ZFS Overview

Dominic Kay
Sun Microsystems Ltd.

Trouble with Existing File Systems?

Good for the time they were designed, but...

No Defense Against Silent Data Corruption

Any defect in datapath can corrupt data... **undetected**

Difficult to Administer–Need a Volume Manager

Volumes, labels, partitions, provisioning and lots of limits

Older/Slower Data Management Techniques

Fixed block size, dirty region logging

What is ZFS?

A new way to manage data

End-to End Data Integrity

With check-summing and copy-on-write transactions

Immense Data Capacity

The world's first 128-bit file system

Easier Administration

A pooled storage model – no volume manager

Data Services

Snapshots
Clones
Replication

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Integrated Data Services

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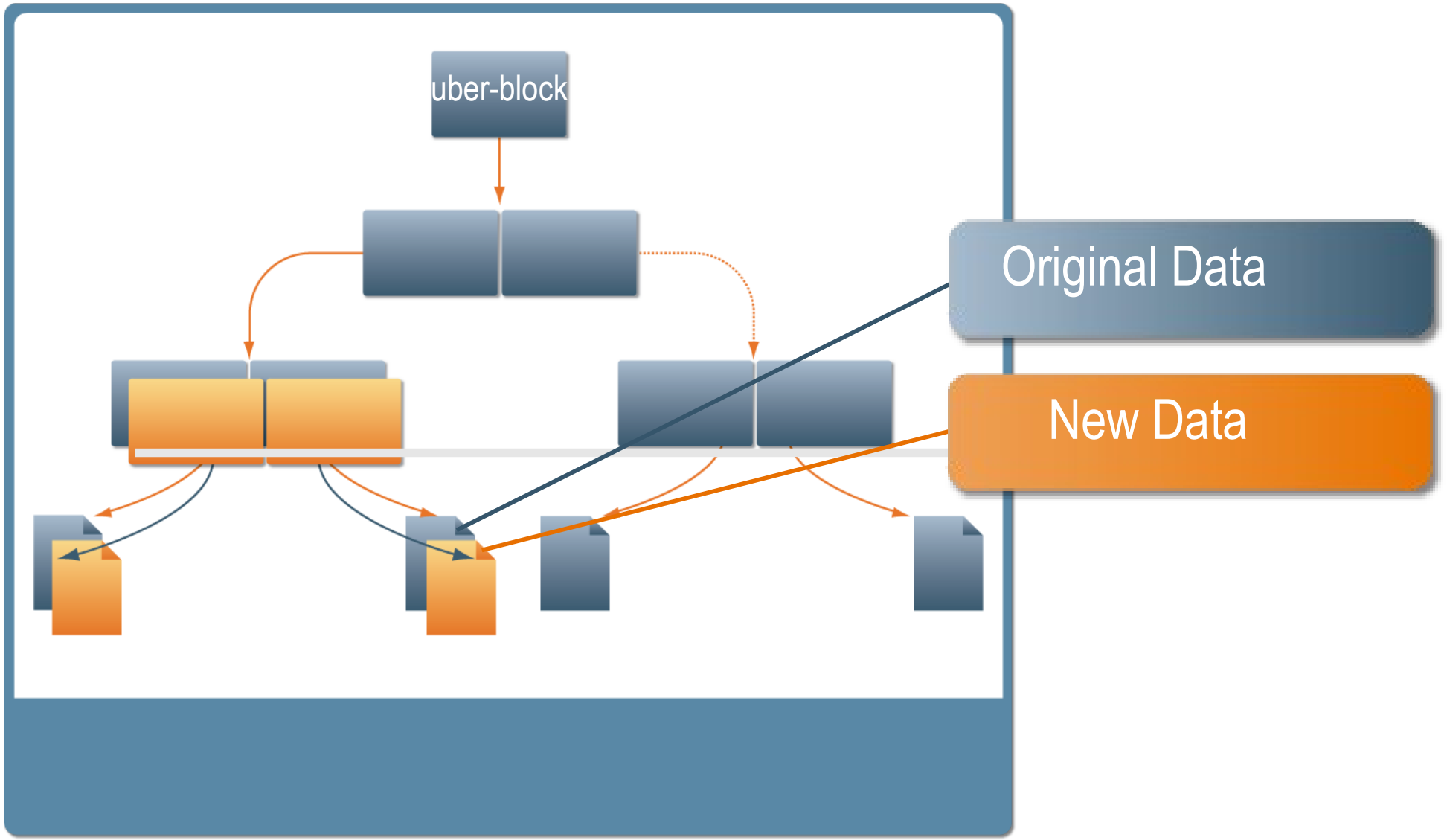
Compression

