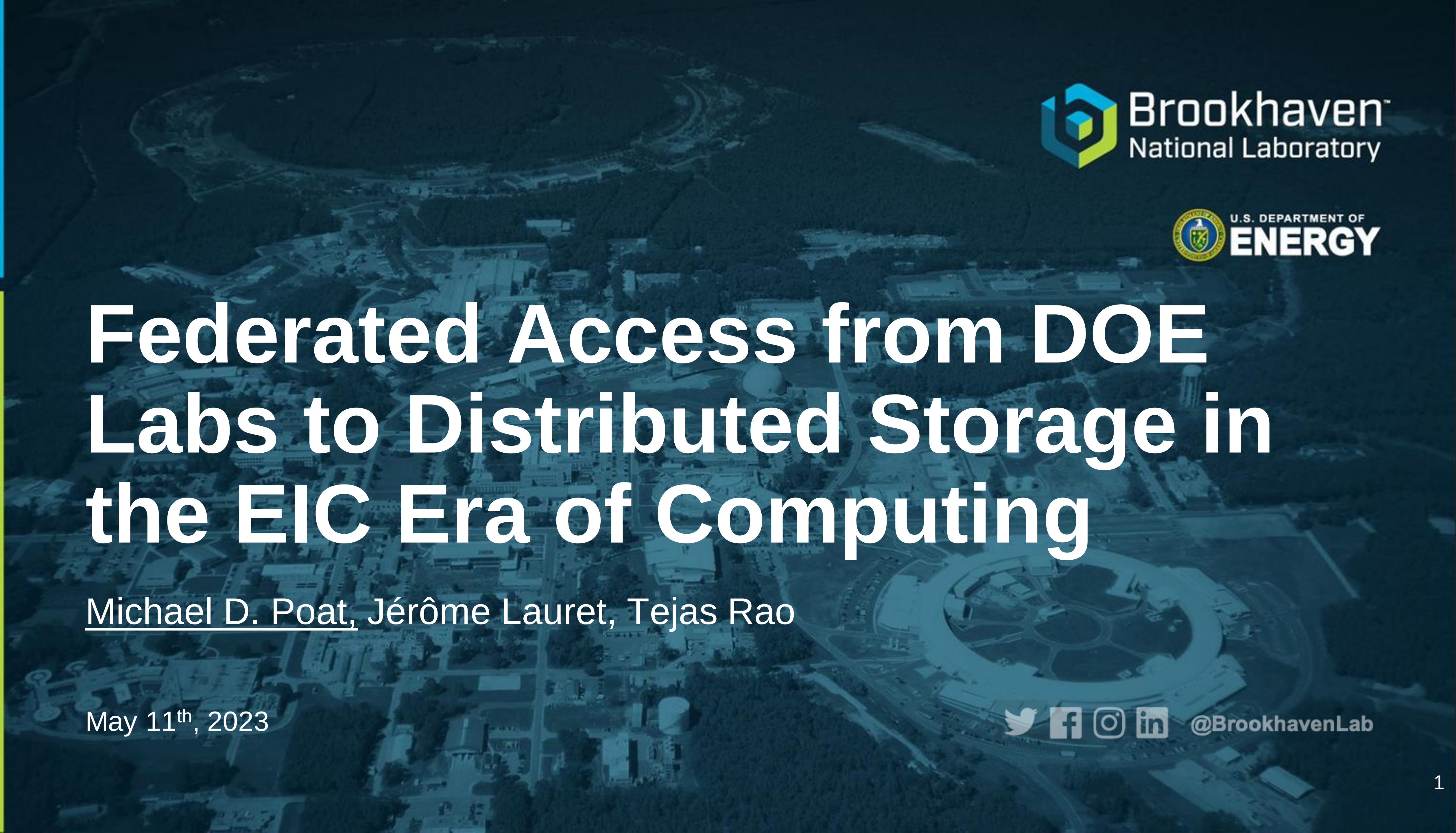

Federated Access from DOE Labs to Distributed Storage in the EIC Era of Computing

