ATPESC 2016

Argonne NATIONAL LABORATORY

FUTURE OF I/O

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St. Charles IL

THE CHANGING LANDSCAPE OF COMPUTER SCIENCE

- Software tools are evolving to support new applications and new data-intensive methodologies:
  - In situ analysis
  - Workflows
  - Advanced programming models
- … and the systems themselves are undergoing key revolutions, particularly in storage technology

  - Notable architectural features on Aurora (2019):
    - On-node persistent memory (NVRAM)
    - Burst buffers
    - Omnipath network with silicon photonics

UPDATING I/O LIBRARIES

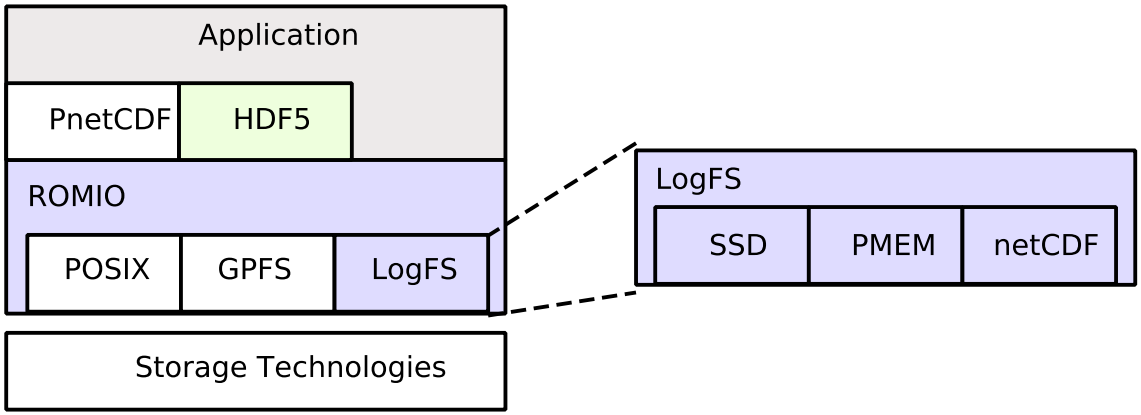
EVOLVING PARALLEL I/O LIBRARIES

- An assortment of libraries are widely adopted already to help translate data models to storage
  - We've talked about MPI-IO, Parallel NetCDF, and HDF5 today
  - The APIs and data models that they present will be continue to be critical on future systems
  - So how do we adapt?

EVOLVING PARALLEL I/O LIBRARIES

Future enhancements

- New collective algorithms and optimizations that take into account the new realities of HPC architectures (e.g., low latency, local or semi-local storage)



- Intermediate storage locations offer a convenient staging area for alternative file formats:
  - Optimize for ingest when writing data, reorganize for analysis when transferring to longer-term storage
- Compression
  - Depends on the application use case, but we have a new opportunity for data transforms in the I/O path

NEW DATA SERVICES

BEYOND PARALLEL FILE SYSTEMS

How will storage software change in the future?

- How exactly are we going to use the various levels of storage available in upcoming systems?
- Observation: successful HPC applications are composed of software components that provide only the communication, concurrency, and synchronization needed for the task at hand.
- Why not storage services too? It doesn't have to be a one-size-fits all global file system for all purposes.

*The community is exploring **software defined storage** principles to provide more specialized, composable storage services for key applications.*

Specialized data services are already here!

ADLB *Data store and pub/sub.*	MPI ranks	MPI	RAM	N/A	N/A
DataSpaces *Data store and pub/sub.*	Indep. job	Dart	RAM (SSD)	Under devel.	N/A
DataWarp *Burst Buffer mgmt.*	Admin./ sched.	DVS/ Inet	XFS, SSD	Ext. monitor	Kernel, Inet
FTI *Checkpoint/restart mgmt.*	MPI ranks	MPI	RAM, SSD	N/A	N/A
Kelpie *Dist. in-mem. key/val store*	MPI ranks	Nessie	RAM (Object)	N/A	Obfusc. IDs
SPINDLE *Exec. and library mgmt.*	Launch MON	TCP	RAMdisk	N/A	Shared secret

COMPOSING HPC STORAGE SERVICES

- Vision: Specialized HPC storage services composed from building blocks that provide required data abstractions, communication, synchronization, resilience, access control, etc.
  - Match service to science requirements and technology available
  - Scope of coherence, etc. constrained to application(s) using service
  - Extend, not replace, the existing storage ecosystem
  - Don't pay for resilience or durability until you need it
- Approach: Lightweight, user-space services that can be quickly instantiated and torn down in response to application needs
- These "micro" services can also be developed and experimentally evaluated more quickly

