Adaptive Concurrency Control for Mixed Analytical Workloads

Dan Kleiman
March, 2023

At Klaviyo, we do targeted messaging, data integrations, and analytics

Analytics via APIs, Dashboards, and Reports

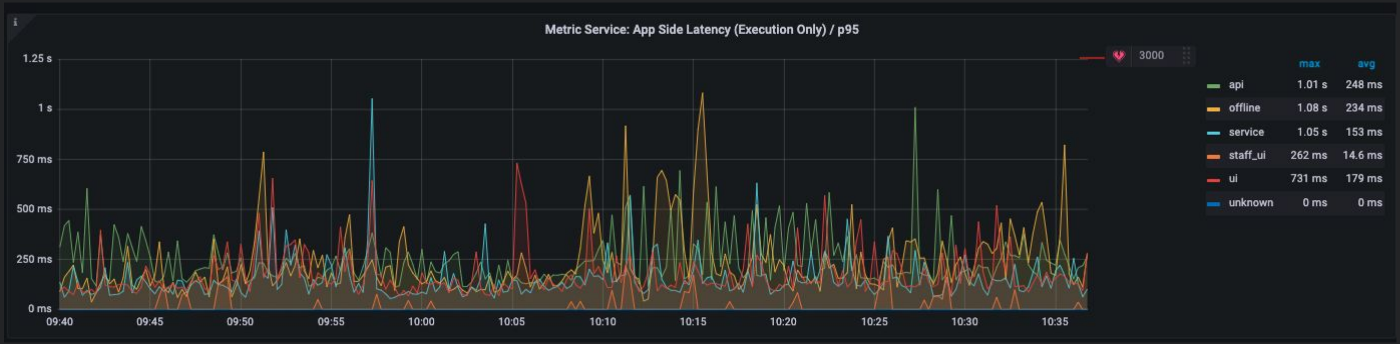
Which email domains have the best open rates?

Who are my most engaged customers?

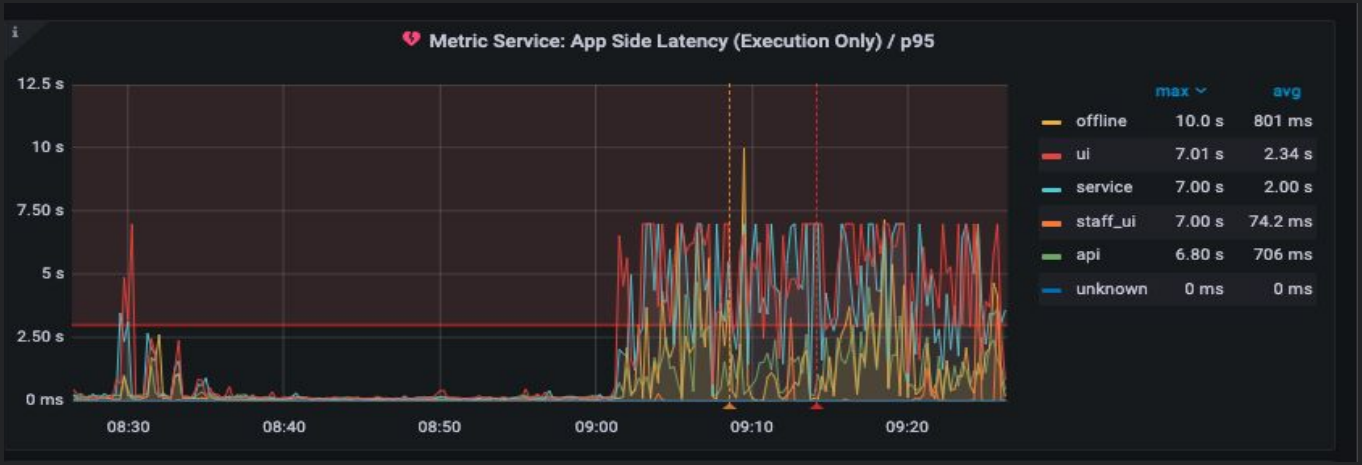
How much revenue did my last campaign generate?

Fast, Flexible Query Services

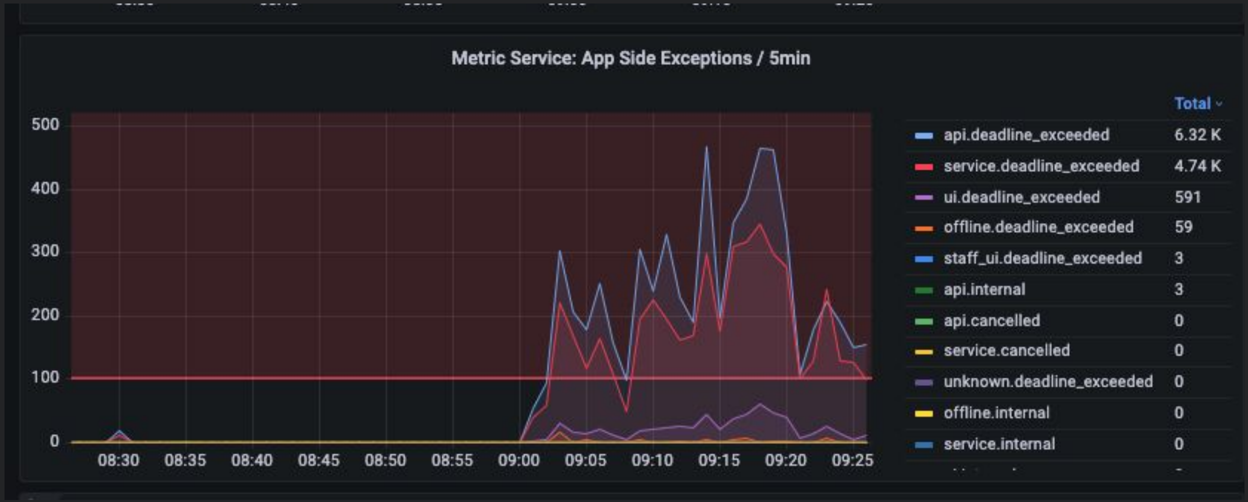
Mixed workloads running on the same "shared calculator"



Healthy request processing for thousands of requests per second

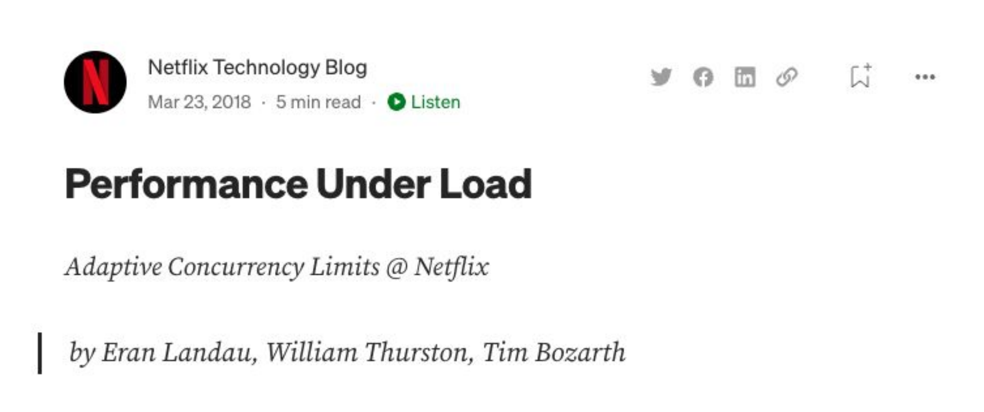


Unhealthy request processing - waves of congestion



“My workload hasn’t changed. Why are my requests suddenly timing out?”