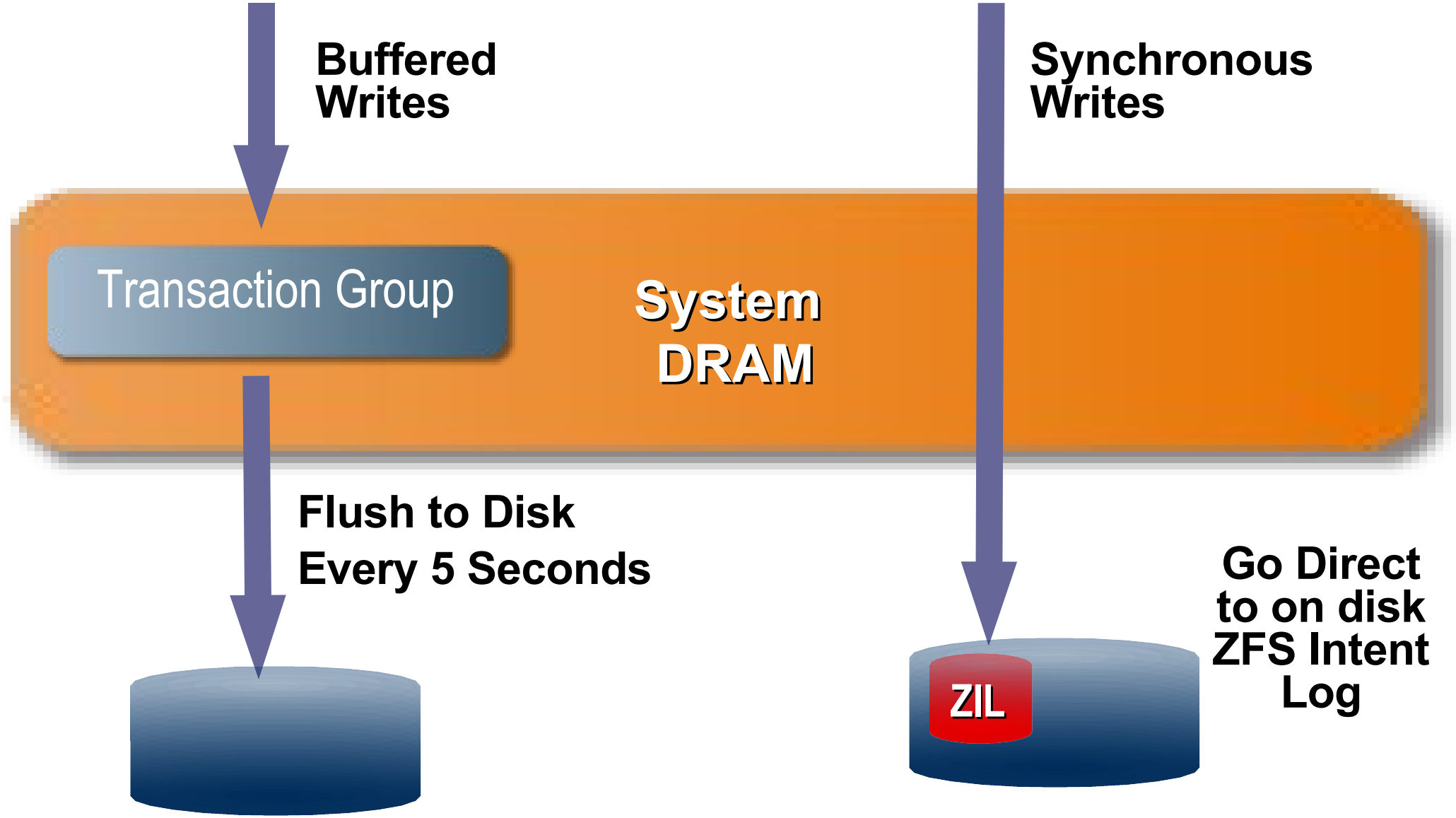
Copy-on-Write

Never Overwrite Existing Data



Transactional

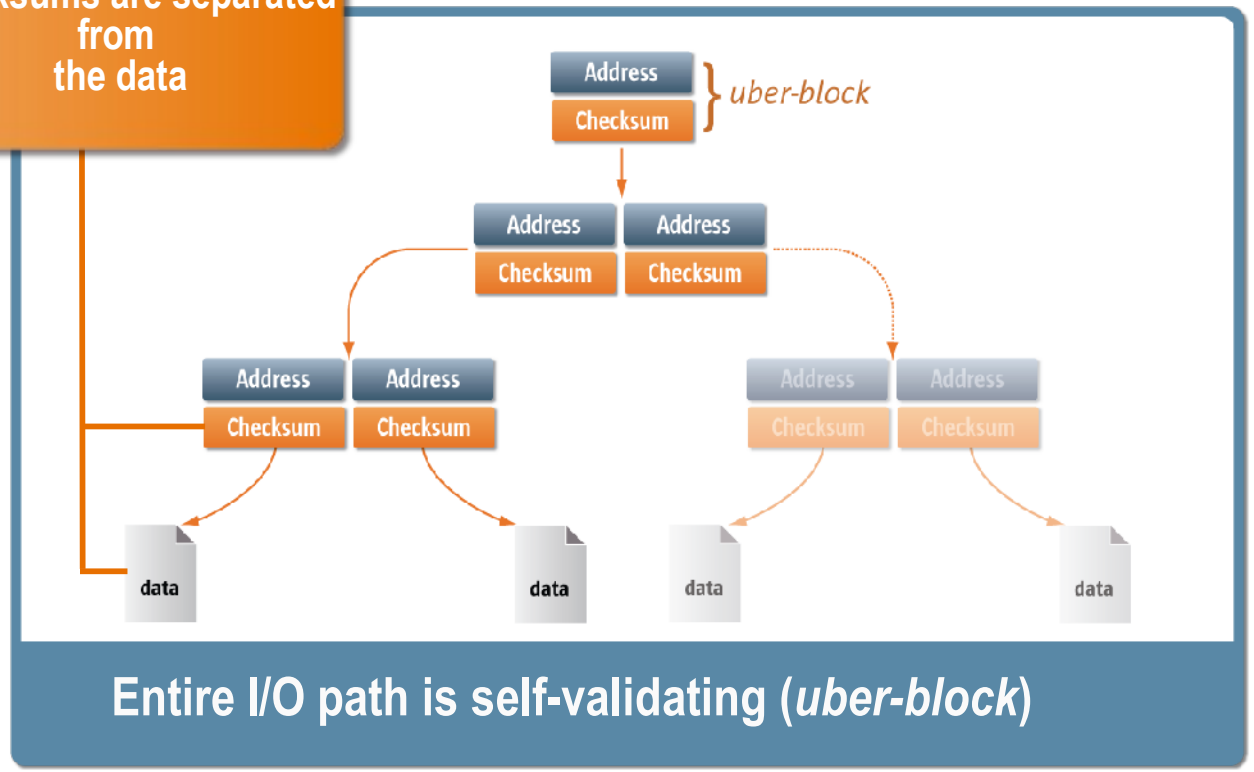
Always Consistent On Disk



How Do We Know What We Just Read Was What We Wrote ?

End-to-End Checksums

Checksums are separated from the data



Prevents:

- Silent data corruption
- Panics from corrupted metadata
- Phantom writes
- Misdirected reads and writes
- DMA parity errors
- Errors from driver bugs
- Accidental overwrites

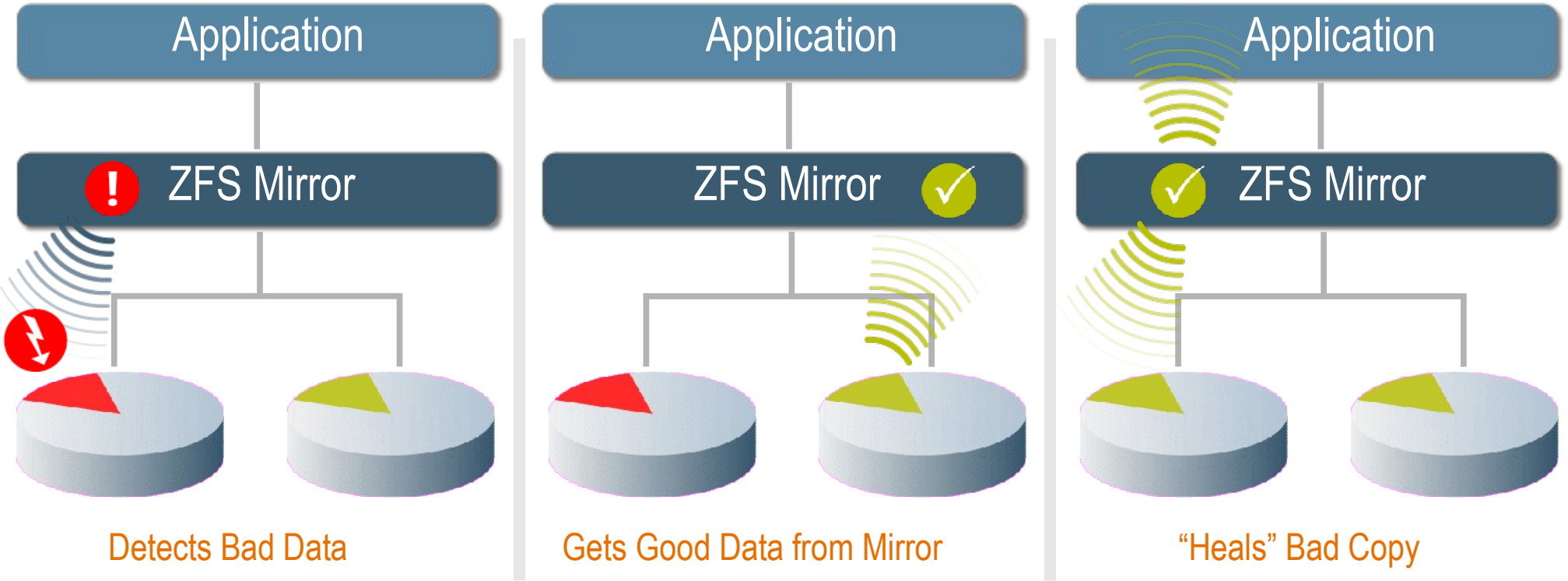
Redundant Copies of Data

Software RAID Protection

- RAID=Redundant Array of *Inexpensive* Disks
- ZFS supports
  - Stripes (RAID-0)
  - Mirroring (RAID-1)
  - RAID-Z (Similar to RAID-5)
  - RAID-Z2 (Double parity, similar to RAID-6)
- ZFS Transactional Design means no “RAID-5 write hole” when using RAID-Z

Self-Healing Data

- Checksums are used to validate blocks
- If a Bad Block is found ZFS can repair it so long as it has another copy
- RAID-1 - ZFS can “heal” bad data blocks using the mirrored copy
- RAID-Z/Z2 - ZFS can “heal” bad data blocks using parity