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May 11th, 2023

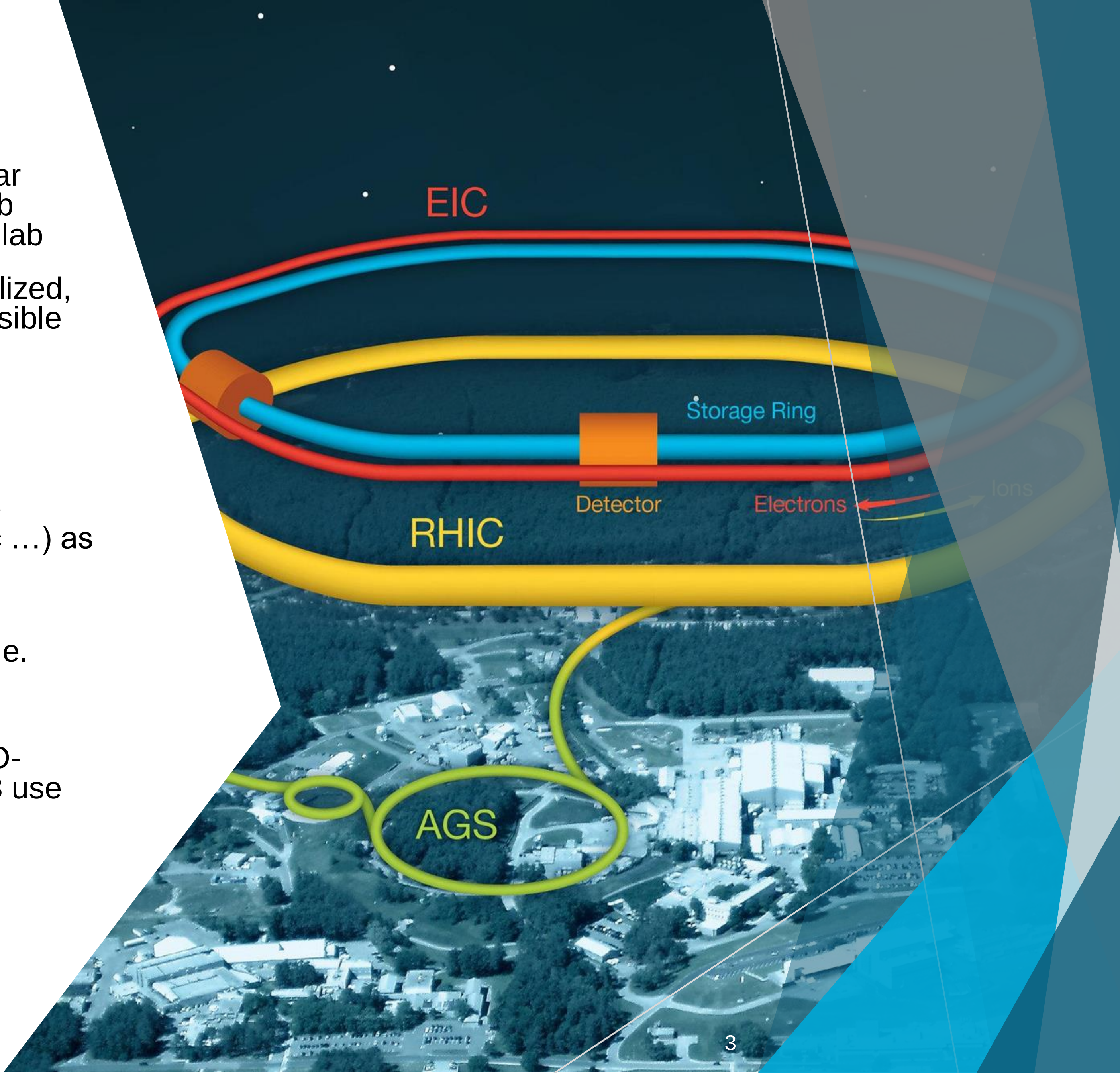
@BrookhavenLab

Outline

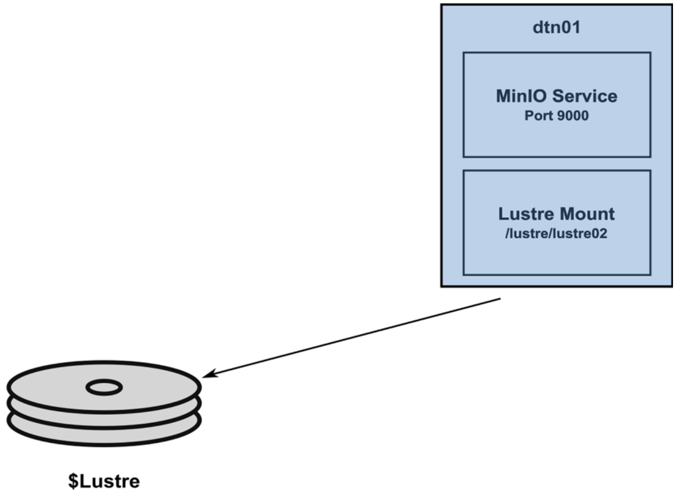
- Introduction
- Evolution / MinIO-Gateway
- Ceph S3
- IO Performance Tests
- Perspective / Federated ID
- Conclusion

Introduction

- The Electron-Ion Collider, a new facility for nuclear physics research to be located at Brookhaven Lab (BNL) but a cross-collaboration between BNL & Jlab
- While the computing model for the EIC is not finalized, we envision to have the storage resources accessible to a wide range of collaborators. This calls for
  - A Federated storage solution
  - A Federated ID access to the storage
- CEPH provides flexible ways to Federate storage (multi-location, pools with replication methods etc …) as well as the S3 protocol integrating Federated ID.
- As part of a “Program Development” funding, we established an S3 demonstrator / proof of principle.
- **Our Deployments:**
  - Initial implementation used Lustre with MinIO-Gateway (Minio GW) for S3 access - test S3 use in EIC
  - Second stage: A Ceph Object Storage with dedicated RadosGW Endpoints / S3

