rethinking

Routing in FreeBSD 13

ALEXANDER CHERNIKOV <MELIFARO@FREEBSD.ORG>

Agenda

- Motivation
- Nexthops & Nexthop groups
- fib(9) KPI
- Lookup algorithms framework
- Algorithms overview
- Performance
- Next steps

Motivation

- Working multipath
- Improving control plane performance under traffic load
- Desire for the new high-performance lookup algos
- Build the base for other new features

Problems with routing subsystem

- Lack of isolation
- Tightly coupled with almost all other network parts
- struct rtentry widely used by external callers (~100 places)
- Extremely hard to change

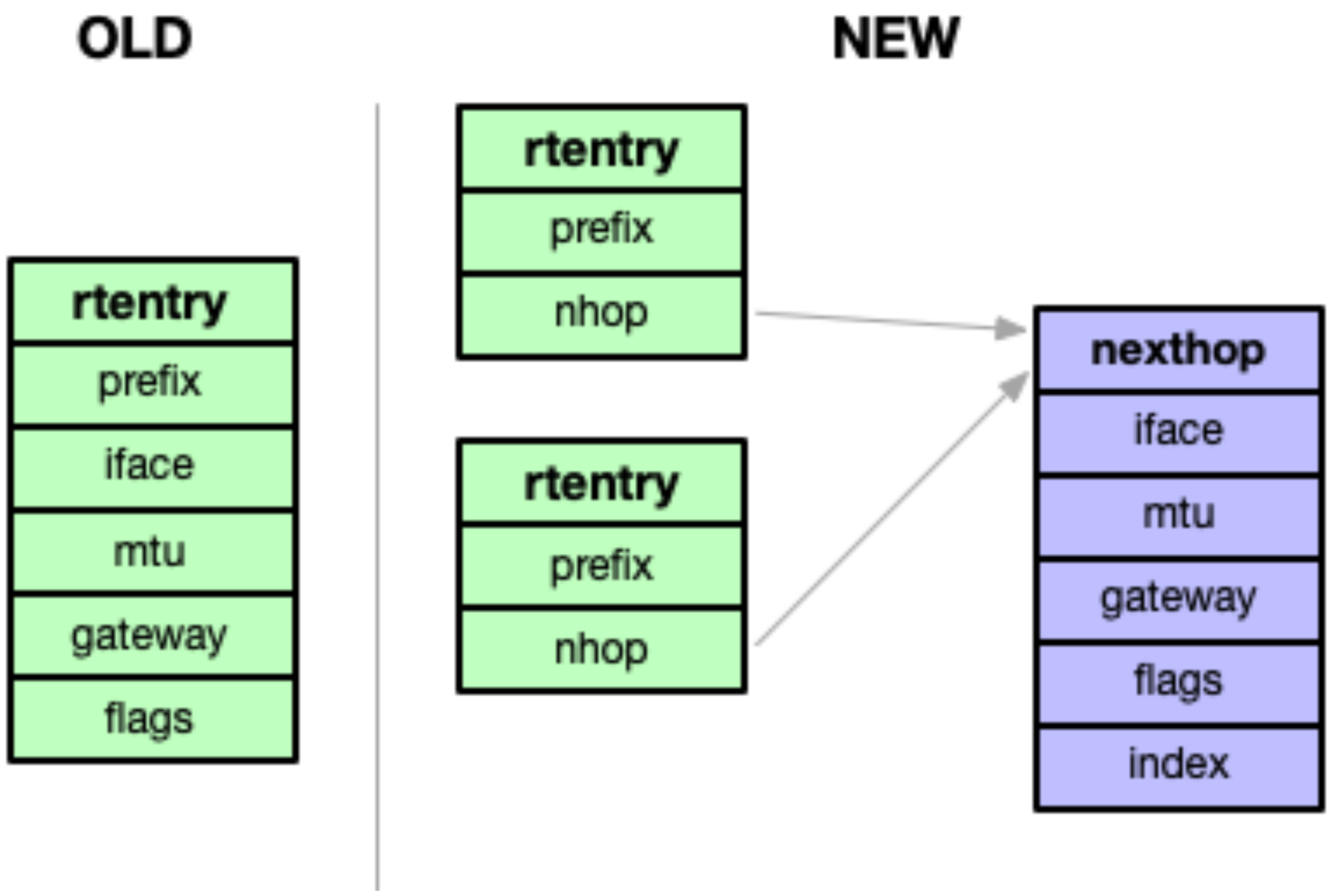
New concepts

- Clear KPI with isolation goal in mind
  - Explicit "private" and "public" parts
- Most lookup consumers don’t require prefix data
  - Nexthop-related information is sufficient
- Construct KPI around the nexthops

ALEXANDER CHERNIKOV <MELIFARO@FREEBSD.ORG>

Basic building blocks: Nexthops

- Structure with data enough to push packet
- Mostly immutable
- epoch(9)-based reclamation
- refcount(9) for tracking
    - control plane & route caching
- Stored in auto-resizable hash table



rtentry -> nhop_object

ALEXANDER CHERNIKOV <MELIFARO@FREEBSD.ORG>

Building blocks: Nexthops #2

- Public part: returned by KPI
- Private part: used internally
  - refcounting
  - housekeeping

```
struct nhop_object {
  uint16_t        nh_flags;
  uint16_t        nh_mtu;
  struct sockaddr         gw_sa;
  struct ifnet   *nh_ifp;
  struct ifaddr  *nh_ifa;
  struct ifnet   *nh_aifp;
  counter_u64_t nh_pksent;
  uint8_t         nh_prepend_len;
  uint8_t         spare[3];
  uint32_t        spare1;
  char   nh_prepend[48];
  struct nhop_priv        *nh_priv;
};
```

```
struct nhop_priv {
  uint8_t          nh_family;
  uint8_t          spare;
  uint16_t         nh_type;
