Understanding Application I/O Behavior with Darshan

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Argonne National Laboratory

ECP Annual Meeting

April 14, 2021

Argonne NATIONAL LABORATORY 75 1946–2021

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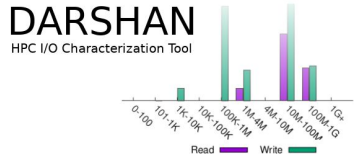
Understanding and improving HPC I/O



- The ability to characterize and understand application I/O workloads is critical to ensuring efficient use of an evolving and increasingly complex HPC I/O stack
  - Deep layers of coordinating I/O libraries and entirely new-to-HPC storage paradigms (e.g., object storage)
  - Emerging storage hardware (e.g., PMEM) and storage architectures (e.g., burst buffers)
- I/O analysis tools are invaluable in helping to navigate this complexity and to better understand I/O
  - Characterize I/O behavior of individual jobs to inform tuning decisions
  - Characterize job populations to better understand system-wide I/O stack usage and optimize deployments

Darshan:
An application I/O characterization tool for HPC

What is Darshan?

- Darshan is a lightweight I/O characterization tool that captures concise views of HPC application I/O behavior
  - Produces a summary of I/O activity for each instrumented job
    - Counters, histograms, timers, & statistics
    - Full I/O traces (if requested)

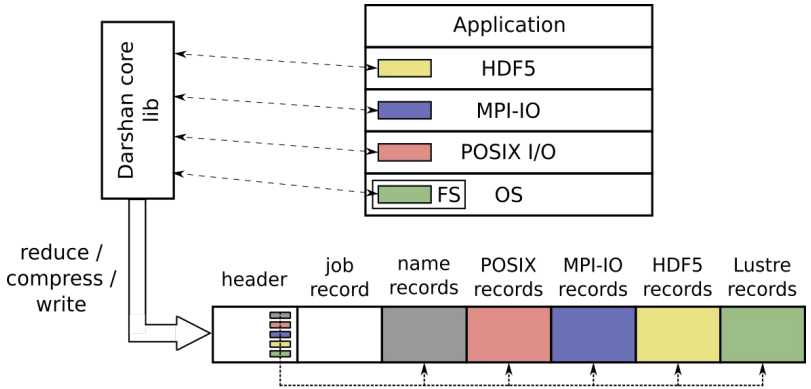
- Widely available
  - Deployed (and commonly enabled by default!) at many HPC facilities around the world
- Easy to use
  - No code changes required to integrate Darshan instrumentation
  - Negligible performance impact; just “leave it on”
- Modular
  - Adding instrumentation for new I/O interfaces or storage components is straightforward

How does Darshan work?

DARSHAN
HPC I/O Characterization Tool

- Darshan can insert application I/O instrumentation at link-time (for static and dynamic executables) or at runtime using LD_PRELOAD (for dynamic executables)
  - Starting in version 3.2.0, Darshan supports instrumentation of any dynamically-linked executable (MPI or not) using the LD_PRELOAD method

- Darshan records file access statistics for each process as app executes
- At app shutdown, collect, aggregate, compress, and write log data
- After job completes, analyze Darshan log data
  - `darshan-job-summary` - provides a summary PDF characterizing application I/O behavior
  - `darshan-parser` - provides complete text-format dump of all counters in a log file
  - *`PyDarshan`* - Python analysis module for Darshan logs

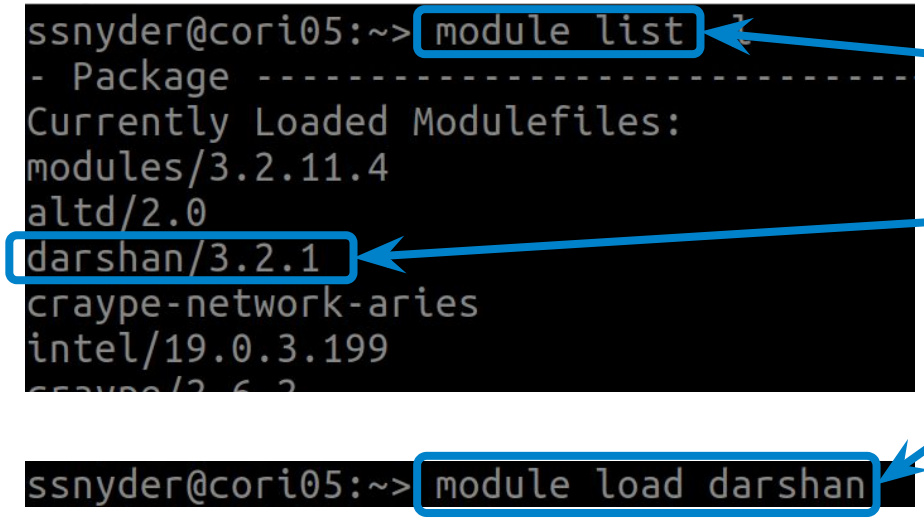


Using Darshan on ECP platforms

Using Darshan on Cori (NERSC)

MPI applications

- Darshan is already installed and on by default on NERSC's Cori system
  - Instrumentation enabled using Cray software module that injects Darshan linker options when compiling MPI applications using Cray compiler wrappers (cc, CC, etc.)



Use '**`module list`**' to confirm Darshan is actually loaded

Darshan 3.2.1 current default version available on Cori

If Darshan not loaded, you can always load manually using '**`module load`**'

Using Darshan on Cori (NERSC)

HDF5 applications

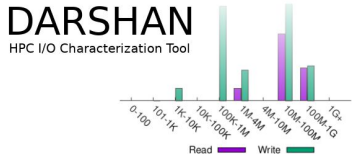
- Note that in addition to the default darshan/3.2.1 module, there is a special darshan/3.2.1-hdf5 that enables instrumentation of HDF5 APIs*
  - Offered as a separate module to prevent non-HDF5 applications from inheriting Darshan's HDF5 library dependency

```
ssnyder@cori07:~> module avail -l 2>&1 | grep darshan | cat
darshan/3.1.7                                          2021/03/03
darshan/3.1.7-test                                     2021/03/03
darshan/3.2.1                                 default  2021/03/03
darshan/3.2.1-hdf5                                     2021/03/03
ssnyder@cori07:~>
ssnyder@cori07:~> module switch darshan/3.2.1 darshan/3.2.1-hdf5
```

Use '**`module switch`**' to switch to the non-default Darshan module built with HDF5 support

***More details to follow shortly**

Using Darshan on Cori (NERSC)



- OK, Darshan is loaded...now what?
  - Just compile and run your application!
  - Darshan inserts instrumentation directly into executable
- LD_PRELOAD is another option for dynamically-linked executables:
  - This method is necessary for Python environments (i.e., mpi4py, h5py)
  - Also helpful for applications that cannot be recompiled