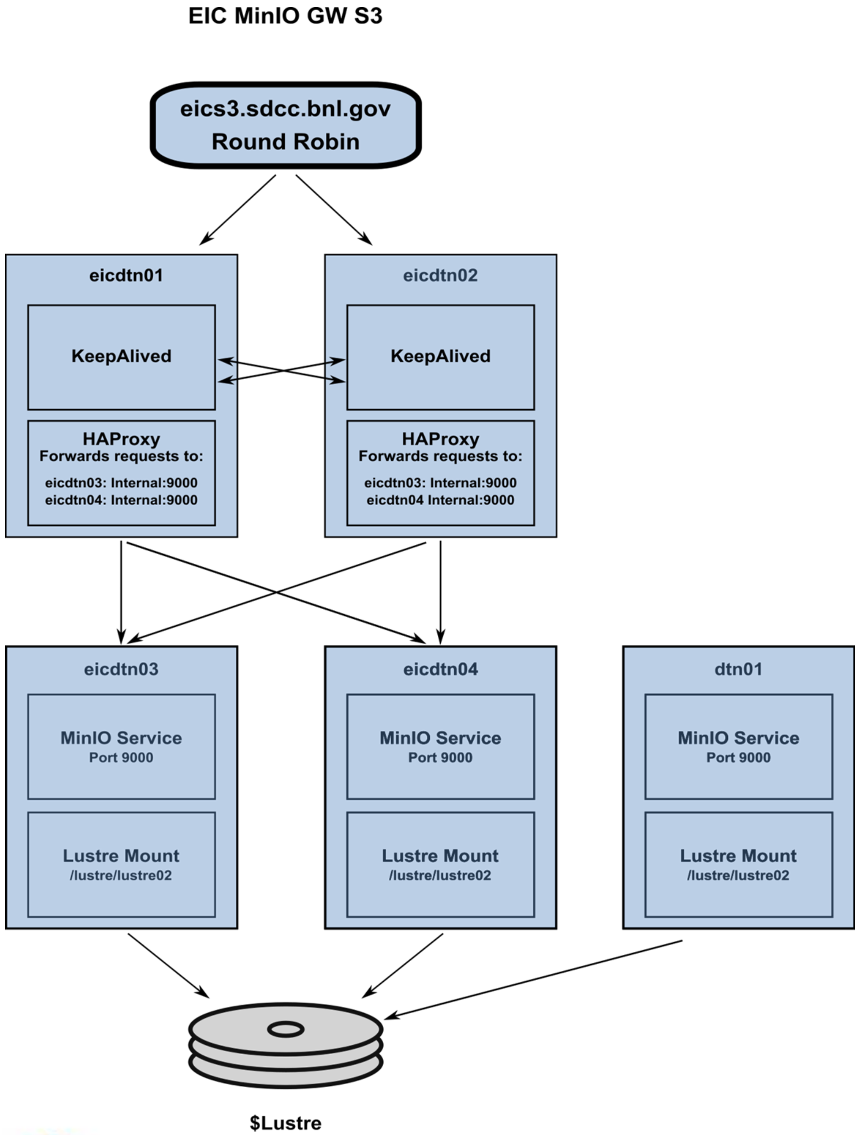


Evolution of the BNL EIC/S3 infrastructure



- Our initial deployment was on a single host running the MinIO GW service with Lustre mounted underneath (dtn01).
- Lustre setup (3PB):
  - 3 Hosts : 48 Core, 392GB RAM, 4 x 25 GbE
  - 100 x 14 TB per host -> 10 x 10-drive RAID6 OSTs
- MinIO GW (v. RELEASE.2022-08-11) provides an S3 interface to GPFS / NFS / Lustre storage as a backend - *quick and easy to set up*.
- It served its purpose, supporting the EIC detector design phase and was a stunning success. Accessible from anywhere, broadly accessible on the grid, BNL/S3 was the only read/write storage accessible