Detects Bad Data

Gets Good Data from Mirror

“Heals” Bad Copy

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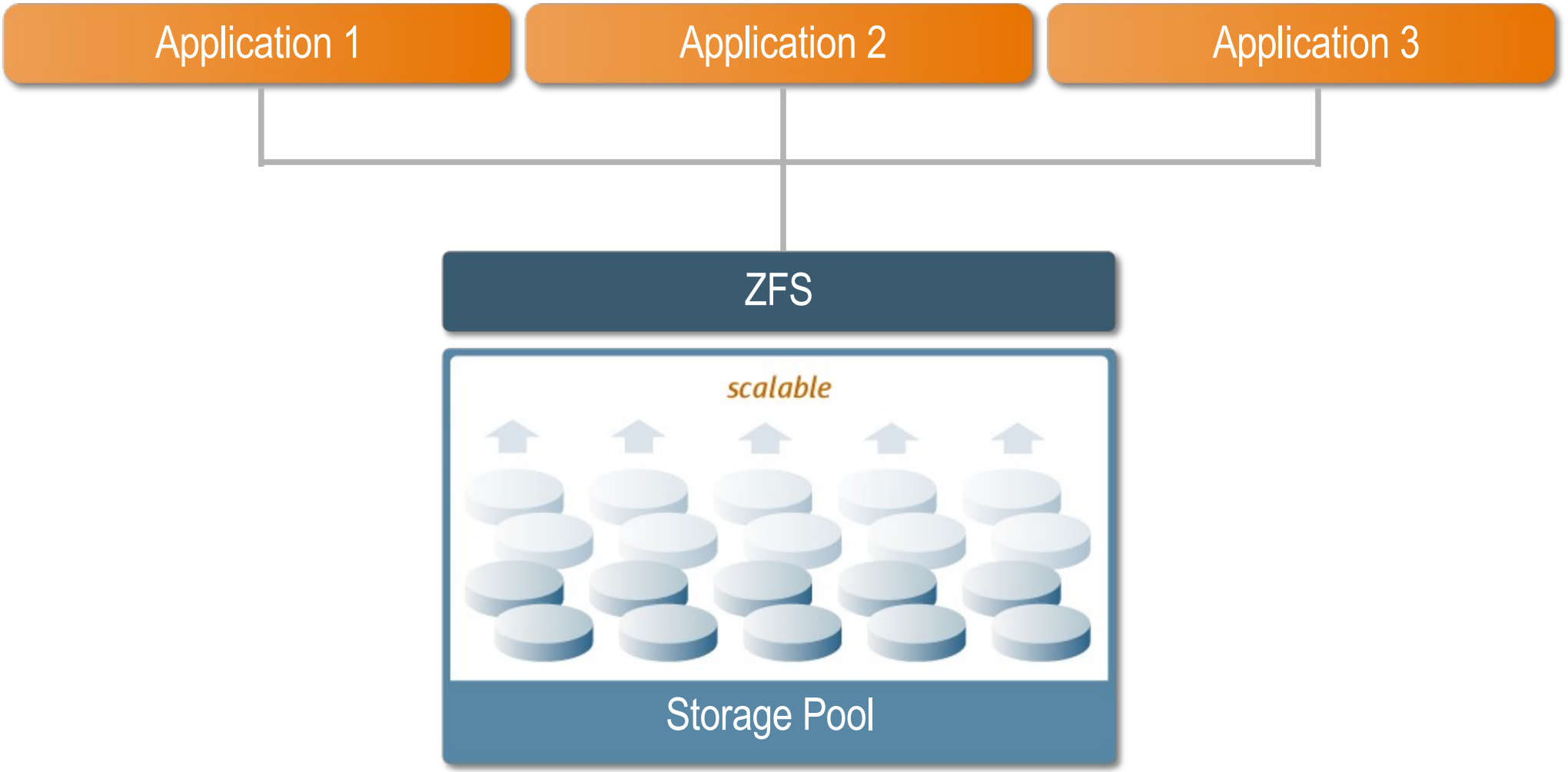
No More Volume Manager!

Automatically add capacity to shared storage pool



Volume Management Made Simple

Solaris Volume Manager + UFS

Partition disks using format

Set up state replicas

```
# metadb -a -f c1t0d0s6 c2t0d0s6 ...
```

Initialise the disks

```
# metainit -f d1 1 2 c1t0d0s6 c1t1d0s6
# metainit -f d2 1 2 c2t0d0s6 c2t1d0s6
```

Construct a mirror

```
# metainit d0 -m d1
# metattach d0 d2
```

Create soft partitions

```
# metainit d10 -p d0 5g
# metainit d11 -p d0 5g
```

Create the file systems

```
# newfs /dev/md/dsk/d10
# newfs /dev/md/dsk/d11
```

Mount them

```
# mkdir /u01 /u02
# mount /dev/md/dsk/d10  /u01
# mount /dev/md/dsk/d11  /u02
```

Persist the mount points in /etc/vfstab

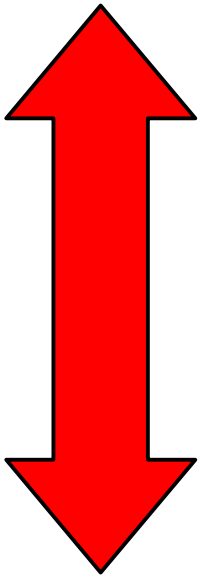
Solaris ZFS

Create a zpool

```
# zpool create tank mirror c1t0d0 c2t0d0 mirror c1t1d0 c2t1d0
```

Create and mount the file systems

```
# zfs create zpool/u01 -o quota=5g
# zfs create zpool/u02 -o quota=5g
```



With just 2 disks SVM would take ~15 minutes, ZFS ~2 minutes

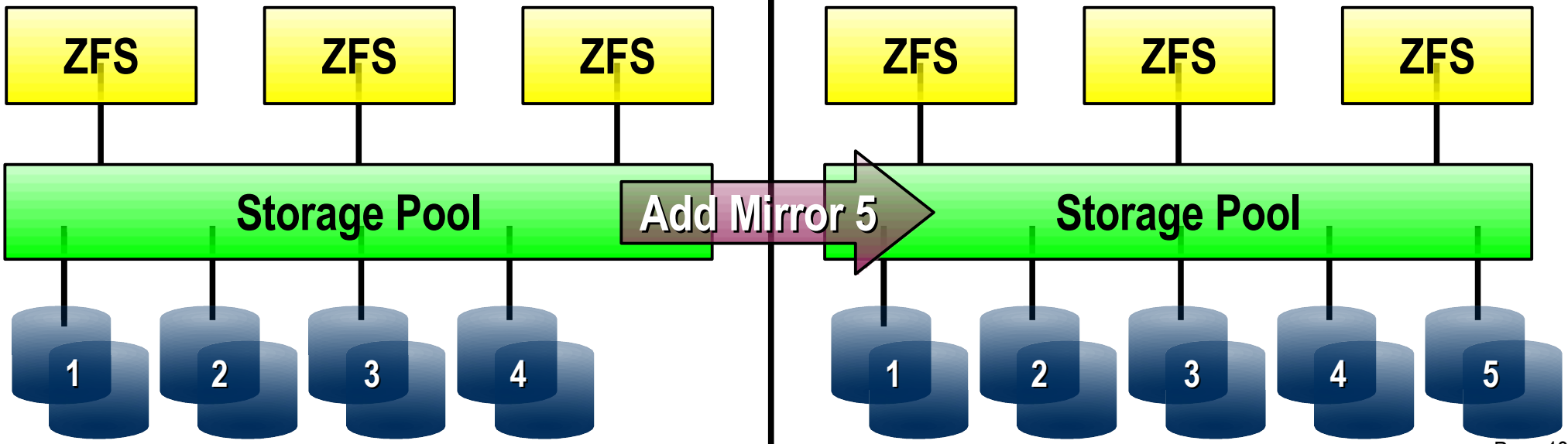
With dozens of disks the time saving would be even greater...

Dynamic Striping

Automatically Distributes Load Across All Device

- Writes: striped across all four mirrors
- Reads: wherever the data was written
- Block allocation policy considers:
  - > Capacity
  - > Performance (latency, BW)
  - > Health (degraded mirrors)

- Writes: striped across all five mirrors
- Reads: wherever the data was written
- No need to migrate existing data
  - > Old data striped across 1-4
  - > New data striped across 1-5
  - > COW gently reallocates old data



ZFS File Systems Security

- ZFS ACLs allow fine grain access control
- File systems become control points
- File system properties are inherited
- Inheritance makes administration a snap
- Manage logically related file systems as a group
- Responsibilities can be delegated

Config Data is Stored within the Data

- When the data moves, so does its config info

Pools can be Exported and Imported

- Allows pools to be moved between systems
- Pools persist between OS upgrades

"Adaptive Endian-ness"

- Hosts always write in their native "endian-ness"

Opposite "Endian" Systems

- Write and copy operations will eventually byte swap all data!

