pNFS:
Extend NFSv4 for Parallel Storage

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The big picture, or, Why are we here?

- **Improve (Market)/(support $) for proprietary advanced FS client SW**
  - Customers: no competitive, interoperable market; vendors: client platform $$$$$
- **Rally behind one open industry-standard advanced FS client SW**
  - Customer acceptance up and vendor support costs for client SW down
- **IETF NFS is unrivalled as open industry-standard FS client SW**
  - Is raising (Market)/(support $) worth giving up proprietary feature control?
- **NFSv4 a big step “advanced” relative to v3**
  - Delegations, kerberos, ACLs, named attributes, failover locations
  - Extensibility
- **Are there a few extensions that would make it worth getting started?**
  - Understanding, from NFS IETF mailing list lurking, that other enhancements are being considered, roadmapped, evolved (e.g. richer delegations).
  - Direct client access per file/dir to multiple storage addrs using SBC, OSD & NFS?
- **Shall we standardize advanced FS client SW? In IETF NFS forum?**

“Out-of-band” Value Proposition

- Out-of-band means client uses more than one storage address for a given file, directory or closely linked set of files

- **Scalable capacity**: file/dir uses space on all storage: can get big
- **Capacity balancing**: file/dir uses space on all storage: evenly
- **Load balancing**: dynamic access to file/dir over all storage: evenly
- **Scalable bandwidth**: dynamic access to file/dir over all storage: big
- **Lower latency under load**: no bottleneck developing deep queues
- **Cost-effectiveness at scale**: use streamlined storage servers
- Wire standards led to **standard client SW**: share client support $$$

Delegations for File Address Maps

- **“Recallable delegations allow clients holding a delegation to locally make many decisions normally made by the server”**
- **Propose that when using delegations**
  - A client requesting a delegation asks for out-of-band file address maps
  - Server protects integrity of maps while delegation lasts, and understands file data may change out-of-band
  - Server can re-synch with file contents by recalling the delegations
- **File address map, logically parts of inode & data pointers**
  - For OSD objects, Panasas uses list of device address, object id, capability, striping parameters, RAID parameters
- **Protocol support in addition to delegation consistency & recovery**
  - What storage systems can a client access
  - When file address map is huge, get in pieces
  - For allocating new space during writing, e.g. begin-allocate & end-writing
  - Requesting changes in the map itself (wider striping, replication, etc)

Multiple Data Server Protocols

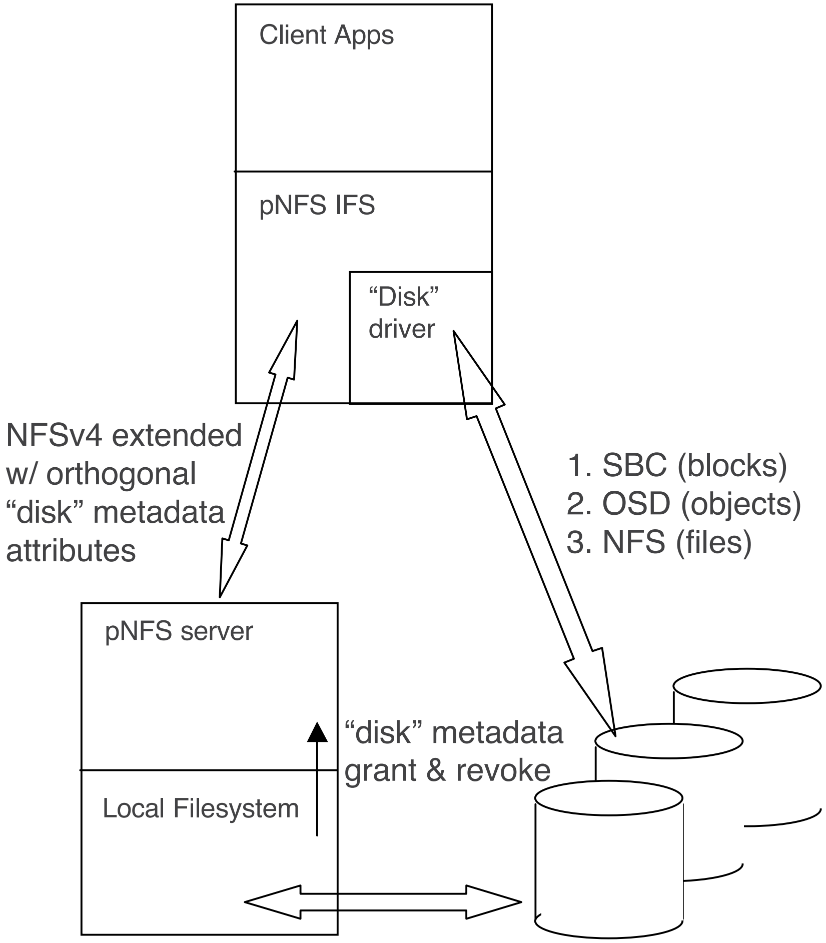
BE INCLUSIVE !!