Evolution of the BNL EIC/S3 infrastructure

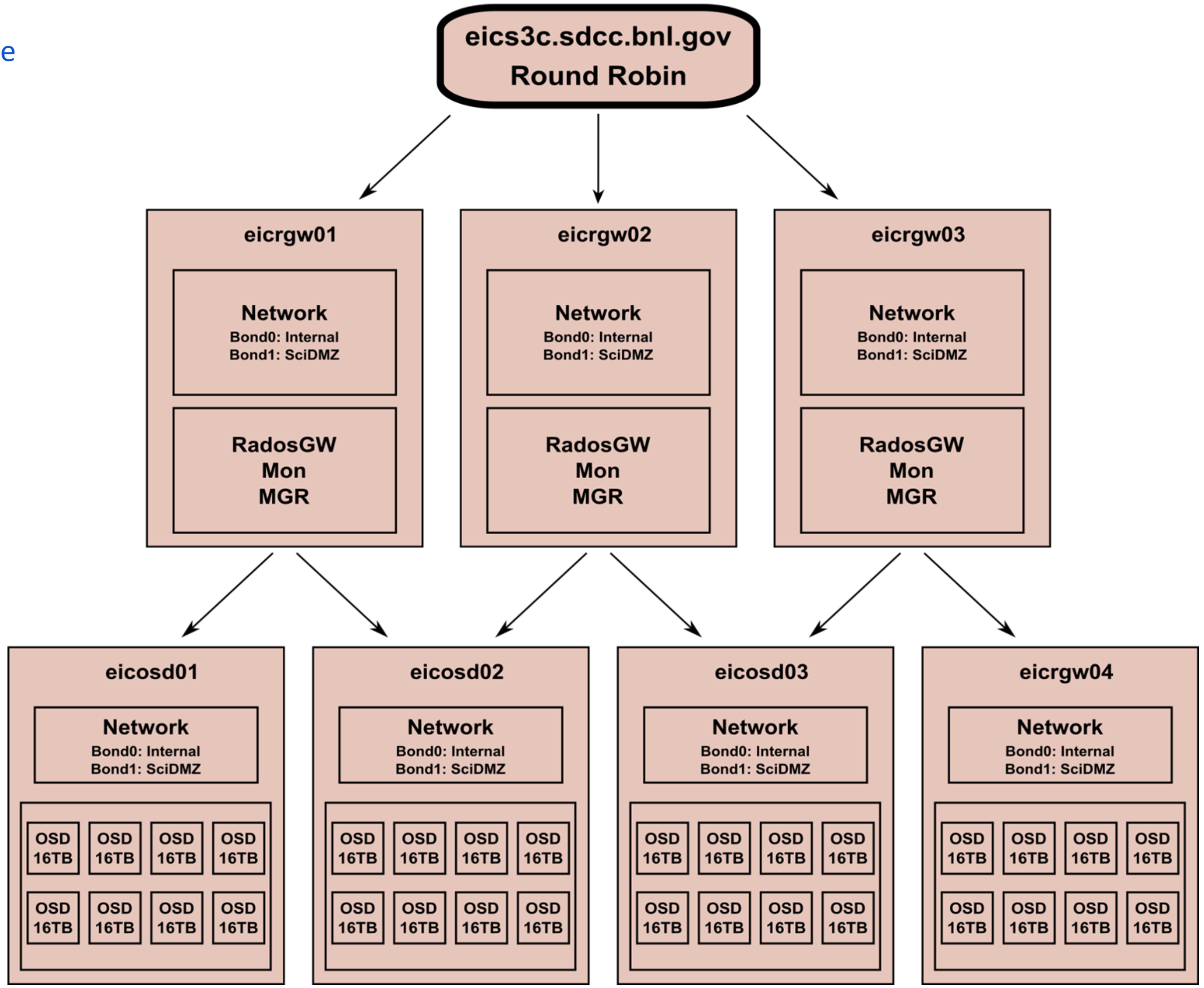


- A more robust setup followed using 4 hosts (28 Core, 132 GB, 4x25 GbE)
  - 2 hosts running HAProxy/KeepAlived for failover and balancing
  - 2 hosts for running MinIO GW/Lustre mount
  - Resilience, fail-over, IO increase
- Setup works well for a single site, but does not support zoning, Federated ID, and cannot scale across datacenters. Our goal is to provide a Federated access to Federated storage (storage could be added from anywhere)
- Additionally, in 2020 MinIO GW over standard FS was announced to be *deprecated* and moving toward pure Object Storage as a focus. There was no path to continue with Lustre. Any evolution would need to support Object Store.

Ceph S3

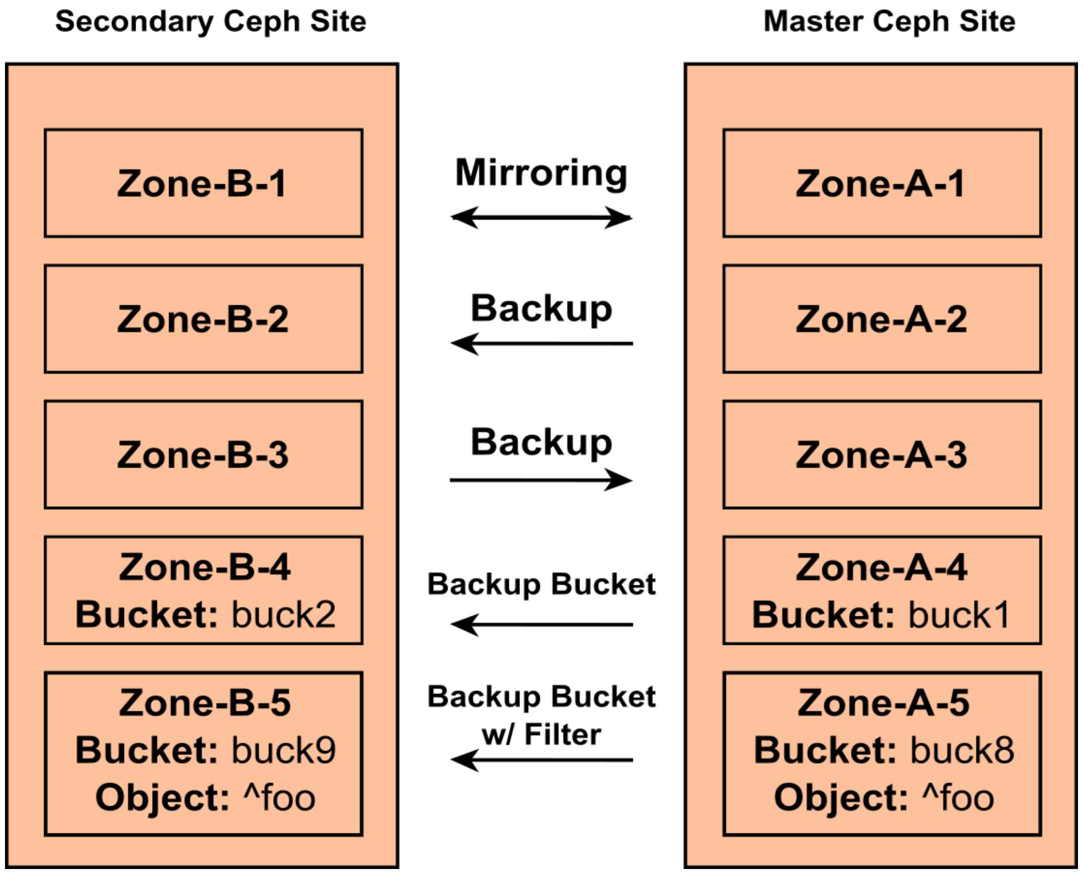
- Ceph is a reliable and scalable storage system based on RADOS (Reliable Autonomic Distributed Object Store) - had experience with Ceph [M. Poat, J. Lauret – "Achieving Cost/Performance Balance Ratio Using Tiered Storage Caching Techniques: A Case Study with CephFS", (2016). (CHEP 2016)]
- It provides high availability and data protection, with features such as erasure coding and replication
- The Ceph Object Gateway is the interface built on top of `librados` providing the RESTful gateway between the storage clusters and the Amazon S3 API.
- OpenID Connect Provider in RGW – Federated ID Access is possible
- **Initial deployment**:
  - 3 - RadosGW: 28 Core, 256 GB RAM, 4x25 GbE
  - 4 - OSD Hosts: 48 Core , 96 GB RAM, 4x25 GbE, 8x16 TB OSD each
- ~450 TB RAW w/ Erasure Coding 4+2 pools (300 TB usable)
- Deployment is easily scalable, can add disks to current nodes or scale horizontally (add more storage nodes), infrastructure in place for scale out