Better way to keep our service healthy for all our users?


Netflix Technology Blog

Mar 23, 2018 · 5 min read · Listen

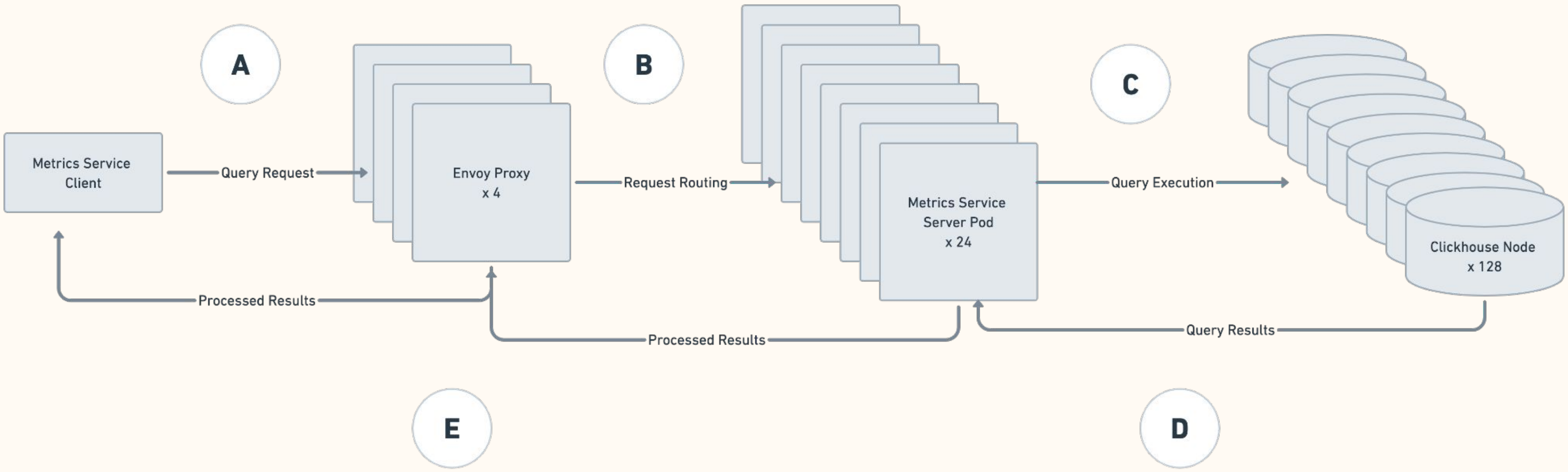
Performance Under Load

Adaptive Concurrency Limits @ Netflix

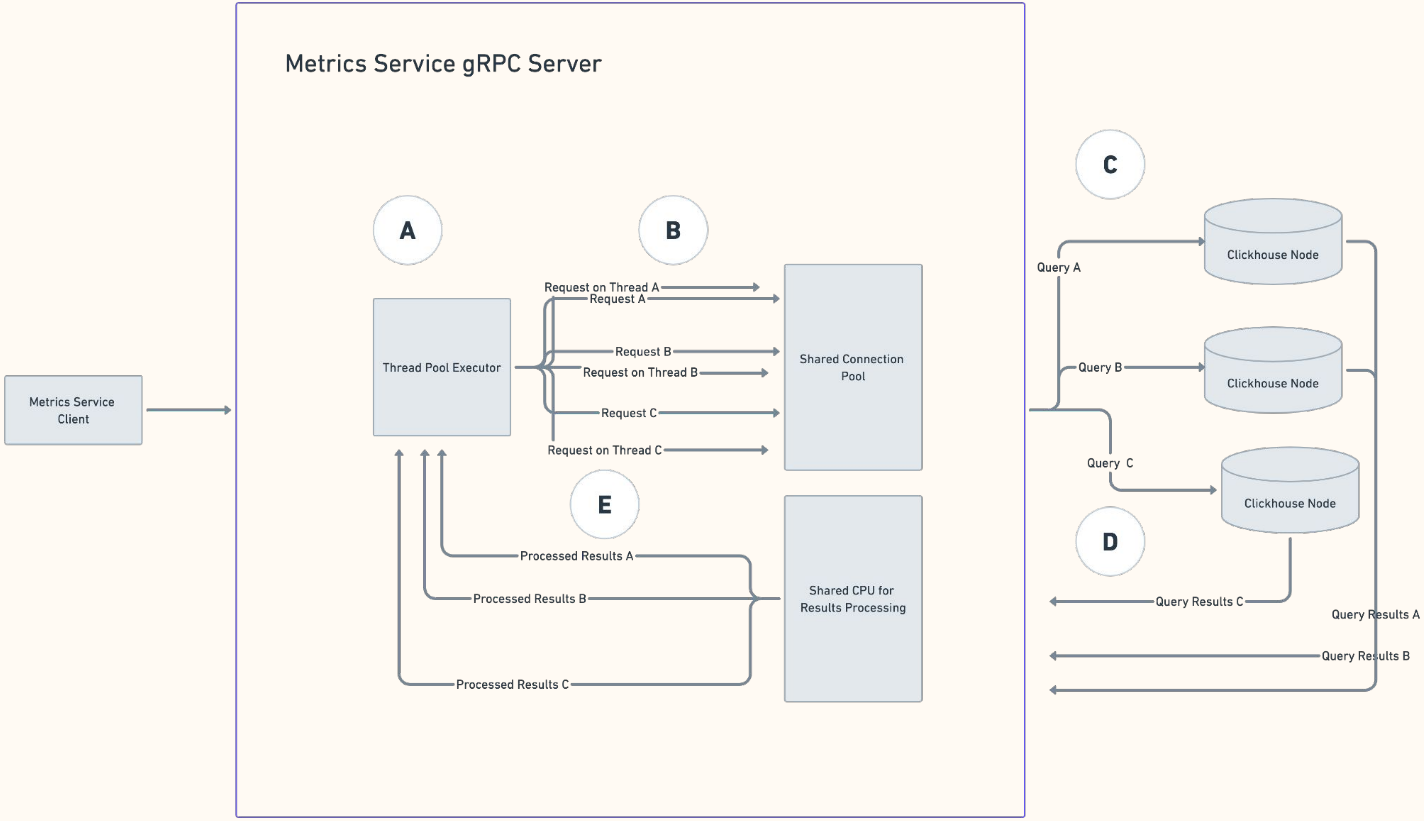
> *by Eran Landau, William Thurston, Tim Bozarth*

