Cloud Performance Root Cause Analysis at Netflix

Brendan Gregg
Senior Performance Architect
Cloud and Platform Engineering

YOW! Conference Australia
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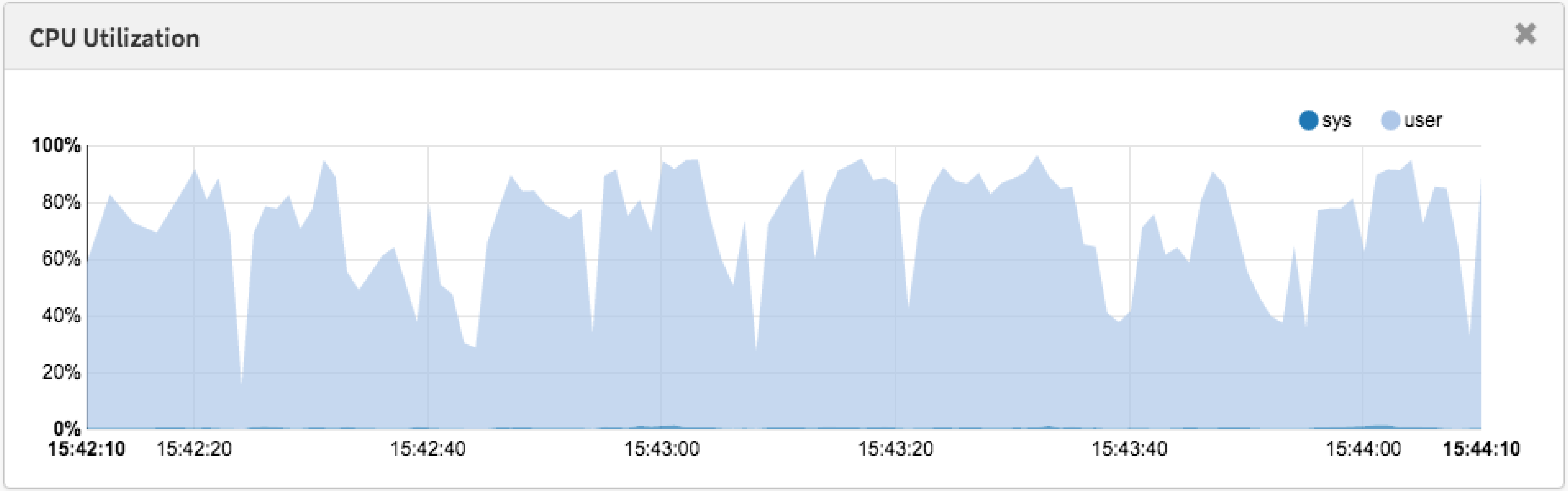
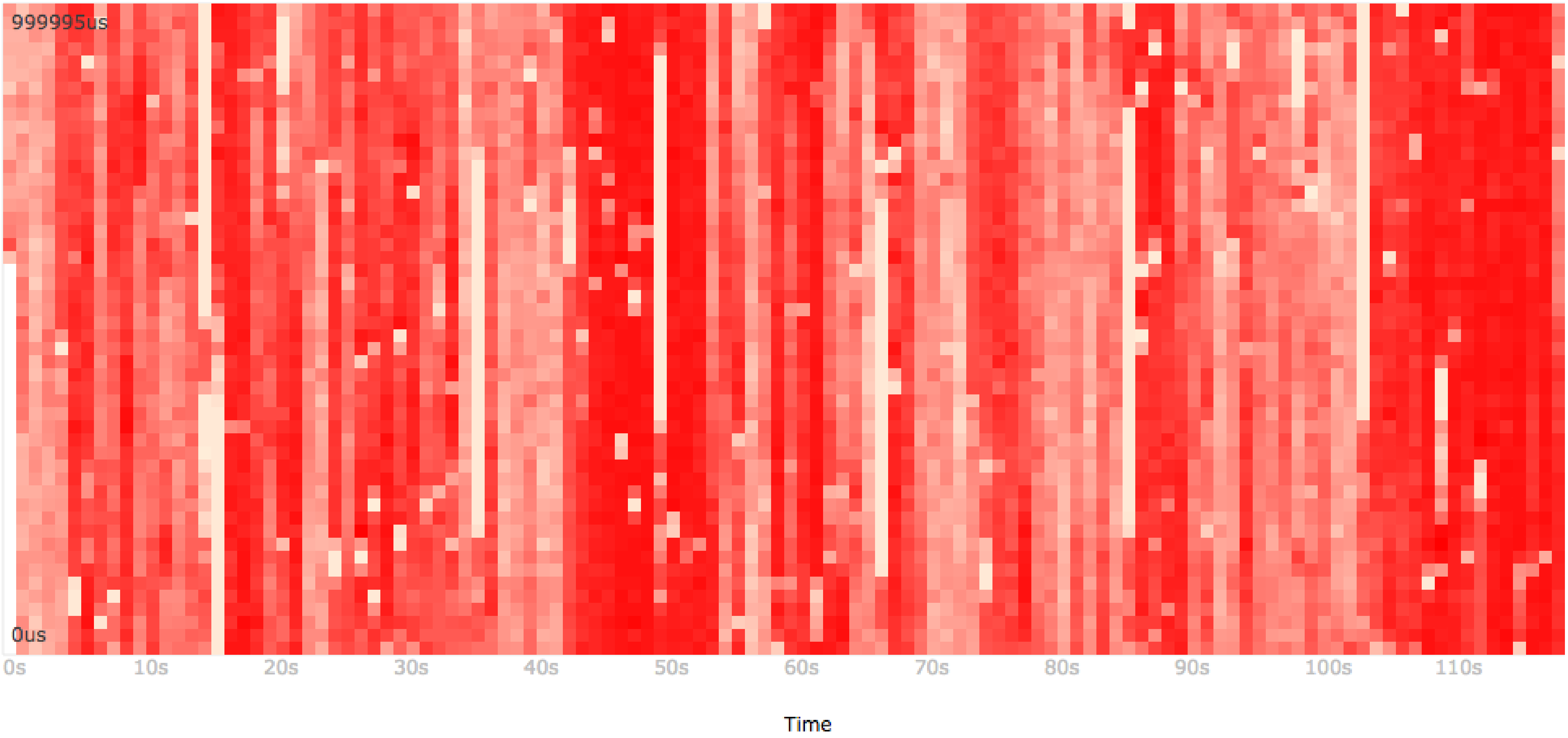
NETFLIX

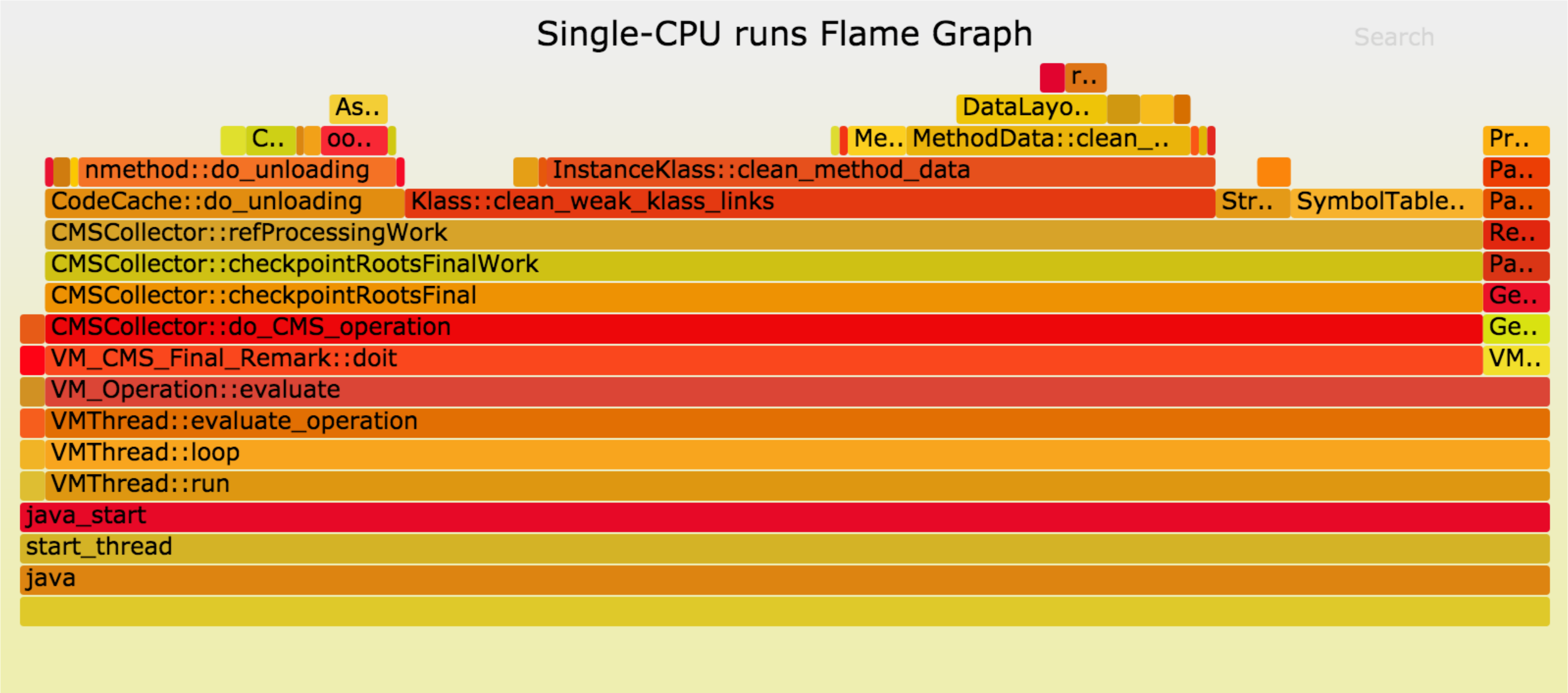
Experience: CPU Dips



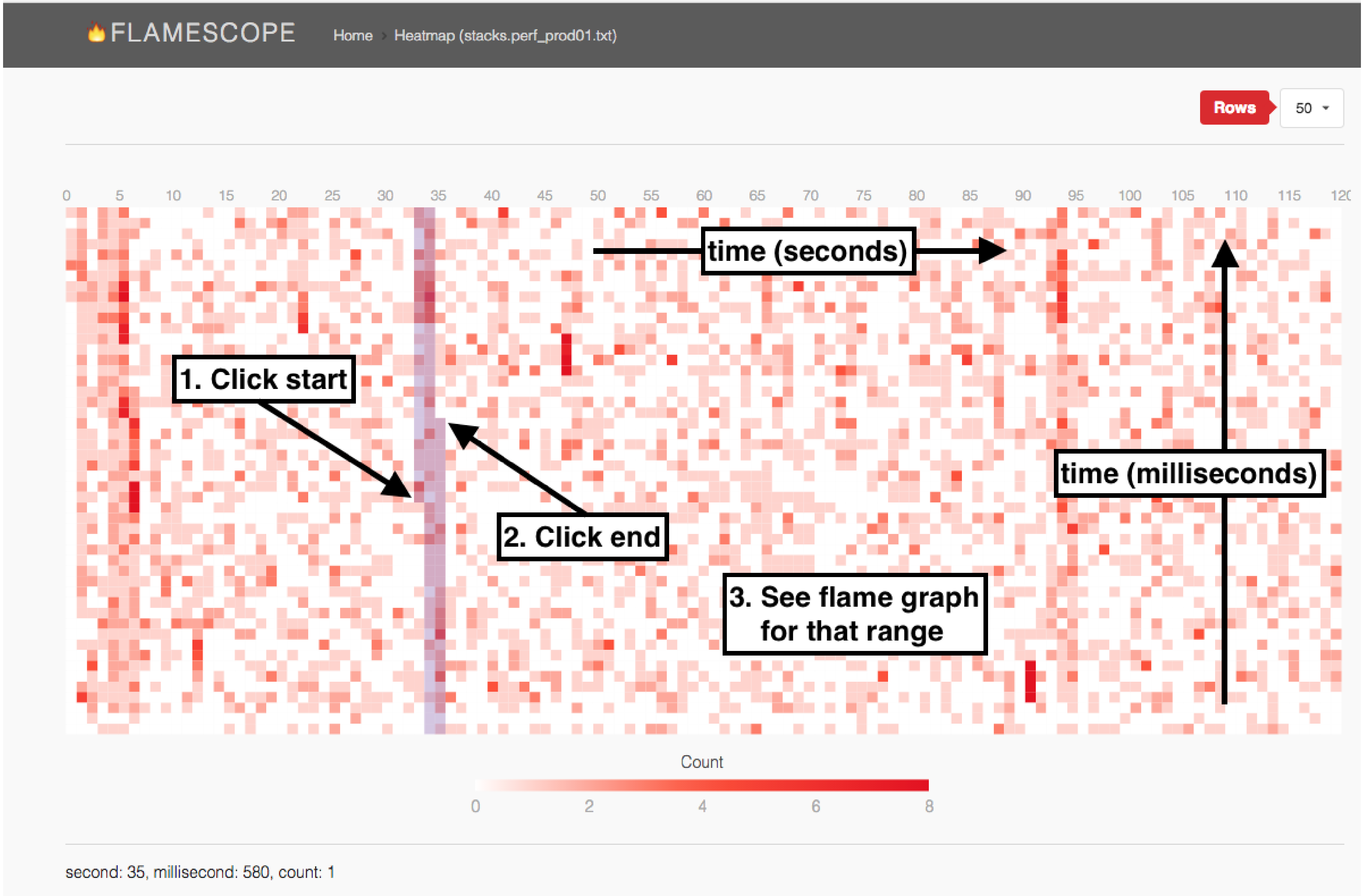
CPU Subsecond-Offset Heat Map



```
# perf record -F99 -a
# perf script
[…]
   java 14327 [022] 252764.179741: cycles:      7f36570a4932 SpinPause (/usr/lib/jvm/java-8
   java 14315 [014] 252764.183517: cycles:      7f36570a4932 SpinPause (/usr/lib/jvm/java-8
   java 14310 [012] 252764.185317: cycles:      7f36570a4932 SpinPause (/usr/lib/jvm/java-8
   java 14332 [015] 252764.188720: cycles:      7f3658078350 pthread_cond_wait@@GLIBC_2.3.2
   java 14341 [019] 252764.191307: cycles:      7f3656d150c8 ClassLoaderDataGraph::do_unloa
   java 14341 [019] 252764.198825: cycles:      7f3656d140b8 ClassLoaderData::free_dealloca
   java 14341 [019] 252764.207057: cycles:      7f3657192400 nmethod::do_unloading(BoolObje
   java 14341 [019] 252764.215962: cycles:      7f3656ba807e Assembler::locate_operand(unsi
   java 14341 [019] 252764.225141: cycles:      7f36571922e8 nmethod::do_unloading(BoolObje
   java 14341 [019] 252764.234578: cycles:      7f3656ec4960 CodeHeap::block_start(void*) c
[…]
```

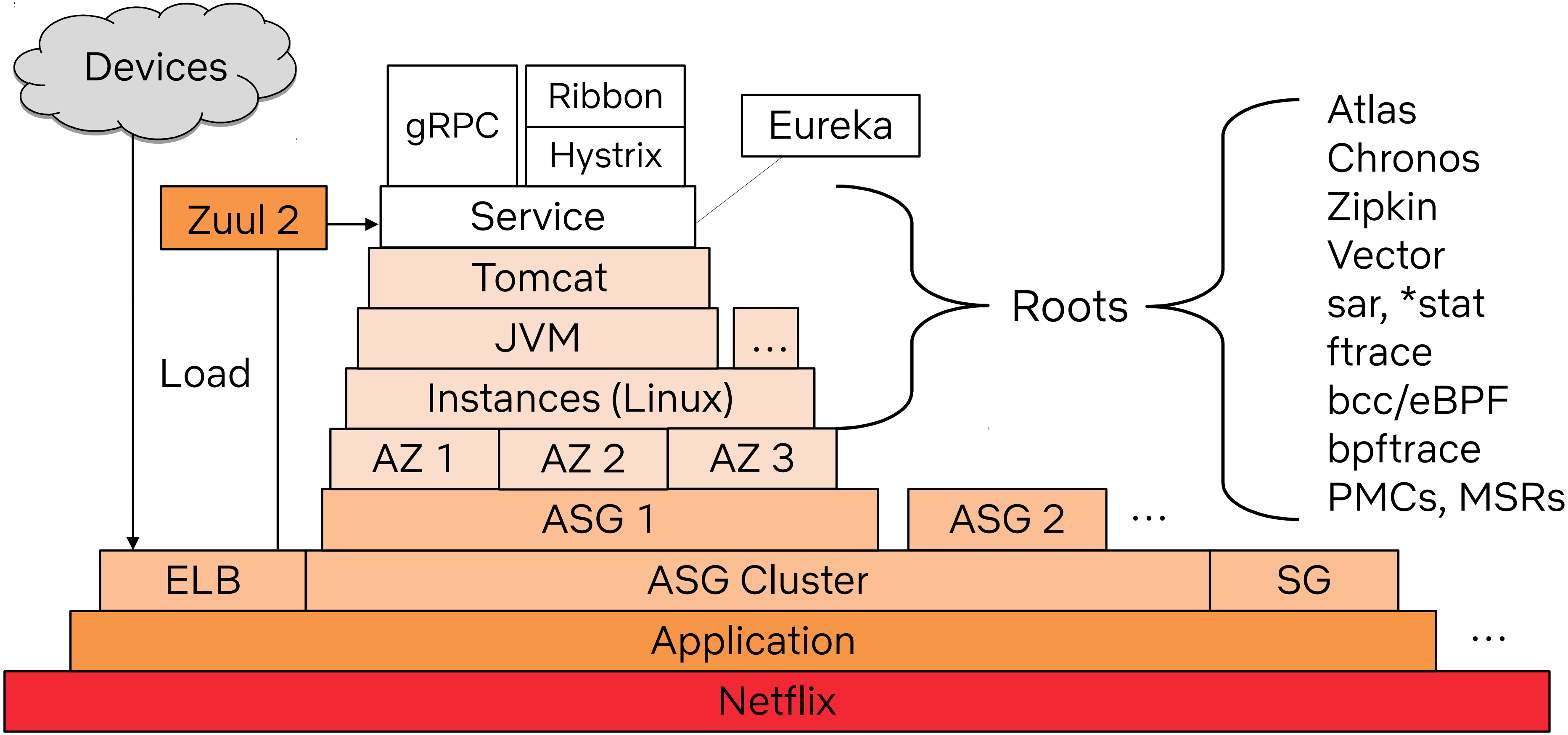


Single-CPU runs Flame Graph
Search
r..
As..
DataLayo..
C..
oo..
Me..
MethodData::clean_..
Pr..
nmethod::do_unloading
InstanceKlass::clean_method_data
Pa..
CodeCache::do_unloading
Klass::clean_weak_klass_links
Str..
SymbolTable..
Pa..
CMSCollector::refProcessingWork
Re..
CMSCollector::checkpointRootsFinalWork
Pa..
CMSCollector::checkpointRootsFinal
Ge..
CMSCollector::do_CMS_operation
Ge..
VM_CMS_Final_Remark::doit
VM..
VM_Operation::evaluate
VMThread::evaluate_operation
VMThread::loop
VMThread::run
java_start
start_thread
java

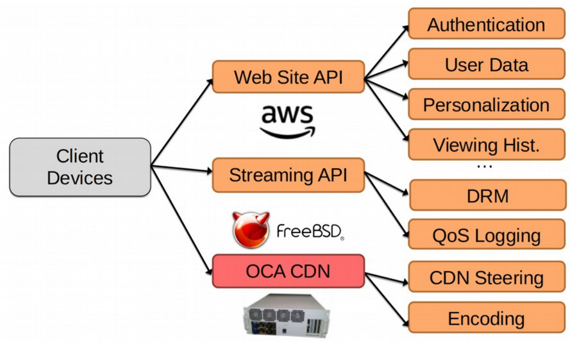

FLAMESCOPE
Home
Heatmap (stacks.perf_prod01.txt)
Rows
50
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
time (seconds)
1. Click start
2. Click end
3. See flame graph for that range
time (milliseconds)
Count
0 2 4 6 8
second: 35, millisecond: 580, count: 1

Observability
Methodology
Velocity

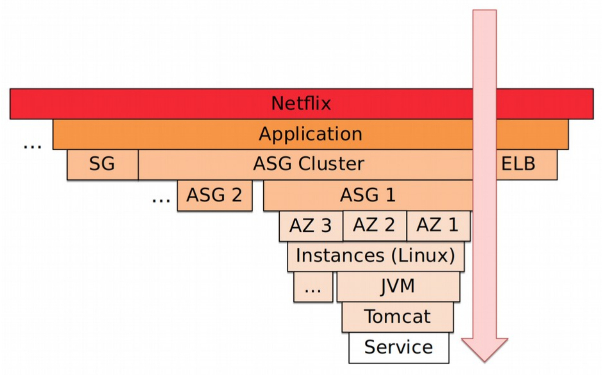
Root Cause Analysis at Netflix



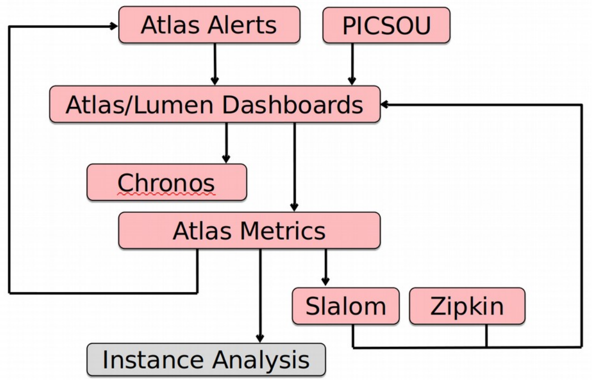
Agenda



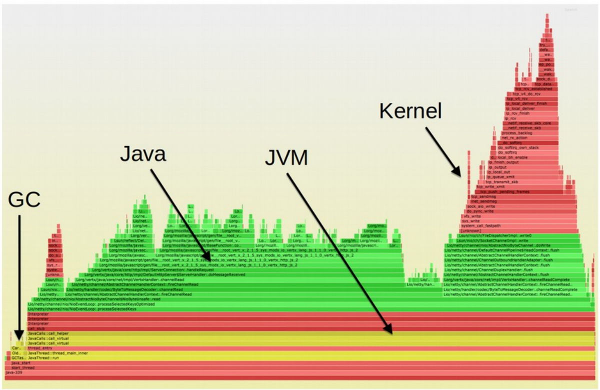
1. The Netflix Cloud



2. Methodology



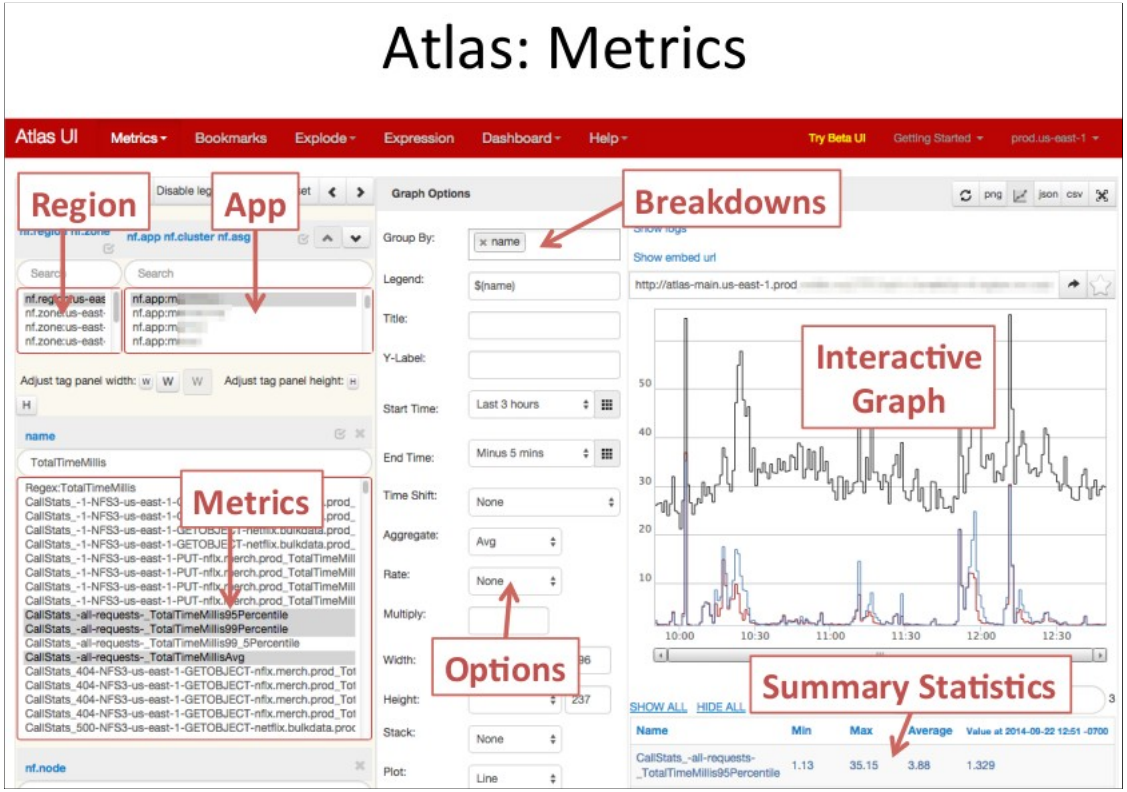
3. Cloud Analysis



4. Instance Analysis

Since 2014

- Asgard → Spinnaker
- Salp → Zipkin
- gRPC adoption
- New Atlas UI & Lumen
- Java frame pointer
- eBPF bcc & bpftrace
- PMCs in EC2
- ...



