DataWarp Transparent Cache: Data Path Implementation

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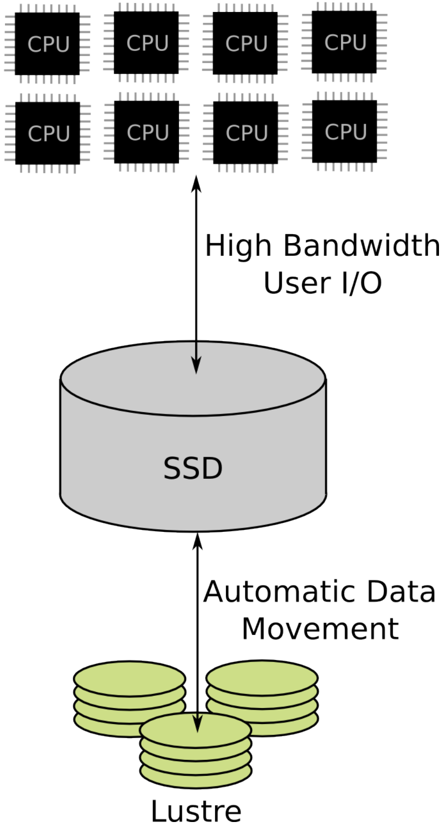
Agenda

- Overview of DataWarp
- Implementation of the DataWarp scratch data path
- Expanding DataWarp for the transparent cache data path

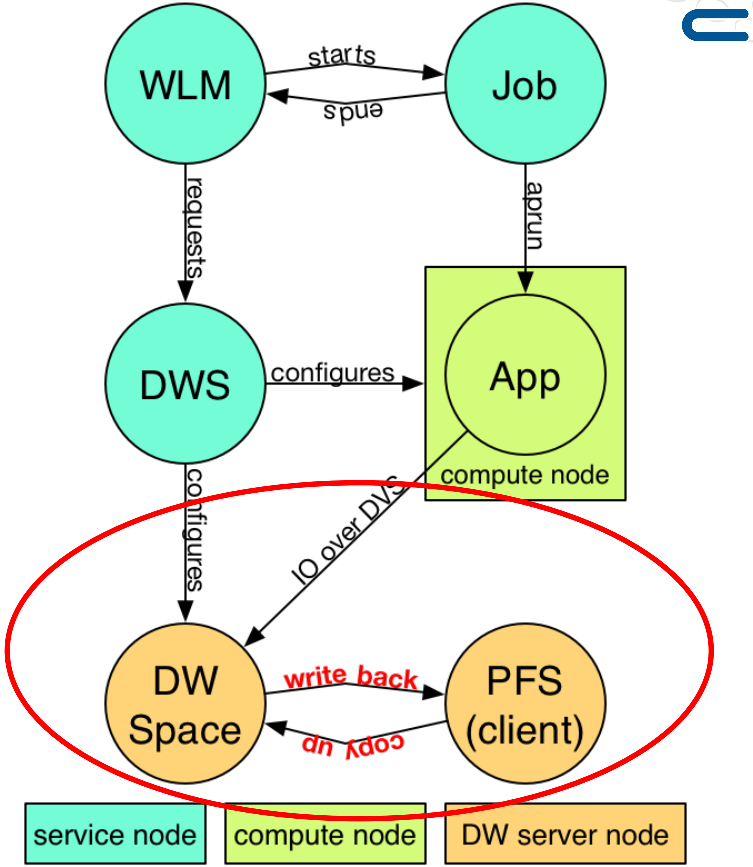
Transparent Cache Overview

- SSDs on service nodes serve as a cache layer between compute nodes and PFS
- DataWarp automatically moves data between SSDs and PFS



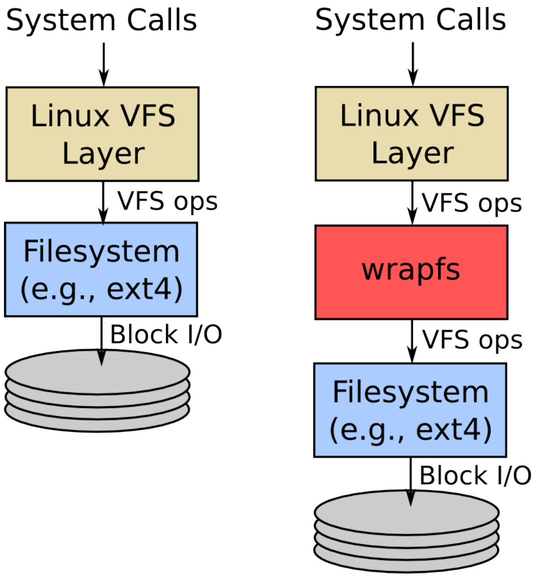
DataWarp Components

- DataWarp has both user space and kernel space components
- Focus is on the kernel level components
- Cray Inc. developed filesystems



