The Triton Data Model

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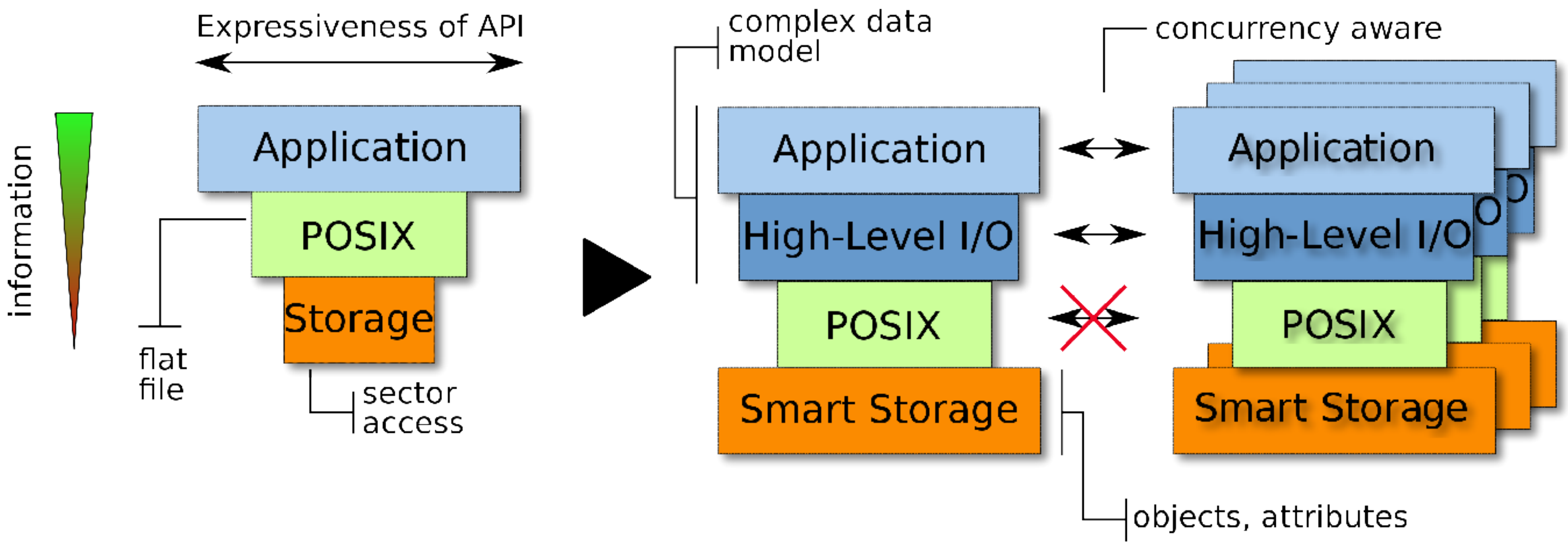
Overview

- Introduction & Context
  - Motivation
  - Overview of research efforts
- Triton Data Model
  - Overview & Situation
  - Operations
  - Examples
- Conclusion
  - Open Questions
  - Future work

Note: Early work, things might change! Feedback welcome!

Why a new data model?



- **Model**? (!= API, != Implementation)
- POSIX I/O API dates from ~1970: Plenty of research above and below POSIX but relatively little changes to POSIX (POSIX HPC extensions?)
- High-Level Libraries adapt to the application’s data model but are more and more restricted by the POSIX API.
- The landscape changed: ***smart*** (object**)** ***distributed*** storage, application ***concurrency*** (need for **scalable synchronization** primitives and **metadata** operations)

