

Hands on with Object Stores

Exercises

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1 Introduction

This sheet details the practical exercises you can undertake within this tutorial. It also describes the system we are using and how to access it. For the first exercises we provide pre-compiled applications for you to run, but you will get the chance to implement the source code for this application in the later exercises.

2 Using the system

For this tutorial we are using the Google (GCP) cloud. We have created a cloud virtual machine (VM) that will act as a login node and batch system host for compute VMs, along with Parallelstore (Google's deployment of DAOS) storage systems that can be used from the login node and the compute VMs. You will need to provide us with an email address and then we will send you an SSH key, username, and IP address for the system. You can then access the system as follows (**note: the username you use will be different from below, this will be emailed to you along with the ssh key**):

```
ssh -AX -I ssh_key tu001@35.188.183.150
```

The system is configured with a login node separate from the compute nodes in the system. To get the initial compiler and MPI libraries setup on the system you should do the following when you log on:

```
module load openmpi/v4.1.x
```

We use the Slurm batch system to access and enquire about the compute nodes. You can discover how many compute nodes there are using the following command:

```
sinfo
```

Or:

```
sinfo -N -l
```

Below is an example of a Slurm batch script we can use to run a job:

```
#!/bin/bash
#SBATCH --job-name=test_job
#SBATCH --output=test.%A.out
#SBATCH --error=test.%A.err
#SBATCH --tasks-per-node=32
#SBATCH --cpus-per-task=1
#SBATCH --time=00:05:00
#SBATCH --nodes=2
```

```
srun hostname
```

To run a job on the system we use the `sbatch` command, i.e. (assuming the script above is called `runtestjob.sh`)

```
sbatch runtestjob.sh
```

You can `squeue` to see running jobs (`squeue -u $USER` will show only your jobs) and `scancel` to cancel a job.

The `srun` command in the script above is the MPI job launcher which runs the executable on the selected number of nodes. The default MPI library being used is the OpenMPI library. We are specifying the number of processes we want to run using the Slurm `sbatch` configuration. The batch script above runs 32 processes per node and is requesting 2 nodes, meaning it will run the application on 64 processes spread across 2 nodes. If you want to vary the number of processes you run an application on you can change the number of nodes, i.e. this line:

```
#SBATCH --nodes=2
```

Or you can change the number of tasks per node, i.e. this line:

```
#SBATCH --tasks-per-node=32
```

A combination of these will specify the overall number of processes to use.

2.1 Available Hardware

Currently we have 48 compute nodes configured in this GCP setup. They are n2-highcpu-32 VM types, configured with Intel IceLake processes each with 32 threads/16 physical cores. Each node has 32 GiB of memory and a 50Gbps network interface.

Alongside this we have a DAOS/ParallelStore configuration using 3 nodes with 6 TiB of NVMe storage and 150GB DRAM each. As this is configured with a redundancy factor (erasure coding of 2+1) we actually have 4 TiB of storage per node, or 12TiB overall in the DAOS.

You can try running jobs up to 8 compute nodes, or 256 processes in total.

3 Exploring filesystem performance

To get started on the system copy the following software into your home directory:

```
git clone https://github.com/adrianjhpc/ObjectStoreTutorial
```

Change to the `ObjectStoreTutorial/Exercises` directory, i.e.:

```
cd ObjectStoreTutorial/Exercises
```

You should be able unpack with the command:

```
tar xf IOR.tar.gz.
```

For IOR you need to go into the `ior` directory and type:

```
make
```

Then you can run a DAOS filesystem IOR benchmark using:

```
sbatch daos_filesystem_ior.sh
```

The aim of this exercise is to run the different IOR benchmarks and compare the performance that Ceph and DAOS are providing. IOR is a common I/O benchmark designed to explore the maximum bandwidth a filesystem can provide to a parallel programme. It uses MPI to run many workers (processes) at once, and reports back the total bandwidth achieved for bulk I/O operations. It can be configured in various ways, but we are looking at relatively large read and write sizes to investigate filesystem performance.

Currently the batch script is setup to run on two nodes, but you can vary this to investigate how well both filesystems scale. The total number of nodes available is 8, and each has 32 cores, so the most you would be able to run is 256 MPI processes.

We only have DAOS configured to provide a filesystem interface at the moment (through a FUSE mount called `dfuse`), Ceph has to be accessed by the librados library for IOR. For this initial exercise simply run the `daos_filesystem_ior.sh` batch file provided using varying number of nodes from 2 to 8 to see what read and write bandwidth you get.

4 DFS IOR

You can also experiment with direct DAOS usage from the IOR benchmark application we have already used in the exercises. It is configured to work both in a direct method (using the DFS IOR interface) as opposed to the FUSE mount that you have run previously.

Then you can run a DFS DAOS IOR benchmark using:

```
sbatch daos_dfs_ior.sh
```

This will run using DFS using 2 nodes, and you can compare with the filesystem performance you saw earlier. You can also compare to the batch script that was used for the FUSE and you will see we no longer require the commands to setup the FUSE mount for I/O, we can simply contact DAOS directly. Explore performance across a range of node counts, what performance do you get?

You can also try exploring different DAOS directory object classes. This is done by adding this parameter to the `ior` run line in your batch script:

```
--dfs.dir_oclass SX
```

Currently this is commented out in the batch script, but you can uncomment it and try various object classes, i.e. S1, S2, S4, and SX. The default (if you do not specify anything it will use S1). How does performance vary?

