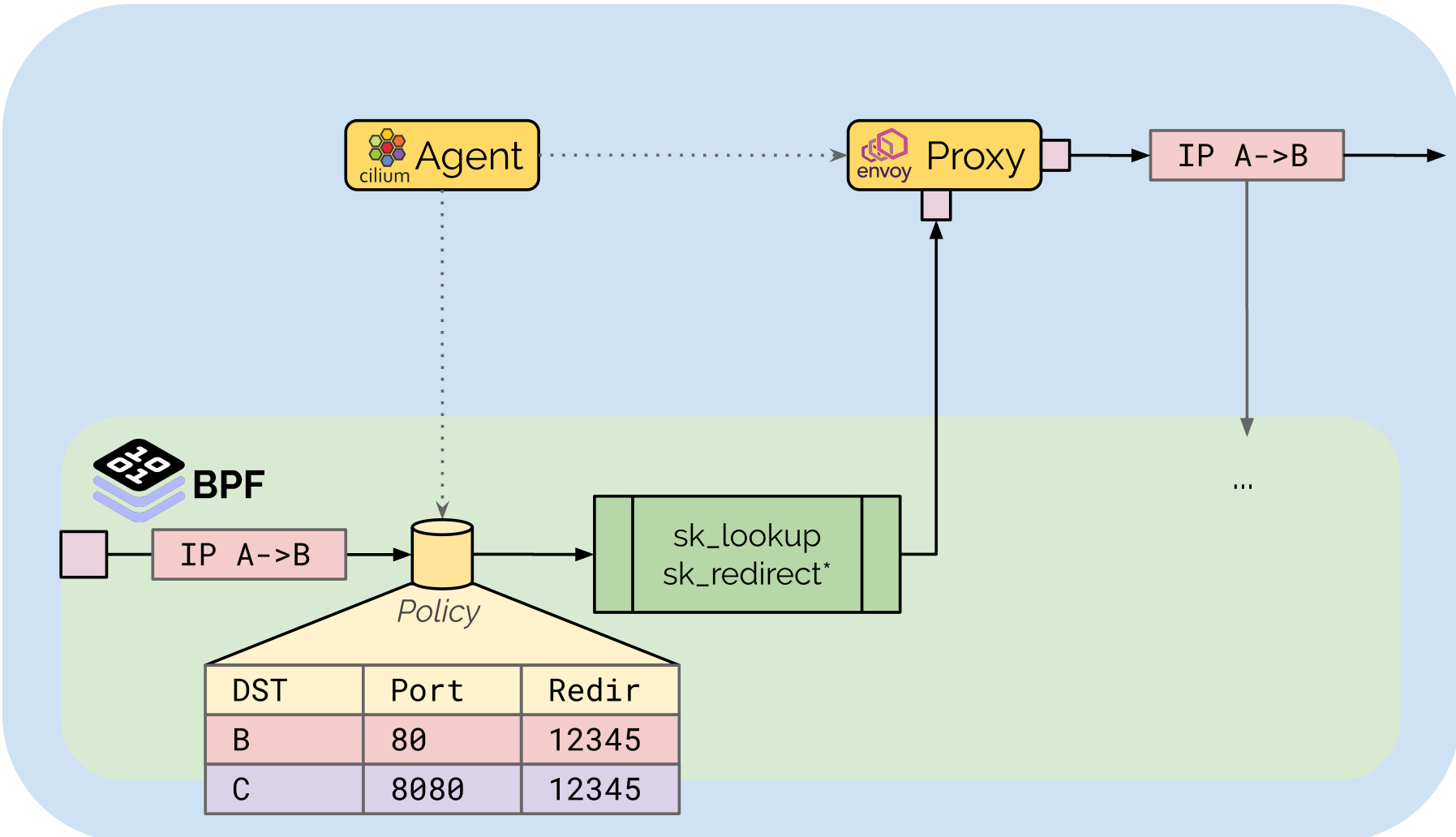


L7 Configuration: Socket redirect



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

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Socket assign: Hiccup

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- `skb_orphan()` invoked directly before `PREROUTING`
- TC folks are already carrying hacks for this[1]
- Just move to `____dev_forward_skb()`[2]?

