Ceph: A Distributed File System

Audience/Presented to LC Staff Meeting

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LLNL-PRES-XXXXXX

Introduction

- What is a Distributed File System (DFS)?
  - A file system that permits various hosts on separate machines to access and share files through a computer network.
  - Data may be distributed across many nodes, but users can access their files as though they were stored on one server.

- Why use distributed file systems?
  - High availability
  - Redundancy
  - Location-independent access
  - Scalability

- Why Ceph?
  - Provides block and file storage
  - Can handle large-scale file systems
  - Reduces traffic to metadata clusters using CRUSH algorithm
  - POSIX compliant

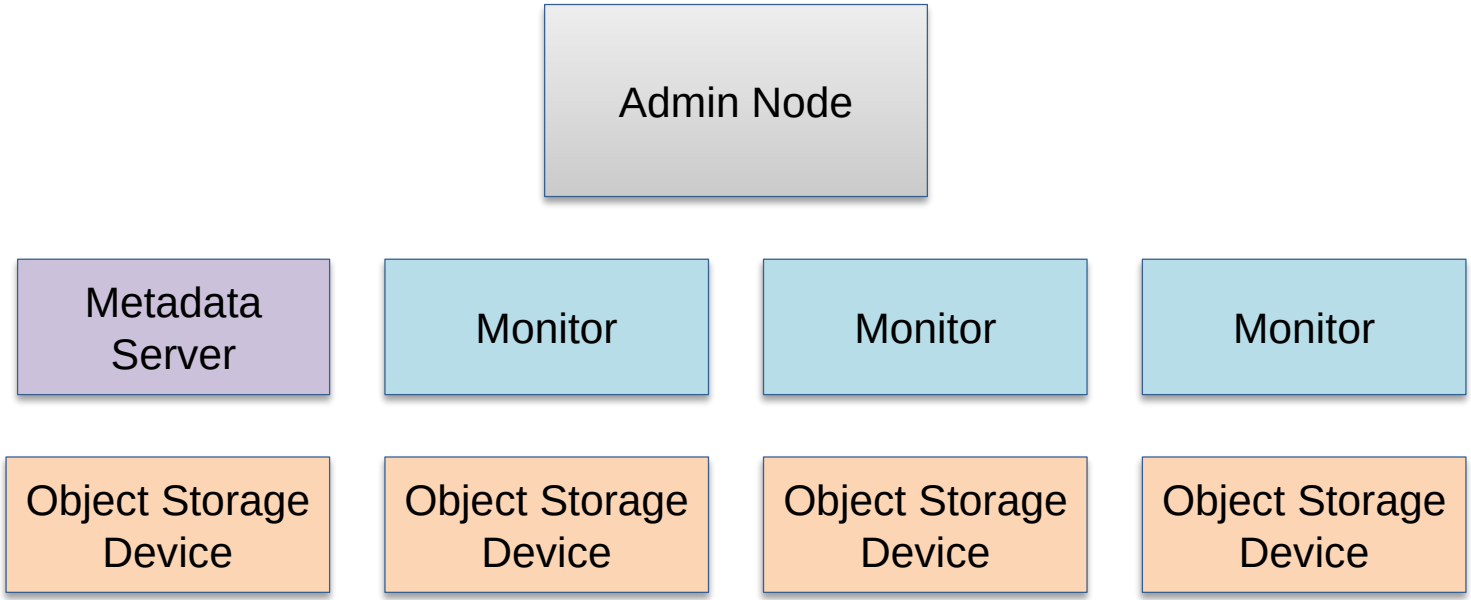
Source: http://3.bp.blogspot.com/-B_UA0D0l6xI/T2ycHjkPdvI/AAAAAAAAAIs/nIm3cjymTwk/s1600/dfs.jpg

How does Ceph work?

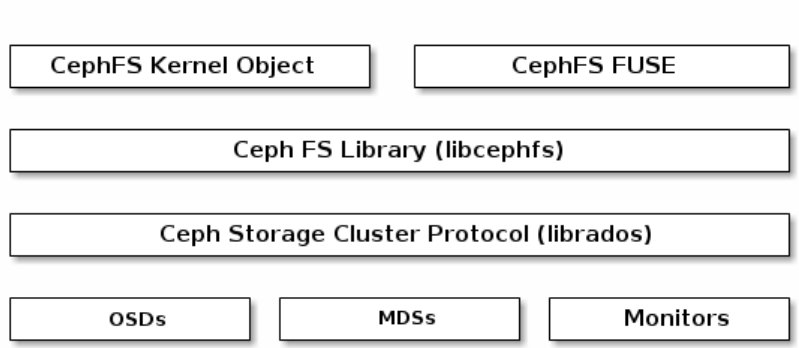
- Components of the Ceph Storage Cluster
  - Monitors
  - Managers
  - Object Storage Daemons
  - Metadata Server (for use with Ceph File System)
- Stores data as objects within logical storage pools
- CRUSH algorithm
  - Controlled Replication Under Scalable Hashing
  - Determines which OSD stores the placement groups
  - Enables scaling, rebalancing, and recovery dynamically
- Ceph File System
  - POSIX-compliant interface
  - Files are mapped to objects and stored in the Ceph Storage Cluster.
  - Metadata Server prevents filesystem operations from consuming resources excessively

Source: http://ceph.com/wp-content/uploads/2016/07/Ceph_Logo_Stacked_RGB_120411_fa.png

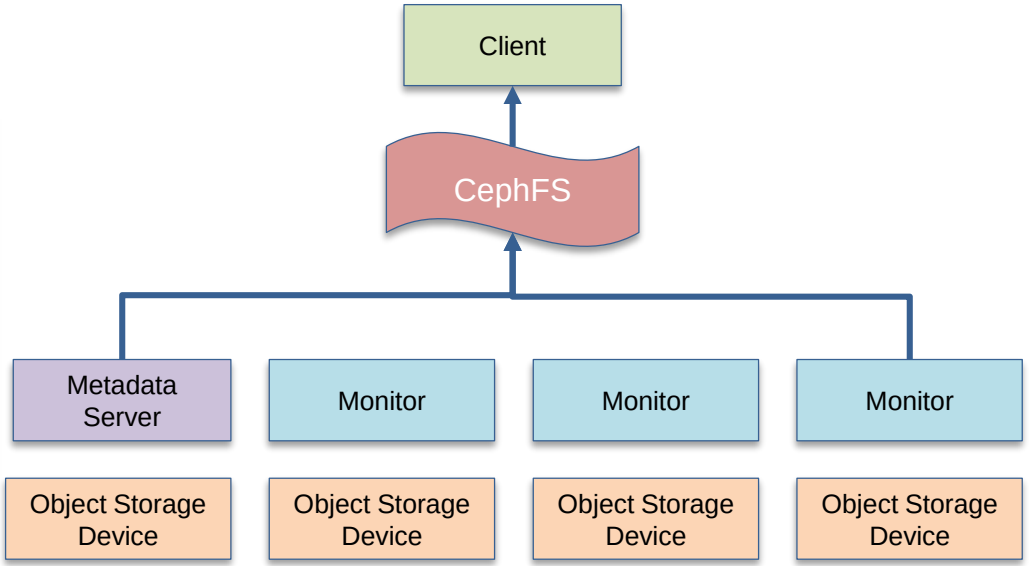
Ceph Storage Cluster



Ceph File System



Source: http://docs.ceph.com/docs/master/_images/ditaa-1cae553f9d207d72257429d572673632afbd108c.png