  uint32_t         rt_flags;
  uint32_t         nh_idx;
  void             *cb_func;
  u_int            nh_refcnt;
  u_int            nh_linked;
  struct nhop_object    *nh;
  struct nh_control     *nh_control;
  struct nhop_priv      *nh_next;
  struct vnet           *nh_vnet;
  struct epoch_context  nh_epoch_ctx;
};
```

ALEXANDER CHERNIKOV <MELIFARO@FREEBSD.ORG>

Building blocks: Nexthops #3

- Better for data plane: smaller cache-friendly footprint
- Better for control plane: pre-calculated entities to deal with
- Peering routers have hundreds nhops, not millions
- Easier to store additional info / iterate

Idx	Type	IFA	Gateway	Flags	Use	Mtu	Netif	Addrif	Refcnt	Prepend
1	v4/resolve	127.0.0.1	lo0/resolve	H	292	16384	lo0		2	
2	v4/resolve	10.0.0.8	vtnet0/resolve		0	1500	vtnet0		2	
3	v4/resolve	127.0.0.1	lo0/resolve	HS	0	16384	lo0	vtnet0	2	
4	v4/gw	10.0.0.8	10.0.0.1	GS	0	1500	vtnet0		2	

netstat -4onW (inet.0)

Building blocks: nexthop groups

- Used to store multipath route data
- Groups of nexhop-weight pairs.
- Internal to the routing subsystem
- Immutable
- refcount(9)
- epoch(9) backed reclamation
- Stored in an auto-resizable hash table
- Can be referenced by pointer or by index

nhgrp_priv	
Flags	
Index	
num_nhops	
Nhop#	Weight
6	100
4	200

struct nhgrp_priv

Building blocks: nexthop groups (cont)

- Need effective dataplane implementation
- Currently uses array of nexthops
- Can be compiled differently
- Max datapath group width: 64
- Default weight: 1 (RT_DEFAULT_WEIGHT)
- route add .. -weight 100

Control plane

Nhop#	Weight
6	200
4	300

Data plane

len:5
6
6
4
4
4

Compilation example

Using nexthop groups

- Transparent to consumers
- flowid-based nexthop selection
- flowid semantics agnostic to the function
- Dataplane part shares flag field with nexthop