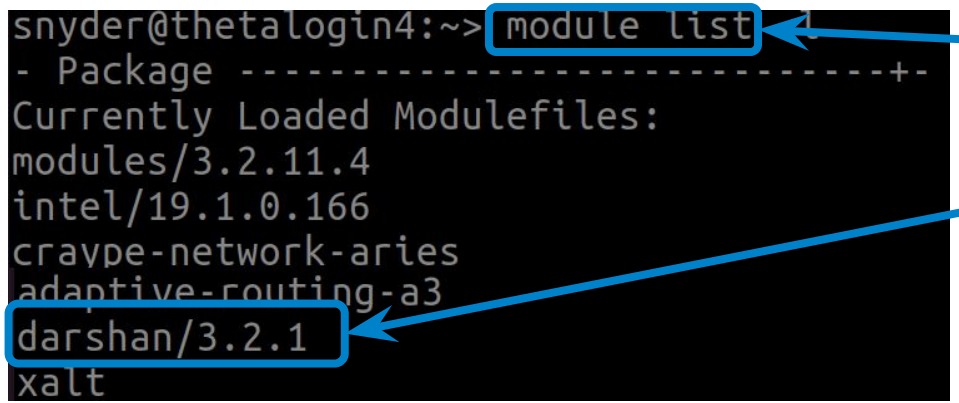
```
ssnyder@nid00010:/global/cscratch1/sd/ssnyder/darshan-test> module show darshan
-------------------------------------------------------------------
/global/common/software/nersc/cle7/extra_modulefiles/darshan/3.2.1:

module-whatis    a scalable HPC I/O characterization tool
prepend-path     PE_PKGCONFIG_LIBS darshan-runtime
prepend-path     PKG_CONFIG_PATH /usr/common/software/darshan/3.2.1/lib/pkgconfig
prepend-path     LD_LIBRARY_PATH /usr/common/software/darshan/3.2.1/lib
prepend-path     PATH /usr/common/software/darshan/3.2.1/bin
-------------------------------------------------------------------

ssnyder@nid00010:/global/cscratch1/sd/ssnyder/darshan-test> export LD_PRELOAD=/usr
/common/software/darshan/3.2.1/lib/libdarshan.so
```

Manually set LD_PRELOAD to point to Darshan's shared library before running your application

Using Darshan on Theta (ALCF)

MPI applications

- Darshan is also installed and enabled by default on ALCF's Theta system, another Cray XC40 system
  - The process for using Darshan is exactly the same as Cori, even though Theta uses static linking by default (compared to dynamic linking on Cori) -- Cray compiler wrappers handle this transparently



Use '**`module list`**' to confirm Darshan is actually loaded

Darshan 3.2.1 current default version available on Theta

Note: Theta does not currently offer a Darshan+HDF5 install, though we hope to have one available soon

Using Darshan on Summit (OLCF)

MPI applications

- Summit is an IBM Power9-based system that uses dynamic linking by default
  - LD_PRELOAD mechanism used to interpose Darshan instrumentation libraries at runtime
  - Like Cori/Theta, software modules used to enable Darshan instrumentation

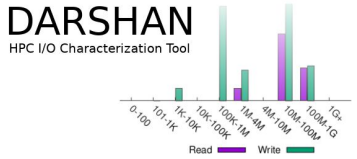
```
[ssnyder@login3.summit ~]$ module list

Currently Loaded Modules:
  1) xl/16.1.1-3                          4) xalt/1.1.4
  2) spectrum-mpi/10.3.0.1-20190611       5) lsf-tools/2.0
  3) hsi/5.0.2.p5                         6) darshan-runtime/3.1.7



[ssnyder@login3.summit ~]$
```

Summit also provides '**`module list`**' command

Darshan 3.1.7 is the default version on Summit.

Note: darshan-runtime and darshan-util are separate modules, with only darshan-runtime loaded by default

Finding Darshan log files



- After the application terminates, look for your log files:

Darshan logs typically stored in a central directory for all users for system-wide deployments, use '**`darshan-config --log-path`**' to find

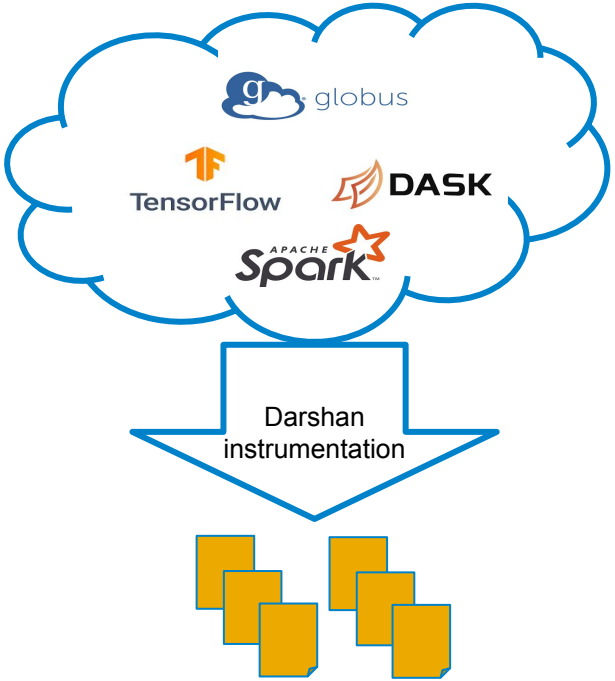
```
ssnyder@cori01:~> darshan-config --log-path
/global/cscratch1/sd/darshanlogs
ssnyder@cori01:~> cd /global/cscratch1/sd/darshanlogs
ssnyder@cori01:/global/cscratch1/sd/darshanlogs>
ssnyder@cori01:/global/cscratch1/sd/darshanlogs> cd 2021/3/4
ssnyder@cori01:/global/cscratch1/sd/darshanlogs/2021/3/4> ls | grep snyder | cat
ssnyder_mpi-io-test_id40245367_3-4-50083-3517743081787486417_1614894884.darshan
```

Logs further indexed using '*year/month/day*' the job executed.