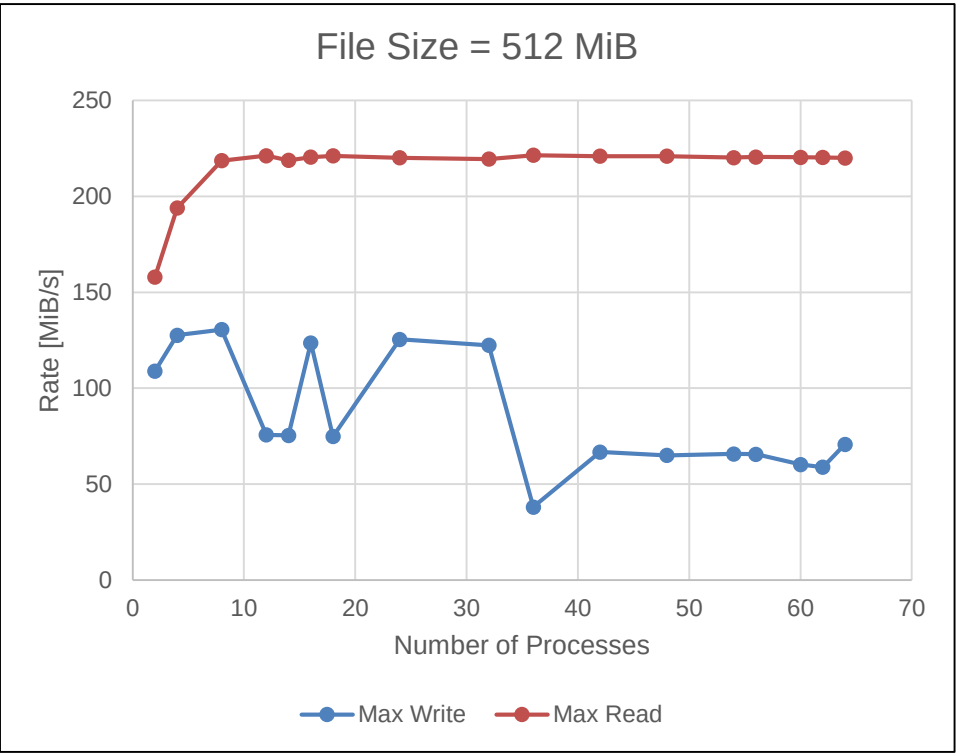


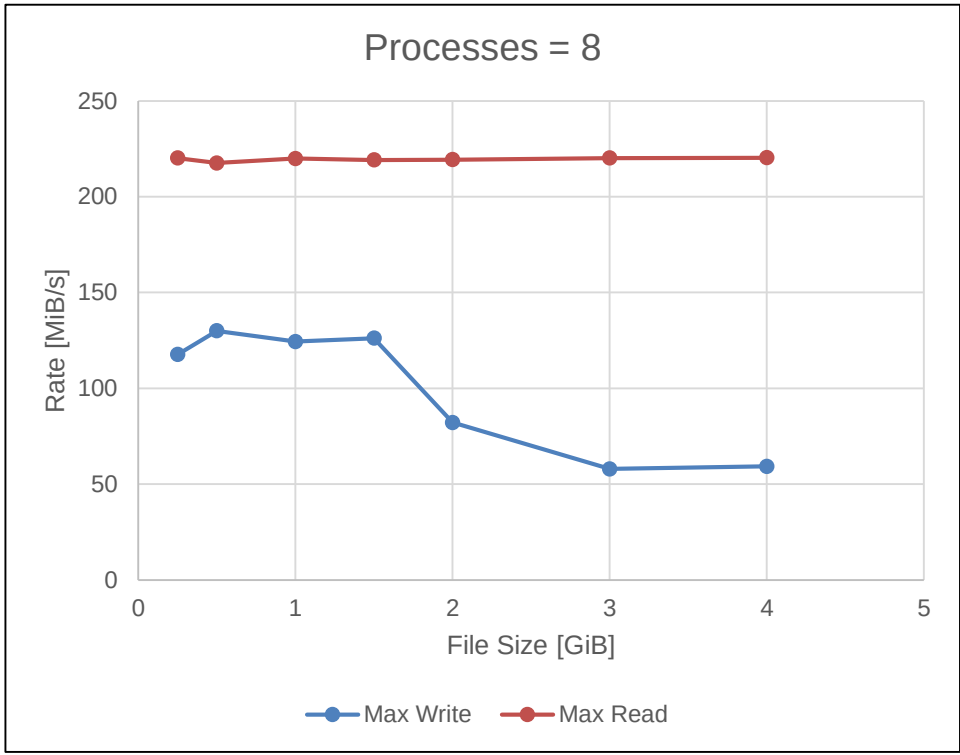
Benchmarking & Results

- Tested POSIX compliance using the POSIX Filesystem Test Suite
  - Passed 1951/1957 tests; failed 6/1957
  - Most UNIX systems aren't 100% POSIX compliant
- Tested read/write speeds using IOR
- Tested file creation/deletion speeds with mdtest

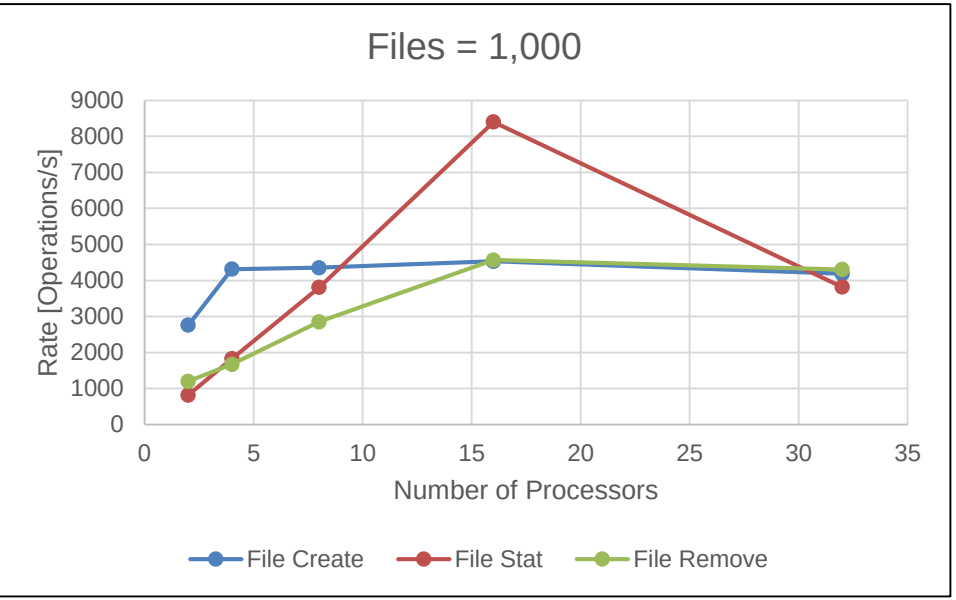
https://www.iag.biz/wp-content/uploads/2016/08/223-Executive-Summary-Business-Analysis-Benchmark.jpg