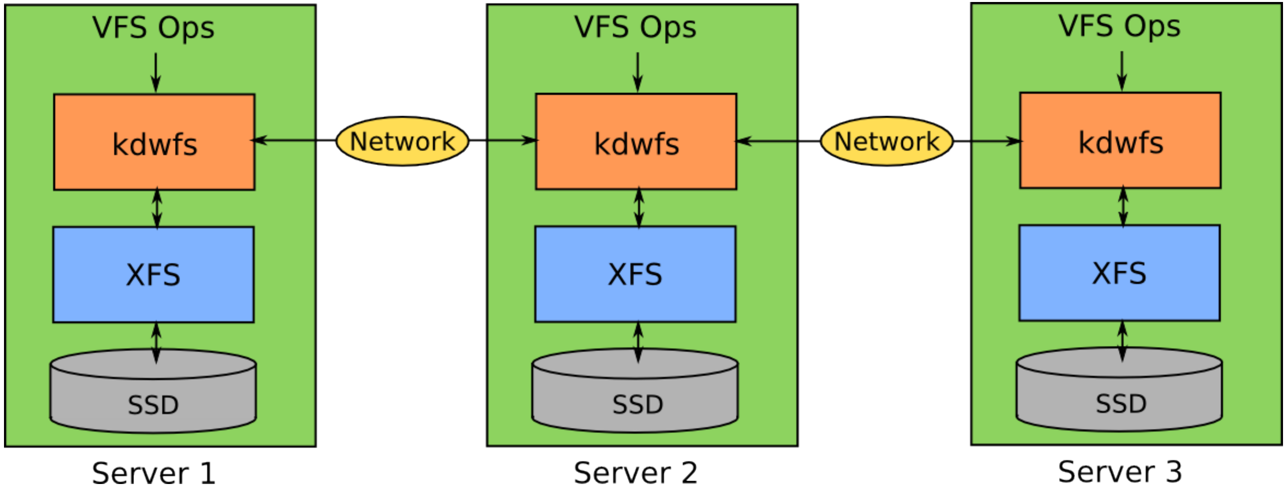
Stackable Filesystems

- **Linux VFS layer allows filesystems to be stacked**
- **VFS operations are the API**
  - Stackable filesystem must appear as a normal filesystem to kernel VFS
  - Stackable filesystem must appear as the kernel VFS to lower filesystem
- **wrapfs is a GPL pass through stackable filesystem**