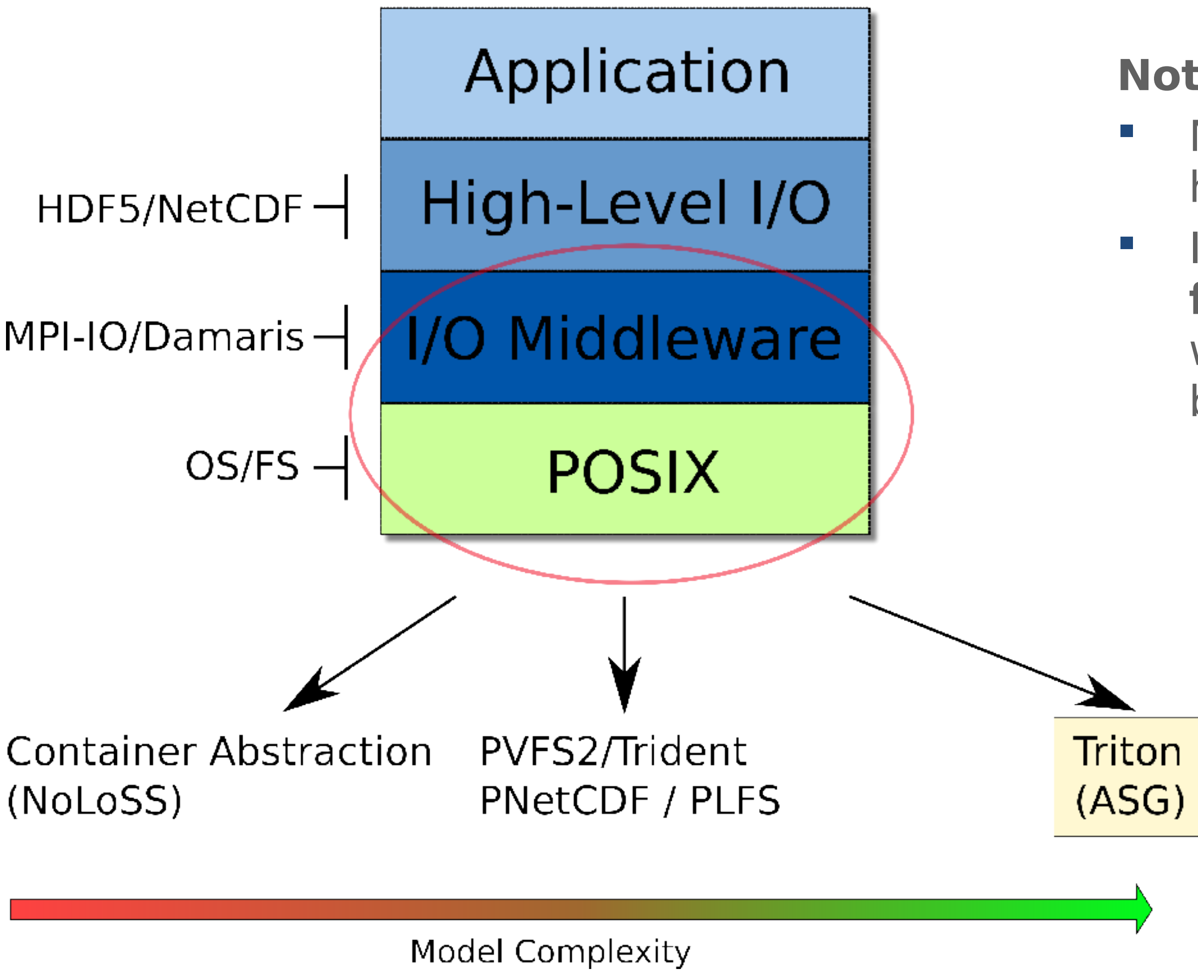
Known Problems

Model Issues → Implementation Issues

- File locking & synchronization (inter-node synchronization)
  - Implementing MPI-IO shared file pointer
  - Manipulate meta data in high level I/O data formats (HDF5)
- Mapping application model to the file model (flat file)
  - Chunking, space efficiency, unlimited dimensions, ...
- **Scalable metadata operations**
  - Readdir + stat (readdirplus)
  - Generic **namespace** support
  - POSIX HPC Extensions (open by handle now in linux kernel)
- File partitioning
  - N-N / N-1 / N-M writing
- **File Provenance**

Situation of this work

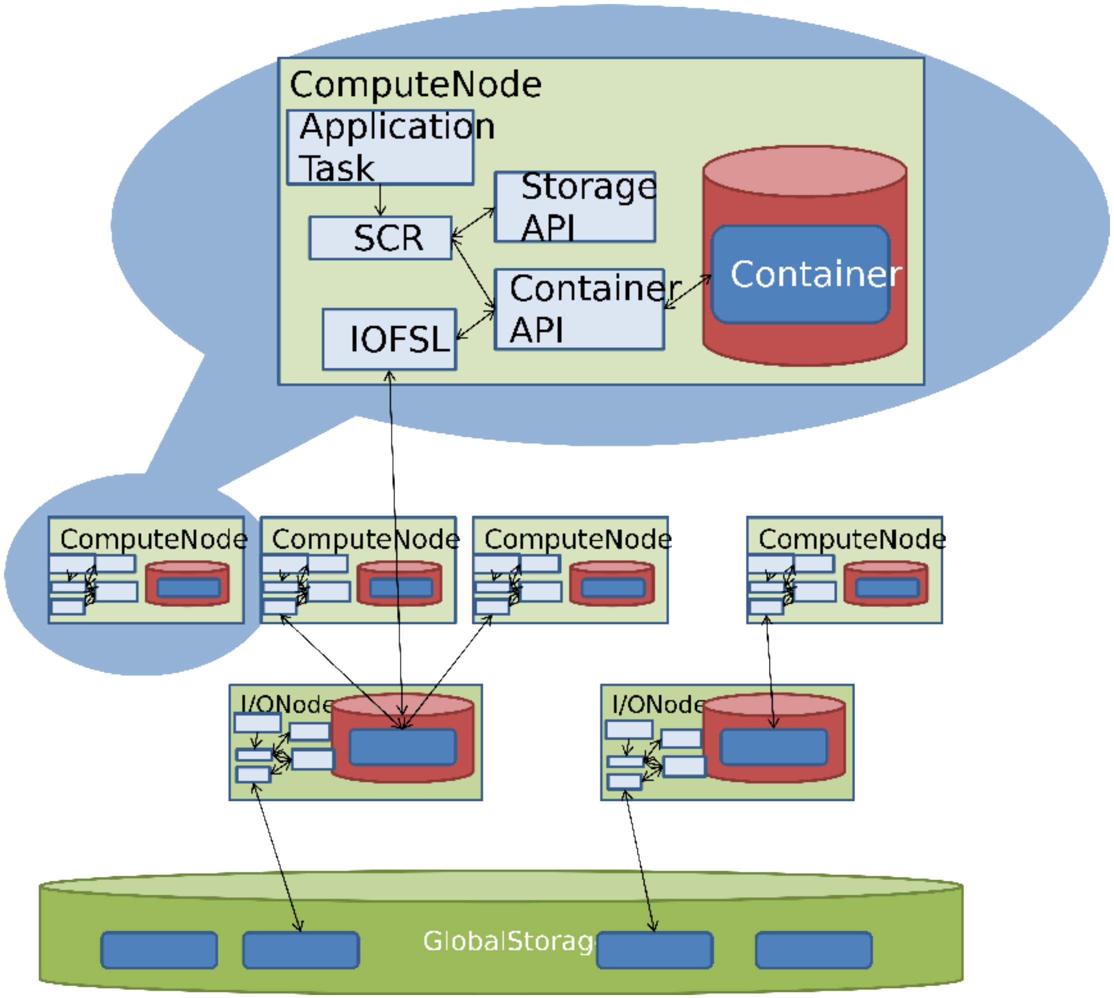
Related Research at Argonne



Note:

- Not trying to create another high level I/O library
- Instead **provide new foundation** for I/O middle ware and high level I/O to build on

Container Abstraction (NoLoSS Project)