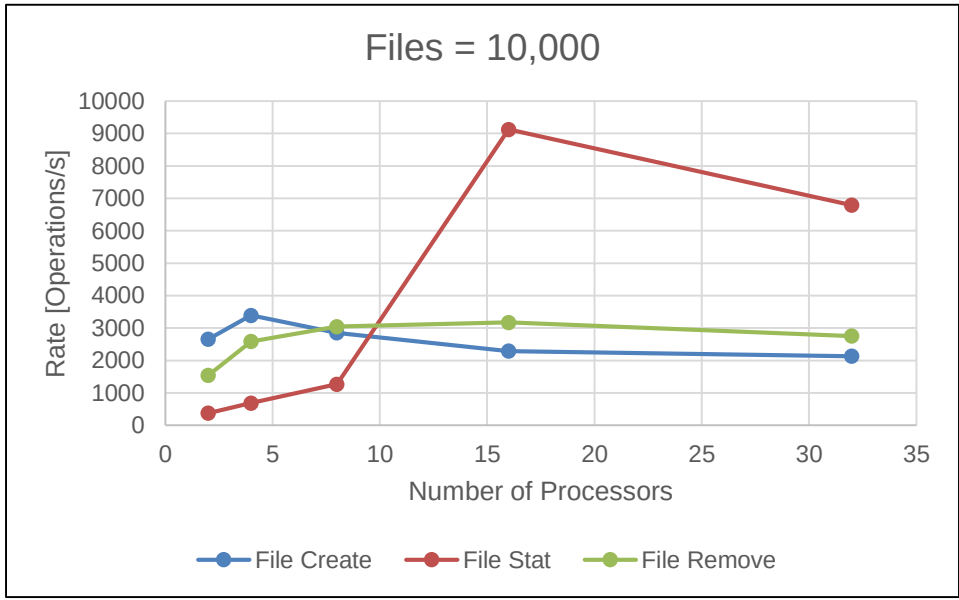
IOR Performance Testing



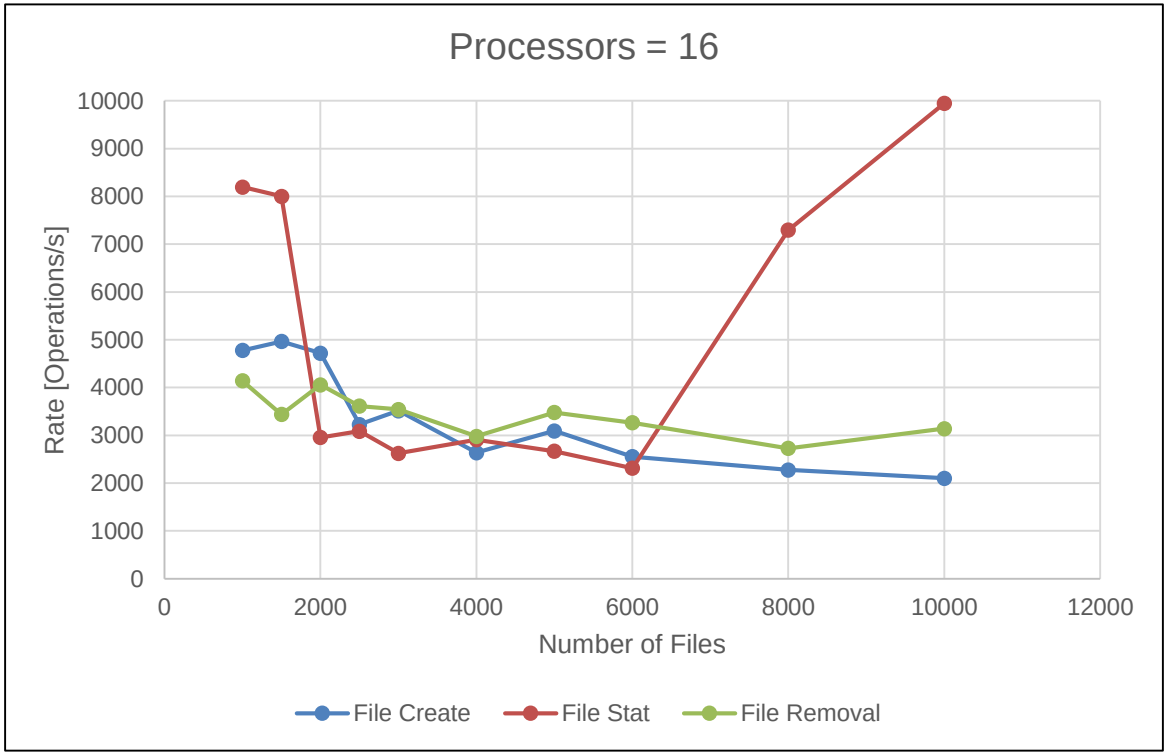


mdtest


Files = 1,000
Rate [Operations/s]
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
Number of Processors
File Create
File Stat
File Remove

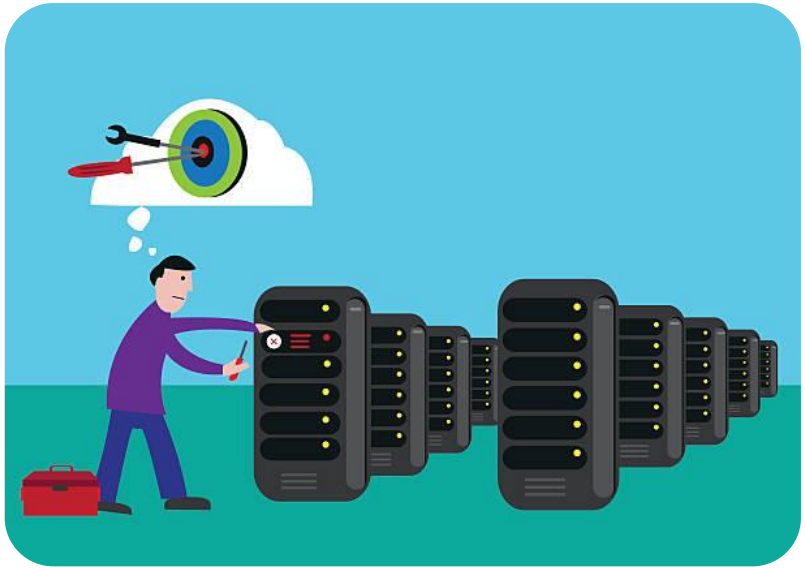

Files = 10,000
Rate [Operations/s]
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
Number of Processors
File Create
File Stat
File Remove

mdtest


Processors = 16
Rate [Operations/s]
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2000
4000
6000
8000
10000
12000
Number of Files
File Create
File Stat
File Removal

Failover Testing

- Demonstrate that our implementation of CephFS can survive a failure of up to ¼ of the total system.
- Explore how the system responds when an OSD, a monitor, or a manager fails.



Source: http://www.istockphoto.com/illustrations/failover?excludenudity=true&sort=mostpopular&mediatype=illustration&phrase=failover

Initial State: Healthy

```
[root@enickel9 ~]# ceph -s
  cluster:
    id:     c7c85f67-7991-45c1-92b5-ace7f7b6344e
    health: HEALTH_OK

  services:
    mon: 3 daemons, quorum enickel5,enickel6,enickel7
    mgr: enickel7(active)
    mds: 1/1/1 up {0=enickel4=up:active}
    osd: 4 osds: 4 up, 4 in

  data:
    pools:   2 pools, 256 pgs
    objects: 43 objects, 33109 kB
    usage:   21409 MB used, 2331 GB / 2351 GB avail
    pgs:     256 active+clean
```

After Taking Down an OSD

```
[root@enickel8 ~]# ceph -s
  cluster:
    id:     c7c85f67-7991-45c1-92b5-ace7f7b6344e
    health: HEALTH_WARN
            1 osds down
            1 host (1 osds) down
            Degraded data redundancy: 31/129 objects degraded (24.031%),
 199 pgs unclean, 199 pgs degraded, 199 pgs undersized

  services:
    mon: 3 daemons, quorum enickel5,enickel6,enickel7
    mgr: enickel7(active)
    mds: 1/1/1 up {0=enickel4=up:active}
    osd: 4 osds: 3 up, 4 in; 199 remapped pgs

  data:
    pools:   2 pools, 256 pgs
    objects: 43 objects, 33109 kB
    usage:   21441 MB used, 2330 GB / 2351 GB avail
    pgs:     31/129 objects degraded (24.031%)
             199 active+undersized+degraded
             57  active+clean
```

Recovered State

```
[root@nickeli ~]# ceph -s
  cluster:
    id:     c7c85f67-7991-45c1-92b5-ace7f7b6344e
    health: HEALTH_OK

  services:
    mon: 3 daemons, quorum enickel5,enickel6,enickel7
    mgr: enickel6(active)
    mds: 1/1/1 up {0=enickel4=up:active}
    osd: 4 osds: 3 up, 3 in

  data:
    pools:   2 pools, 256 pgs
    objects: 43 objects, 33112 kB
    usage:   16164 MB used, 1748 GB / 1763 GB avail
    pgs:     256 active+clean
```

After Taking down a Monitor

```
[root@nickeli ~]# ceph -s
  cluster:
    id:     c7c85f67-7991-45c1-92b5-ace7f7b6344e
    health: HEALTH_WARN
            no active mgr
            1/3 mons down, quorum enickel5,enickel6

  services:
    mon: 3 daemons, quorum enickel5,enickel6, out of quorum: enickel7
    mgr: no daemons active
    mds: 1/1/1 up {0=enickel4=up:active}
    osd: 4 osds: 3 up, 3 in

  data:
    pools:   2 pools, 256 pgs
    objects: 43 objects, 33109 kB
    usage:   16164 MB used, 1748 GB / 1763 GB avail
    pgs:     256 active+clean
```

Partially Recovered

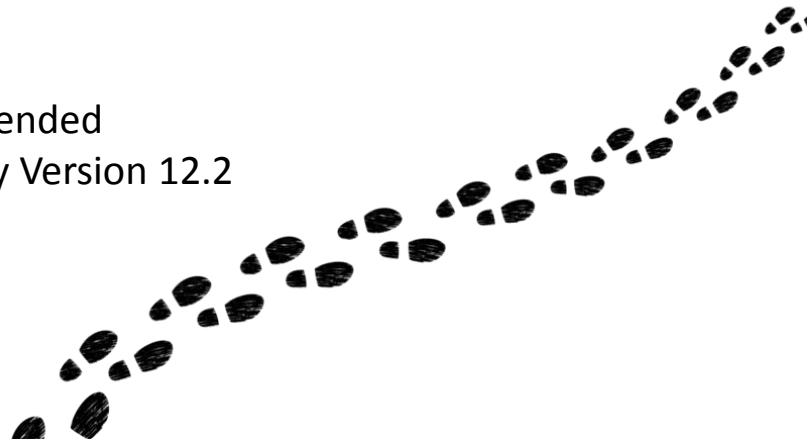
```
[root@nickeli ~]# ceph -s
  cluster:
    id:     c7c85f67-7991-45c1-92b5-ace7f7b6344e
    health: HEALTH_WARN
            1/3 mons down, quorum enickel5,enickel6

  services:
    mon: 3 daemons, quorum enickel5,enickel6, out of quorum: enickel7
    mgr: enickel6(active)
    mds: 1/1/1 up {0=enickel4=up:active}
    osd: 4 osds: 3 up, 3 in

  data:
    pools:   2 pools, 256 pgs
    objects: 43 objects, 33109 kB
    usage:   16164 MB used, 1748 GB / 1763 GB avail
    pgs:     256 active+clean
```

Discussion

Challenges	Solutions
LVMs already installed	Installed OSDs manually
Benchmarking: Tests read from cache	Re-ran tests using 2 clients
New version released halfway through	Updated all of our nodes to Version 12.1.2
Not enough troubleshooting documentation	Trial and error; reinstalling Ceph

Next Steps

- Integrate Ceph with NFS
  - We would like to mount CephFS on clients that don't have Ceph installed.
  - Currently, we do this by having one node of the cluster act as a NFS server.
  - This methods is flawed: if the NFS server goes down, clients lose access to the file system.
- Improve performance, particularly write speeds
- Incorporate additional metadata servers
  - Multiple metadata servers is not currently recommended
  - Ceph plans to support multiple metadata servers by Version 12.2



Thank you for your help and support!

