# Abstract Storage

## Moving file format-specific abstractions into petabyte-scale storage systems

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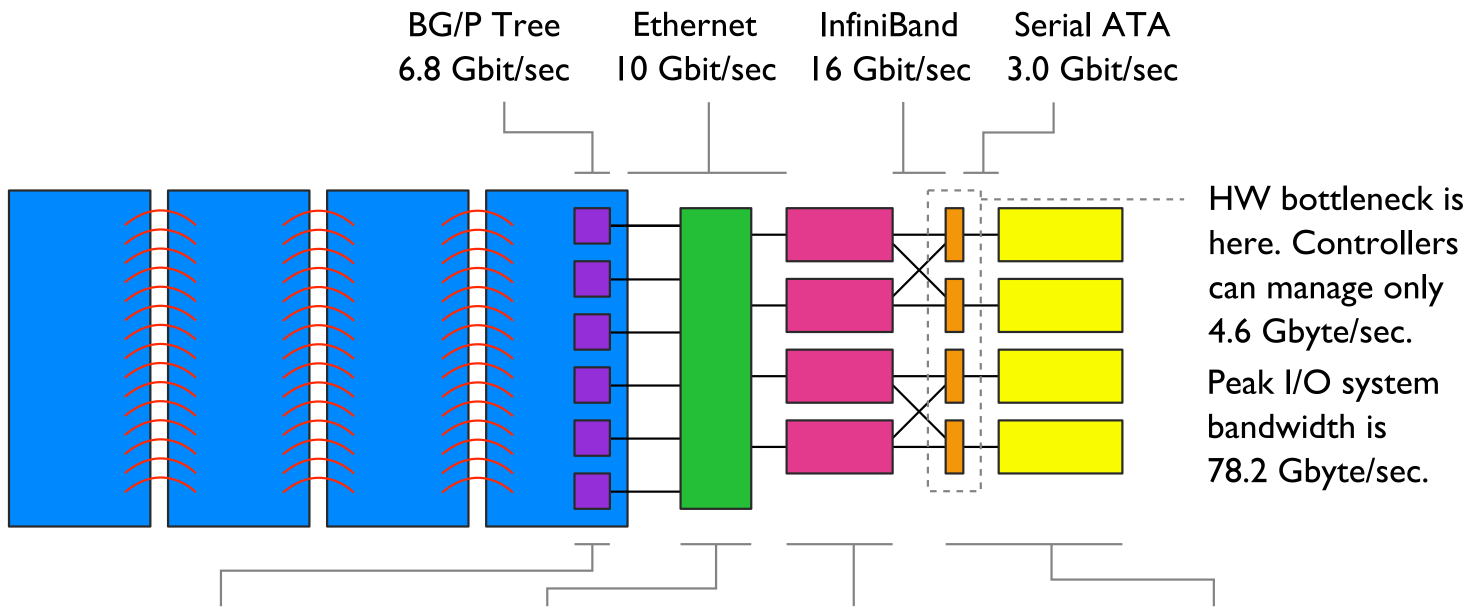
# Introduction

- Current HPC environment separates computation from storage
  - Traditional focus on computation, not I/O
  - Applications require I/O architecture independence
- Many scientific applications are data intensive
- Performance increasingly limited by data-movement