Log file name starts with the following pattern: '*username_exename_jobid*…'

Using Darshan with non-MPI applications

- Starting in version 3.2.0, Darshan supports instrumentation of non-MPI applications using LD_PRELOAD (i.e., dynamically-linked binaries)
  - Users must additionally export '**`DARSHAN_ENABLE_NONMPI=1`**' to enable Darshan in this case
- **Note**: due to a bug in version 3.2.1, the previously mentioned Darshan deployments do not support this feature currently
  - Users can manually install a non-MPI version for now (e.g., '**`spack install darshan-runtime~mpi`**' and '**`spack install darshan-util`**')
  - Spack-installed Darshan versions put log files in HOME by default -- override using DARSHAN_LOG_DIR_PATH env variable



Analyzing Darshan logs

Analyzing Darshan logs

- After generating and locating your log, use Darshan analysis tools to inspect log file data:

```
ssnyder@cori07:.../4> cp ssnyder_mpi-io-test_id40245367_3-4-50083-35177430817874
86417_1614894884.darshan ~/tmp-analysis/
ssnyder@cori07:.../4> cd ~/tmp-analysis/
ssnyder@cori07:~/tmp-analysis> darshan-parser ssnyder_mpi-io-test_id40245367_3-4
-50083-3517743081787486417_1614894884.darshan
```

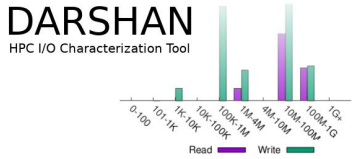
Copy the log file somewhere else for analysis

Invoke `darshan-parser` (already in PATH on Cori) to get detailed counters

```
#<module>       <rank>  <record id>      <counter>       <value> <file name>
POSIX   -1      4212256932904785913     POSIX_OPENS     16      /global/csc
POSIX   -1      4212256932904785913     POSIX_FILENOS   0       /global/csc
POSIX   -1      4212256932904785913     POSIX_DUPS      0       /global/csc
POSIX   -1      4212256932904785913     POSIX_READS     4       /global/csc

MPI-IO  -1      4212256932904785913     MPIIO_INDEP_OPENS       8       /glo
MPI-IO  -1      4212256932904785913     MPIIO_COLL_OPENS        0       /glo
MPI-IO  -1      4212256932904785913     MPIIO_INDEP_READS       4       /glo
MPI-IO  -1      4212256932904785913     MPIIO_INDEP_WRITES      4       /glo
```

Modules use a common format for printing counters, indicating the module, rank, record ID, counter name, counter value, filename, etc. -- here sample counters are shown for both POSIX and MPI-IO modules

Analyzing Darshan logs



- But, `darshan-parser` output isn't so accessible for most users… use `darshan-job-summary` tool to produce summary PDF of app I/O behavior
  - Due to LaTeX and Perl dependencies, it may be easier just to copy Darshan logs to a personal workstation for analysis

Invoke `darshan-job-summary` on log file to produce PDF

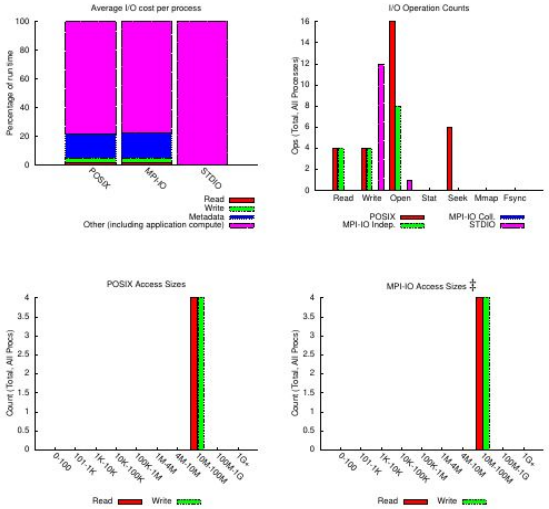
```
shane@shane-x1-carbon ~/tmp-analysis $ darshan-job-summary.pl ssnyder_mpi-io-test_i
d40245367_3-4-50083-3517743081787486417_1614894884.darshan
shane@shane-x1-carbon ~/tmp-analysis $
shane@shane-x1-carbon ~/tmp-analysis $ ls
ssnyder_mpi-io-test_id40245367_3-4-50083-3517743081787486417_1614894884.darshan
ssnyder_mpi-io-test_id40245367_3-4-50083-3517743081787486417_1614894884.darshan.pdf
```

Output PDF file name based on Darshan log file name

Analyzing Darshan logs

jobid: 403177	uid: 31074	nprocs: 4	runtime: 2 seconds

I/O performance *estimate* (at the MPI-IO layer): transferred 642 MiB at 266.40 MiB/s
I/O performance *estimate* (at the STDIO layer): transferred 0.0 MiB at 2.08 MiB/s



Most Common Access Sizes
(POSIX or MPI-IO)

	access size	count
POSIX	16777216	8
MPI-IO ‡	16777216	8

‡ NOTE: MPI-IO accesses are given in terms of aggregate datatype size.

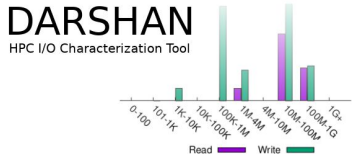
File Count Summary
(estimated by POSIX I/O access offsets)

type	number of files	avg. size	max size
total opened	2	33M	64M
read-only files	0	0	0
write-only files	1	642	642
read/write files	1	64M	64M
created files	2	33M	64M

Result is a multi-page PDF containing graphs, tables, and performance estimates characterizing the I/O workload of the application

We will summarize some of the highlights in the following slides

Analyzing Darshan logs



PDF header contains some high-level information on the job execution

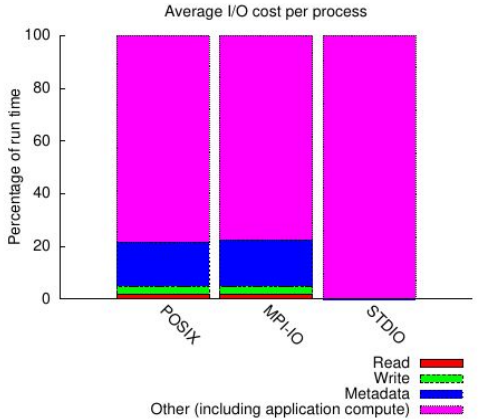
jobid: 403177	uid: 31074	nprocs: 4	runtime: 2 seconds

I/O performance *estimate* (at the MPI-IO layer): transferred 642 MiB at 266.40 MiB/s
I/O performance *estimate* (at the STDIO layer): transferred 0.0 MiB at 2.08 MiB/s

I/O performance estimates (and total I/O volumes) provided for MPI-IO/POSIX and STDIO interfaces

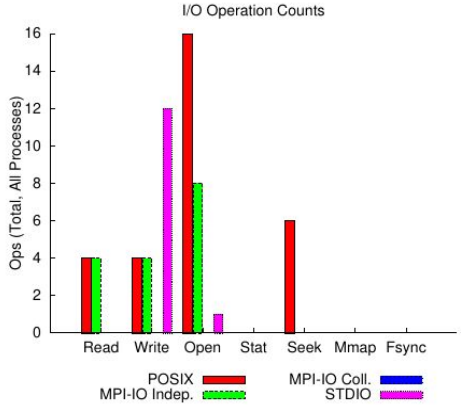
Analyzing Darshan logs

DARSHAN
HPC I/O Characterization Tool



Across main I/O interfaces, how much time was spent reading, writing, doing metadata, or computing?