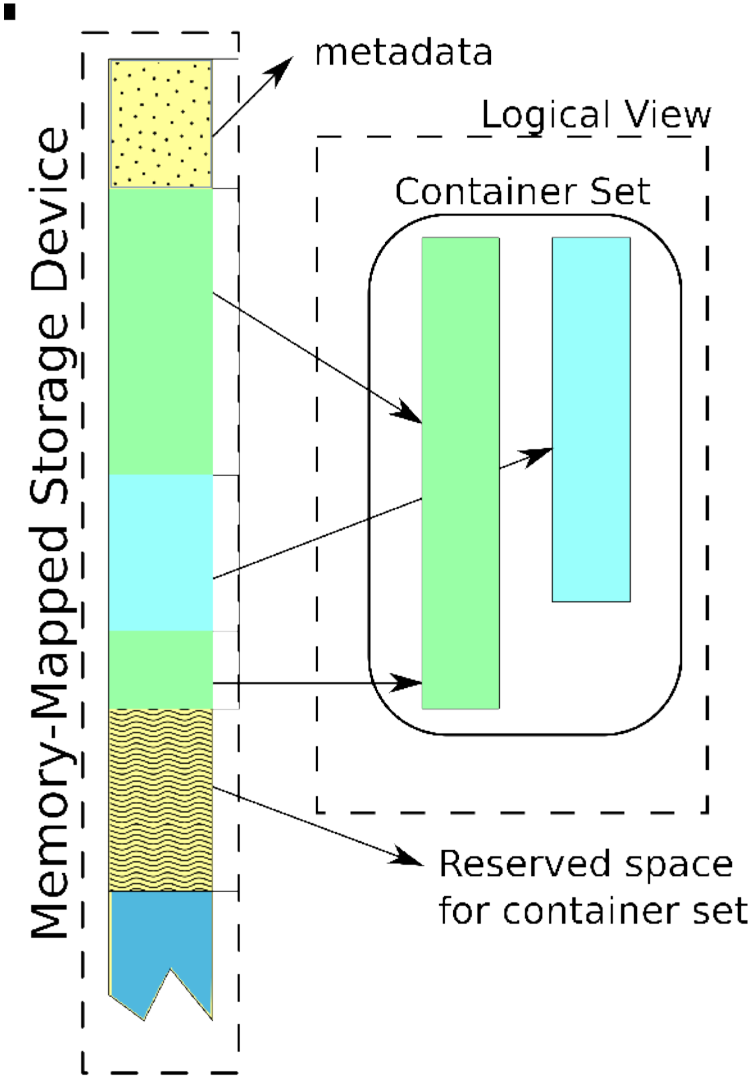


- Designed for **in-system storage**
- Expects **memory mapped** storage hardware.
- Targets **checkpointing**, **staging**, **in-situ** analysis
- Currently porting *SCR*
- People:
  - **LLNL:** Maya Gokhale, Kathryn Mohror, Brian Van Essen, Adam Moody, Bronis de Supinski
  - **ANL:** Kamil Iskra, Dries Kimpe, Rob Ross

Integrated In-System Storage Architecture for High Performance Computing (ROSS 2012)
Dries Kimpe, Kathryn Mohror, Adam Moody, Brian Van Essen, Maya Gokhale, Rob Ross and Bronis R. de Supinski

Container Abstraction (NoLoSS Project)
(Continued)

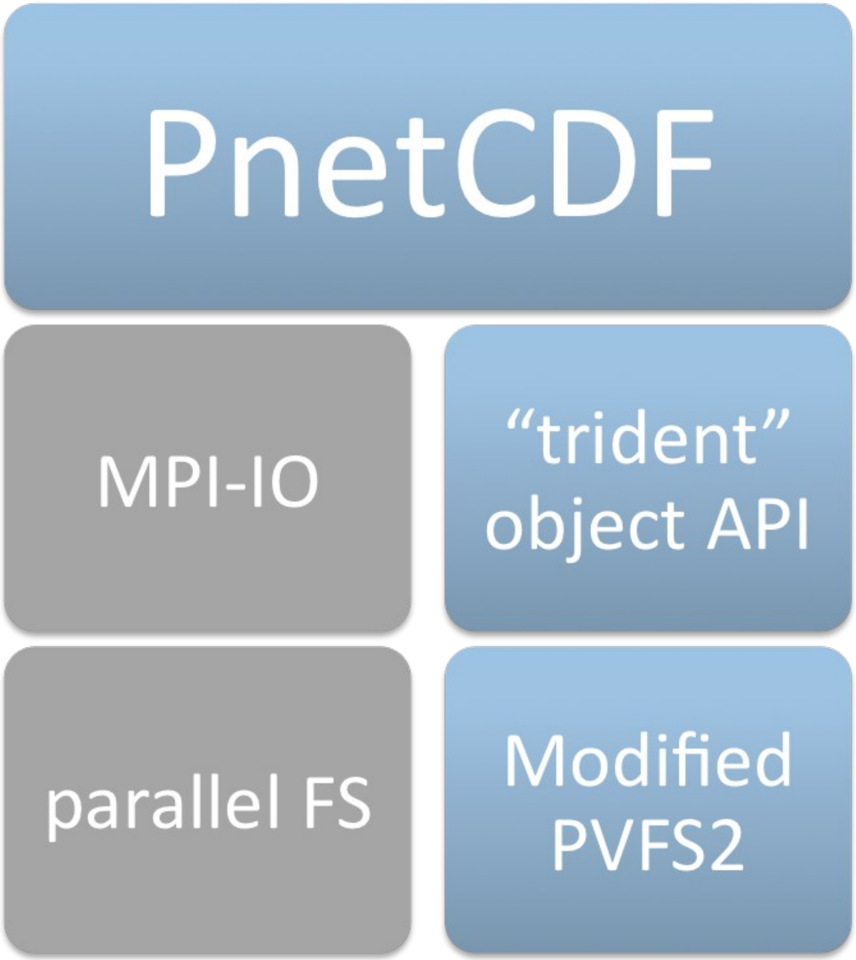
- Explicit **location** (also remote)
- More restrictive than POSIX
  Drop costly (unused?) features
- Restricted model enables some new features
  - *`Direct Storage Access*'
    (True zero-copy)
  - Space reservation
    (!= preallocation)
  - 3rd party transfers
- **Status:** Early evaluation



High-Level Data Models over Object Storage

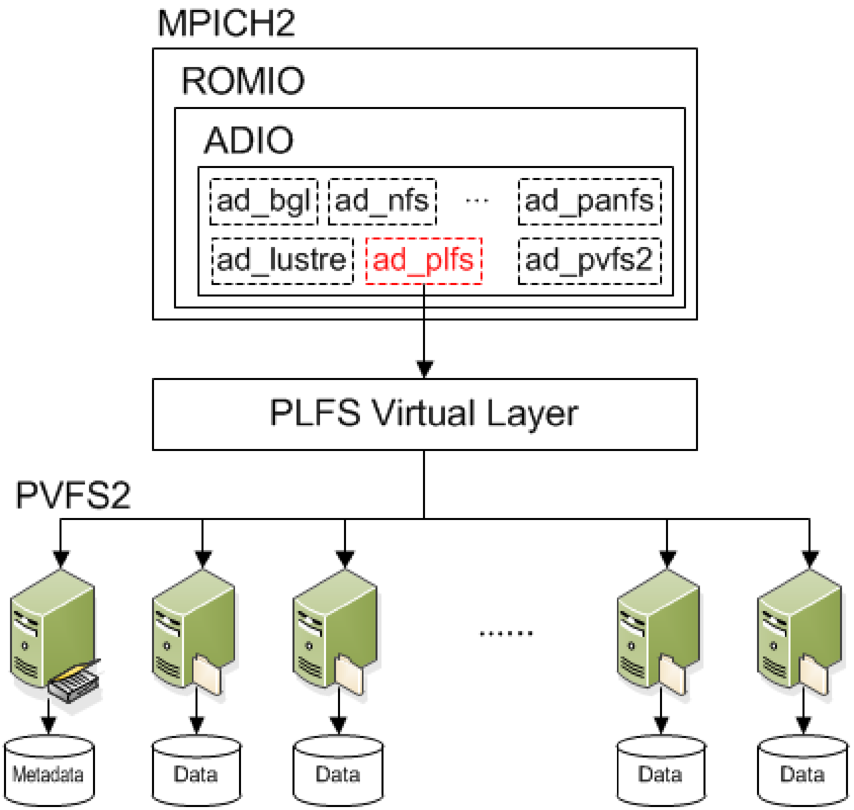
- Investigating object storage as a **more natural fit** for high level libraries
- Objects are independently accessed byte streams, **with attributes**
- Objects grouped into “containers”, roughly similar to traditional “file names”