# HPC Architecture




**Gateway nodes** run parallel file system client software and forward I/O operations from HPC clients.

*640 Quad core PowerPC 450 nodes with 2 Gbytes of RAM each*

**Commodity network** primarily carries storage traffic.

*900+ port 10 Gigabit Ethernet Myricom switch complex*

**Storage nodes** run parallel file system software and manage incoming FS traffic from gateway nodes.

*136 two dual core Opteron servers with 8 Gbytes of RAM each*

**Enterprise storage** controllers and large racks of disks are connected via InfiniBand or Fibre Channel.

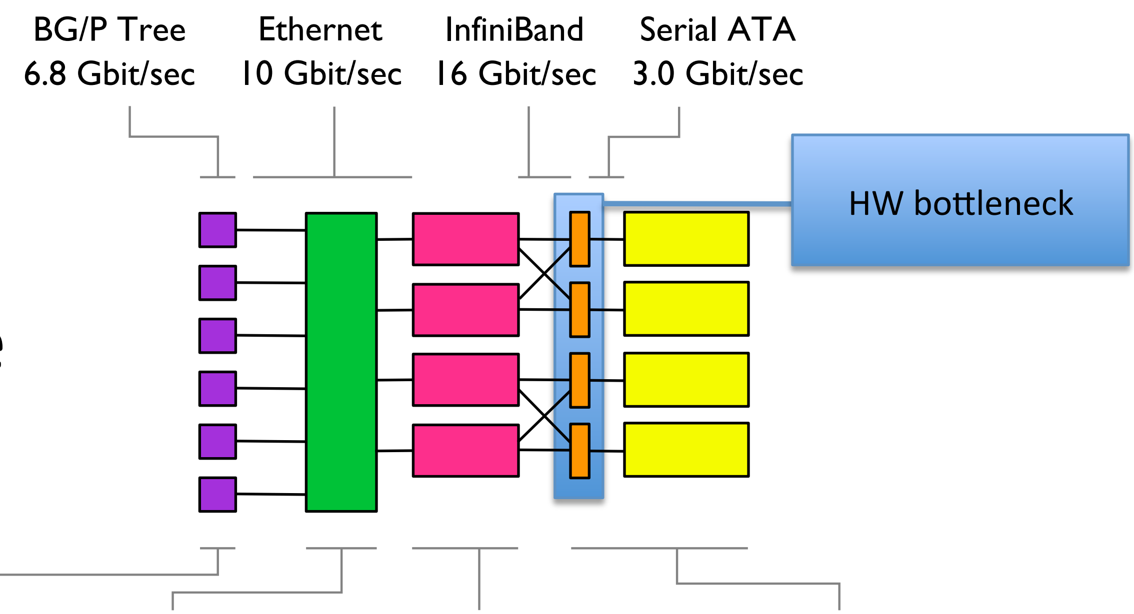
*17 DataDirect S2A9900 controller pairs with 480 1 Tbyte drives and 8 InfiniBand ports per pair*

Architectural diagram of the 557 TFlop IBM Blue Gene/P system at the Argonne Leadership Computing Facility.

Diagram courtesy of Rob Ross, Argonne National Laboratory

# HPC Architecture

Current bottleneck in the controllers

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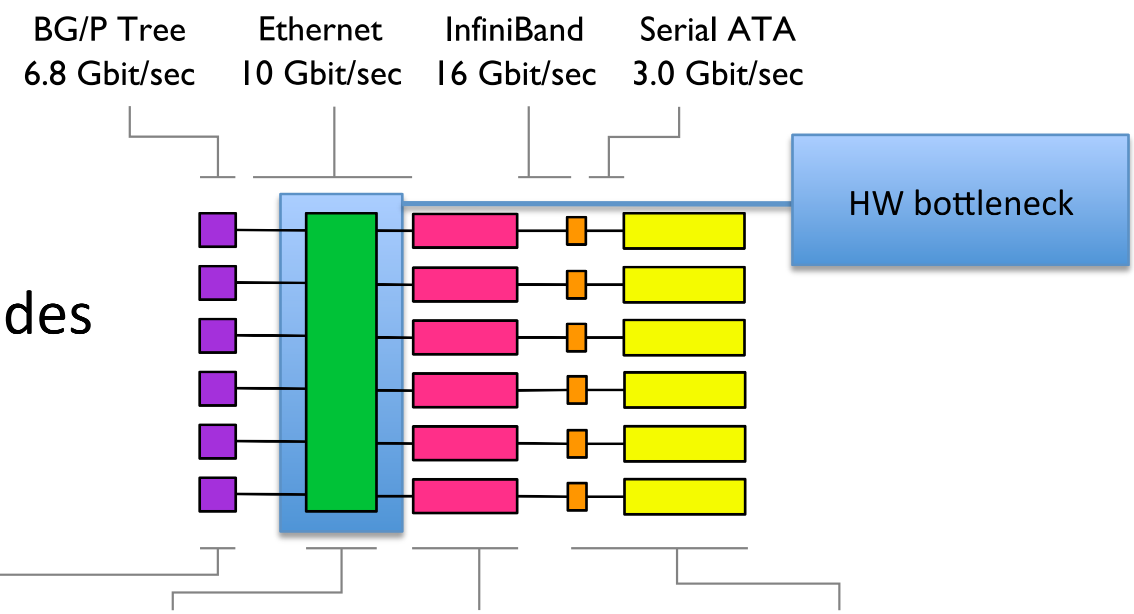
# HPC Architecture