EIC Ceph S3



Concept for Multi-Site Ceph

- A multi-site Ceph cluster can be configured as Multi-Realm, Multi-Zonegroup, or Multi-Zone
- Replication / mirroring / backups possible as some of the actions you can perform between sites:



Secondary Ceph Site

Master Ceph Site

Zone-B-1 ⟷ Mirroring ⟷ Zone-A-1

Zone-B-2 ← Backup ← Zone-A-2

Zone-B-3 → Backup → Zone-A-3

Zone-B-4 **Bucket:** buck2 ← Backup Bucket ← Zone-A-4 **Bucket:** buck1

Zone-B-5 **Bucket:** buck9 **Object:** ^foo ← Backup Bucket w/ Filter ← Zone-A-5 **Bucket:** buck8 **Object:** ^foo

Mirroring: Mirrors two Zones across sites. Can write Objects back to either Zone, but all metadata must be written to the master - full sample at 2 sites

Backup To/From Zones: Directional Zone backup across sites (as read-only on secondary location)

Sync To/From Buckets: Directional Bucket backup or Bucket Mirroring

Sync To/From Buckets with Filter: Sync Objects that match name regex to/from Zone/Bucket (*.daq, *.root, …)

Federated ID Access / STS for Ceph

- S3 authenticates with an ACCESS_KEY & SECRET_KEY not a secure method for distributed access
- **STS:** Secure Token Service is a web service that returns a Token & a temporary set of credentials for authenticating federated users. STS in Ceph Object Storage - Pritha Srivastava (RH)
  - Token contains the AuthN/AuthZ to the RadosGW (Roles - Who can assume a role & Role Permissions)
  - **AssumeRoleWithWebIdentity**: Used for any external application that wants to access S3 resource
    - Does not require owning any permanent credentials in S3
    - Users authenticate w/ external OpenID Connect/OAuth 2.0 compliant IDP
- Federated Access for our Ceph
  - We are currently in progress of implementing this - (was not fully functional in time for the conference [hardware delivery delays] but detailed configuration will be provided)
  - The OpenID connect provider in RGW should enable us to enable Federated Access. This is the key to unify cross-collaboration

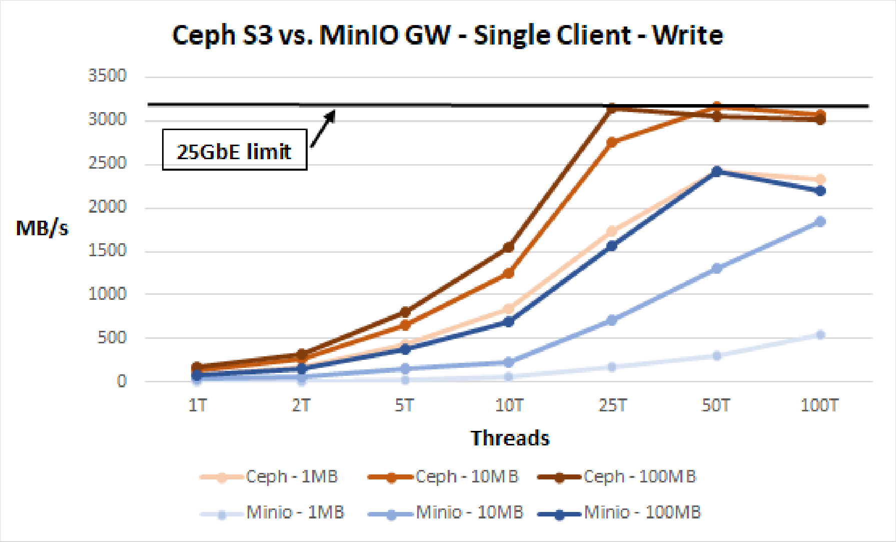
IO Performance Tests - Ceph vs. MinIO GW