Thomas Bennett

Elsa Gonsiorowski

Dave Fox

Geoff Cleary

Bryan Dixon

Pam Hamilton

Go Team Cephalopod!

Source: https://www.pinterest.com/pin/445504588117025745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Elastic Stack Installation & Configuration

Anna Gassen, Ciara Goetze, James Gadson III
Team G Code

LLNL-PRES-XXXXXX
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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Objective

- Install and configure Elastic Stack on the Academy clusters
- Gather logs from all nodes
- Develop some insightful searches
- Research data analysis concepts

Elastic Stack

You know, for search

- Our clusters produce more than 1500 log messages per minute
- Comprised of six open-source tools: Elasticsearch, Logstash, Kibana, Beats, X-Pack, Elastic Cloud
- Allows quick analyzation, visualization, and mining of millions of log files
- Identify trends, statistics, and abnormalities

Logstash

- Collects data from many different sources at the same time
- Filters and parses each message, converts it into a common format for easier analysis
- Aggregates and transports data to Elasticsearch (or the software of your choice)

Filebeat

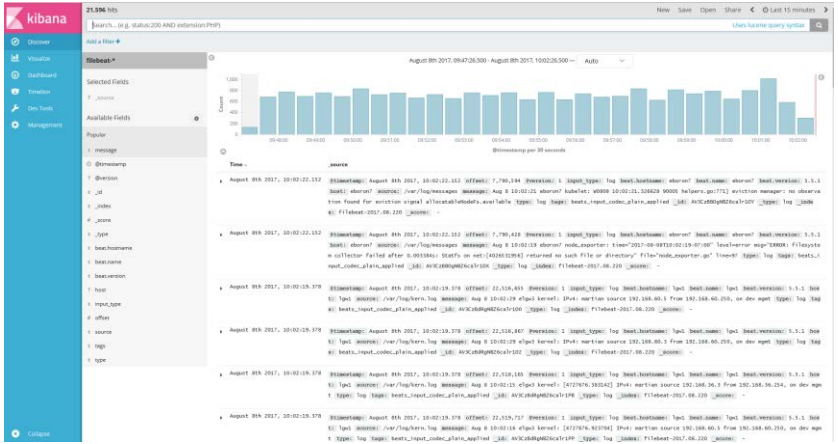
- A lightweight log file shipping agent
- Part of the Beats family of data shippers
- Communicates directly with Logstash or Elasticsearch
- Easily forwards and centralizes log files

Elasticsearch

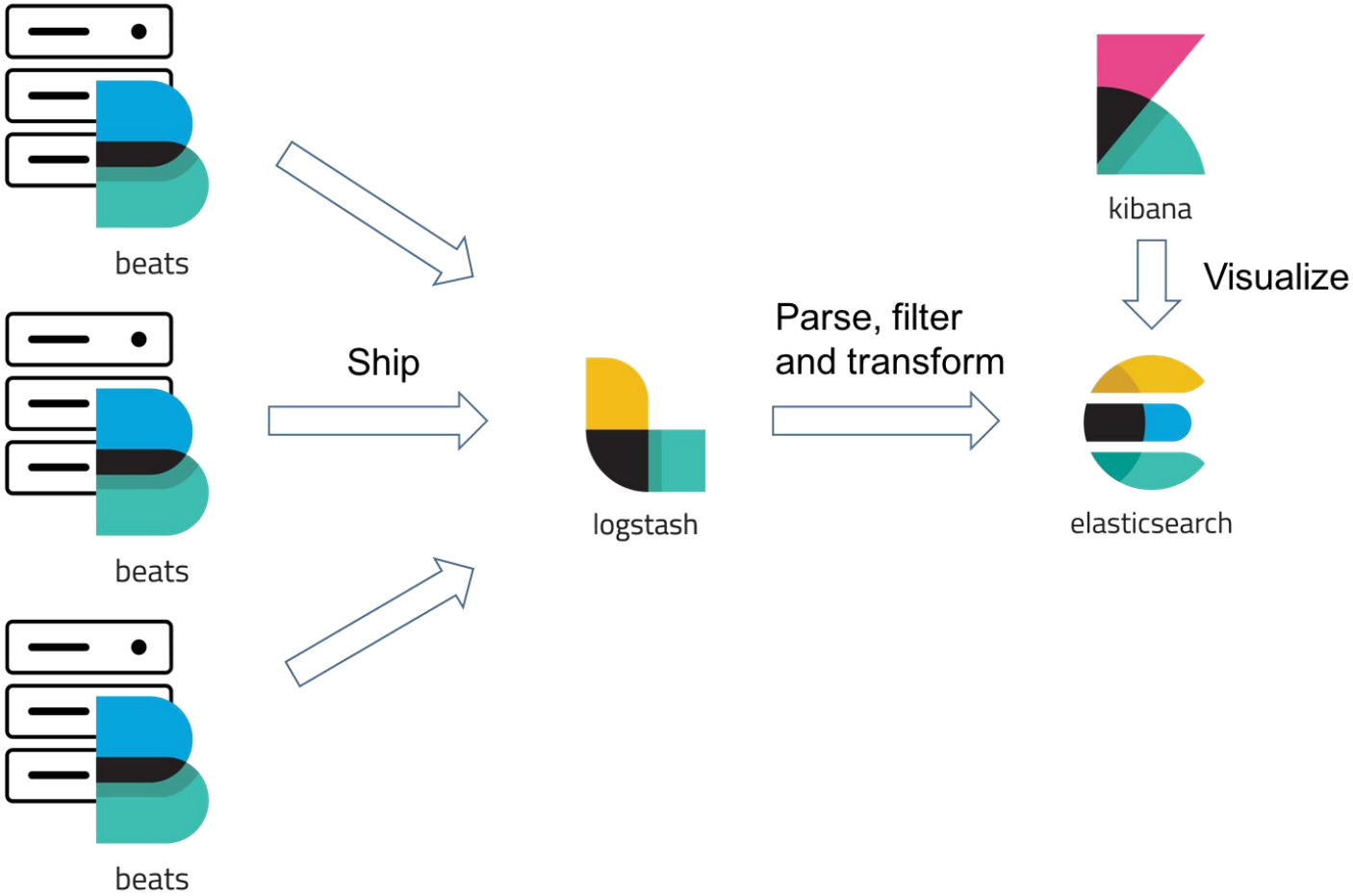
- Full-text search engine that searches and centrally stores data
- Quickly find, retrieve, and analyze big volumes of data
- Distributed and highly scalable
- Near real time search
- Uses RESTful API, JSON, and Lucene

Kibana

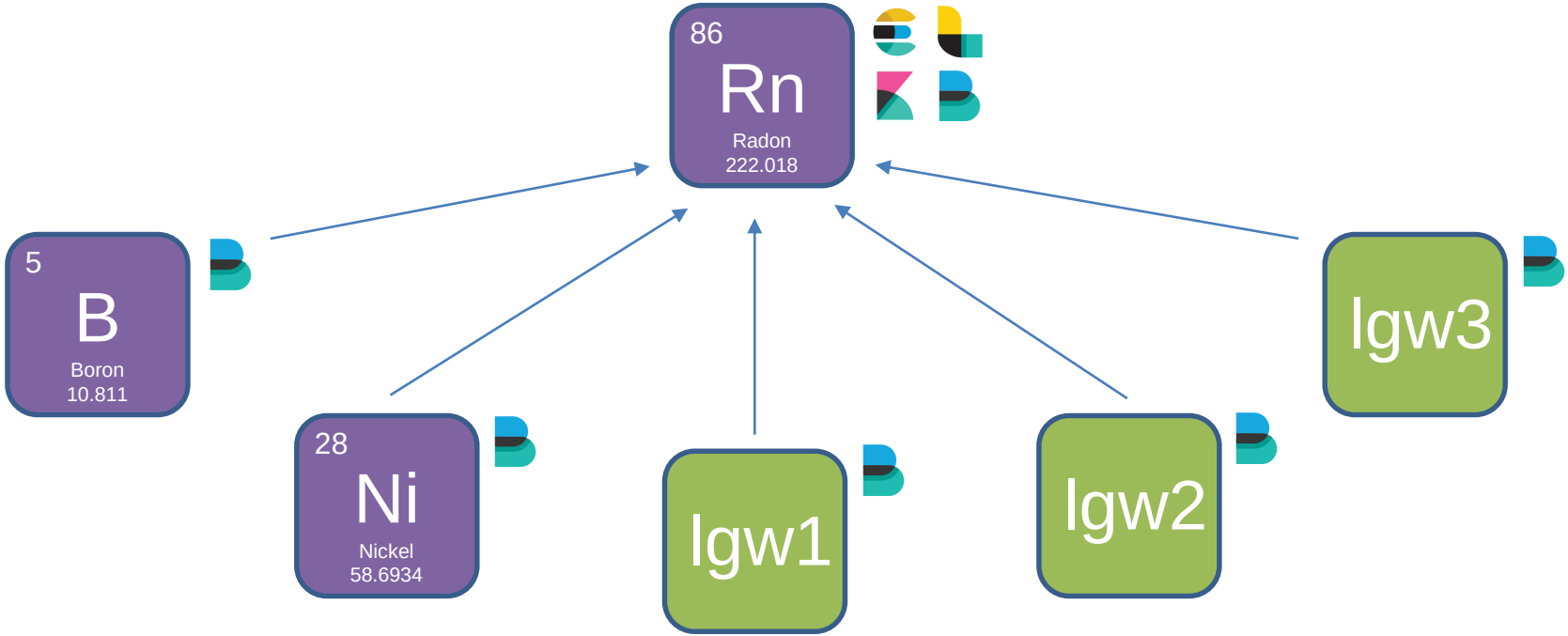
- Data visualization tool for log and time series analytics
- Makes navigation and monitoring of logs more intuitive
- Provides numerous graph and dashboard options to display information



