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MarFS and Multi-Tier Erasure

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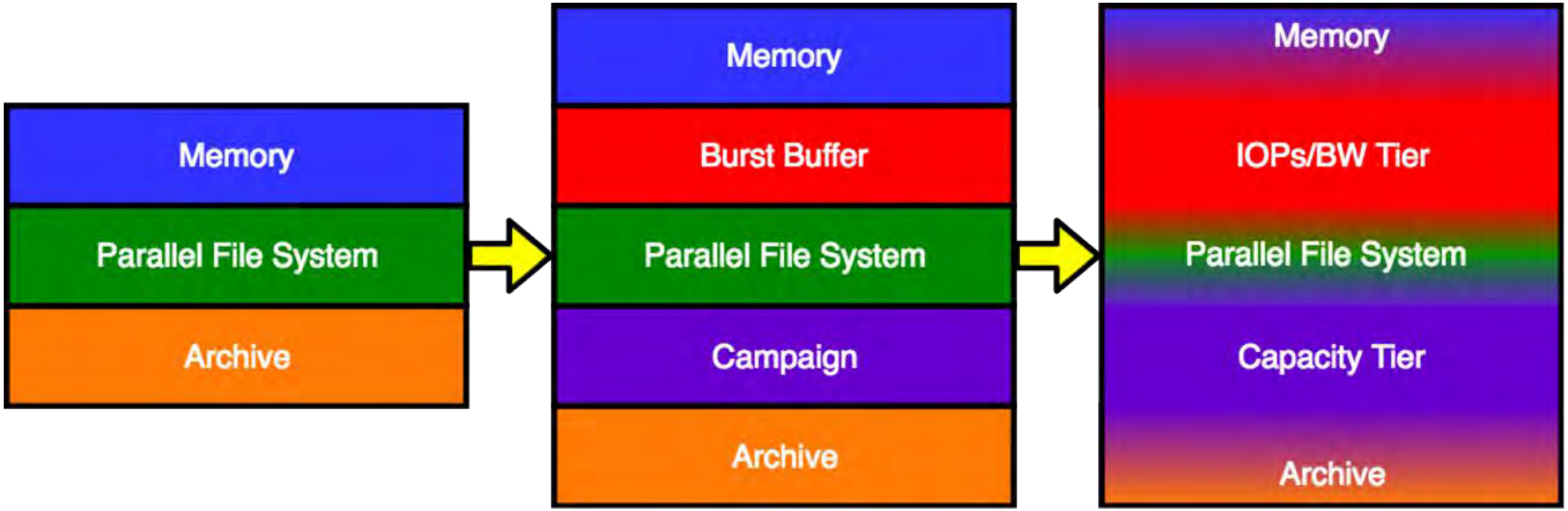
HPC Storage Trends at LANL



HPC Storage Trends at LANL – Capacity Tier

- **Data sets are growing faster than long-term storage can support**
  - Trinity: 2PB of memory / 4PB of flash
  - Crossroads: (maybe) 4PB mem / 10-100PB flash
  - HPSS Archive ~60PB Total, near capacity
- **Bandwidth of archive is a limiting factor**
  - Usable bandwidth of traditional archive (HPSS) ingest is roughly 3 GB/sec
  - HPSS ingests data much faster than it recalls
  - Storing petabytes of job checkpoints is infeasible

Implementing a Capacity Tier

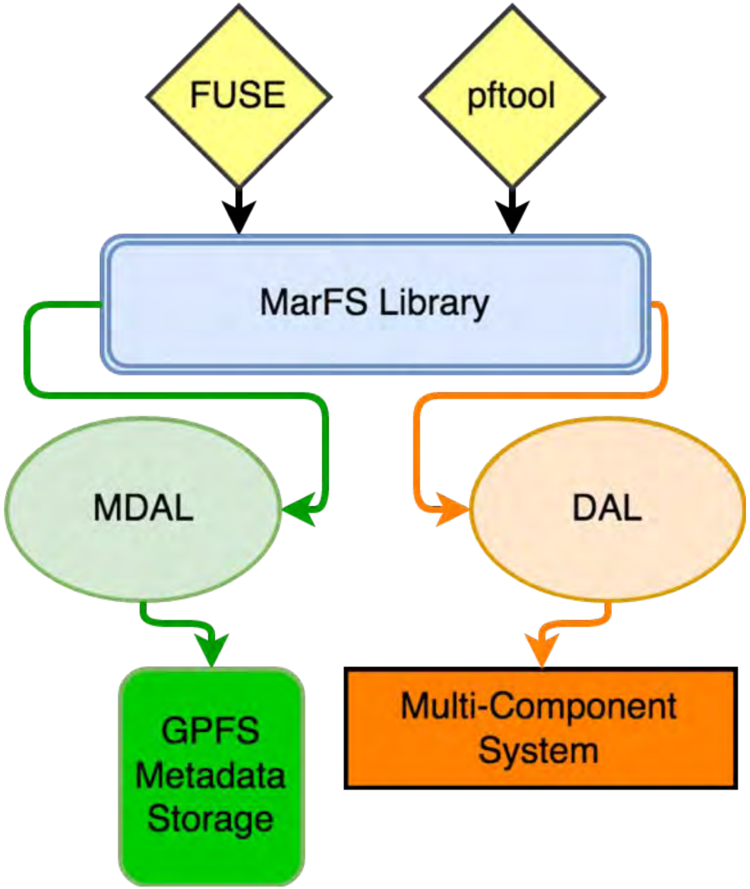
- **Tape is likely not the approach to take**
  - Tape is effective for truly cold data, not data sets that require periodic recall
  - Designing tape storage solutions is complex
- **Object Storage seems promising**
  - Flat namespace allows easy scalability
  - Erasure coding allows for cheaper disk media
- **Object Storage has limitations**
  - Machines love object-IDs, people generally don’t
  - Potentially billions $ in applications expecting ‘POSIX-like’ file trees

What is MarFS?