Metrics Service Request Flow

Metrics Service Request Flow

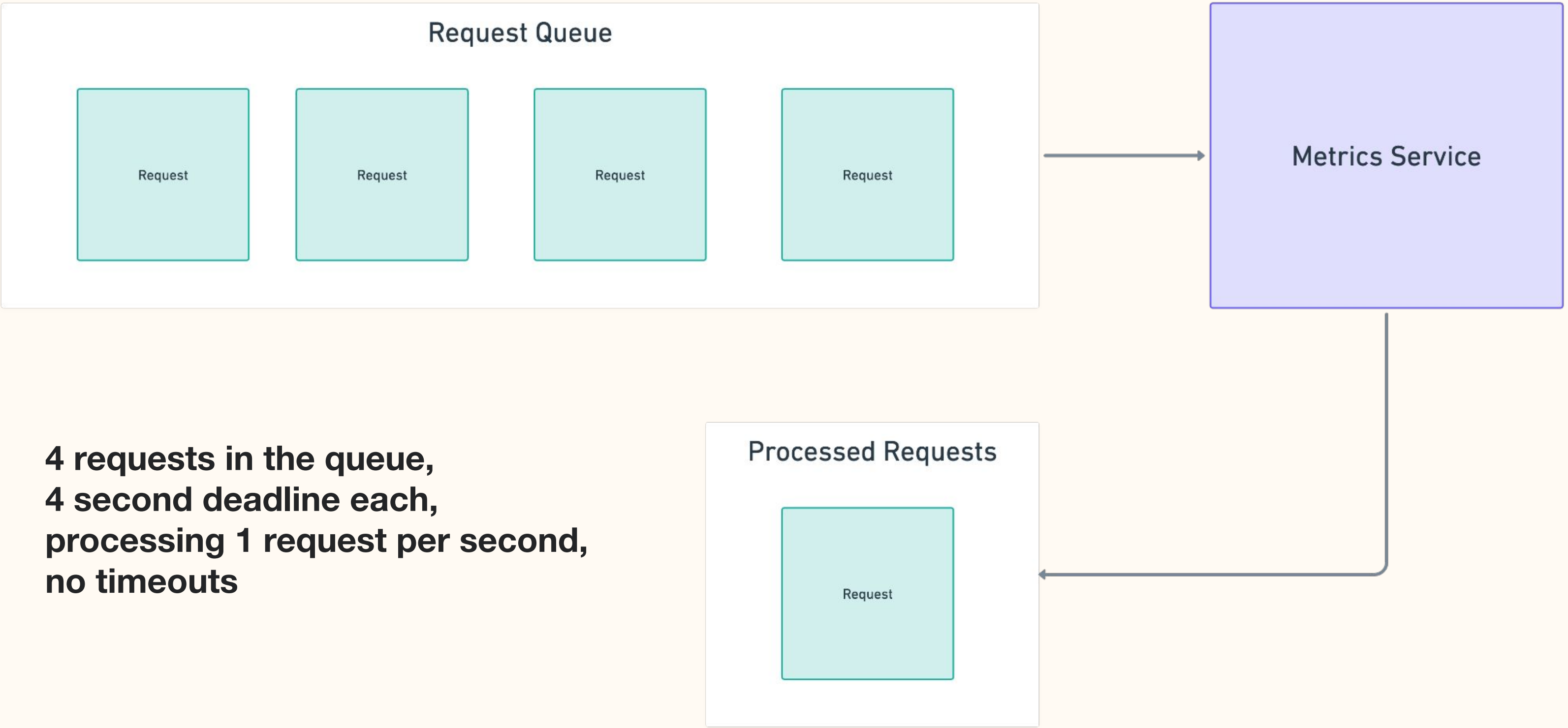


Metrics Service Request Flow - gRPC Server



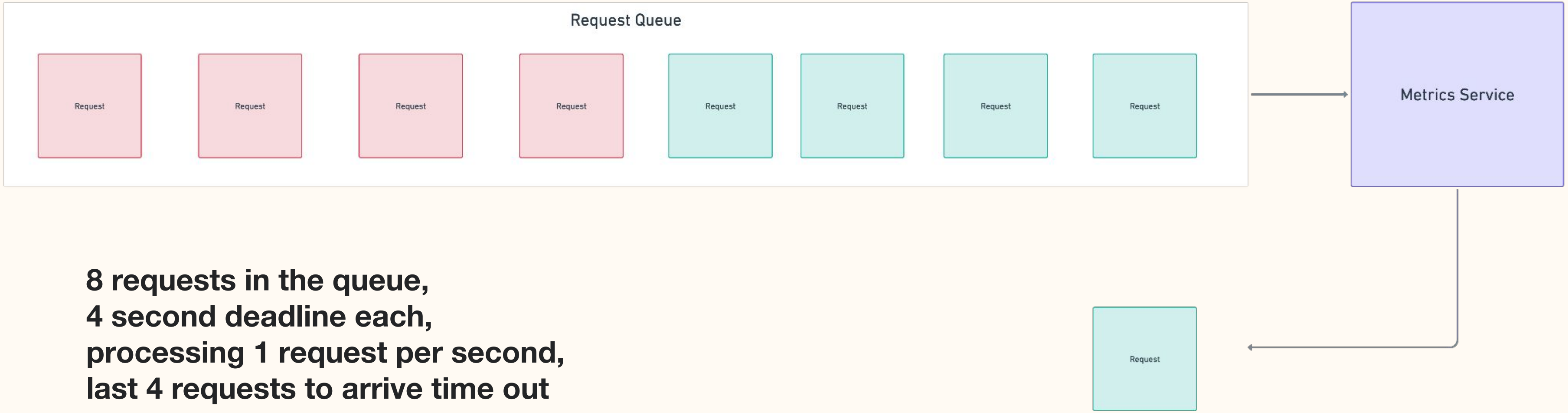
Request Queuing and Concurrency

Healthy State - Queuing Balanced with Processing



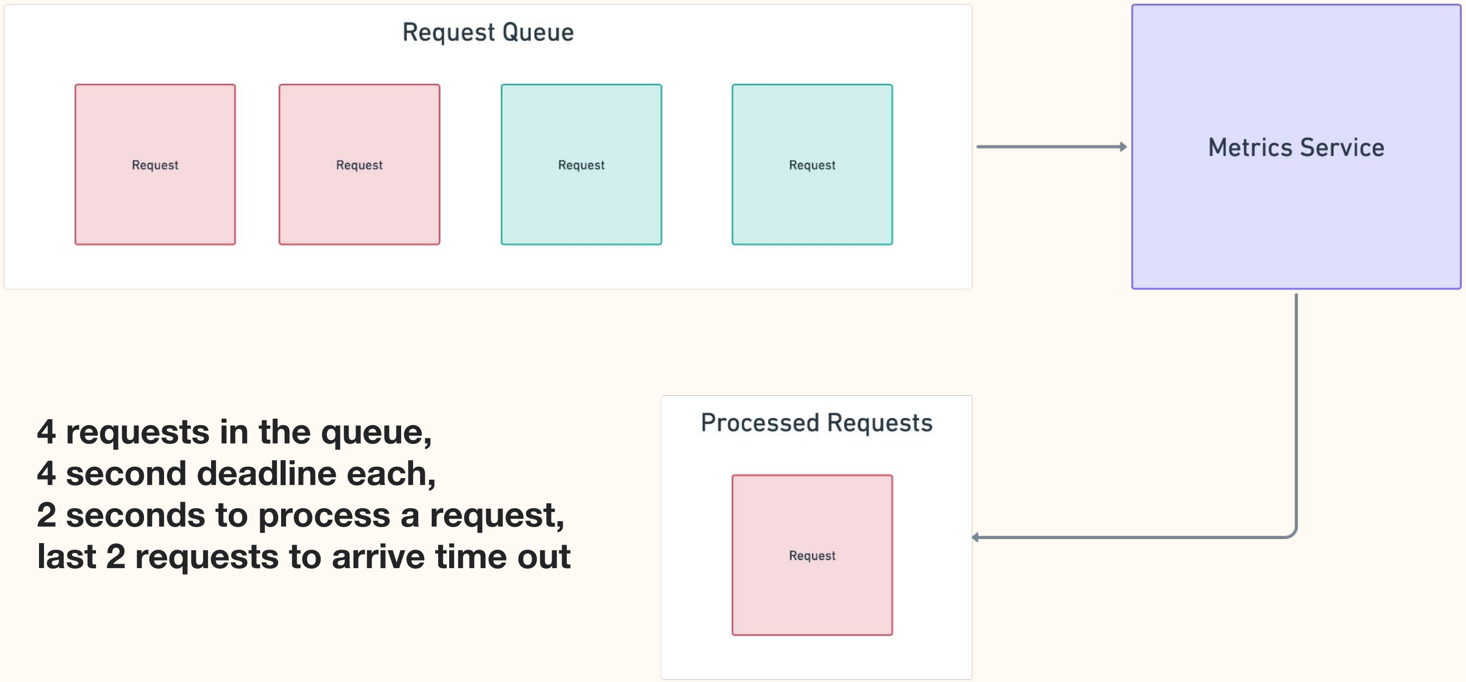
**4 requests in the queue,
4 second deadline each,
processing 1 request per second,
no timeouts**