Future bottleneck:
I/O nodes / storage nodes network

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# Approach: Move functions closer to data

- Use spare CPU cycles at intelligent storage nodes
  - Replace communication with CPU cycles
- Provide storage interfaces with higher abstractions
- Enable file system optimizations due to knowledge of data structure
- Do this for small selection of data structures
  - This is **not** another object-oriented database!

# Why Now?

- Parallel file systems move more intelligence into storage nodes anyways
- Advances in performance management and virtualization
- Moving bytes slated to be a dominant cost in exa-scale systems
- Scientific file formats and operators increasingly standard
  - NetCDF, HDF
- Structured abstractions have seen recent success
  - BigTable, MapReduce
  - CouchDB

# Abstract Storage
## Storage as an Abstract Data Type

- ADT decouples interface from implementation
- Only few ADTs necessary, e.g.:
  - Dictionary (Key/value pairs)
  - Hypercube (Coordinate Systems)
  - Queue
- Optimize each one for each parallel architecture
  - Data placement
  - Performance management
  - Buffer cache management (incl. pre-fetching)
  - Coherence

# ADTs and Scientific Data

- Scientific data is normally multi-dimensional, lending itself well to this approach
  - Multi-dimensional and hierarchical structures are readily mapped onto data types
- Multiple structures mapped onto (portions) of the same data for more efficient access
  - Operate on the appropriate structure (matrix, row, element, etc)

# Implementation Challenges

- **Programming model** for implementing ADTs
- Everything based on **byte streams**
  - Current storage APIs (e.g. POSIX)
  - Current file system subsystems
    - Buffer cache
    - Striping strategies
    - Storage node interfaces
- Need awareness of **structured data**
  - New interfaces at various storage layers