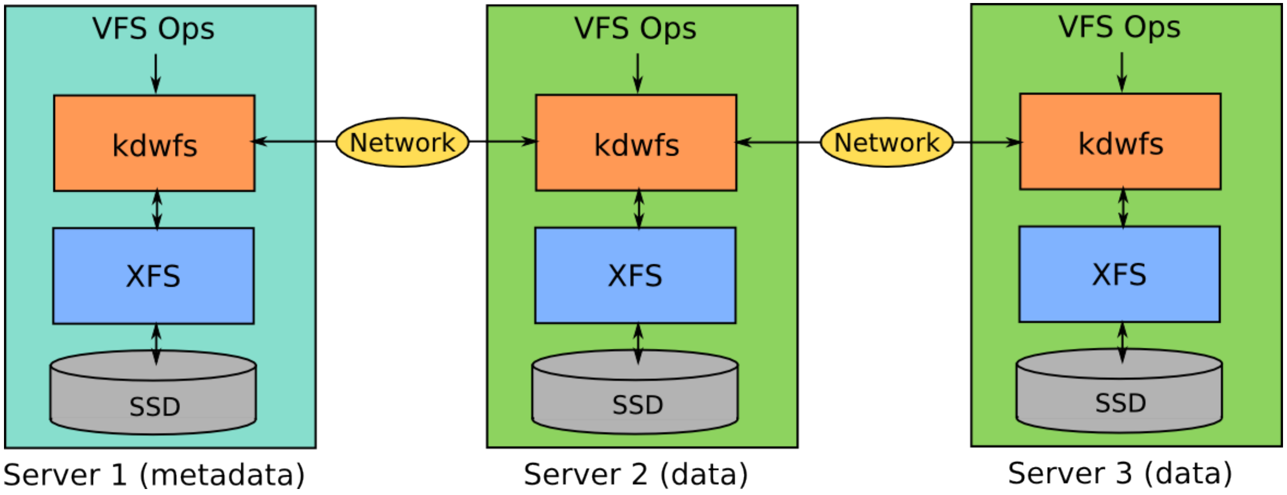
DataWarp Scratch Filesystem

- kdwfs – simple distributed filesystem
- Based on wrapfs



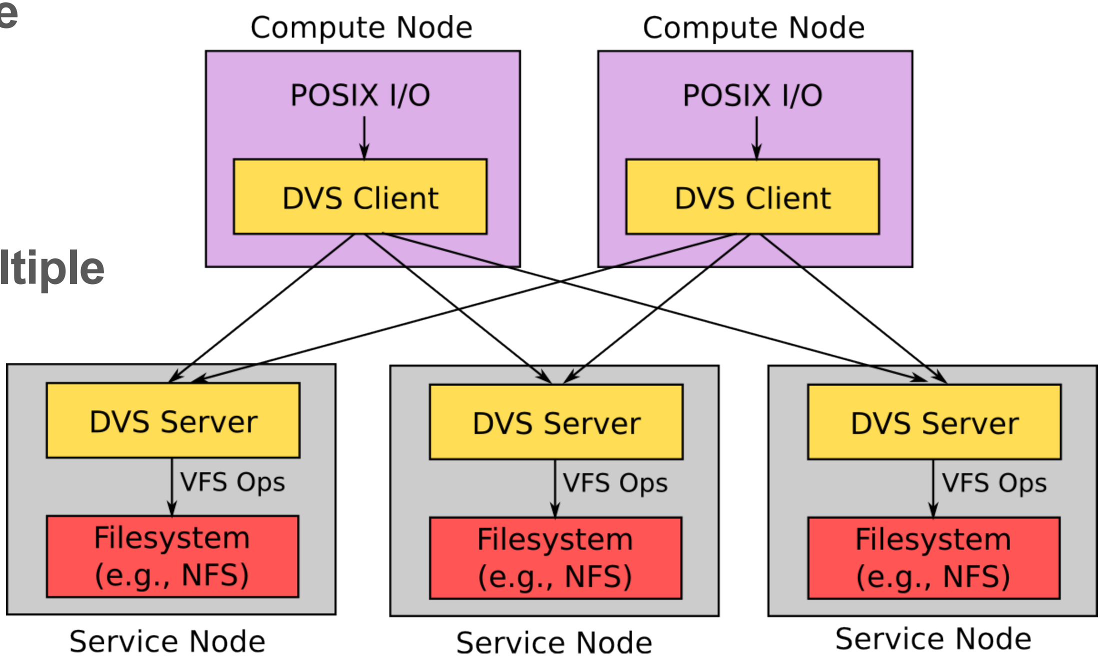
DataWarp Scratch Filesystem (cont.)

- Metadata and data are separated
- Single metadata server
- Data is striped across multiple SSDs