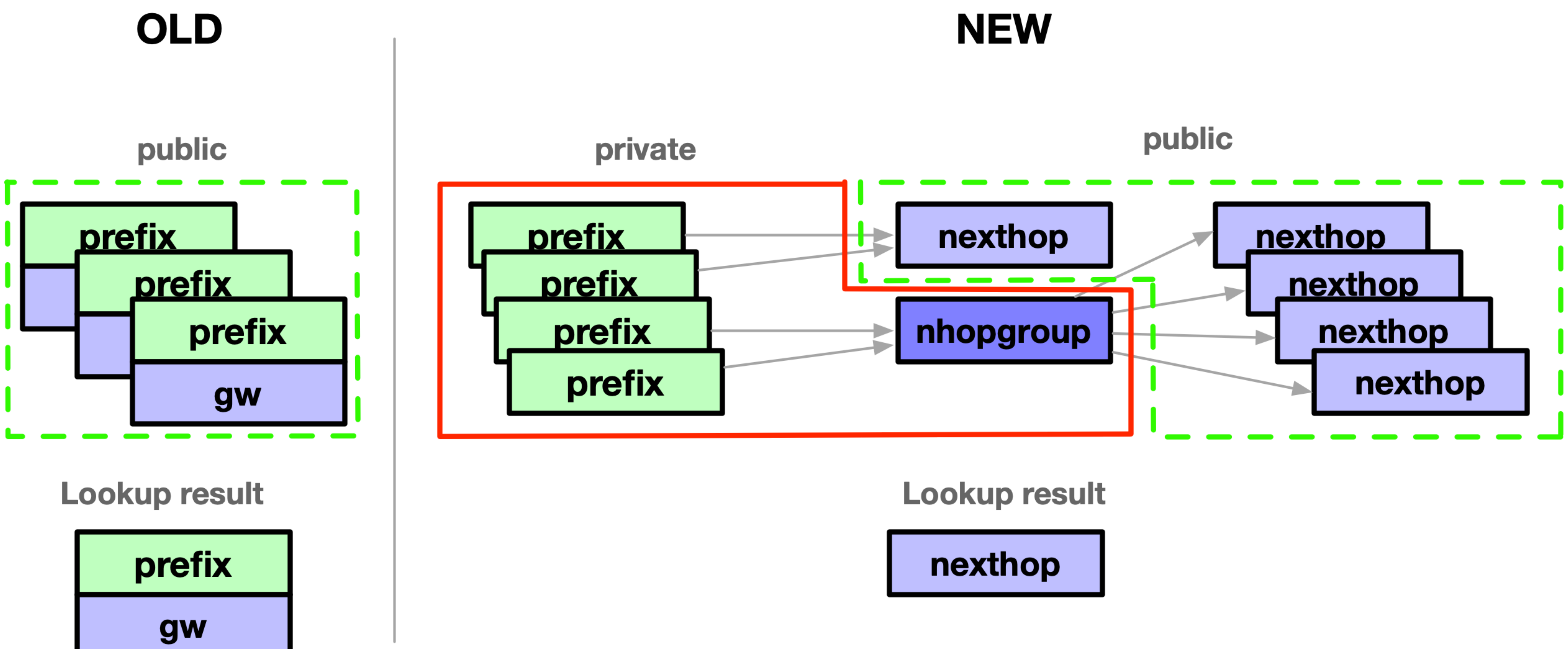
```
struct nhop_object *
fib4_lookup(uint32_t fibnum, struct in_addr dst,
    uint32_t scopeid, uint32_t flags, uint32_t flowid)
{
        struct nhop_object *nh;
        ...
        if (nh->nh_flags & NHF_MULTIPATH) {
                struct nhgrp_object *nhg;
                nhg = (struct nhgrp_object *)nh;
                nh = nhg->nhops[flowid % nhg->nhg_size];
        }

        return (nh);
}
```

nexthop selection in fib4_lookup()