- Experimenting with modified versions of PnetCDF and PVFS2
  - Early results show **complexity reduction** for PnetCDF
  - Explicit control over variable striping
    (downside: explicit control over variable striping)



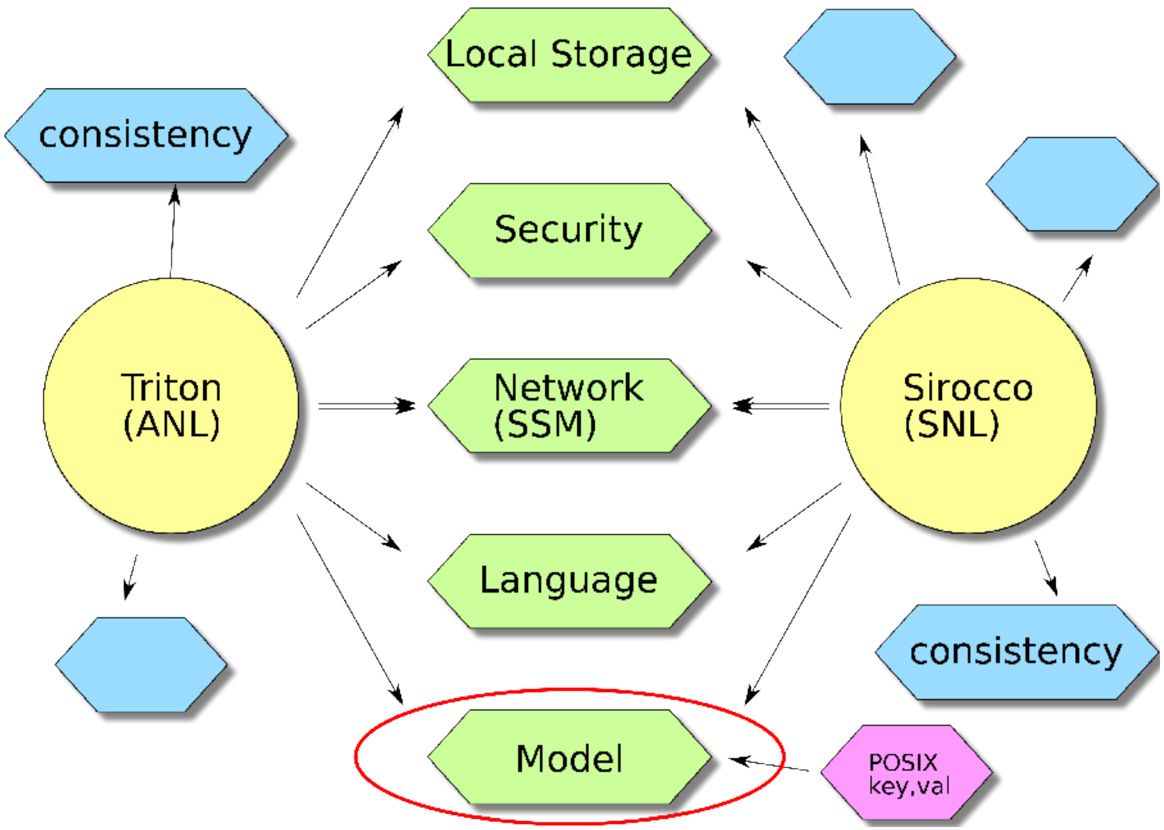
Dave Goodell (ANL)

PLFS on Trident



- Port of **PLFS** to Trident
- Research directions:
  - Control **placement**
  - Reduce **metadata** overhead
- Status:
  - ad_plfs complete
  - Starting work on PLFS port
- Shawn Kim (Penn State) [summer internship @ ANL]

Situation of this work
Advanced Storage Group (ASG)

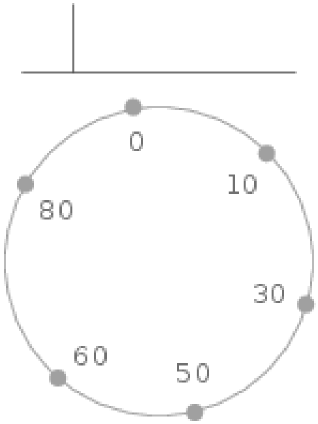


- **Concept:** Friendly competition in designing an exascale storage system
- Different design choices, but **shared building blocks** simplifying exchange (codes, ideas)
- Periodical **evaluation** of design decisions with adoption of the best one.

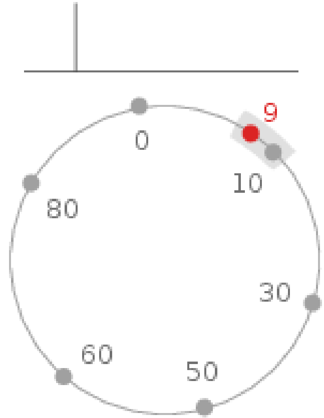
Triton
Introduction

- Triton: ANL effort towards development of an exascale **storage system**
- Comparison to **T10 OSD**:
  - Triton is more like PanFS
  - Own local storage abstraction
- The model presented in this talk is **one of** the models implemented by Triton.
  - (key,val), POSIX, variants
- **Self-healing**, resilient

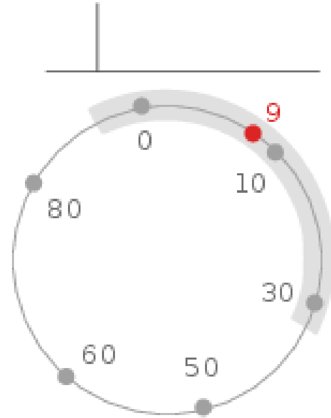
Servers (grey) are arranged in an n-dimensional address space and referenced by an ID in that space. Here, n=1.