Storage Pool Migration

Easier Administration

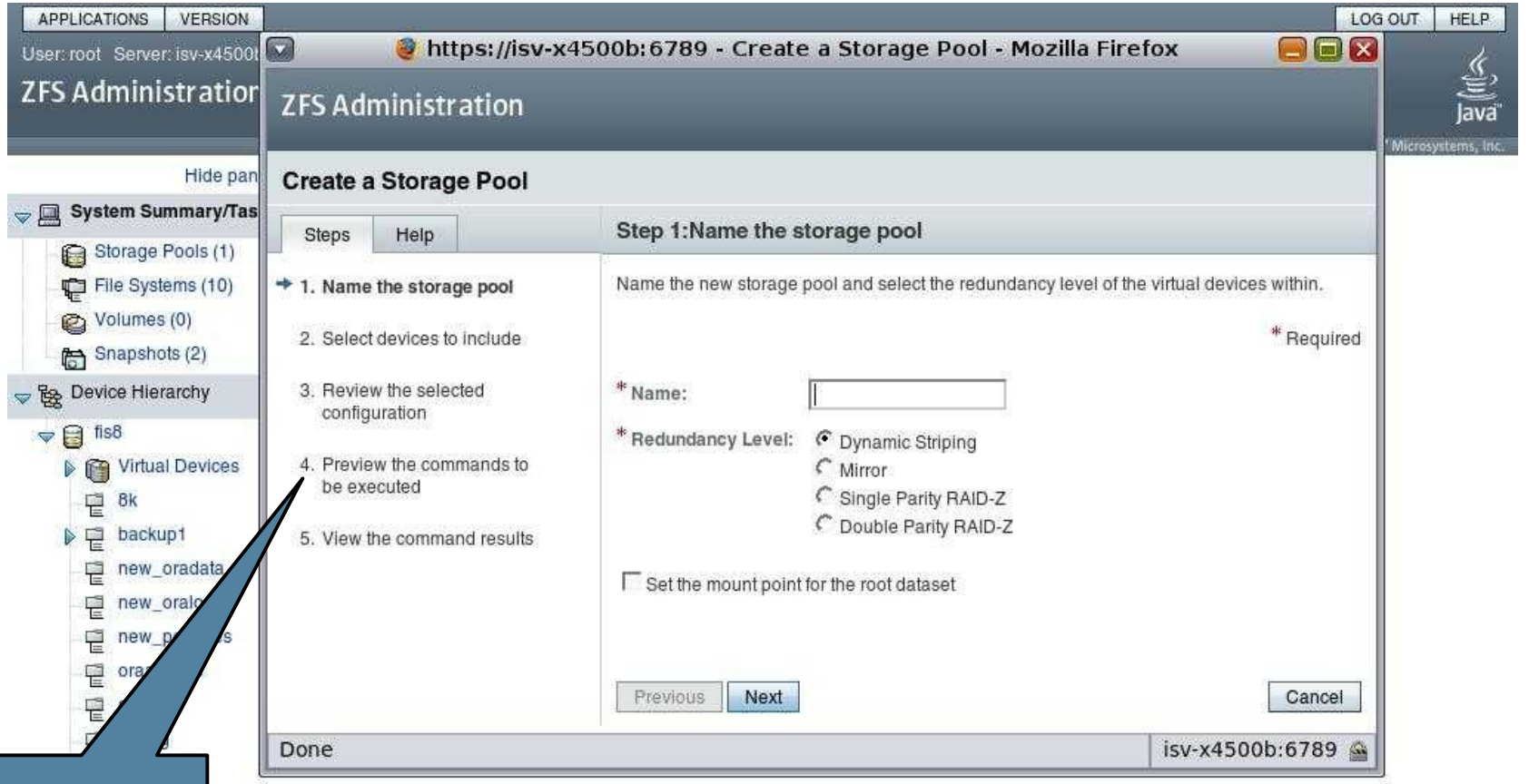
- Pooled Storage Design makes for Easier Administration
- Straightforward Commands and a GUI