Using nexthops: data plane KPI

- Per-family functions
- Do not require sockaddrs
- Transparently handles multipath
- fib4_lookup(fibnum, flags, addr, scopeid, flowid) -> nhop ptr
- fib6_lookup(fibnum, flags, *addr, scopeid, flowid) -> nhop ptr

Using nexthops: data plane KPI #2



Part of new KPI: the only "public-visible" datastructure

ALEXANDER CHERNIKOV <MELIFARO@FREEBSD.ORG>

Using nexthops: control plane KPI

- Single function to control routing table: `rib_action()`
- As before, `struct rt_addrinfo` contains all necessary data
- Nexthop and nexthop group creation happens within routing subsystem
- NET_EPOCH is required

Using nexthops: control plane KPI

- Some callers still need to know the matched prefix
- `route get`, netflow
- Provide fib[46]_lookup_rt() functions returning rtentry
  - With nhop/weight data at the time of lookup
- No direct rtentry access, special accessor functions
  - rt_get_inet[6]_prefix_plen()
  - rt_get_family()

Using nexthops: locking/refcounting

- Nhops/nhop groups are (mostly) immutable
- Change in the route attributes forces creation of a new nexthop
- No per-nexthop/nexhop groups locks
- Shared per-routing-table rwlock for hash operations
- refcount(9): control plane, route caching(nexthop caching)
- No refcounts/locking for rtentry

Userland

- Changes are mostly transparent
- Old binaries (route(8), routing daemons) should work on 13-S
- Multipath works with quagga out-of-the box
- More work required to support multipath in bird

ALEXANDER CHERNIKOV <MELIFARO@FREEBSD.ORG>

Nexthops summary

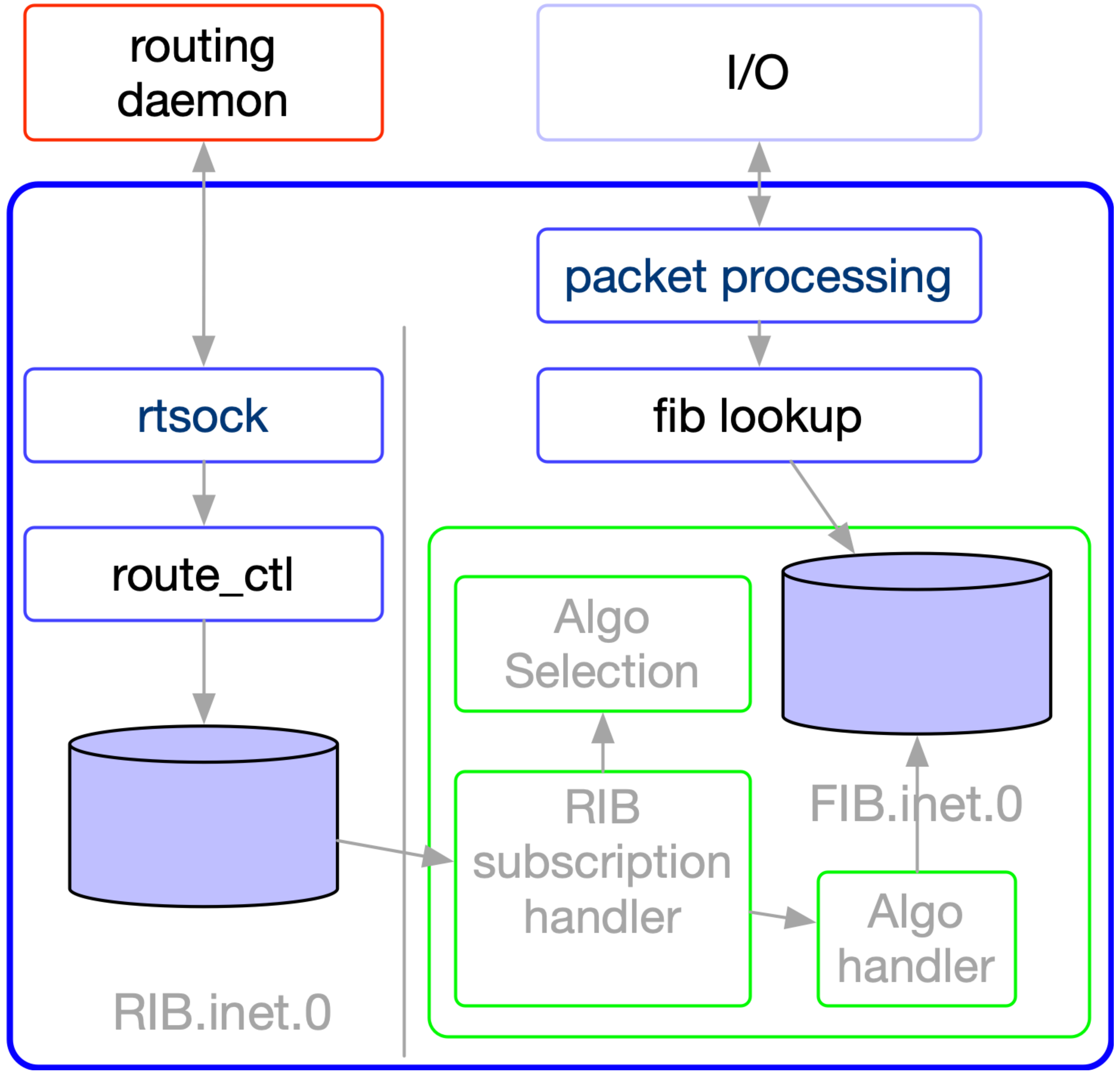
- Decouples all routing specifics from the lookup algo
- Now it’s a pure function of IPv[46] -> #index
- Nexthop pointers/indexes are required for the high-perf algorithms