- **A near-POSIX interface layered over distinct metadata and data implementations**
  - Data stored as erasure coded objects
  - Metadata mirrored within a parallel file system (GPFS)
  - Object IDs stored as extended attributes of metadata files
- **Familiar semantics, fast metadata, stable objects**
  - Storing metadata to a real PLFS gives us POSIX-style directory trees and permissions almost for free
  - Storing data as objects simplifies implementation and data protection
- **With tradeoffs, of course**
  - no update in place or file locking
  - restricted interactive use

The Structure of MarFS

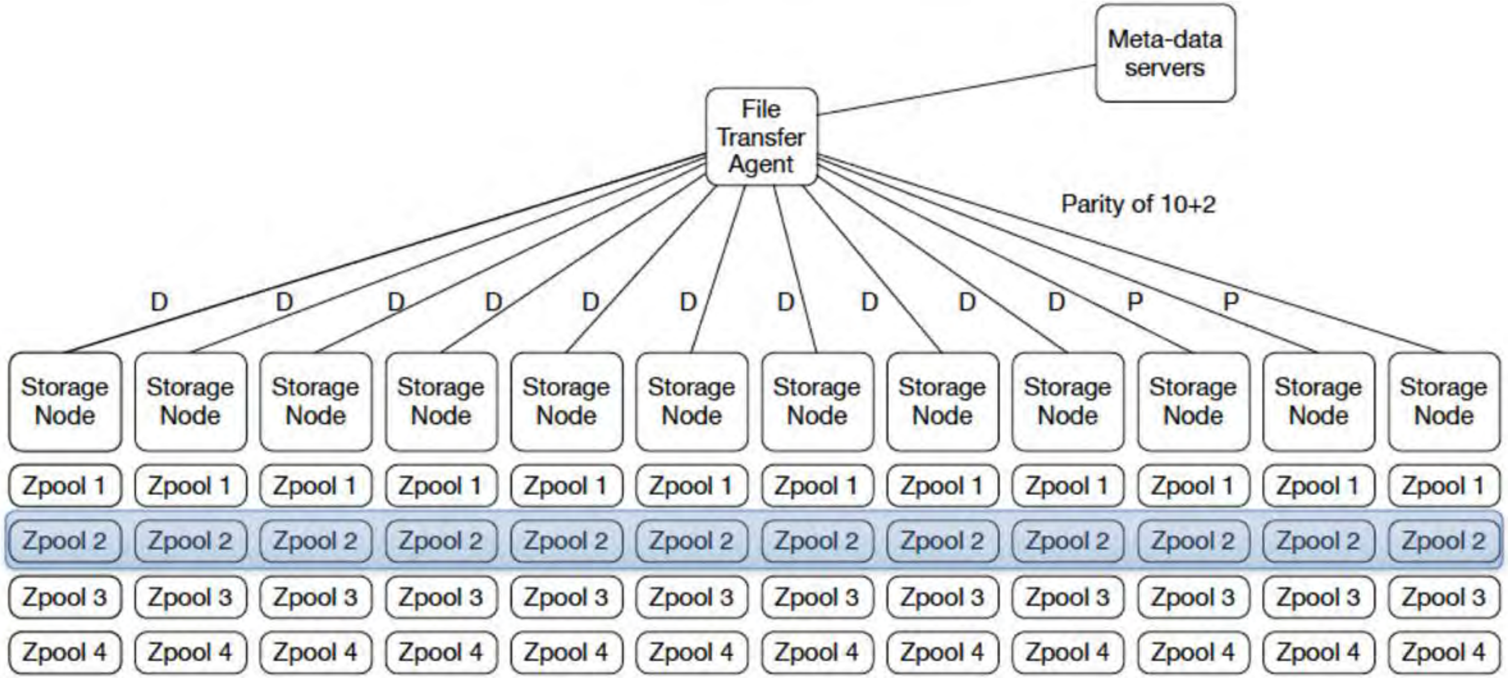
- **Pftool**
  - Parallel MPI file transfer utility
- **FUSE mount**
  - Provides user view of metadata
- **MarFS Library**
  - Heart of the software infrastructure
- **DAL/MDAL**
  - Abstraction layers atop data and metadata respectively
  - Allow easy swapping of underlying storage



Multi-Component

- **Current data storage solution for Campaign**
  - Integrated via the MarFS DAL
  - Stores data as pseudo-objects
- **Cross-server erasure coding atop ZFS pools**
  - Allows failure tolerance at both the disk and server level
  - More reliability allows the use of cheaper disk
  - Erasure coding performed through Intel’s Storage Acceleration Library (isa-l)
- **Performance through parallelism**
  - Threaded I/O to multiple servers