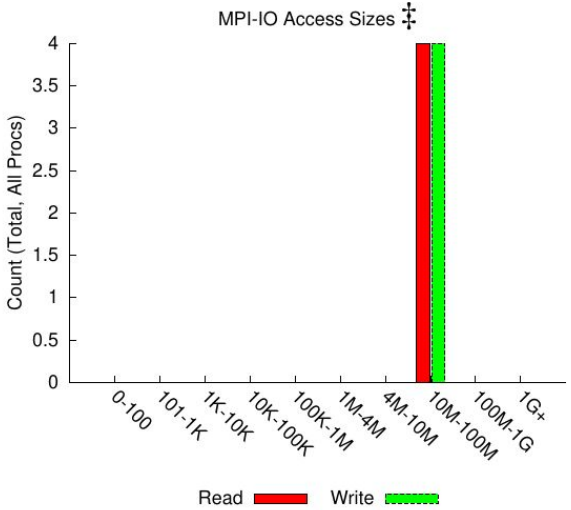
If mostly compute, limited opportunities for I/O tuning



What were the relative totals of different I/O operations across key interfaces?

Lots of metadata operations (open, stat, seek, etc.) could be a sign of poorly performing I/O

Analyzing Darshan logs



Histograms of POSIX and MPI-IO access sizes are provided to better understand general access patterns

In general, larger access sizes perform better with most storage systems

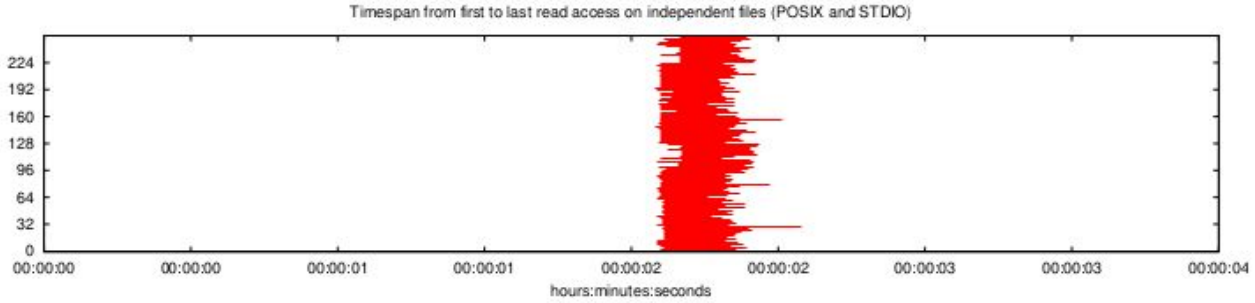
File Count Summary
(estimated by POSIX I/O access offsets)

type	number of files	avg. size	max size
total opened	2	33M	64M
read-only files	0	0	0
write-only files	1	642	642
read/write files	1	64M	64M
created files	2	33M	64M

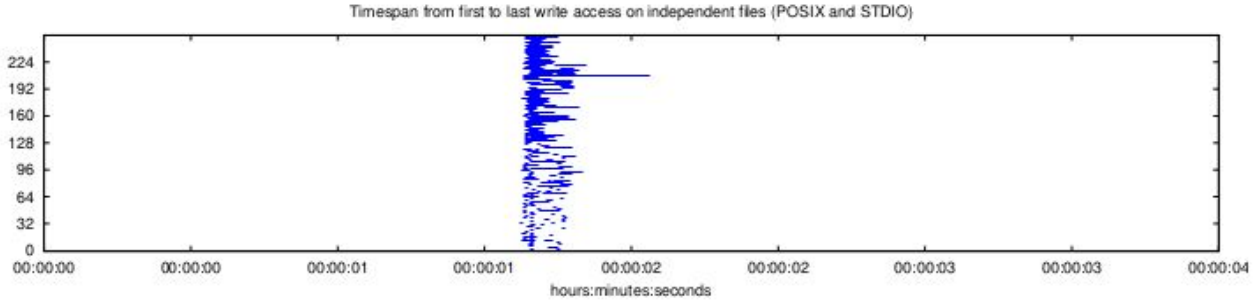
Table indicating total number of files of different types (opened, created, read-only, etc.) recorded by Darshan

Analyzing Darshan logs

reads



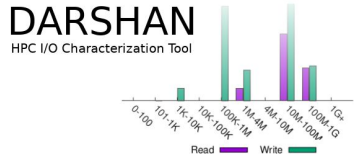
writes



Darshan can also provide basic timing bounds for read/write activity, both for independent file access patterns (illustrated) or for shared file access patterns

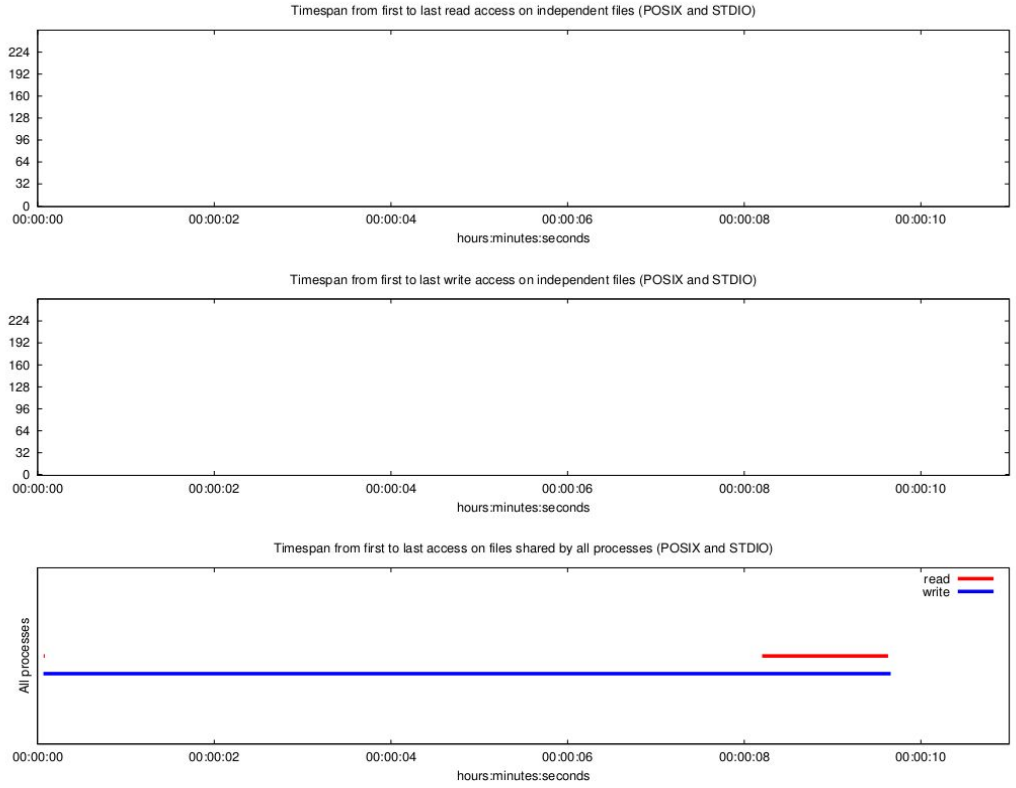
Obtaining finer-grained details with Darshan

Focusing analysis on individual files



- If we want to focus Darshan analysis tools on a specific file, Darshan offers a couple of different options
  - `darshan-convert` utility can be used to create a new Darshan log file containing a specified file record ID (obtainable from *darshan-parser* output)
    - e.g., ‘darshan-convert --file RECORD_ID input_log.darshan output_log.darshan’
    - New log file can be ran through existing log utilities we have already covered
  - `darshan-summary-per-file` tool can be used to generate separate job summary PDFs for every file in a given Darshan log
    - Do not use if your application opens a lot of files!

