KubeCon | CloudNativeCon

Europe 2022

WELCOME TO VALENCIA

KubeCon CloudNativeCon Europe 2022

Logs Told Us It Was DNS
It Felt Like DNS
It Had To Be DNS
It Wasn't DNS

Elijah Andrews, Datadog
Laurent Bernaille, Datadog

Datadog

Over 500 integrations
Over 3,000 employees
Over 18,500 customers
Runs on millions of hosts
Tens of trillions of events per day

Tens of thousands of nodes
Hundreds of thousands of pods
10s of k8s clusters with 100-4000 nodes
Multi-cloud
Very fast growth

Who are we?

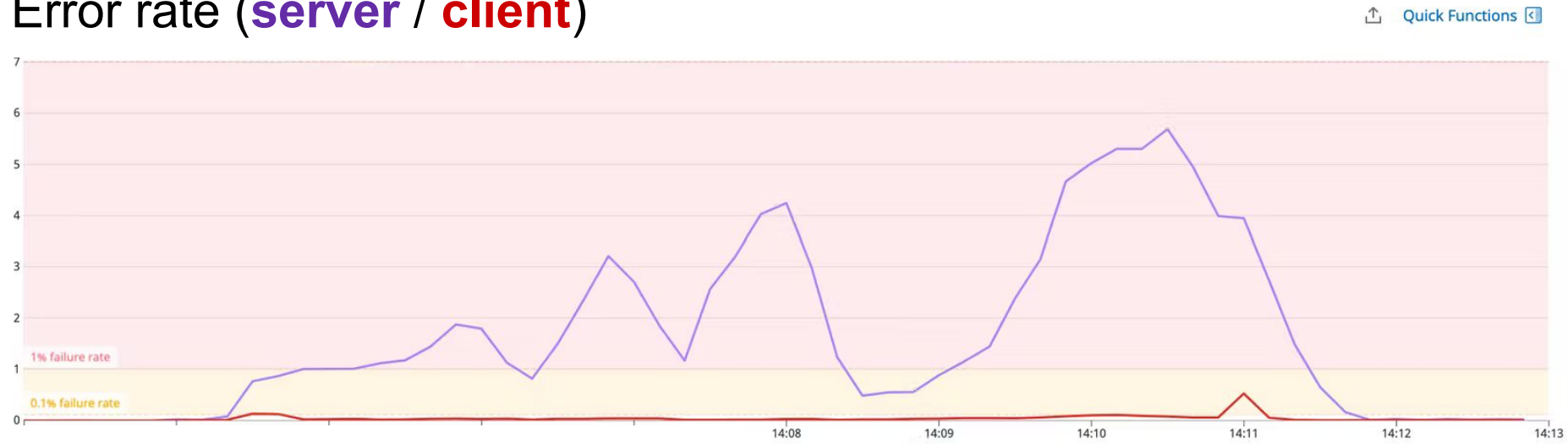
Elijah Andrews
Senior Software Engineer
Datadog
@elijahca

Laurent Bernaille
Staff Engineer
Datadog
@lbernail

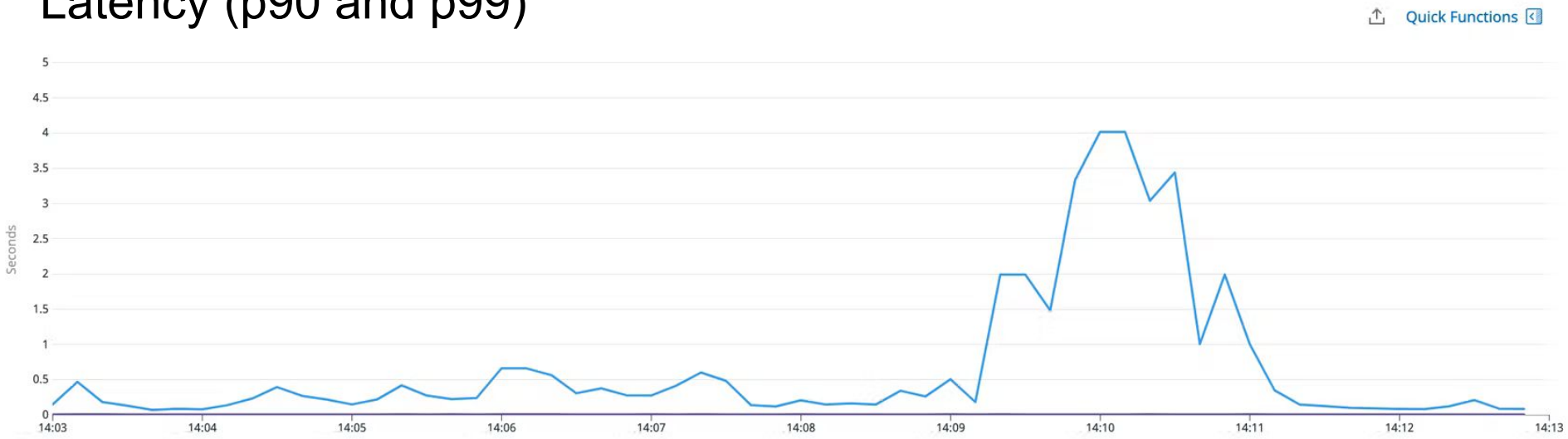
How it all started

Metrics service errors during rollouts

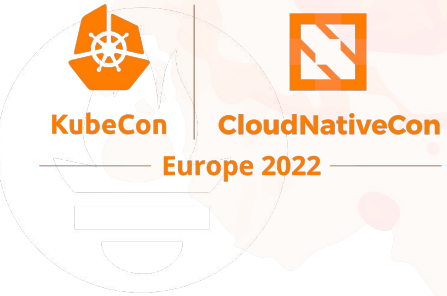
Error rate (**server** / **client**)



Latency (p90 and p99)



It's always DNS



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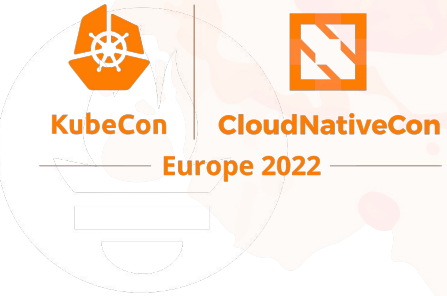

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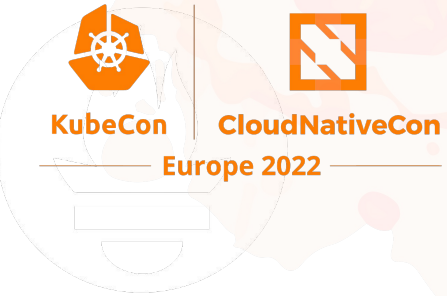

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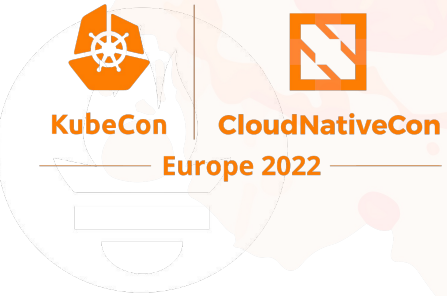


Logs told us it was DNS

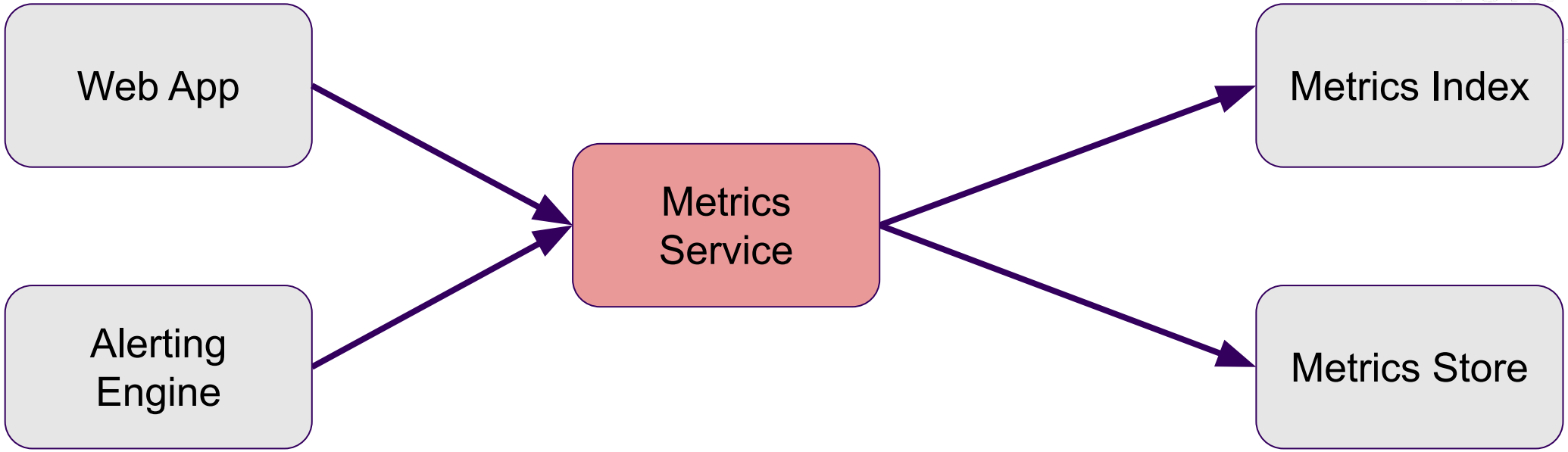
It looked like DNS

It had to be DNS

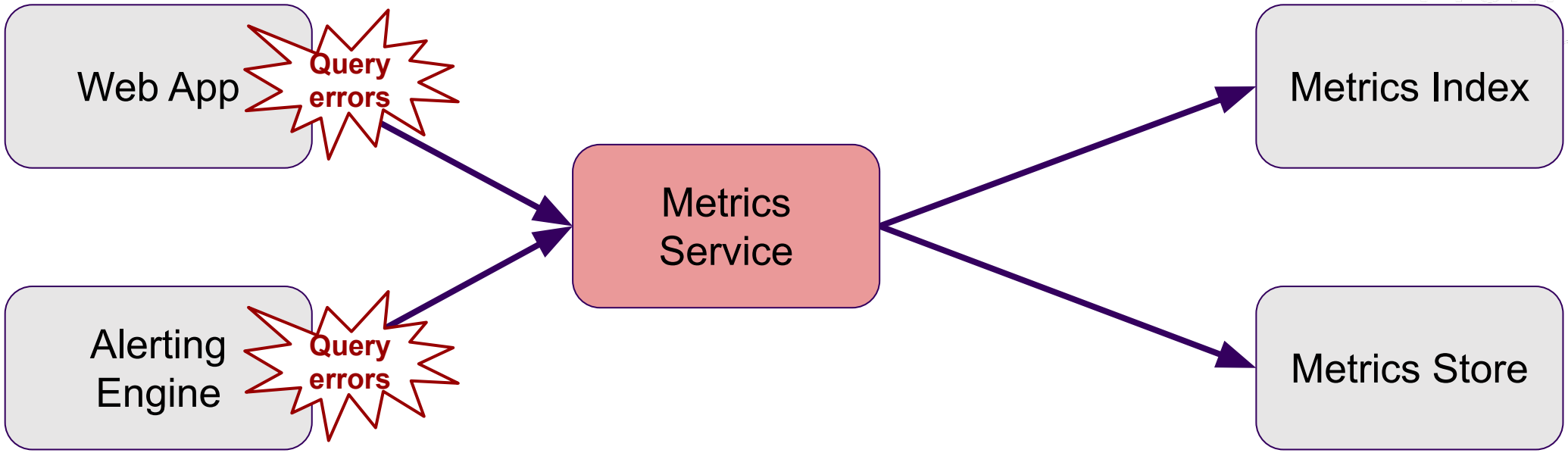
Right?