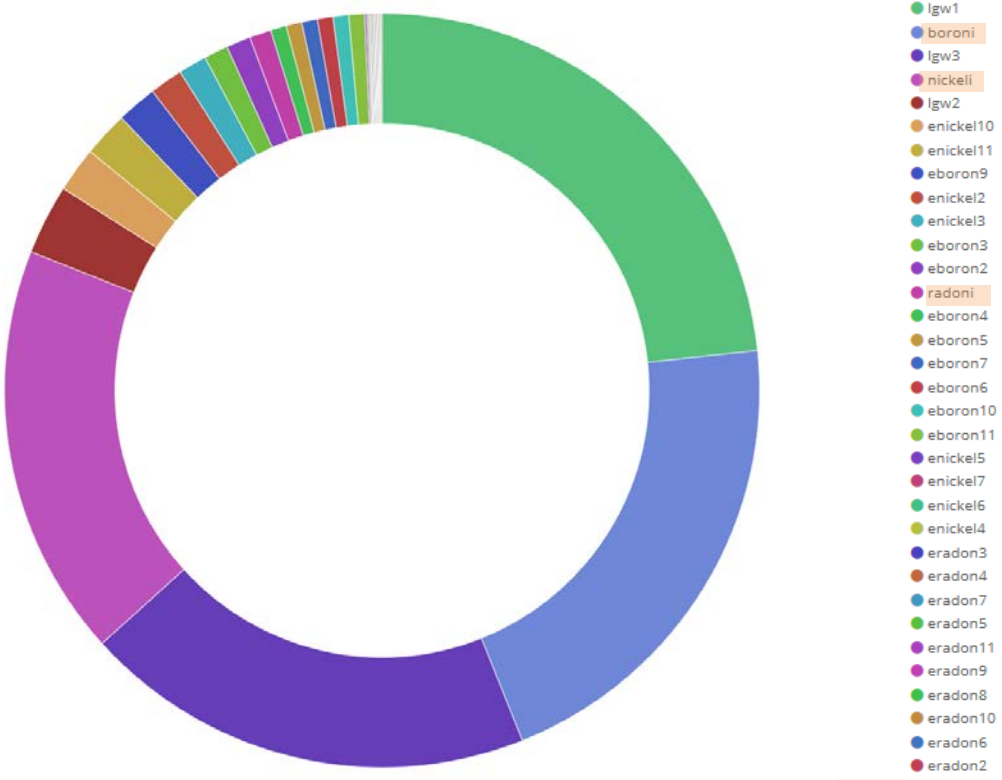
```
{
  "_index": "filebeat-2017.08.220",
  "_type": "log",
  "_id": "AV3CzBBOgNBZ6calr1OY",
  "_score": 1,
  "_source": {
    "@timestamp": "2017-08-08T17:02:22.152Z",
    "offset": 7790594,
    "@version": "1",
    "input_type": "log",
    "beat": {
      "hostname": "eboron7",
      "name": "eboron7",
      "version": "5.5.1"
    },
    "host": "eboron7",
    "source": "/var/log/messages",
    "message": "Aug  8 10:02:21 eboron7 kubelet: W0808 10:02:21.326628   90005 helpers.go:771] eviction manager: no observation found for eviction signal allocatableNodeFs.available",
    "type": "log",
    "tags": [
      "beats_input_codec_plain_applied"
    ]
  },
  "fields": {
    "@timestamp": [
      1502211742152
    ]
  }
}
```


beats
beats
beats
Ship
logstash
Parse, filter
and transform
kibana
Visualize
elasticsearch