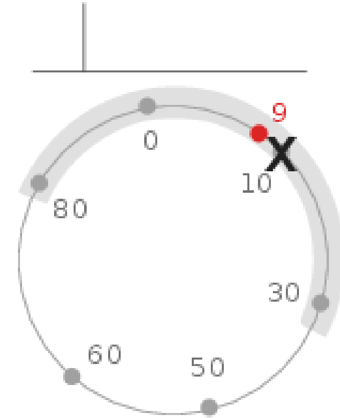
Objects (red) are likewise addressed by an ID in this space. The primary for an object is located at the server with the closest ID in the address space.



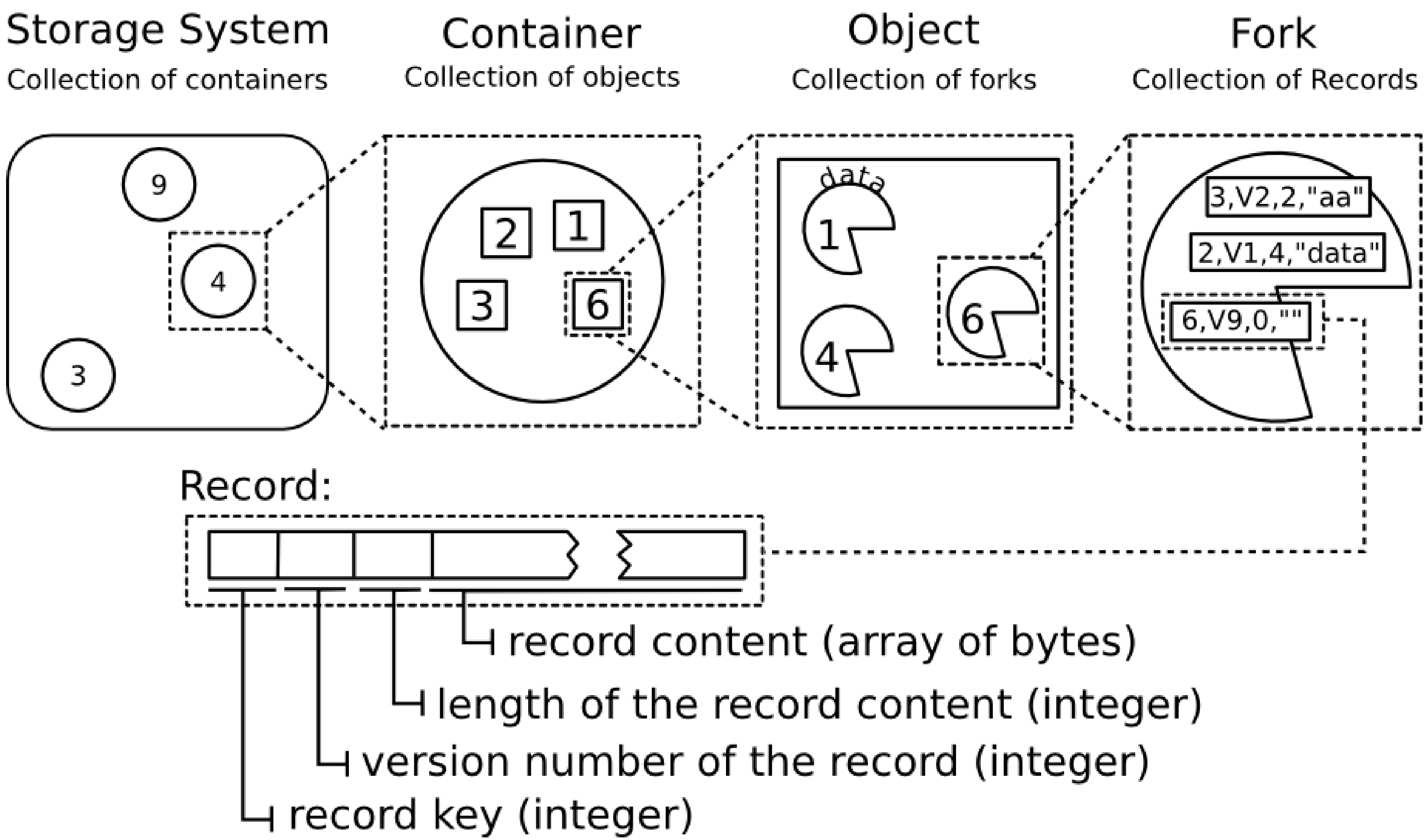
For a replicated object, replicas are placed on the k-1 next closest servers in the address space.



In the event of a server failure, the object will be re-replicated to the next closest server in the address space.



ASG Data Model
Overview



ASG Data Model
Example

Version

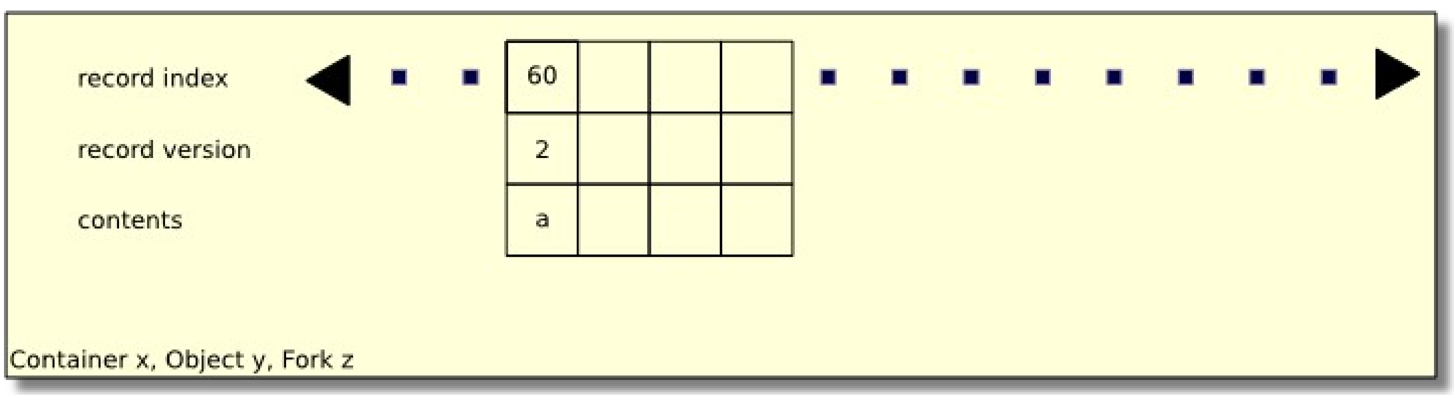
- `write (loc,cid,oid,fid, 60, 1, 2, “a”)`