Chapter 1: DNS

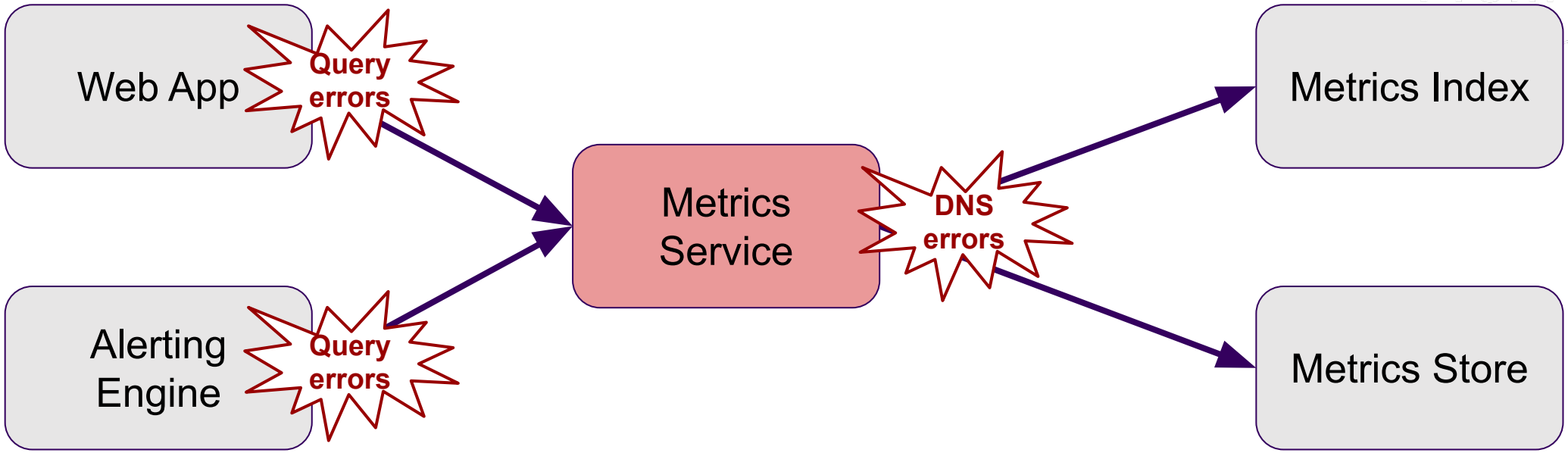
Applications involved



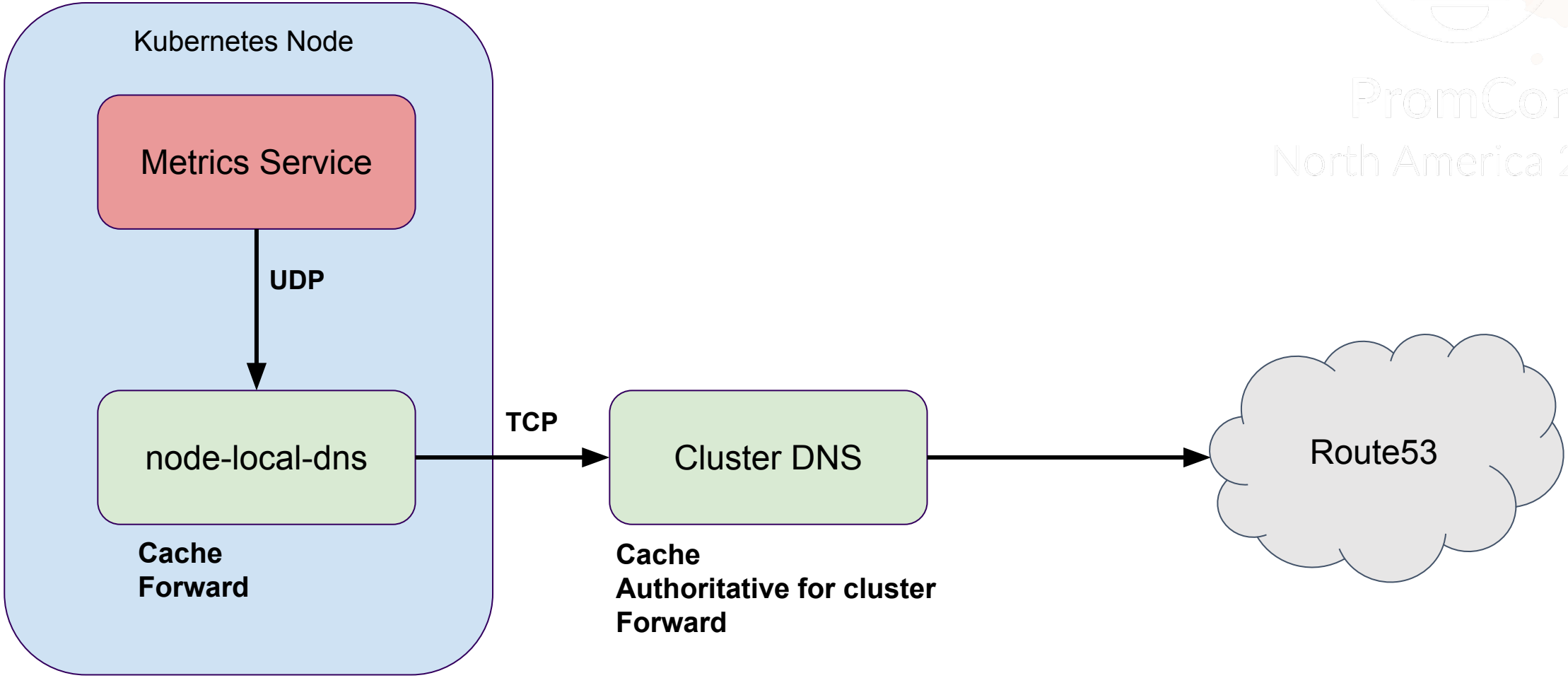
Applications involved



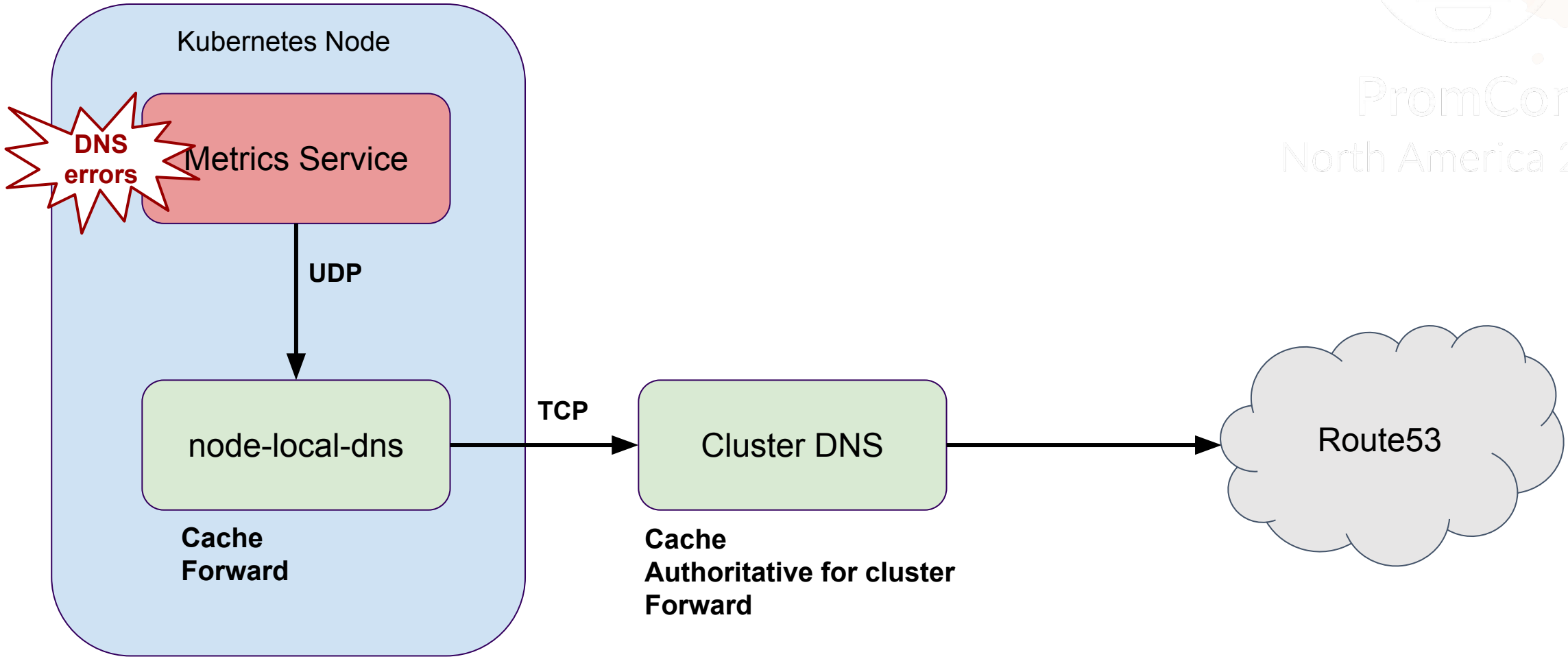
Applications involved



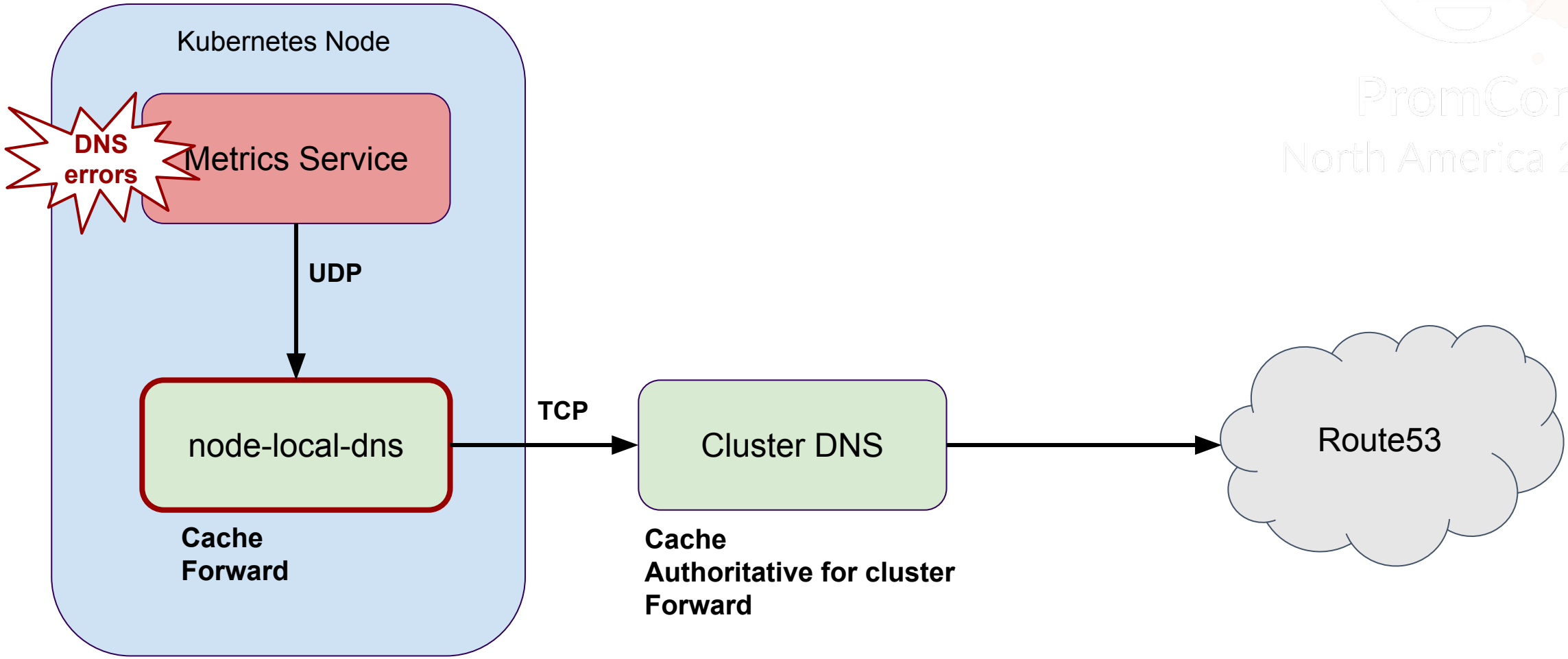
DNS setup



DNS setup

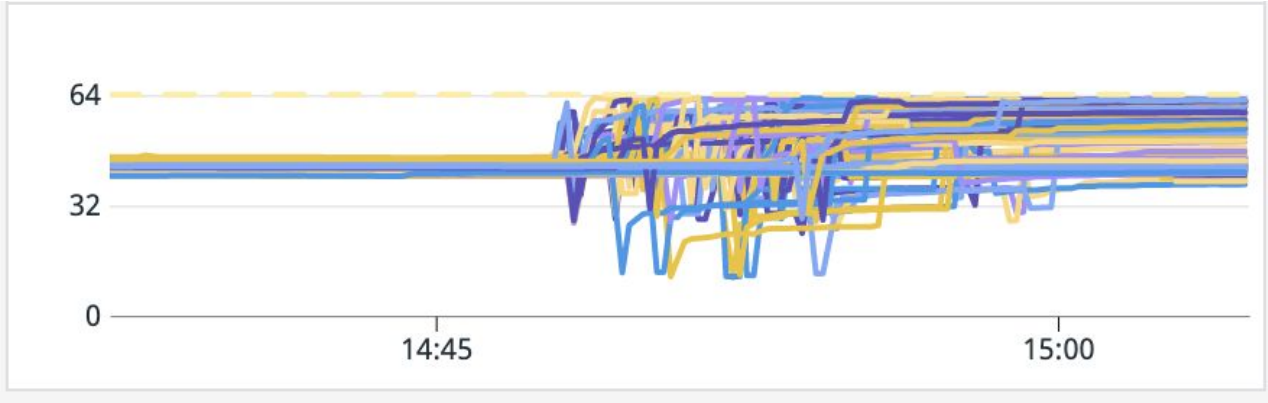


DNS setup



Node-Local-DNS (NLD)

NLD Memory per pod on Metrics Service hosts (and limit)

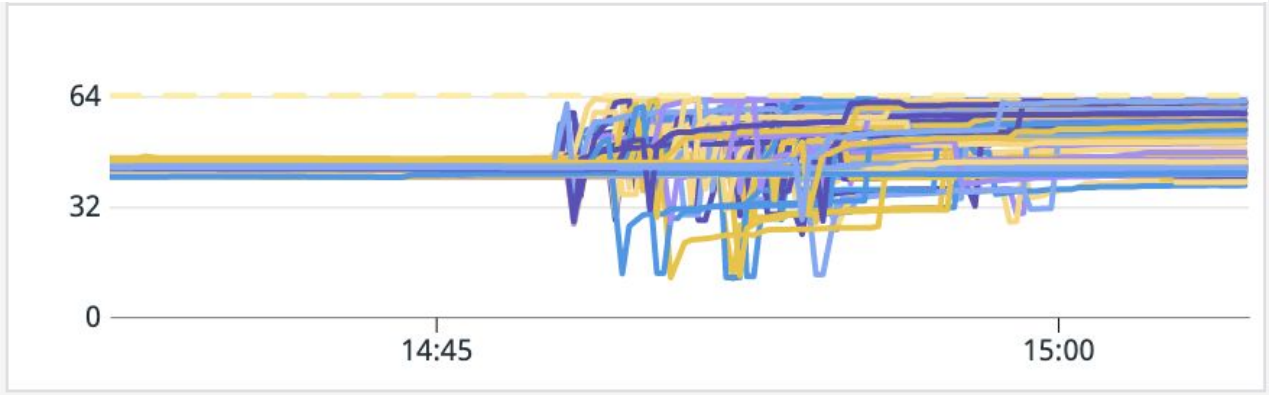


OOM-killed during rollouts

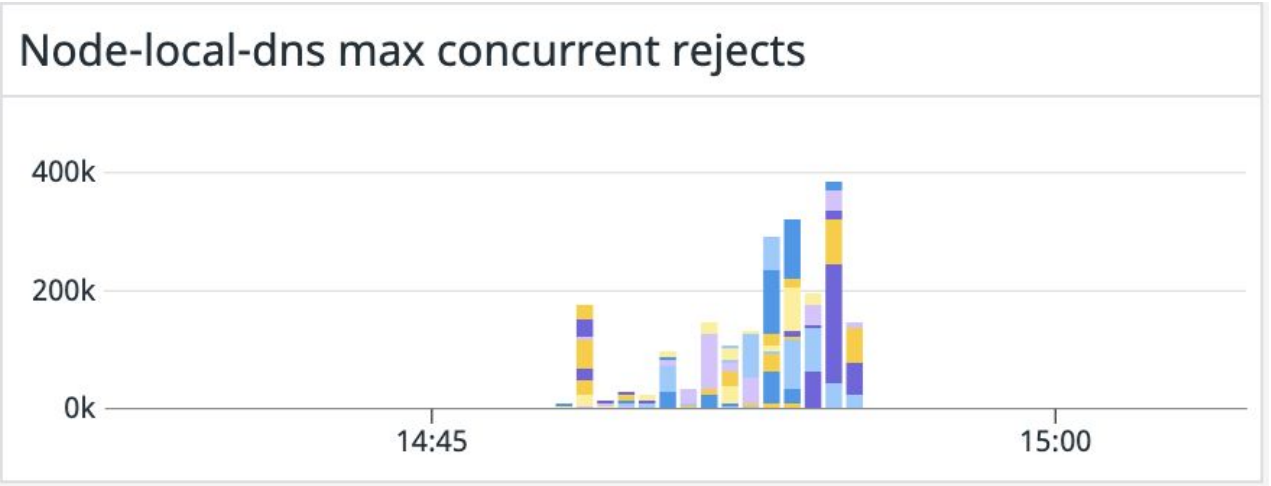
Should *never* happen

Node-Local-DNS (NLD)

NLD Memory per pod on Metrics Service hosts (and limit)



Node-local-dns max concurrent rejects



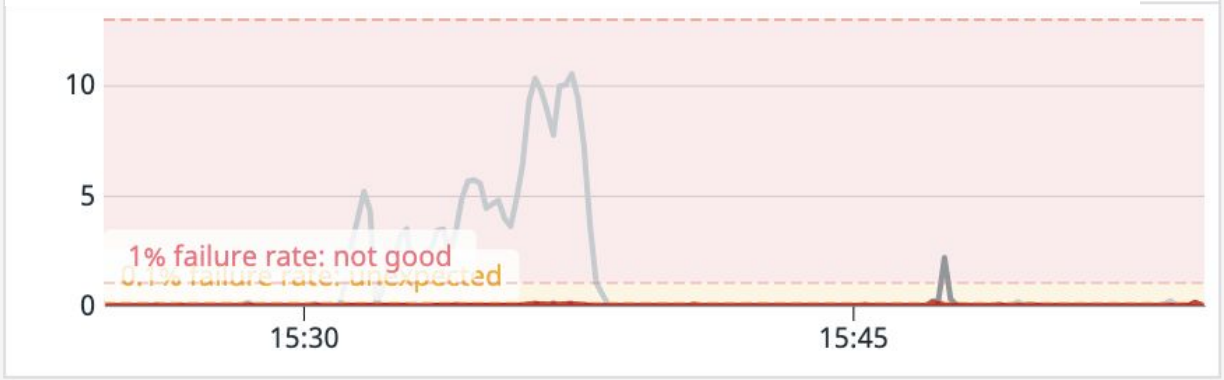
max_concurrent is working

Sizing is wrong

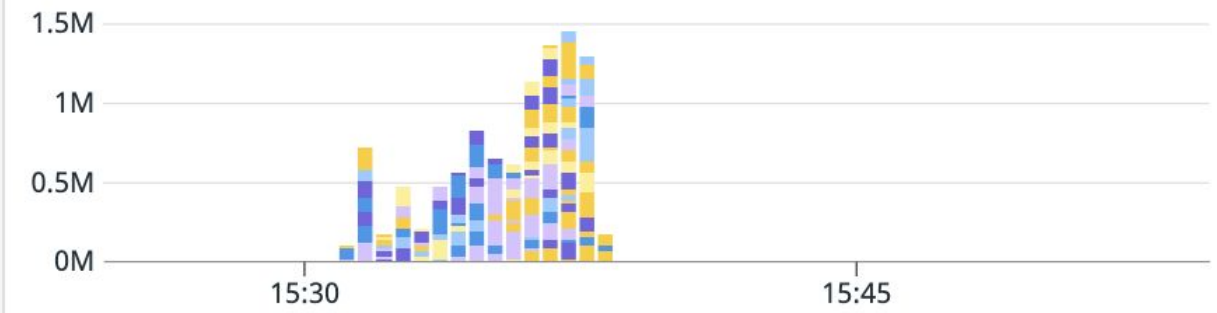
Node-local-dns, 64MB => 256MB

NLD Memory per pod on Metrics Service hosts (and limit)

Metrics Service Error rate (**server** / **client**)



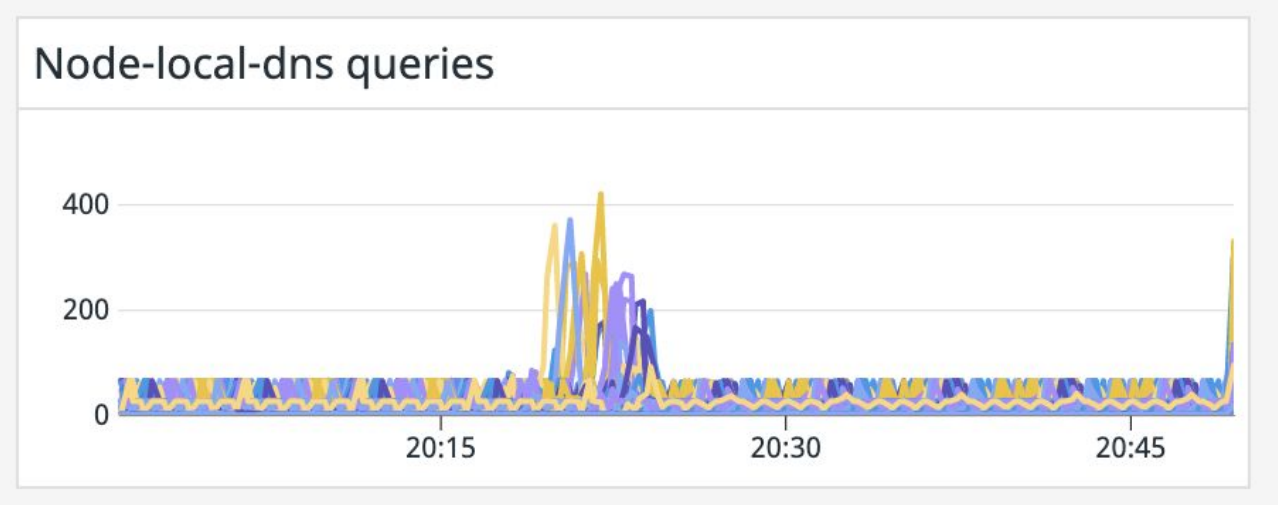
Node-local-dns max concurrent rejects



No more OOM-kills

But not any better for Metrics Service

Too many queries at startup?