Unhealthy State - Queue Depth Exceeds Processing Rate



8 requests in the queue,
4 second deadline each,
processing 1 request per second,
last 4 requests to arrive time out

Unhealthy State - Processing Rate Slows Down



4 requests in the queue,
4 second deadline each,
2 seconds to process a request,
last 2 requests to arrive time out

Concurrency is nothing more than the number of requests a system can service at any given time and is normally driven by a fixed resource such as CPU.

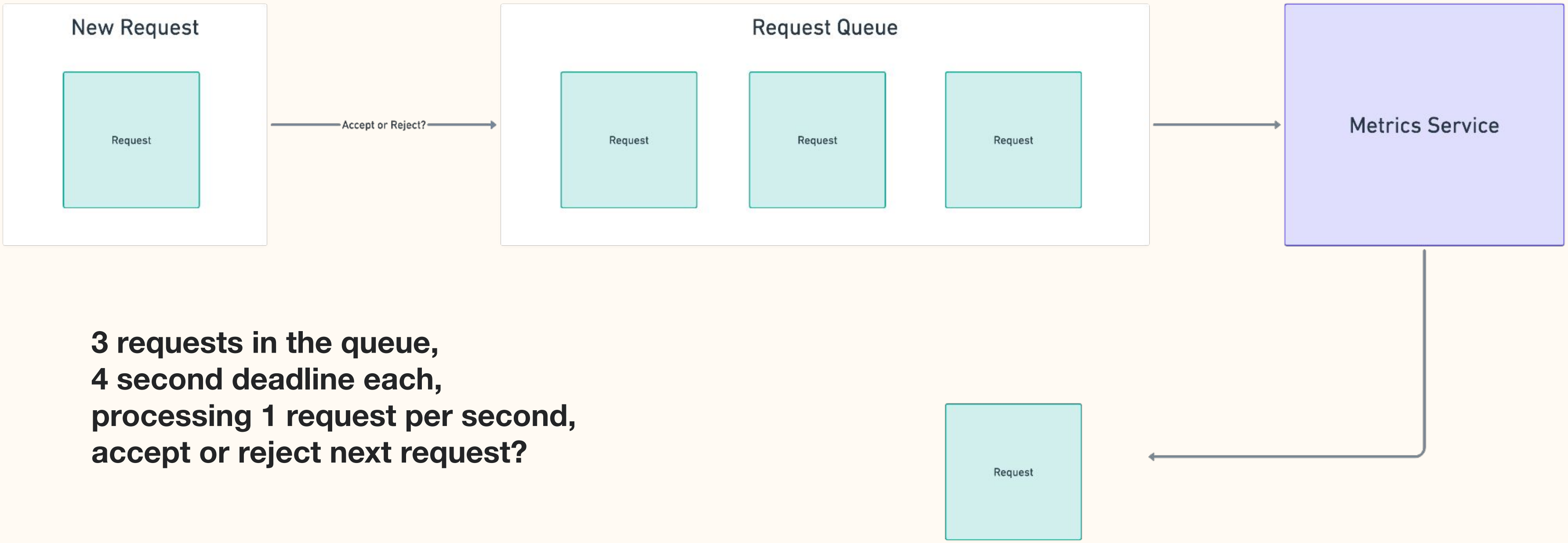
A system's concurrency is normally calculated using Little's law, which states: For a system at steady state, concurrency is the product of the average service time and the average service rate ($L = \lambda W$). Any requests in excess of this concurrency cannot immediately be serviced and must be queued or rejected. With that said some queueing is necessary as it enables full system utilization in spite of non-uniform request arrival and service time.

Systems fail when no limit is enforced on this queue, such as during prolonged periods of time where the arrival rate exceeds the exit rate. As the queue grows so will latency until all requests start timing out and the system will ultimately run out of memory and crash. If left unchecked latency increases start adversely affecting its callers leading to cascading failures through the system.

from Netflix's Performance Under Load

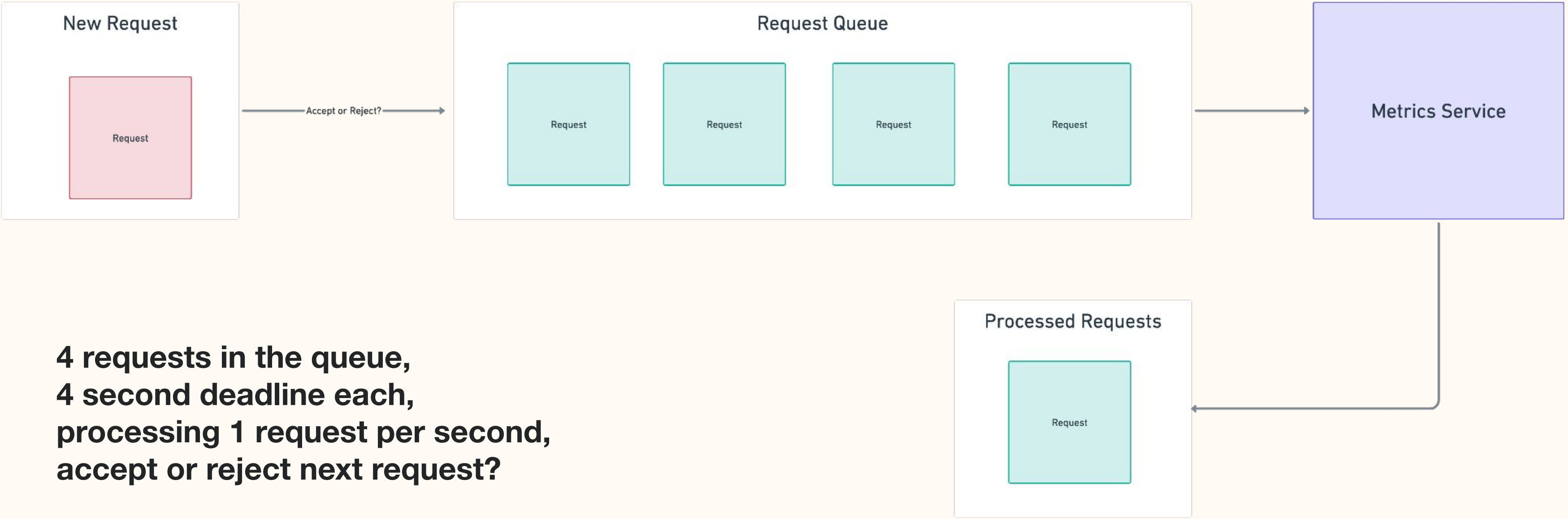
Accept or Reject the Next Request?