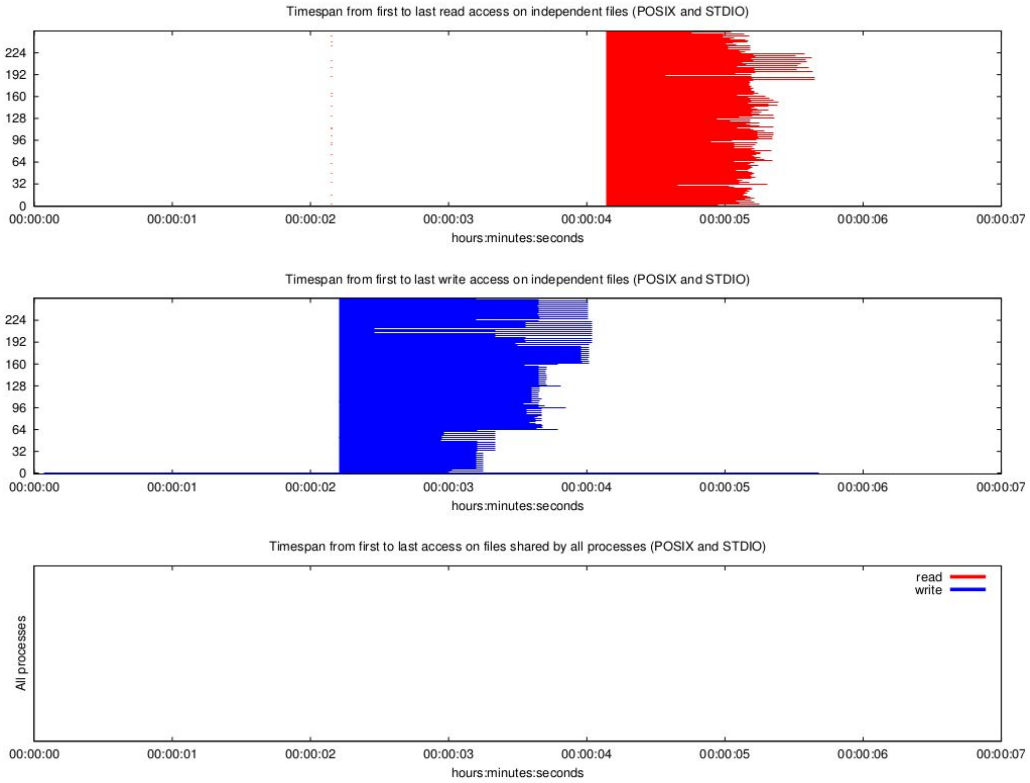
Disabling reductions of shared records



You may notice that Darshan is unable to provide more detailed access information for shared file workloads, as illustrated here

For shared files, information from each rank is combined into a single record to save space

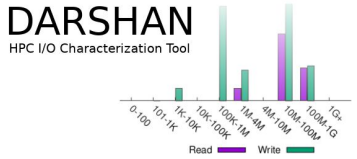
Disabling reductions of shared records



Setting the ‘DARSHAN_DISABLE_SHARED_REDUCTION’ environment variable will force Darshan to skip the shared file reduction step, retaining each process’s independent view of access information

This results in larger log files, but may be useful in better understanding underlying access patterns in collective workloads

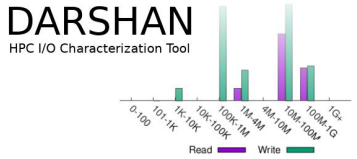
Obtaining fine-grained traces with DXT



- Darshan's DXT module can be enabled at runtime for users wishing to capture detailed I/O traces for MPI-IO and POSIX interfaces
  - Fine-grained trace data comes at cost of larger per-process memory overheads
  - Set the `DXT_ENABLE_IO_TRACE` environment variable to enable
- `darshan-dxt-parser` can be then be used to dump text-format trace data:

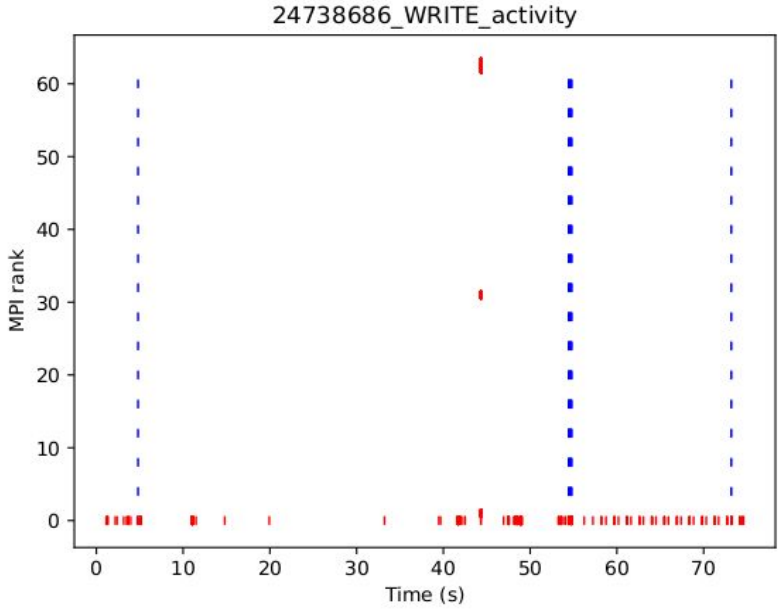
```
# ************************************************
# DXT_POSIX module data
# ************************************************

# DXT, file_id: 11542722479531699073, file_name: /global/cscratch1/sd/pcarns/ior/ior.dat
# DXT, rank: 0, hostname: nid00511
# DXT, write_count: 16, read_count: 16
# DXT, mnt_pt: /global/cscratch1, fs_type: lustre
# DXT, Lustre stripe_size: 1048576, Lustre stripe_count: 24
# DXT, Lustre OST obdidx: 49 185 115 7 135 3 57 95 43 27 191 1 163 51 15 153 187 55 151 239 79
25 137 47
# Module    Rank  Wt/Rd  Segment          Offset       Length    Start(s)      End(s)  [OST]
 X_POSIX       0  write        0               0      1048576      0.7895      0.8267  [ 49]
 X_POSIX       0  write        1         1048576      1048576      0.8267      0.9843  [185]
 X_POSIX       0  write        2         2097152      1048576      0.9843      1.0189  [115]
```