Contents

Identify fork

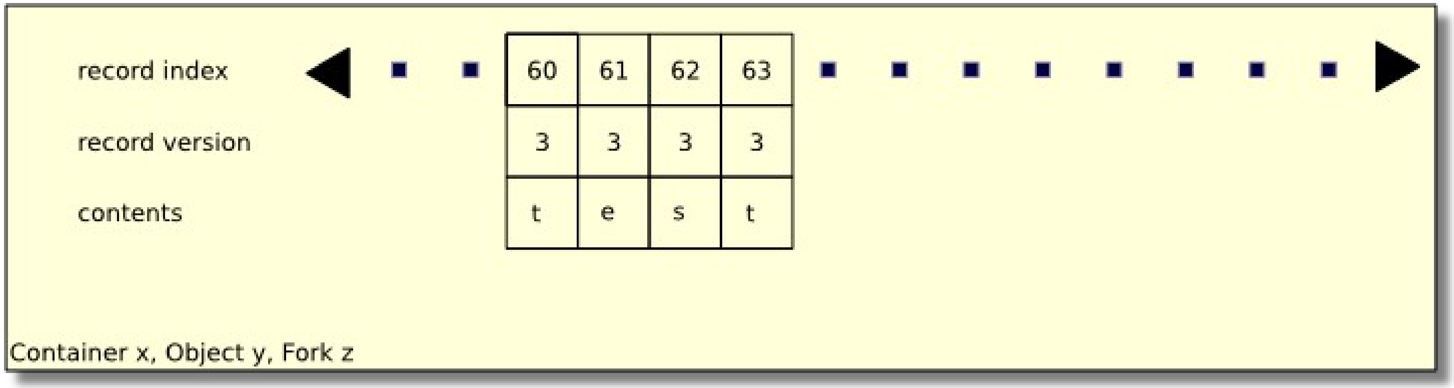
First record

Number of records



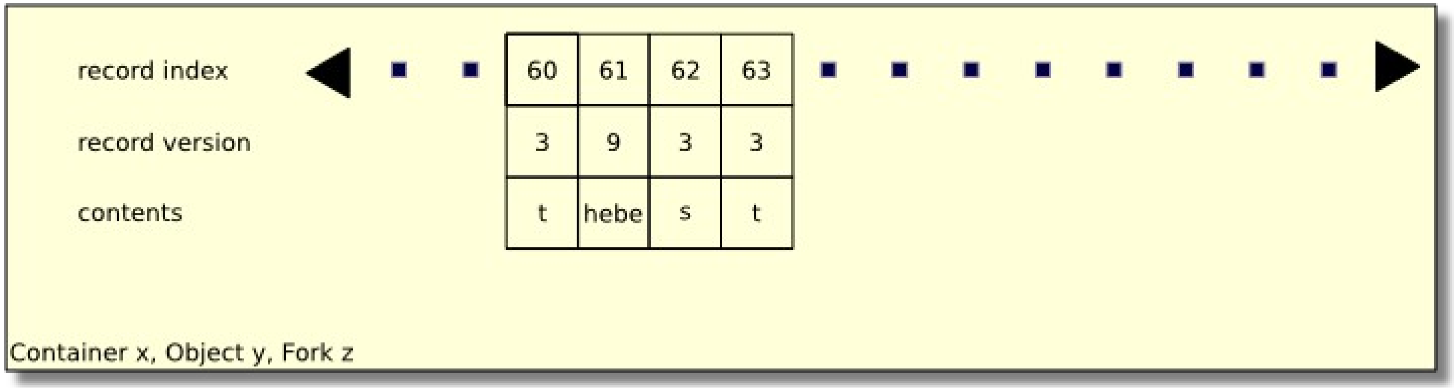
ASG Data Model
Example

- `write (loc,cid,oid,fid, 60, 1, 2, "a")`
- `write (loc,cid,oid,fid, 60,` **`4`**`,` **`3`**`, "test")`
  - Writing **4** records with version number **3**



ASG Data Model
Example

- `write (loc,cid,oid,fid, 60, 1, 2, “a”)`
- `write (loc,cid,oid,fid, 60, 4, 3, “test”)`
- `write (loc,cid,oid,fid,` **`61`**`,` **`1`**`, 9, “hebe”)`
  - `Writing` **`1`** `record of` **`length 4`** `with version` **`9`**



Data Model: Operations

A limited set of operations:

- **Write**: **overwrite one or more** records (atomic)
- **Read**: **retrieve one or more** records (including **metadata**)
- **Probe:** only retrieve **metadata (version** and **length** etc.); No data
- **Punch:** Like write, but writes **zero-length** records

- **Reset:** Sets the entity back to the default state (i.e. `erase’)
  - Note: no 'create' (implementation: no file descriptors)

- Write, read and punch support **conditional execution** based on the **expected** version (more about this later).
- Client generally provides version number; API also supports **auto increment**.
- Write, read, punch operate on **records**
- Probe and reset operate on **records, forks, objects** and **containers**
- Version: Used to order **transactions;** No retrieval of **obsolete** versions

Conditional Operations

- Enables the user to provide a condition on the **version** of **one or more** of the specified records.
- If the condition is not satisfied, the operation does not **retrieve** or **update** record contents; However, information **is** returned.
- Currently:
  - **`COND_UNTIL`**: Transfer (read or write) records as long as the existing version (if any) is strictly **smaller** than the specified version.
  - **`COND_ALL:`** Only transfer data if **all** existing records in the range have a version number **strictly smaller** than the specified version.