Accept or Reject Before Queuing - Load Shedding



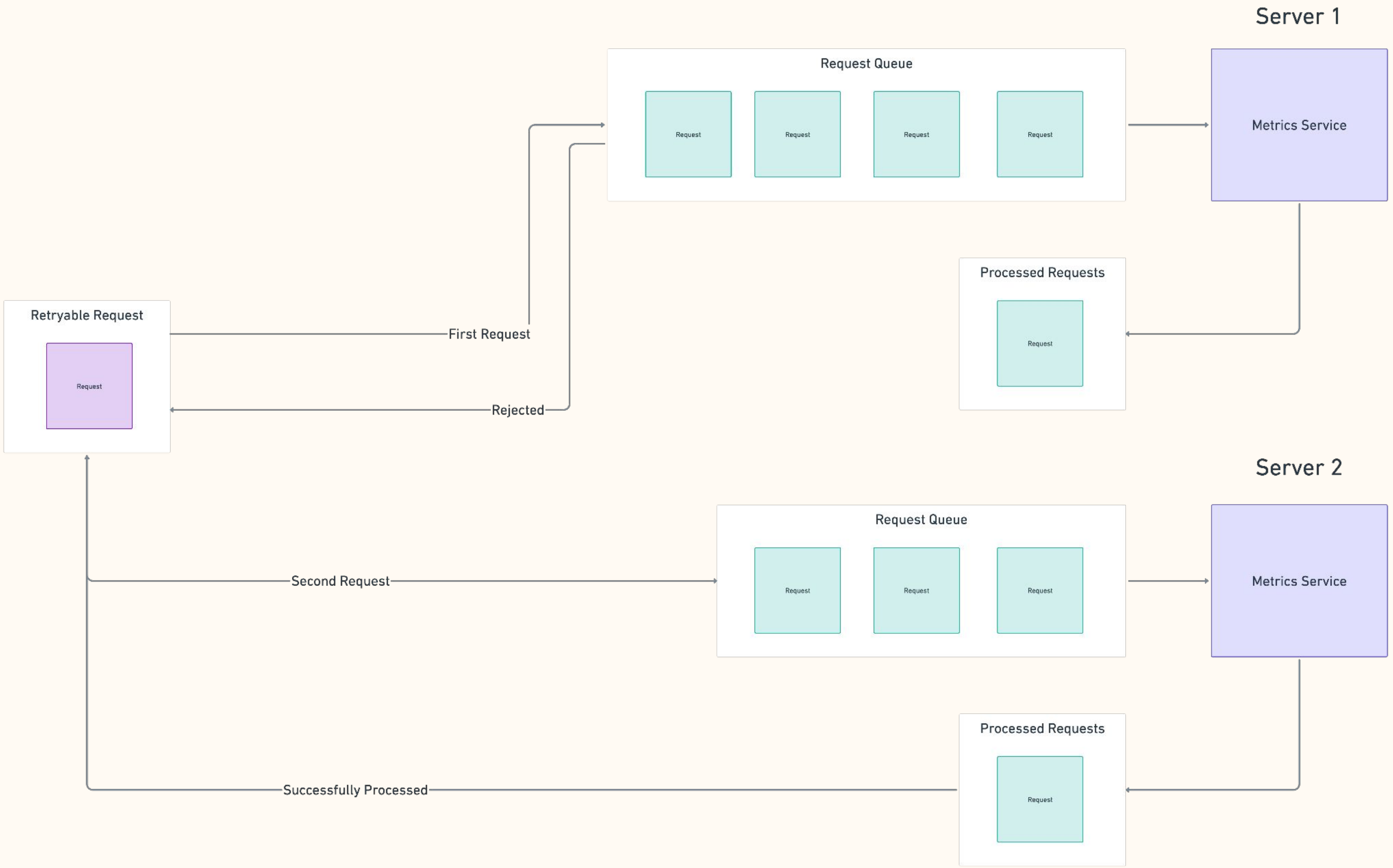
3 requests in the queue,
4 second deadline each,
processing 1 request per second,
accept or reject next request?

Accept or Reject Before Queuing - Load Shedding



4 requests in the queue,
4 second deadline each,
processing 1 request per second,
accept or reject next request?