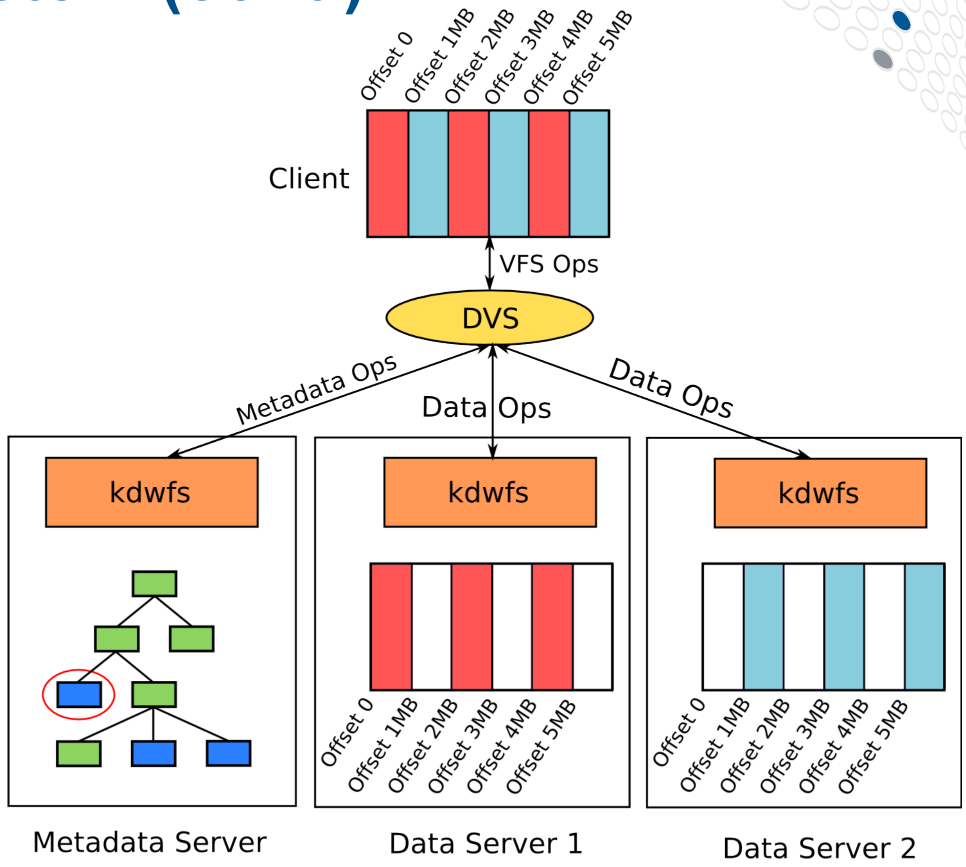
DataWarp Scratch Filesystem (DVS)

- DVS is an I/O forwarder
- POSIX filesystem interface
  - Some limitations
- DVS servers interact with underlying filesystem
- Data can be striped to multiple servers
- Scalable



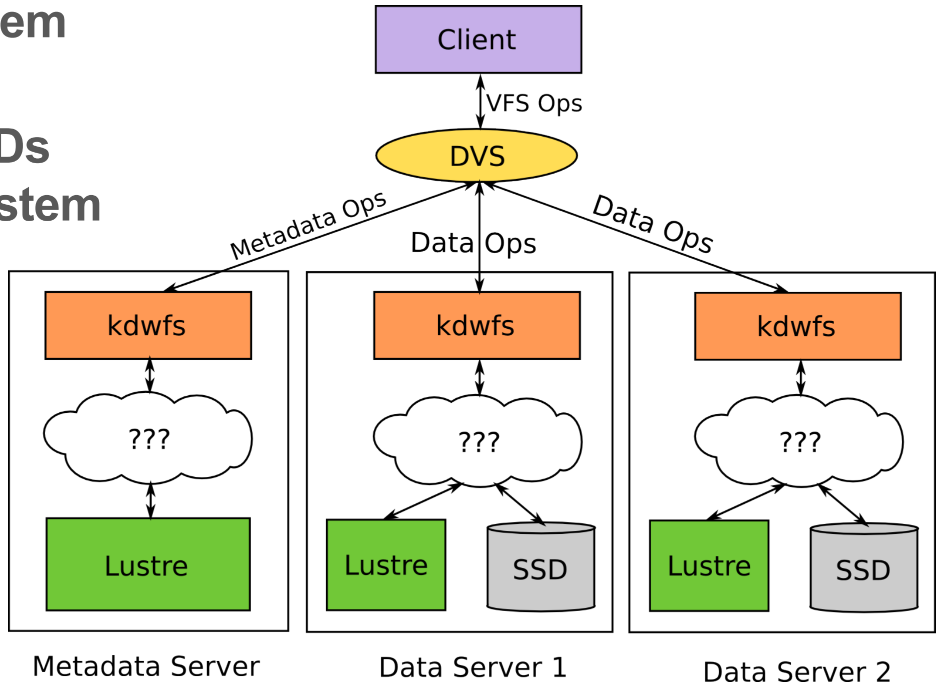
DataWarp Scratch Filesystem (cont.)

