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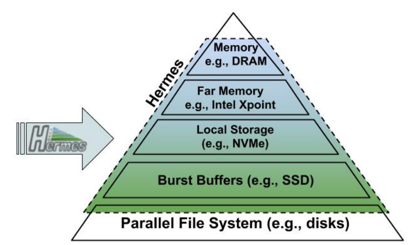
Main Scenario

Consider an HPC cluster equipped with a deep, distributed storage hierarchy (DDSH), the bottom layer of which is typically a parallel file system (PFS). DDSH was introduced to boost or to at least improve the I/O (POSIX, MPI-IO, HDF5, ...) performance of applications performing poorly otherwise. Unfortunately, DDSH is not a turn-key solution and, from a developer's or user's perspective everything but seamless. It seems that users are expected to take control, to learn all the necessary DDSH details, and to make the necessary code changes. Even if successful, this is a distraction from solving domain problems and, worse, it will be harder to maintain and port the application to other or future systems.



Deep Distributed Storage Hierarchy (DDSH)

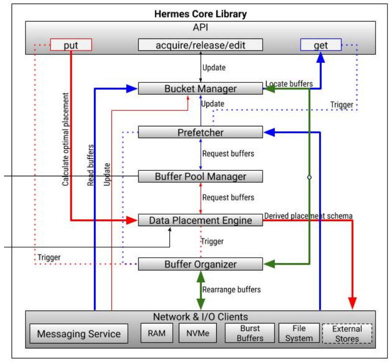
The goal of the Hermes project is to provide a *seamless* solution that utilizes DDSH without or requiring only minor application changes.

(Even without a deep DDSH, determined users have created original solutions to overcome I/O performance challenges. See use cases for an example. Many of them can be considered custom, i.e., application-specific, I/O buffering systems.)

How We Do It

We implement an *I/O buffering system* with the following characteristics:

- Being seamless, it's a go-between by-and-large unmodified applications and the PFS. Applications will see a hopefully more performant PFS.
- Users designate certain resources to be used for I/O buffering. Like most buffering systems, it has a finite capacity. When that capacity is reached, the buffering system can no longer deliver noticeable benefits and may perform as poorly as (or worse) than the unbuffered system (going to PFS).
- Users express I/O priorities, constraints, and hints via buffering policies.
- Given individual or batches of I/O operations (writes and reads), the **main challenge** for such a buffering system is to determine where in DDSH a given data item is *best/well/optimally*-placed at that point in time.
- To that end, the system consists of the following major components:
    - Strategies and algorithms that implement policies and facilitate data placement decisions: see Data Placement Reloaded, Data Placement, Data Placement Strategies and Experiments, Optimization. Speculative data placement for read operations is also known as prefetching.
    - These strategies work with (dynamic) sets of buffering targets and are applicable more broadly
    - The physical buffering resources are managed in a distributed buffer pool (see also Batching System).
    - Buffer Organizer
    - Profiler
    - To separate concerns and for portability, system buffers are **not** directly exposed to applications. There is a set of intermediate primitives targeted by adapters for different I/O libraries. A generic metadata manager (MDM), supports the bookkeeping needs of the various components.
- The whole system is deployed in a server-less fashion



Hermes Core

Note: A buffering system does *not* provide the same semantics as storage.

Other Scenarios and Use Cases

Our main scenario, a parallel application running on an HPC system and writing files to a parallel file system, might be referred to as operating in Hermes *persistent mode*. This might be extended to multiple applications "communicating" via the PFS. Another important scenario and set of use cases include applications that operate in a more 'transient mode*: they tend to produce massive amounts of temporary data that need not be persisted in a PFS after the application completes. With DDSH, the use of PFS appears as a matter of last resort ("out-of-core"), and an I/O buffering system might offer a more performant solution.*

DDSH are by no means limited to HPC clusters. Today, cloud-based VMs from major providers offer half a dozen or more storage options and multiple interconnects. Since customers/users have the ability to customize the target system, it may seem that good I/O performance might be a little easier to achieve. In practice, the picture is more complicated. For one, this is no longer just a technical decision, but economic considerations (price and supply) play an important role. To write applications that perform well across a fleet of instance types and storage options is almost more challenging than to target a by-comparison stable HPC system. The concepts and techniques behind Hermes are by no means specific to HPC systems and their suitability should be examined in cloud-based environments.

Resources

- Hermes: a heterogeneous-aware multi-tiered distributed I/O buffering system (https://par.nsf.gov/servlets/purl/10063843)
- Google Drive (https://drive.google.com/drive/u/0/folders/0ALuH0a_m3nGWUk9PVA)