Load Shedding at the Cluster Level

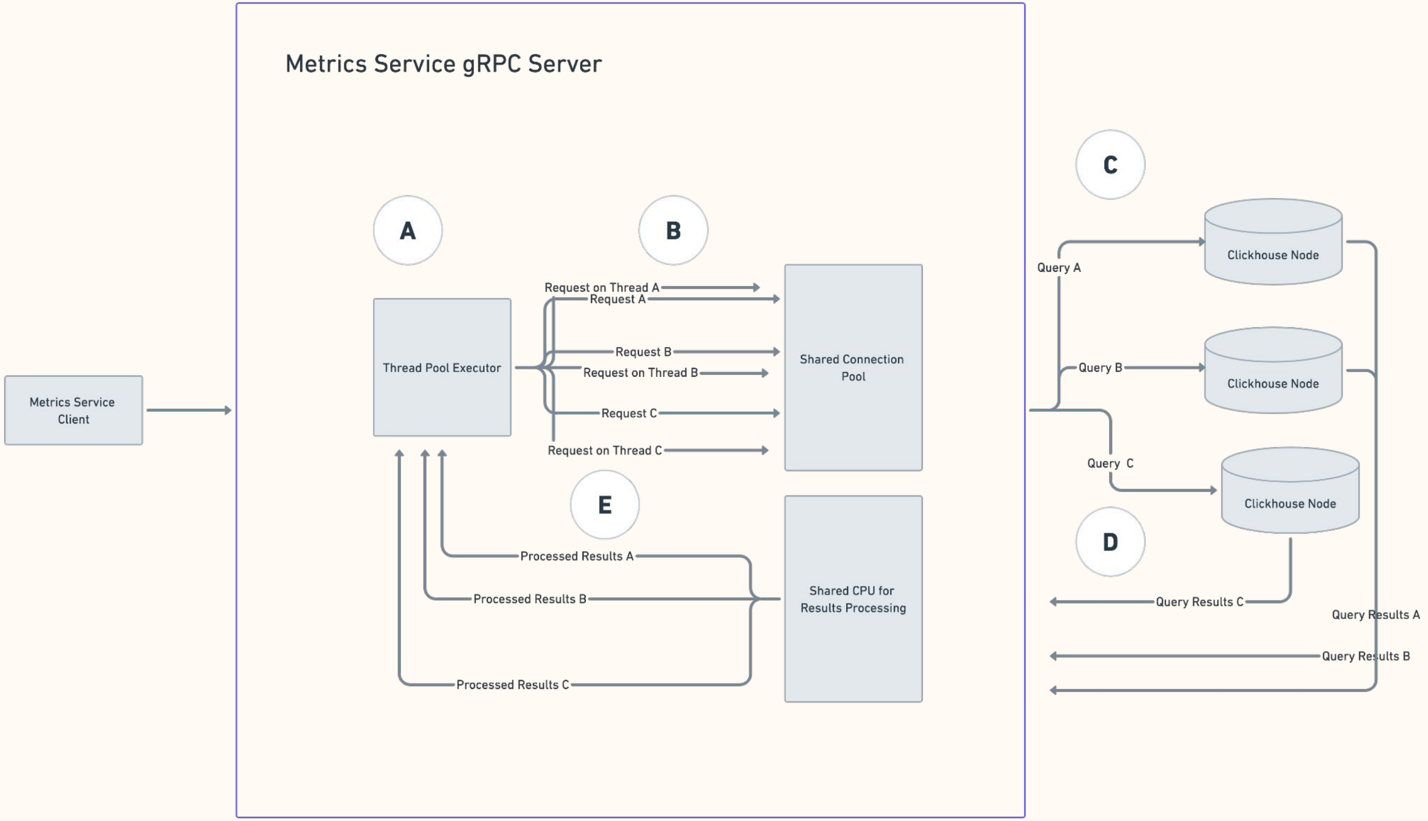


Load Shedding and Concurrency Control

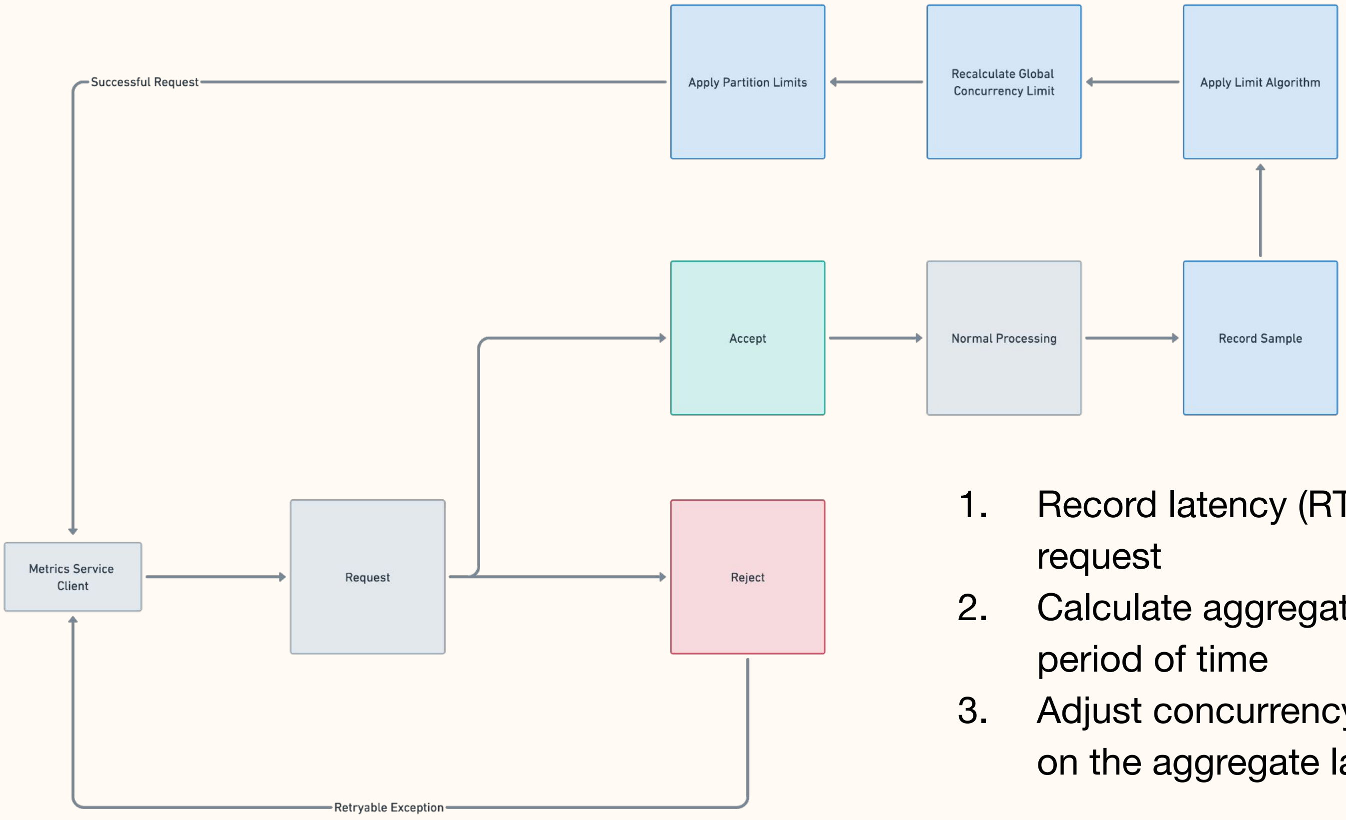
1. How many requests are we already processing – *inflight requests*?
2. What our maximum number of requests we can process at once – *concurrency limit*?
3. If inflight request count < concurrency limit, accept the new request.
4. Otherwise, reject it.

Adaptive Concurrency Control

Adaptive Concurrency Control - Measuring Latency



Adaptive Concurrency Control - Record, Recalculate, React



1. Record latency (RTT) of each request
2. Calculate aggregate latency over a period of time
3. Adjust concurrency limits based on the aggregate latency value

Additive Increase

When we are within our latency tolerance, we can increase the concurrency limit by 1.

Multiplicative Decrease

When we cross the latency threshold, we decrease the concurrency limit by a backoff multiplier.

```python
# AIMD - Additive Increase, Multiplicative Decrease - Algorithm
# used to update concurrency limits, given current latency, number
# of inflight requests and whether there has been an absolute timeout
def _update(
    self,
    start_time: float,
    rtt: float,
    inflight: int,
    timeout_observed: bool
):
    # if we cross the latency threshold,
    # we backoff by our pre-configured backoff ratio
    if timeout_observed or rtt > self._latency_threshold_ms:
        self._current_limit = math.floor(
            self._current_limit * self._backoff_ratio
        )
    # otherwise, we can increase the limit if the current inflight
    # request count is approaching the limit
    # if they are far apart, we don't do anything
    elif inflight * 2 >= self._current_limit:
        self._current_limit += 1

    # finally, we make sure the limit is within the min/max bounds
    self._current_limit = min(
        self._max_limit, max(self._min_limit, self._current_limit)
    )
```

Python implementation of Netflix's java version

```python
# AIMD - Additive Increase, Multiplicative Decrease - Algorithm
# used to update concurrency limits, given current latency, number
# of inflight requests and whether there has been an absolute timeout
def _update(
    self,
    start_time: float,
    rtt: float,
    inflight: int,
    timeout_observed: bool
):
    # if we cross the latency threshold,
    # we backoff by our pre-configured backoff ratio
    if timeout_observed or rtt > self._latency_threshold_ms:
        self._current_limit = math.floor(
            self._current_limit * self._backoff_ratio
        )
    # request count is approaching the limit
    # if they are far apart, we don't do anything
    elif inflight * 2 >= self._current_limit:
        self._current_limit += 1

    # finally, we make sure the limit is within the min/max bounds
    self._current_limit = min(
        self._max_limit, max(self._min_limit, self._current_limit)
    )
```