- The above concept is being pursued by a collaborative effort between Argonne National Laboratory, Carnegie Mellon University, the HDF Group, and Los Alamos National Laboratory

SDS: STATUS AND USE CASES

- Identifying initial use cases
- Assembling building blocks
- Building prototypes

- Not necessarily files and directories, could use objects, key/value pairs, or other constructs

Example use cases:

- Shared, in-system databases
  - Equation of state
  - Opacity
  - Out of core computation
- On-demand metadata service allocation
- Workflow coordination
  - Coupling
  - In-situ
- Analysis
  - Data subsetting
  - Indexing
- Checkpoint/restart

BETTER INSTRUMENTATION

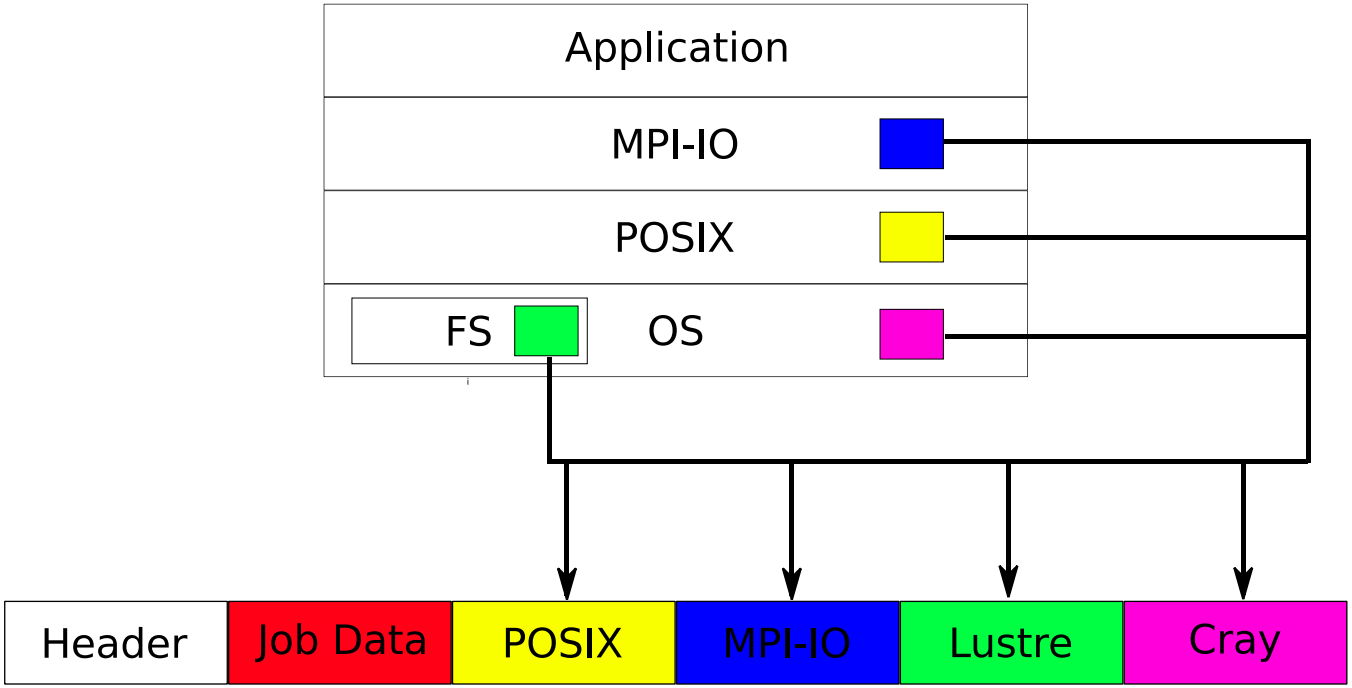
DARSHAN FUTURE: EXPANDING COVERAGE

- Darshan has to track advancements in I/O architectures as well
- Darshan 3.x has been redesigned to enable the addition of new *instrumentation modules*
- Turning Darshan into a more flexible instrumentation platform
- Modules can gather data from a variety of sources
  - I/O libraries (e.g., POSIX, MPI-IO, HDF5, PnetCDF)
  - FS interfaces (e.g., Lustre API)
  - System-specific data (e.g., BG/Q or Cray runtime environment)