Max_concurrent: **1000**

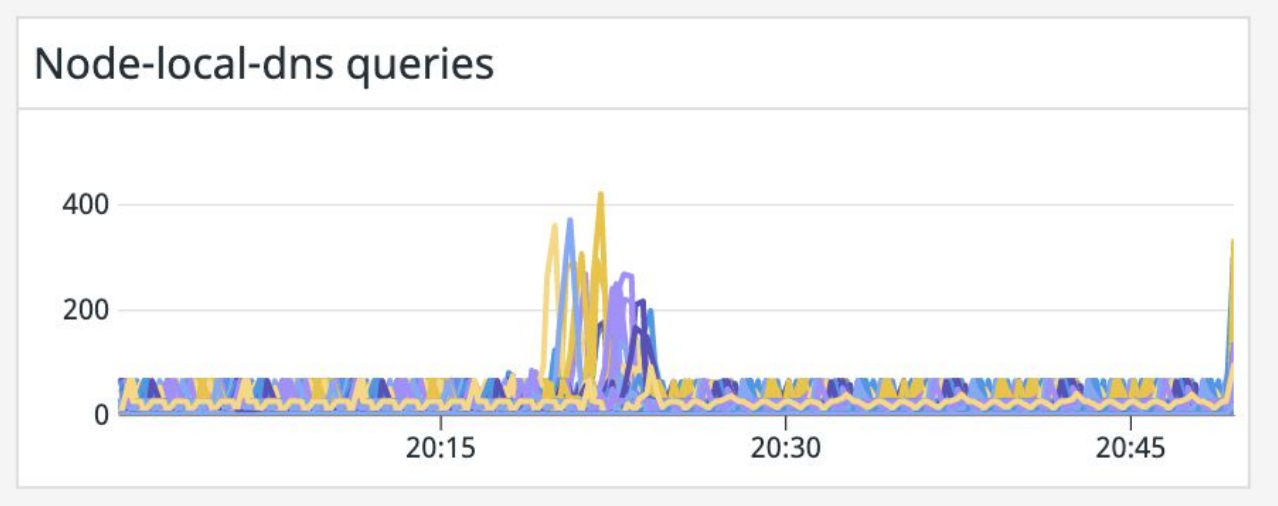
Upstream queries: ~5ms

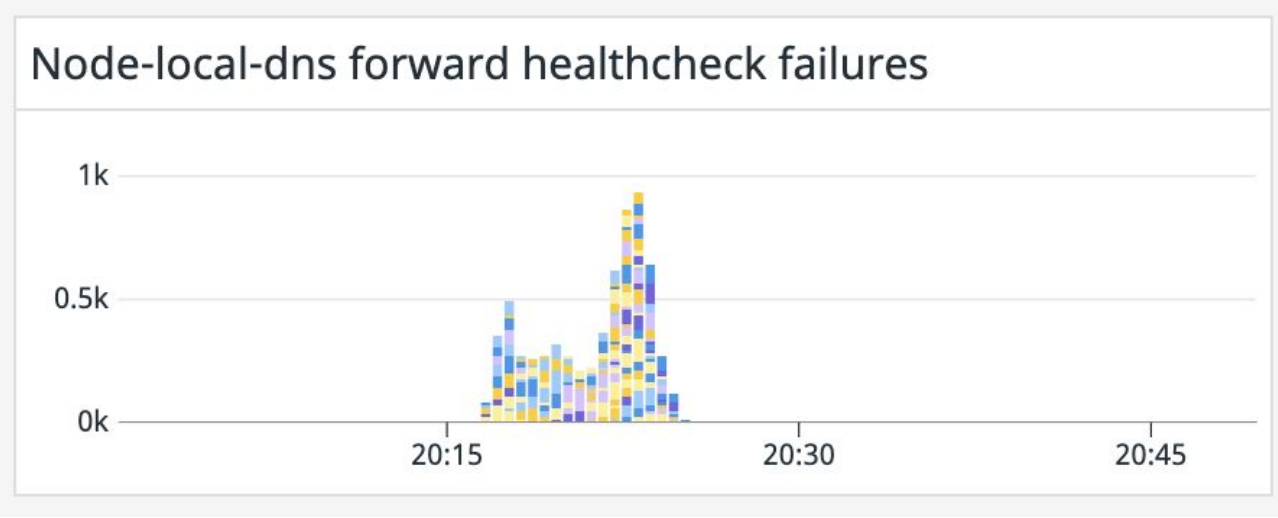
=> NLD should do **> 200k rps**

=> with **<400 rps** we hit max_concurrent

What's happening?

Too many queries at startup?





Upstream marked unhealthy

Upstream is TCP

Connections are reused

but expire=10s

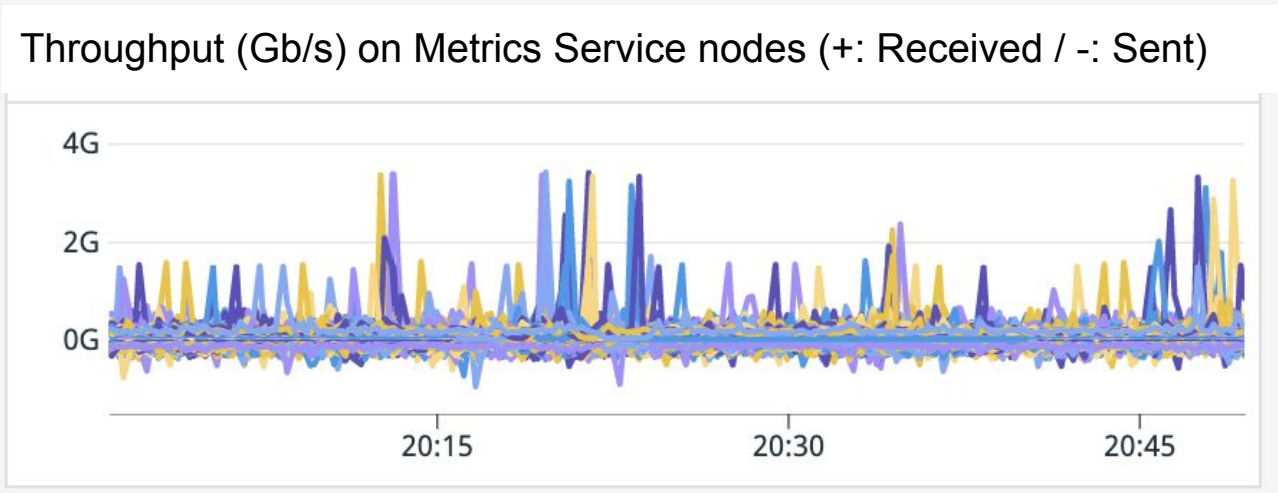
NLD can't create connections?

Why we hit max_concurrent

- NLD can't establish connections to upstreams
- The Forward plugin has a 5s timeout by default
- Incoming queries occupy a query slot for 5s

=> We hit max_concurrent=1000 with only 200rps

Networking issues?



m5.4xlarge

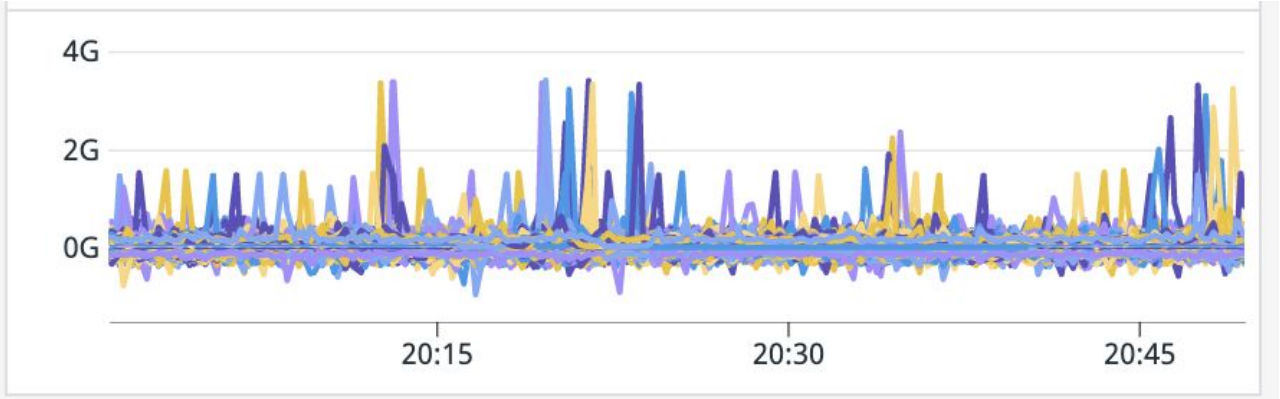
Max: 10Gb/s

Sustained: 5Gb/s

=> looks ok

Networking issues?

Throughput (Gb/s) on Metrics Service nodes (+: Received / -: Sent)



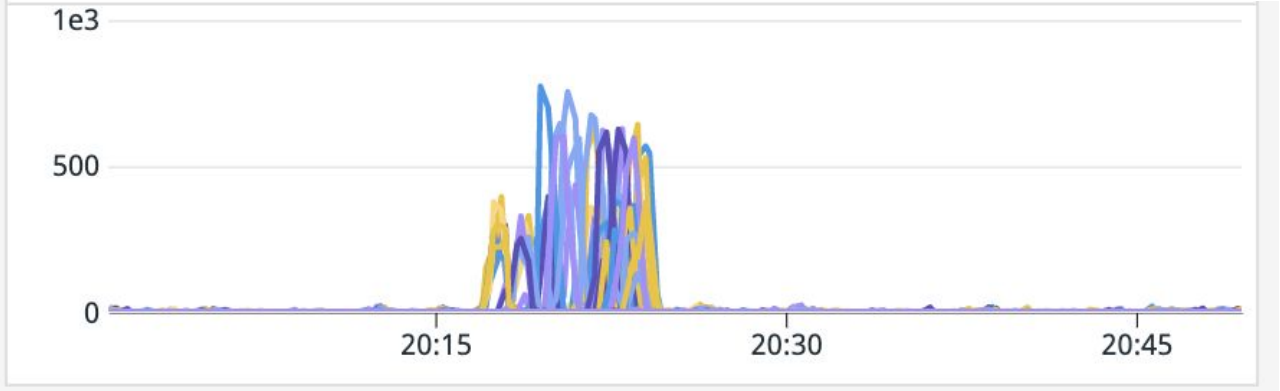
m5.4xlarge

Max: 10Gb/s

Sustained: 5Gb/s

=> looks ok

TCP retransmits on Metrics Service nodes



But we are dropping packets

Microbursts?

=> Elastic Network Adapter (ENA) metrics

Status

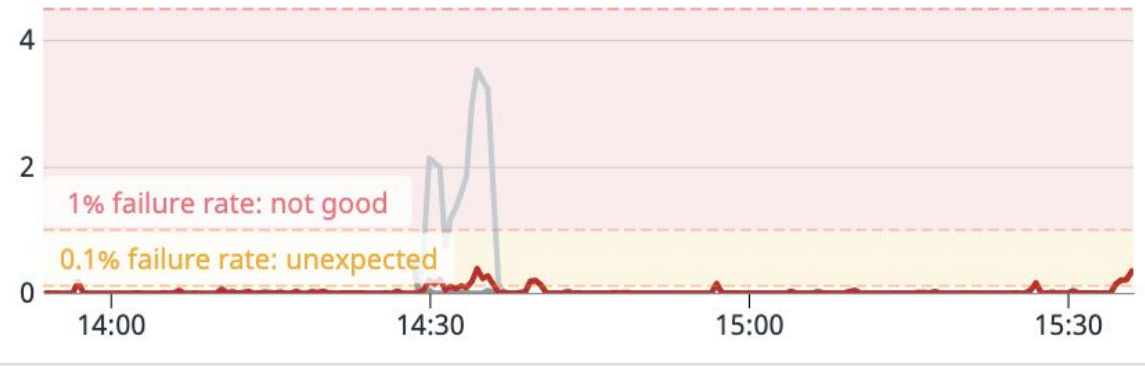
- DNS errors in Metrics Service on rollouts
- Node-local-DNS can't establish connections

=> *Network issue?*

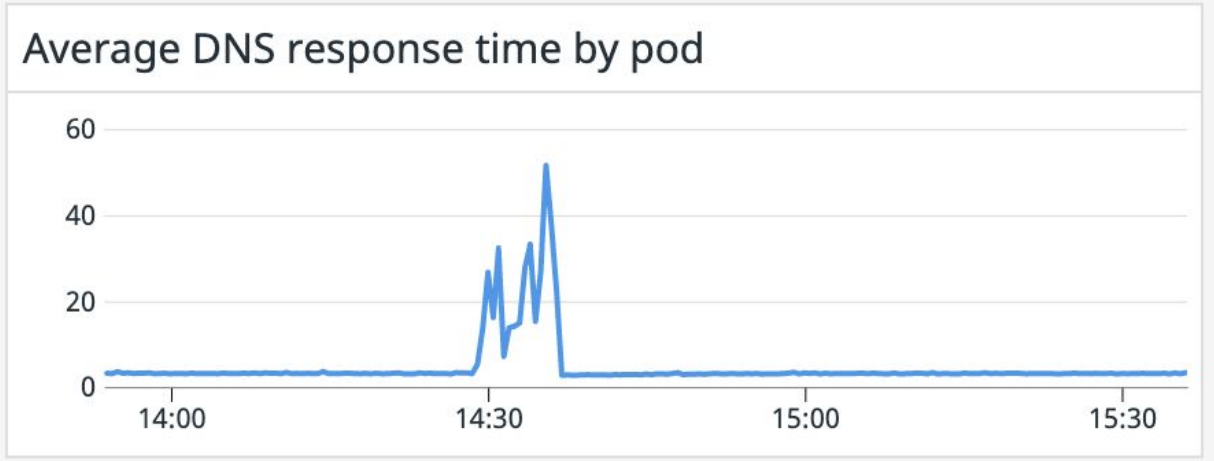
Chapter 2: AWS Networking

Are we bursting over the instance limits?

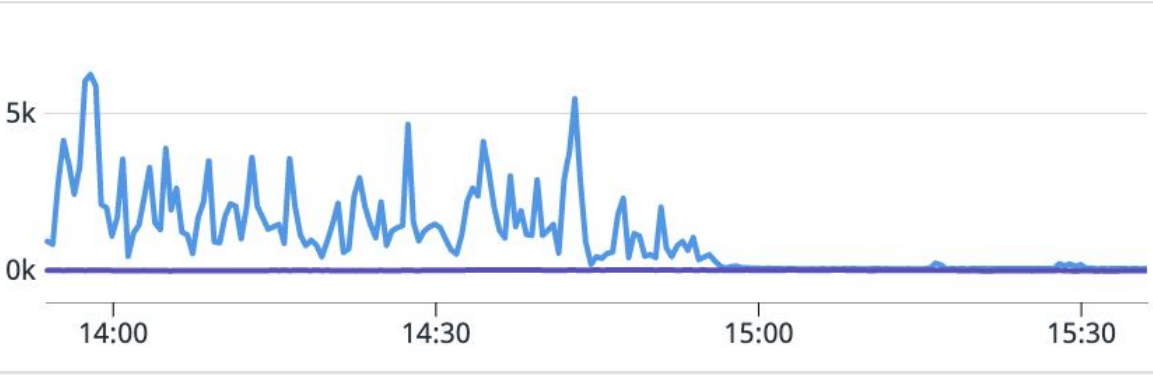
Metrics Service Error rate (**server** / **client**)



Average DNS response time by pod



ENA: Bandwidth exceeded (**+:in** / **-:out**)

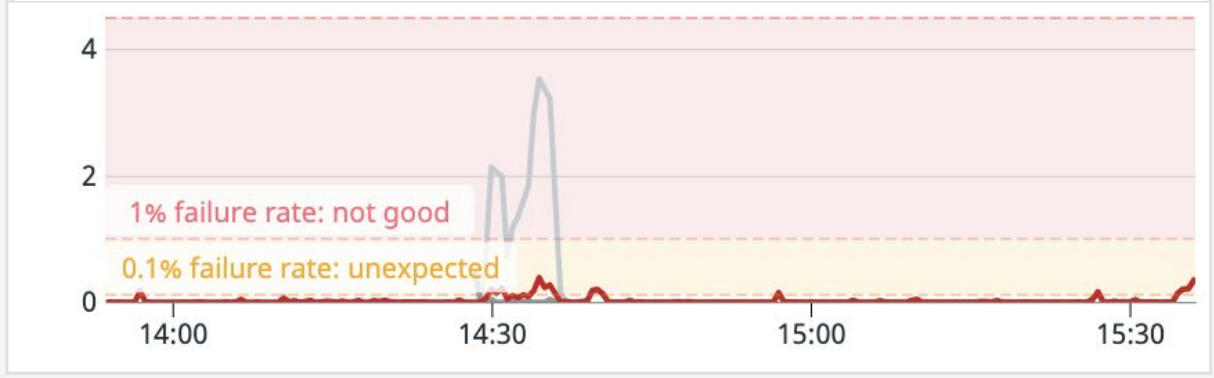


We are saturating the interface

But no correlation with errors

Are we bursting over the instance limits?

Metrics Service Error rate (**server** / **client**)



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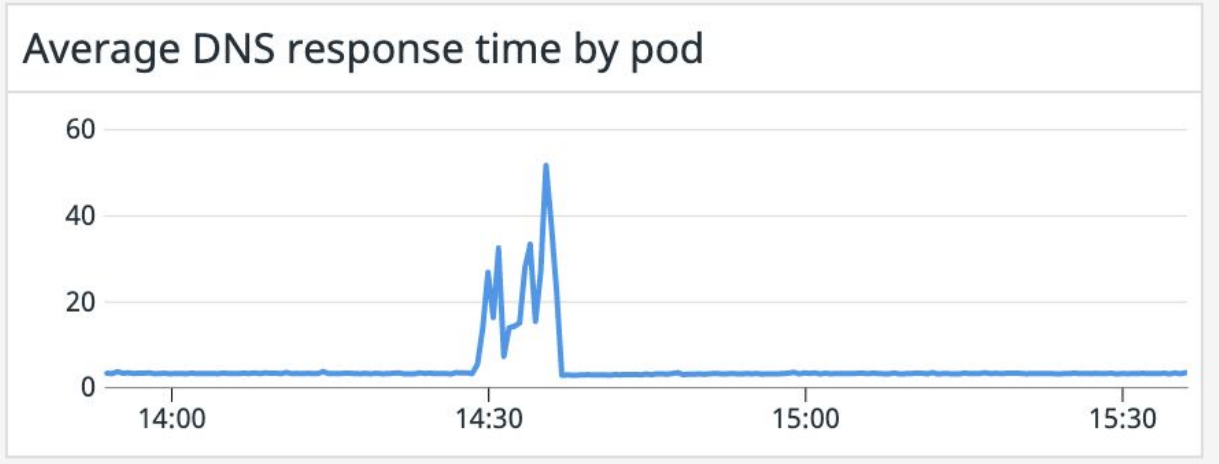
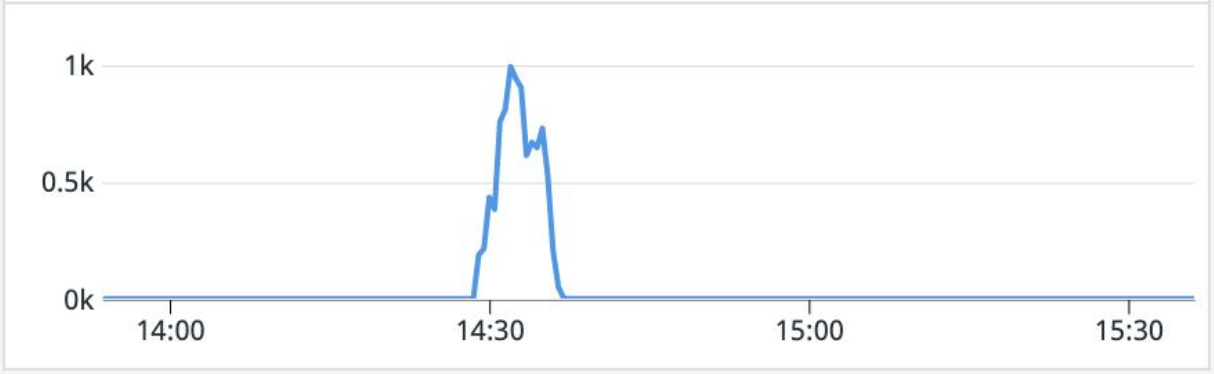


ENA: Conntrack exceeded



conntrack allowance exceeded?