Example:

```
write (..., 60, 3, 2, “abc”) = OK
```

60	61	62

60	61	62
2	2	2
a	b	c

Conditional Operations

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Example:

```
write (..., 62, 1, 4, “d”) = OK
```

60	61	62
2	2	2
a	b	c

60	61	62
2	2	4
a	b	d

Conditional Operations

- Enables the user to provide a condition on the **version** of **one or more** of the specified records.
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Example:

```
write (..., 60, 2, 3, “efgh”, COND_ALL) = OK
```

60	61	62
2	2	4
a	b	d

60	61	62
3	3	4
ef	gh	d

Conditional Operations

- Enables the user to provide a condition on the **version** of **one or more** of the specified records.
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Example:

```
write (..., 60, 3, 4, “abc”, COND_ALL) = ECOND
```

60	61	62
3	3	4
ef	gh	d

No change

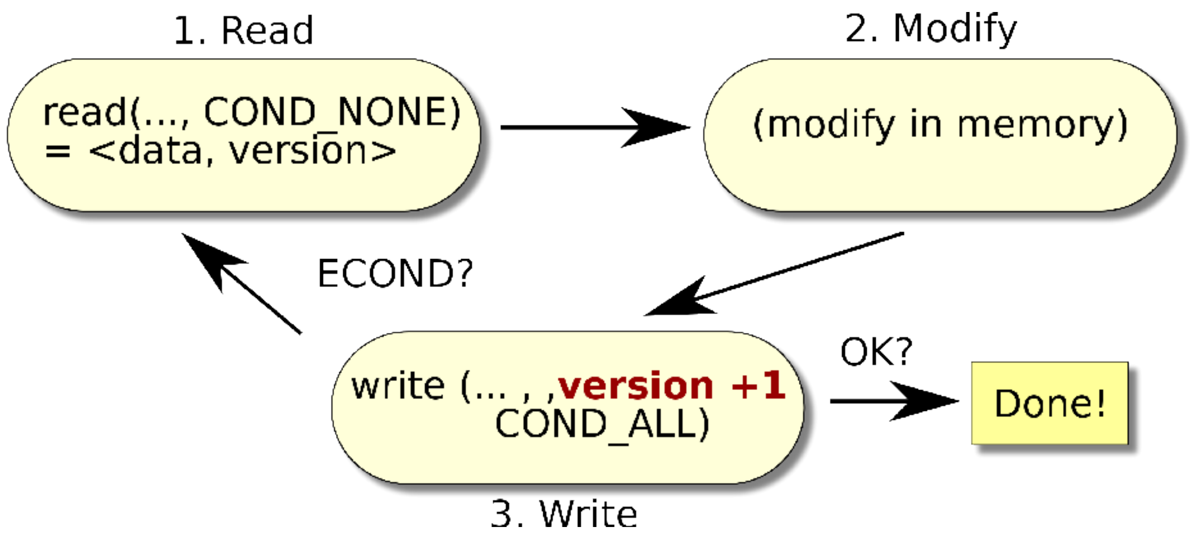
60	61	62
3	3	4
ef	gh	d

Example

Synchronization: R-M-W using versioning

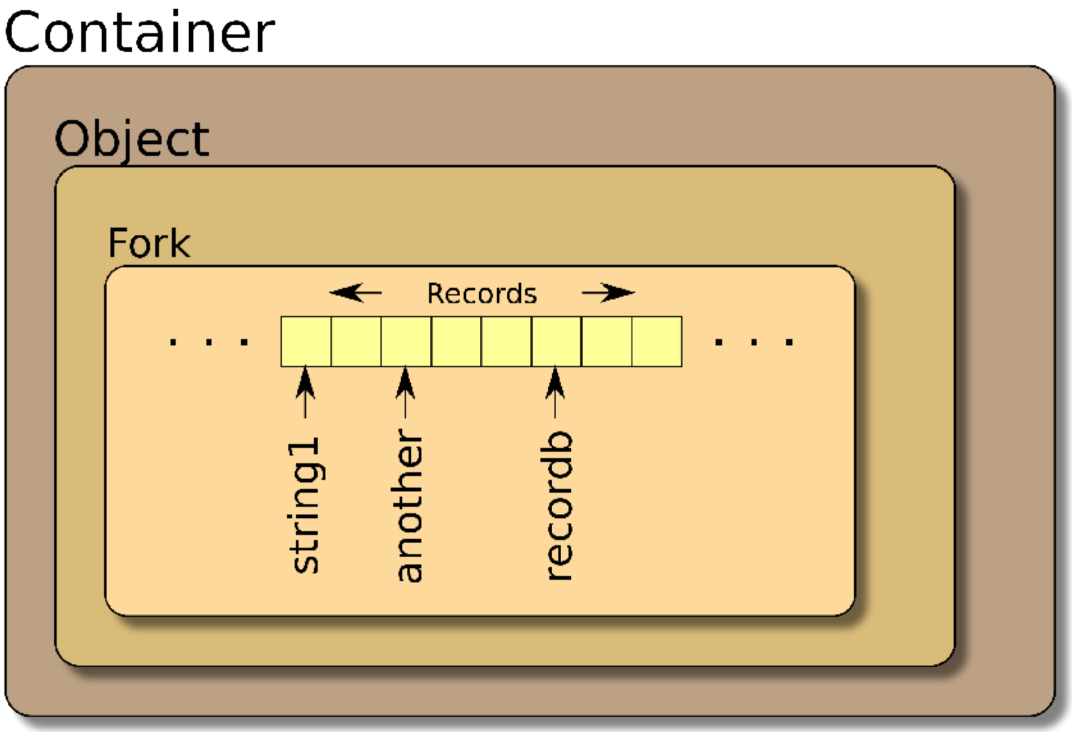
- The model does not support **locking**
  - Read and write are **atomic**
  - However: what about **Read-Modify-Write**?

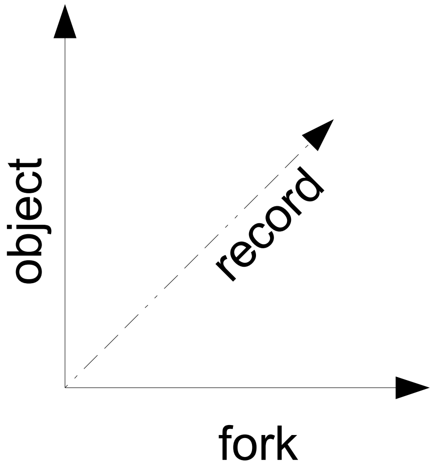
- **Conditional** operations can be used to implement R-M-W