From Clouds to Roots (2014 presentation): Old Atlas UI

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>150k AWS EC2 server instances

~34% US Internet traffic at night

>130M members

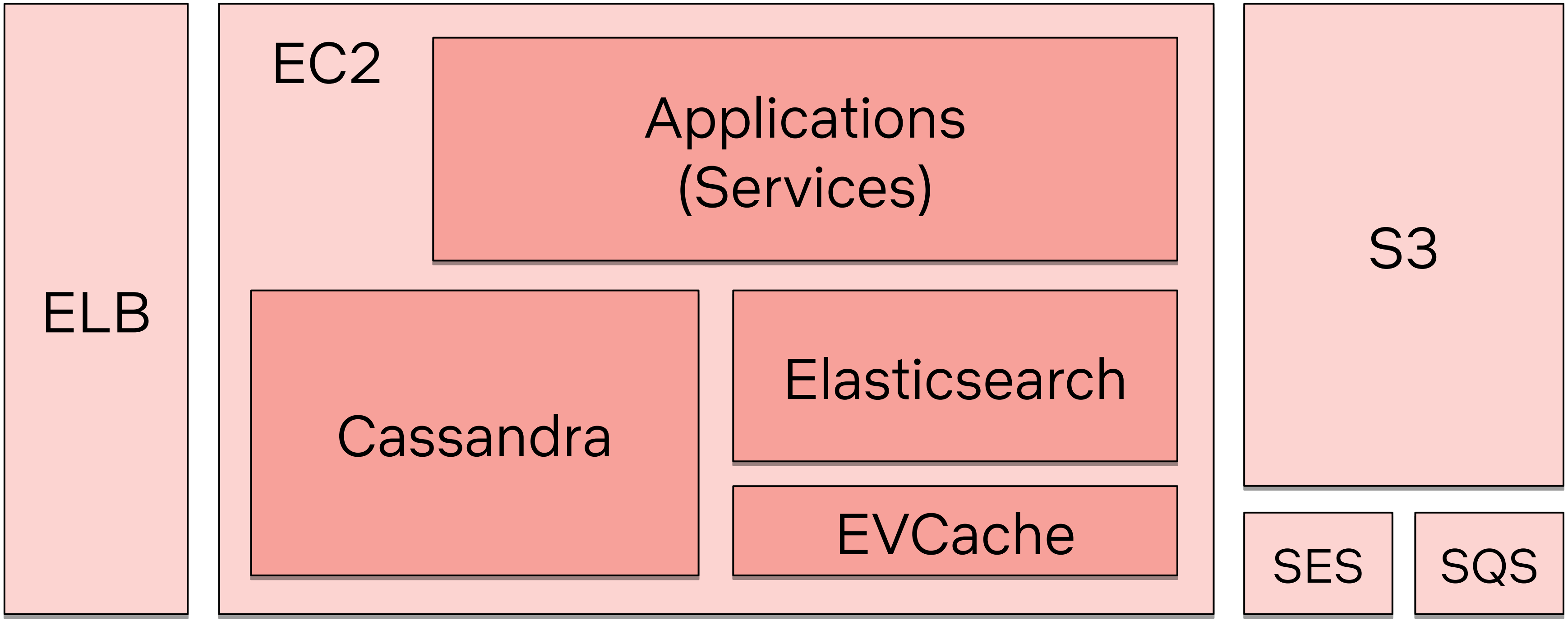
Performance is customer satisfaction & Netflix cost

Acronyms

AWS: Amazon Web Services
EC2: AWS Elastic Compute 2 (cloud instances)
S3: AWS Simple Storage Service (object store)
ELB: AWS Elastic Load Balancers
SQS: AWS Simple Queue Service
SES: AWS Simple Email Service
CDN: Content Delivery Network
OCA: Netflix Open Connect Appliance (streaming CDN)
QoS: Quality of Service
AMI: Amazon Machine Image (instance image)
ASG: Auto Scaling Group
AZ: Availability Zone
NIWS: Netflix Internal Web Service framework (Ribbon)
gRPC: gRPC Remote Procedure Calls
MSR: Model Specific Register (CPU info register)
PMC: Performance Monitoring Counter (CPU perf counter)
eBPF: extended Berkeley Packet Filter (kernel VM)

1. The Netflix Cloud

The Netflix Cloud



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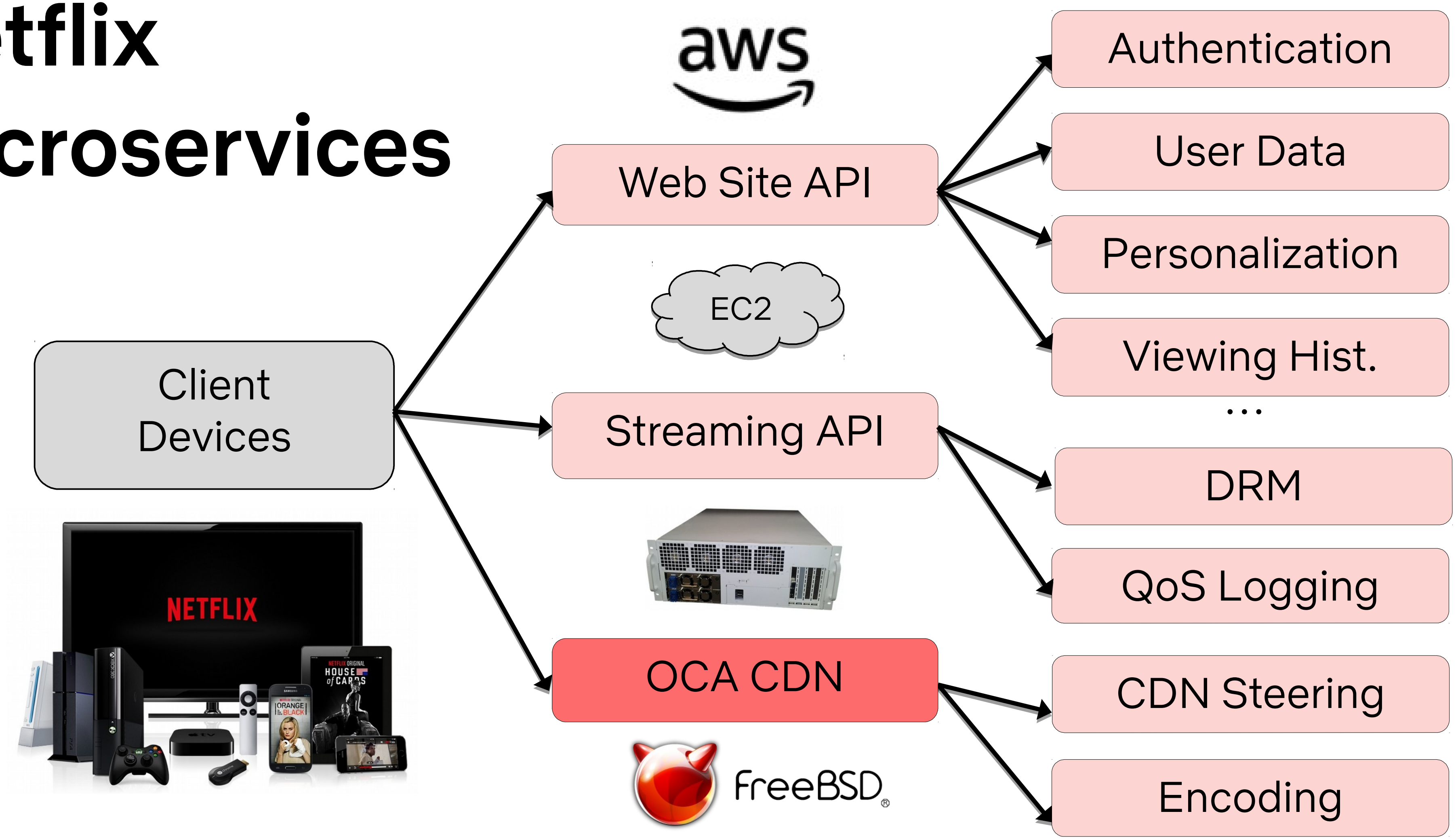
Netflix Microservices

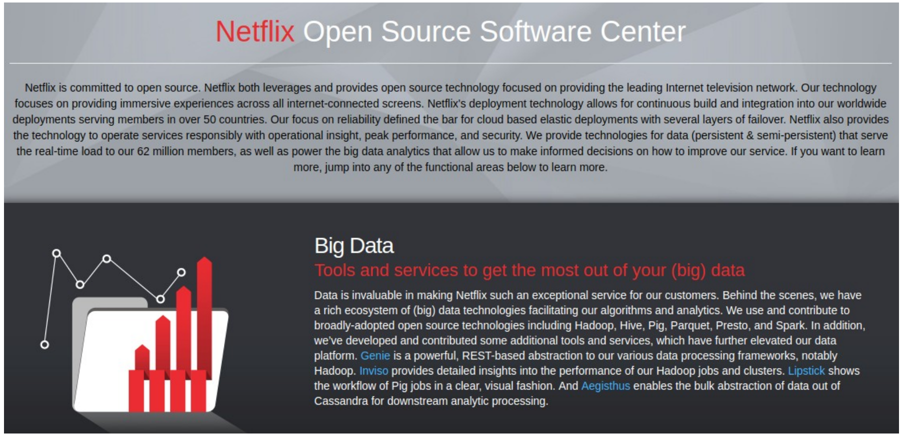


Freedom and Responsibility

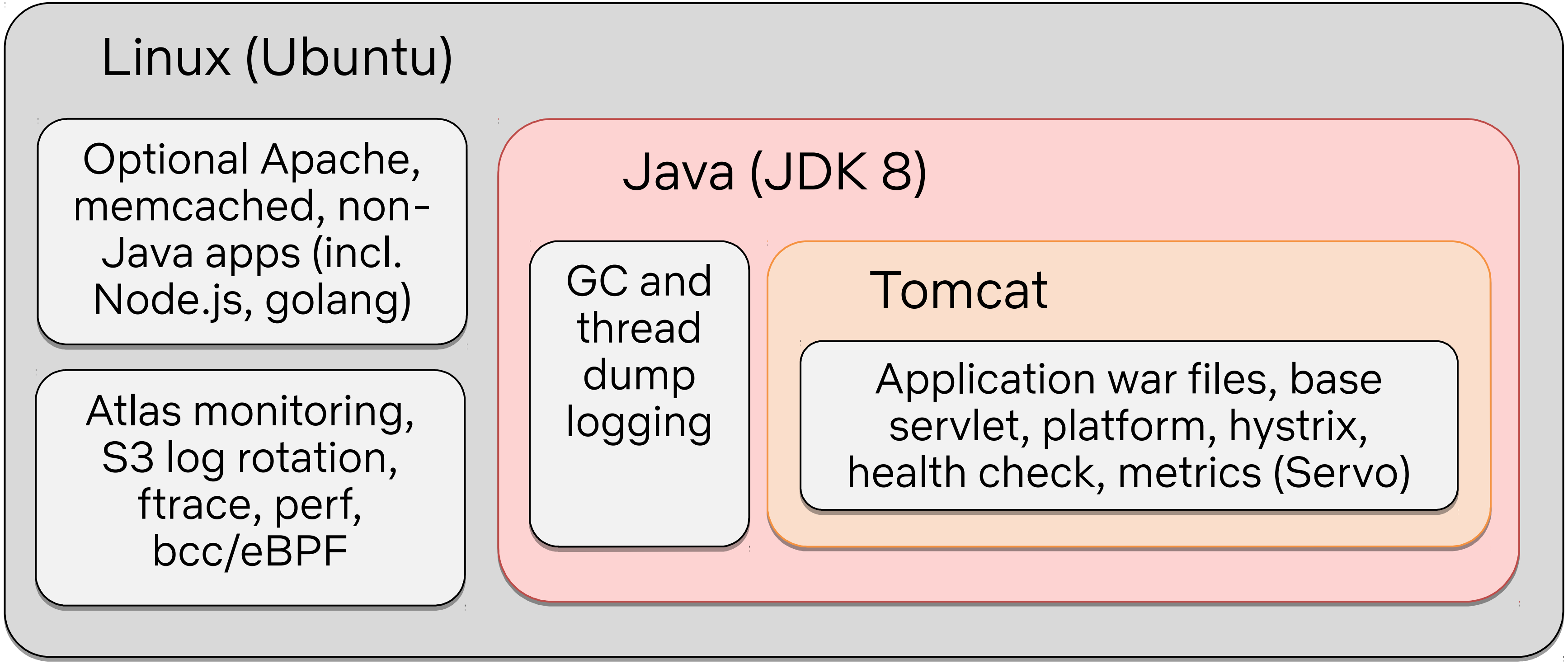
- Culture ~~deck~~ memo is true
  - https://jobs.netflix.com/culture
- Deployment freedom
  - Purchase and use cloud instances without approvals
  - Netflix environment changes fast!

Cloud Technologies

- Usually open source
- Linux, Java, Cassandra, Node.js, …
- http://netflix.github.io/



Cloud Instances



Typical BaseAMI

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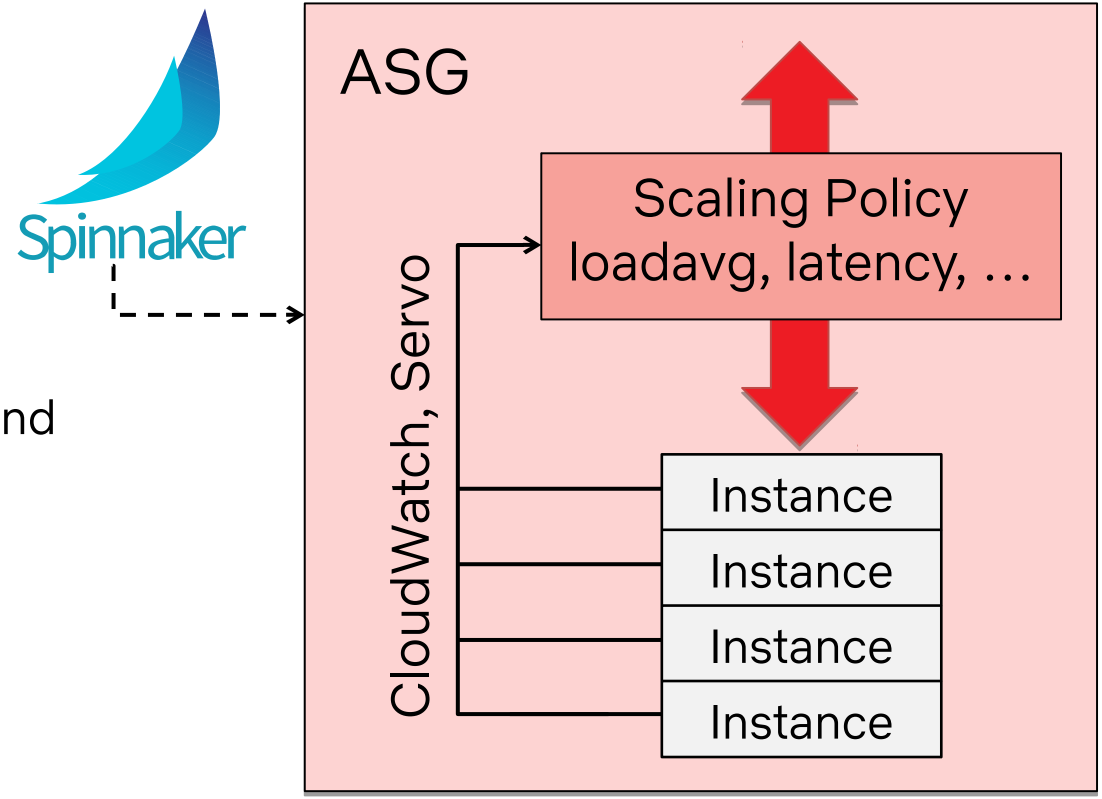
5 Key Issues

And How the Netflix Cloud is Architected to Solve Them

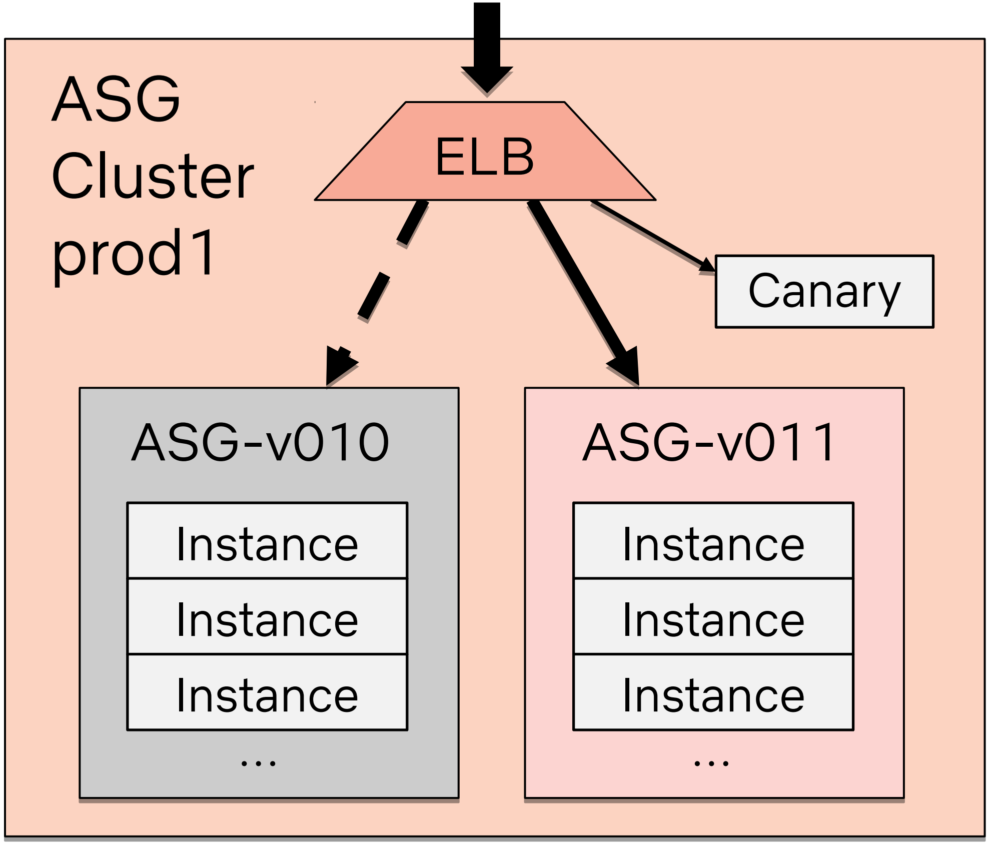
1. Load Increases → Auto Scaling Groups

- Instances automatically added or removed by a custom scaling policy
- Alerts & monitoring used to check scaling is sane
- Good for customers: Fast workaround
- Good for engineers: Fix later, 9-5



2. Bad Push → ASG Cluster Rollback

- ASG red black clusters: how code versions are deployed
- Fast rollback for issues
- Traffic managed by Elastic Load Balancers (ELBs)
- Automated Canary Analysis (ACA) for testing

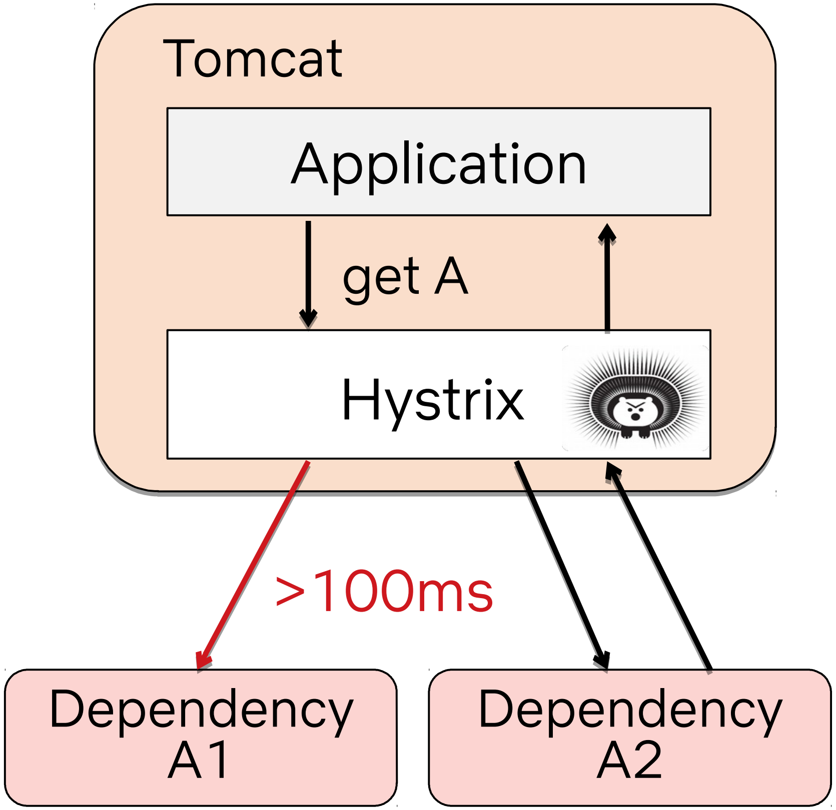


3. Instance Failure → Hystrix Timeouts

- Hystrix: latency and fault tolerance for dependency services

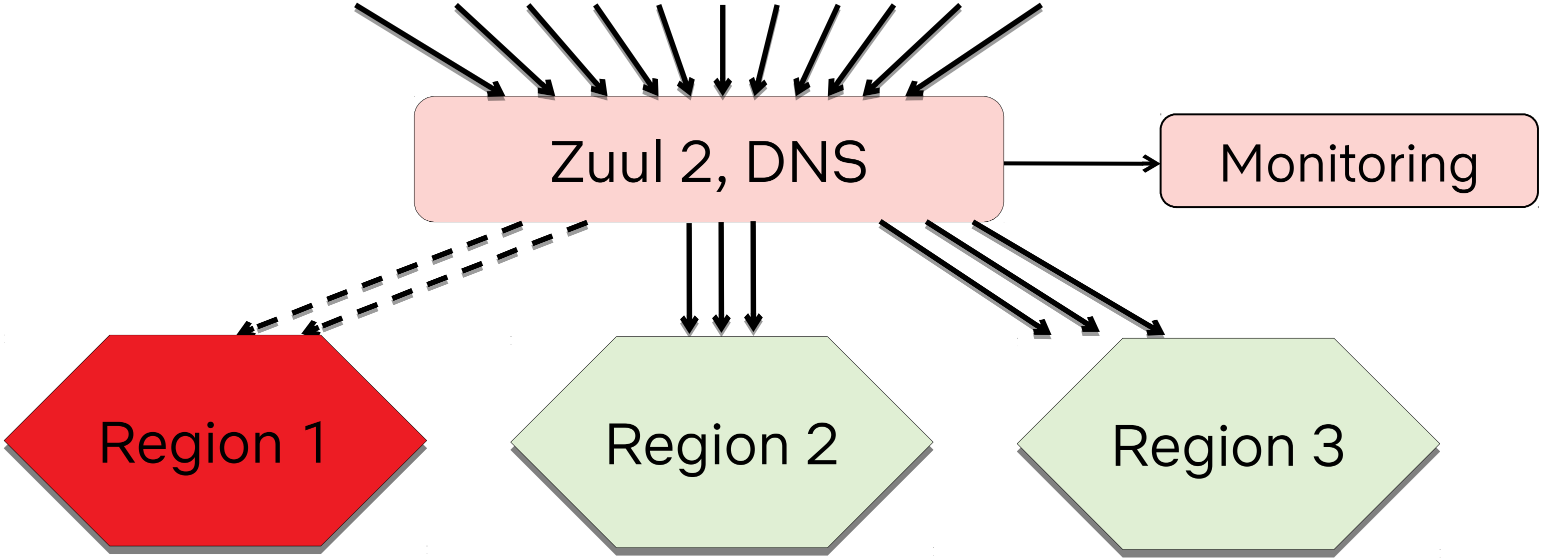
  Fallbacks, degradation, fast fail and rapid recovery, timeouts, load shedding, circuit breaker, realtime monitoring

- Plus Ribbon or gRPC for more fault tolerance



4. Region failure → Zuul 2 Reroute Traffic

- All device traffic goes through the Zuul 2 proxy: dynamic routing, monitoring, resiliency, security
- Region or AZ failure: reroute traffic to another region

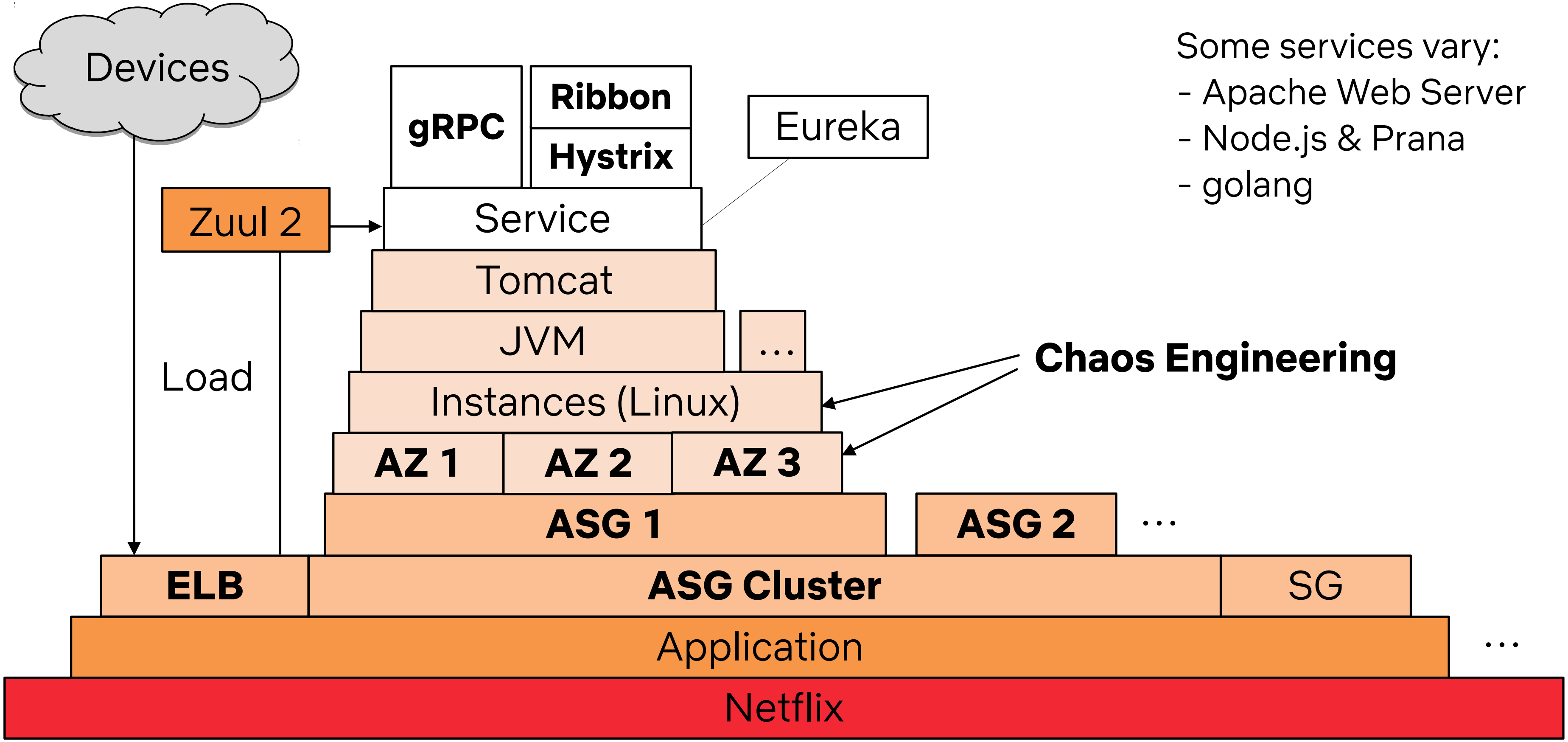


5. Overlooked Issue → Chaos Engineering

(Resilience)

- **Instances**: termination
- **Availability Zones**: artificial failures
- **Latency**: artificial delays by ChAP
- **Conformity**: kills non-best-practices instances
- **Doctor**: health checks
- **Janitor**: kills unused instances
- **Security**: checks violations
- **10-18**: geographic issues

A Resilient Architecture



Some services vary:
- Apache Web Server
- Node.js & Prana
- golang

2. Methodology

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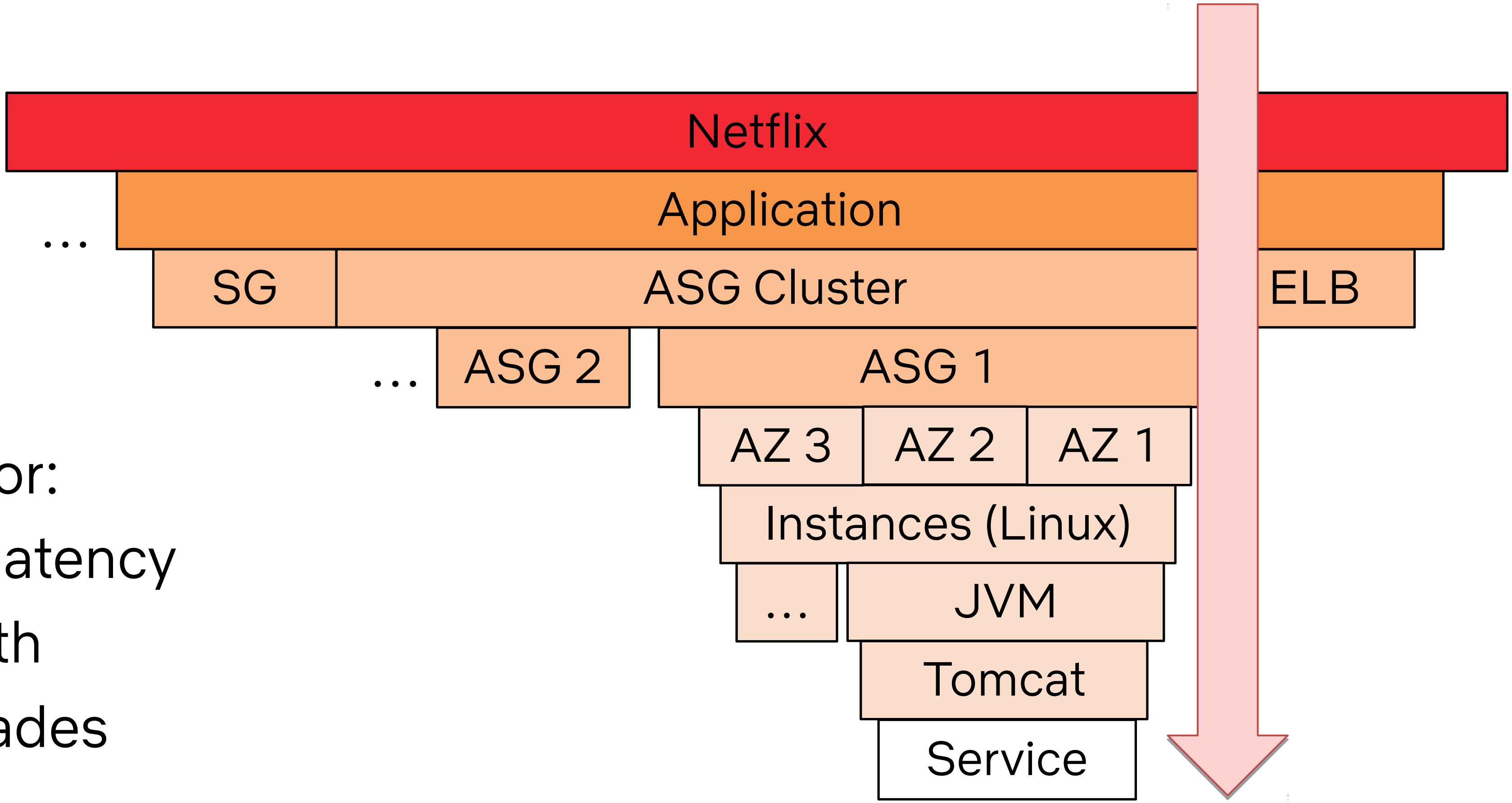
Why Do Root Cause Perf Analysis?