- **Each metadata inode has one or more data objects**
- **DVS handles I/O forwarding between computes and DW servers**
  - Metadata and data operations target correct server
  - Data is striped based on set block size
- **kdwfs handles communication between DW servers**



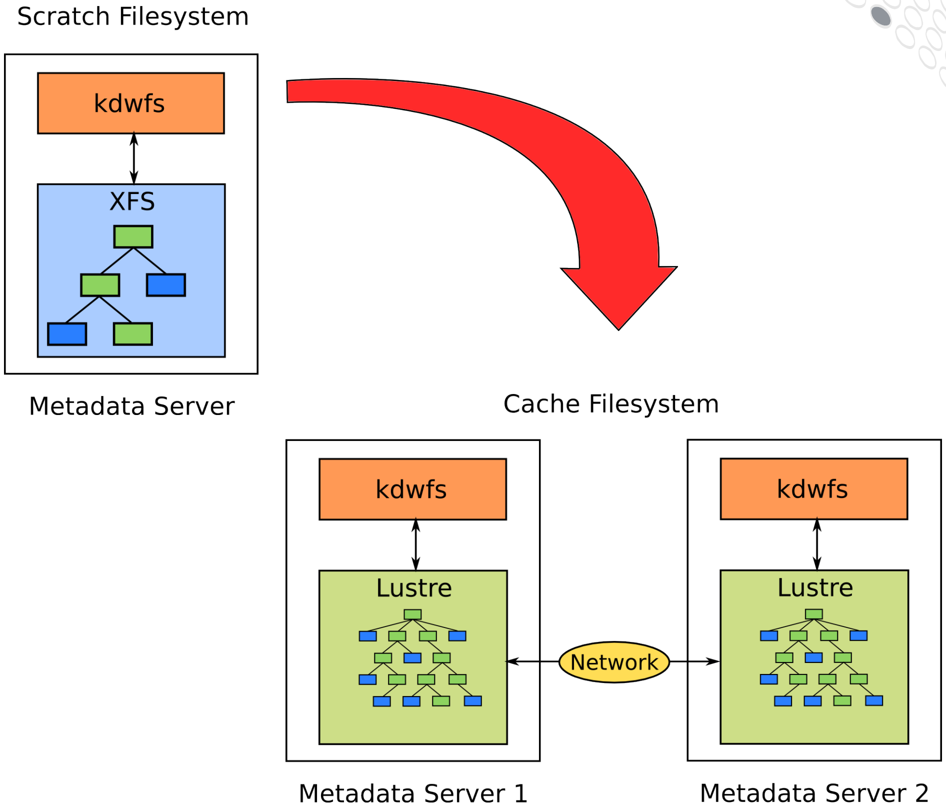
DataWarp Cache Filesystem

- Extension of the scratch filesystem infrastructure
- Use DVS and kdwfs to stitch SSDs together into a distributed filesystem
- How does Lustre get tied in?



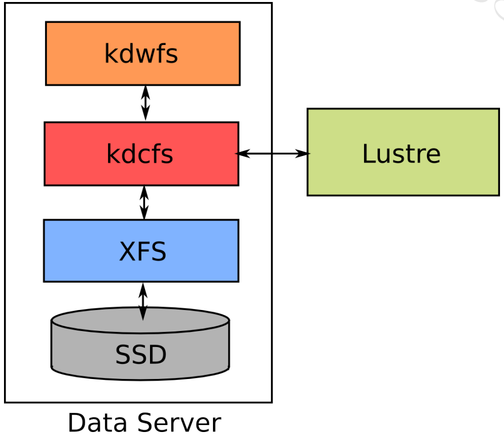
DataWarp Cache Filesystem (metadata)

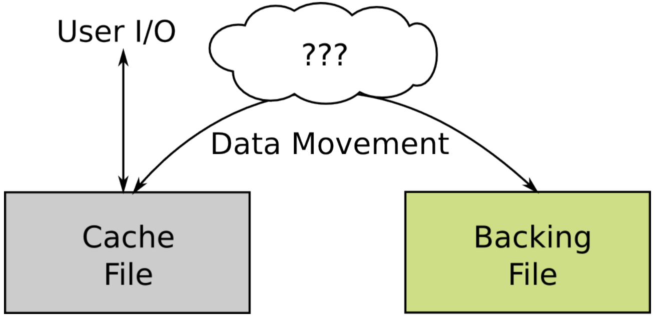
- **kdwfs on metadata server is stacked on top of PFS (Lustre)**
  - PFS client is DW server
  - DW metadata directory tree is identical to PFS
- **PFS keeps coherency between clients**
  - Multiple DW metadata servers are possible
  - DW metadata servers have to handle remote changes