Easier Administration

Web Based GUI

Easier Administration

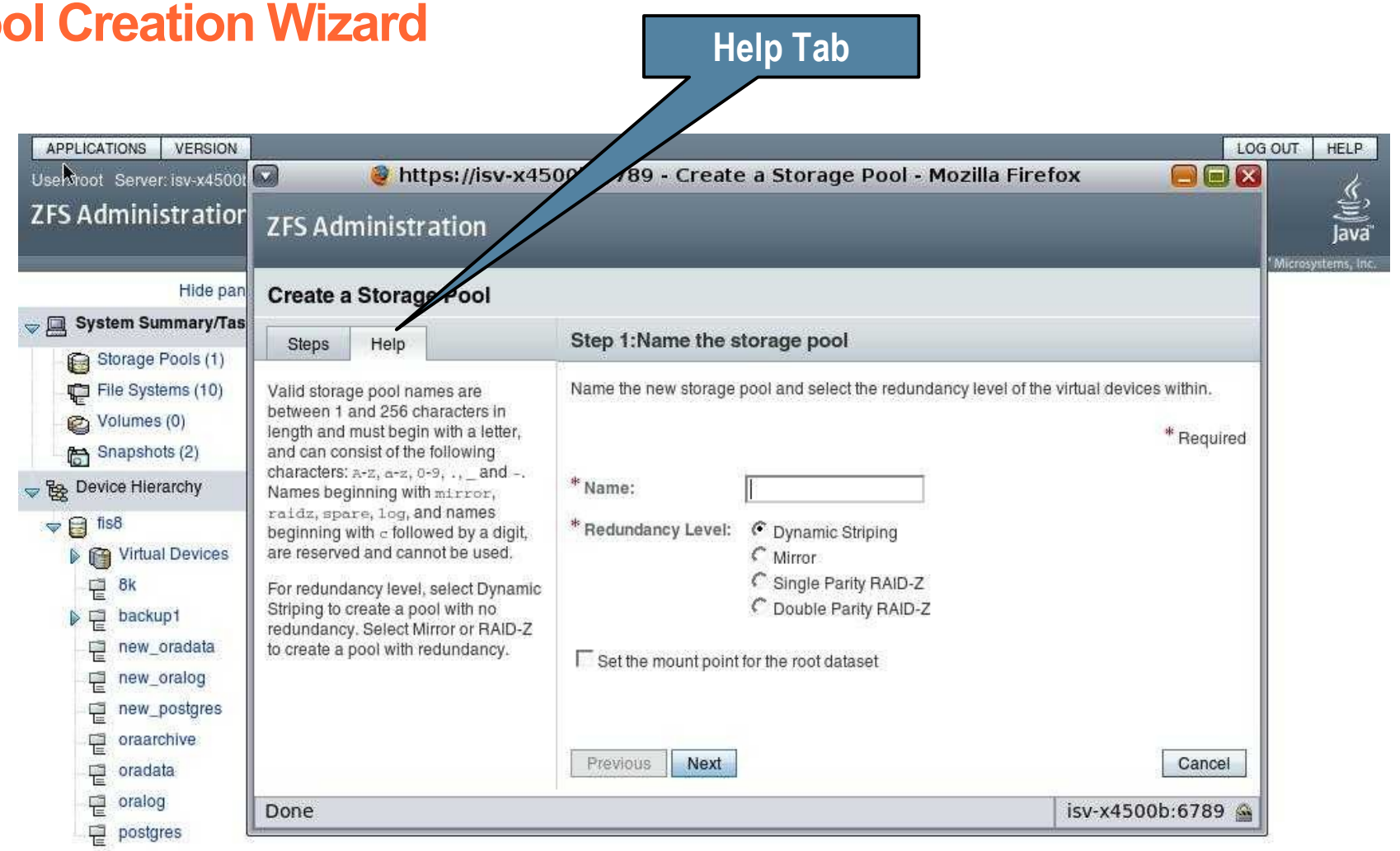
Pool Creation Wizard



Can Save Commands as a Shell Script

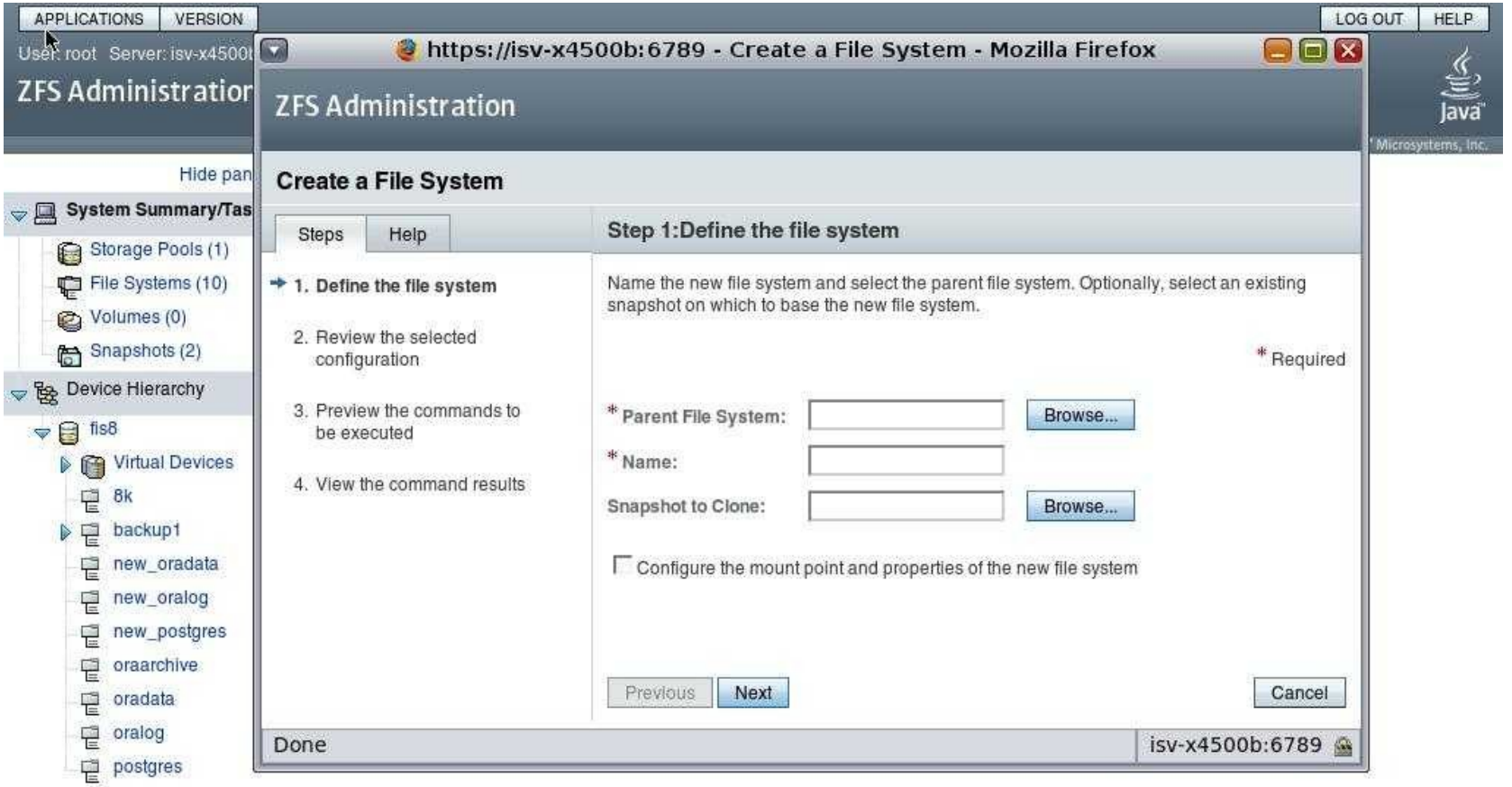
Easier Administration

Pool Creation Wizard



Easier Administration

File System Creation Wizard



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Integrated Data Services

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Clones
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128-bit File System

No Practical Limitations on File Size, Directory Entries, etc.

Concurrent Everything

Uses capacity efficiently

Immense Data Capacity

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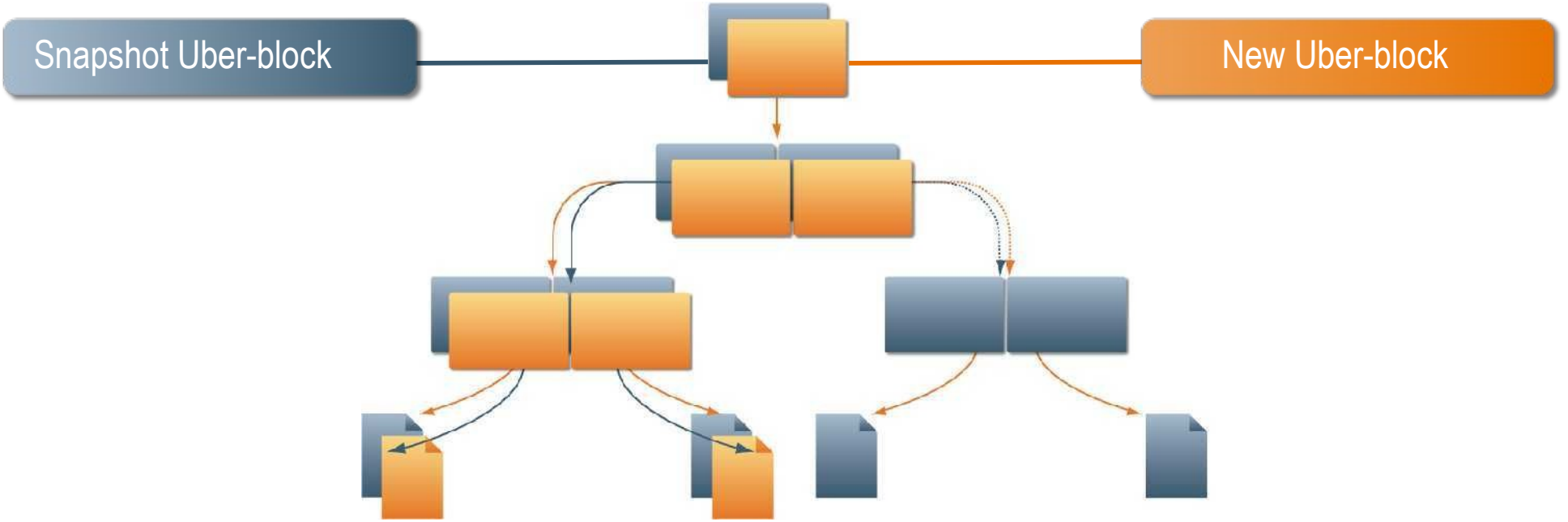
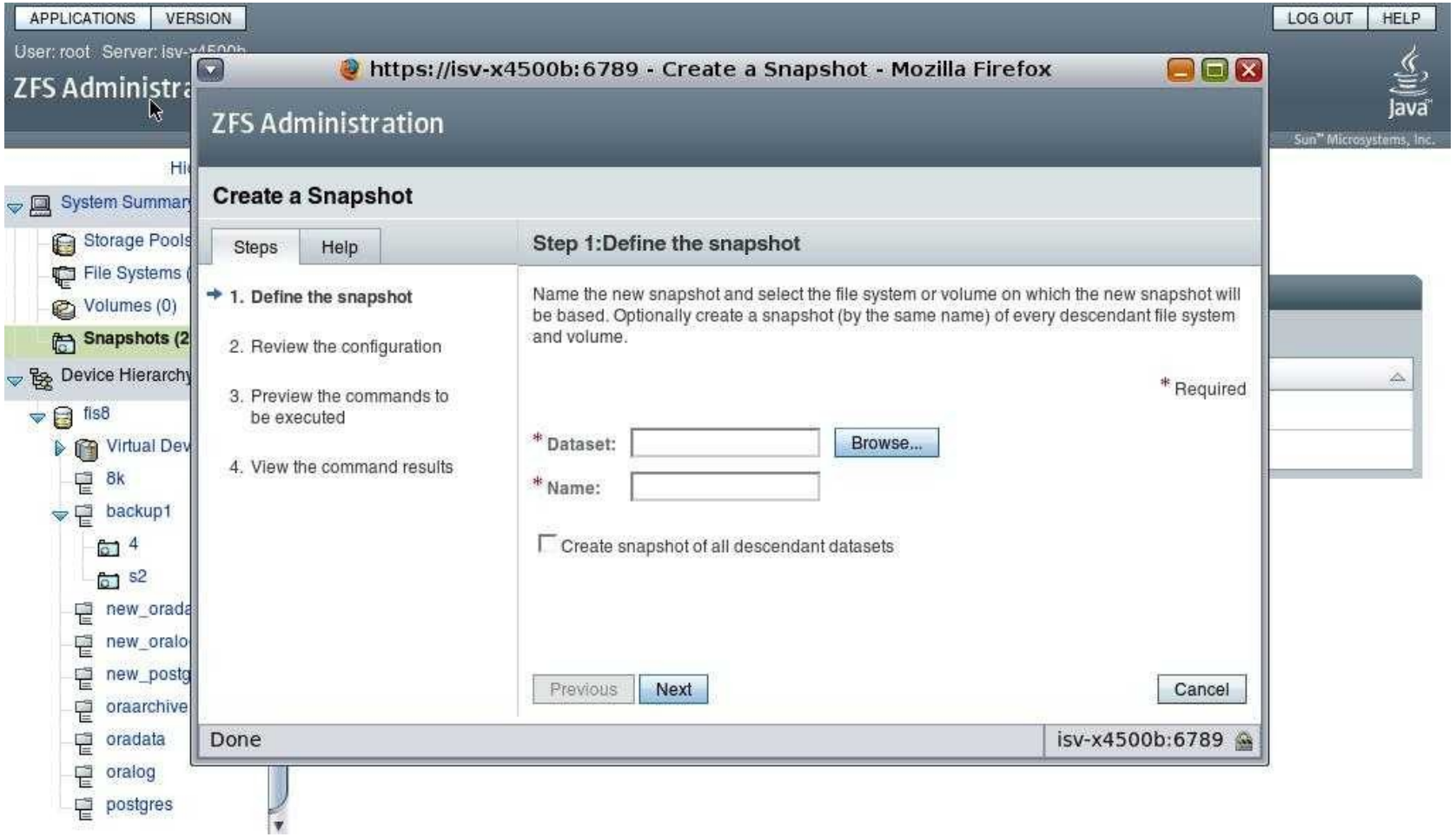
ZFS Snapshots