Lookup algorithms framework

- Optimal performance for the specific use-case
    - IPv6 is different from IPv4
    - Full-view is different from 10 routes
- Lockless lookups
    - Better control plane performance during convergence
    - Routing daemon does not compete with dataplane for the rtable locks
- Foundation for the other families (MPLS)
- Reducing the bar for the the new algorithms implementation & testing

Lookup framework: features

- Algorithms can be loaded on the fly
- Automatic algorithm selection
  - Based on the amount of routes/nhops
- No dataplane locks
- Control plane decoupled from the data plane
- Updates batching if requested



RIB/FIB separation

Lookup framework: internals

- Reliable subscriptions to the route changes
- Ability to keep multiple instances of same/different algo for a table in sync
- Handling every failure by spinning up new algo instance
- Delayed updates / batch updates

Lookup framework: algo selection

- Each algo has to implement a preference callback
- Based on the #of routes/nhops -> return value 0..255
- Framework compares values of all algos to select the best
- Periodic re-evaluation (100 routes or 30 seconds)
- New has to be at least 5% better to switch

Lookup framework: updates batching

- Conflicting requirement for batching
- Batch more to amortise cost
- Minimise update delay
- Need to find the sweet spot

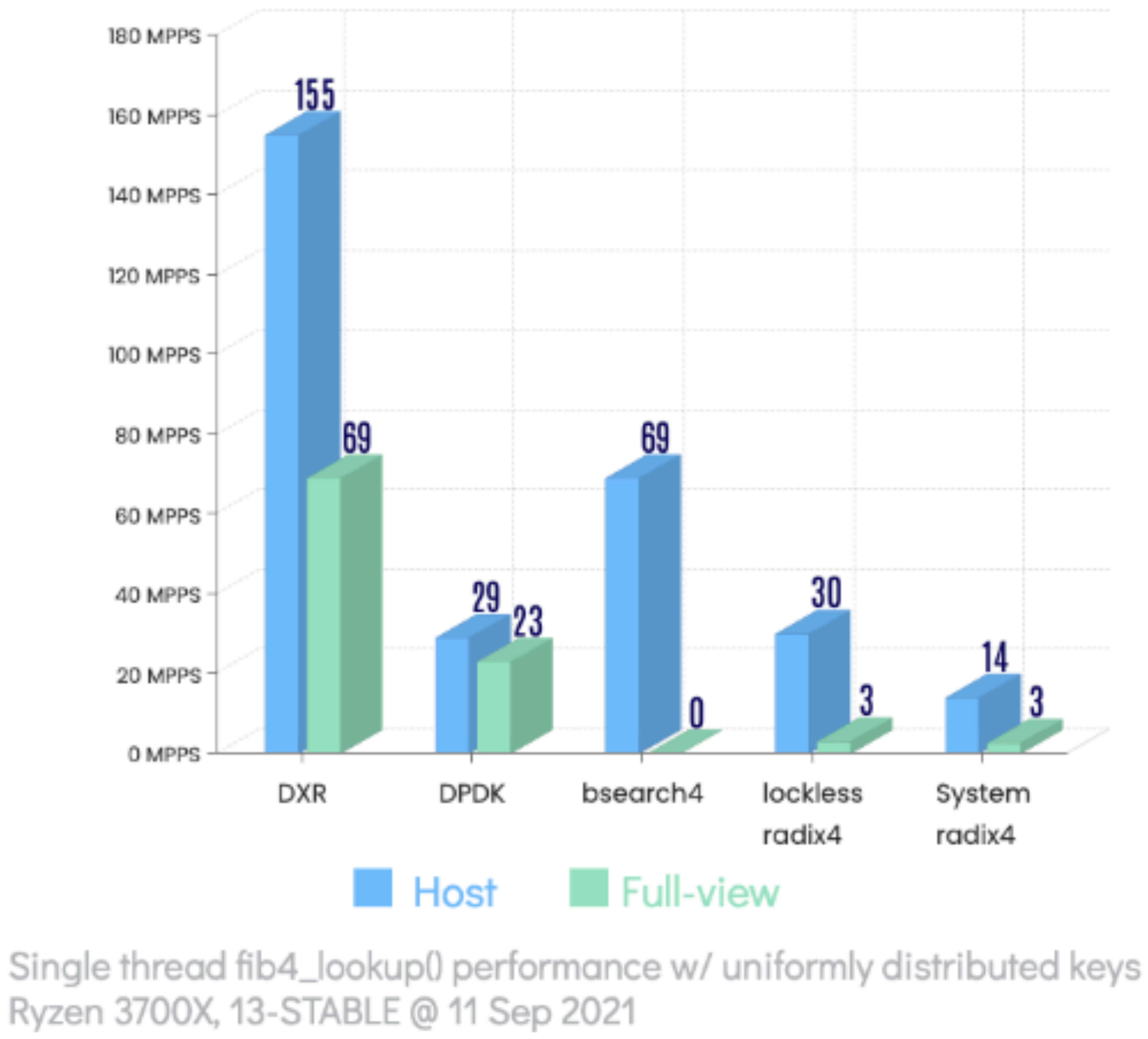
- Force commit for non-gw or static routes
- Bucket updates in 50ms chunks
- Commit if # below the threshold (500 routes)
- Otherwise delay & check next bucket
- Max delay 1000ms
- Each value configurable in net.route.algo

Lookup framework: control plane perf

- Data path does not contest RIB lock
- Improved converge times
- 8x improvement for BGP full-view going down (~300 -> 40 seconds)

Lookup algorithms

- dpdk_lpm4
- dpdk_lpm6
- dxr
- bsearch4
- bsearch6
- radix4_lockless
- radix6_lockless



Algo lookup performance

Lookup algorithms: dpdk_lpm

- Wrapper for DPDK rte_lpm[6] library
- IPv4: variation of DIR-24-8
- IPv6: 26 strides
- Immediate updates
- IPv6 link-local lookups handled by system radix

Lookup algorithms: DXR

- Tailored for the large-scale FIBs
- Works well for small-scale too
- Implementation by Marko Zec
- Uses update batching