DataWarp Cache Filesystem (data)

- **Data is still striped to multiple data objects**
- **Data objects read and write to SSD**
- **DW manages data movement**
  - SSD holds cache file
  - PFS holds backing file
- **kdcfs (kernel data caching filesystem)**
  - Based on wrapfs
  - Node local
  - File handles
  - I/O targets cache file



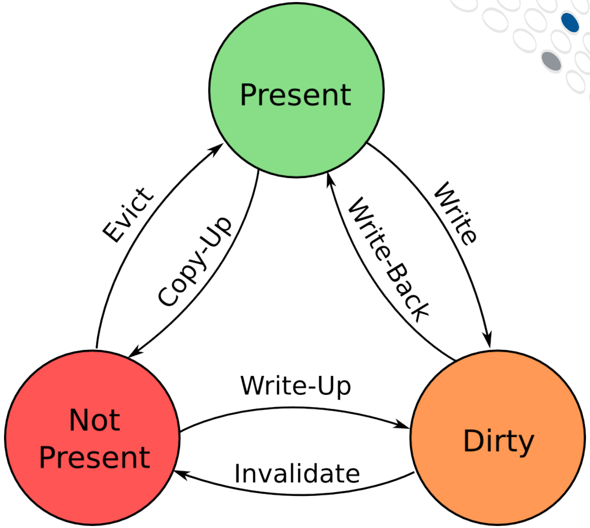


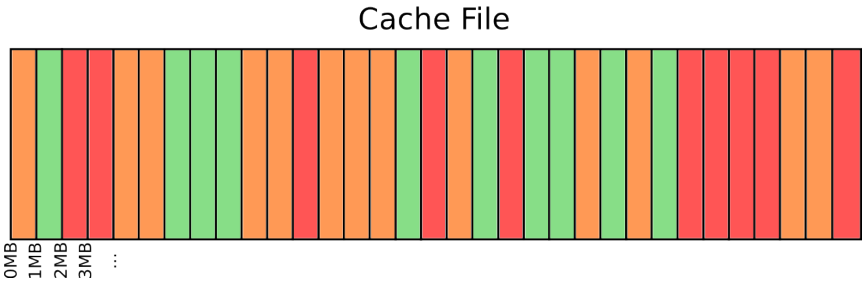
kdcfs Internals (cache operations)

- **Cache operations modify cache file data**
  - Implemented as a pool of worker threads
- **Cache operations: copy-up, write-back, evict, invalidate**
  - Copy-up – Copy data from PFS to cache file
  - Write-back – Copy data from cache file to PFS
  - Evict – Deallocate a clean region from the cache file
  - Invalidate – Deallocate a dirty or clean region from the cache file
- **fallocate() is used to allocate and deallocate space in the cache file**

kdcfs Internals (extents)

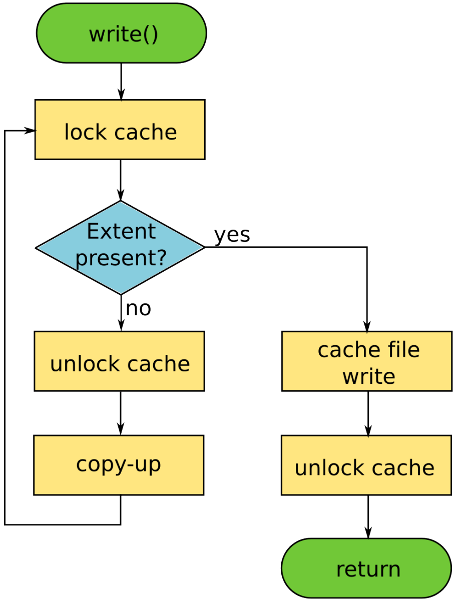
- **Cache file is logically divided into extents**
  - Default size is 1MB
- **Data in each extent is handled independently**
- **Extent states:**
  - Not-present – Cache data is older than PFS data
  - Present – Cache data is the same as PFS data
  - Dirty – Cache data is newer than PFS data
- **Per inode extent states are tracked in an in-memory tree**