Multi-Component



Meta-data servers

File Transfer Agent

Parity of 10+2

D D D D D D D D D D P P

Storage Node	Storage Node	Storage Node	Storage Node	Storage Node	Storage Node	Storage Node	Storage Node	Storage Node	Storage Node	Storage Node	Storage Node
Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1	Zpool 1
Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2	Zpool 2
Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3	Zpool 3
Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4	Zpool 4

Each Zpool is a 17+3

Storage nodes in separate racks

Multiple JBODs per Storage Node

Data and Parity are round-robined to storage nodes

Storage Nodes NFS export to FTAs

Thanks to Kyle Lamb, Dave Bonnie, and Jeff Inman

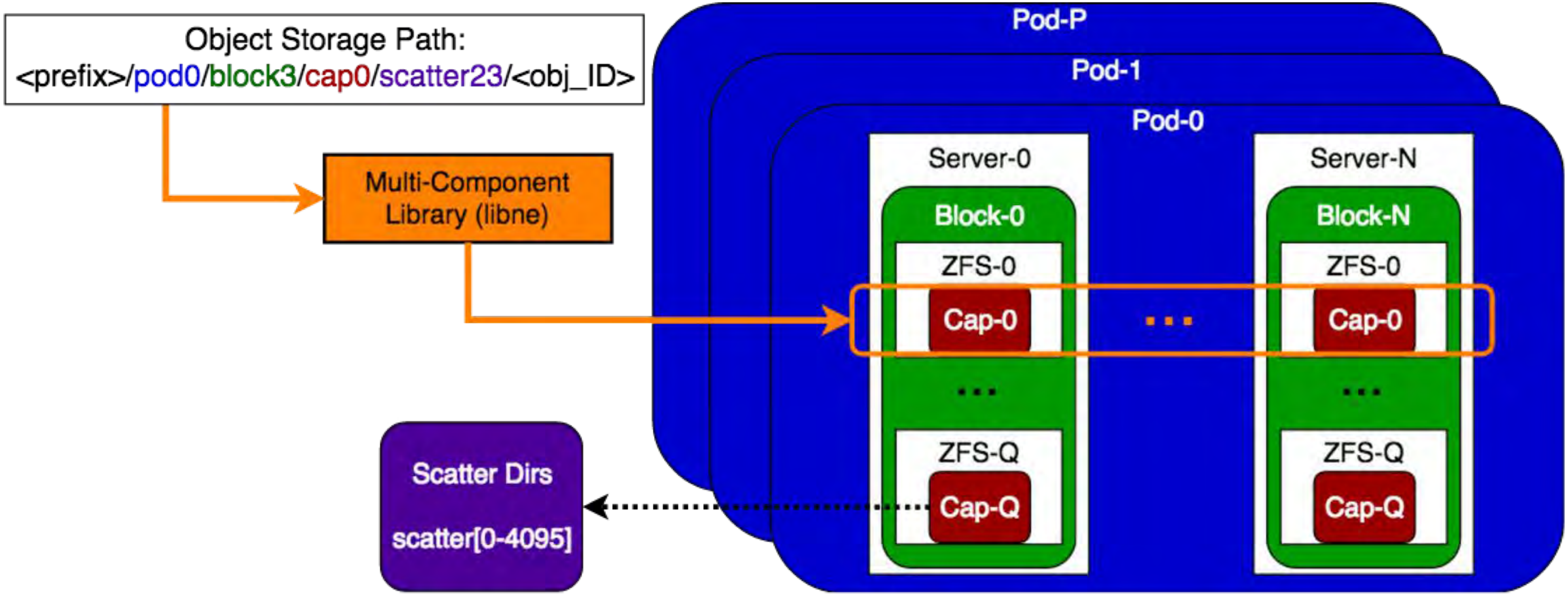
Multi-Component

- **Parallelism**
  - Objects hashed across all available servers
- **Transparency**
  - Object stripes simply stored as files in ZFS
- **Resiliency**
  - Data recoverable even after losing entire server racks

Multi-Component: Parallelism

- **GB Objects are hashed across a multi-level tree**
  - …/pod#/block#/cap#/scatter#/…
    - Pod: Corresponds to a server set (12, for 10+2)
    - Block: Corresponds to an individual starting server (object will still be striped across all servers in a given pod)
    - Capacity-Unit (Cap): Corresponds to a ZFS Pool within each storage server
    - Scatter Directory: Purely logical subdivision to avoid overloaded directories
- **Provides automatic load-balancing**
  - Utilizes all available disk bandwidth, provided enough I/O is issued in parallel