We also have created a DAOS pool that has not been configured for POSIX access. To use this you should change this line in your batch script:

```
export pool=default-pool
```

to:

```
export pool=libdaos-pool
```

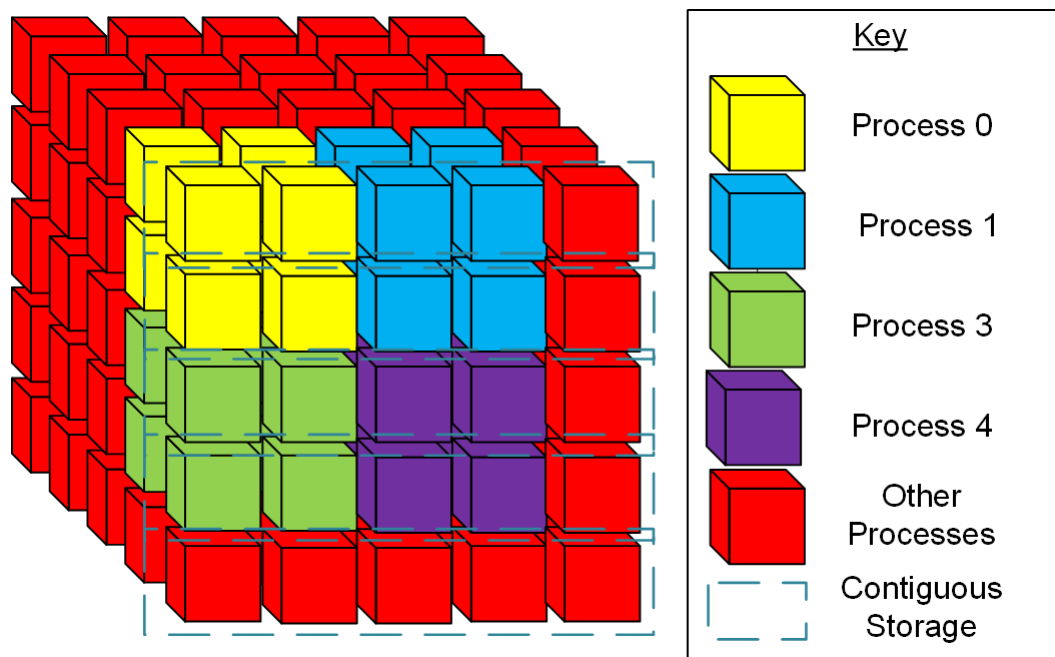
Try re-running your benchmarks with this pool, does it make a difference to the performance?

5 Exploring DAOS

There is a separate exercise sheet/presentation in the GitHub repository for the tutorial, under the `ObjectStoreTutorial/Exercises/DAOS/Handout` directory. You can follow this for the DAOS API practical exercises.

6 Porting an application to object storage technologies

To give you experience of what is required to port a larger application to an object store we have provided you with an application that uses HDF5 to store data to a file. It follows a relatively common pattern for file I/O for large scale parallel applications, i.e. each process has its own portion of a share dataset that it writes to a common file, an example of this is illustrated in this figure:



The question is; how do you map this pattern from a single file to an object store. There are a range of options, from creating a key-value pair (or object) for each element in the array, to creating a single array for all the data shared by all processes. What you actually do depends on how you'd like to be able to index/share/search that data in the future. If you simply need to find the full dataset in the future then you could create a single array, although not all object stores give good performance for a single large array (i.e. Ceph might be limited in how big this array could be). You can also create an array per process, and then indexes that track those to enable searching/using the full dataset. You may also want to create an array/object per row or per column of data, or across some other decomposition that makes sense for your application.

If you know a bit about HDF5 you will be able to see that the current application we have provided uses a hyper-slab approach, which is writing the individual parts of data held by each process into a single shared dataset, ignoring the edges of the data held locally (data used for MPI halos) and ensuring it ends up in a single file.

We have a number of choices when porting this approach to an object store. DAOS supports using an array object, where each process writes their part of the array into the object, ending up with the same situation as

the HDF5 hyperslab, albeit as an object rather than a file. It is possible to do this in Ceph but it is a bit more involved.

Another approach would be to write a single array or object per process, but then create a set of keys or objects that let you identify each part of the data and search/query them. This is possible in both Ceph and DAOS. For this practical we have provided you with three different skeleton files that you can use to implement these approaches, as well as the original HDF5 implementation:

- `hdf5.c`: The original HDF5 file
- `ceph.c`: A file containing the setup code and outline for implementing storage in Ceph
- `daos_individual.c`: The equivalent code and instructions for implementing this using the DAOS api but with an array per process
- `daos_array.c`: Code to do the same but using a single DAOS array for all process.

There are also batch scripts (the files ending in `*.sh`) and a `Makefile` to build them all. Your task is to take one (or more) of the Ceph or DAOS examples and complete the code to get it to write the dataset to the object store(s). The code is commented with what needs to be added (functions and function arguments) and you can build and run them through the Slurm batch system.

This task will involve a bit of reading the code and looking up the function call syntax for the file you have chosen, but you can ask the instructors or email/message us if you have any questions. We will release sample solutions for each of these after the tutorial has finished.

Thanks for attending and we hope it was useful!