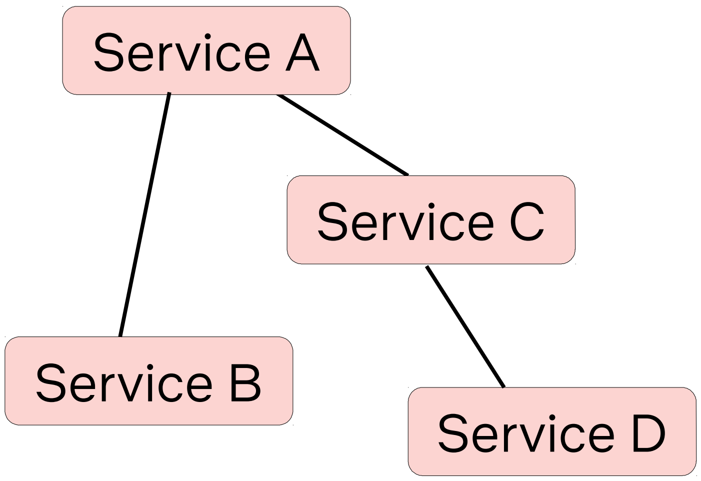
Often for:

- High latency
- Growth
- Upgrades

Cloud Methodologies

- Resource Analysis
- Metric and event correlations
- Latency Drilldowns
- RED Method

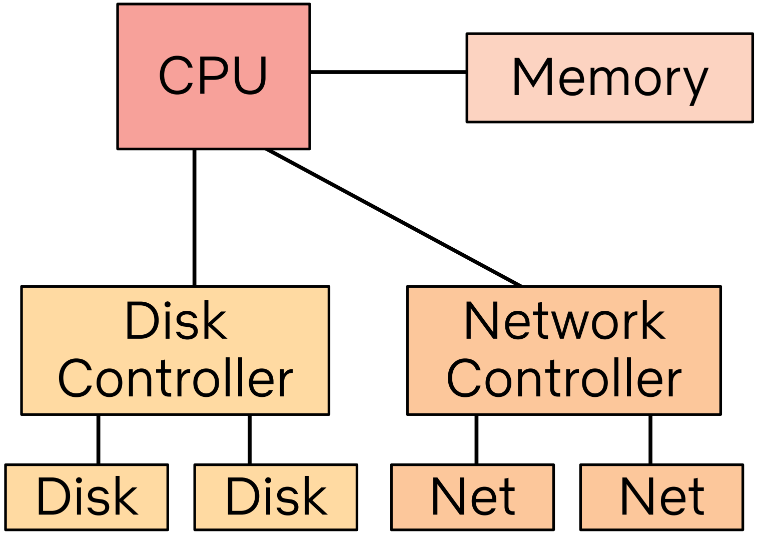
For each microservice, check:
- Rate
- Errors
- Duration



Instance Methodologies

- Log Analysis
- Micro-benchmarking
- Drill-down analysis
- USE Method

For each resource, check:
- Utilization
- Saturation
- Errors

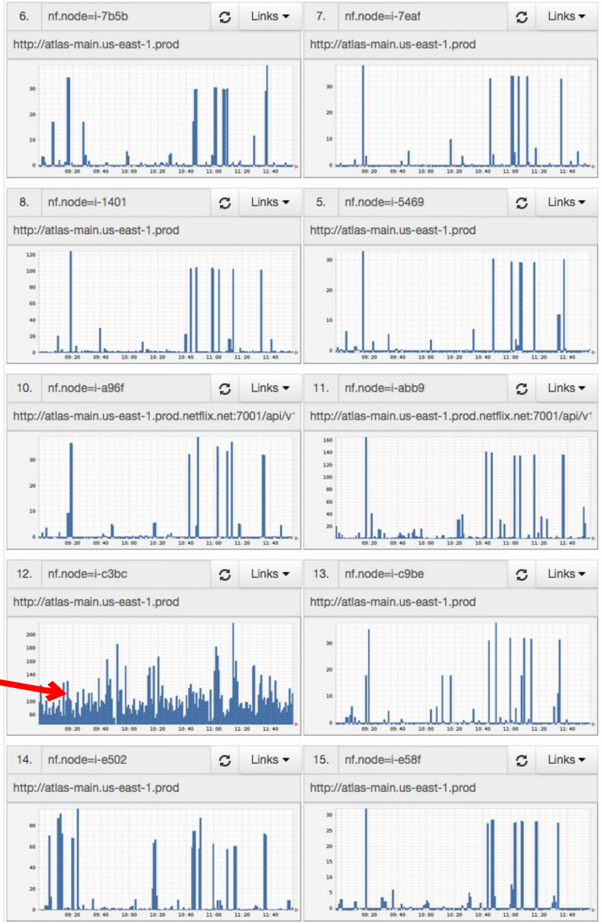


Bad Instance Anti-Method

1. Plot request latency per-instance
2. Find the bad instance
3. Terminate it
4. Someone else's problem now!

Bad instance latency

Terminate!



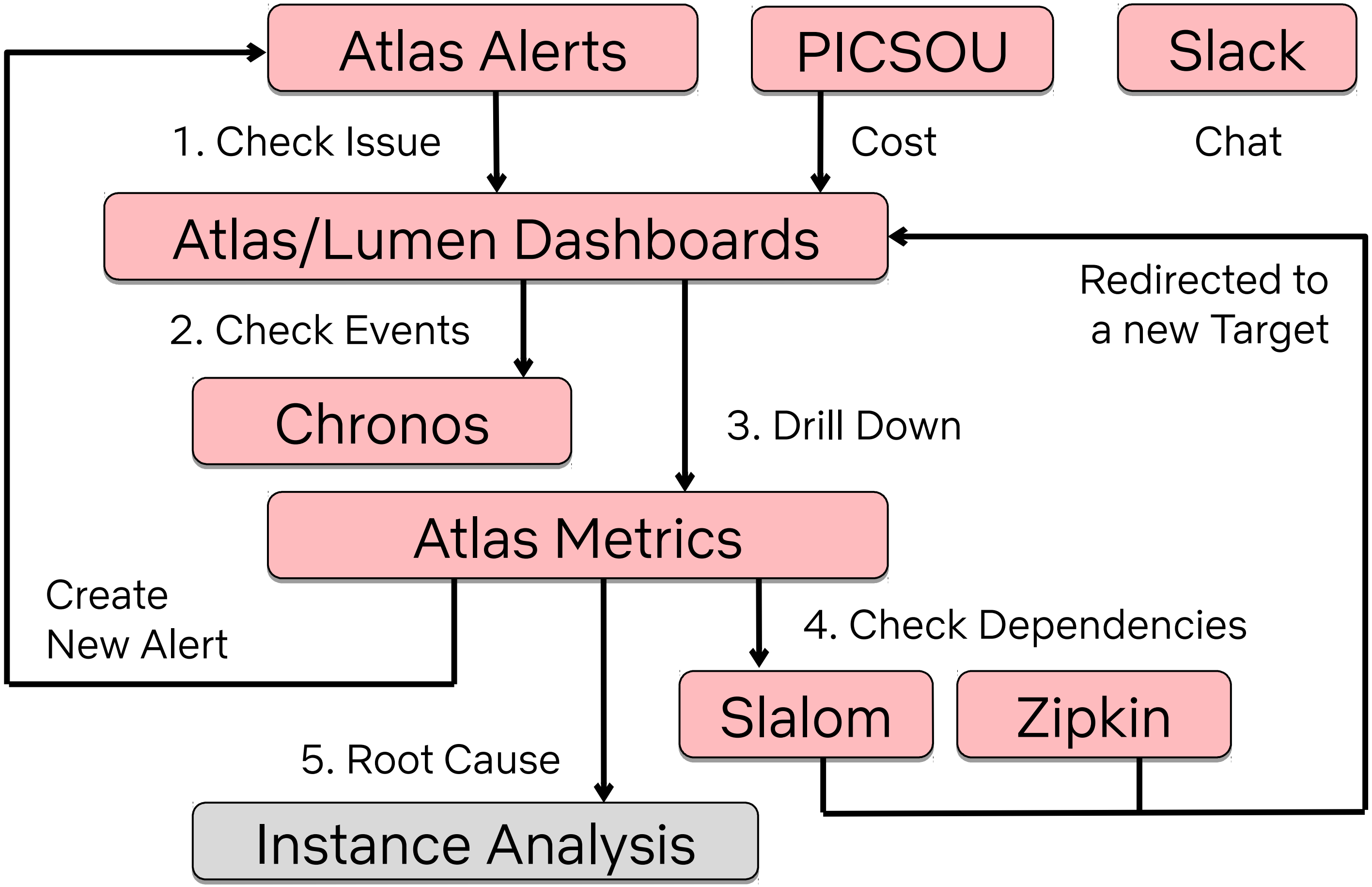
Could be an early warning of a bigger issue

3. Cloud Analysis

Atlas, Lumen, Chronos, ...

Netflix Cloud Analysis Process

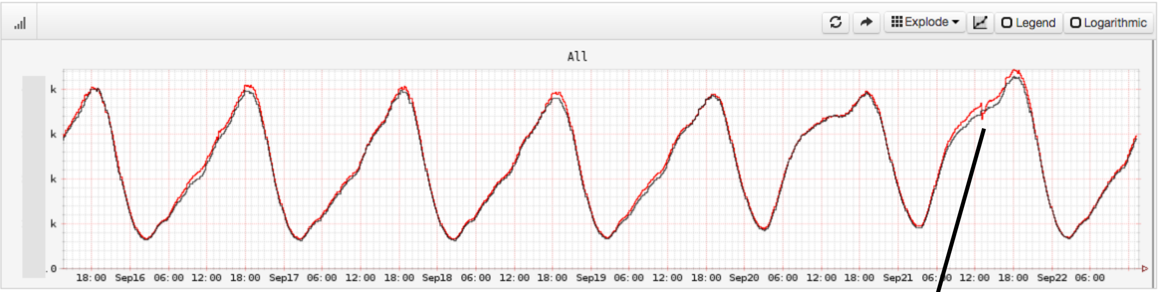
Example path
enumerated

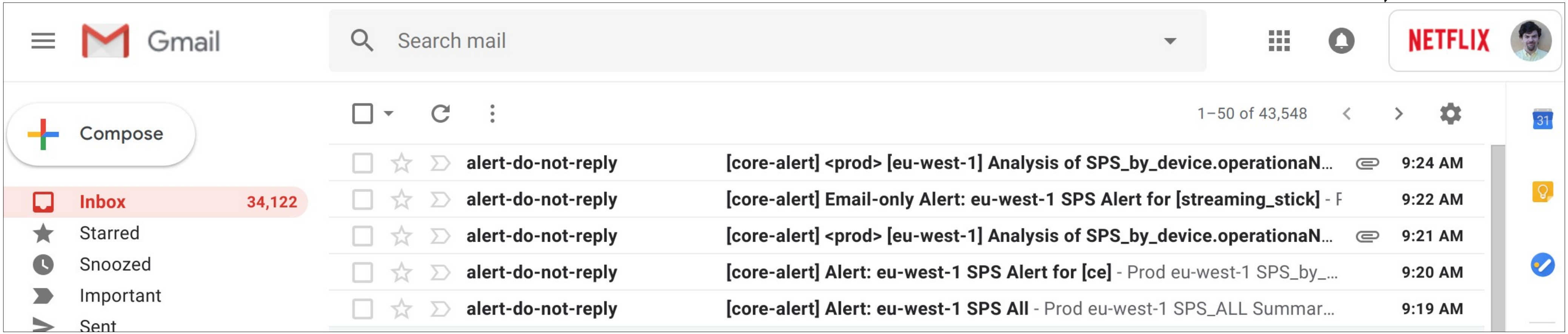


Plus some other
tools not pictured

Atlas: Alerts

Custom alerts on streams per second (SPS) changes, CPU usage, latency, ASG growth, client errors, …





[core-alert] <prod> [eu-west-1] Analysis of SPS_by_device.operationName_[illegible] [streaming_stick] [illegible] Inbox ×

alert-do-not-reply@[illegible]
to core-alerts

9:24 AM (1 hour ago)

Italian > English Translate message Turn off for: Italian ×

Prod eu-west-1 **SPS_by_device.operationName** [illegible]

Summary: [eu-west-1] Analysis of SPS_by_device.operationName_[illegible]

Check time: 2018-11-28 14:21:59
Time of alert: 2018-11-28 14:17:00

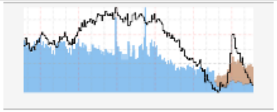
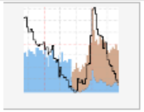
Environment: prod
Region: eu-west-1

Match set: streaming_stick
Incident Key: [illegible]

Winston Diagnostics and Remediation

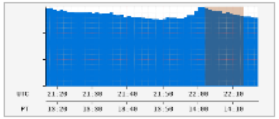
Did this correlate with a new or dying ASG?

Note: ASGs are listed in order of correlation confidence (starting with the highest) for at least one of the ASGs in the cluster.

ASG	3h View	Correlation Window (*60m*)
[illegible] PagerDuty [illegible] *Pearson: 83%* *Spearman: 88%*		

Related to a Fast Property Change?

The highlighted portion of this graph shows the range of time evaluated for Fast Property changes. The query performed filters *things* which we believe are NOT related to typical streaming issues. Here's an unfiltered list of Fast Properties in Chronos UI.

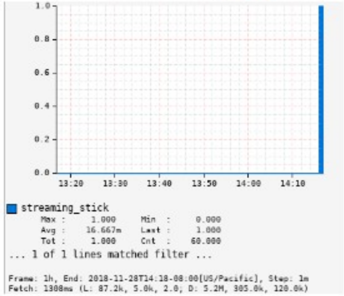


time	region	action	name	app	cluster	stack
14:10:56	eu-west-1	delete	[illegible]	[illegible]	[illegible]	[illegible]
14:10:19		delete	[illegible]	[illegible]	[illegible]	[illegible]
14:09:19		update	[illegible]	[illegible]		
14:06:00		delete	[illegible]	[illegible]		
14:05:49		delete	[illegible]	[illegible]		
14:04:19		delete	[illegible]	[illegible]		
14:03:58		delete	[illegible]	[illegible]		

Metrics

View the status of key metrics below. These can be changed or redefined in the Alert configuration.

Alert Signal (as of 2018-11-28 14:17:00) (PNG | UI)

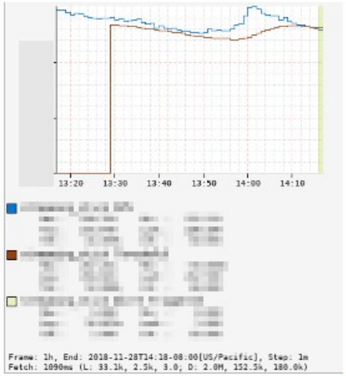


Description / Instructions

This is the signal the alert is based on.

View Current Graph (PNG | UI)

REGIONAL: Alert Visualization (as of 2018-11-28 14:17:00) (PNG | UI)



Description / Instructions

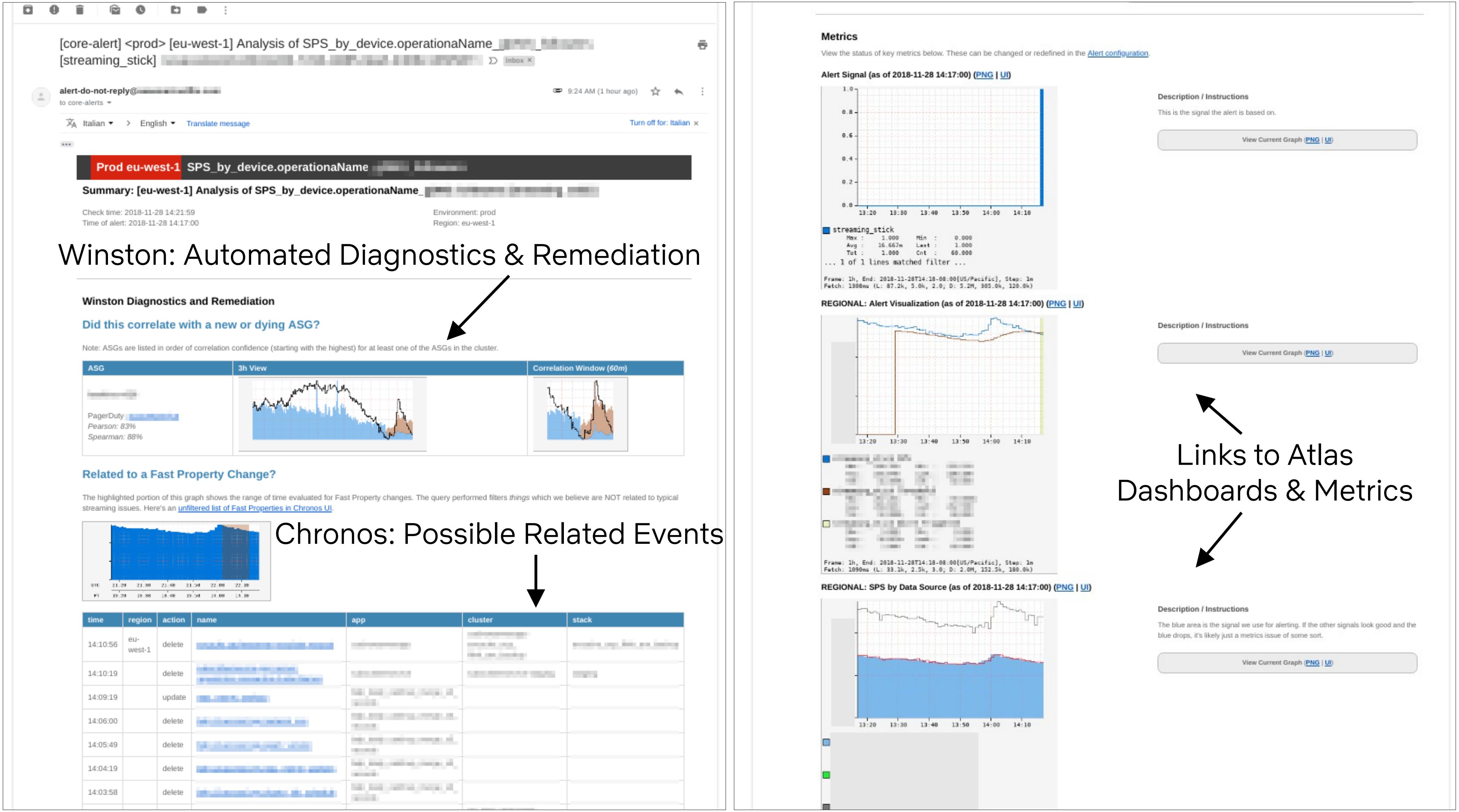
View Current Graph (PNG | UI)

REGIONAL: SPS by Data Source (as of 2018-11-28 14:17:00) (PNG | UI)

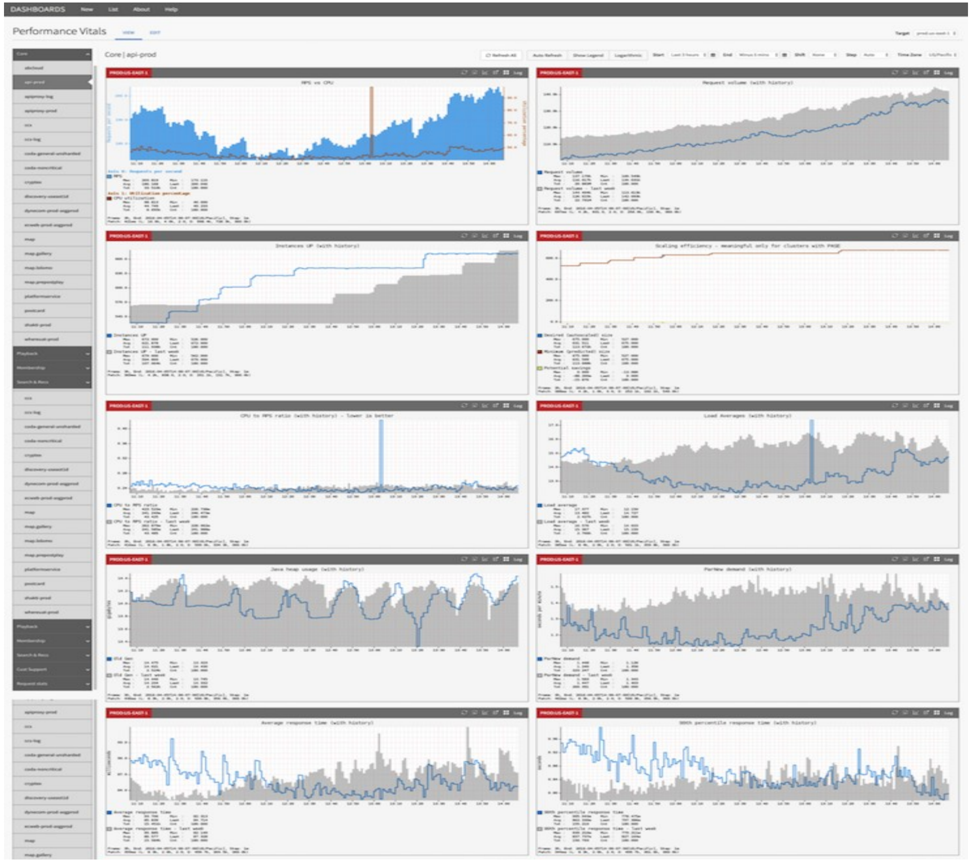
Description / Instructions

The blue area is the signal we use for alerting. If the other signals look good and the blue drops, it's likely just a metrics issue of some sort.