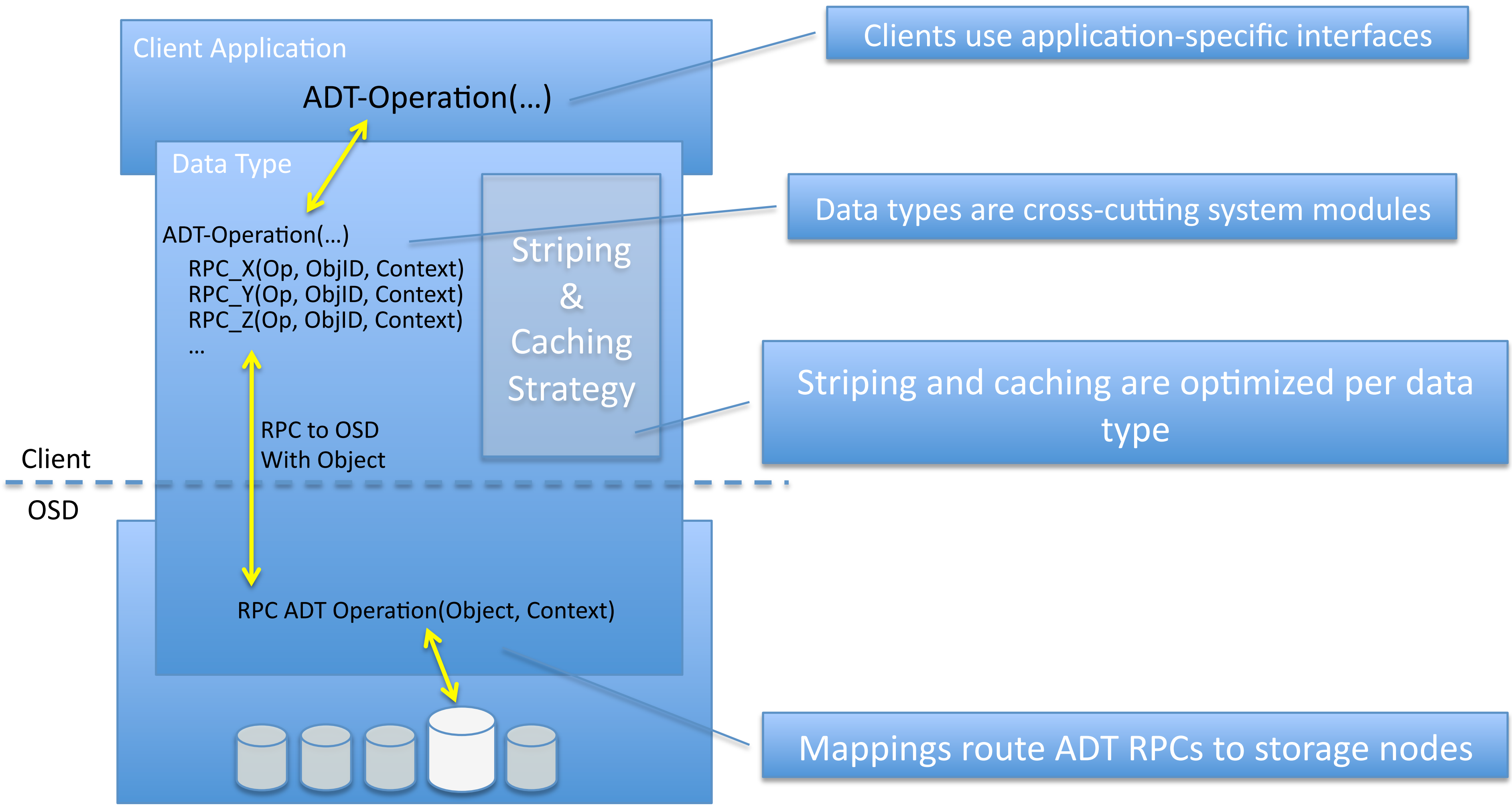
# Prototype: Ceph Doodle

- Focus: Programming model for implementing ADTs
- Construction and test framework for:
  - Storage abstractions
  - ADT implementations
  - Programming models (flexibility, ease-of-use)
- Based on object-based parallel file system architecture (e.g. Ceph).