Backoff Condition

Python implementation of Netflix's java version

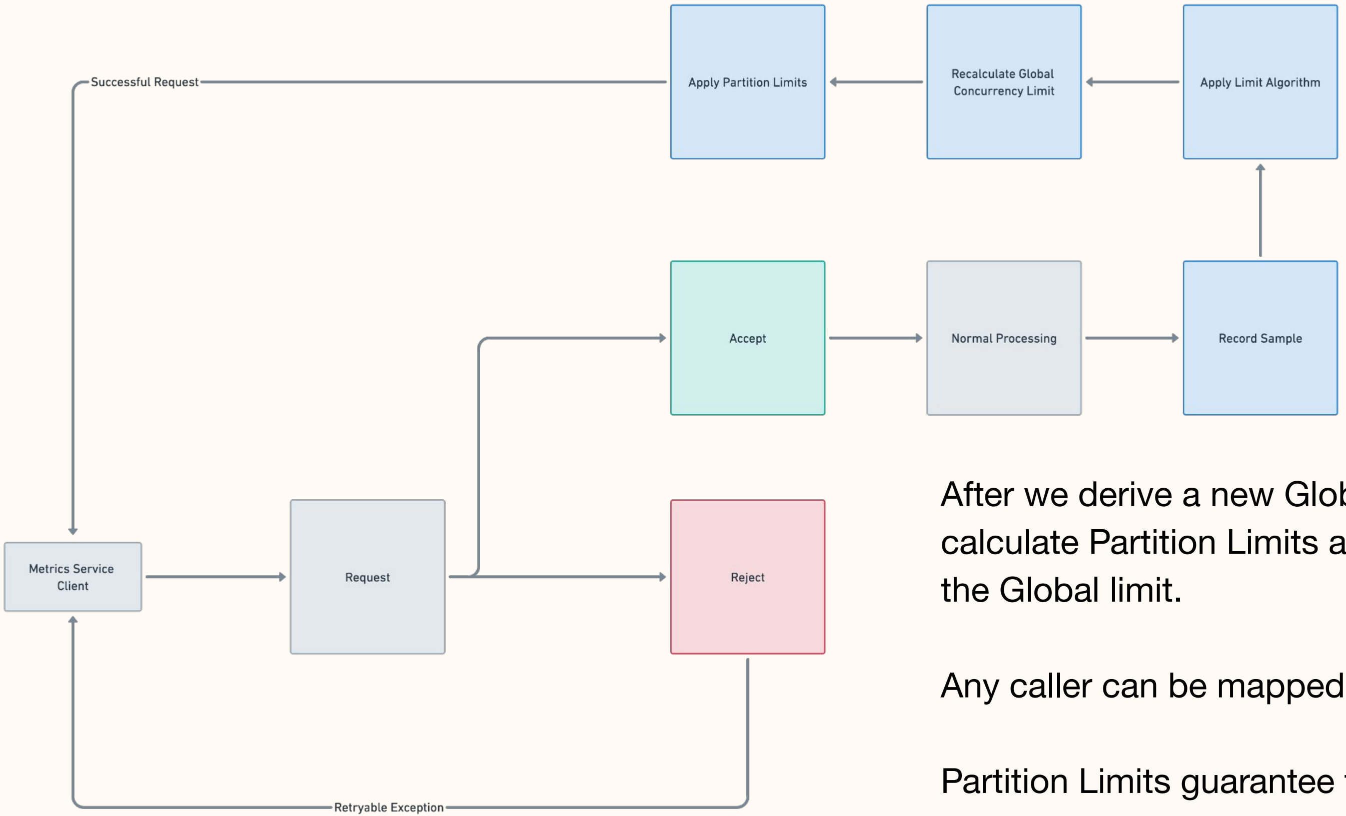
```python
# AIMD - Additive Increase, Multiplicative Decrease - Algorithm
# used to update concurrency limits, given current latency, number
# of inflight requests and whether there has been an absolute timeout
def _update(
    self,
    start_time: float,
    rtt: float,
    inflight: int,
    timeout_observed: bool
):
    # if we cross the latency threshold,
    # we backoff by our pre-configured backoff ratio
    if timeout_observed or
        self._current_limit
            self._current_l
        )
    # otherwise, we can increase the limit if the current inflight
    # request count is approaching the limit
    # if they are far apart, we don't do anything
    elif inflight * 2 >= self._current_limit:
        self._current_limit += 1

    # finally, we make sure the limit is within the min/max bounds
    self._current_limit = min(
        self._max_limit, max(self._min_limit, self._current_limit)
    )
```

Possible Increase Condition

Python implementation of Netflix's java version

“My workload hasn’t changed…”

Adaptive Concurrency Control - Partition Limits

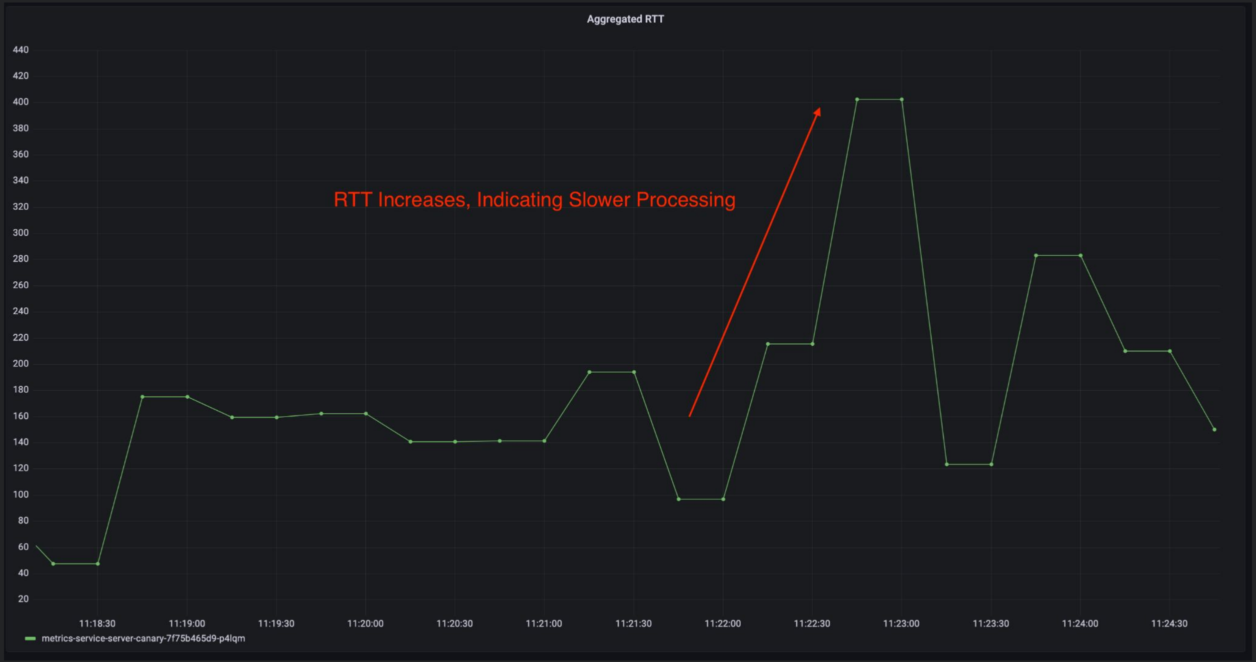


After we derive a new Global Limit, we calculate Partition Limits as percentages of the Global limit.