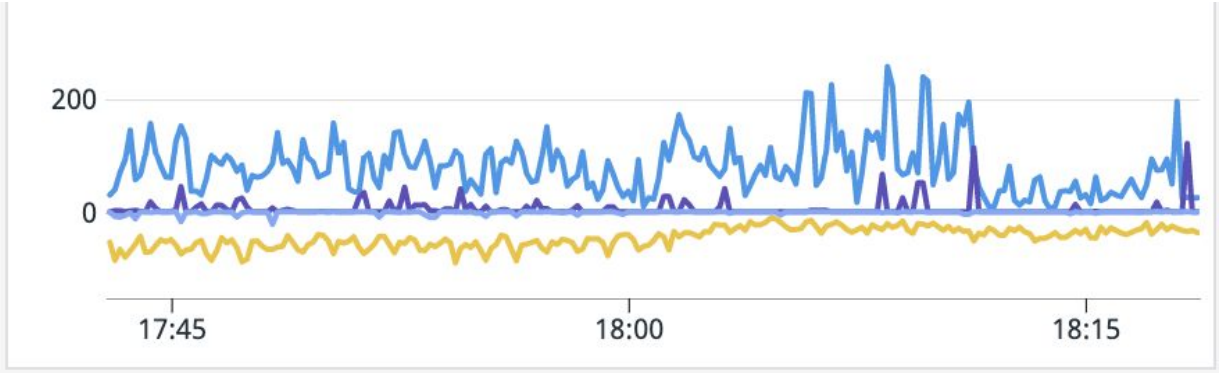
aws.ec2.conntrack_allowance_exceeded

The number of packets dropped because connection tracking exceeded the maximum for the instance and new connections could not be established. This can result in packet loss for traffic to or from the instance

Connection tracking is required for security groups (stateful)

Let's test with network optimized instances

ENA: Bandwidth exceeded

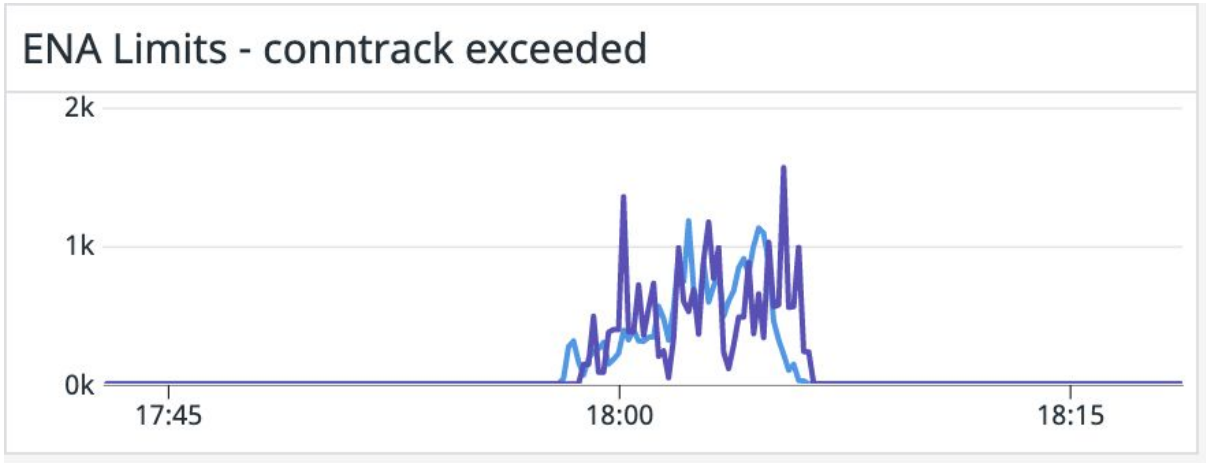


blue/**yellow** => m5.4xlarge

purple/**grey** (~0) => m5n.4xlarge

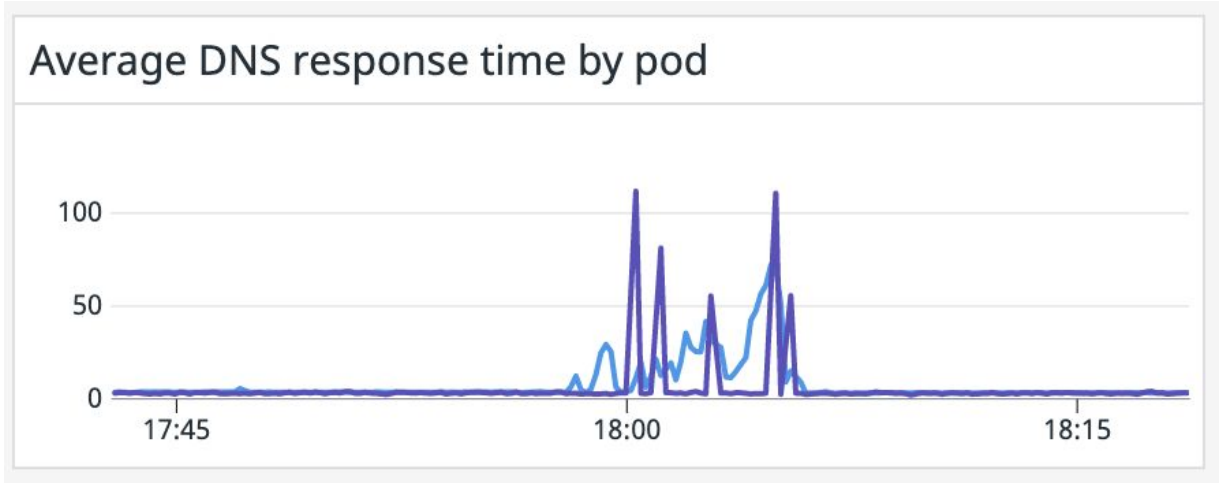
Promising!

Let's test with network optimized instances



m5.4xlarge

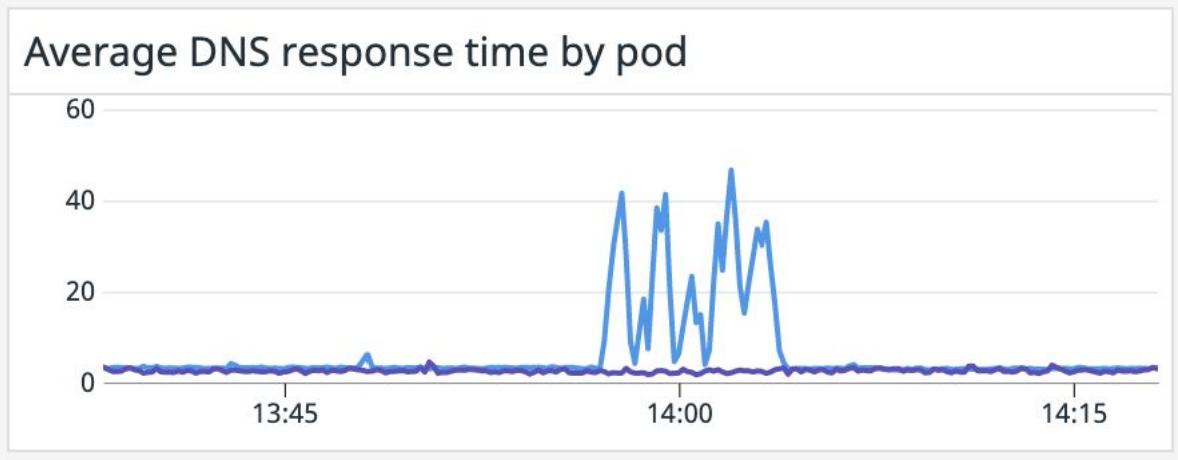
m5n.4xlarge



No impact on

- Conntrack
- Metrics Service errors / latency

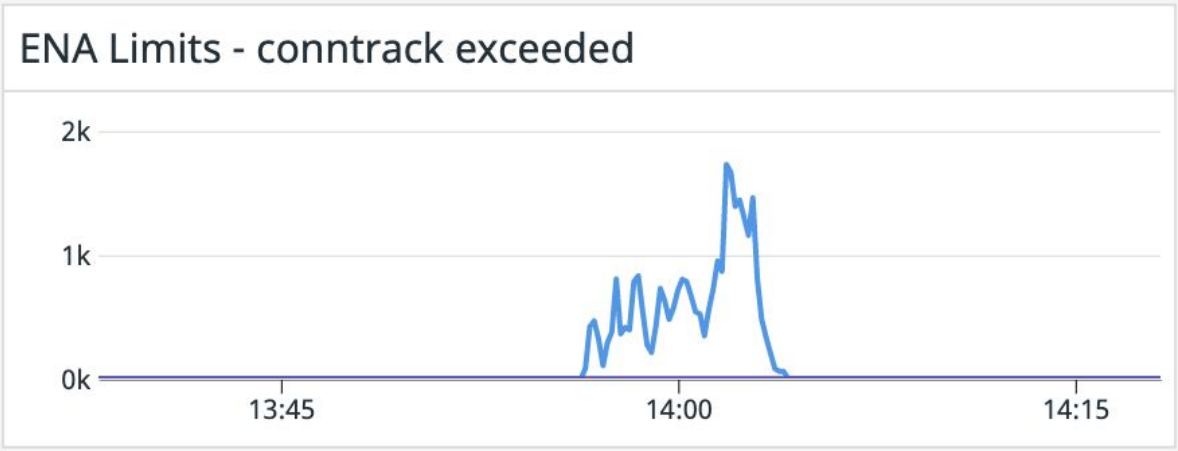
What about bigger instances?

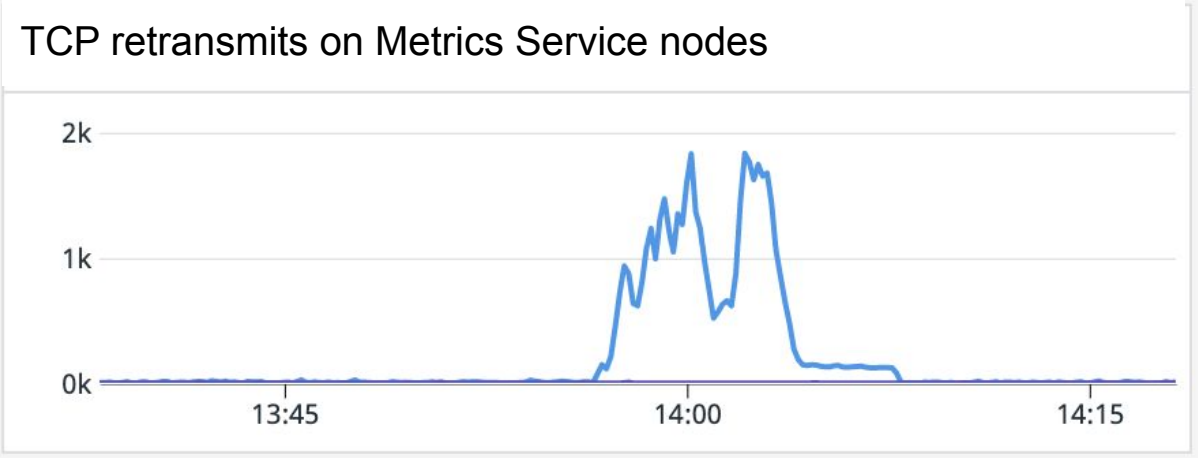


m5.4xlarge

m5.8xlarge

Much better!





Conntrack limits?

From AWS

- Hypervisor conntrack can track hundreds of thousands of flows
- m5.8xlarge : can track 2x the flows compared to m5.4xlarge
- m5n.4xlarge : same as m5.4xlarge

=> Makes sense based on our tests

How can we saturate this conntrack?

Stable state: **~13k** connections

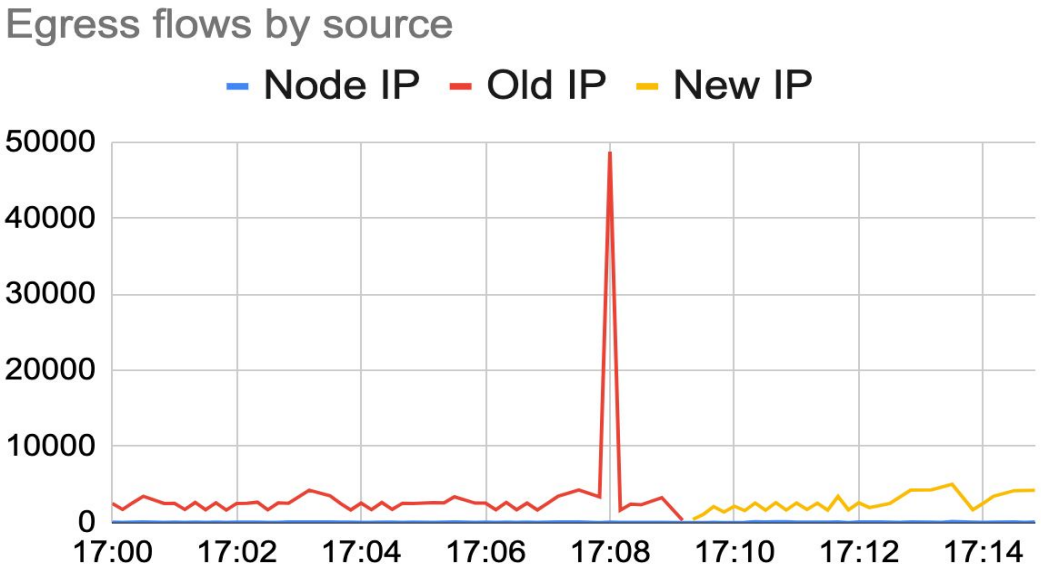
Rollouts: **~60k**

Pretty high but **60k vs X00k ????**

VPC Flow Logs

- Capture IP flow information on Elastic Network Interfaces (ENI)
- **Flow level: 5-tuple, 2 flows per TCP connection**
- Flow record: 5 tuple, bytes, packets, TCP flags...
- Aggregated every 1mn and delivered to S3
- **Not always complete**
- Huge amount for large VPCs (we filtered with Athena)

Flows initiated by a Metrics Service node

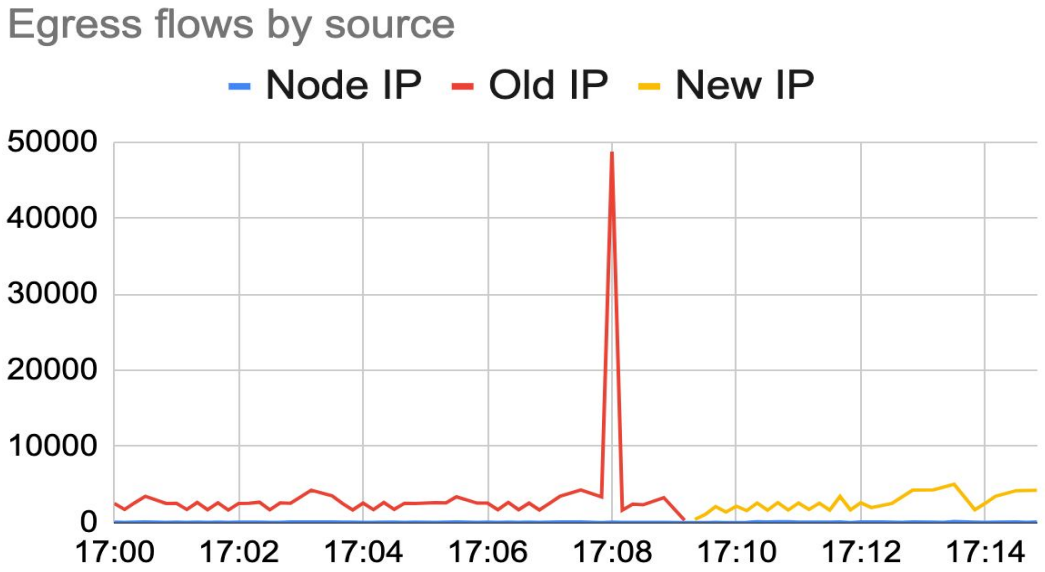


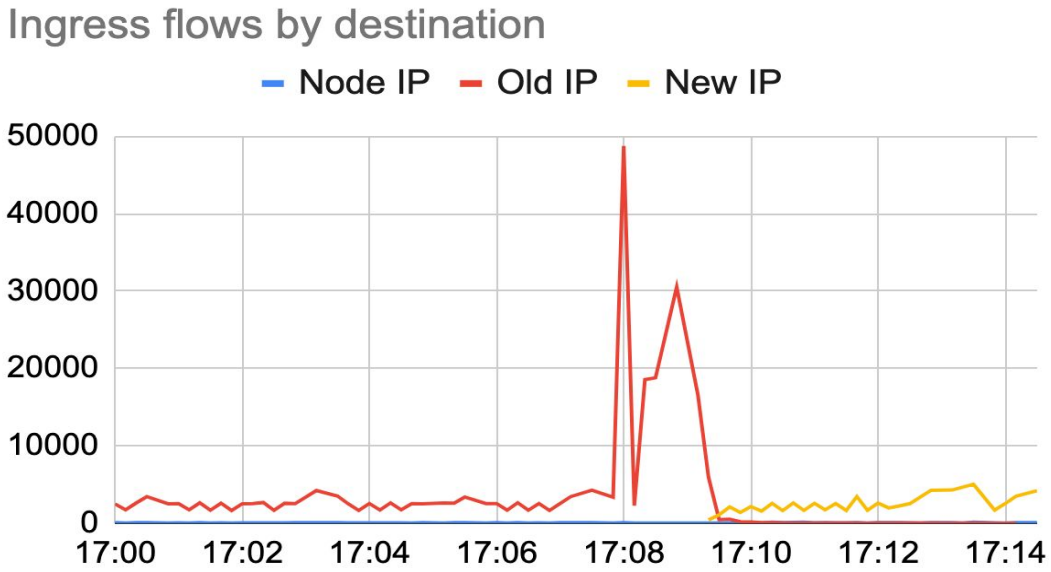
Old pod IP disappears after ~60s

Spike in flows at pod deletion

50k flows in 1mn feels very high

What about ingress flows?