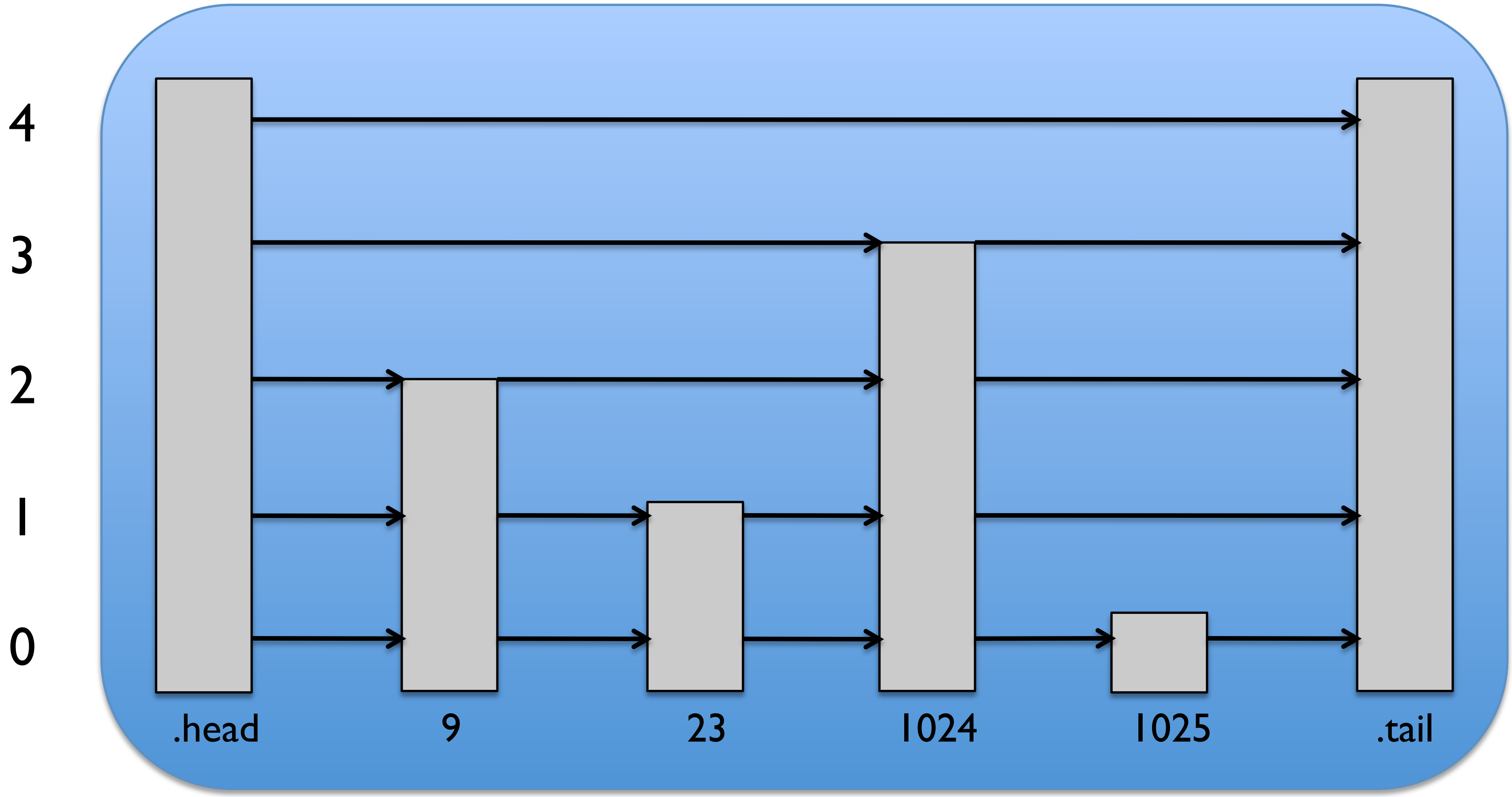
# Ceph Doodle Features

- Rapid prototyping:
  - Uses RPC mechanism
  - Written in Python
- Support for plugins for different ADTs
  - Byte stream (implemented as storage objects)
  - Dictionary (implemented as **skip lists**)