Example
Exploiting Object Structure

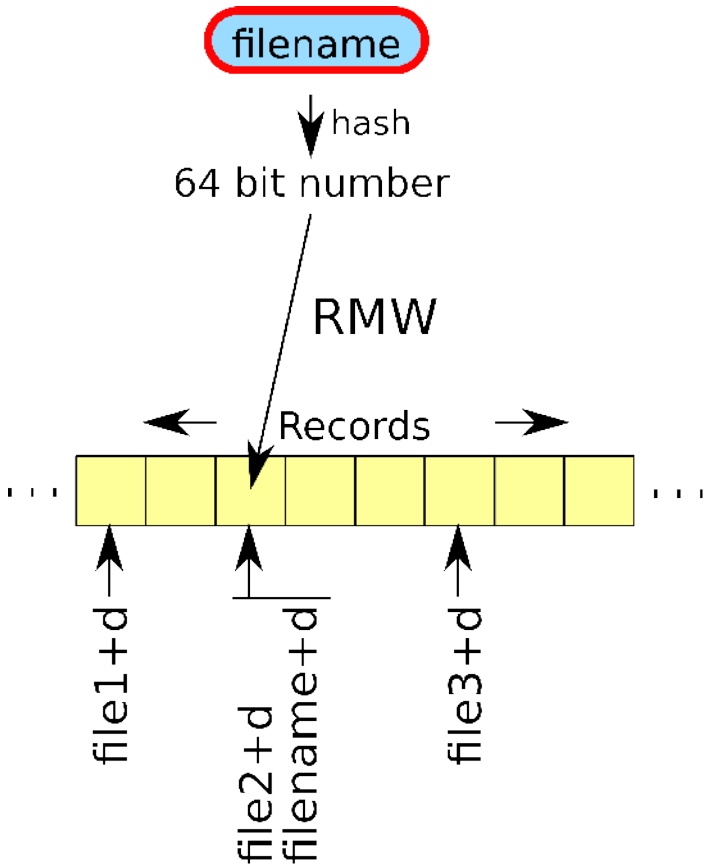
- Performance of preliminary **implementation** is not affected by choice of fork
- Fork + record can be used as **2-dimensional** record space
  - Record *contents* additional dimension (access granularity)
- Example: (key,value) structures





Example
Implementing extended attributes and directories

- (key,value) mapping (with key a *string*) data structure which supports **atomic insert, overwrite, lookup** and **remove (rename?)**

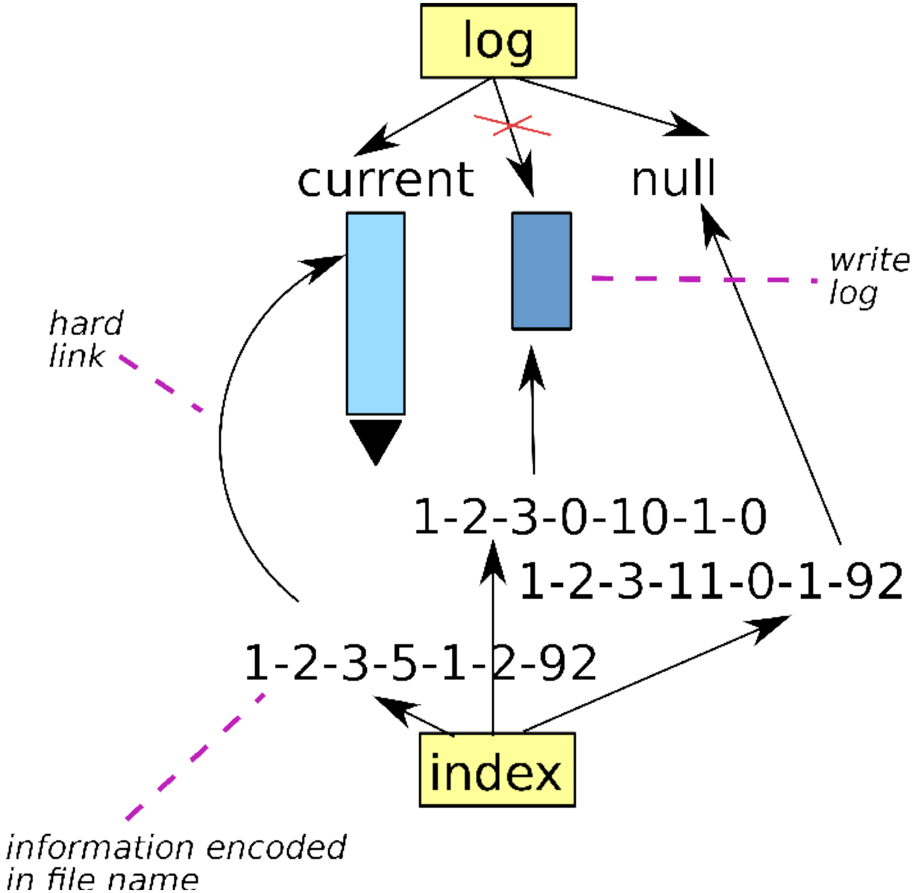


Preparation: **Hash** the string key, use as destination record number.

- Insert: write-conditional with default version
- Overwrite: R-M-W
- Remove: R-M-W with empty data
- Lookup: unconditional read (is atomic)

Note: each object can support 2^64 of these data structures!

Reference Implementation



- Implements the **model** focusing on **functionality** and **useability**, not performance, resilience or scalability.
- No external dependencies
- Uses underlying FS
  - **Hardlink** support req.
  - Write logging
  - Uses directory as DB, filename to encode data

Source: git://git.mcs.anl.gov/asg/reference

Open Questions
(ongoing work)

- Namespaces
  - Reddy Narasimha & students (Texas A&M Uni): Legacy support (POSIX)
  - Cengiz Karakoyunlu (UConn) summer project @ ANL
- Location-Awareness
  - Do we need to expose location in the model?
    - If not: how do we offer placement control?
- Auditing & Security
  - Collaboration with Richard Brooks & Jill Gemmill (Clemson)
  - Building on LWFS work (validation, simulation)
- Provenance
  - Bradley Settlemeyer (ORNL)

Acknowledgements

- Team at Argonne
  - Phil Carns, Dave Goodell, Kevin Harms, **Dries Kimpe**, Rob Ross, Justin Wozniak

- Collaborators (ASG)
  - ORNL: Stephen Poole, Bradley Settlemeyer
  - SNL: Lee Ward, Matthew Curry, Ruth Klundt
  - Clemson: Jill Gemmil, Richard Brooks, Haiying Shen
  - UAB: Anthony Skjellum, Matthew Farmer

  … and people I forgot to mention here!

- More information about Triton:
  - Triton: http://trac.mcs.anl.gov/projects/triton
  - ***Object storage semantics for replicated concurrent-writer file systems***
    Philip Carns, Robert Ross and Samuel Lang

- Questions?
  dkimpe@mcs.anl.gov