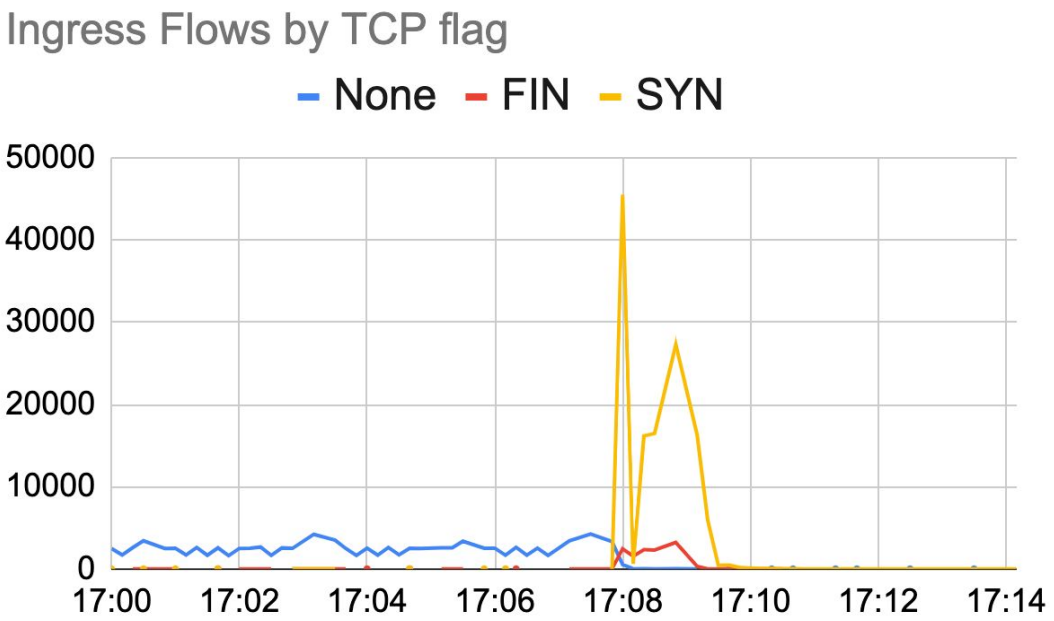


Ingress flows should ~match Egress

Very weird second spike

What are these flows?

Zoom on ingress flows to old IP

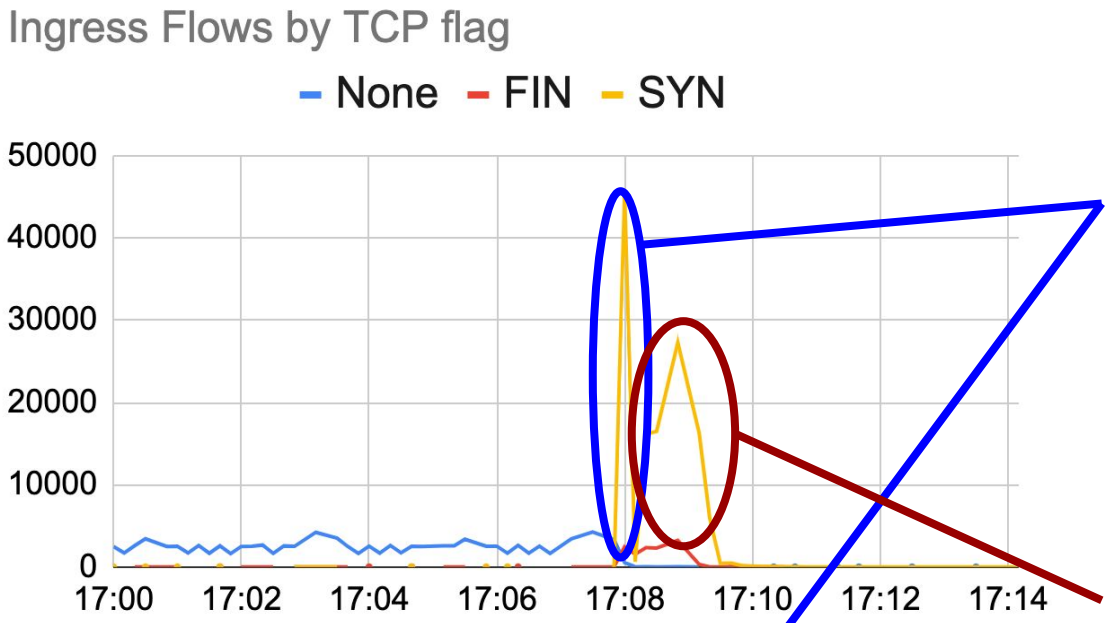


None: already established

FIN: terminating

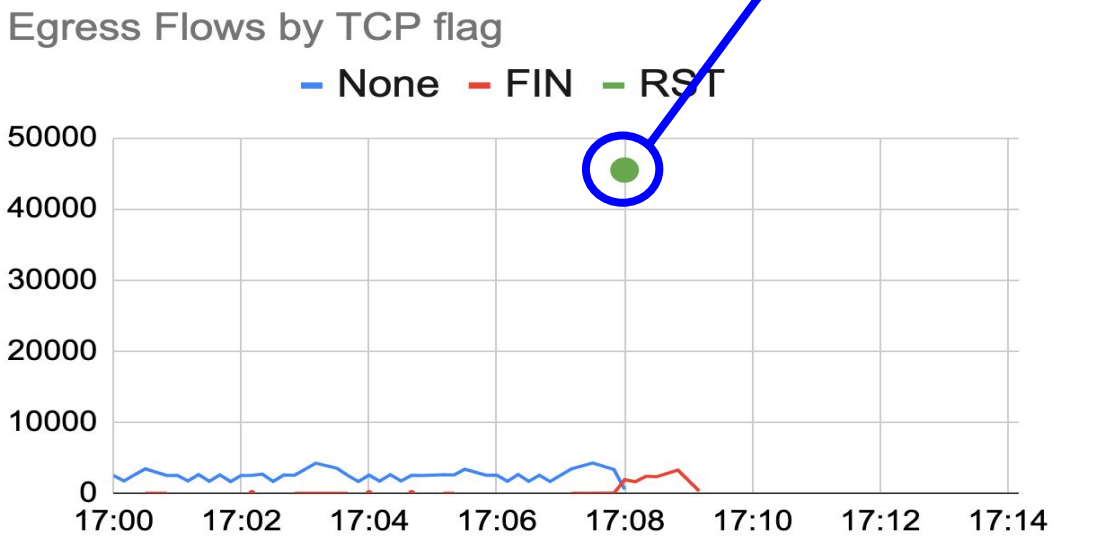
SYN: reconnect attempts: **130k over 90s!**

What about egress?



RST match first SYN spike

What about this second spike?

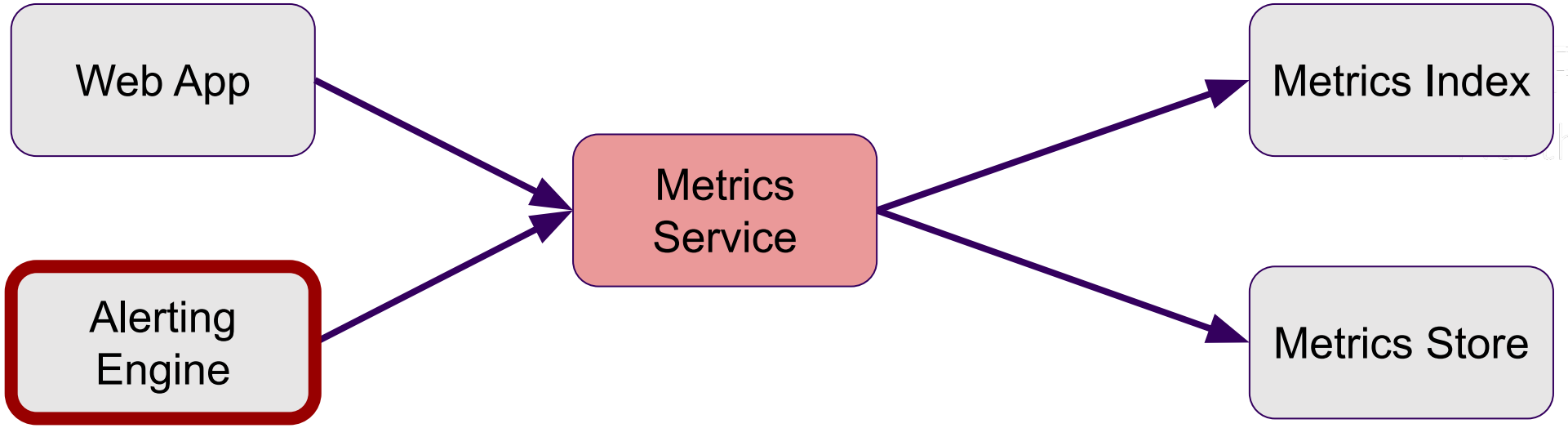


Why do we get RST for a few seconds only?

- Metrics Service performs a grpc.GracefulStop with 10s timeout
  - Server stops accepting new connections
  - Server waits for existing RPC to finish
  - Server tells clients to disconnect (HTTP2 GoAway)
- During these 10s, incoming connection attempts get an RST
- After these 10s, the pod is deleted and its IP is not bound by anything

Where are these attempts coming from?

Only a few IPs => Alerting Engine



Where are these attempts coming from?

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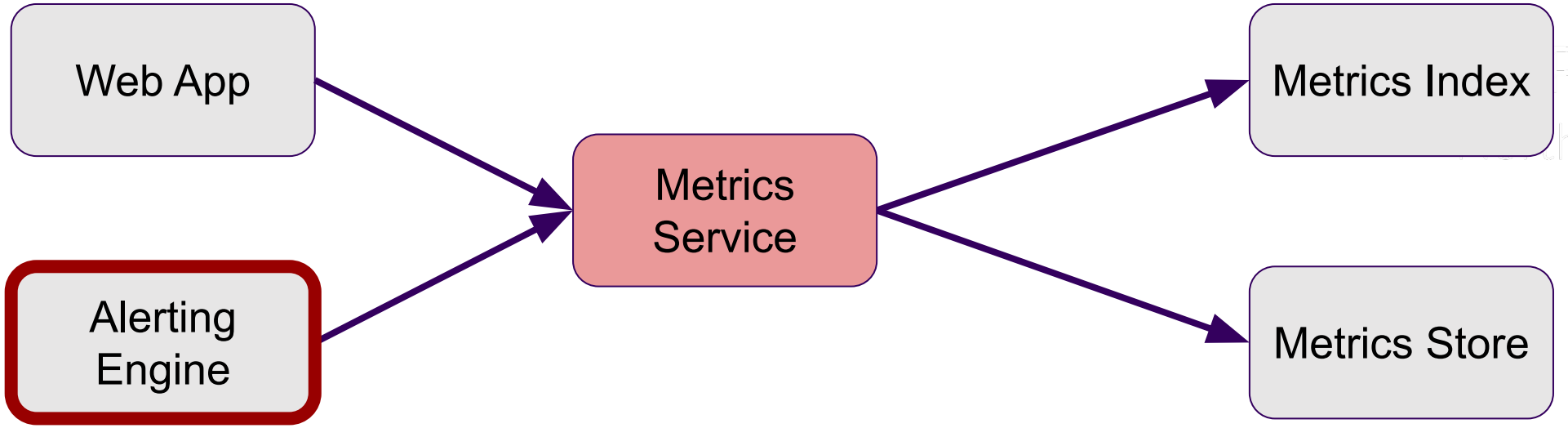
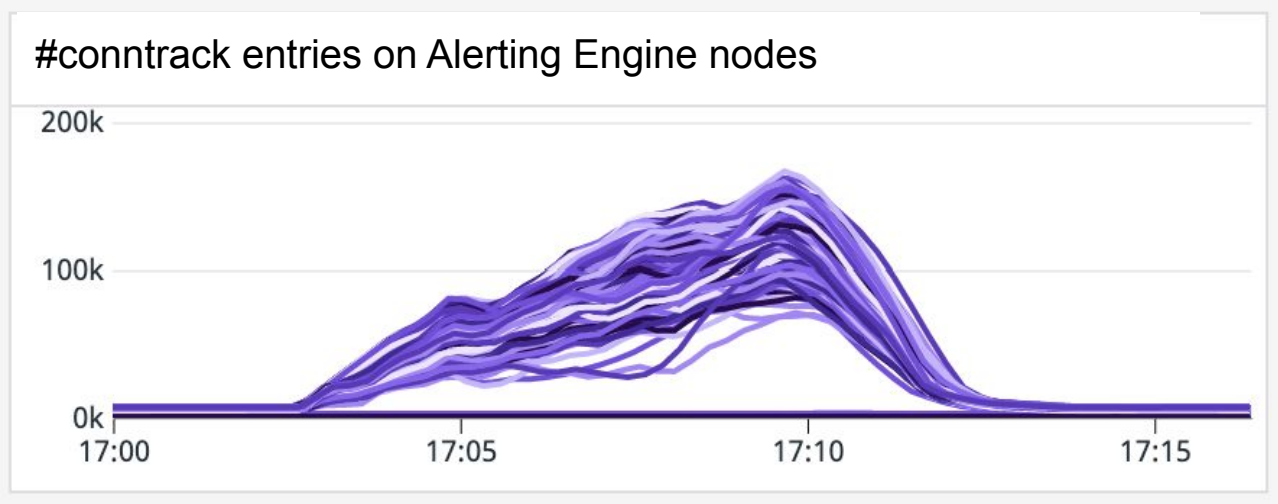




Seems to confirm!

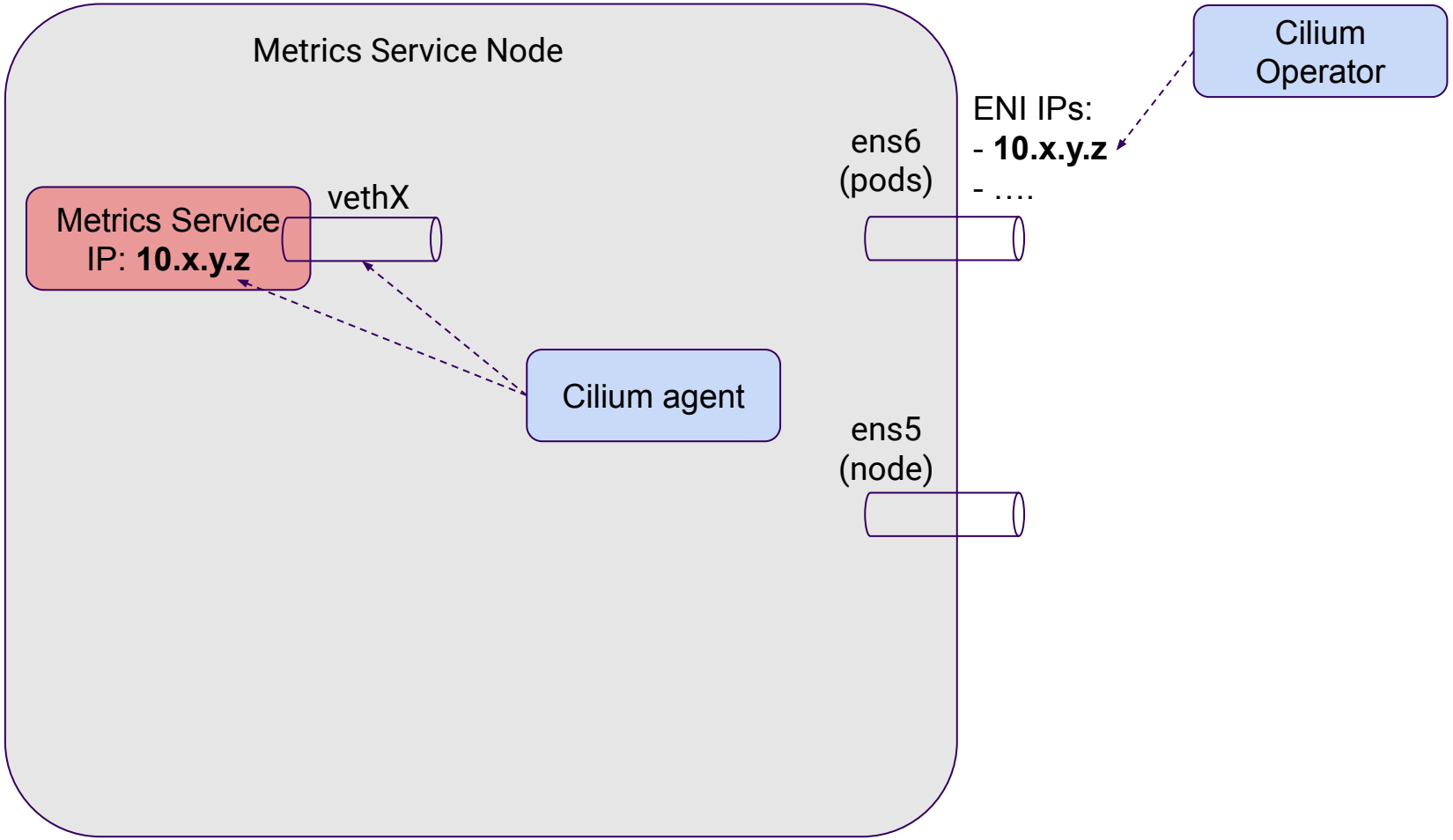
Status

- DNS errors in Metrics Service on rollouts
- Node-local-DNS can't establish connections
- AWS conntrack for instance is saturated
- Alerting Engine is SYN-Flooding Metrics Service on rollouts

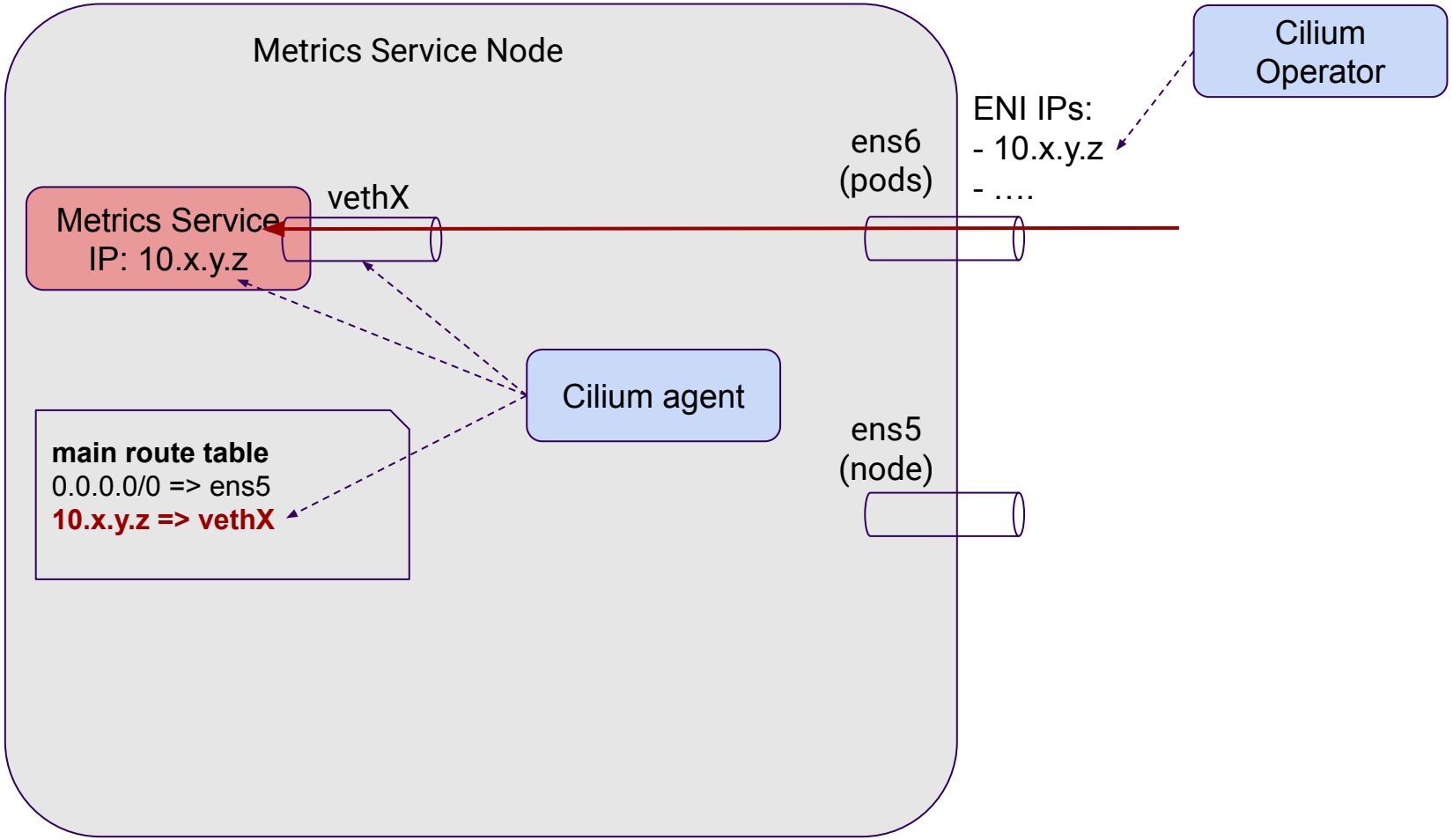
=> *Why don't we see these connections on Metric Service Nodes?*