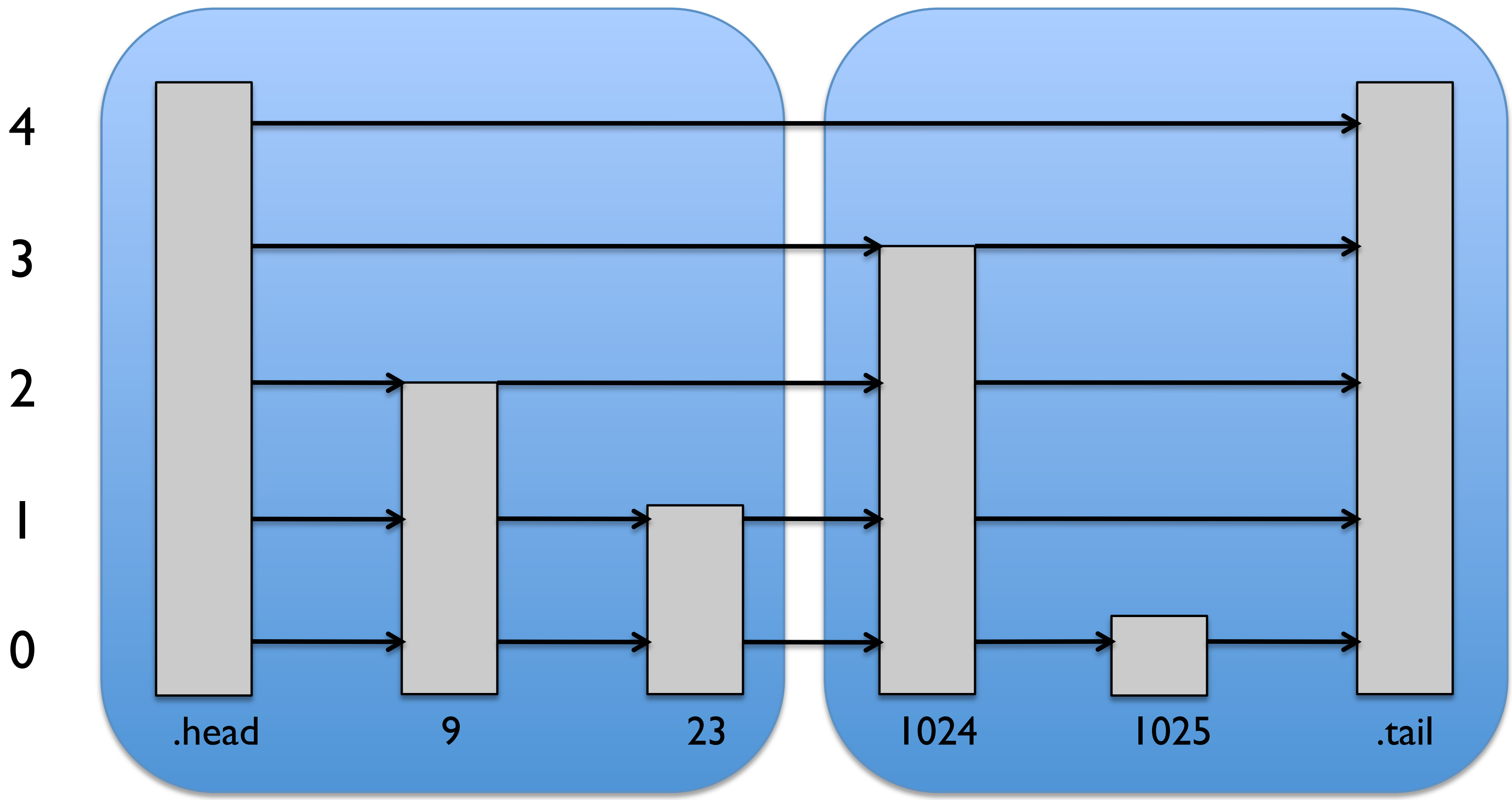
# Ceph Doodle Overview



# Dictionary Implementation: Skip lists



# Splitting skip lists across nodes



# Future Work

- Building on top of Ceph
  - New dynamically loadable object libraries
- Redesigning caching
  - Data structure boundary aware v.s. pages
  - Pre-fetching = access patterns = ADT parameters
- Rethinking striping strategies
- Unified views supported by virtual ADT layer
- Embedding versioning and provenance capturing into file system

# Thank you

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SRL

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