Multi-Component: Parallelism

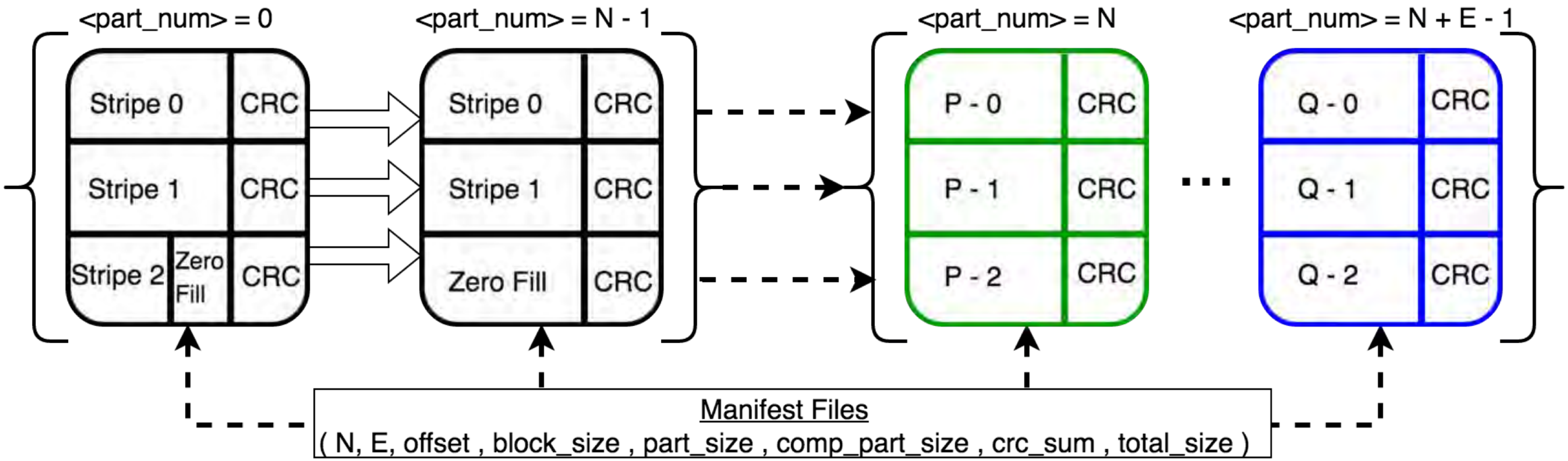


Multi-Component: Transparency

- **Storing to ZFS systems means that objects are plainly visible to administrators**
  - Each object ‘part’ is paired with a manifest file, providing data and erasure structure info
  - Admins can literally ‘ls’ object parts and ‘cat’ manifest info
- **Utilities exist for interacting directly with objects**
  - Read/write data independent of the entire MarFS stack
  - Object integrity checks
  - Erasure rebuild of damaged objects

Multi-Component: Transparency

Storage Path: <prefix>/repo<N>/pod<P>/block<Q>/cap<X>/scatter<Y>/<obj_ID>.<part_num>



<part_num> = 0

<part_num> = N - 1

<part_num> = N

<part_num> = N + E - 1

Stripe 0		CRC
Stripe 1		CRC
Stripe 2	Zero Fill	CRC

Stripe 0	CRC
Stripe 1	CRC
Zero Fill	CRC

P - 0	CRC
P - 1	CRC
P - 2	CRC

...