- Provide a read-only point-in-time copy of file system
- Copy-on-write makes them essentially “free”
- Very space efficient – only changes are tracked
- And instantaneous – just doesn't delete the copy



Easier Administration

Snapshot Creation Wizard



ZFS Clones

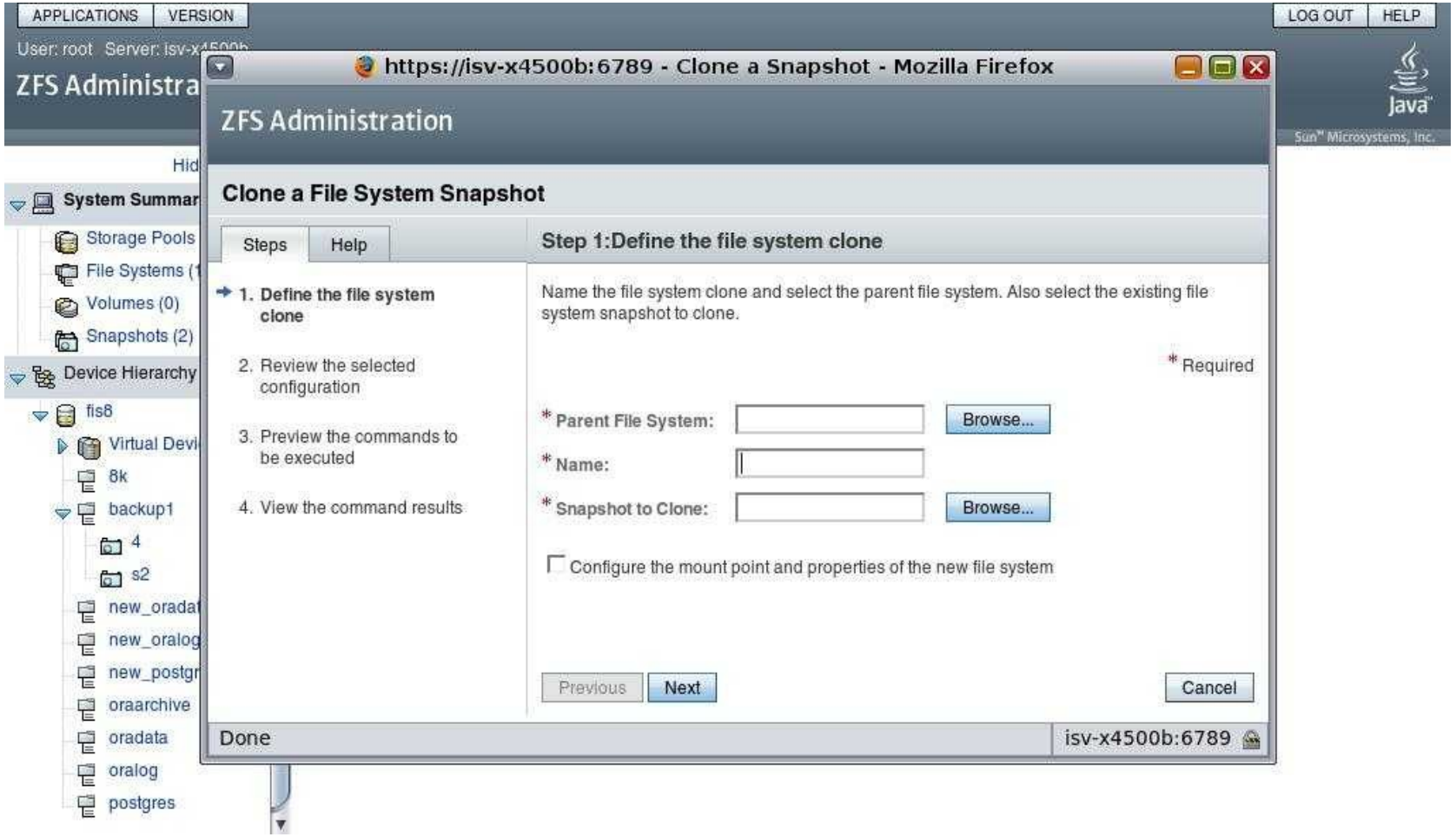
- A Clone is a **Writable** copy of a snapshot

```
# zfs clone tank/myfiles@monday tank/myclone
```

- Near instant creation
- Uses zero space until changes are made to the Clone
- Can safely make available multiple writable copies of the same data to multiple users using clones without making full physical copies
- You can make snapshots of Clones
- Clones can be promoted to replace original file system

Easier Administration

Clone Creation Wizard



Replication
ZFS Send/Receive

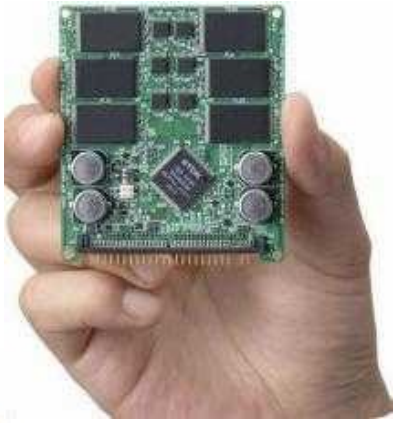
- Powered by snapshots
  - > Full backup: any snapshot
  - > Incremental backup: any snapshot delta
- Generate a full backup to another system

```
# zfs send tank/fs@A | ssh host2 zfs recv newtank/fs
```

- Generate an incremental backup

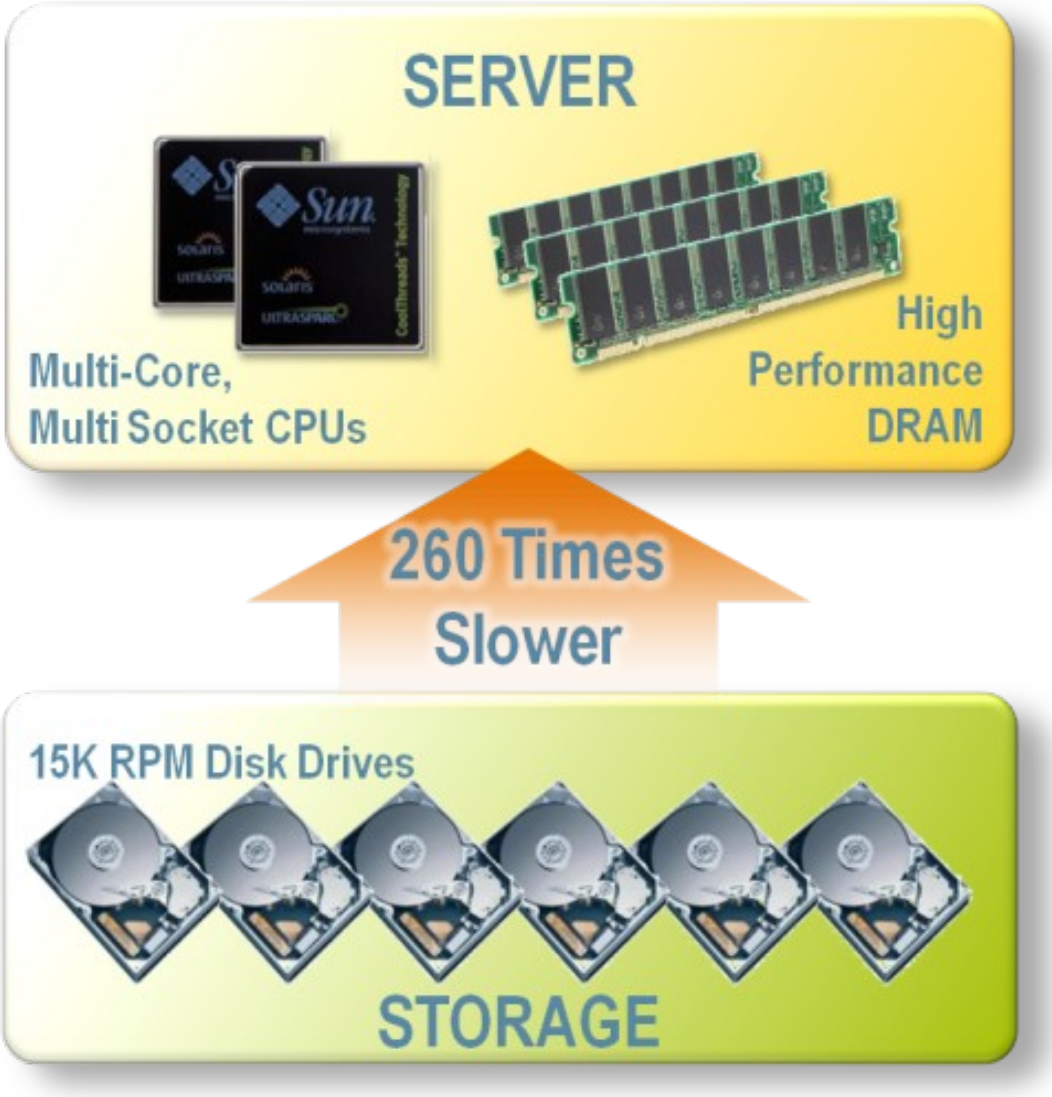
```
# zfs send -i tank/fs@A tank/fs@B | ssh host2 zfs recv newtank/fs
```