Chapter 3: Node Networking

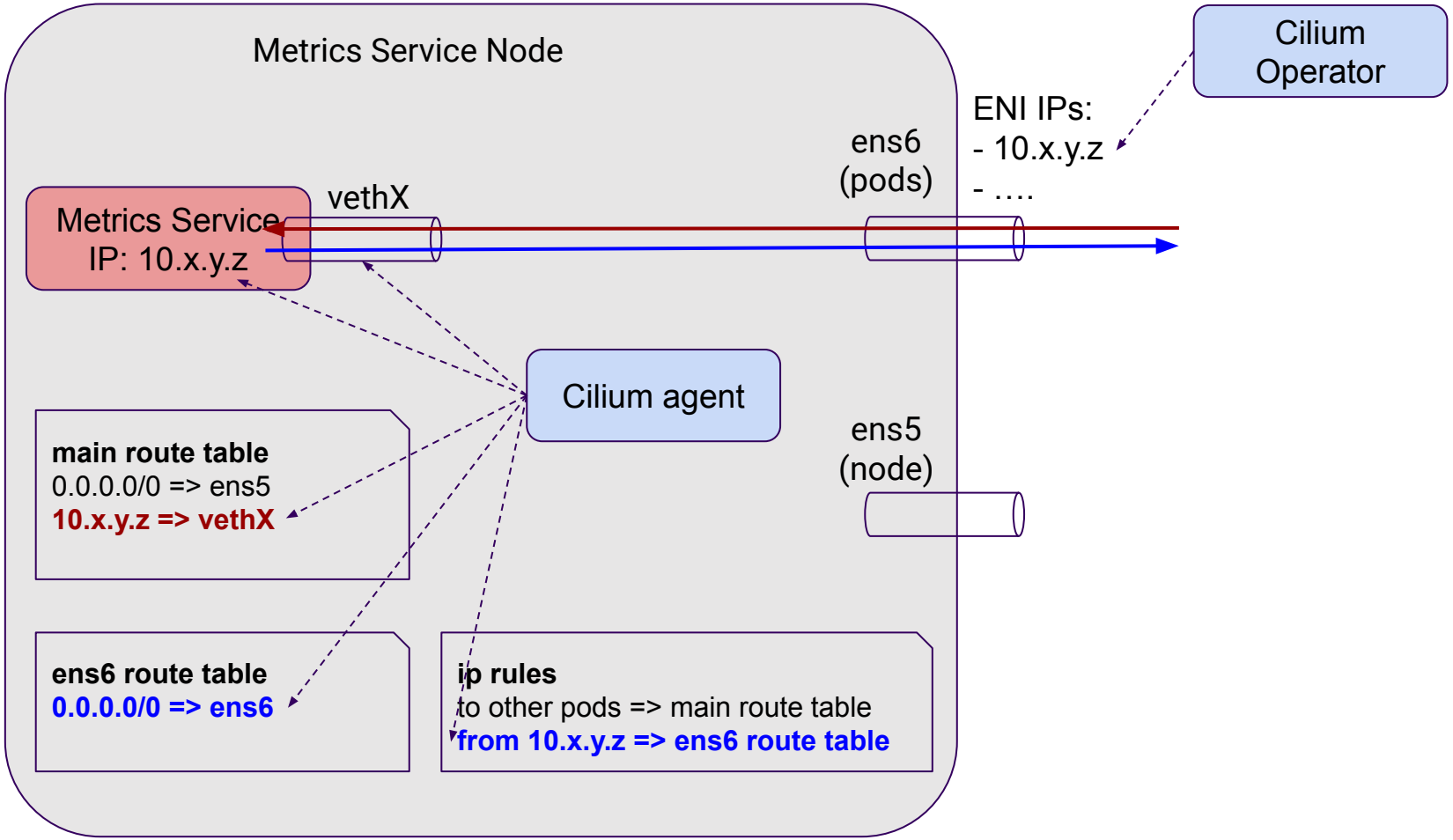
Routing on nodes



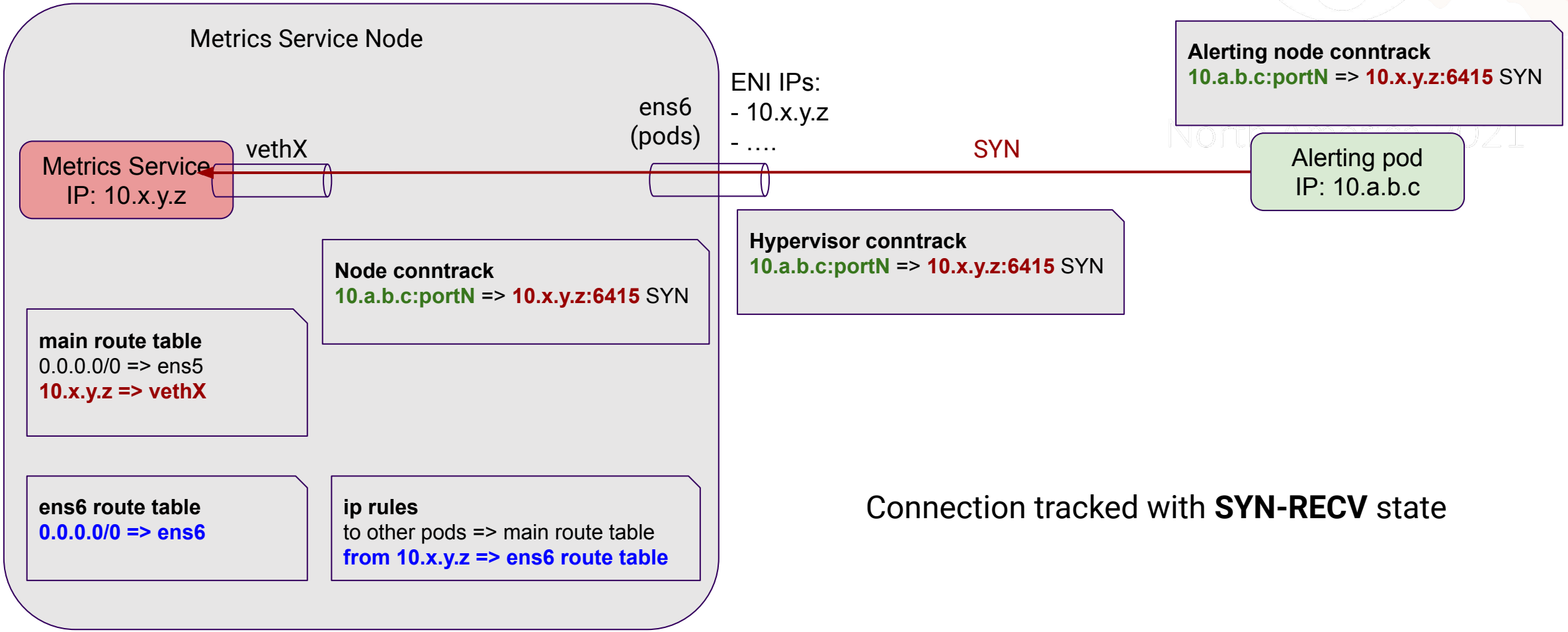
Routing on nodes



Routing on nodes

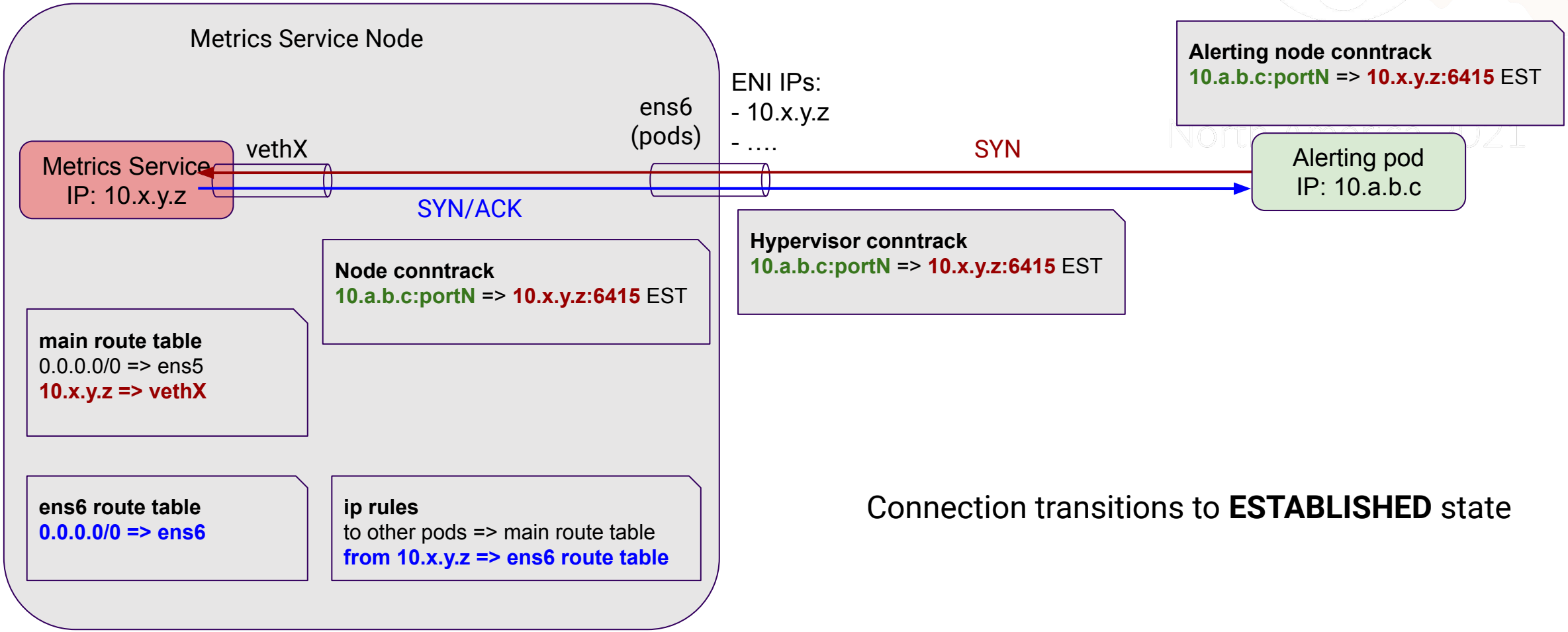


Stable state



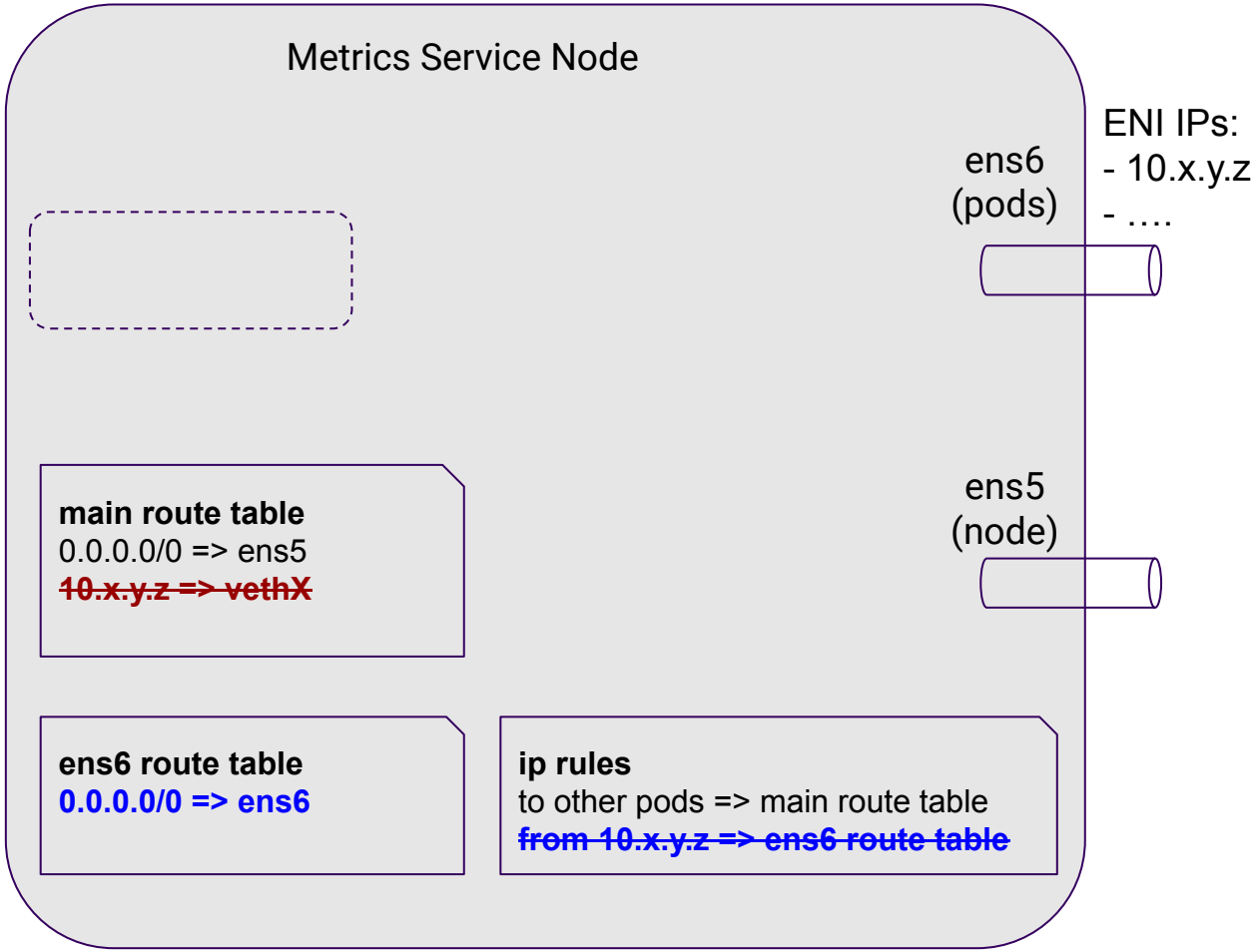
Connection tracked with **SYN-RECV** state

Stable state

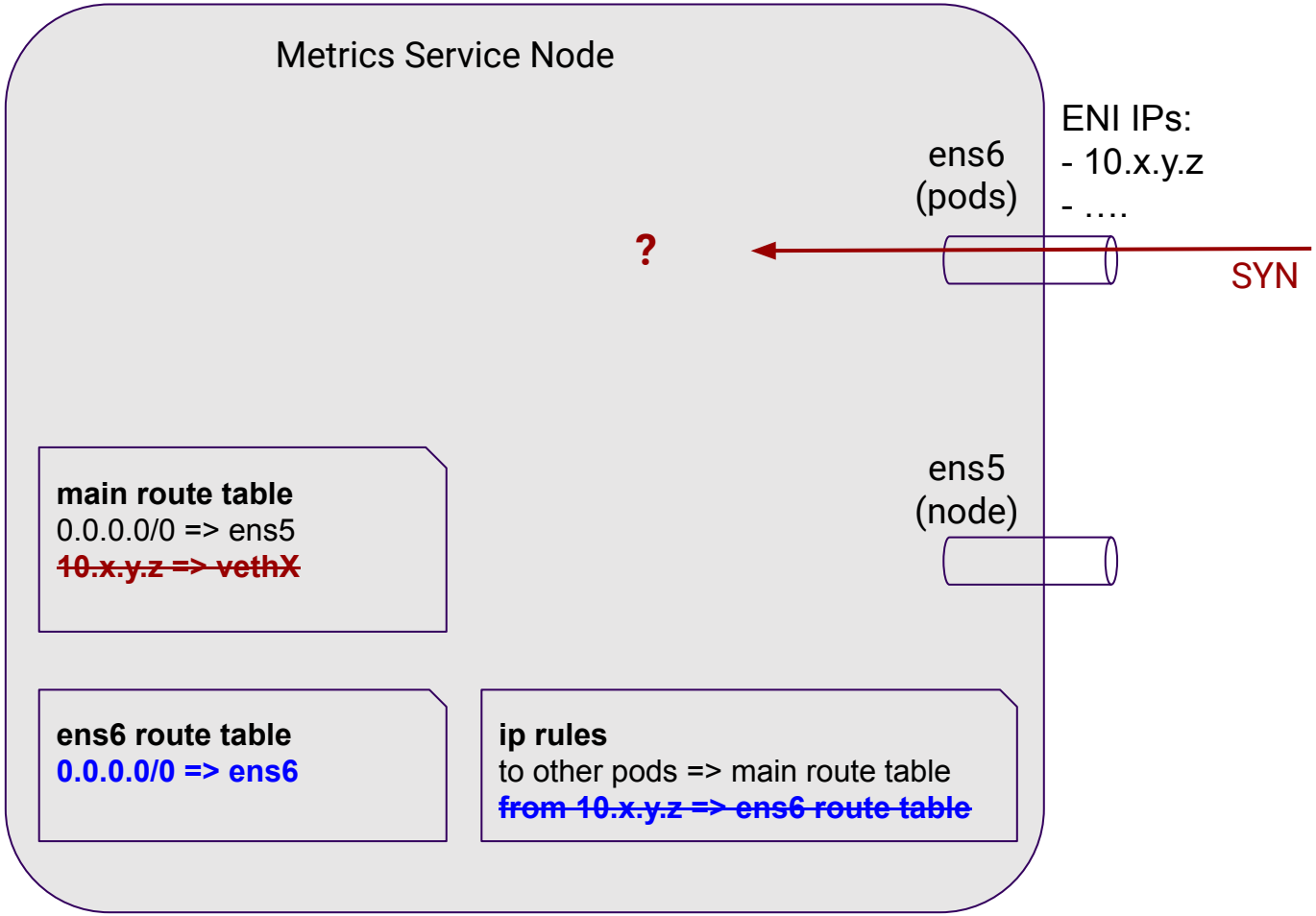


Connection transitions to **ESTABLISHED** state

What happens on pod deletion?