Obtaining fine-grained traces with DXT



- `dxt_analyzer` Python script installed with darshan-util can be used to help visualize read/write trace activity:

Provides details on each I/O operation issued by each rank, providing a complete picture of which ranks are performing I/O and how long they are spending on I/O



New and upcoming Darshan features: HDF5 instrumentation

HDF5 instrumentation

Available in Darshan 3.2.0+

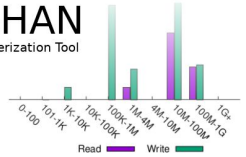
- HDF5 offers a convenient abstraction for large data collections, but it can be difficult to understand how it interacts with lower layers of the I/O stack that most impact performance

- To help better understand HDF5 usage and performance, we have developed Darshan instrumentation modules for HDF5 file (H5F) and dataset (H5D) APIs
  - What are file and dataset properties?
  - How are datasets accessed?
  - How are datasets organized within files?
  - Do HDF5 accesses decompose efficiently to lower-level (i.e., MPI-IO and POSIX) accesses? If not, do any optimizations make sense?

HDF5 instrumentation

Available in Darshan 3.2.0+

DARSHAN
HPC I/O Characterization Tool



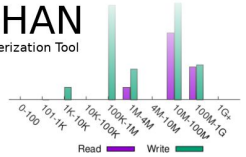
- H5F instrumentation highlights:
  - Operation counts
    - open/create
    - flush
  - MPI-IO usage
  - Metadata timing

```
#<module>   <rank>  <record id> <counter>   <value> <file na
H5F -1  11831850109748558379    H5F_OPENS   8   /home/shane/
H5F -1  11831850109748558379    H5F_FLUSHES 0   /home/shane/
H5F -1  11831850109748558379    H5F_USE_MPIIO   1   /home/sh
H5F -1  11831850109748558379    H5F_F_OPEN_START_TIMESTAMP
H5F -1  11831850109748558379    H5F_F_CLOSE_START_TIMESTAMP
H5F -1  11831850109748558379    H5F_F_OPEN_END_TIMESTAMP
H5F -1  11831850109748558379    H5F_F_CLOSE_END_TIMESTAMP
H5F -1  11831850109748558379    H5F_F_META_TIME 0.019466
```

HDF5 instrumentation

Available in Darshan 3.2.0+

DARSHAN
HPC I/O Characterization Tool



- H5D instrumentation highlights:
  - Operation counts:
    - open/create
    - read/write
    - flush
  - Total bytes read/written
  - Access size histograms
  - Dataspace selection types
    - Regular hyperslab
    - Irregular hyperslab
    - Points
  - Dataspace total dimensions, points
  - Chunking parameters
  - MPI-IO collective usage
  - Deprecated function usage
  - Read, write, and metadata timing

```
#<module>   <rank>  <record id> <counter>   <value>
H5D -1  7600138186531619366 H5D_OPENS   8   /home/sh
H5D -1  7600138186531619366 H5D_READS   16  /home/sh
H5D -1  7600138186531619366 H5D_WRITES  16  /home/sh
H5D -1  7600138186531619366 H5D_FLUSHES 0   /home/sh
H5D -1  7600138186531619366 H5D_BYTES_READ  4194304
H5D -1  7600138186531619366 H5D_BYTES_WRITTEN   4194
H5D -1  7600138186531619366 H5D_RW_SWITCHES 4   /hom
H5D -1  7600138186531619366 H5D_REGULAR_HYPERSLAB_SE
xt4
H5D -1  7600138186531619366 H5D_IRREGULAR_HYPERSLAB_
xt4
H5D -1  7600138186531619366 H5D_POINT_SELECTS   0
H5D -1  7600138186531619366 H5D_MAX_READ_TIME_SIZE
H5D -1  7600138186531619366 H5D_MAX_WRITE_TIME_SIZE
H5D -1  7600138186531619366 H5D_SIZE_READ_AGG_0_100
```

HDF5 instrumentation

Available in Darshan 3.2.0+

DARSHAN
HPC I/O Characterization Tool

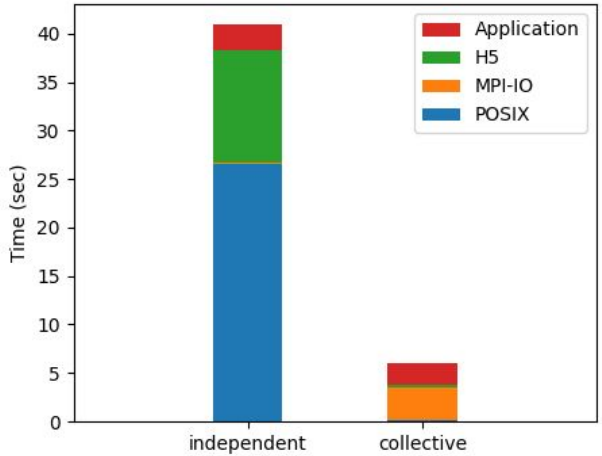
- Using the MACSio[1] HDF5 plugin, run a couple of simple examples demonstrating the types of insights HDF5 I/O instrumentation can enable
  - 60-process (5-node) single shared file, 3d mesh, write roughly 1 GiB of cumulative H5D data
  - Compare performance of collective and independent I/O configurations

b/w: **~30 MB/sec**

POSIX I/O dominates, **H5** incurs non-negligible overhead forming this workload

Negligible time spent in **MPI-IO**

Average per-process time spent in I/O



b/w: **~290 MB/sec**

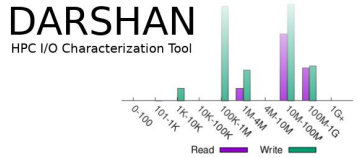
H5 and **POSIX** incur minimal overhead for this workload

MPI-IO collective I/O algorithm dominates

1. https://github.com/LLNL/MACSio

HDF5 instrumentation

Available in Darshan 3.2.0+



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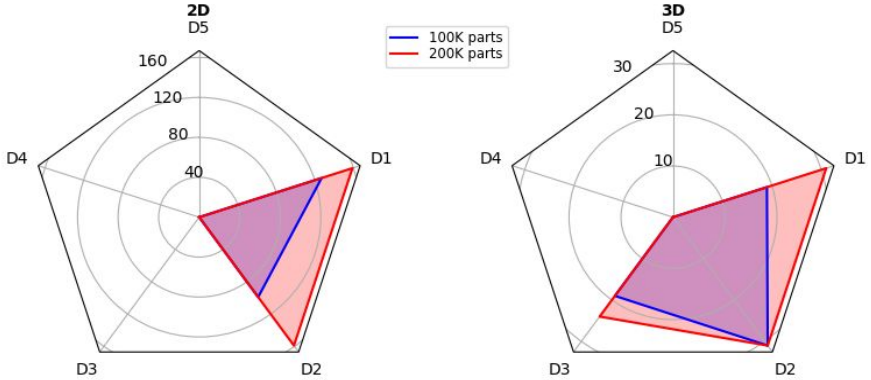