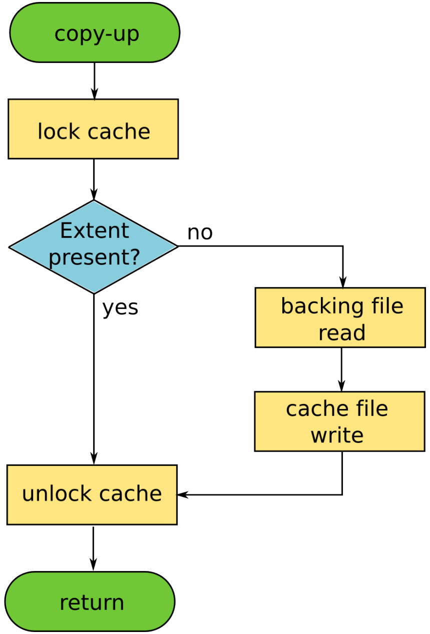




kdcfs Internals (example)

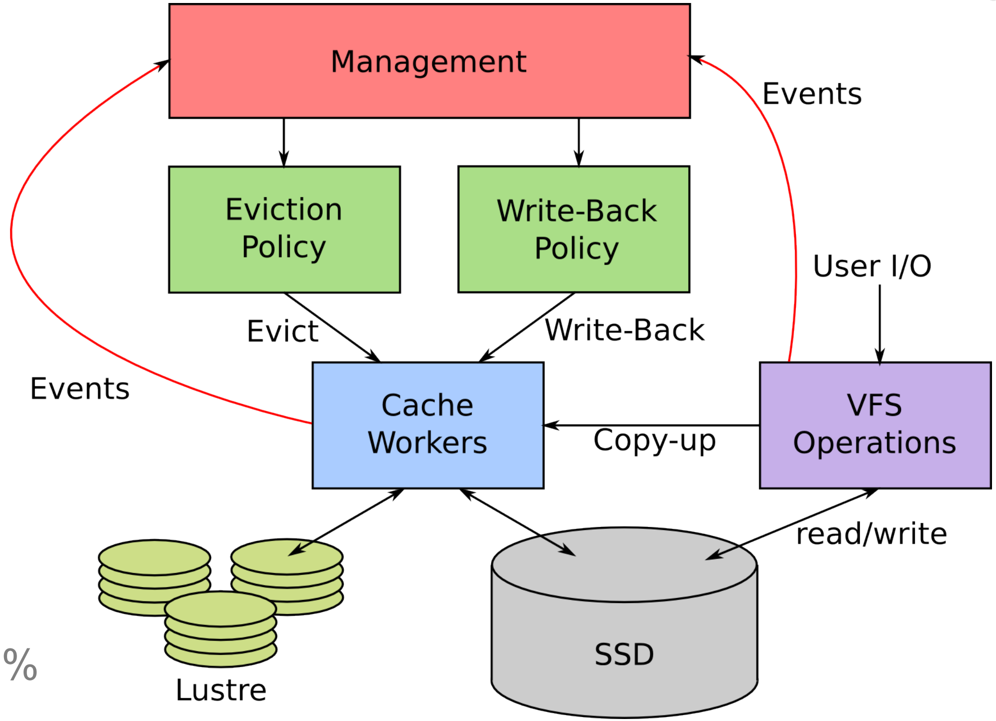
- **VFS operations can trigger cache work**
  - Example: write() results in copy-up





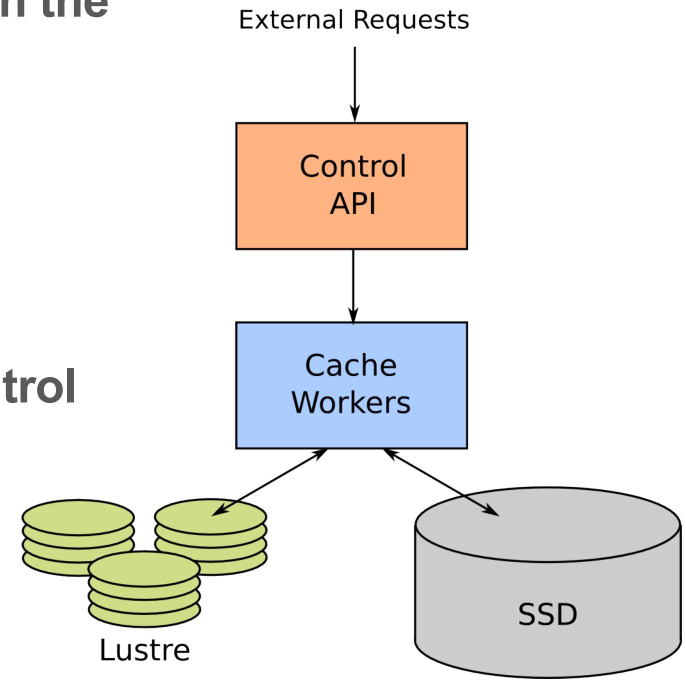
kdcfs Internals (management)