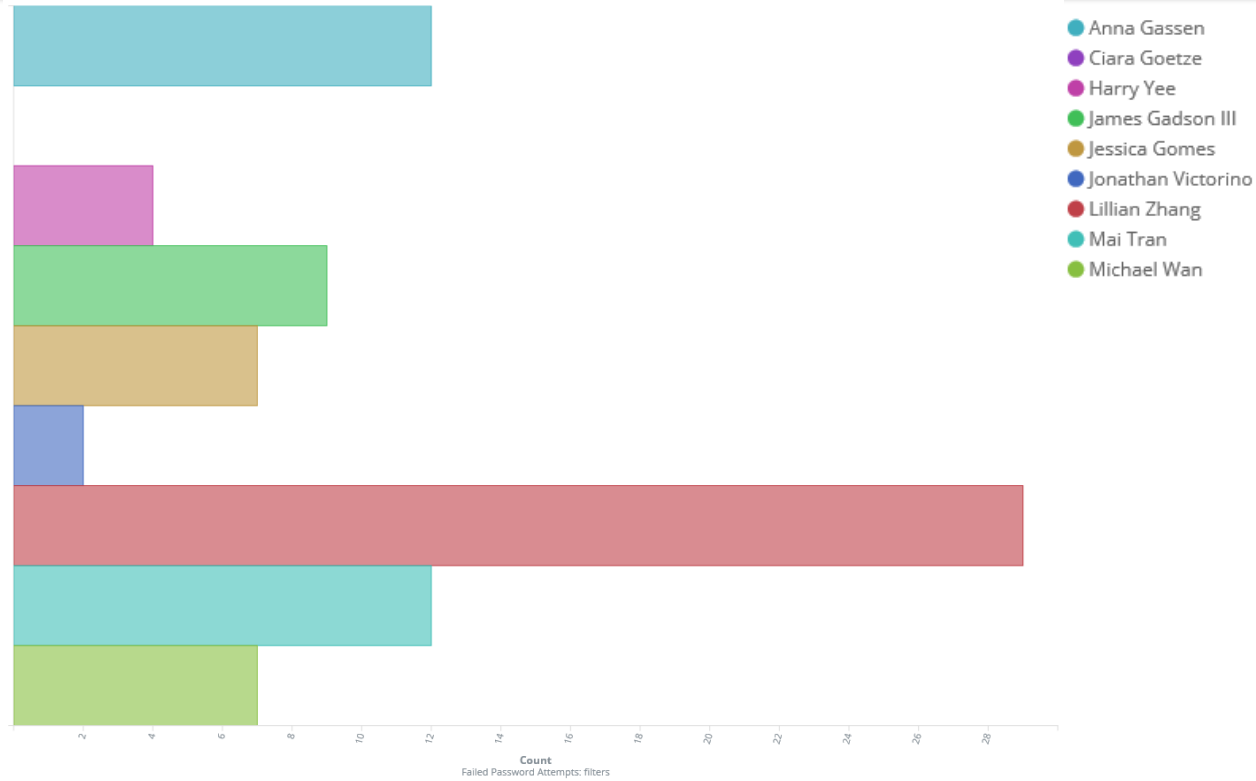
Approach


86
Rn
Radon
222.018
5
B
Boron
10.811
28
Ni
Nickel
58.6934
lgw1
lgw2
lgw3

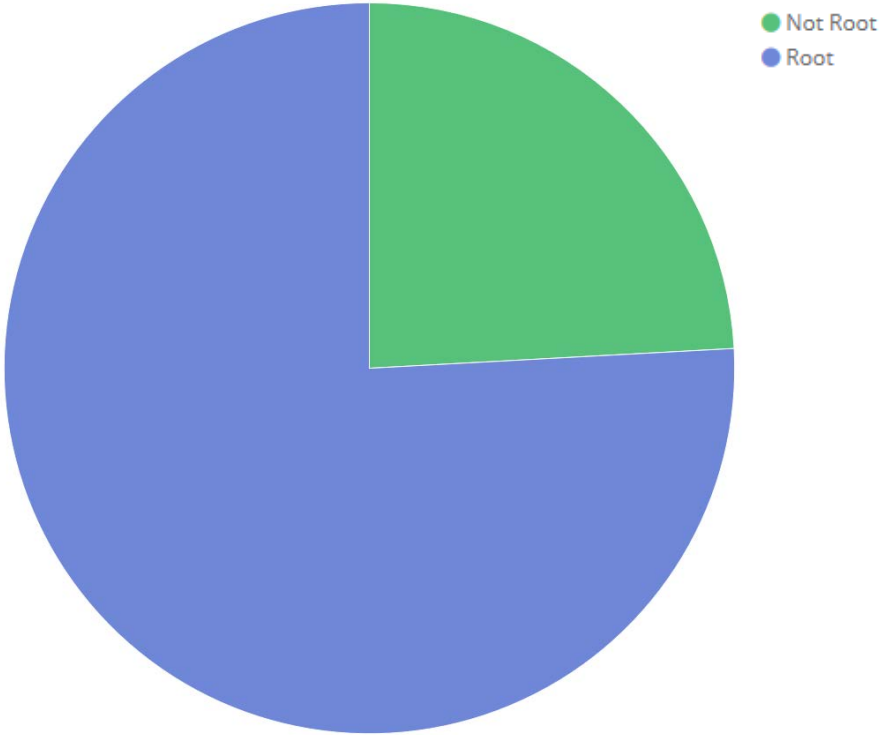
Number of Documents per Node



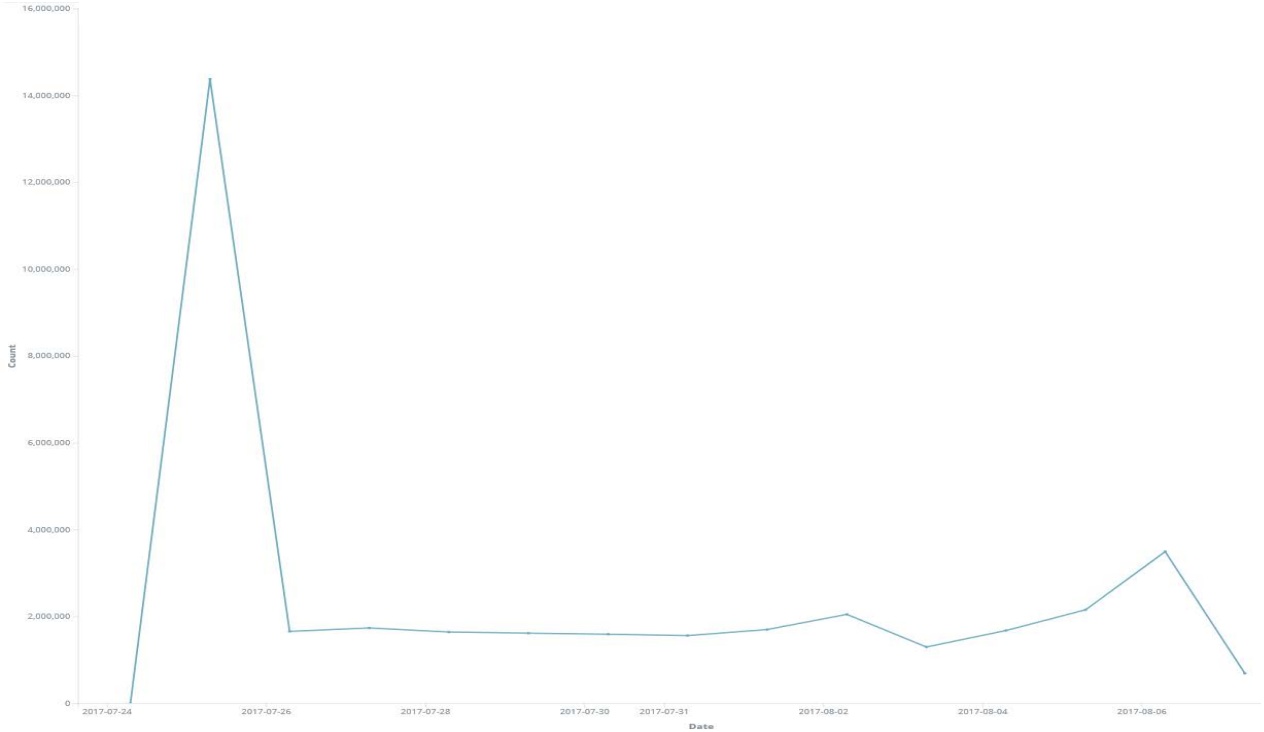
Failed Login Attempts



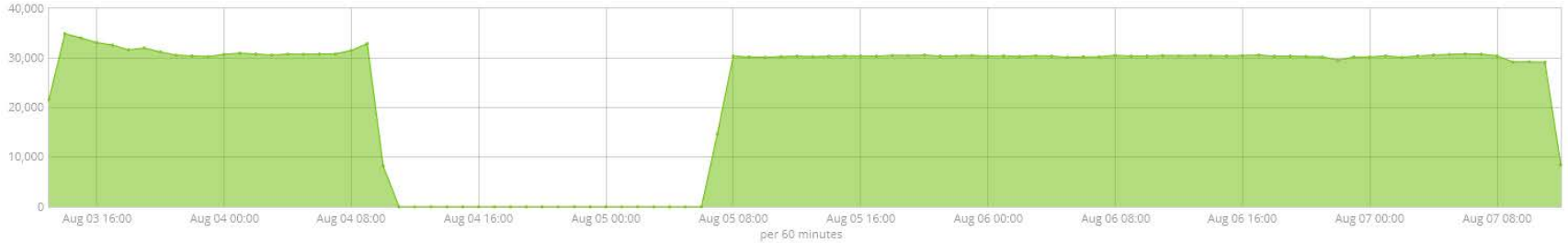
Root vs Non-Root Logins



Number of Documents per Day



Martian Source Warnings



August 7th 2017, 13:22:09.461 @timestamp: August 7th 2017, 13:22:09.461 offset: 35,971,095 @version: 1 beat.hostname: lgw1 beat.name: lgw1 beat.version: 5.5.1 input_type: log host: lgw1 source: /var/log/kern.log message: Aug 7 13:22:23 elgw3 kernel: IPv4: martian source 192.168.36.2 from 192.168.36.254, on dev mgmt type: log tags: beats_input_codec_plain_applied _id: AV2-XKtGgNBZ6calhzUk _type: log _index: filebeat-2017.08.219 _score: -

Future work

- Research Logstash pipeline configuration options
- Utilize Beats and X-Pack
- Perform more complex Elasticsearch queries
- Configuring Elastic Stack to be useful to future Academy interns

Acknowledgements

- David Fox
- Geoff Cleary
- Pam Hamilton
- Bryan Dixon
- Richard Randall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National Laboratory

Kubernetes Implementation into HPC

Livermore Computing

Jessica Gomes, Jonathan Victorino, Harry Yee
HPC CEA Interns

August 10, 2017

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Meet Team Kubes

Harry Yee
UCLA

Jessica Gomes
University of Illinois at Urbana-Champaign

Jonathan Victorino
Stanford University

Objectives

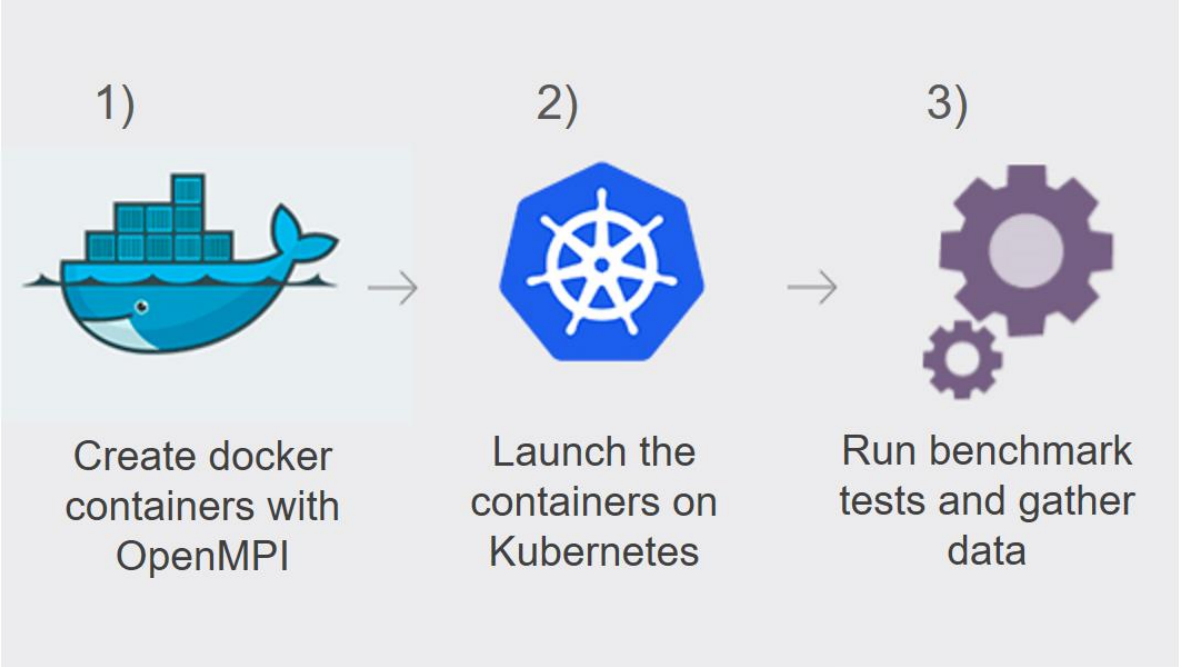
I. Setup a Kubernetes cluster using Docker containers