Number of elements accessed in each dataset dimension for the most common access for each MACSio configuration

Radar plots, or other methods, can be used to help visualize characteristics of HDF5 dataset accesses

Dataset access patterns could be used to help set/optimize chunking parameters to limit accesses to as few chunks as possible

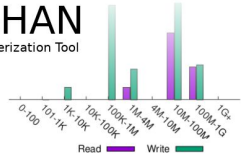
1. https://github.com/LLNL/MACSio

New and upcoming Darshan features: DAOS instrumentation

DAOS instrumentation

Work in progress

DARSHAN
HPC I/O Characterization Tool



- Intel's DAOS offers an exciting new storage paradigm for HPC apps, utilizing object-based storage interfaces over a combo of SCM and SSD devices
  - libdfs: DAOS's POSIX file system emulation API
  - libdaos: DAOS's native object (key-val) API
- Darshan will instrument libdaos and libdfs APIs to help provide insight into application and I/O middleware usage of DAOS
  - Legacy POSIX app usage and performance characteristics
  - Usage and performance characteristics of libdaos users (libdfs, HDF5 VOL, MPI-IO, etc.)

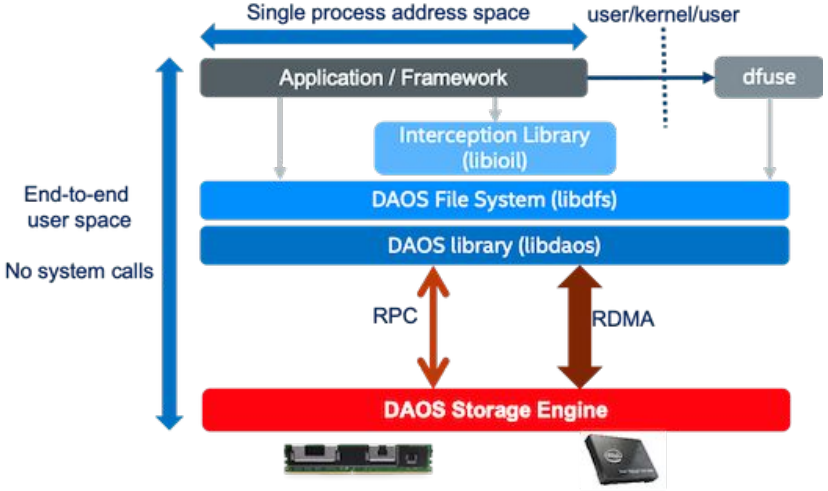


Figure courtesy of Intel

DAOS instrumentation

Work in progress

- libdfs instrumentation highlights:
  - Operation counts:
    - open
    - read/write
    - punch
    - stat
  - Total bytes read/written
  - Access size histograms
  - File chunk size
  - DTX usage (strict consistency mode)
  - Corresponding DAOS object record ID
    - Necessary to link Darshan's DFS records with native DAOS records
  - Read, write, and metadata timing

```
#<module>   <rank>  <record id> <counter>   <value>
DFS 0   8492698188889325809 DFS_OPENS   0   c3bcfc9a
DFS 0   8492698188889325809 DFS_GLOBAL_OPENS    0
DFS 0   8492698188889325809 DFS_LOOKUPS 1   c3bcfc9a
DFS 0   8492698188889325809 DFS_DUPS    0   c3bcfc9a
DFS 0   8492698188889325809 DFS_READS   0   c3bcfc9a
DFS 0   8492698188889325809 DFS_READXS  0   c3bcfc9a
DFS 0   8492698188889325809 DFS_WRITES  0   c3bcfc9a
DFS 0   8492698188889325809 DFS_WRITEXS 0   c3bcfc9a
DFS 0   8492698188889325809 DFS_NB_READS    0   c3bc
DFS 0   8492698188889325809 DFS_NB_WRITES   0   c3bc
DFS 0   8492698188889325809 DFS_GET_SIZES   0   c3bc
DFS 0   8492698188889325809 DFS_PUNCHES 0   c3bcfc9a
```

Note: Unsurprisingly, Darshan's DFS instrumentation module closely follows the design of the POSIX module

DAOS instrumentation

Work in progress

- libdaos instrumentation highlights:
  - Operation counts:
    - open
    - fetch (read) and update (write)
    - list (enumeration)
    - punch
  - Total bytes read/written
  - Access size histograms
  - Object class parameters
    - layout (static or dynamic striping)
    - redundancy (replication, erasure coding)
  - Container/pool UUIDs
  - Read, write, and metadata timing

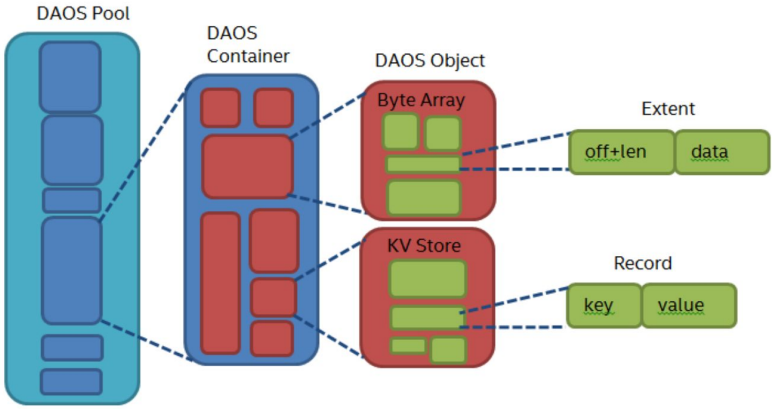


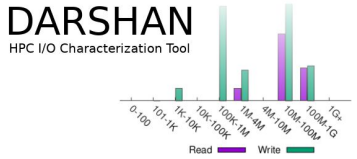
Figure courtesy of Intel

Note: Each DAOS object is multi-level key-val store, creating challenges for deciding what can be instrumented using a fixed set of Darshan counters -- we are still investigating what characteristics about key access patterns to capture

New and upcoming Darshan features: PyDarshan

PyDarshan log file analysis

Available for Darshan 3.3.0 (coming soon!)