View Current Graph (PNG | UI)

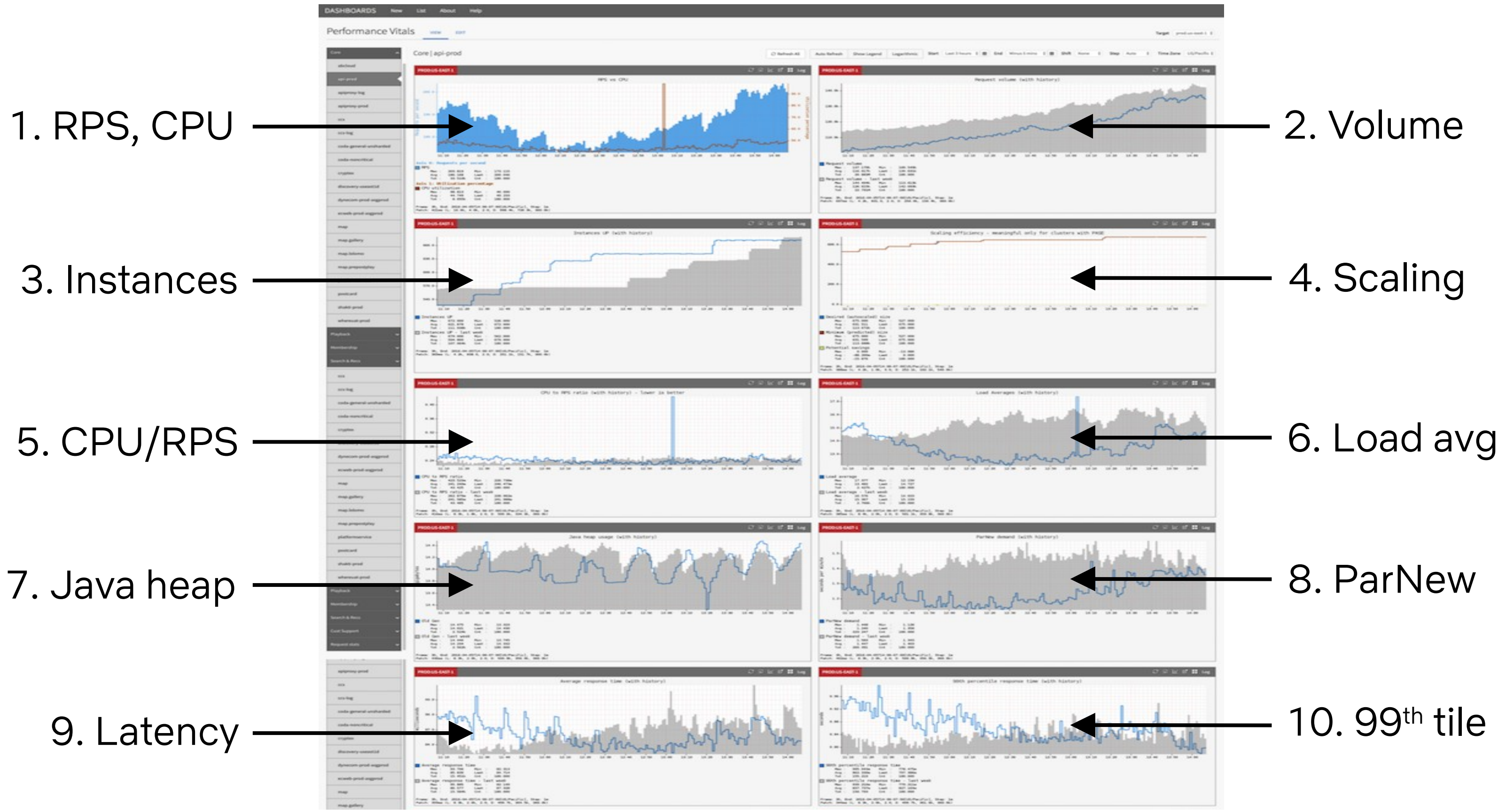

[core-alert] <prod> [eu-west-1] Analysis of SPS_by_device.operationName_
[streaming_stick]
Inbox
alert-do-not-reply@
to core-alerts
9:24 AM (1 hour ago)
Italian
English
Translate message
Turn off for: Italian
Prod eu-west-1
SPS_by_device.operationName
Summary: [eu-west-1] Analysis of SPS_by_device.operationName_
Check time: 2018-11-28 14:21:59
Time of alert: 2018-11-28 14:17:00
Environment: prod
Region: eu-west-1
Winston: Automated Diagnostics & Remediation
Winston Diagnostics and Remediation
Did this correlate with a new or dying ASG?
Note: ASGs are listed in order of correlation confidence (starting with the highest) for at least one of the ASGs in the cluster.
ASG
3h View
Correlation Window (60m)
PagerDuty
Pearson: 83%
Spearman: 88%
Related to a Fast Property Change?
The highlighted portion of this graph shows the range of time evaluated for Fast Property changes. The query performed filters things which we believe are NOT related to typical streaming issues. Here's an unfiltered list of Fast Properties in Chronos UI.
Chronos: Possible Related Events
time
region
action
name
app
cluster
stack
14:10:56
eu-west-1
delete
14:10:19
delete
14:09:19
update
14:06:00
delete
14:05:49
delete
14:04:19
delete
14:03:58
delete
Metrics
View the status of key metrics below. These can be changed or redefined in the Alert configuration.
Alert Signal (as of 2018-11-28 14:17:00) (PNG | UI)
streaming_stick
... 1 of 1 lines matched filter ...
Description / Instructions
This is the signal the alert is based on.
View Current Graph (PNG | UI)
REGIONAL: Alert Visualization (as of 2018-11-28 14:17:00) (PNG | UI)
Description / Instructions
View Current Graph (PNG | UI)
Links to Atlas
Dashboards & Metrics
REGIONAL: SPS by Data Source (as of 2018-11-28 14:17:00) (PNG | UI)
Description / Instructions
The blue area is the signal we use for alerting. If the other signals look good and the blue drops, it's likely just a metrics issue of some sort.
View Current Graph (PNG | UI)

Atlas: Dashboards



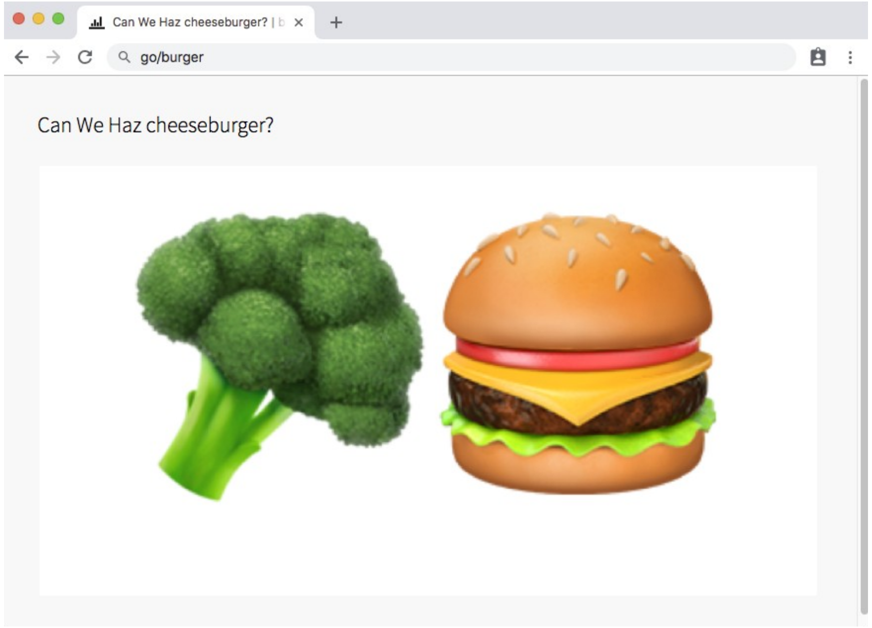
Atlas: Dashboards

Netflix perf vitals dashboard



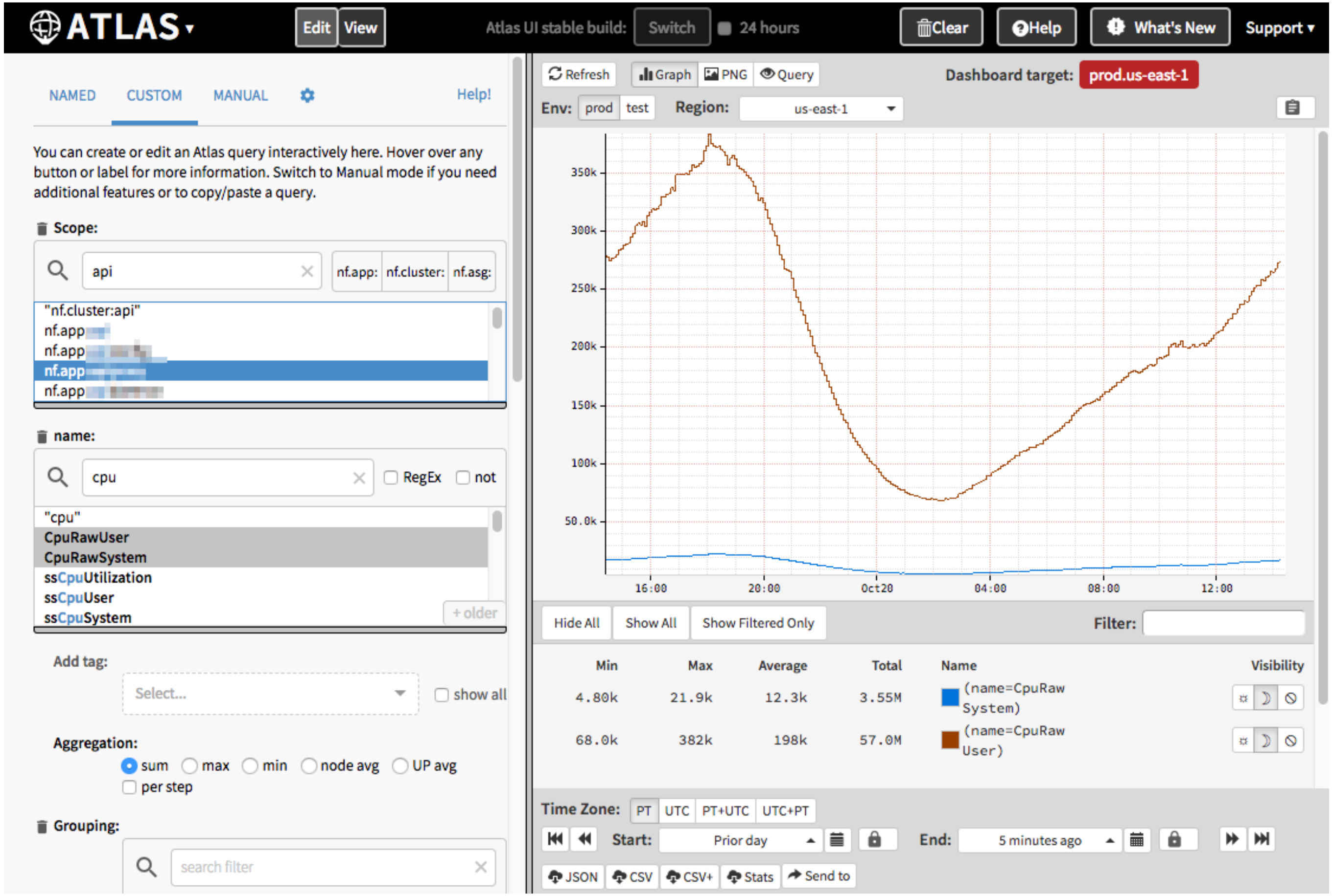
Atlas & Lumen: Custom Dashboards

- Dashboards are a checklist methodology: what to show first, second, third...
- Starting point for issues
  1. Confirm and quantify issue
  2. Check historic trend
  3. Atlas metrics to drill down

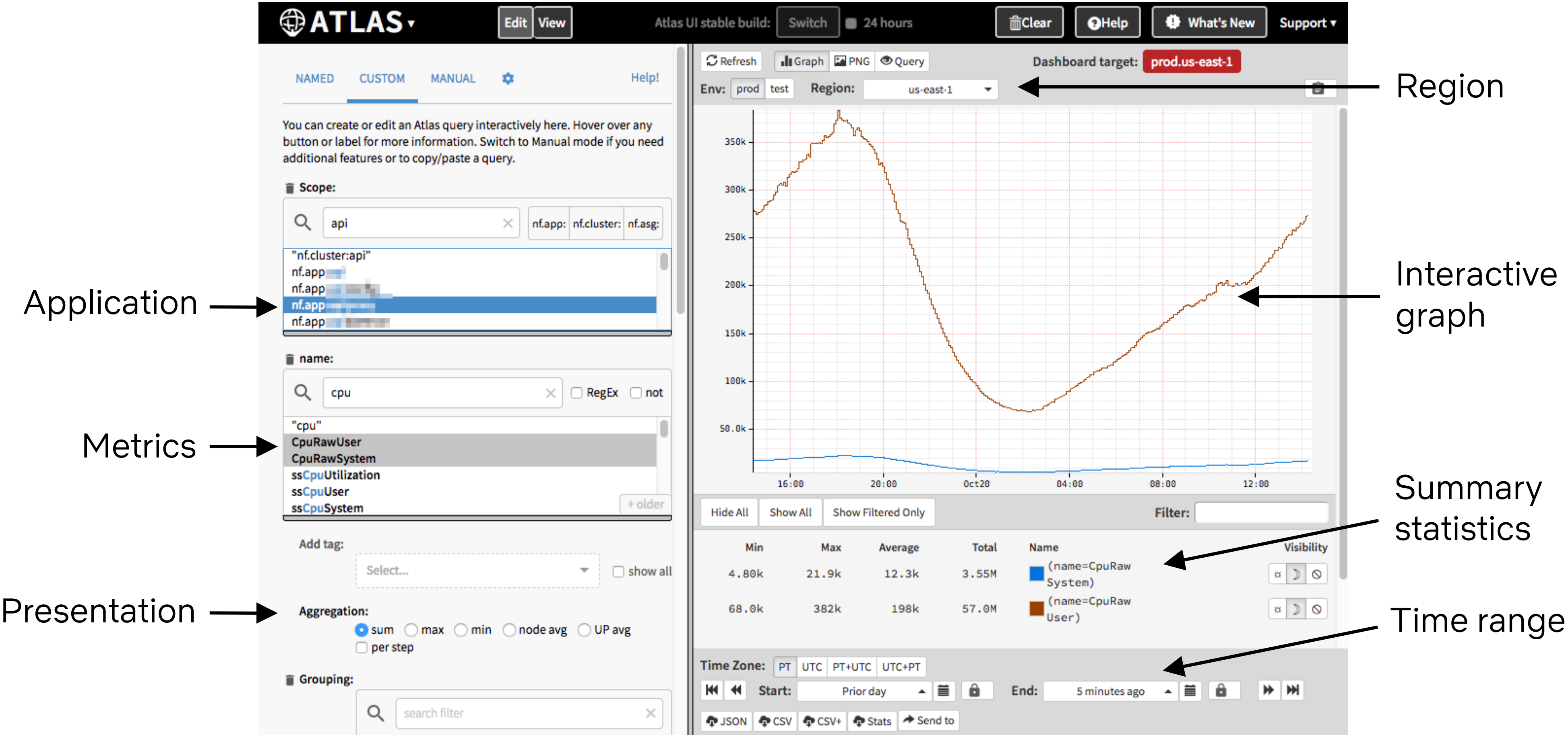


Lumen: more flexible dashboards
eg, go/burger

Atlas: Metrics

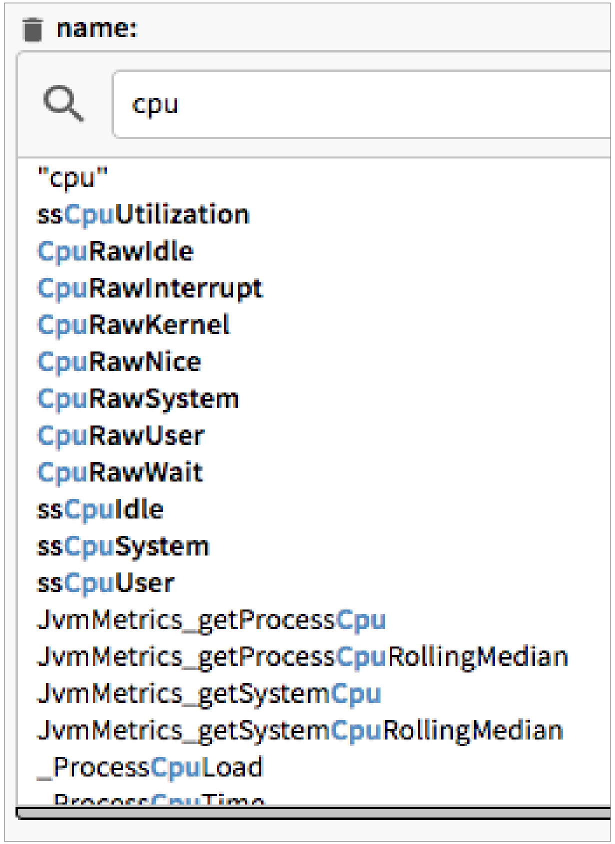


Atlas: Metrics

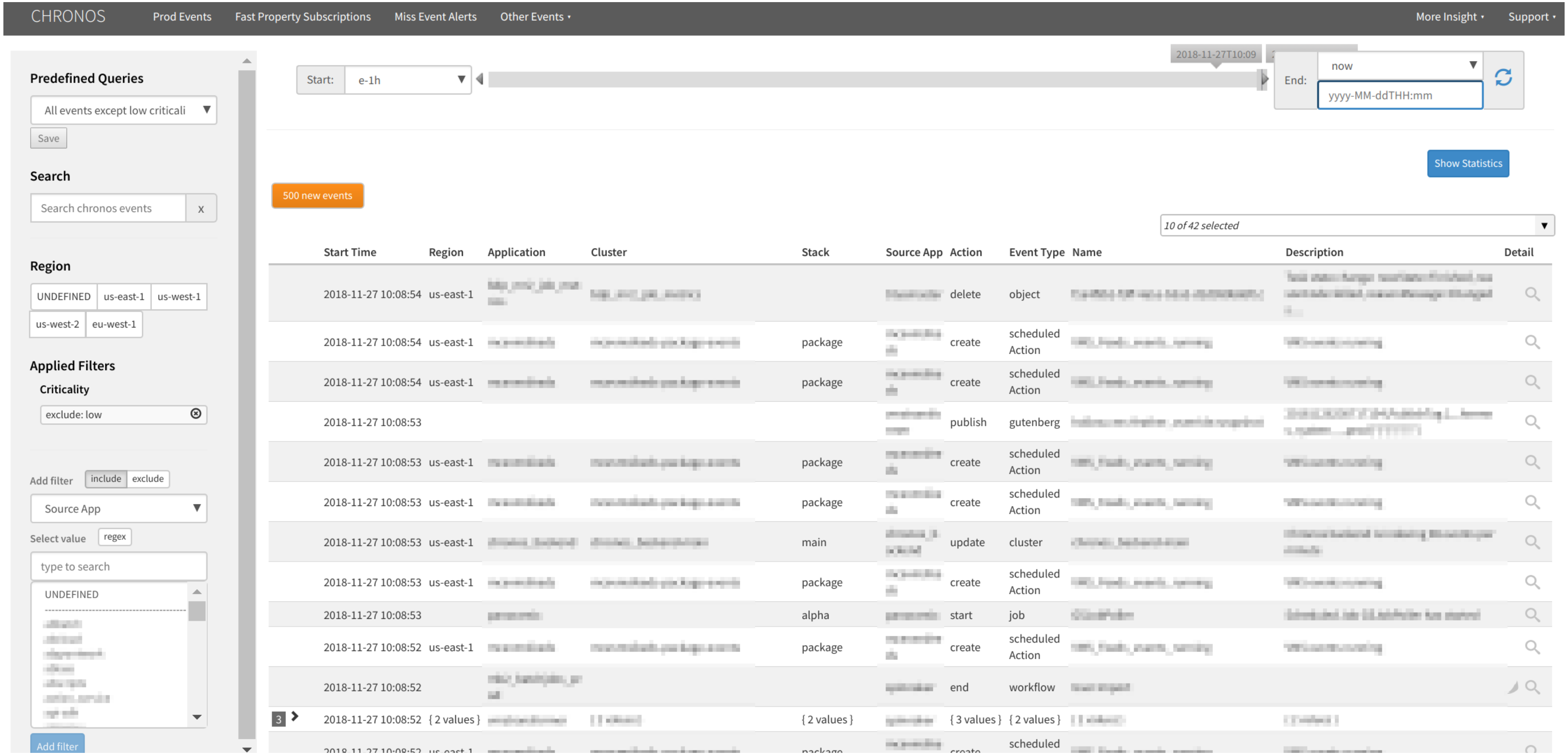


Atlas: Metrics

- All metrics in one system
  - System metrics: CPU usage, disk I/O, memory, …
  - Application metrics: latency percentiles, errors, …
- Filters or breakdowns by region, application, ASG, metric, instance
- URL has session state: shareable



Chronos: Change Tracking



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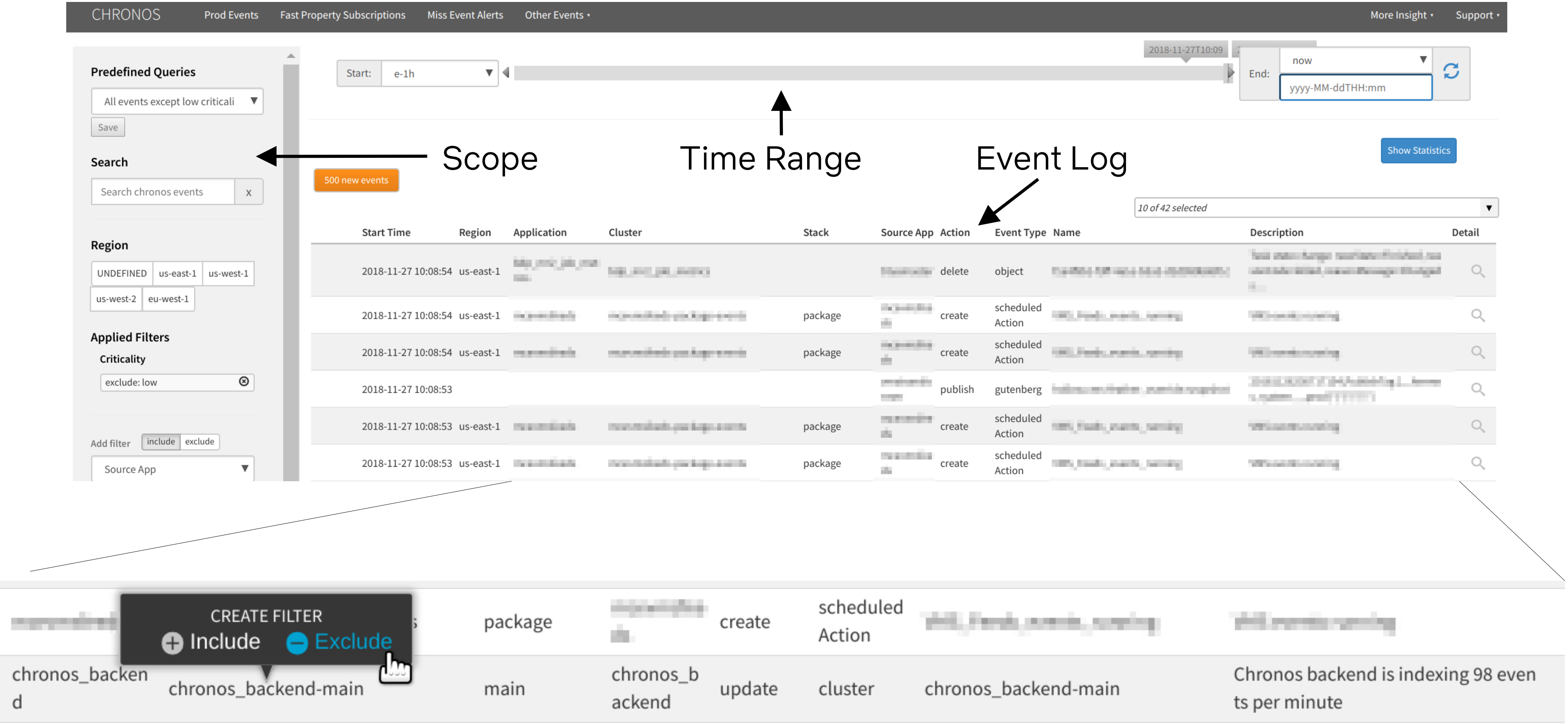
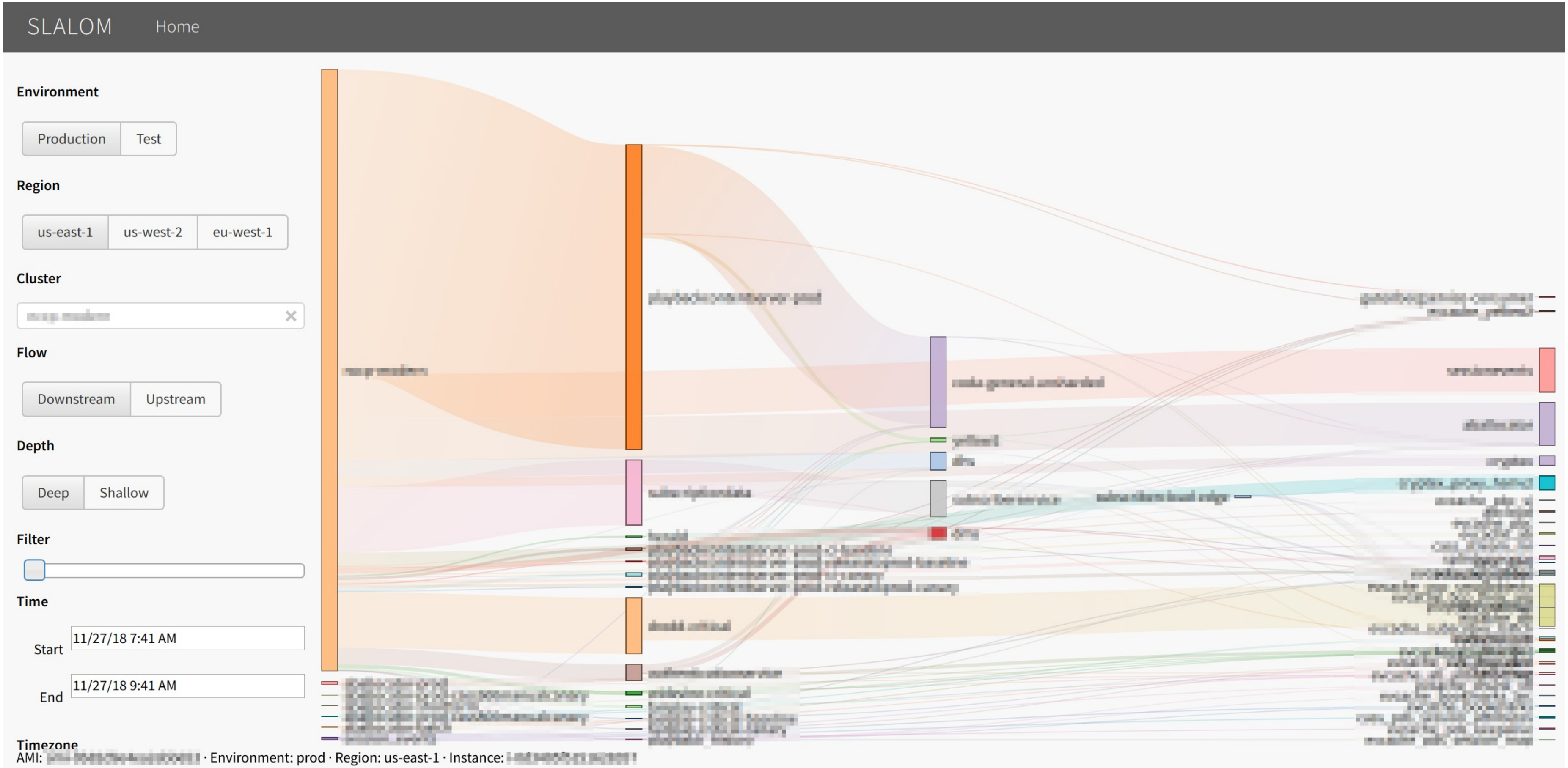