Lookup algorithms: bsearch

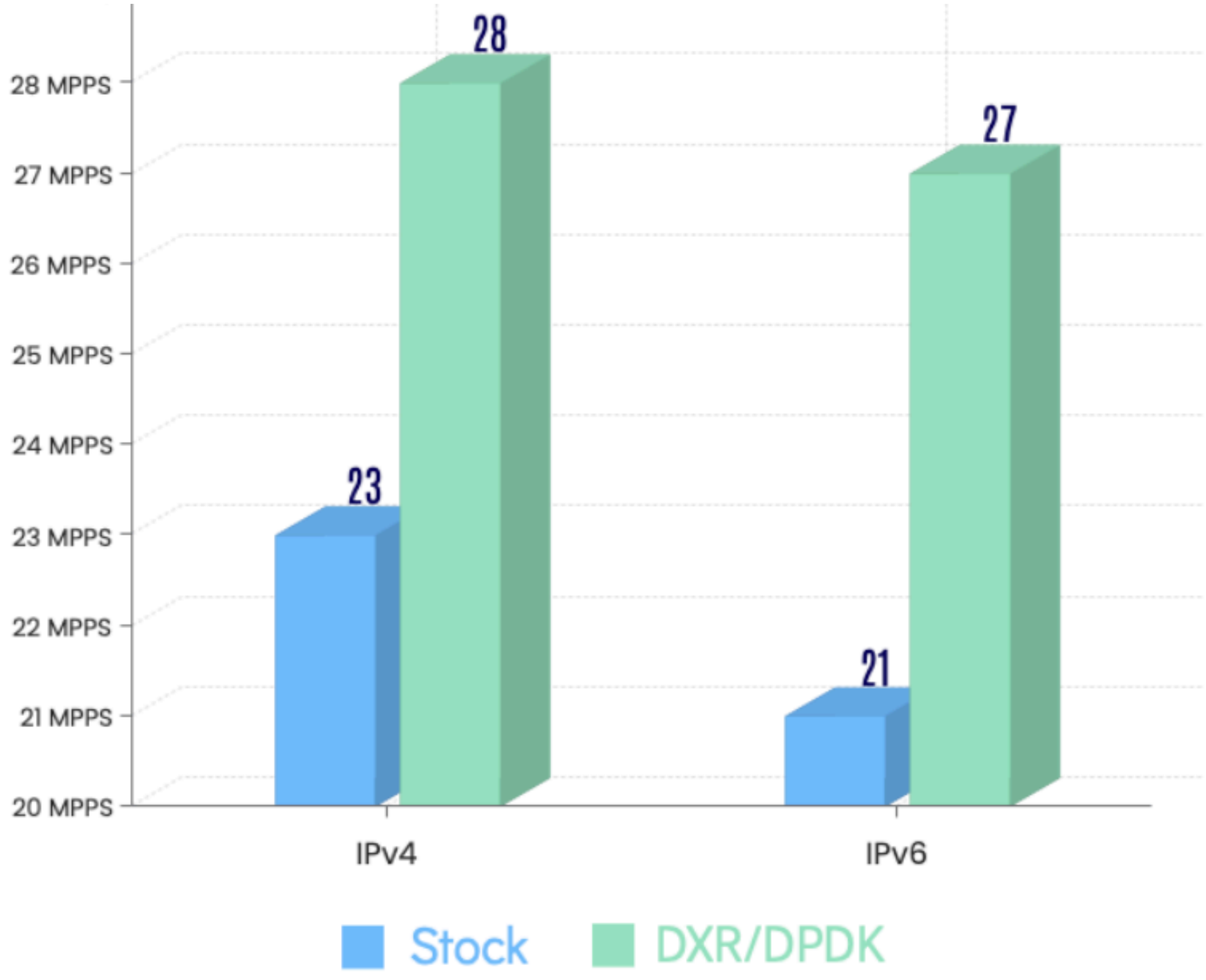
- Array binary search
- Simple and cache-effective for small route scale
- Array is immutable and is rebuild on every route change
- 1-20 routes

Lookup algorithms: radix_lockless

- Immutable tree in contiguous memory chunk
- Backed by system-default trie
- Rebuild on every route change
- 20-1000 routes

Lookup algorithms: performance

- +30% for IPv6
- +21% for IPv4



Next steps

- Add direct nexthop/nhop group handling to rtsock
- Add netlink support