II. Run LINPACK benchmark tests comparing Kubernetes and bare metal cluster

III. Determine performance overhead of running the cluster in Kubernetes

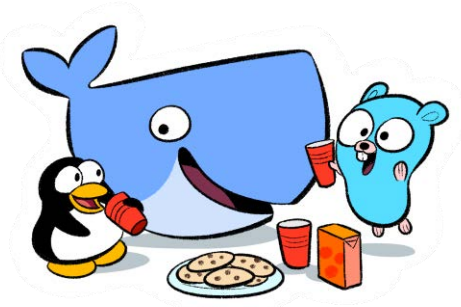
IV. Automate Kubernetes builds and deployments using Puppet

Our Project


1)
2)
3)
Create docker containers with OpenMPI
Launch the containers on Kubernetes
Run benchmark tests and gather data

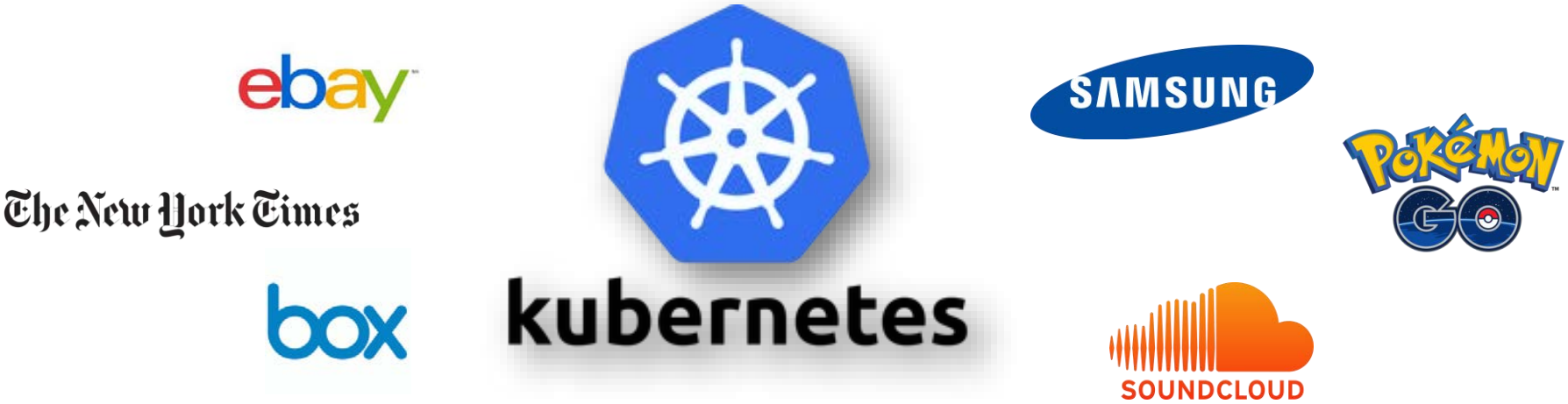
Docker

- World's leading software container platform
- **Container**: stand-alone package that includes everything needed to run it
- Easily create images for containers using Dockerfiles
- Use Docker Hub to automatically update the containers



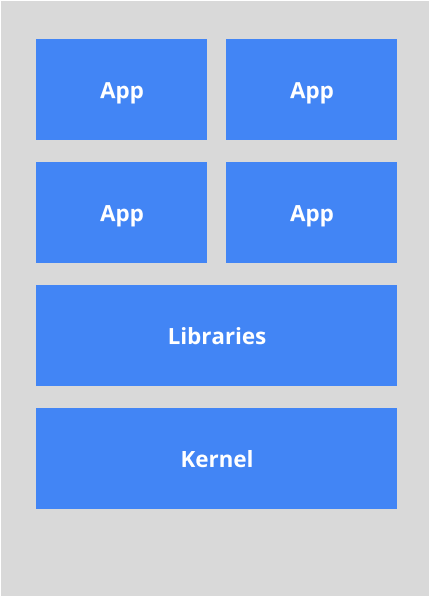
What is Kubernetes?

- Open-source system for automating deployment, scaling, and management of containerized applications
- Schedule and deploy any number of Docker container replicas onto a node cluster



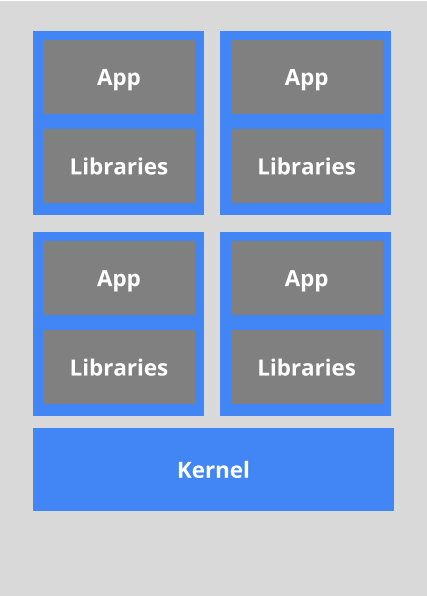
Kubernetes Container Visualization

The old way: Applications on host



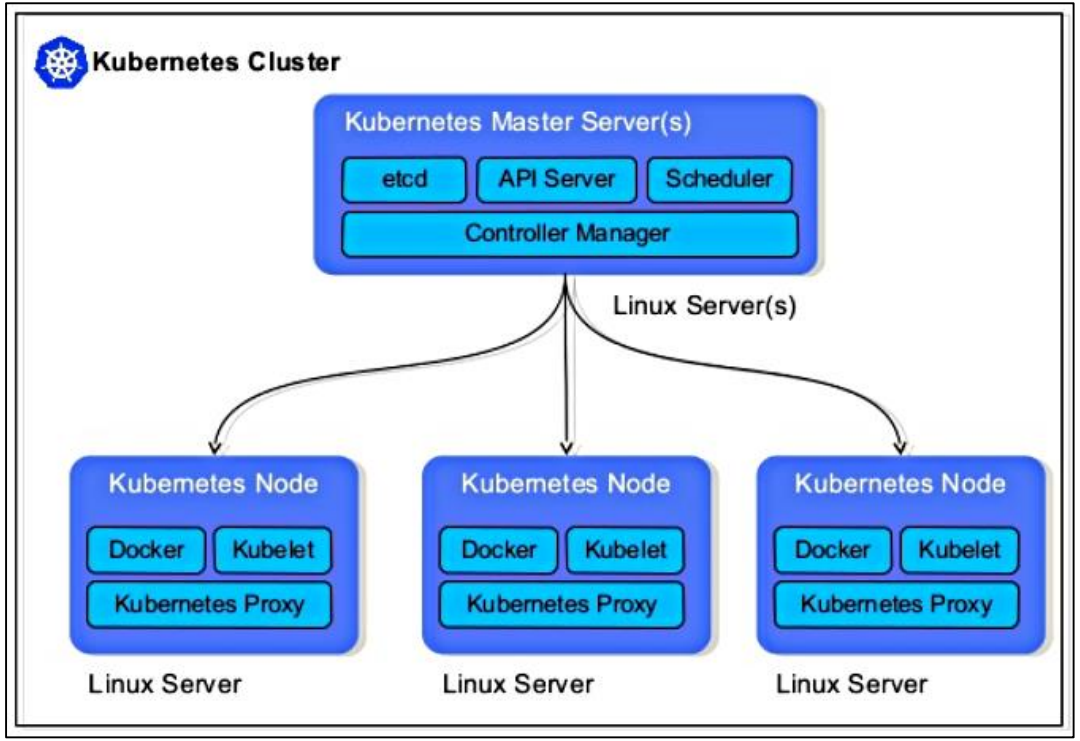
Heavyweight, non-portable
Relies on OS package manager