Slalom: Dependency Graphing



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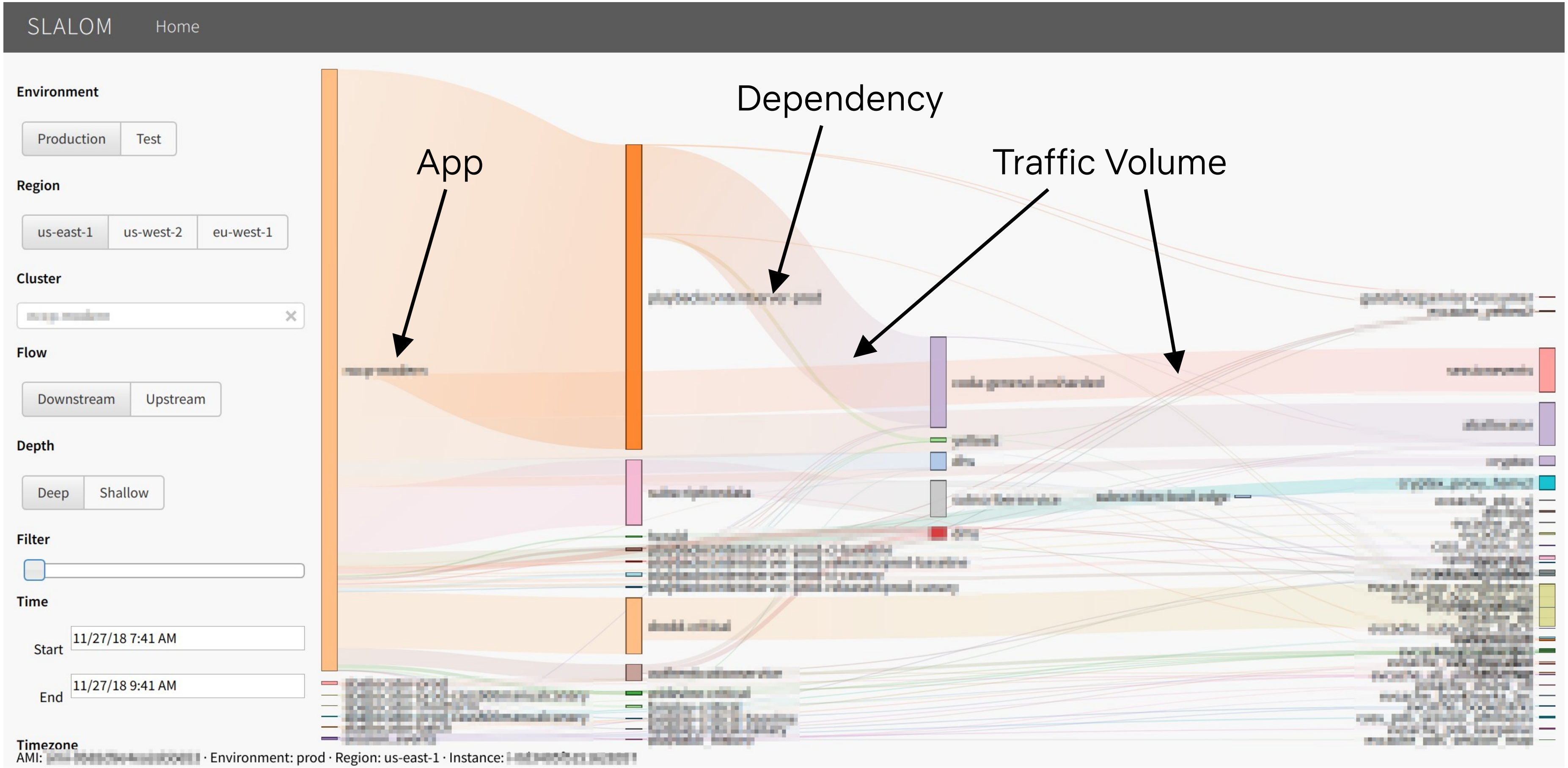
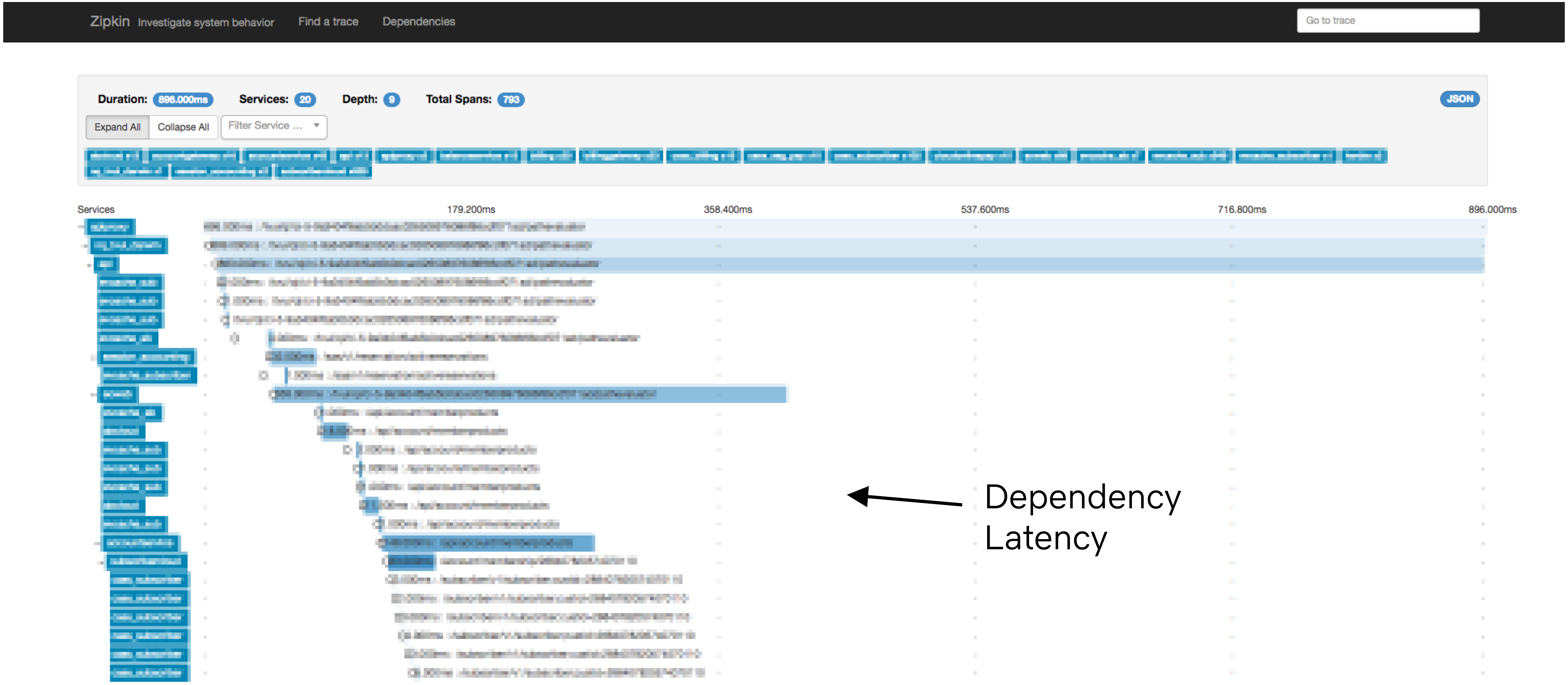


Zipkin UI: Dependency Tracing



Dependency Latency

PICSOU: AWS Usage

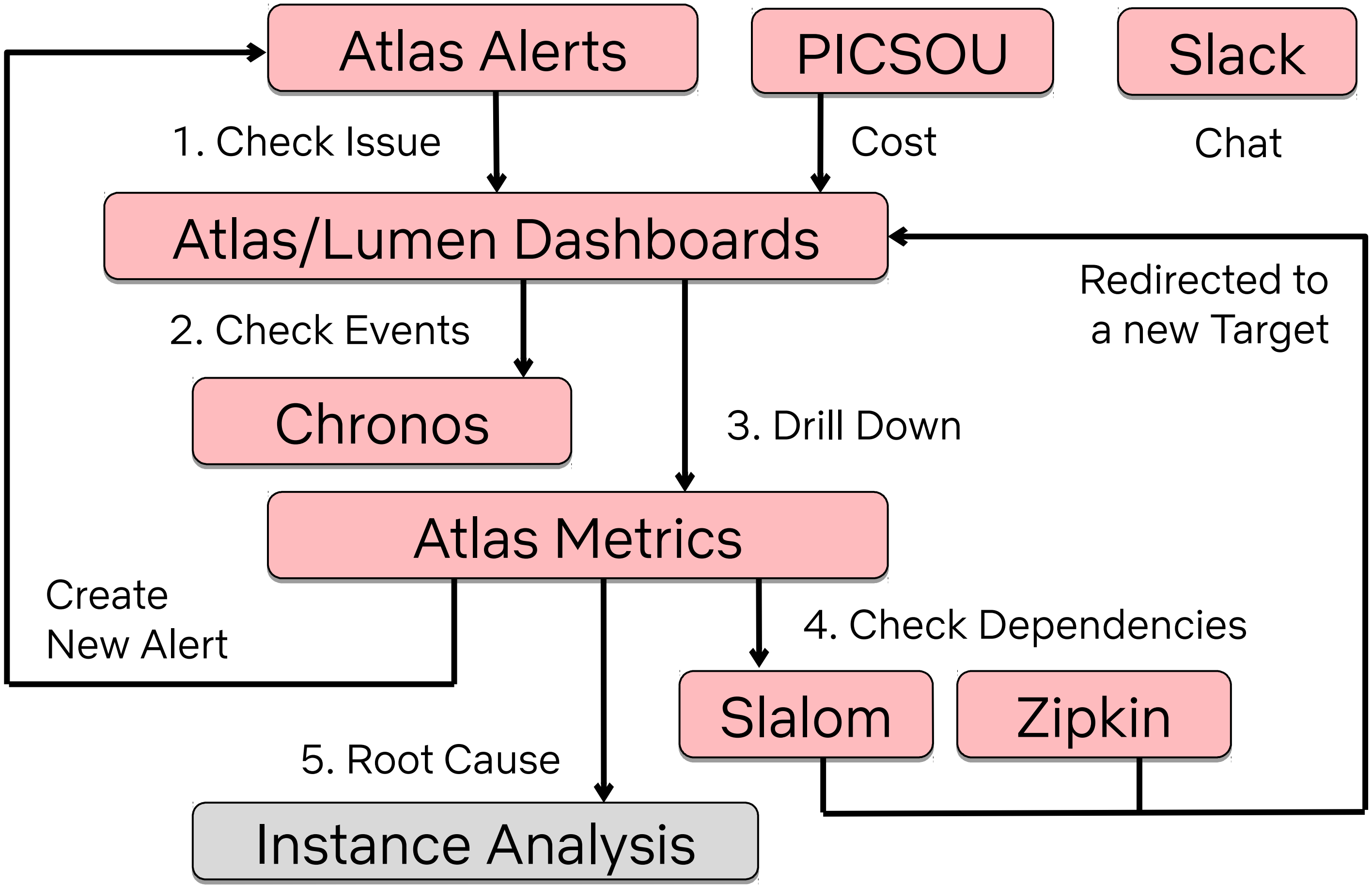
Slack: Chat

Latency is high in us-east-1

Sorry
We just did a bad push

Netflix Cloud Analysis Process

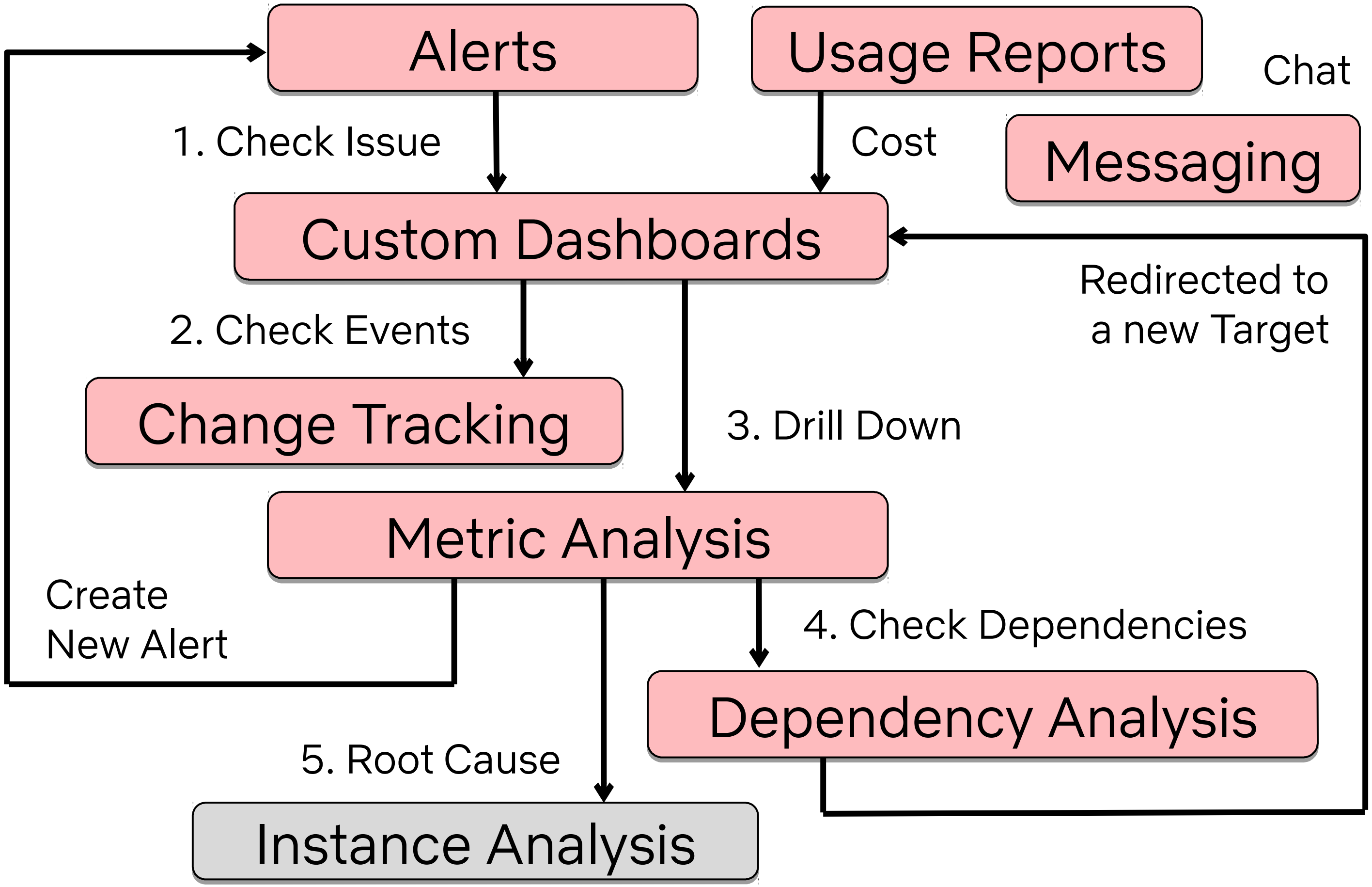
Example path enumerated



Plus some other tools not pictured

Generic Cloud Analysis Process

Example path enumerated



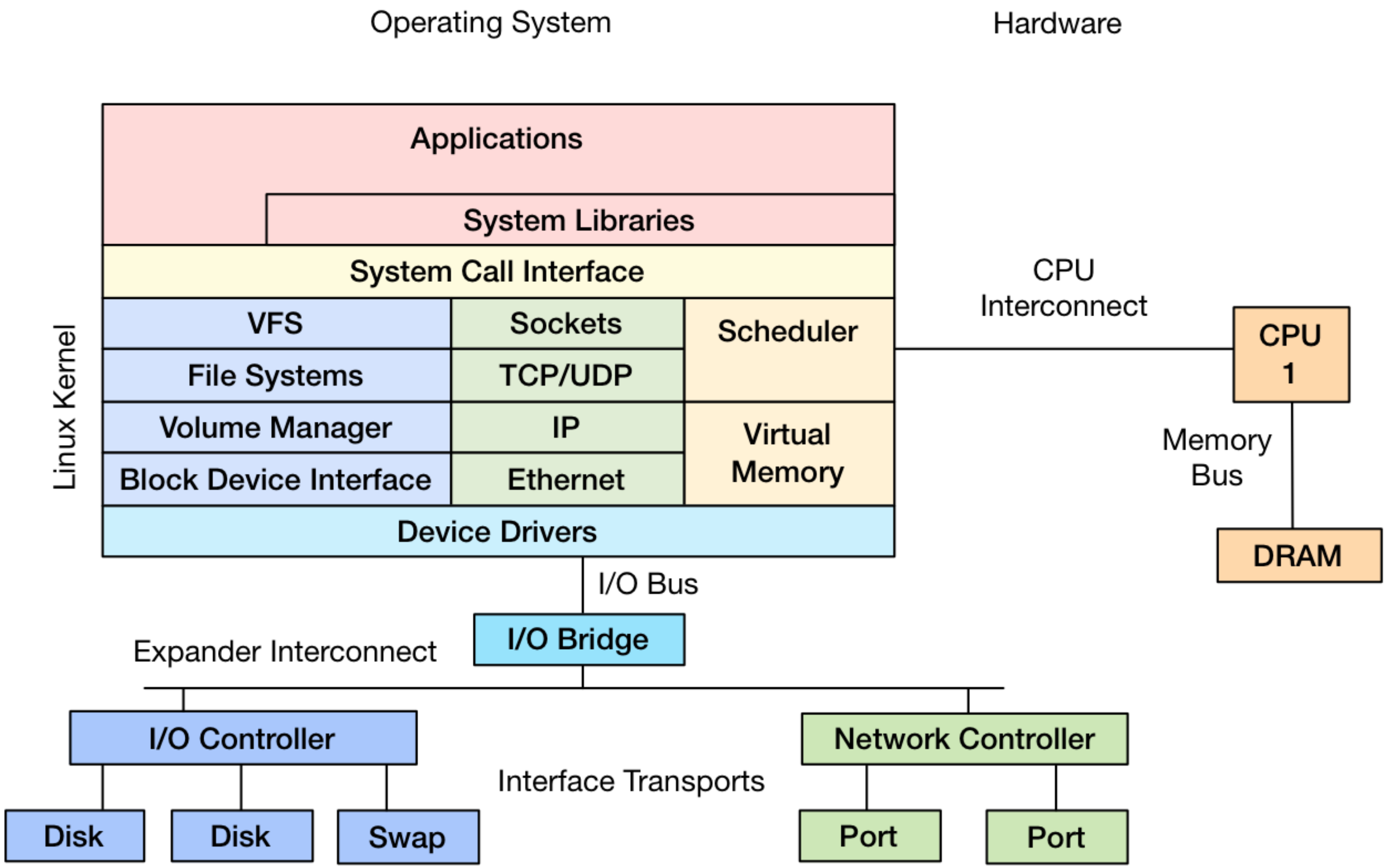
Plus other tools as needed

4. Instance Analysis

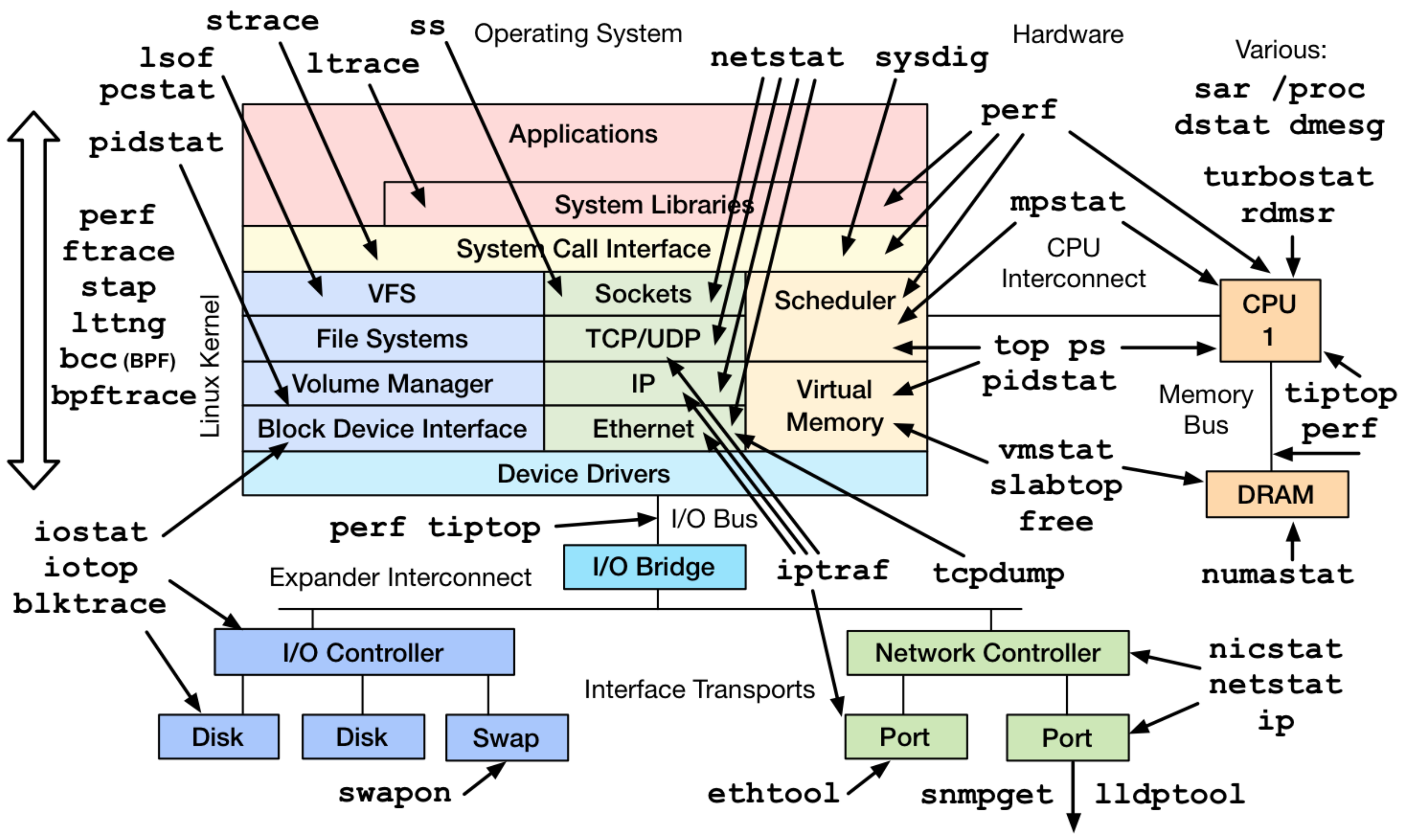
1. Statistics
2. Profiling
3. Tracing
4. Processor Analysis

NETFLIX

Linux Performance



Linux Performance Observability Tools



http://www.brendangregg.com/linuxperf.html 2018

1. Statistics

Linux Tools

- vmstat, pidstat, sar, etc, used mostly normally

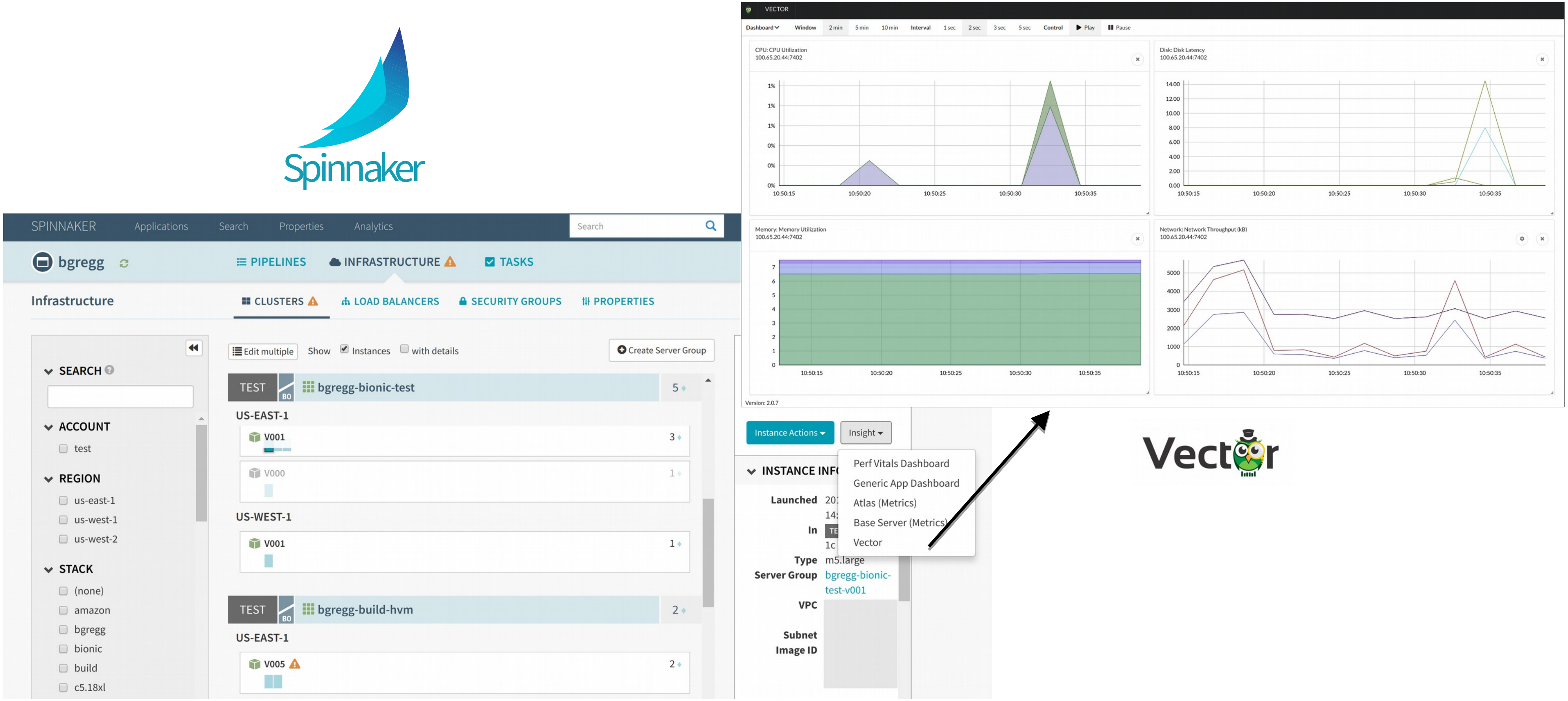
```
$ sar -n TCP,ETCP,DEV 1
Linux 4.15.0-1027-aws (xxx)     12/03/2018    _x86_64_ (48 CPU)

09:43:53 PM IFACE   rxpck/s   txpck/s    rxkB/s    txkB/s   rxcmp/s   txcmp/s rxmcst/s %ifutil
09:43:54 PM    lo     15.00     15.00      1.31      1.31      0.00      0.00      0.00    0.00
09:43:54 PM  eth0  26392.00  33744.00 19361.43 28065.36      0.00      0.00      0.00    0.00

09:43:53 PM  active/s passive/s    iseg/s    oseg/s
09:43:54 PM     18.00    132.00  17512.00  33760.00

09:43:53 PM  atmptf/s  estres/s retrans/s isegerr/s   orsts/s
09:43:54 PM      0.00      0.00     11.00      0.00      0.00
[…]
```

- Micro benchmarking can be used to investigate hypervisor behavior that can't be observed directly

Exception: Containers

- Most Linux tools are still not container aware
  - From the container, will show the full host
- We expose cgroup metrics in our cloud GUIs: Vector