What about traffic to old IP?



Let's simulate

Delete pod with IP 10.x.y.z on nodeB and attempt to connect from nodeA

Connection attempt

```
nodeA:~$ nc -vz 10.x.y.z 12345
```

Let's simulate

Delete pod with IP 10.x.y.z on nodeB and attempt to connect from nodeA

Connection attempt

```
nodeA:~$ nc -vz 10.x.y.z 12345
```


On nodeB => SYN without an answer

```
nodeB:~$ sudo tcpdump -pni ens6 "port 12345"
listening on ens5, link-type EN10MB (Ethernet), capture size 262144 bytes
08:28:52.086251 IP 10.a.b.c.51718 > 10.x.y.z.12345: Flags [S], seq 4126537246, win 26883, options [mss
8961,sackOK,TS val 2002199904 ecr 0,nop,wscale 9], length 0
```

Let's simulate

Delete pod with IP 10.x.y.z on nodeB and attempt to connect from nodeA

Connection attempt

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nodeA:~$ nc -vz 10.x.y.z 12345
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8961,sackOK,TS val 2002199904 ecr 0,nop,wscale 9], length 0
```

Where would the SYN be routed to? => Reverse Path filter!

```
$ ip route get 10.x.y.z from 10.a.b.c iif ens6
RTNETLINK answers: Invalid cross-device link
```

Let's simulate

Delete pod with IP 10.x.y.z on nodeB and attempt to connect from nodeA

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```
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```

Where would the SYN be routed to? => Reverse Path filter!

```
$ ip route get 10.x.y.z from 10.a.b.c iif ens6
RTNETLINK answers: Invalid cross-device link
```

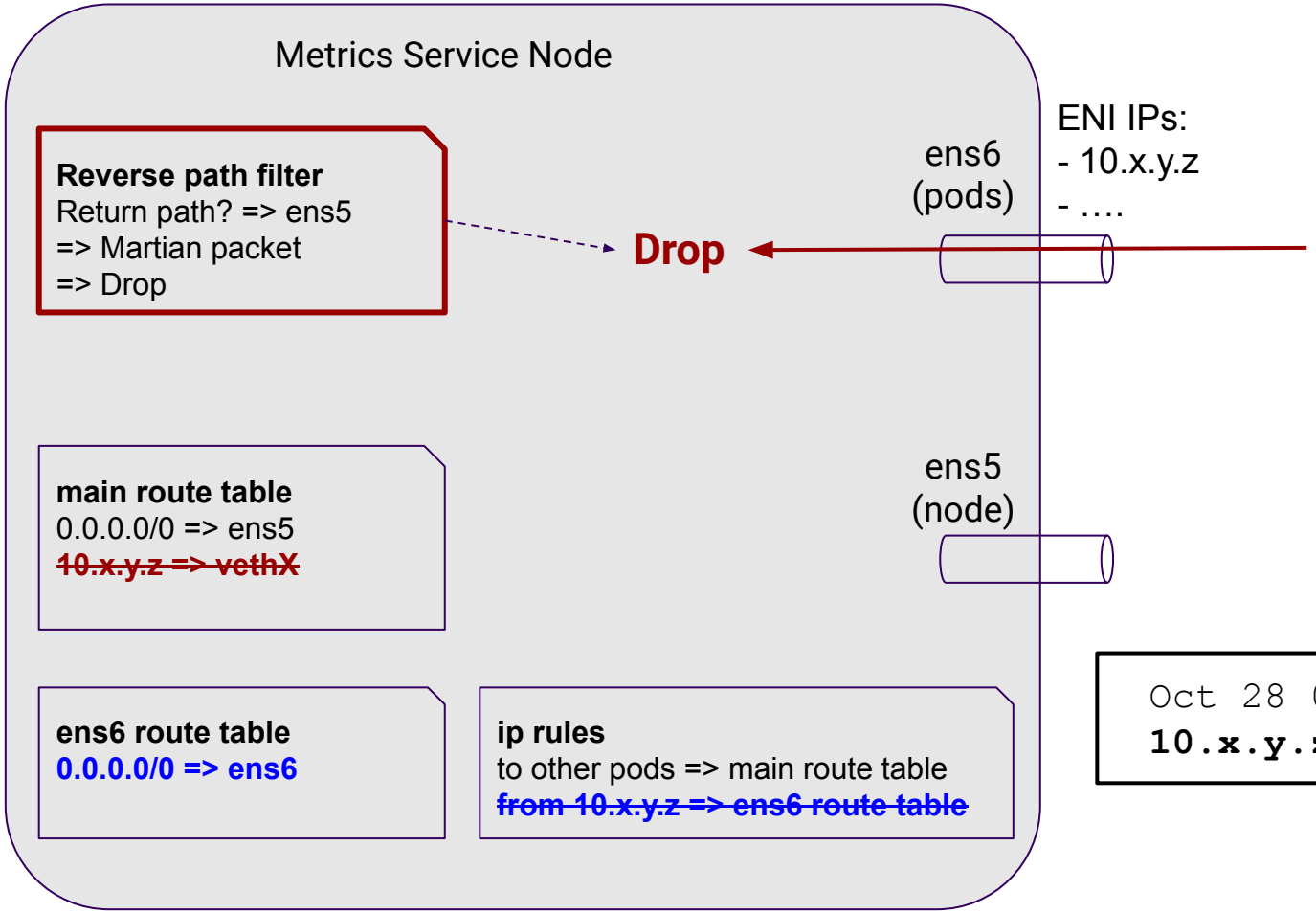
Sure enough, martian packet warning in kernel logs

```
Oct 28 08:25:54 nodeB kernel: IPv4: martian source 10.x.y.z from 10.a.b.c, on dev ens6
```

Reverse Path filtering

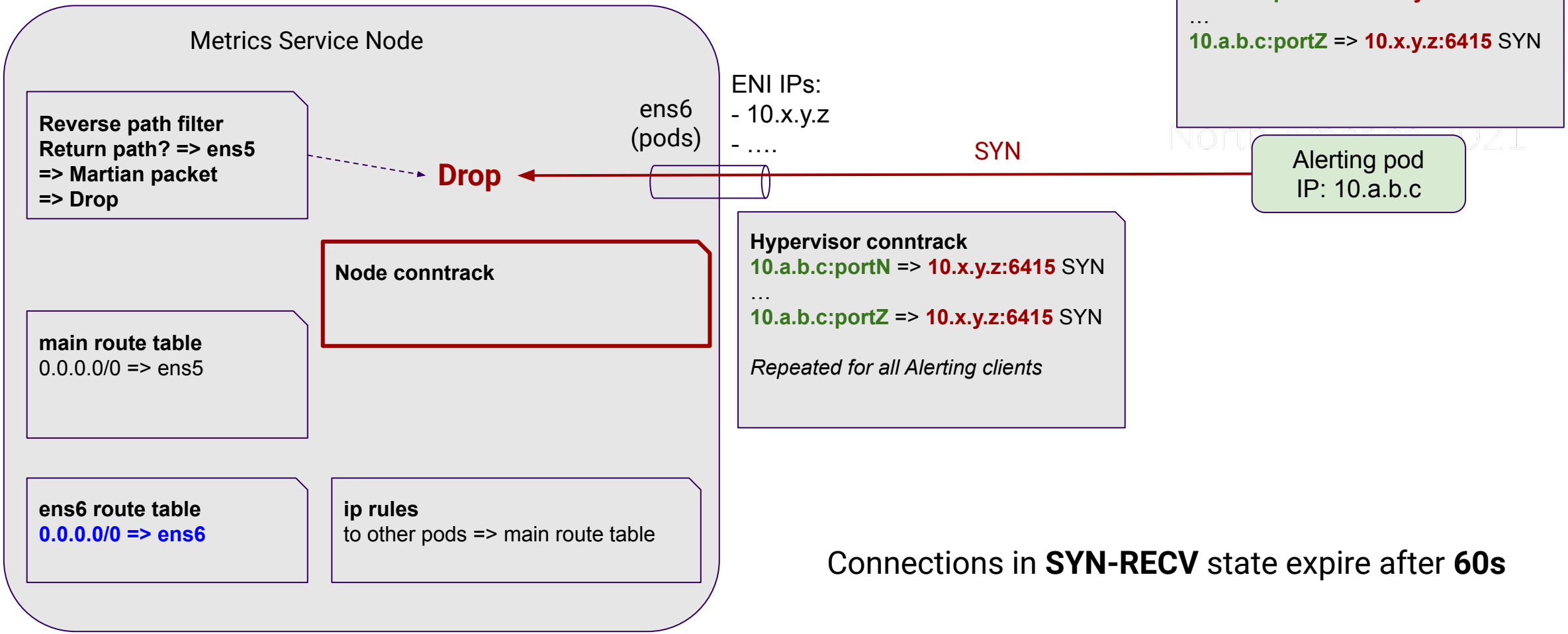
- Security feature from the kernel to prevent IP spoofing
  - If return path uses incoming interface accept the packet
  - Otherwise drop it
- Log these events : "Martian Packets"
- Loose mode: only drop if there is no return route

Back to our node




```
Oct 28 08:25:54 kernel: IPv4: martian source
10.x.y.z from 10.a.b.c, on dev ens6
```

What about conntracks?



Connections in **SYN-RECV** state expire after **60s**

But, we use "loose" mode


```
$ ip route get 10.x.y.z from 10.a.b.c iif ens6
RTNETLINK answers: Invalid cross-device link

$ sysctl net.ipv4.conf.ens6.rp_filter
net.ipv4.conf.ens6.rp_filter = 2
```

- rp_filter = 2 => loose mode
- Loose + default route (ens5) => we should not drop
- What's happening?

Let's have a look

https://github.com/torvalds/linux/blob/master/net/ipv4/fib_frontend.c#L344

```
336  /* Given (packet source, input interface) and optional (dst, oif, tos):
337   * - (main) check, that source is valid i.e. not broadcast or our local
338   *   address.
339   * - figure out what "logical" interface this packet arrived
340   *   and calculate "specific destination" address.
341   * - check, that packet arrived from expected physical interface.
342   * called with rcu_read_lock()
343   */
344  static int __fib_validate_source(struct sk_buff *skb, __be32 src, __be32 dst,
345                                   u8 tos, int oif, struct net_device *dev,
346                                   int rpf, struct in_device *idev, u32 *itag)
347  {
```

Let's have a look

```
416  e_rpf:
417          return -EXDEV;
```

```
22   #define EXDEV           18      /* Cross-device link */
```

Let's have a look

```
416   e_rpf:
417           return -EXDEV;


408   last_resort:
409           if (rpf)
410                   goto e_rpf;
```

Let's have a look


```
416   e_rpf:
417           return -EXDEV;


408   last_resort:
409           if (rpf)
410                   goto e_rpf;


395           if (no_addr)
396                   goto last_resort;
```

Let's have a look


```
416   e_rpf:
417           return -EXDEV;


408   last_resort:
409           if (rpf)
410                   goto e_rpf;


395           if (no_addr)
396                   goto last_resort;


367           no_addr = idev->ifa_list == NULL;
```

ifa_list => List of IPs associated with device

But pod interfaces don't have IPs assigned

Let's test

```
$ ip route get 10.x.y.z from 10.a.b.c iif ens6
RTNETLINK answers: Invalid cross-device link
```


Expected, Let's now give ens6 a random IP unrelated to our network