The new way: Deploy containers



Small and fast, portable
Uses OS-level virtualization

Kubernetes Architectural Overview



Installation Process

```
root@boron:~/boron_puppet/manifests
    ensure => "file",
    owner => "root",
    group => "root",
    mode => "644",
    source => "/root/boron_puppet/tftpboot/pxelinux.cfg/default",
}


file { '/etc/dhcp/dhcpd.conf':
    ensure => "file",
    owner => "root",
    group => "root",
    mode => "644",
    source => "/root/boron_puppet/etc/dhcp/dhcpd.conf",
}

$packages = ['ntp', 'openmpi', 'openmpi-devel', 'slurm', 'munge',
 'nfs-utils', 'sudo', 'yum-utils', 'device-mapper-persistent-data', 'lvm2']
package { $packages:
    ensure => installed,
}

exec {'dockerInstall':
    command => "/root/boron_puppet/scripts/dockerInstallScript.sh",
    #unless => 'test -e /usr/bin/docker',
}

package {'docker-ce':
    ensure => installed,
}

exec {'kubeInstall':
    command => "/root/boron_puppet/scripts/kubeInstallScript.sh",
    #unless => 'test -e /usr/bin/kubelet && test -e /usr/bin/kubeadm',
}

$kubepackages = ['kubelet', 'kubeadm']
package { $kubepackages:
    ensure => installed,
}
```

Puppet Manifest File

```
root@boron:~/boron_puppet/scripts
#!/bin/bash

# Docker installation
sudo yum-config-manager --add-repo
https://download.docker.com/linux/
centos/docker-ce.repo

sudo yum makecache fast
sudo yum -y install docker-ce
sudo systemctl start docker
sudo systemctl enable docker
```

Docker Installation Script

```
root@boron:~/boron_puppet/scripts
#!/bin/bash

# Kubectl Installation
curl -LO https://storage.googleapis.com/kubernetes-release/release/$(curl -s
https://storage.googleapis.com/kubernetes-release/release/stable.txt)/bin/linux/amd64/kubectl

# Change Permissions
chmod +x ./kubectl
sudo mv ./kubectl /usr/local/bin/kubectl

# Install Packages Kubelet and Kudeadm
touch /etc/yum.repos.d/kubernetes.repo
sudo echo "[kubernetes]
name=Kubernetes
baseurl=https://packages.cloud.google.com/yum/repos/kubernetes-el7-x86_64
enabled=1
gpgcheck=1
repo_gpgcheck=1
gpgkey=https://packages.cloud.google.com/yum/doc/yum-key.gpg
       https://packages.cloud.google.com/yum/doc/rpm-package-key.gpg" >
       /etc/yum.repos.d/kubernetes.repo

# Disable SELinux Enforcement
setenforce 0
```

Kubernetes Packages Installation Script

.yaml Files

Branch: master ▾ MPI-Kubernetes-Cluster / master.yaml — Find file | Copy path

U-THE-LAB\dixon30 Reduced CPU amount to 15 vs 16 — 9603fcf 23 hours ago

2 contributors @h @j

Executable File | 65 lines (64 sloc) | 1.59 KB — Raw | Blame | History

```yaml
apiVersion: v1
kind: Service
metadata:
  name: mpi-master
  labels:
    service: mpi-master
spec:
  type: NodePort
  ports:
  - port: 22
    nodePort: 30001
    protocol: TCP
  selector:
    app: mpi-master-deployment
---
apiVersion: apps/v1beta1
kind: Deployment
metadata:
  # Unique key of the Deployment instance
  name: mpi-master-deployment
spec:
  # 3 Pods should exist at all times.
  replicas: 1
  template:
    metadata:
      labels:
        # Apply this label to pods and default
        # the Deployment label selector to this value
        app: mpi-master-deployment
```

Branch: master ▾ MPI-Kubernetes-Cluster / worker.yaml — Find file | Copy path

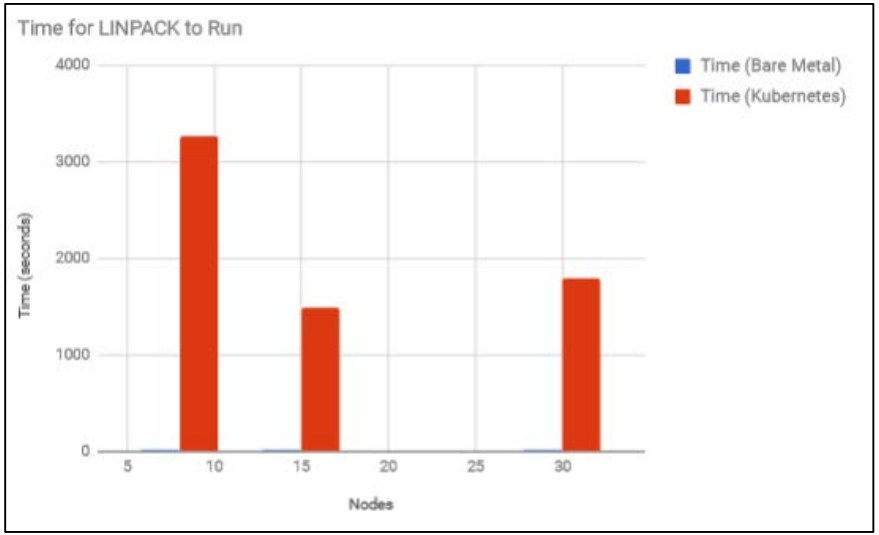
U-THE-LAB\dixon30 Reduced CPU amount to 15 vs 16 — 9603fcf 23 hours ago

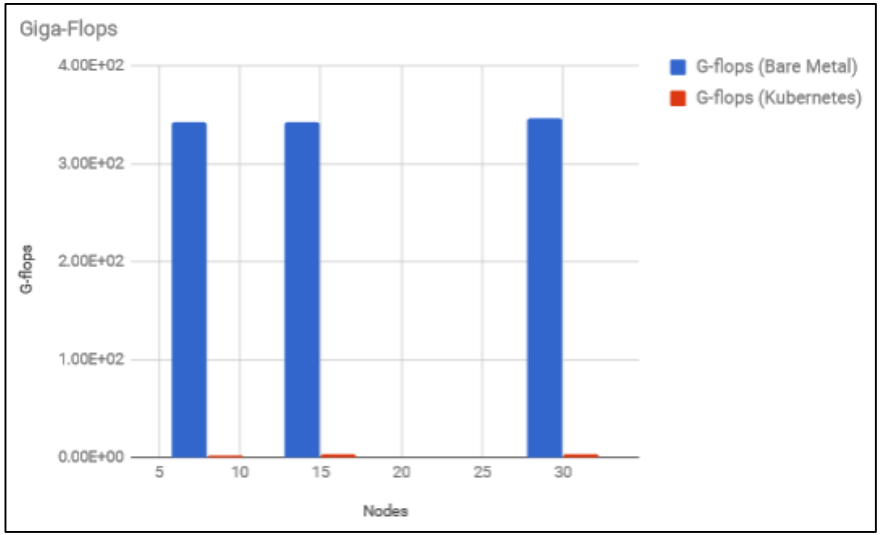
2 contributors @h @j

Executable File | 39 lines (38 sloc) | 988 Bytes — Raw | Blame | History

```yaml
apiVersion: apps/v1beta1
kind: Deployment
metadata:
  # Unique key of the Deployment instance
  name: mpi-worker
spec:
  # 3 Pods should exist at all times.
  replicas: 5
  template:
    metadata:
      labels:
        # Apply this label to pods and default
        # the Deployment label selector to this value
        app: mpi-worker
    spec:
      volumes:
        - name: ssh-keys
          secret:
            secretName: ssh-key-secret
        # - name: test-volume
        #   persistentVolumeClaim:
        #     claimName: test-pvc
      containers:
      - name: kube-mpi
        # Run this image
        image: javawolfpack/base-centos-mpi
        imagePullPolicy: Always
        ports:
          - containerPort: 22
```

LINPACK Benchmarks





	Time (seconds)	G-flops
Bare Metal	15.39	3.47E+02
Kubernetes	1796.654	2.99E+00

Conclusion

- Kubernetes
  - Large performance overhead on clusters
  - Extra setup steps
  - Not ideal for HPC
- Use bare metal cluster
- After further testing, the bottleneck was found to be due to a networking issue
- Time and G-flops were comparable for containers running on the same node to the bare metal configuration

Future Plans

- Use Puppet to automate builds and deployments
- Automatically ssh from worker to master
- Run more Benchmark tests on Kubernetes cluster
- Find out how to fix the bottleneck and improve communication between containers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