Vector: Instance/Container Analysis

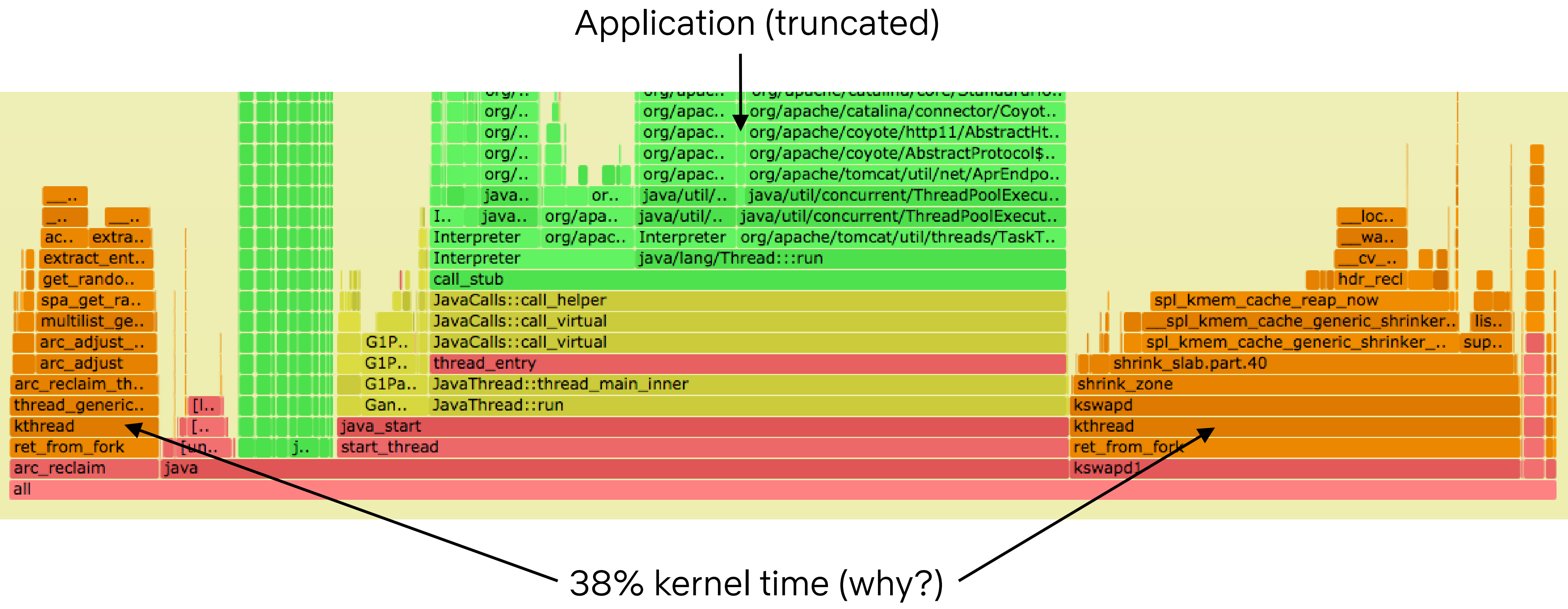


2. Profiling

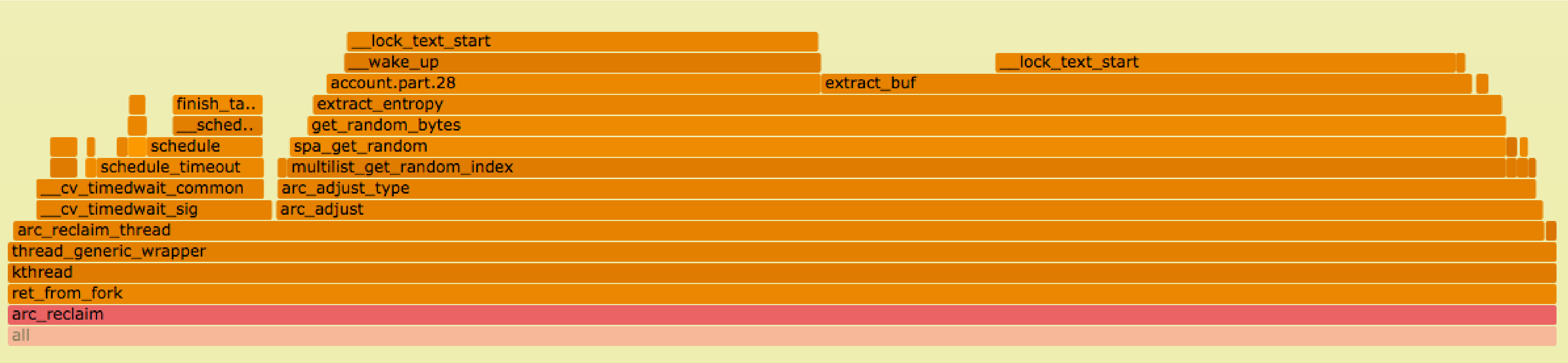
Experience:

“ZFS is eating my CPUs”

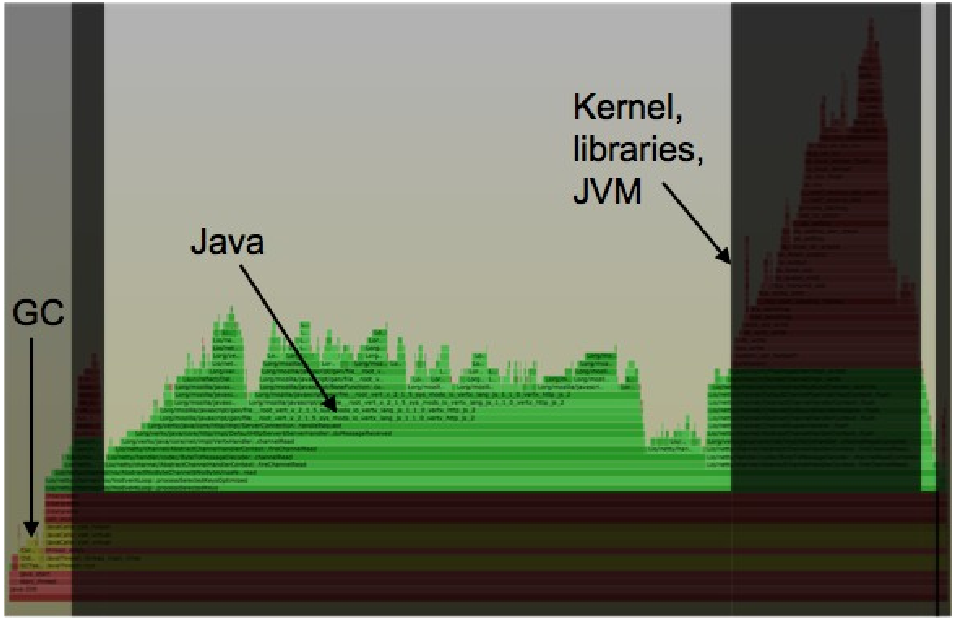
CPU Mixed-Mode Flame Graph



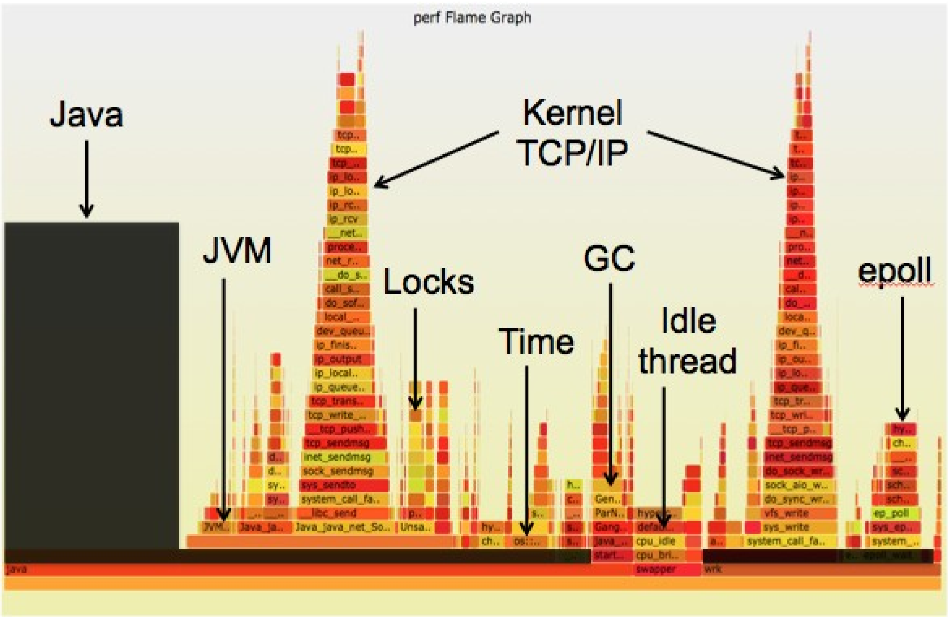
Zoomed


__lock_text_start
__wake_up
__lock_text_start
account.part.28
extract_buf
finish_ta..
extract_entropy
__sched..
get_random_bytes
schedule
spa_get_random
schedule_timeout
multilist_get_random_index
__cv_timedwait_common
arc_adjust_type
__cv_timedwait_sig
arc_adjust
arc_reclaim_thread
thread_generic_wrapper
kthread
ret_from_fork
arc_reclaim
all

2014: Java Profiling

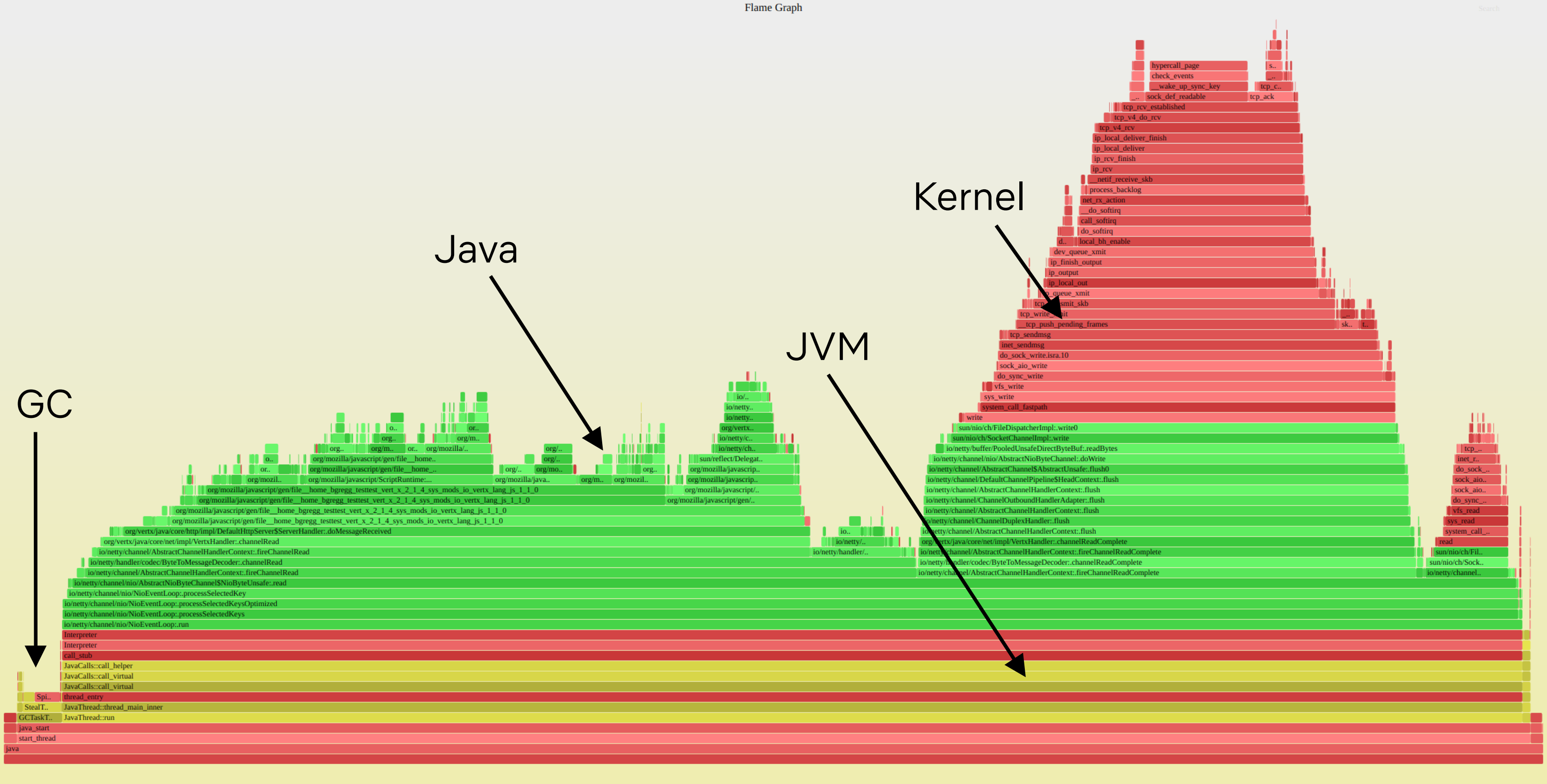


Java Profilers



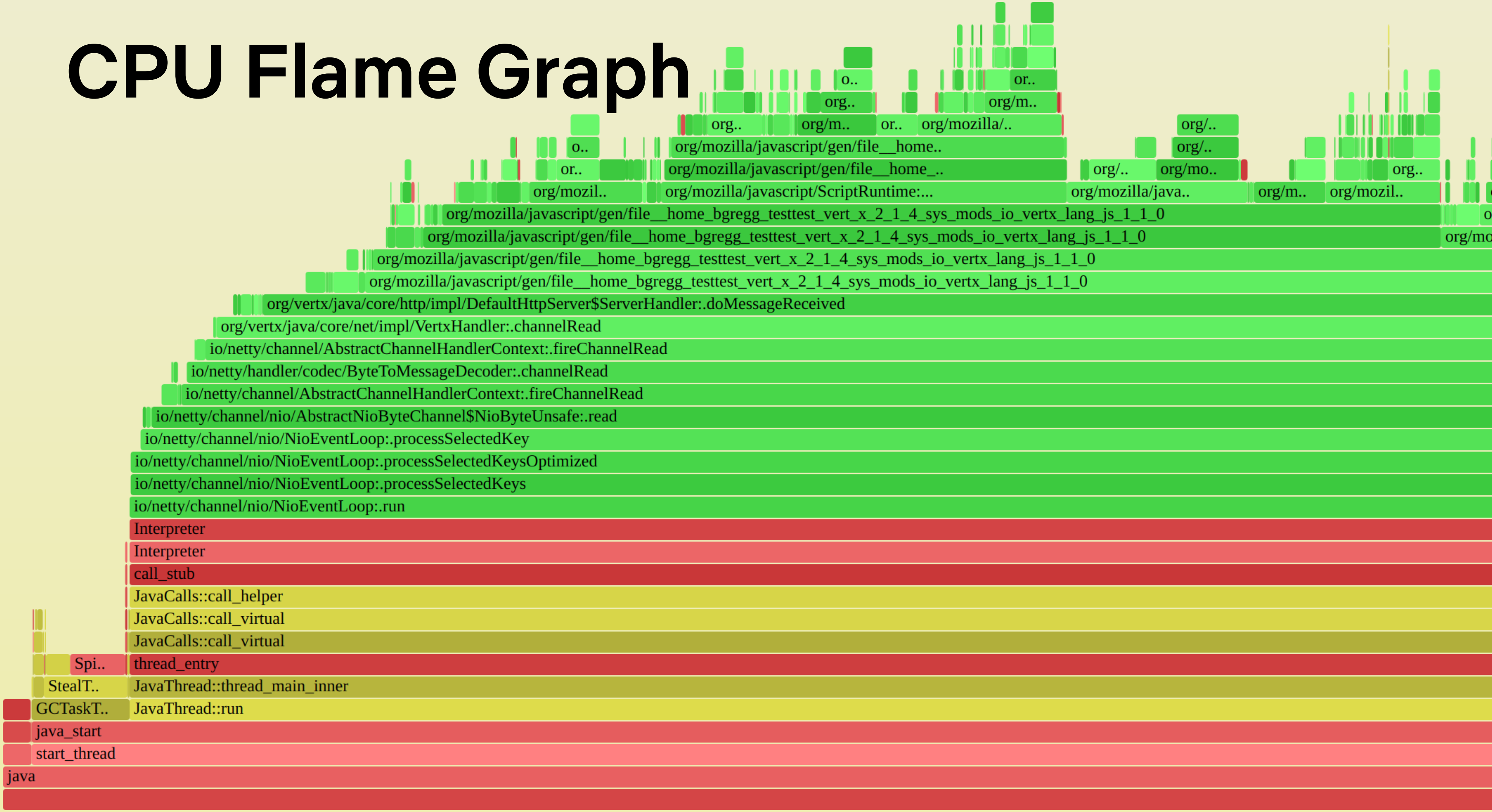
System Profilers

2018: Java Profiling

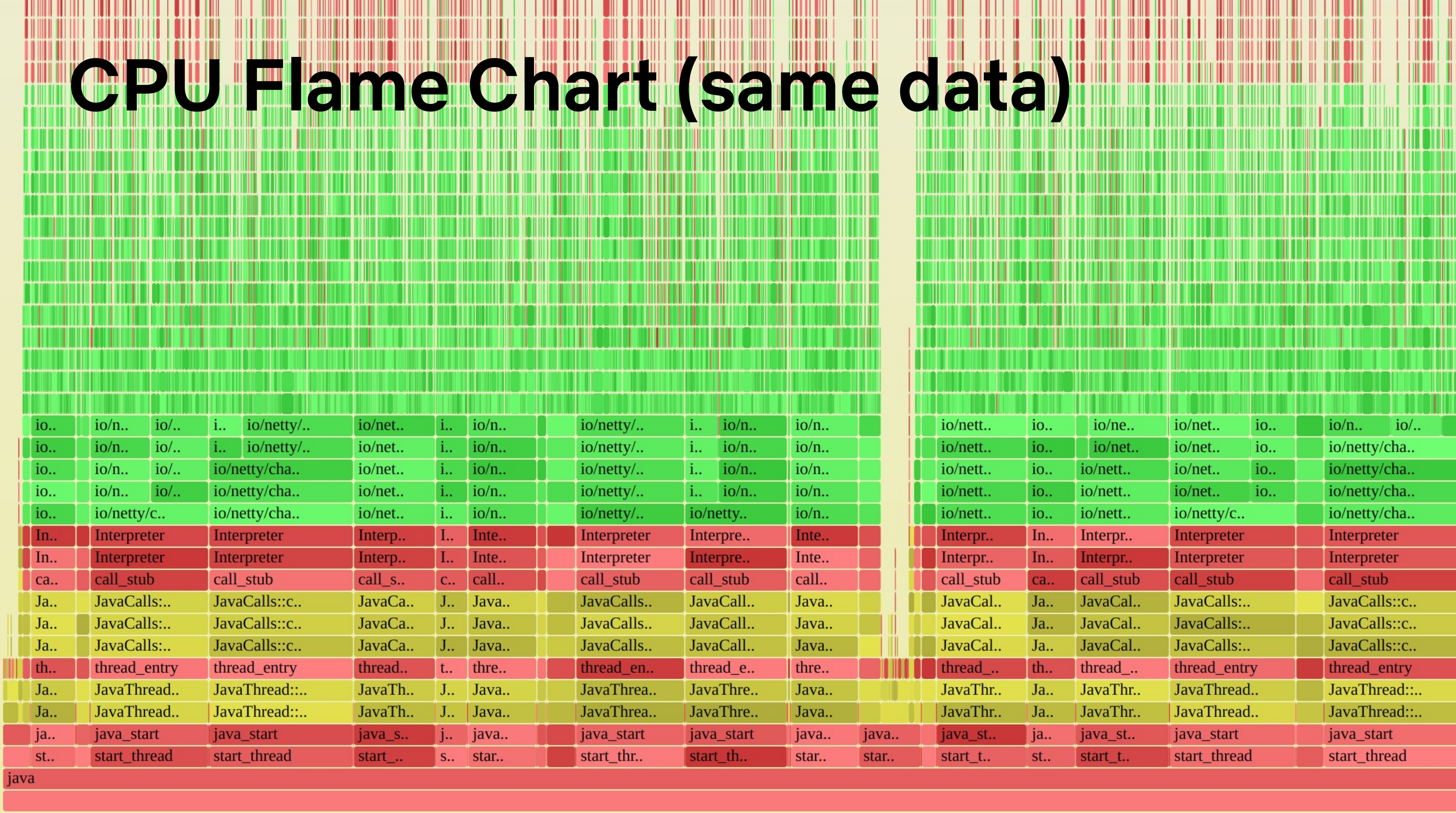


CPU Mixed-mode Flame Graph

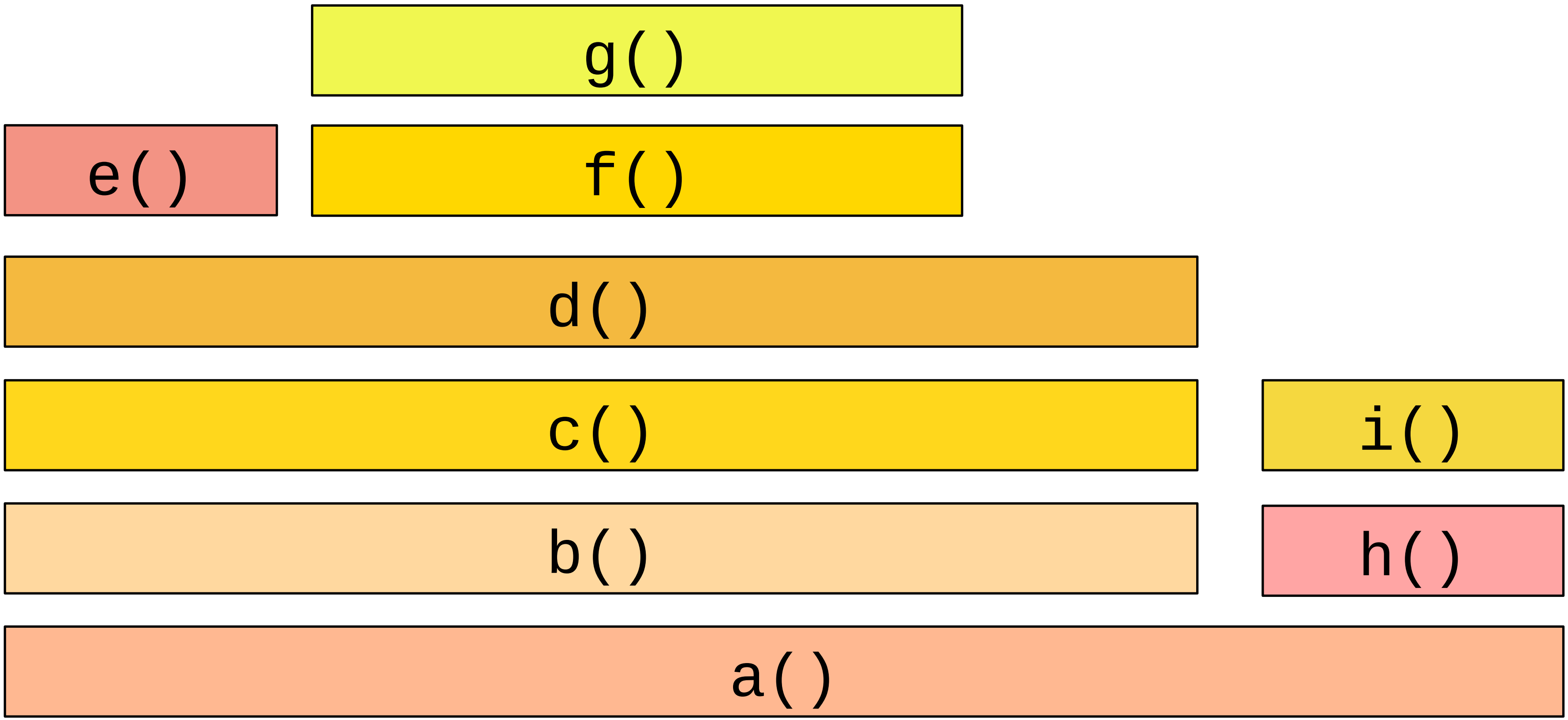
CPU Flame Graph



CPU Flame Chart (same data)

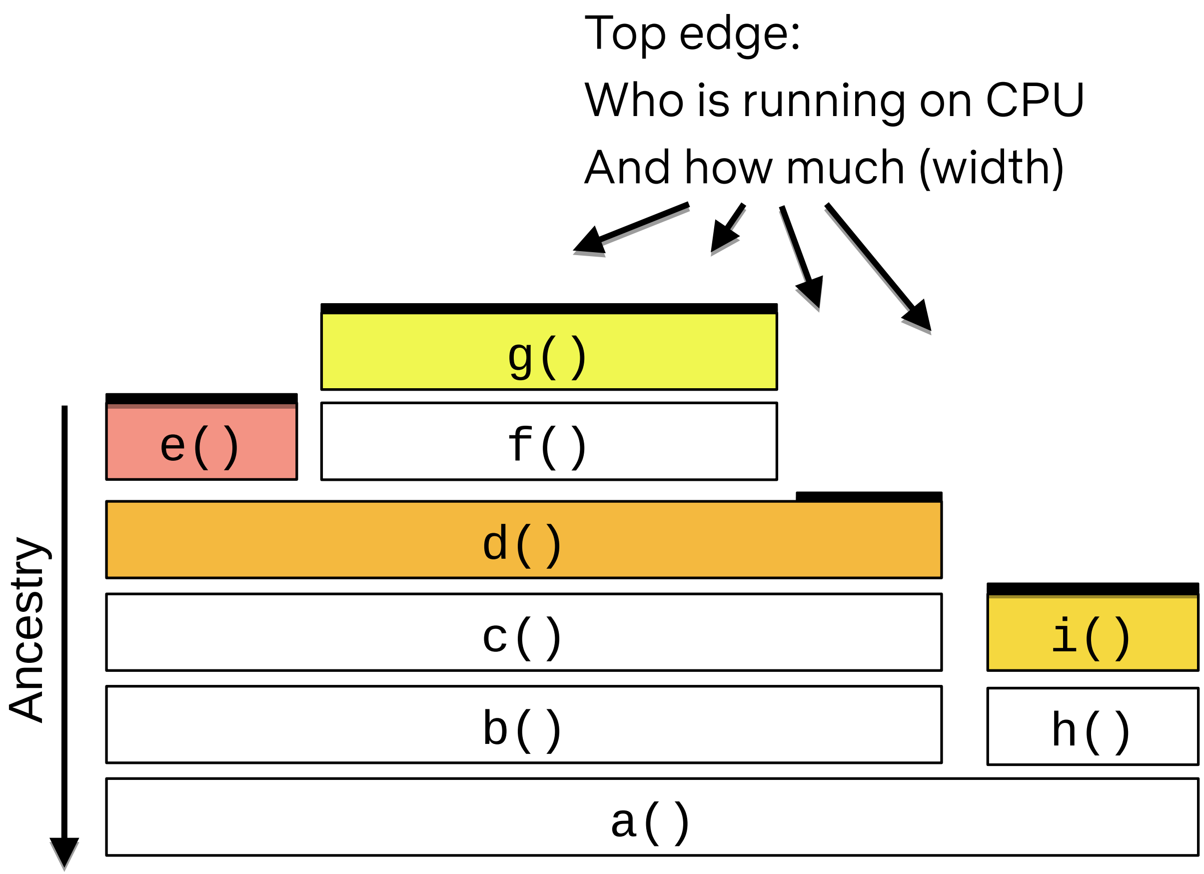


CPU Flame Graphs



CPU Flame Graphs

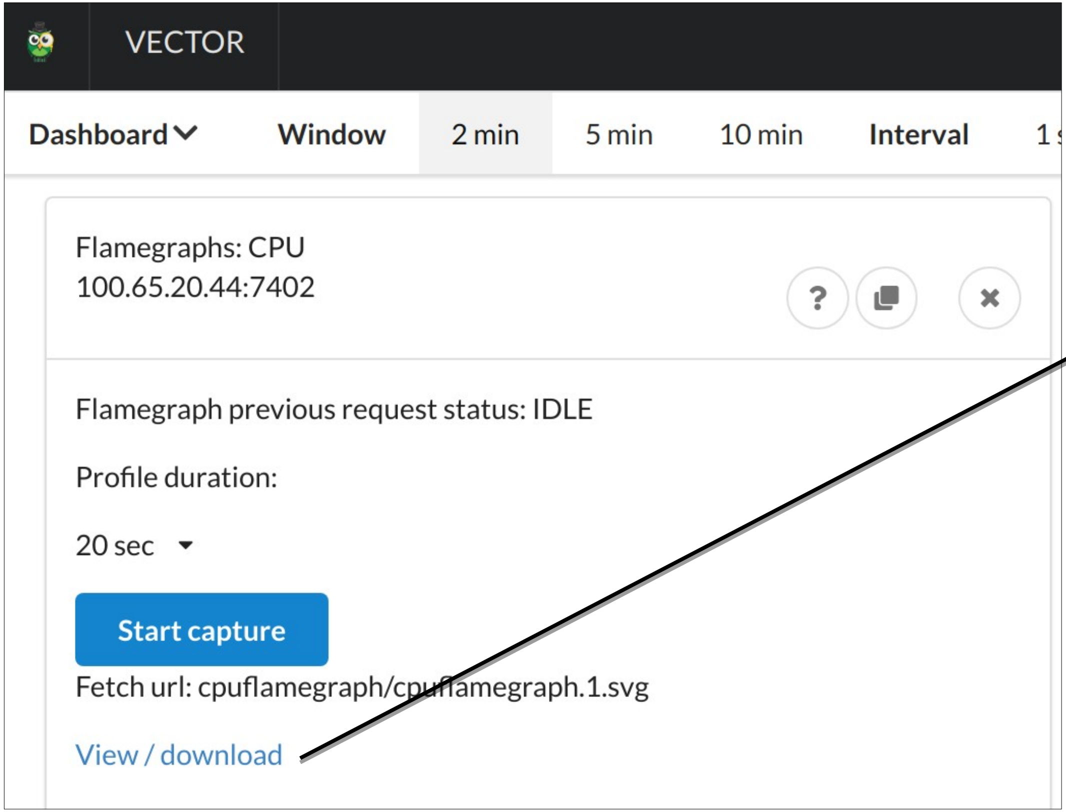
- Y-axis: stack depth
  - 0 at bottom
  - 0 at top == icicle graph
- X-axis: alphabet
  - Time == flame chart
- Color: random
  - Hues often used for language types
  - Can be a dimension eg, CPI