```
$ ip addr add 192.168.1.1/32 dev ens6

$ ip route get 10.x.y.z from 10.a.b.c iif ens6
10.x.y.z from 10.a.b.c via 10.m.n.1 dev ens5
    cache iif ens6
```

We are hitting reverse path filtering because the pod interface has no IP…

- Recent versions of Cilium give it an IP
- If it has an IP, SYN are still dropped but conntrack sizes are consistent (and no martian packet warnings)
- We contributed a PR to make old IPs unreachable and send ICMP errors to clients
  https://github.com/cilium/cilium/pull/18505

Status

- DNS errors in Metrics Service on rollouts
- Node-local-DNS can't establish connections
- AWS conntrack for instance is saturated
- Alerting Engine is SYN-Flooding Metrics Service on rollouts
- Conntracks are not consistent because Reverse Path Filtering drops SYNs
- We hit Reverse Path filtering because of an edge case in the kernel

=> *Why do we have so many SYNs?*

Chapter 4: gRPC client configuration

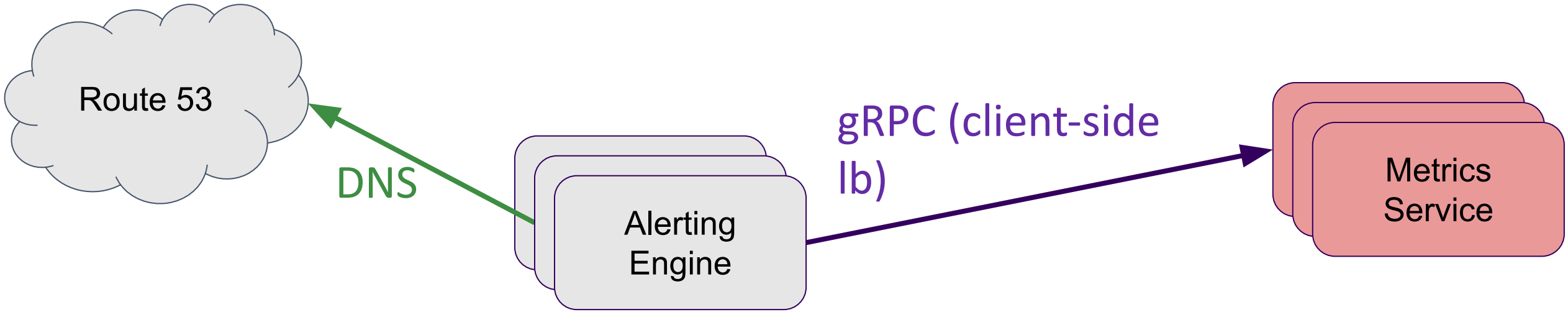
2 questions

1. Why were clients sending SYN requests for so long?
2. Why were clients sending SYN requests so frequently?

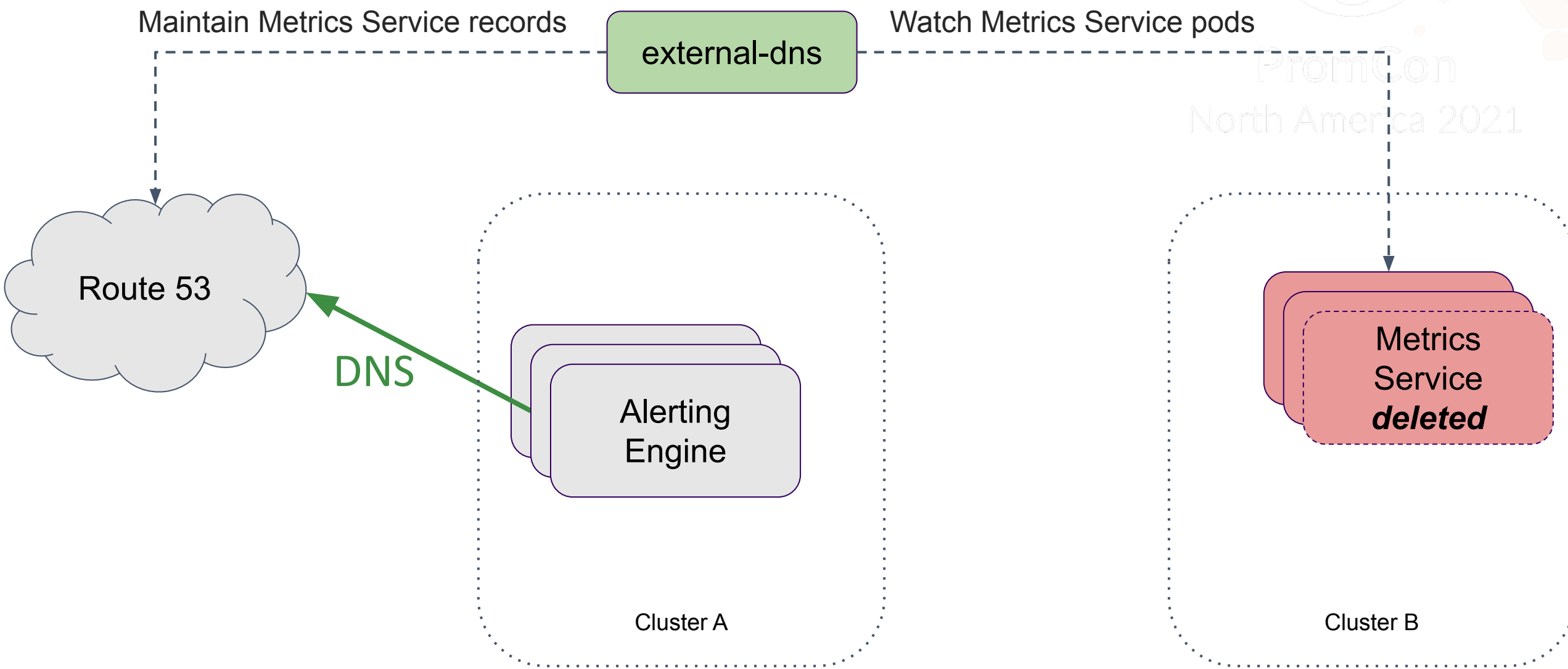
RPC setup

1. Service Discovery

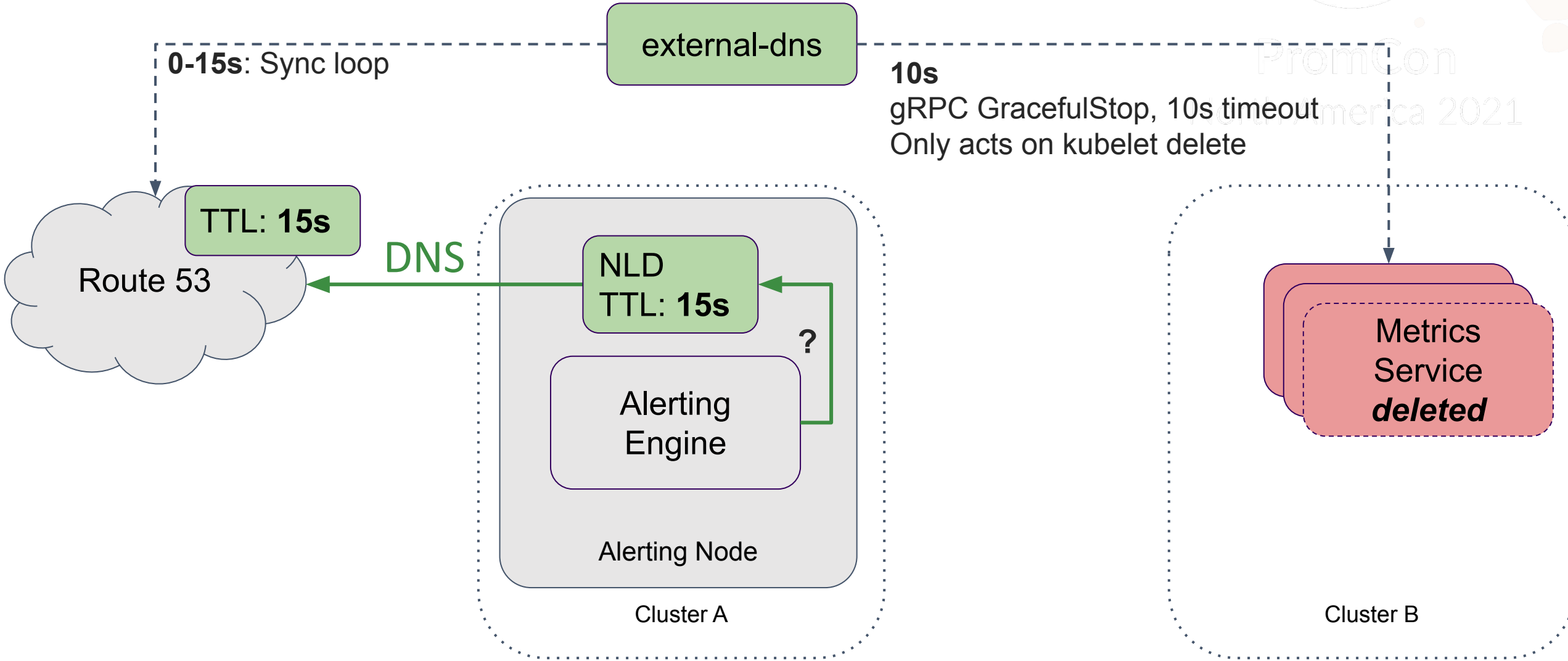
2. Query



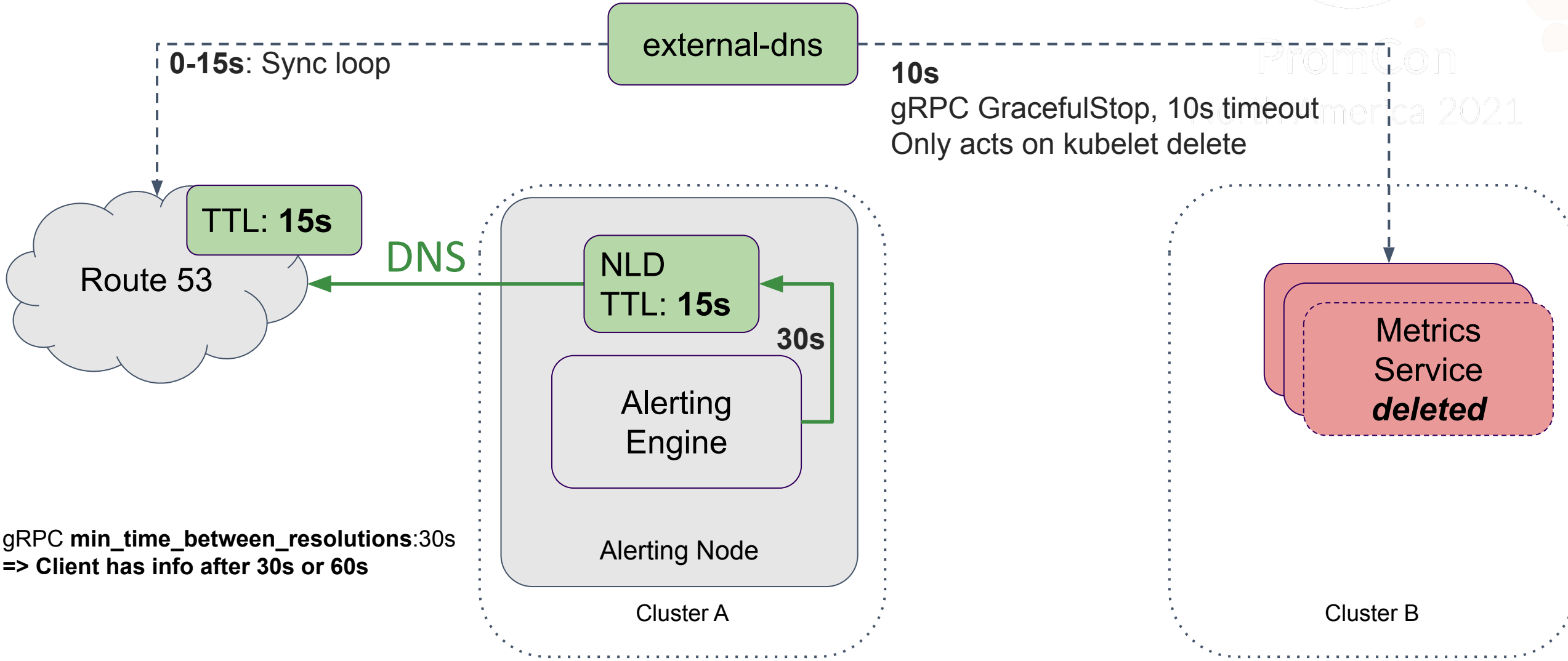
DNS propagation time during Rollouts



DNS propagation time during Rollouts

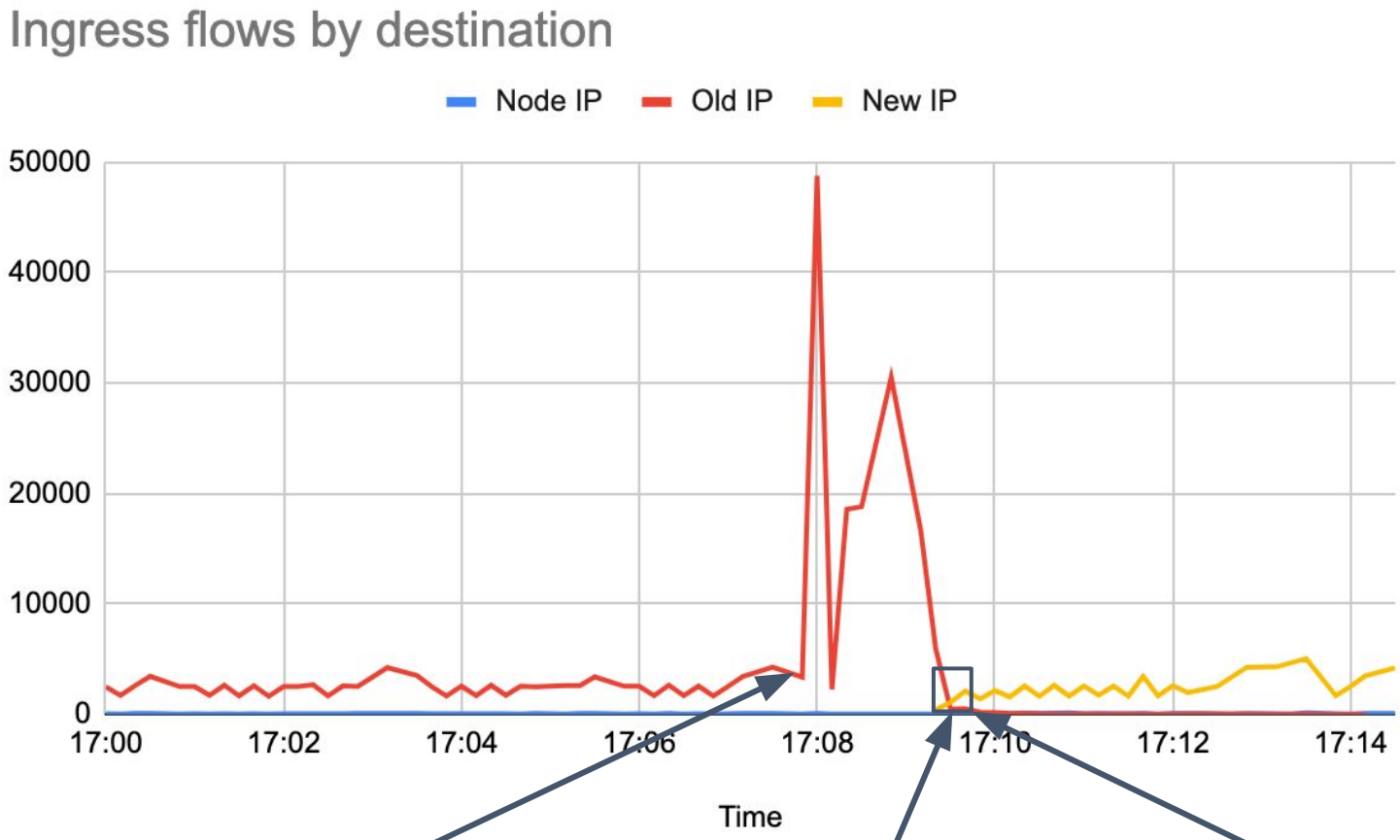


DNS propagation time during Rollouts



gRPC **min_time_between_resolutions**:30s
=> Client has info after 30s or 60s

DNS propagation time during Rollouts



Deletion starts

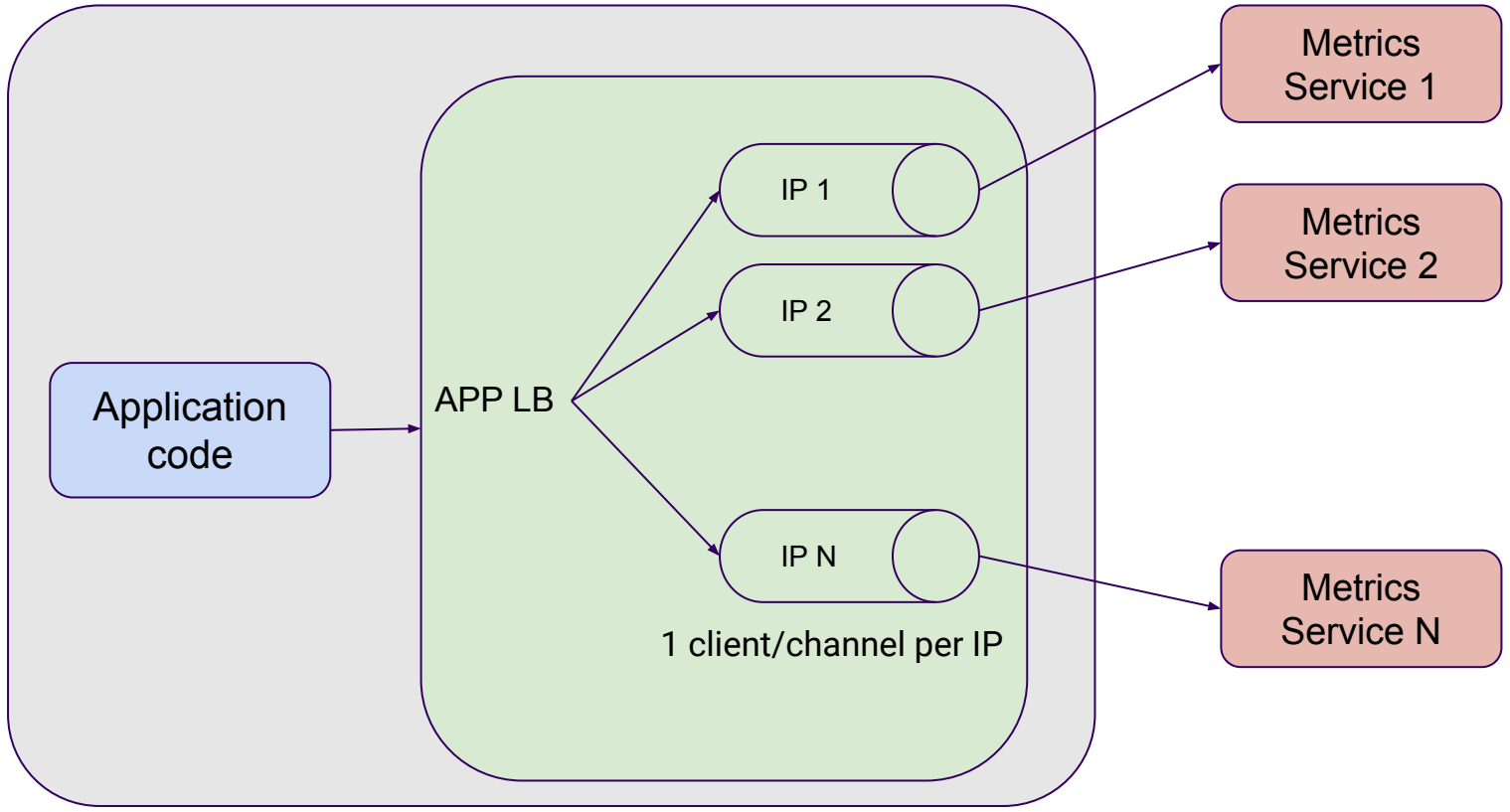
Clients progressively start using new IP

No client is using the Old IP

gRPC history at Datadog

- Originally, clients optimized for complex logic
  - DNS resolution in application code
  - One channel per backend IP
  - **pick_first** gRPC load balancing
- We changed the default to gRPC "standards"
  - Channels get a domain name and gRPC resolves
  - **round_robin** load balancing policy
  - This is when the issue started!

Alerting still had one channel per backend



Alerting Engine Pod

Reconnection differences

- pick_first and round_robin **have very different policies on connection failures**
  - pick_first: do not attempt to reconnect until the application asks for it
  - round_robin: automatically attempt to reconnect using reconnect options
- when using pick_first, we used **max_reconnect_backoff_ms=300 ms**
- ~reasonable for on-demand reconnects

Does it add up?

Alerting Engine

*** X000**

reconnect every 0.3 s

= X0,000 SYN / sec to each Metric Service Pod!

The fix

Use default reconnect parameters

Browse files

lbernail/default-reconnect

lbernail committed yesterday Verified

Showing 1 changed file with 0 additions and 4 deletions.

Split Unified

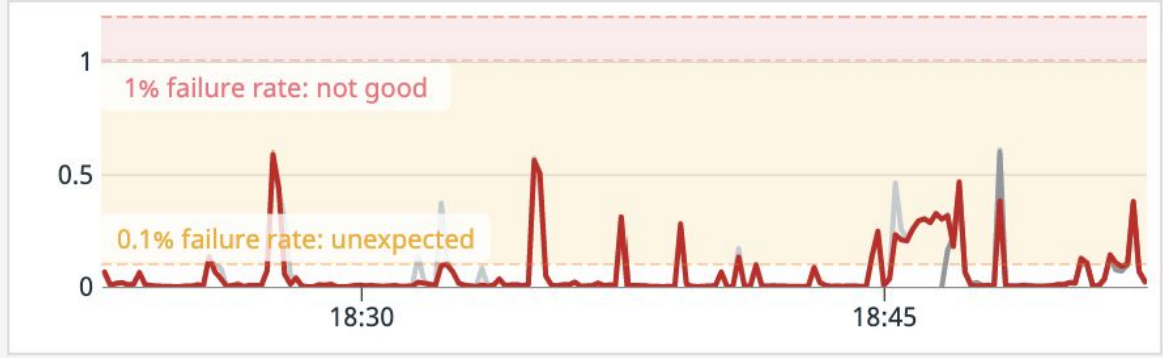
4 grpc-reconnect.py

```
@@ -981,10 +981,6 @@ def get_channel_for_service(host, dns_provider=None):
981  ("grpc.max_send_message_length", (16 << 20) - 1),
982  # receive max size is max uint, 2 GB
983  ("grpc.max_receive_message_length", (1 << 31) - 1),
984 -# default is 20s, let's retry faster
985 -("grpc.min_reconnect_backoff_ms", 100),
986 -("grpc.initial_reconnect_backoff_ms", 200),
987 -("grpc.max_reconnect_backoff_ms", 300),
```

Finally

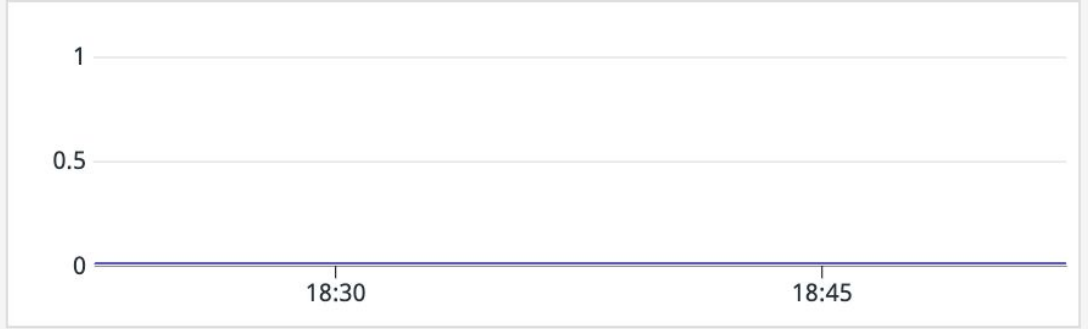
Metrics Service pod replacements (rollout)

Metrics Service Error rate (**server** / **client**)



average DNS response time by Metrics Service pod (ms)

ENA Limits - conntrack exceeded



conntrack count for Alerting Engine

Lessons Learned

Lessons Learned

- Sometimes it's not DNS
- Powerful abstractions leak in complex ways
- gRPC setup can be complex, making changes dangerous
- ENA metrics and VPC flow logs are extremely useful
- Required complex team efforts (thanks Wendell, Matt, Nayef!)
- Debugging this incident was long and painful but we learned a lot

Thank you

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