Solid State Disks, ZFS & Hybrid Storage Pools



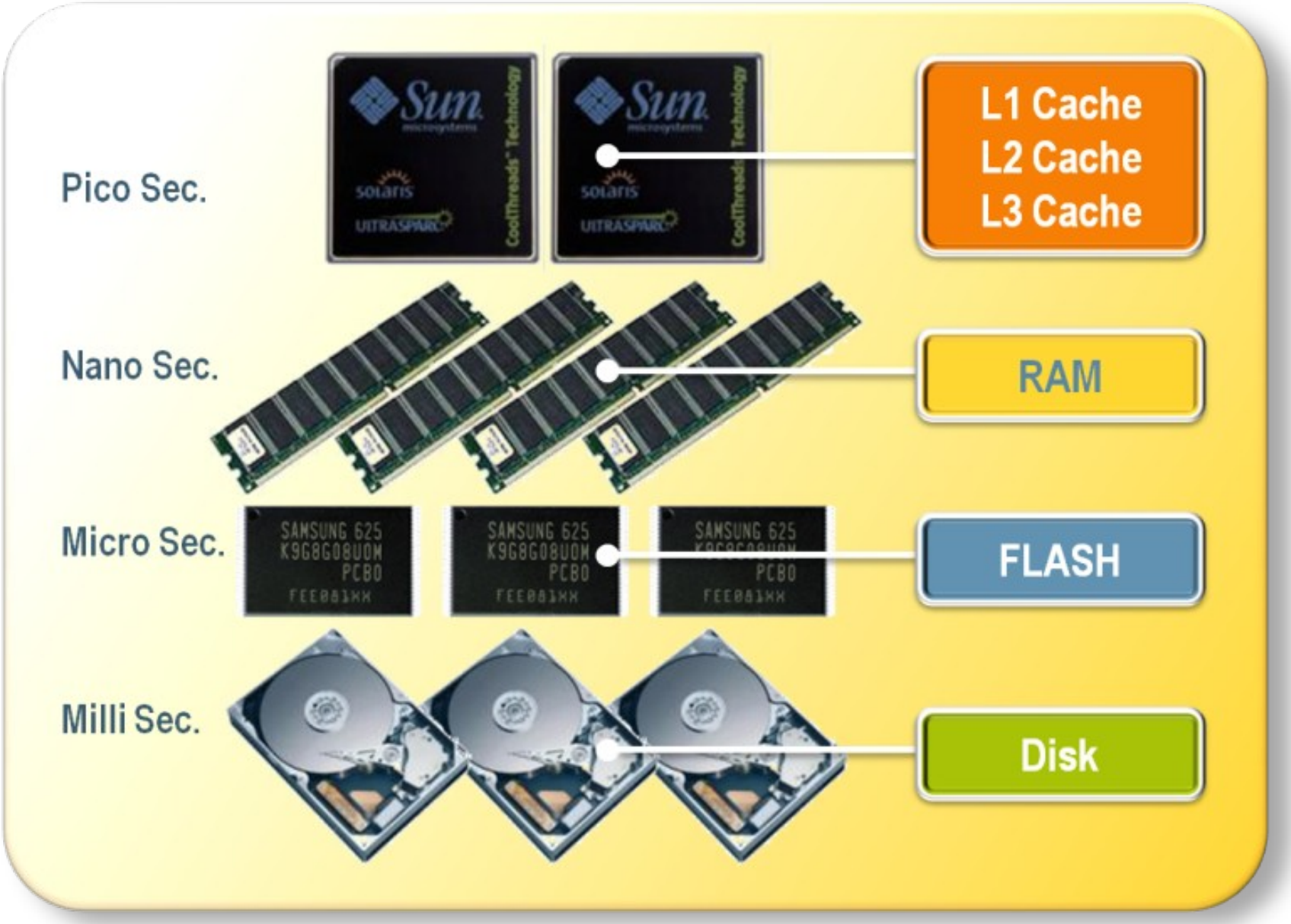
Why Applications Don't Perform

Waiting for DATA – HDDs can't keep up



- Today's Multi-Core, Multi-Socket application server design are increasingly held back by slow storage
- When requesting data, the server spends most of it's time waiting for storage
- Application performance remain sluggish regardless of the Server CPU horsepower
- The traditional remedy of adding more expensive DRAM may no longer suffice as data sets double every 2 years

New Server Memory Hierarchy



Solid State Drives (SSD)

Enterprise advantage from commodity FLASH

- SSD has three major parts:
  - A) Controller
  - B) DRAM
  - C) FLASH bank
- Controller also performs
  - Wear leveling
  - CRC
  - Bad block mapping
- Controller provides the host interface such as SATA, SAS or FC

Cost Effective Performance

SSDs are 70X more cost effective

- Enterprise HDD
  - > $5 GB
  - > 180 Write IOPS
  - > 320 Read IOPS
  - > 300 GB
  - > ~18W
- $ per IOPS: 2.43

- Enterprise SSD
  - > $35 GB
  - > 7,000 Write IOPS
  - > 35,000 Read IOPS
  - > 32GB
  - > ~3W
- $ per IOPS: 0.04

Sun SSD Strategy

HDD Replacement

- High performance 15K HDDs are replaced with 150X higher performance SSDs
- HDDs now only play a High Capacity role

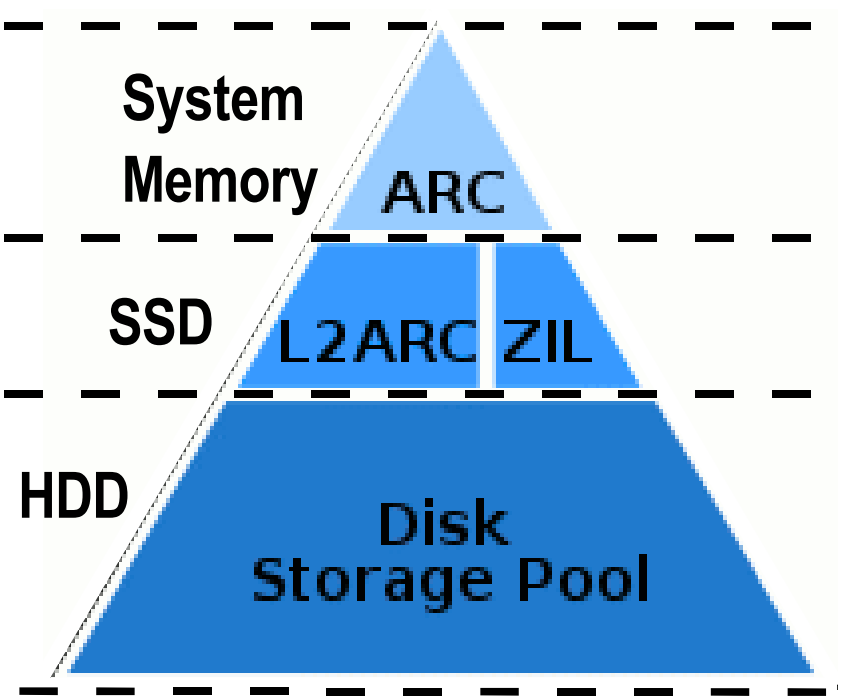
Enterprise Class SSD

Arrays and JBODs

Servers

ZFS Hybrid Storage Pools
SSDs Accelerate Synchronous Writes

- ZFS caches blocks in system main memory
- The Cache is called the ZFS Adaptive Replacement Cache (ARC)
- All synchronous writes go to the ZFS Intent Log (ZIL) before they can complete
- ZFS can separate the ZIL onto separate devices (ZFS log devices or slogs)
- Putting the ZIL on SSDs will improve the response times of synchronous writes