- Instrumentation modules are only recognized by Darshan when they are actually activated
  - Darshan assigns memory to modules for storing I/O data
  - Instrumentation module provide callback functions so Darshan can interface with them at shutdown time

DARSHAN FUTURE: EXPANDING COVERAGE

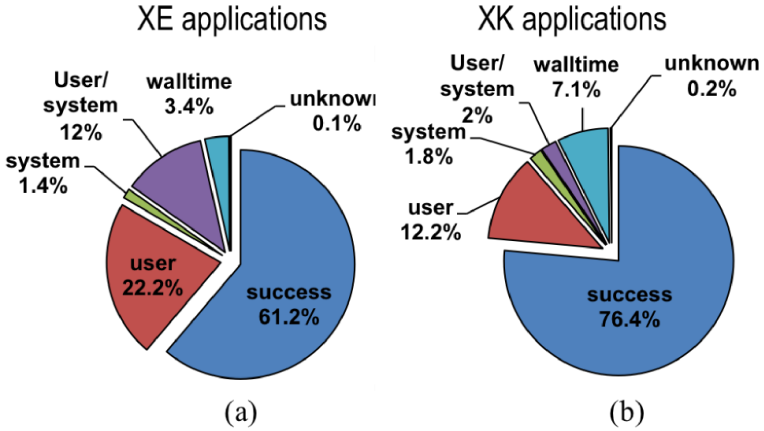
- At shutdown, Darshan:
  - Retrieves I/O data from each module
  - Compresses data
  - Collectively writes data to Darshan log



DARSHAN FUTURE: EXPANDING COVERAGE

- Applications that do not shut down cleanly cause a gap in coverage
  - Darshan's normal shutdown procedure hooks into MPI_Finalize()
  - If you run to the wall clock limit or the application crashes, then Darshan cannot store its data
- We are now developing low-overhead techniques to store ongoing data and retrieve it after application exit

Applications that don't exit cleanly are more common than you might think: example from NCSA.

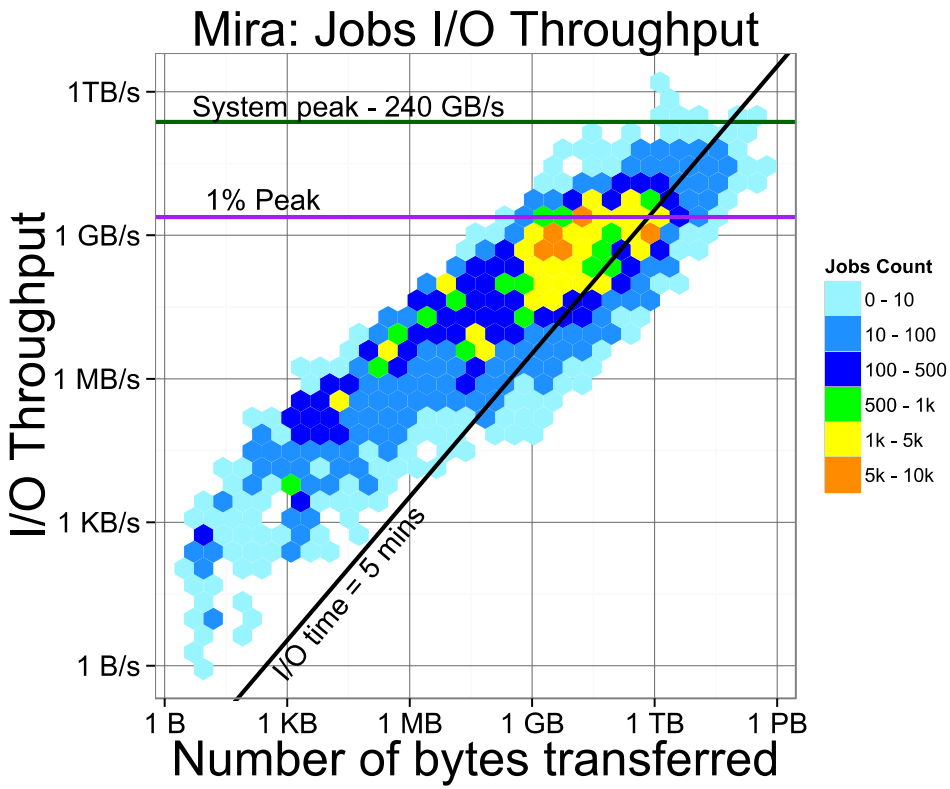


Martino, Catello Di, et al. "LogDiver: A Tool for Measuring Resilience of Extreme-Scale Systems and Applications." Proceedings of the 5th Workshop on Fault Tolerance for HPC at eXtreme Scale. ACM, 2015.