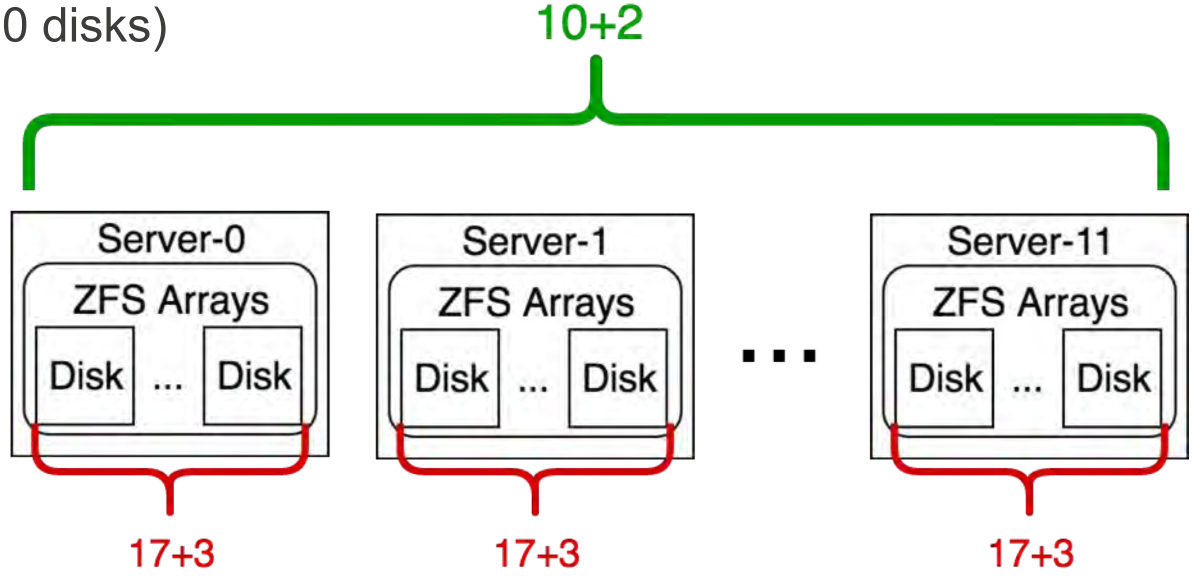
Q - 0	CRC
Q - 1	CRC
Q - 2	CRC

Manifest Files

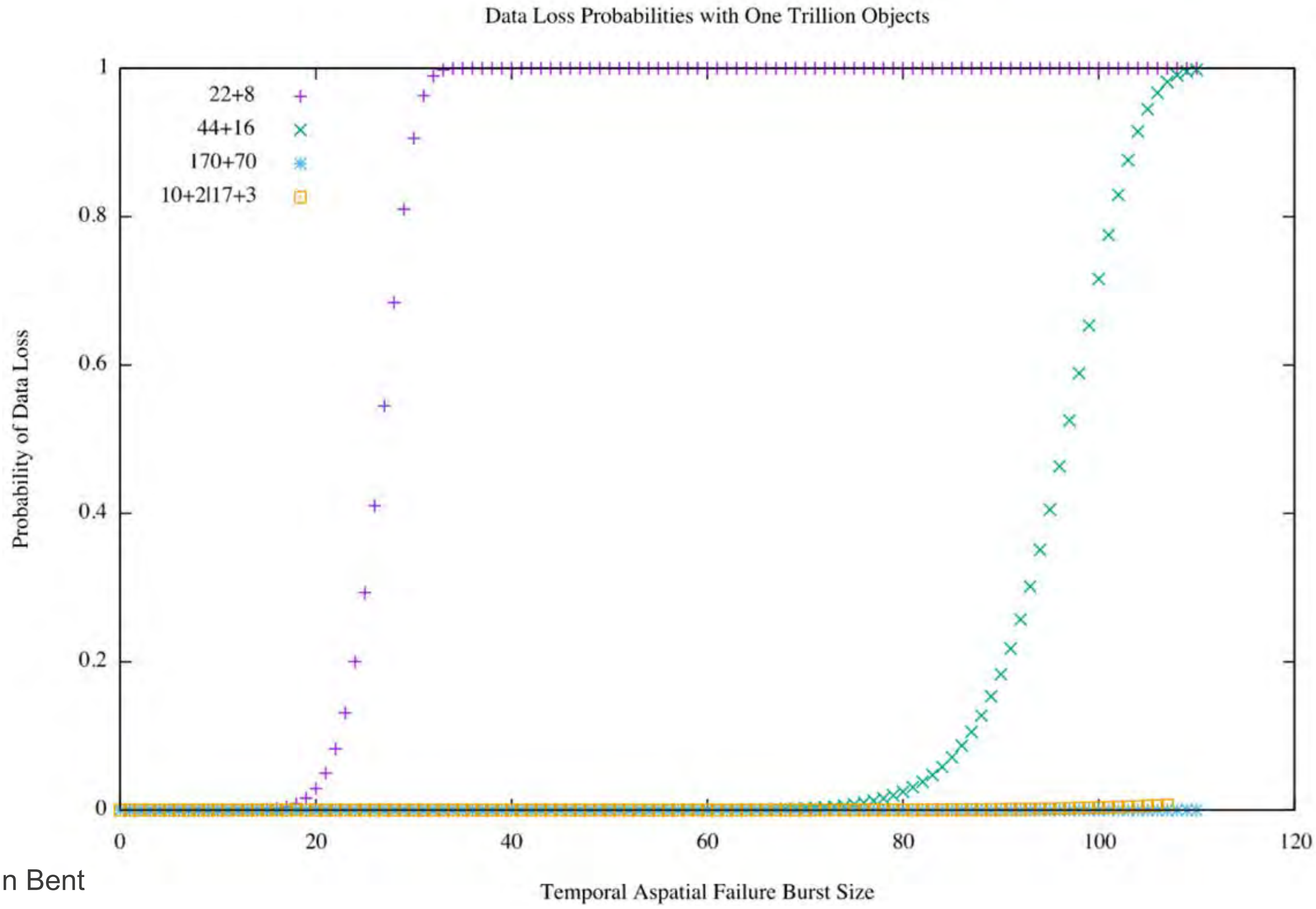
(N, E, offset , block_size , part_size , comp_part_size , crc_sum , total_size)

Multi-Component: Resiliency

- **Multi-tier erasure**
  - Multi-Component: **10+2** across servers
  - ZFS: **17+3** across disks
  - Tolerates min 11 and max 70 disk failures per stripe (set of 240 disks)