- Darshan has traditionally offered only the C-based darshan-util library and a handful of corresponding utilities to users
  - Development of custom Darshan analysis utilities is cumbersome, requiring users to either:
    - Develop analysis tools in C using the low-level darshan-util library
    - Perform an inconvenient conversion from `darshan-parser` text output
- PyDarshan has been developed* to simplify the interfacing of analysis tools with Darshan log data
  - Use Python CFFI module to provide Python bindings to the native darshan-utils C API
  - Expose Darshan log data as dictionaries, pandas dataframes, and numpy arrays
- We are hopeful PyDarshan will lead to a richer ecosystem for Darshan log analysis utilities

* Thanks to **Jakob Luettgau (DKRZ)** for contributing most of the PyDarshan code, examples, and documentation

PyDarshan log file analysis

Available for Darshan 3.3.0 (coming soon!)

- We've already found Jupyter notebooks to be an effective way of sharing PyDarshan analysis examples (code, documentation, visualizations) with users, collaborators, etc.

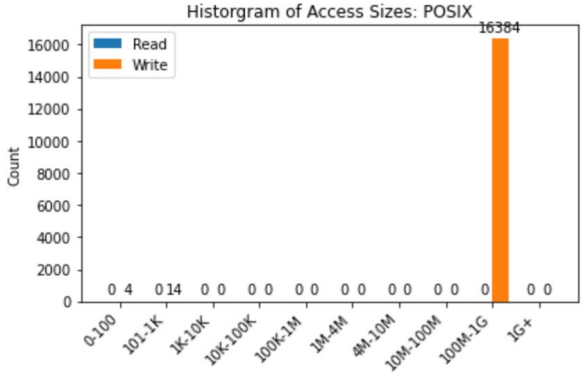
```
In [1]: import darshan

        report = darshan.DarshanReport("example-logs/example.darshan", read_all=True)  # Default
        report.info()
```

```
Filename:       example-logs/example.darshan
Times:          2017-03-20 04:07:47 to 2017-03-20 04:09:43 (Duration 0:01:56)
Executeable:    /global/project/projectdirs/m888/glock/tokio-abc-results/bin.edison/vpici
rs/glock/tokioabc-s.4478544/vpicio/vpicio.hdf5 32
Processes:      2048
JobID:          4478544
UID:            69615
Modules in Log: ['POSIX', 'MPI-IO', 'LUSTRE', 'STDIO']
Loaded Records: {'POSIX': 1, 'MPI-IO': 1, 'STDIO': 1, 'LUSTRE': 1}
Name Records:   4
Darshan/Hints:  {'lib_ver': '3.1.3', 'h': 'romio_no_indep_rw=true;cb_nodes=4'}
DarshanReport:  id(140124449925824) (tmp)
```

```
In [3]: # access histograms
        plt = plot_access_histogram(report, 'POSIX')
        plt.show()
```

```
Summarizing... iohist POSIX
```

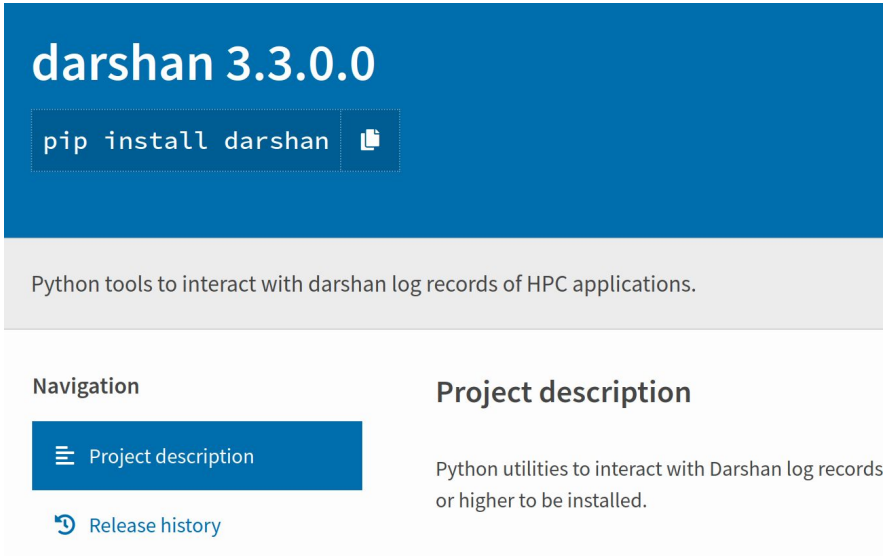


In just a few lines of code, users can read a Darshan log into memory and generate plots describing access patterns

PyDarshan log file analysis

Available for Darshan 3.3.0 (coming soon!)

- The first stable version (3.3.0.0) of PyDarshan is currently available and ready for users to analyze Darshan logs with
  - Use '**`pip install darshan`**' to install the PyDarshan module from PyPI on your system
  - Alternatively, PyDarshan can be installed directly from the Darshan source, by running '**`python3 setup.py install --user`**' from the 'darshan-util/pydarshan' directory

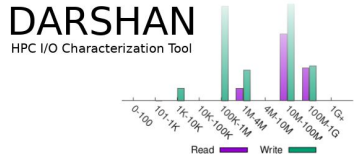


https://pypi.org/project/darshan/

Darshan roadmap

- In addition to those covered today, the following features are also on the Darshan roadmap:
  - Autoperf instrumentation module (available in Darshan 3.3.0)
    - APMPI - MPI communication counters
    - CrayXC - compute and network counters for Cray XC systems
    - Thanks to **Sudheer Chunduri (ALCF)** for this contribution!
  - PnetCDF instrumentation module (work in progress)
    - Full instrumentation of PnetCDF blocking/nonblocking APIs
    - Thanks to **Claire Lee (NWU)** and **Wei-keng Liao (NWU)** for this contribution!
  - Fork handlers for non-MPI mode (work in progress, available in ‘dev-fork-safe’ branch)
    - Numerous updates to allow forked processes to generate their own Darshan logs
  - Enhanced analysis tools and report generation (???)
    - Building off of our pydarshan log utility bindings, we want to revamp our analysis tools and report generation using Python

Wrapping up



- We've covered a lot of ground today, but hopefully there was helpful information for new Darshan users and experienced Darshan users alike
- Come to our breakout session tomorrow (**“Interpreting Darshan Logs”**, 2:30-3:30 PM EST) to learn more about how to best interpret Darshan log data to gain meaningful insight into I/O behavior
  - Feel free to provide us logs you would like to see analyzed (or even job IDs on one of the systems we’ve covered), but we also have our own interesting examples we can share if nothing else
- Please reach out with any questions, comments, or feedback!

- Darshan website: https://www.mcs.anl.gov/research/projects/darshan/
- Darshan-users mailing list: darshan-users@lists.mcs.anl.gov
- Source code, issue tracking: https://xgitlab.cels.anl.gov/darshan/darshan

This research was supported by the Exascale Computing Project (17-SC-20-SC), a joint project of the U.S. Department of Energy's Office of Science and National Nuclear Security Administration, responsible for delivering a capable exascale ecosystem, including software, applications, and hardware technology, to support the nation's exascale computing imperative.