[1] https://www.mail-archive.com/netdev@vger.kernel.org/msg303851.html
[2] https://www.mail-archive.com/netdev@vger.kernel.org/msg304057.html

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

- https://cilium.io
- https://cilium.io/slack
- https://github.com/cilium/cilium
- https://twitter.com/ciliumproject

Thank you

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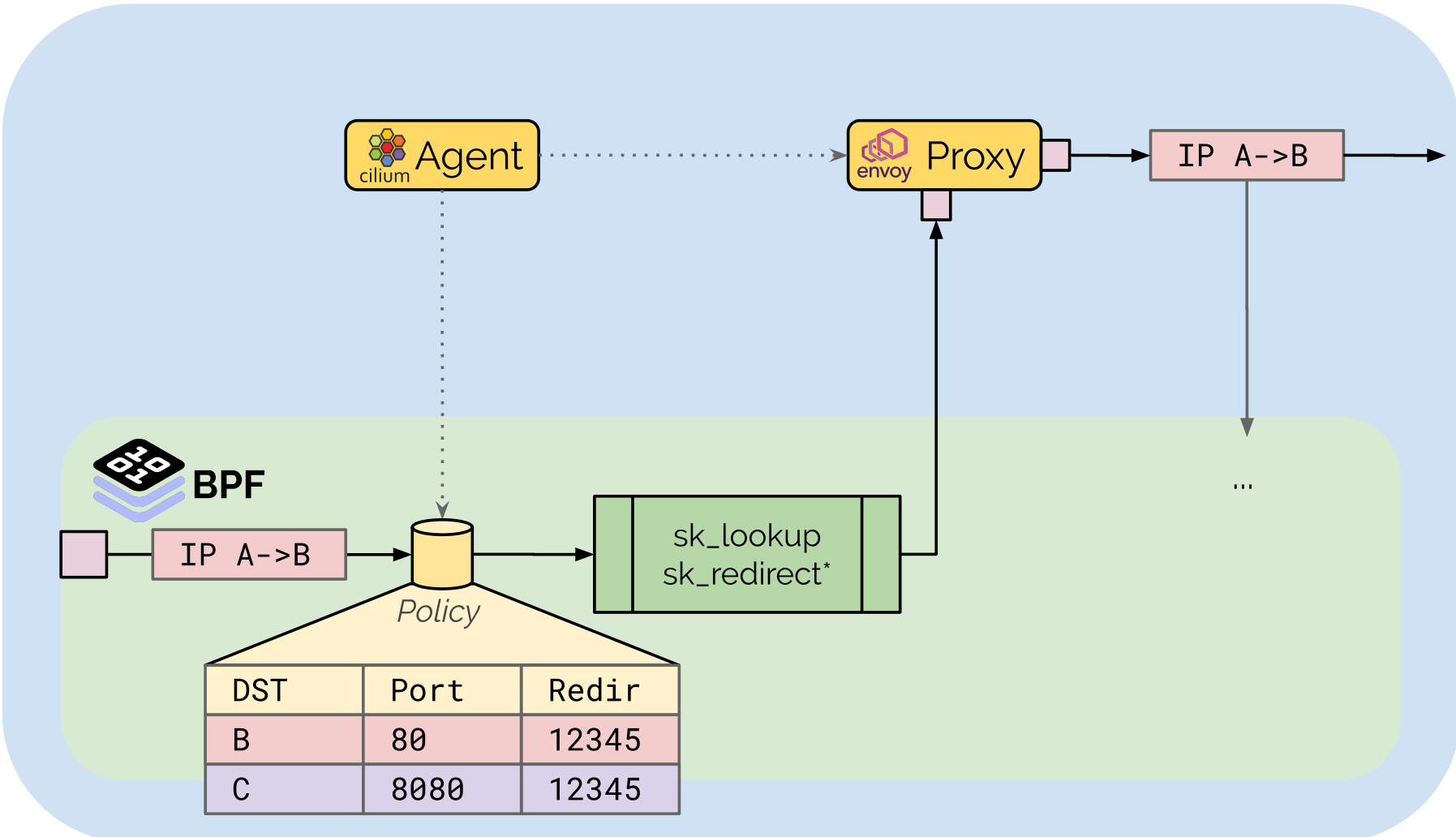

Early demux

```
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;
}
```

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: API quirks

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

ELF Templating: 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
- Copy ELF, replacing values in symbol table with desired constants
- Loader relocation copies the value from the symbol table into the instructions

ELF Templating: 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

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https://lwn.net/ml/bpf/d406e2487f0dc1bf0326ed12e5e0cd0d17eae89c.1554314902.git.daniel@iogearbox.net/