Multi-Component: Resiliency

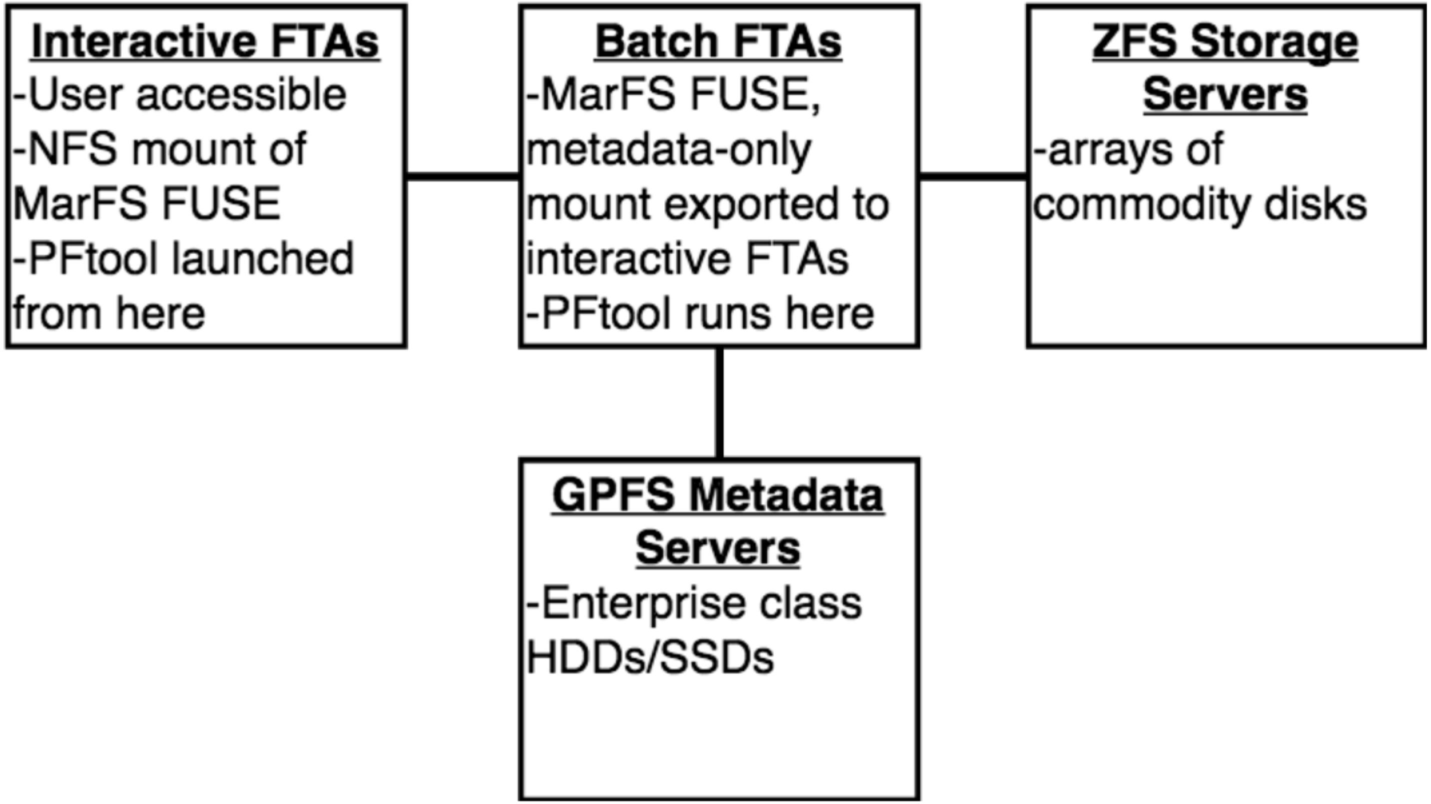


Thanks to John Bent

Multi-Component: Resiliency

- **The Multi-Component Library (libne) automatically responds to read failures and makes use of erasure code if necessary**
- **'Degraded' writes are permitted up to a configurable safety threshold**
  - 10+2 can be written as 10+1 or 9+2 and later rebuilt to full width
- **Any degraded objects detected during read/write are logged**
  - A utility crawls these logs and calls into the Multi-Component Library to rebuild objects
  - The rebuilder utility can also be run against entire capacity-units to assess overall health or recover from catastrophic failures

Deployment



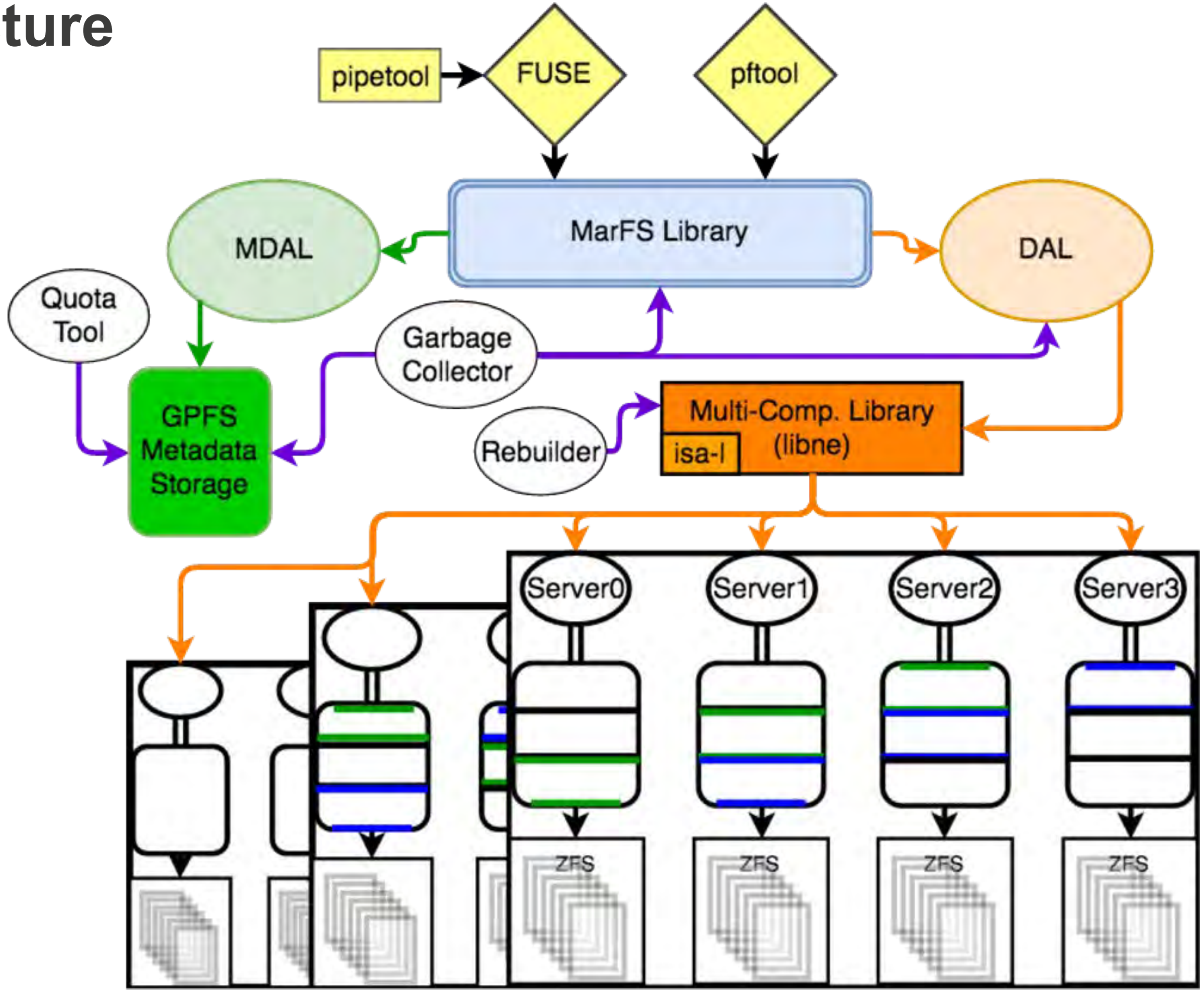
Interactive FTAs
-User accessible
-NFS mount of MarFS FUSE
-PFtool launched from here