These observations are corroborated by internal metrics at NERSC

DARSHAN FUTURE: DATA MINING AND HOLISTIC I/O CHARACTERIZATION

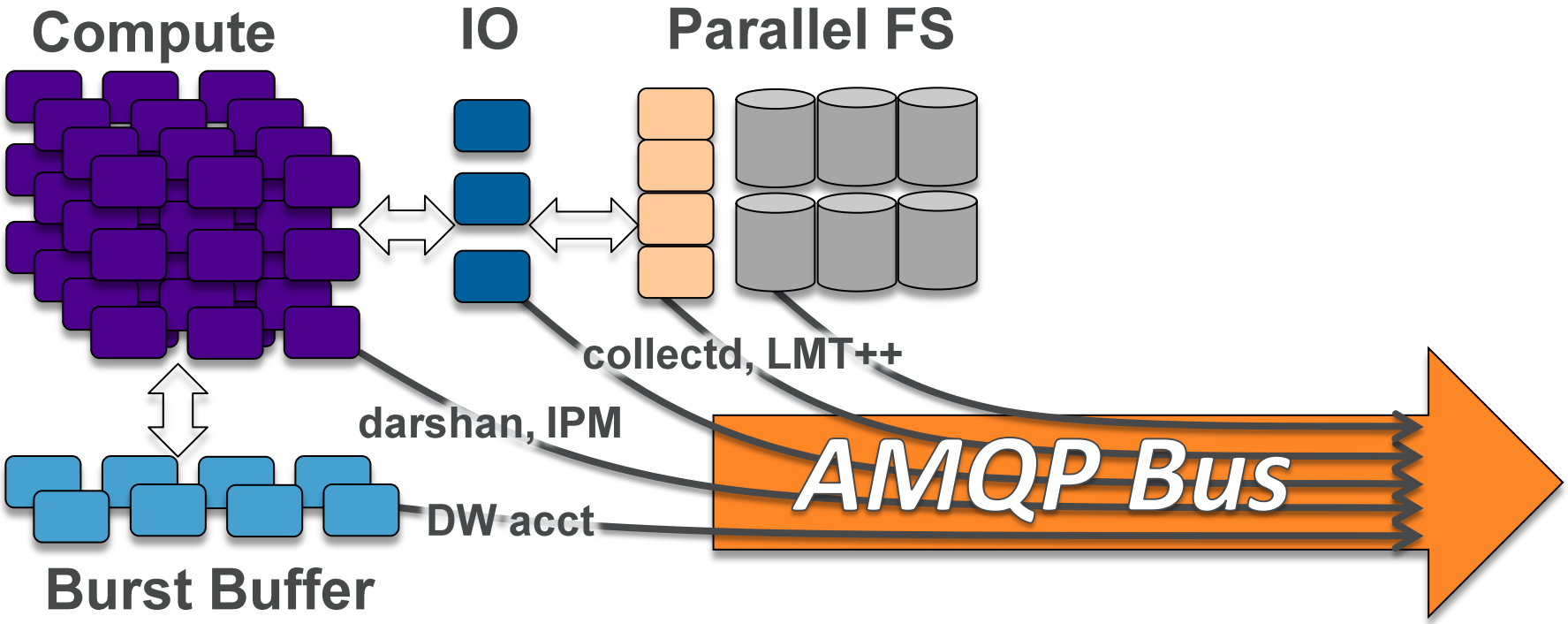
- Mining Darshan data
  - Ongoing work led by M. Winslett (UIUC)
  - Mining Darshan logs for interactive visualization and generation of representative workloads
- Holistic I/O characterization framework
  - Ongoing work led by N. Wright (LBL/NERSC)
  - Deploy best-in-class characterization tools for applications, servers, devices, network, etc.
  - Combine and correlate data for deeper insight into the system as a whole



Thanks to Huong Luu (UIUC) for providing this figure.

Web dashboard for ad-hoc analysis: https://github.com/huongluu/DarshanVis

NERSC HOLISTIC MONITORING: SCALABLE COLLECTION



1. Component-level monitoring data fed into RabbitMQ
   - Slurm plugins (kernel counters, Darshan, IPM)
   - Native support (procmon, collectd)

THANK YOU!

THIS CONCLUDES THE “FUTURE OF I/O” SESSION