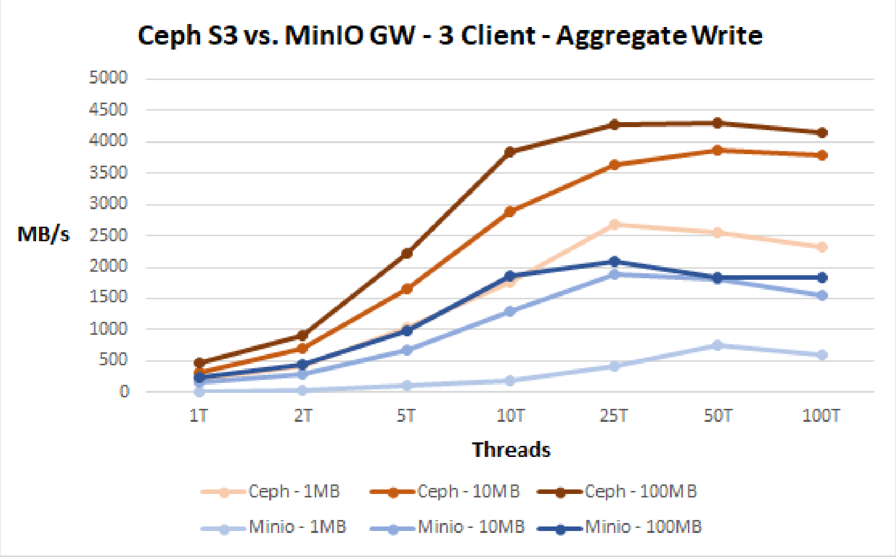
Ceph S3 vs MinIO GW Single client Write tests.

- S3bench IO perf tool used for testing
  - 1 MB - 100 MB chunk size
  - 1 - 100 Threads

- Despite drive and size discrepancy, Ceph outperforms our MinIO GW setup among all chunk sizes.
- MinIO GW: Lustre is not using striping
- Single Ceph client can saturate it's outgoing 25 GbE link with intensive writing.

- Ceph S3 vs MinIO GW - Multi (3) - client write tests.
- Ceph peak perf: **4.3 GB/s** - Peak 100 MB chunks @ 25T
- MinIO GW peak perf: **2.1 GB/s** - Peak 100 MB chunks @ 25T