Batch FTAs
-MarFS FUSE, metadata-only mount exported to interactive FTAs
-PFtool runs here

ZFS Storage Servers
-arrays of commodity disks

GPFS Metadata Servers
-Enterprise class HDDs/SSDs

The Big Picture



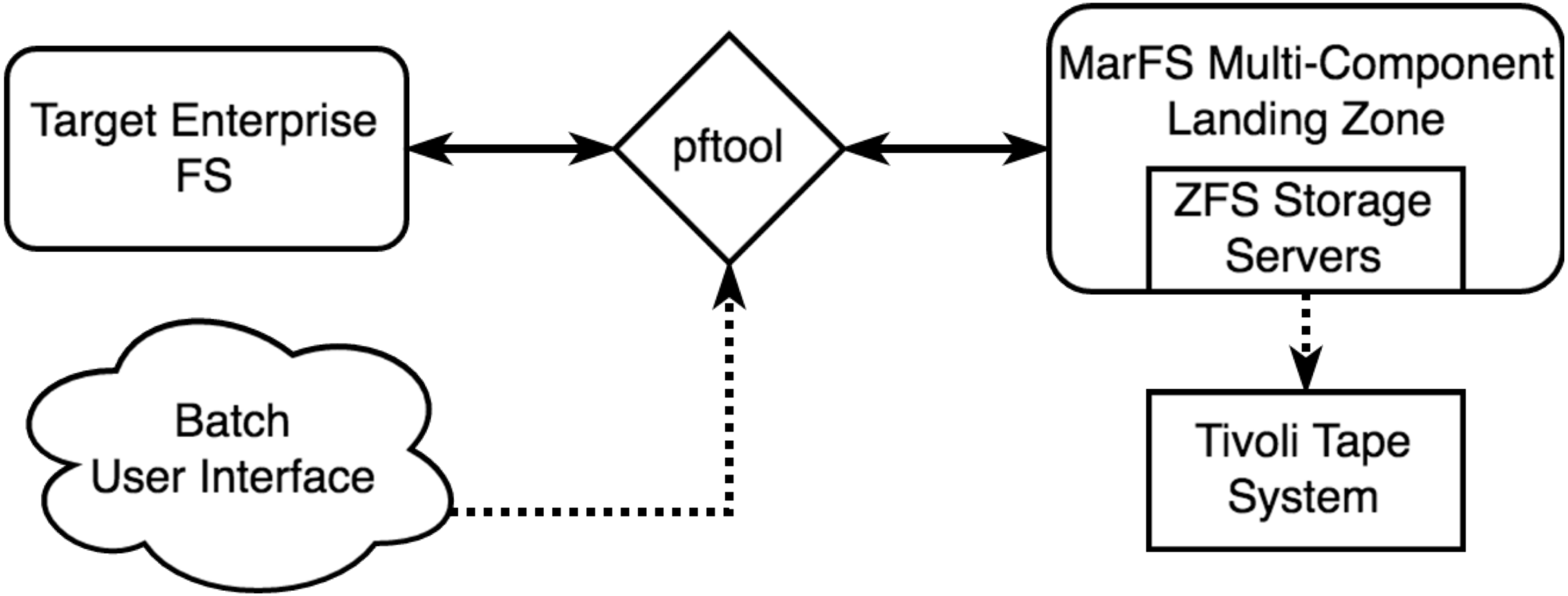
Current Status

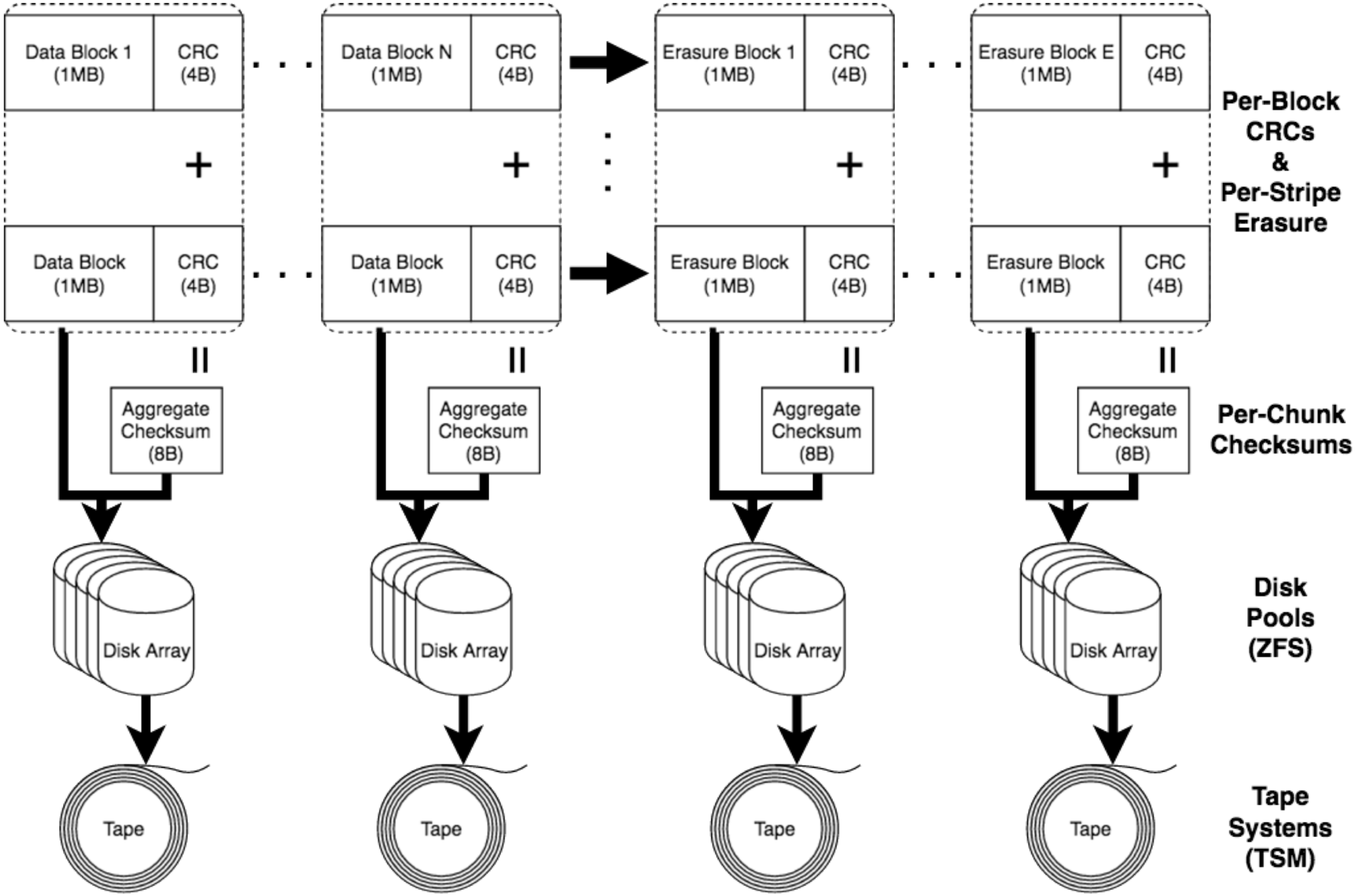
- **MarFS Multi-Component has been in production use for two years now**
  - 5 interactive and 25 batch FTAs
  - 60PB of total storage
  - Roughly 25 GB/sec aggregate bandwidth for both read and write
  - NFS seems to be the bottleneck
- **Additional deployments in progress for this year**
- **Infiniband RDMA based Multi-Component currently in development**
  - Initial testing yielded 35 GB/sec with a fraction of the mpi ranks

Future Work

- **Better documentation and administrator controls**
- **Capacity-unit migration**
  - Migration of objects to new storage with no downtime
- **Job scheduling for transfers?**
  - Current lack of scheduling means simultaneous transfers always compete for resources
- **Tape-backed MarFS Multi-Component (Marchive)**

Marchive Conceptual Implementation




Data Block 1 (1MB)
CRC (4B)
Data Block N (1MB)
CRC (4B)
Erasure Block 1 (1MB)
CRC (4B)
Erasure Block E (1MB)
CRC (4B)
+
Data Block (1MB)
CRC (4B)
Erasure Block (1MB)
CRC (4B)
=
Aggregate Checksum (8B)
Disk Array
Tape
Per-Block CRCs & Per-Stripe Erasure
Per-Chunk Checksums
Disk Pools (ZFS)
Tape Systems (TSM)

Github Organization – https://github.com/mar-file-system

- **MarFS – https://github.com/mar-file-system/marfs**
- **LibNE – https://github.com/mar-file-system/erasureUtils**

Pftool – https://github.com/pftool/pftool