- **Management sub-component monitors cache events**
- **Management policies for write-back and evict**
  - Policies are swappable
  - Separate for write-back and eviction
- **File LRU policy for write-back**
  - High water 50% low water 0%
- **File LRU policy for eviction**
  - High water 100% low water 95%



kdcfs Internals (control API)

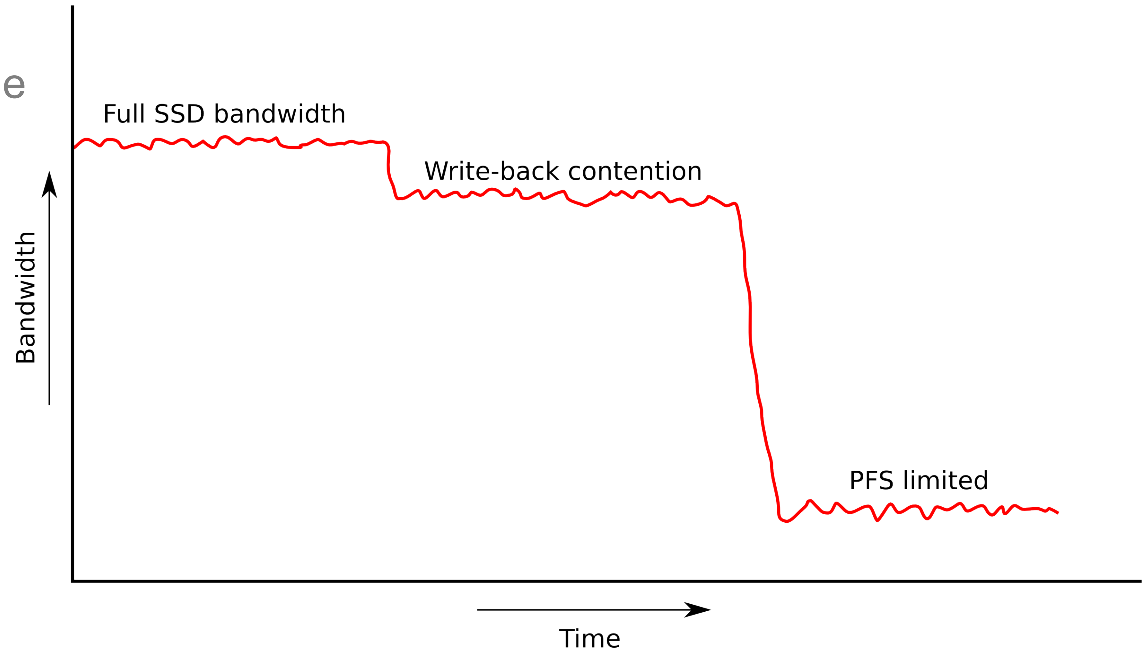
- **External components can influence data in the cache**
- **Ioctl() interface**
  - Individual files
  - Mount point
- **DWS flushes data at job end**
- **Exported to compute nodes as cache control API (future release)**



Transparent Cache Performance

- **Cache size is important**
  - PFS interaction is slow
  - Files larger than the cache are limited by PFS
- **Good workloads**
  - Bursty writes
  - Read after write
  - Multiple reads

Relative Write Bandwidth to Empty Cache



Summary

- **DataWarp transparent cache builds on existing scratch filesystem**
  - Scratch already has good performance
  - Increased stability
  - Fixes and features benefit both modes
- **Metadata operations go through Lustre**
  - All files within the mount are accessible
- **Filesystem implementation allows easy integration of different caching policies**
- **Cache control API will allow manual data movement similar to scratch**

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Q&A

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