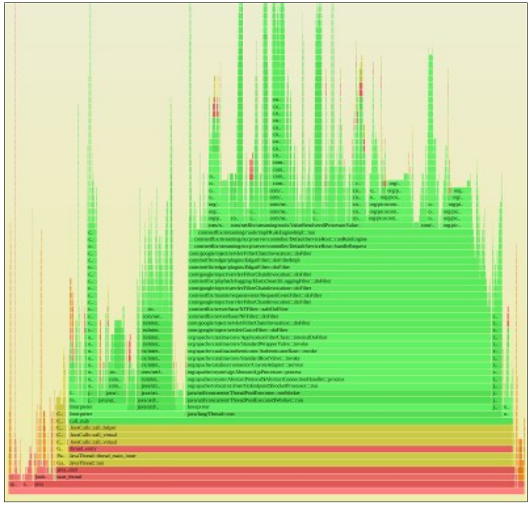


Application Profiling

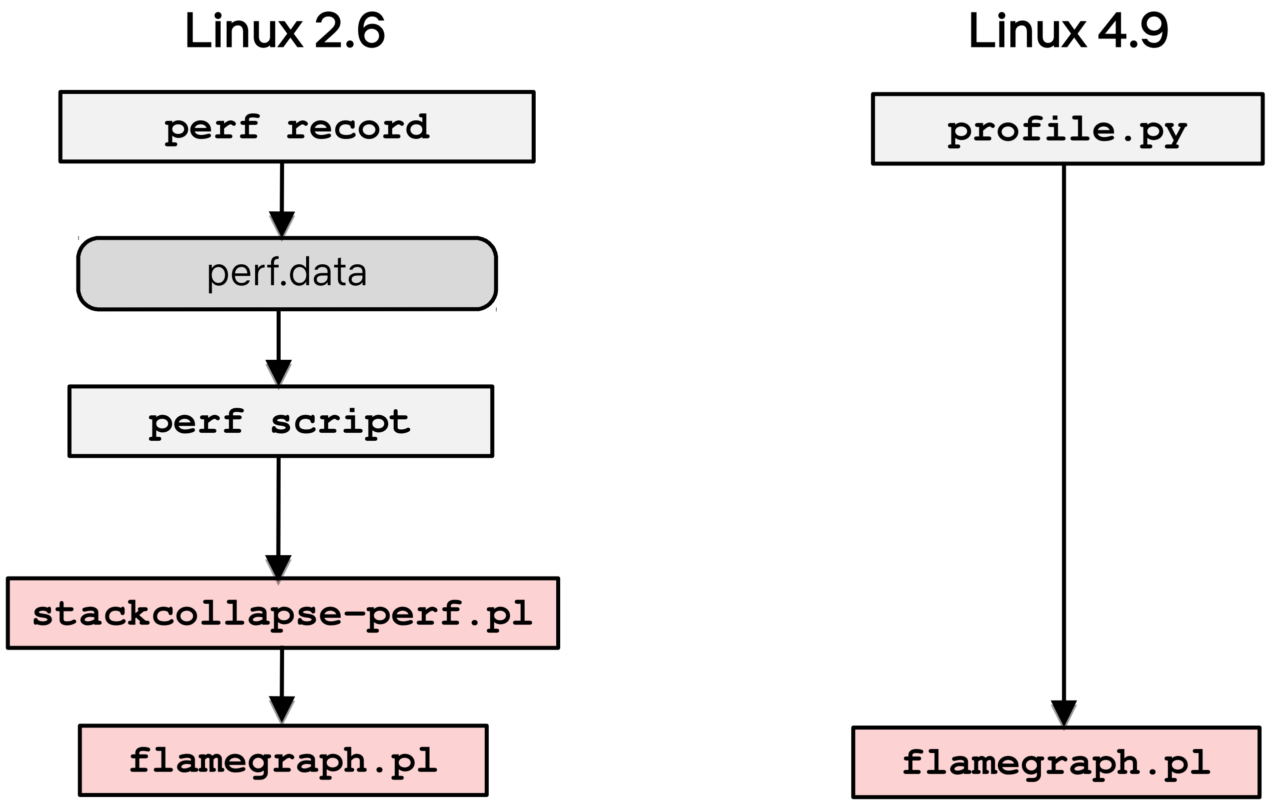
- Primary approach:
  - CPU mixed-mode flame graphs (eg, via Linux perf)
  - May need frame pointers (eg, Java -XX:+PreserveFramePointer)
  - May need a symbol file (eg, Java perf-map-agent, Node.js --perf-basic-prof)
- Secondary:
  - Application profiler (eg, via Lightweight Java Profiler)
  - Application logs

Vector: Push-button Flame Graphs





Future: eBPF-based Profiling



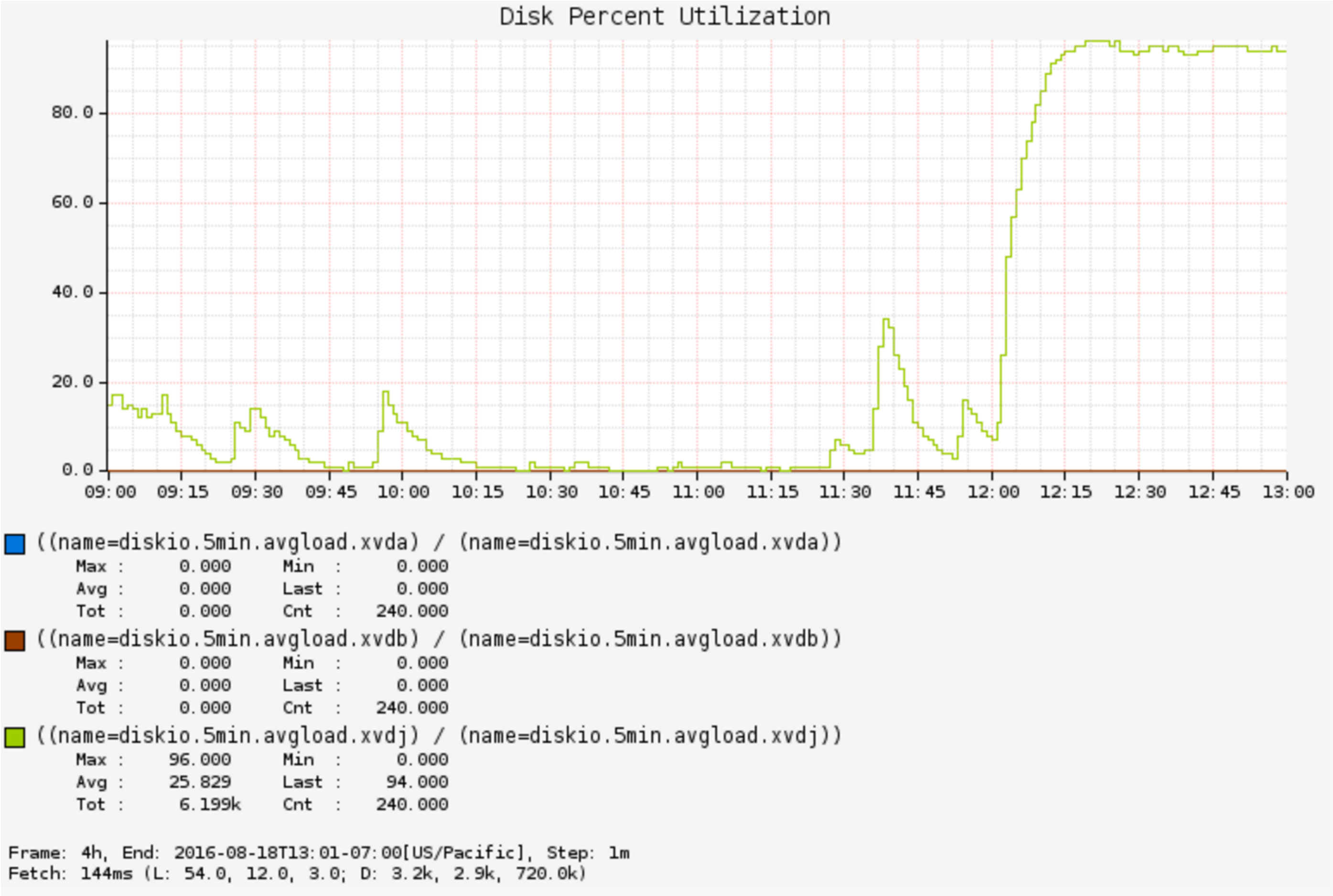
3. Tracing

Core Linux Tracers

	Ftrace	2.6.27+	Tracing views
	perf	2.6.31+	Official profiler & tracer
	eBPF	4.9+	Programmatic engine
	bcc	-	Complex tools
	bpftrace	-	Short scripts

Plus other kernel tech:
kprobes, uprobes

Experience: Disk %Busy

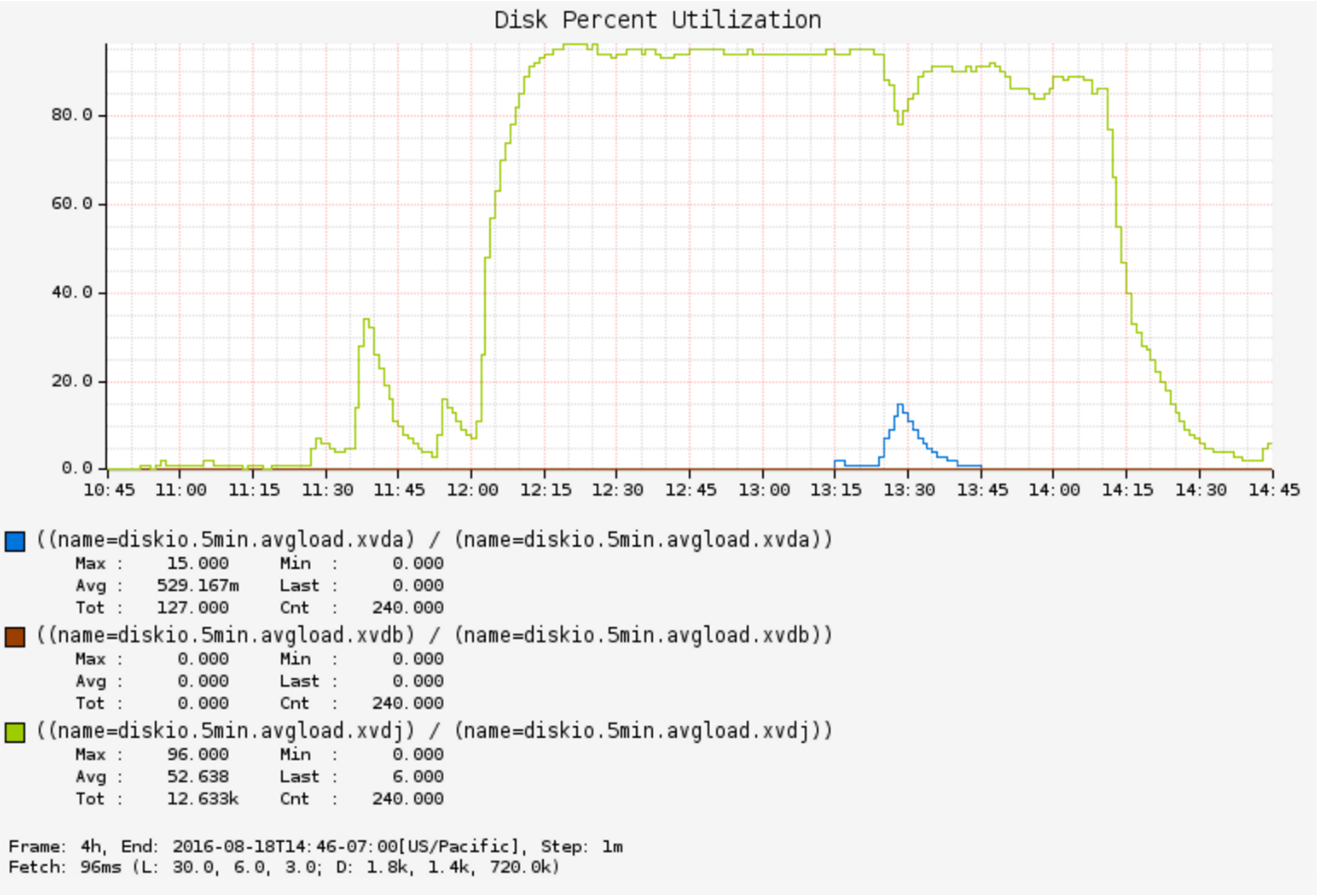


```
# iostat -x 1
[...]
avg-cpu:  %user   %nice %system %iowait  %steal   %idle
           5.37    0.00    0.77    0.00    0.00   93.86

Device:    rrqm/s   wrqm/s     r/s     w/s    rkB/s    wkB/s avgrq-sz avgqu-sz   await r_await w_await  svctm  %util
xvda         0.00     0.00    0.00    0.00     0.00     0.00     0.00     0.00    0.00    0.00    0.00   0.00   0.00
xvdb         0.00     0.00    0.00    0.00     0.00     0.00     0.00     0.00    0.00    0.00    0.00   0.00   0.00
xvdj         0.00     0.00  139.00    0.00  1056.00     0.00    15.19     0.88    6.19    6.19    0.00   6.30  87.60
[...]
```

```
# /apps/perf-tools/bin/iolatency 10
Tracing block I/O. Output every 10 seconds. Ctrl-C to end.

  >=(ms) .. <(ms)   : I/O      |Distribution                          |
       0 -> 1       : 421      |######################################|
       1 -> 2       : 95       |#########                             |
       2 -> 4       : 48       |#####                                 |
       4 -> 8       : 108      |##########                            |
       8 -> 16      : 363      |#################################     |
      16 -> 32      : 66       |######                                |
      32 -> 64      : 3        |#                                     |
      64 -> 128     : 7        |#                                     |
^C
```

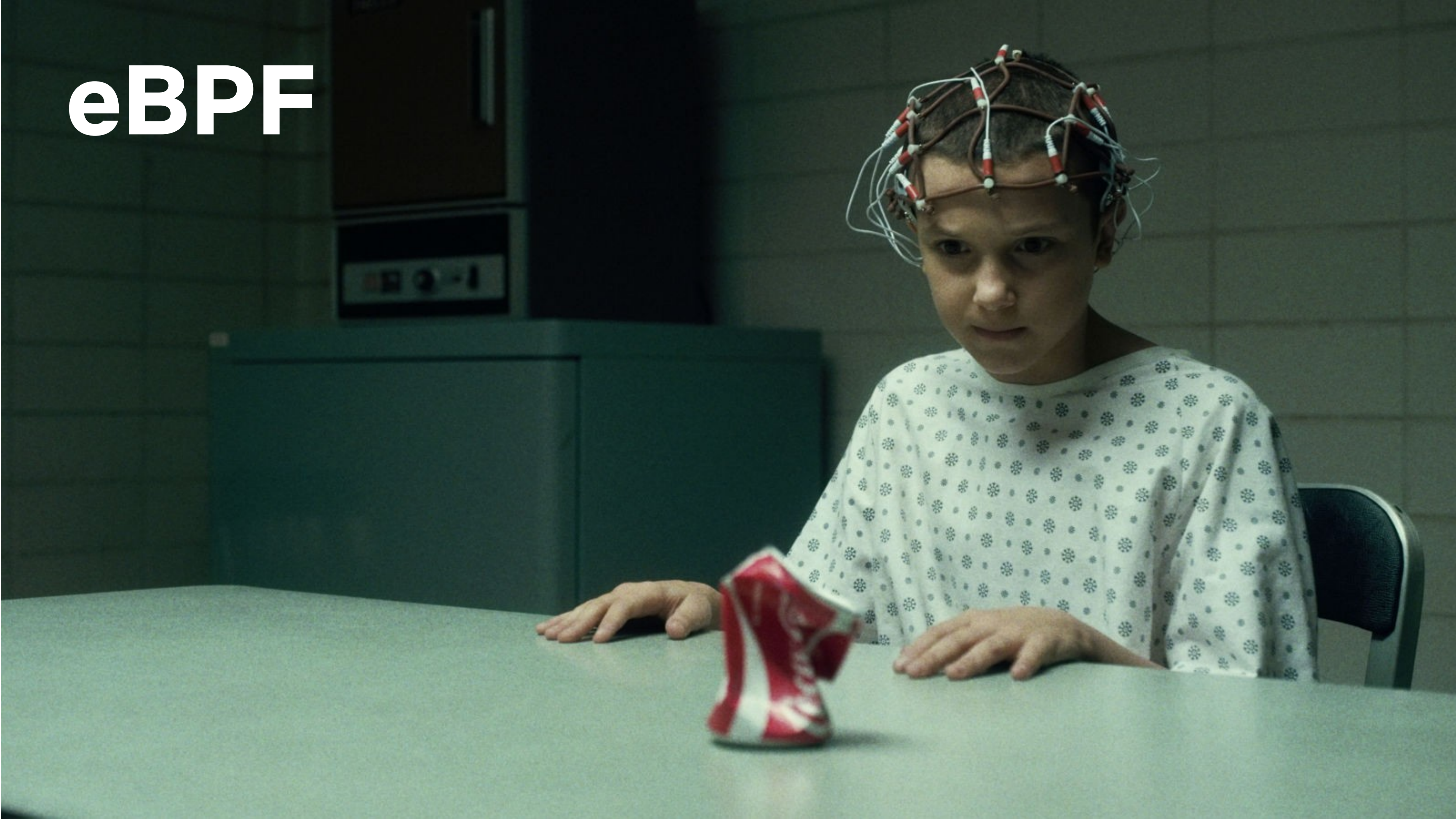
```
# /apps/perf-tools/bin/iosnoop
Tracing block I/O. Ctrl-C to end.
COMM             PID    TYPE DEV      BLOCK        BYTES     LATms
java             30603  RM   202,144  1670768496   8192       0.28
cat              6587   R    202,0    1727096      4096      10.07
cat              6587   R    202,0    1727120      8192      10.21
cat              6587   R    202,0    1727152      8192      10.43
java             30603  RM   202,144  620864512    4096       7.69
java             30603  RM   202,144  584767616    8192      16.12
java             30603  RM   202,144  601721984    8192       9.28
java             30603  RM   202,144  603721568    8192       9.06
java             30603  RM   202,144  61067936     8192       0.97
java             30603  RM   202,144  1678557024   8192       0.34
java             30603  RM   202,144  55299456     8192       0.61
java             30603  RM   202,144  1625084928   4096      12.00
java             30603  RM   202,144  618895408    8192      16.99
java             30603  RM   202,144  581318480    8192      13.39
java             30603  RM   202,144  1167348016   8192       9.92
java             30603  RM   202,144  51561280     8192      22.17
[...]
```

```
# perf record -e block:block_rq_issue --filter rwbs ~ "*M*" -g -a
# perf report -n -stdio
[...]
# Overhead       Samples       Command      Shared Object                Symbol
# ........  ............  ............  .................  ....................
#
    70.70%           251          java  [kernel.kallsyms]  [k] blk_peek_request
                     |
                     --- blk_peek_request
                         do_blkif_request
                         __blk_run_queue
                         queue_unplugged
                         blk_flush_plug_list
                         blk_finish_plug
                         _xfs_buf_ioapply
                         xfs_buf_iorequest
                        |
                        |--88.84%-- _xfs_buf_read
                        |          xfs_buf_read_map
                        |          |
                        |          |--87.89%-- xfs_trans_read_buf_map
                        |          |          |
                        |          |          |--97.96%-- xfs_imap_to_bp
                        |          |          |          xfs_iread
                        |          |          |          xfs_iget
                        |          |          |          xfs_lookup
                        |          |          |          xfs_vn_lookup
                        |          |          |          lookup_real
                        |          |          |          __lookup_hash
                        |          |          |          lookup_slow
                        |          |          |          path_lookupat
                        |          |          |          filename_lookup
                        |          |          |          user_path_at_empty
                        |          |          |          user_path_at
                        |          |          |          vfs_fstatat
                        |          |          |          |
                        |          |          |          |--99.48%-- SYSC_newlstat
                        |          |          |          |          sys_newlstat
                        |          |          |          |          system_call_fastpath
                        |          |          |          |          __lxstat64
                        |          |          |          |Lsun/nio/fs/UnixNativeDispatcher;.lstat0
                        |          |          |          |          0x7f8f963c847c
```

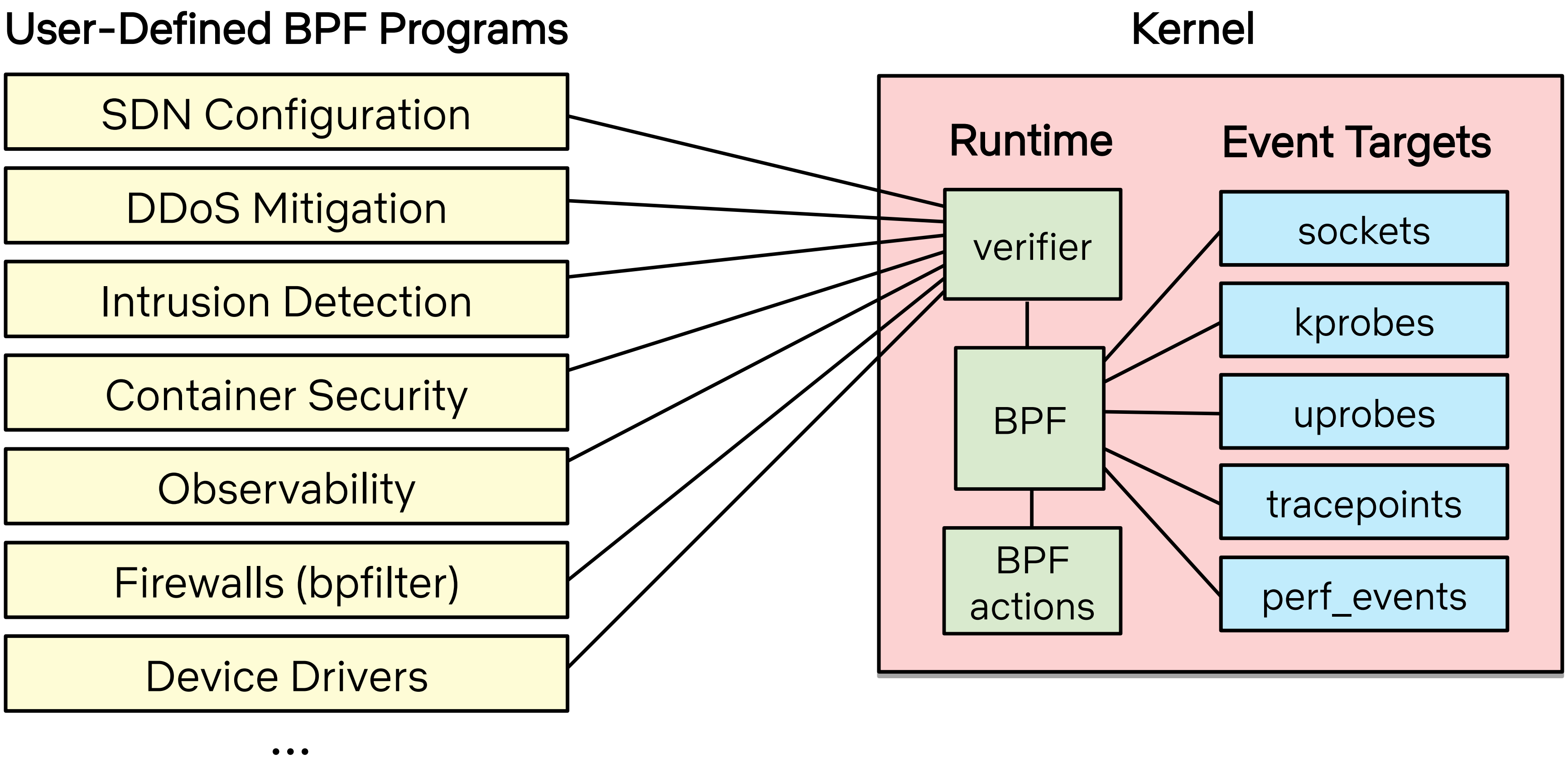

Disk Percent Utilization
80.0
60.0
40.0
20.0
0.0
10:45 11:00 11:15 11:30 11:45 12:00 12:15 12:30 12:45 13:00 13:15 13:30 13:45 14:00 14:15 14:30 14:45
((name=diskio.5min.avgload.xvda) / (name=diskio.5min.avgload.xvda))
Max : 15.000 Min : 0.000
Avg : 529.167m Last : 0.000
Tot : 127.000 Cnt : 240.000
((name=diskio.5min.avgload.xvdb) / (name=diskio.5min.avgload.xvdb))
Max : 0.000 Min : 0.000
Avg : 0.000 Last : 0.000
Tot : 0.000 Cnt : 240.000
((name=diskio.5min.avgload.xvdj) / (name=diskio.5min.avgload.xvdj))
Max : 96.000 Min : 0.000
Avg : 52.638 Last : 6.000
Tot : 12.633k Cnt : 240.000
Frame: 4h, End: 2016-08-18T14:46-07:00[US/Pacific], Step: 1m
Fetch: 96ms (L: 30.0, 6.0, 3.0; D: 1.8k, 1.4k, 720.0k)

```
# /usr/share/bcc/tools/biosnoop
TIME(s)        COMM           PID    DISK    T  SECTOR    BYTES   LAT(ms)
0.000000000    tar            8519   xvda    R  110824    4096       6.50
0.004183000    tar            8519   xvda    R  111672    4096       4.08
0.016195000    tar            8519   xvda    R  4198424   4096      11.88
0.018716000    tar            8519   xvda    R  4201152   4096       2.43
0.019416000    tar            8519   xvda    R  4201160   4096       0.61
0.032645000    tar            8519   xvda    R  4207968   4096      13.16
0.033181000    tar            8519   xvda    R  4207976   4096       0.47
0.033524000    tar            8519   xvda    R  4208000   4096       0.27
0.033876000    tar            8519   xvda    R  4207992   4096       0.28
0.034840000    tar            8519   xvda    R  4208008   4096       0.89
0.035713000    tar            8519   xvda    R  4207984   4096       0.81
0.036165000    tar            8519   xvda    R  111720    4096       0.37
0.039969000    tar            8519   xvda    R  8427264   4096       3.69
0.051614000    tar            8519   xvda    R  8405640   4096      11.44
0.052310000    tar            8519   xvda    R  111696    4096       0.55
0.053044000    tar            8519   xvda    R  111712    4096       0.56
0.059583000    tar            8519   xvda    R  8411032   4096       6.40
0.068278000    tar            8519   xvda    R  4218672   4096       8.57
0.076717000    tar            8519   xvda    R  4218968   4096       8.33
0.077183000    tar            8519   xvda    R  4218984   4096       0.40
0.082188000    tar            8519   xvda    R  8393552   4096       4.94
[...]
```