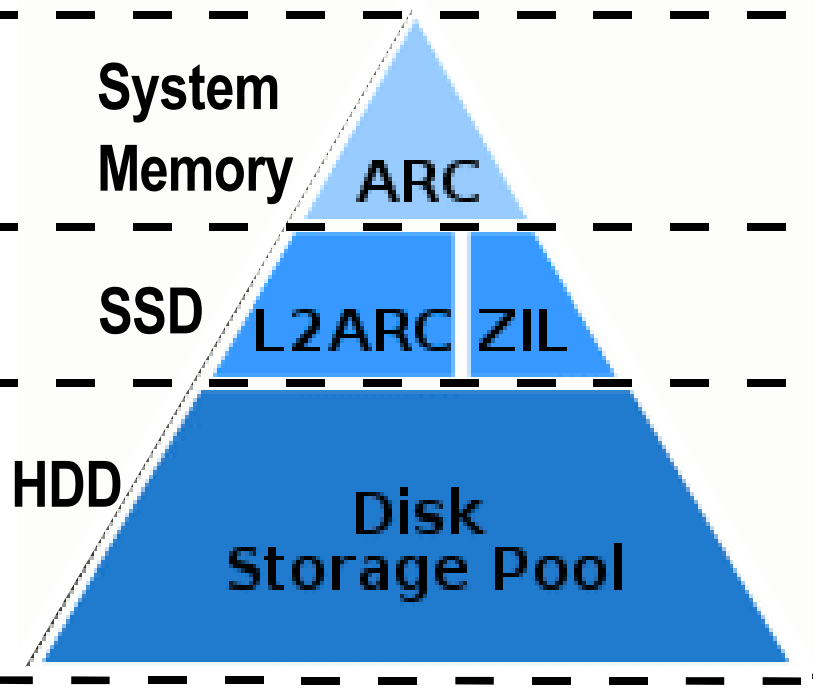


Read Neil Perrin's blog on blogs.sun.com for more on ZFS log devices

ZFS Hybrid Storage Pools

SSDs Accelerate Reads – ARC & L2ARC

- Older/least frequently accessed blocks are evicted from ARC by newer data or due to application demands for memory
- Blocks evicted from the ARC are written into L2ARC
- On reads, if we miss the ARC we go to the L2ARC
- If the reads miss the L2ARC we go to disk
- Pre-fetched data does not go into L2ARC

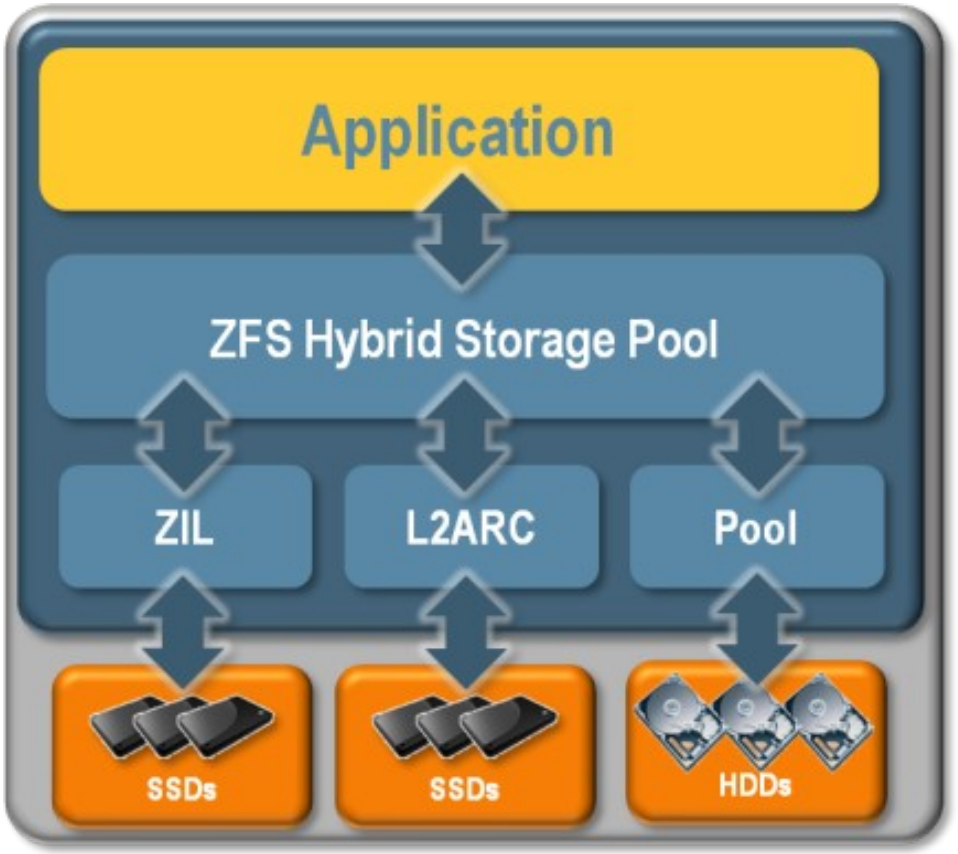


- SSDs used as L2ARC gave a 730% performance improvement over just 7200RPM drives in a recent benchmark

For more see Brendan Greg's blog: http://blogs.sun.com/brendan/entry/test

ZFS Turbo Charges Applications

Hybrid Storage Pool Data Management

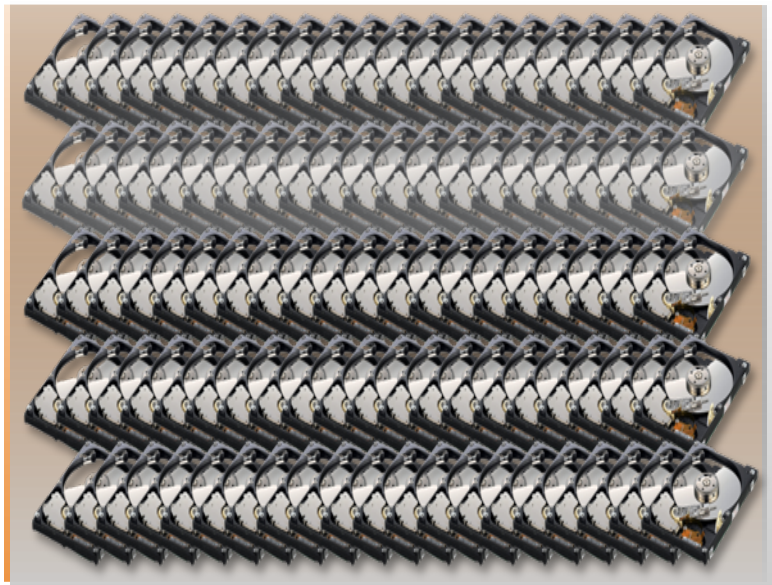


- Latency Sensitive Writes & Reads handled by SSDs
- Bulk transfers handled by HDDs

ZFS Hybrid Storage Pools

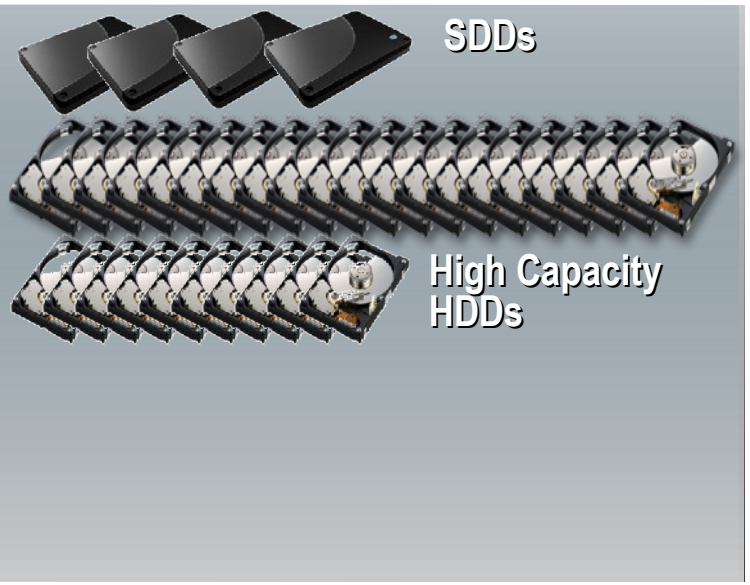
Faster, Cheaper, Less Power

Enterprise HDDs



More IOPS
Lower $GB
Lower Power Consumption
Less Rack Space

Hybrid Storage Pool



For more on HSPs, see Adam Leventhal's article in the Communications ACM Magazine http://mags.acm.org/communications/200807/

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