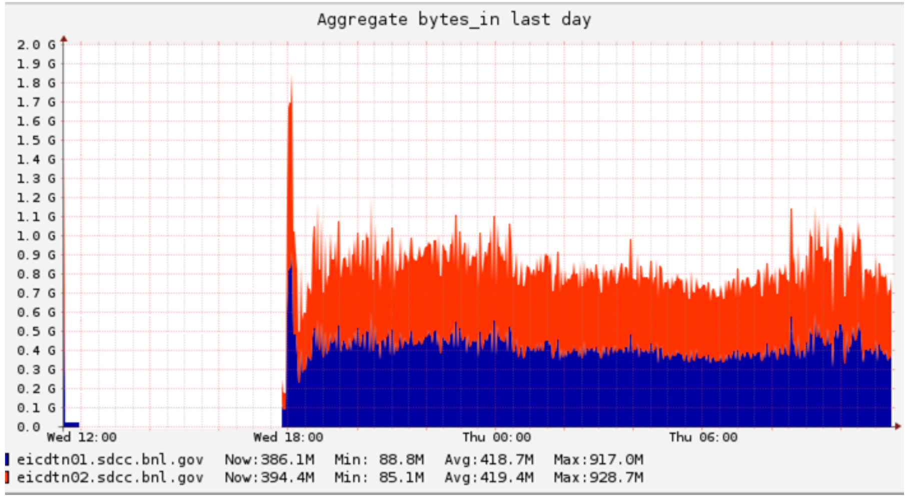


MinIO GW vs Lustre backend - 2,000 clients

MinIO GW S3

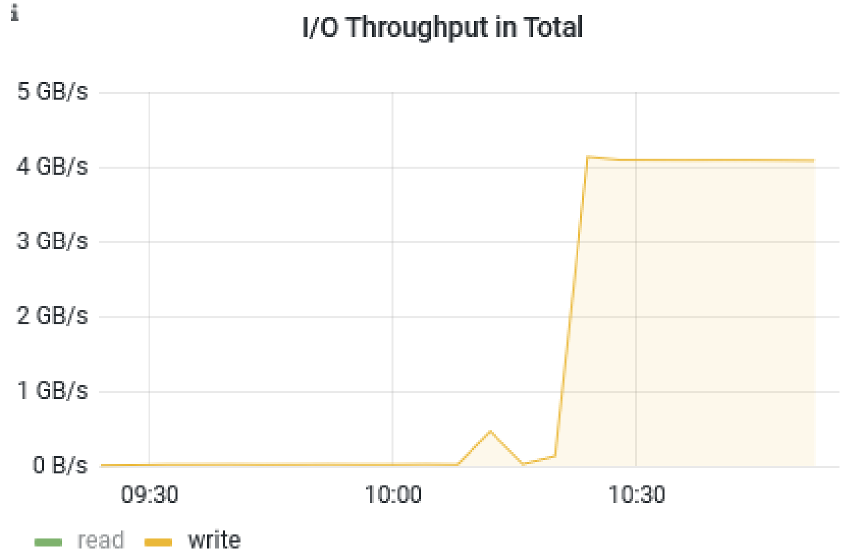
- Submitted 2000 batch jobs using S3bench - 10,000 - 10 MB chunks per host (1 Thread per Endpoint (x2))
- MinIO GW: Peak write performance **~1.8 GB/s** (on par with isolated tests)

2 MinIO GW Endpoints



Lustre Backend

- **IOZONE** IO performance tool used
- 2000 jobs Writing 10,000 - 10 MB chunks per host
- Peak Aggregate IO Throughput: **4.09 GB/s**



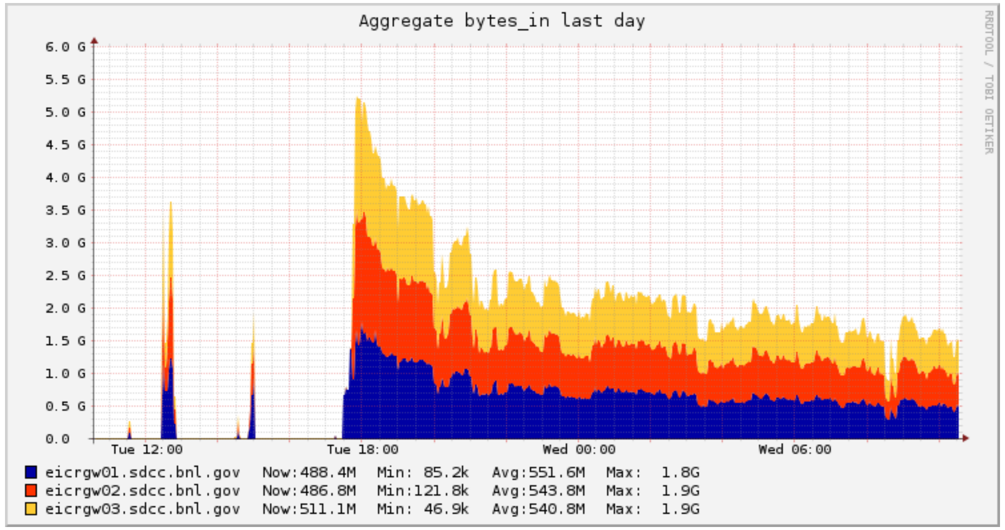
Peak MinIO GW write performance at ~50% of the underlying of our Lustre storage. Our Lustre is tuned for read performance over writes.

Ceph Object Storage (S3) - 2,000 clients

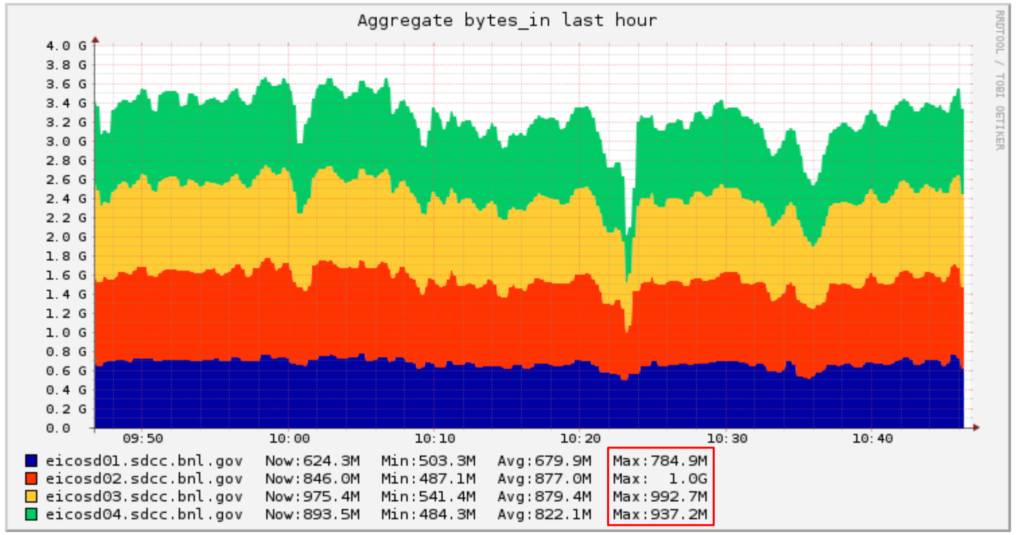
- Seagate 16TB Exos X16 - **Manufacture Spec**: Max. Sustained Transfer Rate: **261MB/s**
- Theoretical Aggregate Raw Speed: **8.1GB/s** (31 disks, 1 failed w/o replacement)
- Ceph Erasure Coding 4+2: Theoretical performance: 66% of Raw speed
- Submitted 2000 jobs: S3bench Writing - 10K - 10MB chunks per host to Ceph S3
  (1 Thread per Endpoint (x3))
- Peak Ceph performance: **~5.5 GB/s** (68% of Raw Speed w/ EC 4+2)
- Performance in inline with what we expect