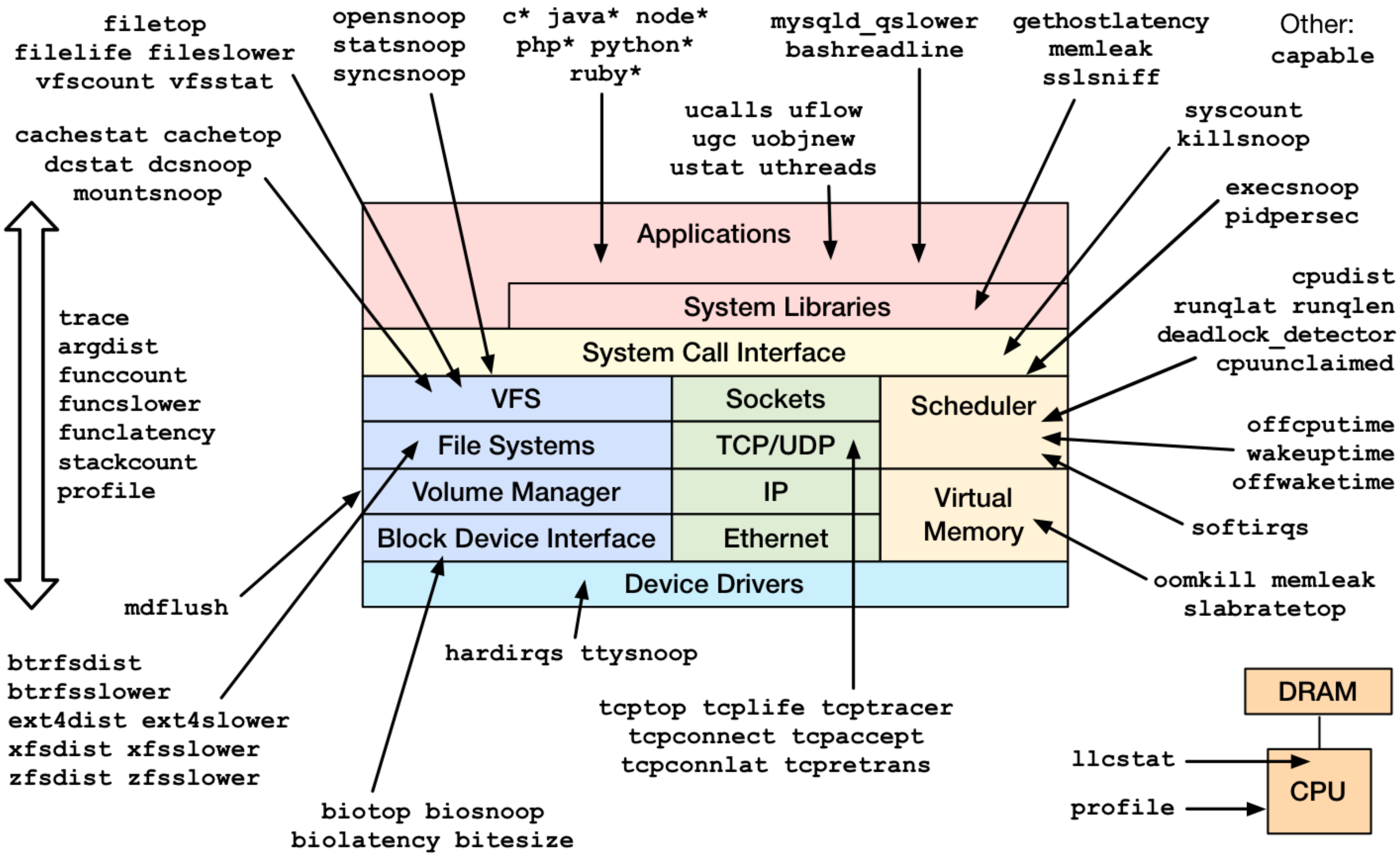
eBPF



eBPF: extended Berkeley Packet Filter



Linux bcc/BPF Tracing Tools



https://github.com/iovisor/bcc#tools 2018

bcc

```
# /usr/share/bcc/tools/tcplife
PID   COMM       LADDR           LPORT RADDR           RPORT TX_KB RX_KB MS
2509  java       100.82.34.63    8078  100.82.130.159  12410     0     0 5.44
2509  java       100.82.34.63    8078  100.82.78.215   55564     0     0 135.32
2509  java       100.82.34.63    60778 100.82.207.252  7001      0    13 15126.87
2509  java       100.82.34.63    38884 100.82.208.178  7001      0     0 15568.25
2509  java       127.0.0.1       4243  127.0.0.1       42166     0     0 0.61
12030 upload-mes 127.0.0.1       34020 127.0.0.1       8078     11     0 3.38
12030 upload-mes 127.0.0.1       21196 127.0.0.1       7101      0     0 12.61
3964  mesos-slav 127.0.0.1       7101  127.0.0.1       21196     0     0 12.64
12021 upload-sys 127.0.0.1       34022 127.0.0.1       8078    372     0 15.28
2509  java       127.0.0.1       8078  127.0.0.1       34022     0   372 15.31
2235  dockerd    100.82.34.63    13730 100.82.136.233  7002      0     4 18.50
2235  dockerd    100.82.34.63    34314 100.82.64.53    7002      0     8 56.73
[...]
```

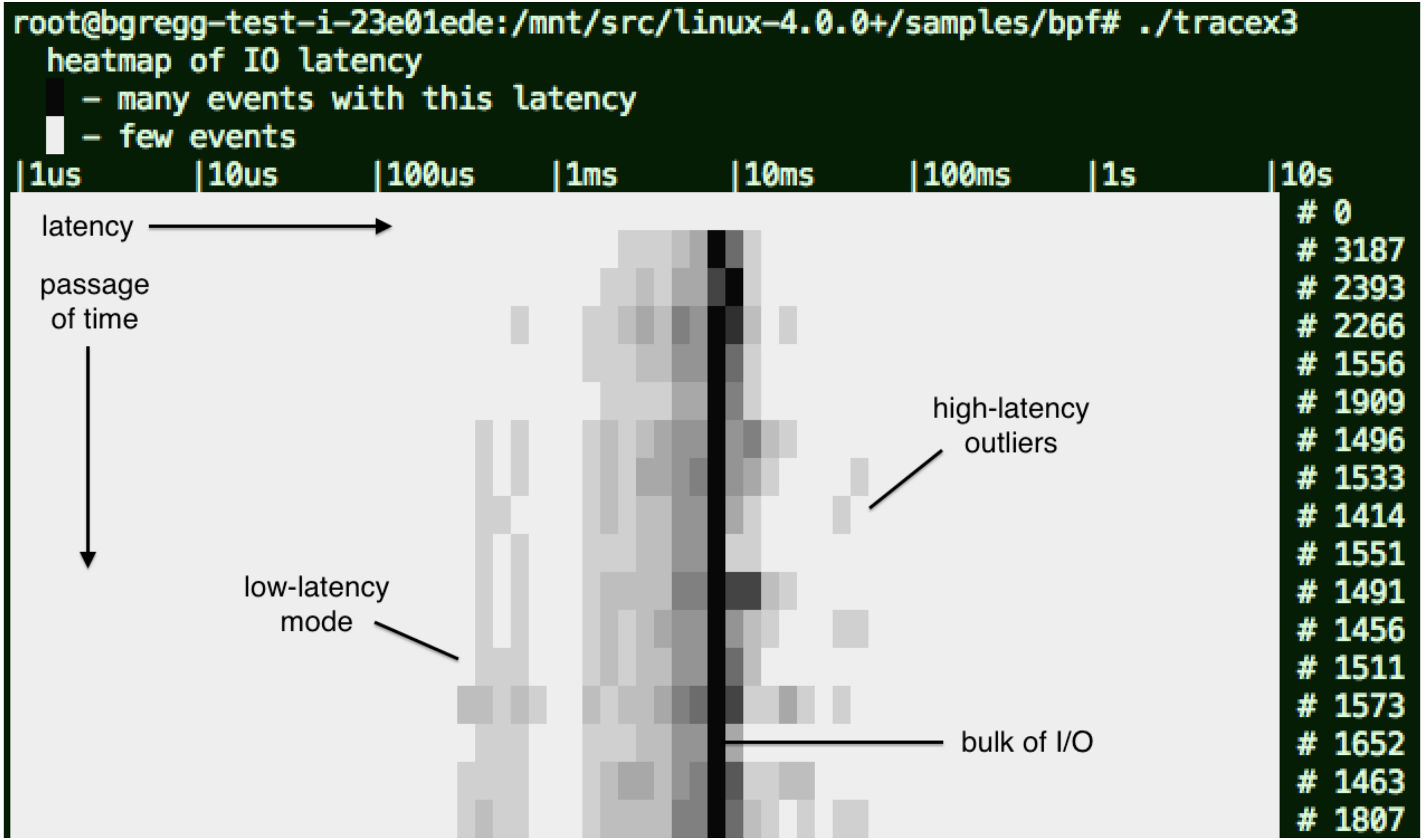
bpftrace

```
# biolatency.bt
Attaching 3 probes...
Tracing block device I/O... Hit Ctrl-C to end.
^C

@usecs:
[256, 512)             2 |                                                    |
[512, 1K)             10 |@                                                   |
[1K, 2K)             426 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@|
[2K, 4K)             230 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@                        |
[4K, 8K)               9 |@                                                   |
[8K, 16K)            128 |@@@@@@@@@@@@@@@                                     |
[16K, 32K)            68 |@@@@@@@@                                            |
[32K, 64K)             0 |                                                    |
[64K, 128K)            0 |                                                    |
[128K, 256K)          10 |@                                                   |
```

bpftrace: biolatency.bt

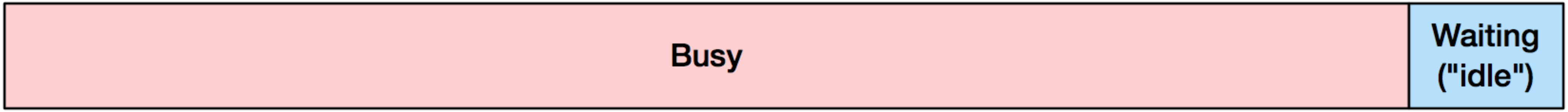
```
#!/usr/local/bin/bpftrace

BEGIN
{
    printf("Tracing block device I/O... Hit Ctrl-C to end.\n");
}

kprobe:blk_account_io_start
{
    @start[arg0] = nsecs;
}

kprobe:blk_account_io_completion
/@start[arg0]/

{
    @usecs = hist((nsecs - @start[arg0]) / 1000);
    delete(@start[arg0]);
}
```

Future: eBPF GUIs

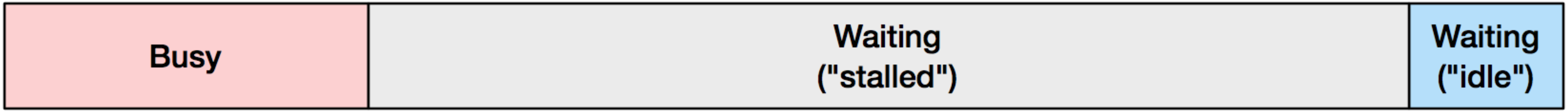


4. Processor Analysis

What "90% CPU Utilization" might suggest:



What it typically means on the Netflix cloud:

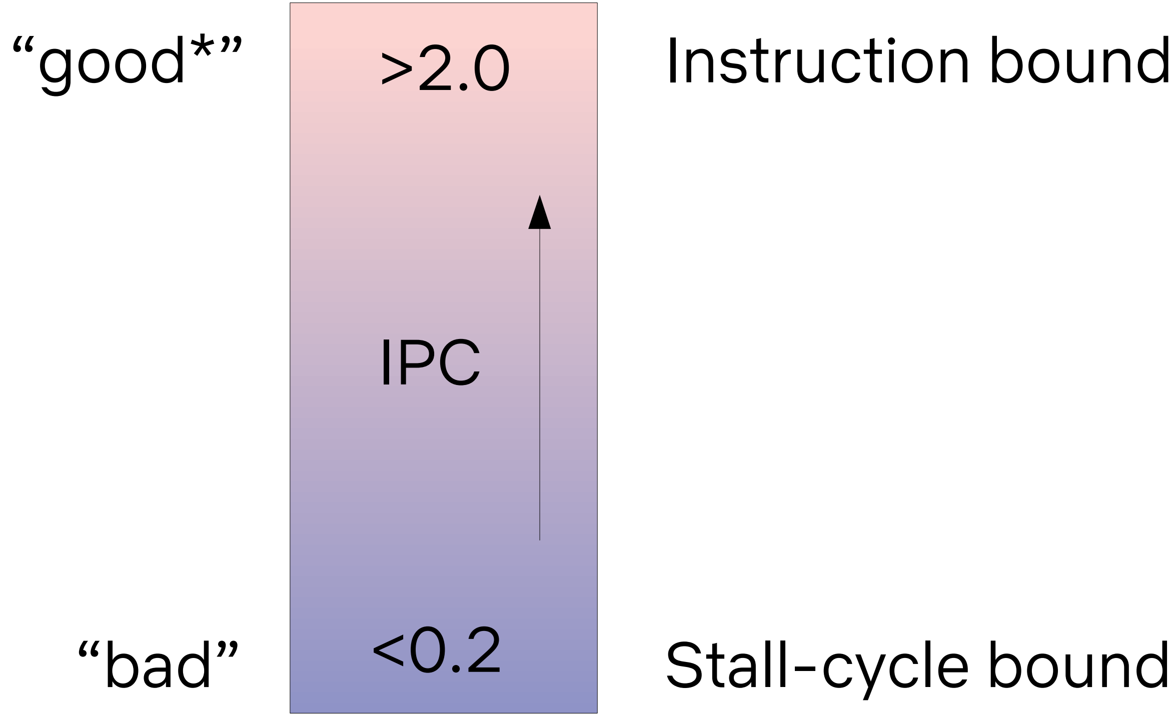


PMCs

- Performance Monitoring Counters help you analyze stalls
- Some instances (eg. Xen-based m4.16xl) have the architectural set:

Event Name	UMask	Event Select	Example Event Mask Mnemonic
UnHalted Core Cycles	00H	3CH	CPU_CLK_UNHALTED.THREAD_P
Instruction Retired	00H	C0H	INST_RETIRED.ANY_P
UnHalted Reference Cycles	01H	3CH	CPU_CLK_THREAD_UNHALTED.REF_XCLK
LLC Reference	4FH	2EH	LONGEST_LAT_CACHE.REFERENCE
LLC Misses	41H	2EH	LONGEST_LAT_CACHE.MISS
Branch Instruction Retired	00H	C4H	BR_INST_RETIRED.ALL_BRANCHES
Branch Misses Retired	00H	C5H	BR_MISP_RETIRED.ALL_BRANCHES

Instructions Per Cycle (IPC)



* probably; exception: spin locks

PMCs: EC2 Xen Hypervisor

```
# perf stat -a -- sleep 30

 Performance counter stats for 'system wide':

    1921101.773240      task-clock (msec)         #   64.034 CPUs utilized            (100.00%)
         1,103,112      context-switches          #    0.574 K/sec                    (100.00%)
           189,173      cpu-migrations            #    0.098 K/sec                    (100.00%)
             4,044      page-faults               #    0.002 K/sec
 2,057,164,531,949      cycles                    #    1.071 GHz                      (75.00%)
   <not supported>      stalled-cycles-frontend
   <not supported>      stalled-cycles-backend
 1,357,979,592,699      instructions              #    0.66  insns per cycle          (75.01%)
   243,244,156,173      branches                  #  126.617 M/sec                    (74.99%)
     4,391,259,112      branch-misses             #    1.81% of all branches          (75.00%)

      30.001112466 seconds time elapsed

# ./pmcarch 1
CYCLES        INSTRUCTIONS     IPC BR_RETIRED   BR_MISPRED   BMR% LLCREF      LLCMISS     LLC%
38222881237   25412094046     0.66 4692322525   91505748     1.95 780435112   117058225  85.00
40754208291   26308406390     0.65 5286747667   95879771     1.81 751335355   123725560  83.53
35222264860   24681830086     0.70 4616980753   86190754     1.87 709841242   113254573  84.05
38176994942   26317856262     0.69 5055959631   92760370     1.83 787333902   119976728  84.76
[...]
```

PMCs: EC2 Nitro Hypervisor

- Some instance types (large, Nitro-based) support most PMCs!
- Meltdown KPTI patch TLB miss analysis on a c5.9xl:

```
nopti:
# tlbstat -C0 1
K_CYCLES    K_INSTR       IPC DTLB_WALKS ITLB_WALKS K_DTLBCYC  K_ITLBCYC  DTLB% ITLB%
2854768     2455917      0.86 565        2777       50         40          0.00  0.00
2884618     2478929      0.86 950        2756       6          38          0.00  0.00
2847354     2455187      0.86 396        297403     46         40          0.00  0.00
[...]

pti, nopcid:
# tlbstat -C0 1
K_CYCLES    K_INSTR       IPC DTLB_WALKS ITLB_WALKS K_DTLBCYC  K_ITLBCYC  DTLB% ITLB%
2875793     276051       0.10 89709496   65862302   787913     650834     27.40 22.63
2860557     273767       0.10 88829158   65213248   780301     644292     27.28 22.52
2885138     276533       0.10 89683045   65813992   787391     650494     27.29 22.55
2532843     243104       0.10 79055465   58023221   693910     573168     27.40 22.63  worst case
[...]
```

MSRs

- Model Specific Registers
- System config info, including current clock rate:

```
# showboost
Base CPU MHz : 2500
Set CPU MHz  : 2500
Turbo MHz(s) : 3100 3200 3300 3500
Turbo Ratios : 124% 128% 132% 140%
CPU 0 summary every 1 seconds...

TIME        C0_MCYC      C0_ACYC        UTIL  RATIO    MHz
23:39:07    1618910294   89419923        64%     5%    138
23:39:08    1774059258   97132588        70%     5%    136
23:39:09    2476365498   130869241       99%     5%    132
^C
```

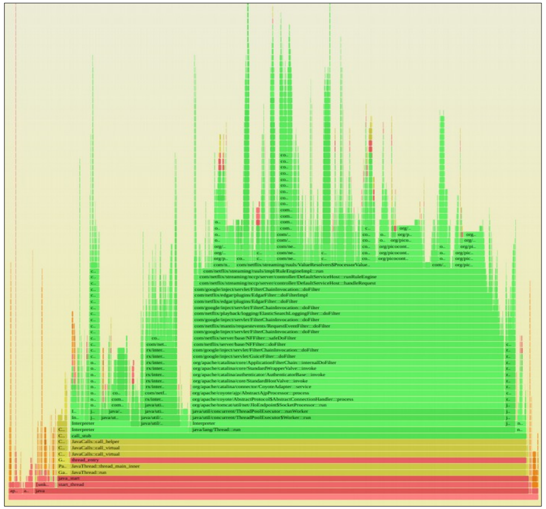
Summary

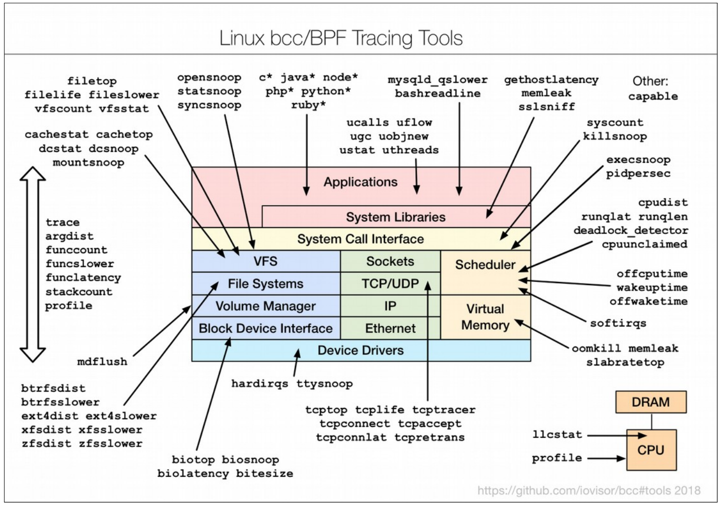
Take-aways

NETFLIX

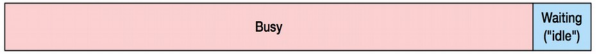
Take Aways

1. Get push-button **CPU flame graphs**: kernel & user
2. Check out **eBPF** perf tools: bcc, bpftrace
3. Measure **IPC** *as well as* CPU utilization using PMCs

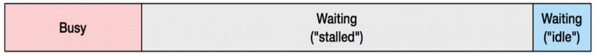




90% CPU busy:



… really means:



Observability
Methodology
Velocity

Observability

Statistics, Flame Graphs, eBPF Tracing, Cloud PMCs

Methodology

USE method, RED method, Drill-down Analysis, ...

Velocity

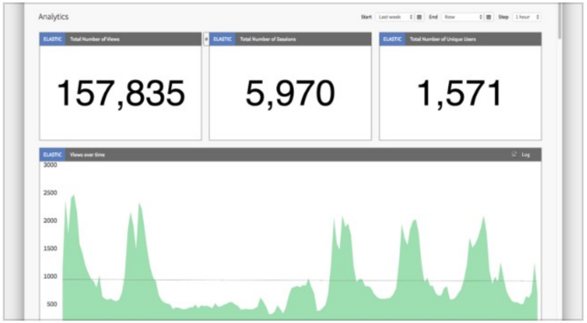
Self-service GUIs: Vector, FlameScope, ...

Resources

- **2014 talk From Clouds to Roots**: http://www.slideshare.net/brendangregg/netflix-from-clouds-to-roots http://www.youtube.com/watch?v=H-E0MQTID0g
- **Chaos**: https://medium.com/netflix-techblog/chap-chaos-automation-platform-53e6d528371f https://principlesofchaos.org/
- **Atlas**: https://github.com/Netflix/Atlas
- **Atlas**: https://medium.com/netflix-techblog/introducing-atlas-netflixs-primary-telemetry-platform-bd31f4d8ed9a
- **RED method**: https://thenewstack.io/monitoring-microservices-red-method/
- **USE method**: https://queue.acm.org/detail.cfm?id=2413037
- **Winston**: https://medium.com/netflix-techblog/introducing-winston-event-driven-diagnostic-and-remediation-platform-46ce39aa81cc
- **Lumen**: https://medium.com/netflix-techblog/lumen-custom-self-service-dashboarding-for-netflix-8c56b541548c
- **Flame graphs**: http://www.brendangregg.com/flamegraphs.html
- **Java flame graphs**: https://medium.com/netflix-techblog/java-in-flames-e763b3d32166
- **Vector**: http://vectoross.io https://github.com/Netflix/Vector
- **FlameScope**: https://github.com/Netflix/FlameScope
- **Tracing ponies**: thanks Deirdré Straughan & General Zoi's Pony Creator
- **ftrace**: http://lwn.net/Articles/608497/ - usually already in your kernel
- **perf**: http://www.brendangregg.com/perf.html - perf is usually packaged in linux-tools-common
- **tcplife**: https://github.com/iovisor/bcc - often available as a bcc or bcc-tools package
- **bpftrace**: https://github.com/iovisor/bpftrace
- **pmcarch**: https://github.com/brendangregg/pmc-cloud-tools
- **showboost**: https://github.com/brendangregg/msr-cloud-tools - also try turbostat

Netflix Tech Blog

A Medium Corporation [US] | https://medium.com/netflix-techblog



Lumen: Custom, Self-Service Dashboarding For Netflix

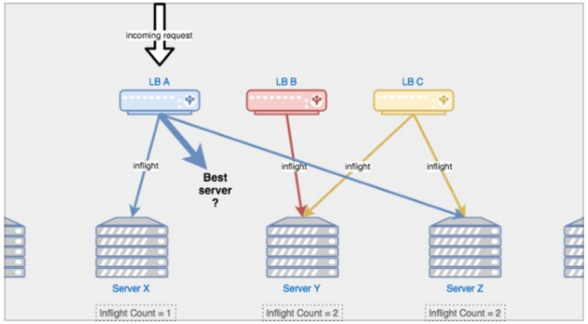
By Trent Willis

Netflix Technology Blog
Oct 18

The Netflix Media Database (NMDB)

This blog post describes the Netflix Media DataBase (NMDB)—a highly queryable data system built on the Netflix micro-services platform…

Netflix Technology Blog
Oct 16



Rethinking Netflix's Edge Load Balancing

The why's, how's and results from rethinking Netflix's edge load balancing

Netflix Technology Blog
Sep 29

Thank you.

Brendan Gregg
@brendangregg

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