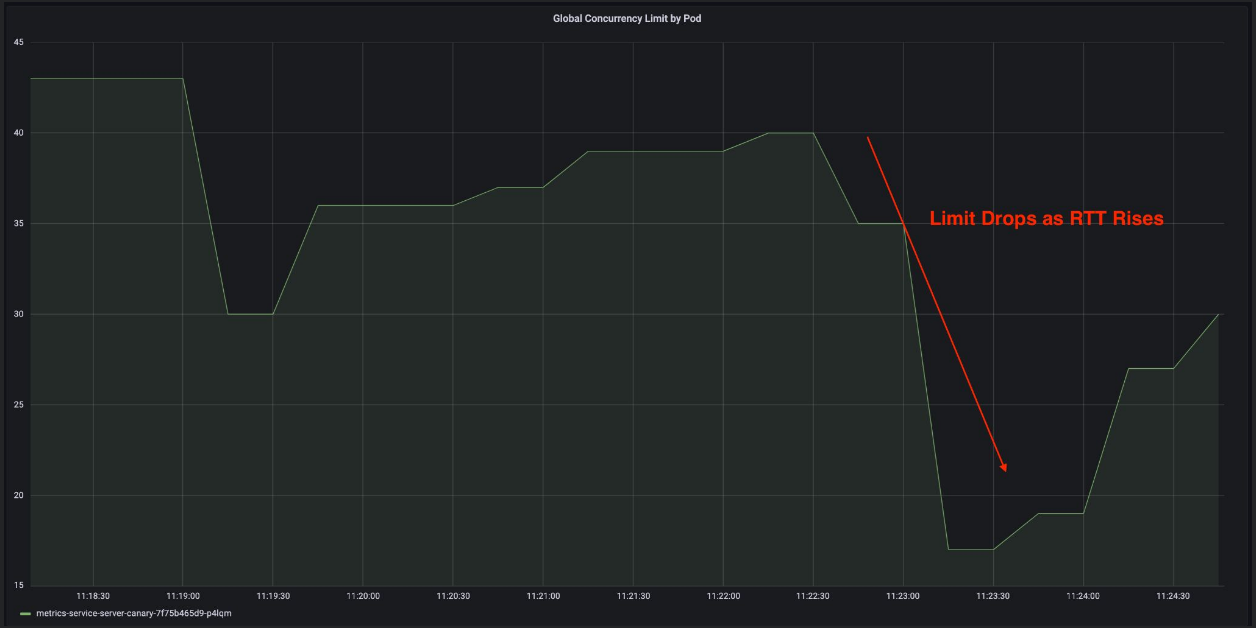
Any caller can be mapped to a Partition.

Partition Limits guarantee throughput allocations on a per caller basis.

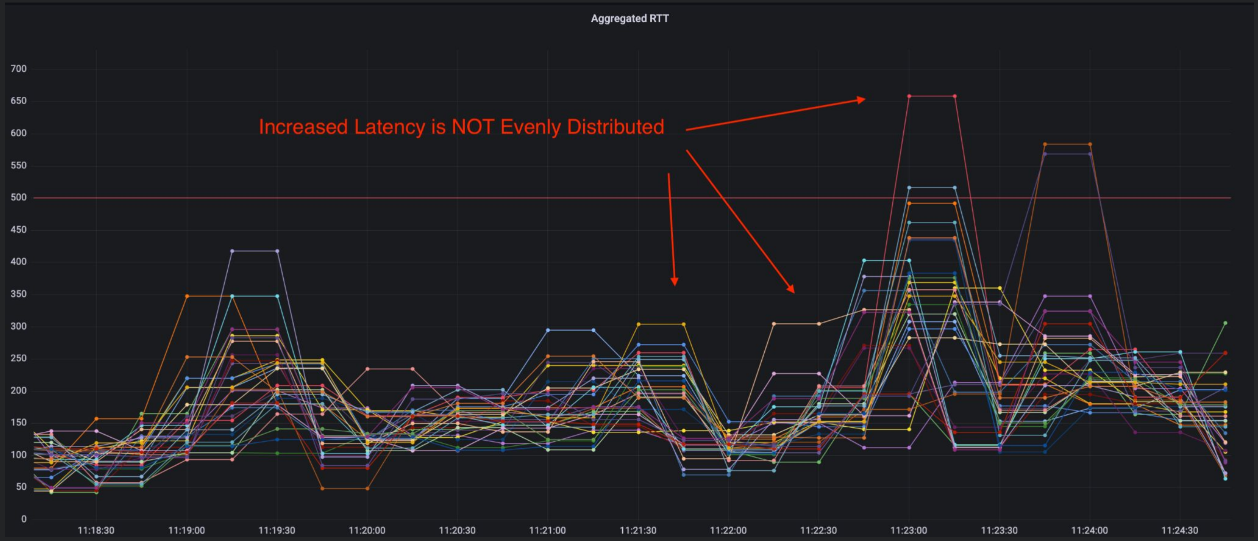
Going Live…



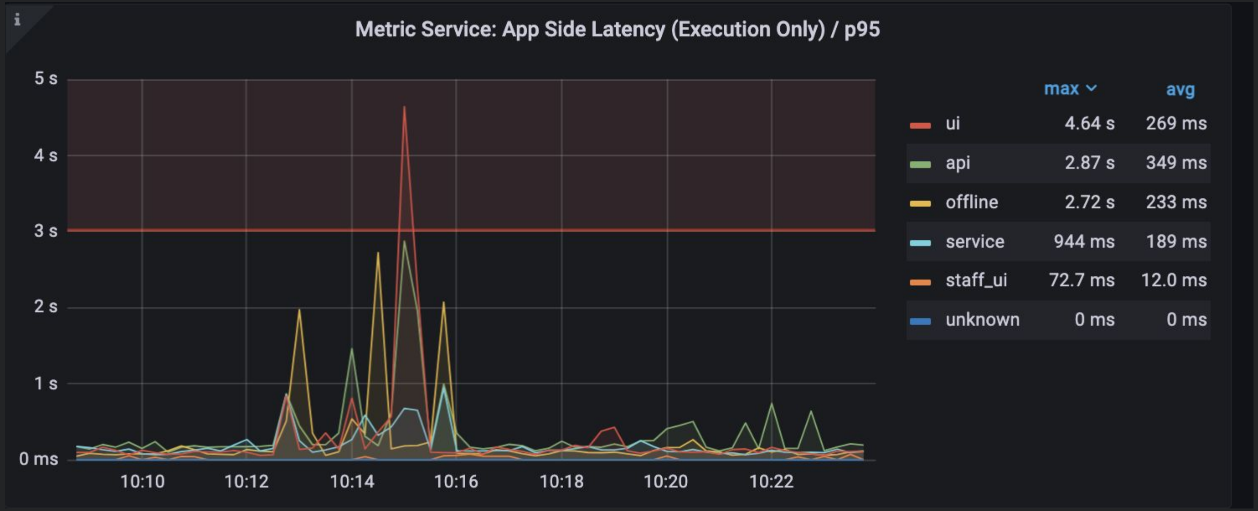
RTT increasing from 100ms to 400ms is a signal that we're slowing down.
Need to accept fewer new requests.



Reducing the limit in response to increased latency allows the system to recover gracefully.



Changes in RTT per server pod vary based on the query mix, so latency can vary considerably across the cluster.



When things did get bad? No more congestion, just spikes.

Thank you!

Any Questions?

Blog post at klaviyo.tech

Ask me more @Dan_Kleiman