- Ceph balances the IO among all disks within the cluster
- With a failed disk on one host, we can decipher the IO down to the disk level
- **~181 MB/s** max throughput per disk with EC 4+2
- We can use this as a baseline to scale towards any aggregate IO requirements

3 Ceph RGW Endpoints



4 Ceph OSD Hosts



Perspective

- A single Realm Multi-Site Ceph Object Storage provides a global object namespace and ensures unique object ID’s across the cluster
- While our Object Storage is focused on Ceph, a full MinIO Object Storage implementation or other object storage with S3 could be tested as options. Ceph provides a familiar technology and as solid baseline.
- By vertically scaling: maximizing disks in current setup from 31 -> 48 disks: **~8.7GB/s Max Throughput**
- By horizontally scaling: Double the number of hosts w/ 12 drives per: **~17.4GB/s Max Throughput**
    - The IO requirements of the EIC are not yet finalized but …
    - The scalability of the Throughput is however predictable

Conclusion

Takeaways

- S3 accessible storage provided to the EIC production workflow - MinIO GW required minimal setup to have a globally accessible storage space (but lacked key features)
- Federated S3 Storage could provide the EIC with a globally accessible storage space that can easily be scaled locally (and has the ability to provide a framework where storage can be added from anywhere).
- Ceph Object Storage provides all the features to deploy a multi-site S3 storage.

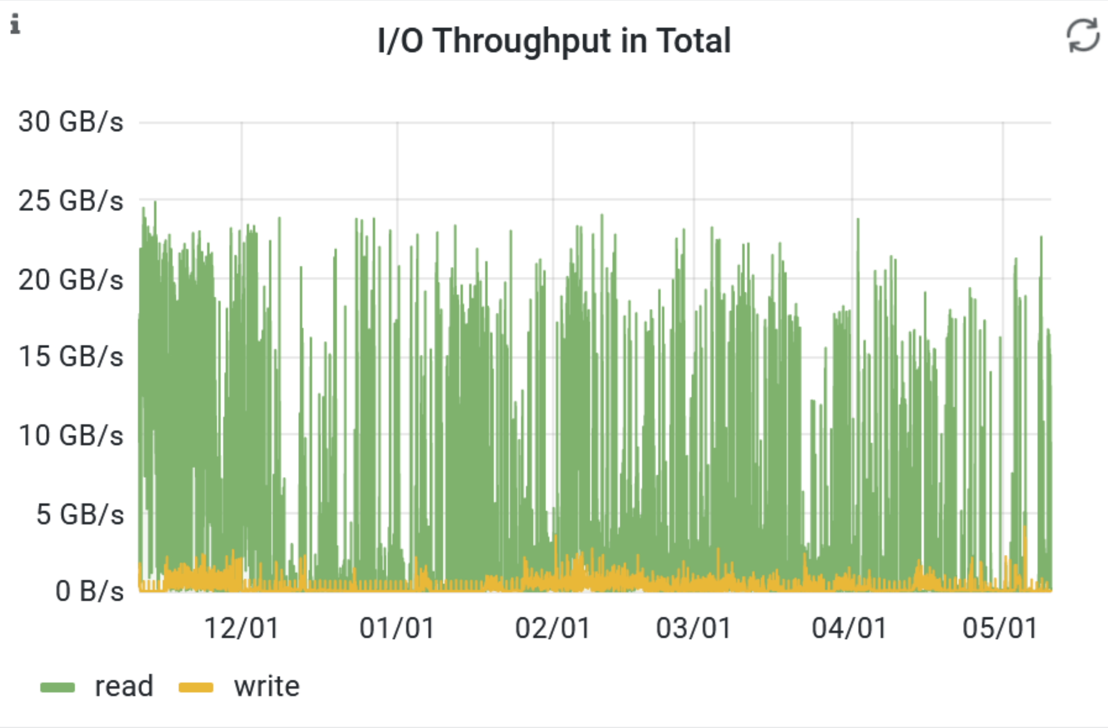
Future/Ongoing work

- Implement and test the OpenID Connect module within Ceph
- Deploy an additional standalone cluster in a different location to test Multi-Site and the synchronization features
- Provide the skeleton/framework of a Multi-Site Ceph cluster with Federated ID access.

Thanks!

Backup

- 6 Month Grafana Chart: Lustre Read/Write


I/O Throughput in Total
30 GB/s
25 GB/s
20 GB/s
15 GB/s
10 GB/s
5 GB/s
0 B/s
12/01
01/01
02/01
03/01
04/01
05/01
🟩 read
🟨 write