- Broaden the market reach

Three (or more) flavors of out-of-band metadata attributes:

- BLOCKS: SBC/FCP/FC or SBC/iSCSI… for files built on blocks
- OBJECTS: OSD/iSCSI/TCP/IP/GE for files built on objects
- FILES: NFS/ONCRPC/TCP/IP/GE for files built on subfiles

Inode-level encapsulation in server and client code



Recommended Principles

- **Orthogonal and complimentary to transport improvements (RDMA)**
- **Start with NFSv4 and stay as close as performance allows**
  - Maybe a roadmap of use cases where specialized workloads benefit from more extensive changes -- should collaborate closely with core NFSv4 team
- **At any time all operations can be completed through server**
  - Make all direct actions idempotent; error recovery by retry against server
  - Concurrent sharing can be simply handled through server
  - Legacy support and simple allocation
- **NFS extentions for control & consistency of metadata, not meaning**
  - Separate docs (per storage type) describe wire format of metadata
  - While only describing wire format, achieve “principles of client function”
- **Clients negotiate ability to use and type of direct access (discovery)**

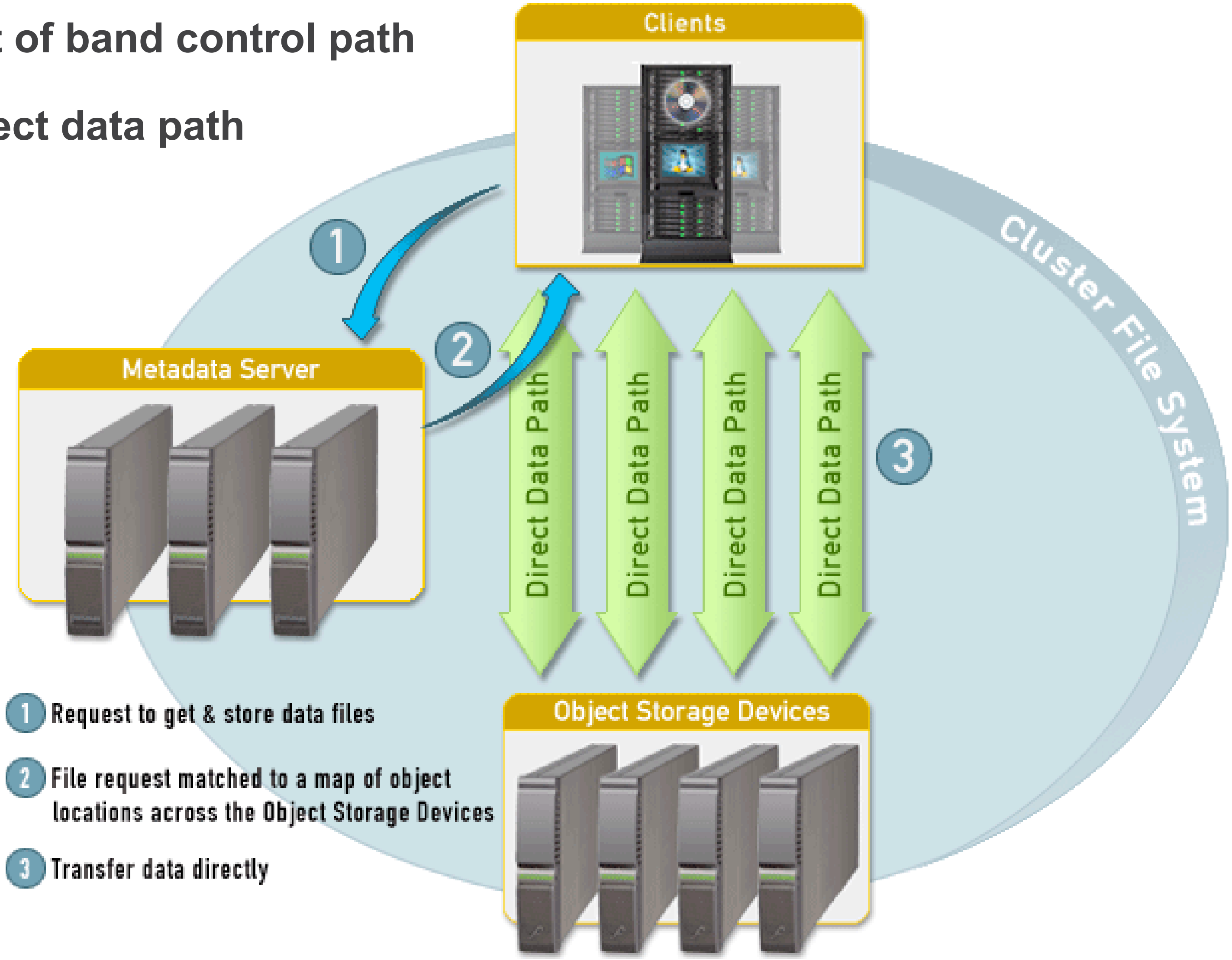
Panasas’ Object Storage:

Redefining Bandwidth for Linux Clusters

December 4, 2003

Object Storage Data Path

- Out of band control path
- Direct data path



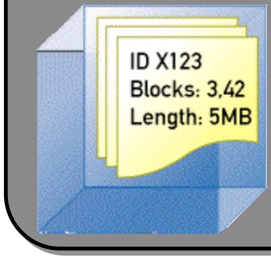
1 Request to get & store data files

2 File request matched to a map of object locations across the Object Storage Devices

3 Transfer data directly

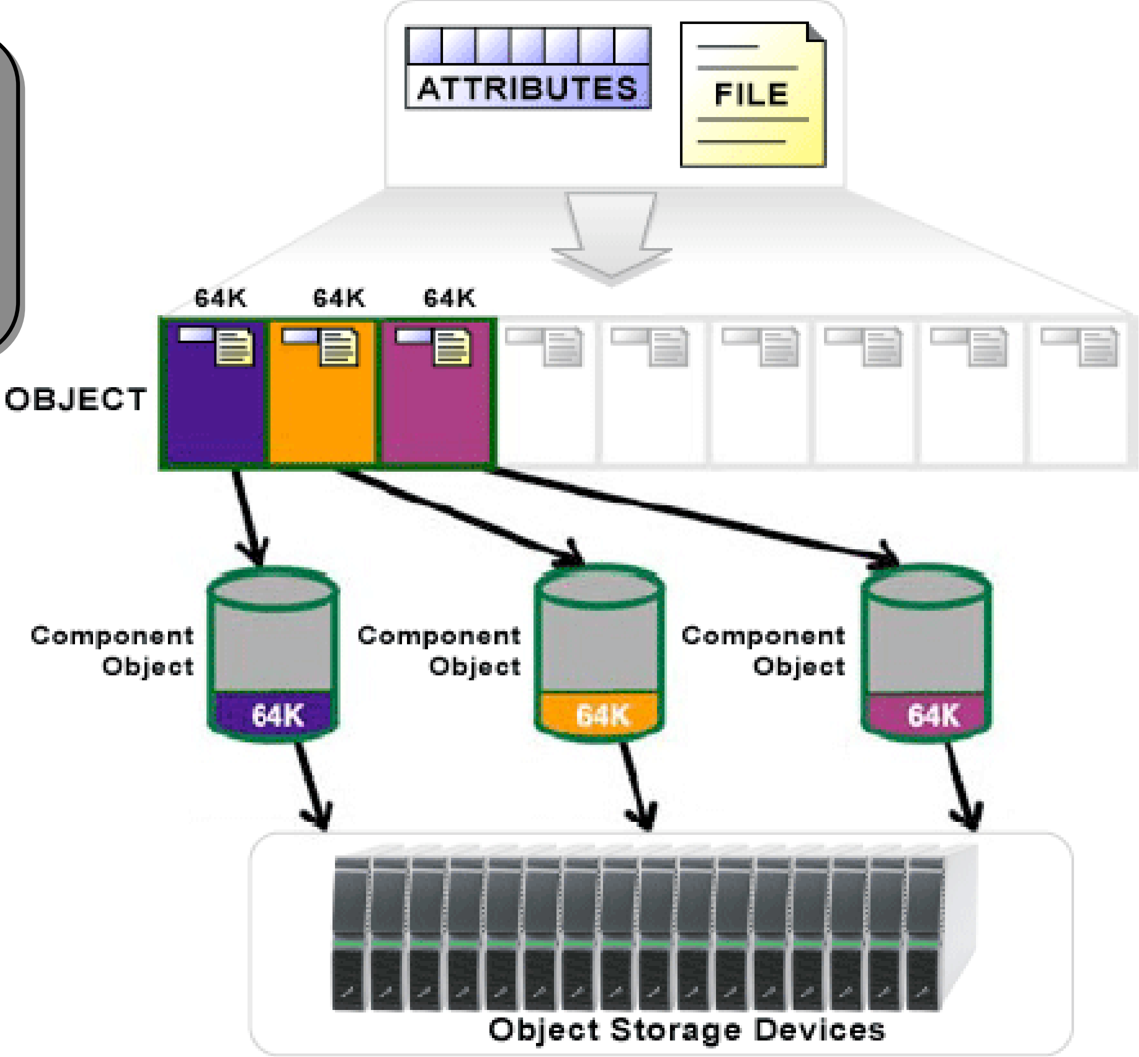
What is an Object?

Object



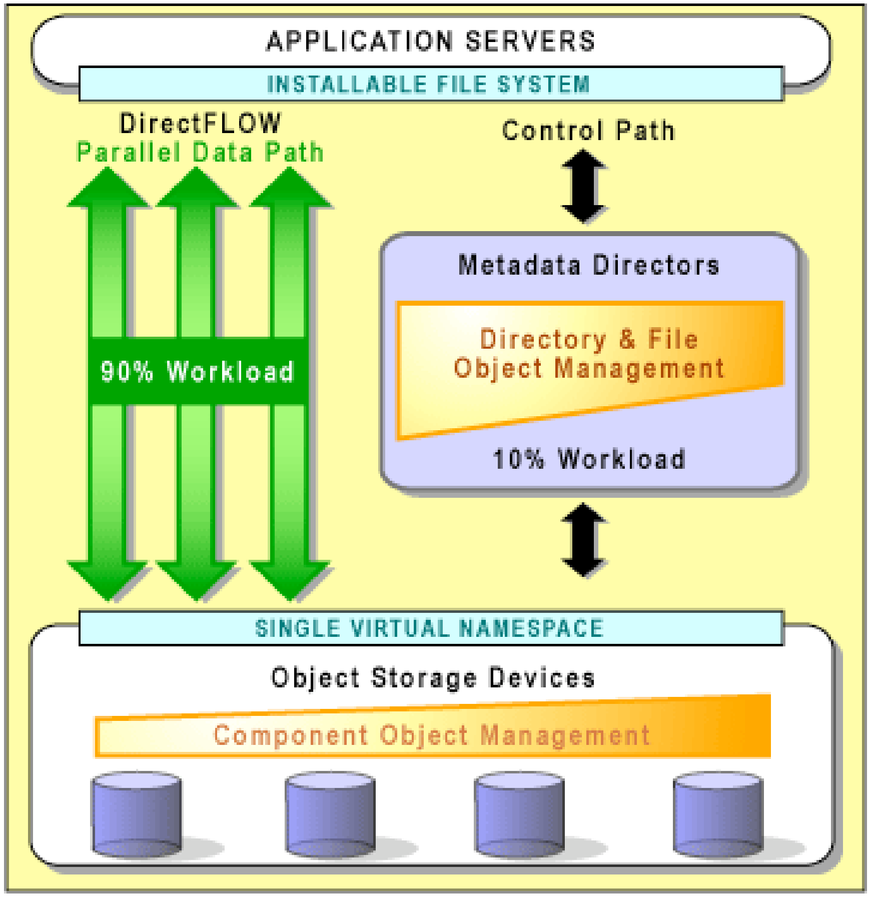
Comprised of:

- User Data
- Attributes
- Layout



Object Storage System Architecture

- **Moves low-level storage functions into the storage device itself**



Key Object Storage Features

Intelligent space management in storage layer

- Media geometry aware placement
- Late binding allocation
- Data aware prefetching, caching & recovery

Encapsulation of data and attributes

- Native object interface, good programming model
- Storage interpreted attributes for per file properties

Key Object Storage Advantages

- Robust, shared access by many clients
- Scalable performance via an offloaded data path
- Strong fine-grained end-to-end security

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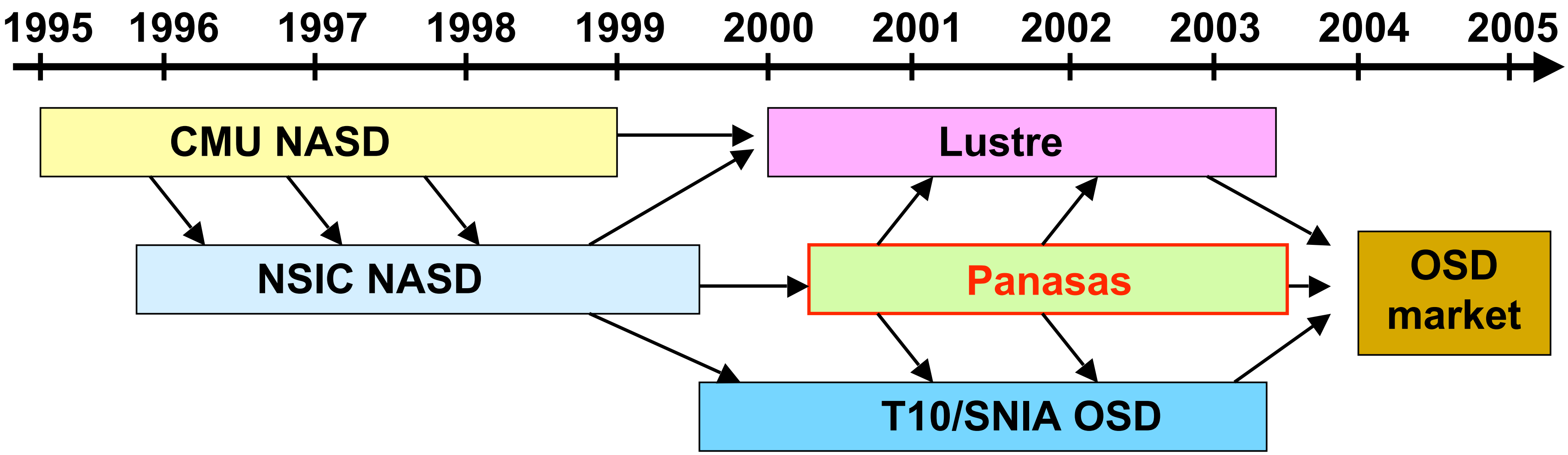
Standardization Timeline



- **SNIA TWG is nearing completion of proposed OSD standard**
  - Great participation by leading storage industry vendors
  - SNIA OSD V1 draft sent for review/ratification to ANSI T10 OSD committee
  - Next steps for OSD standards is under development
    - Roadmap includes SMIS & Information Life Cycle management support

hp invent IBM intel. EMC² where information lives Seagate We turn on ideas VERITAS

Object Storage Systems

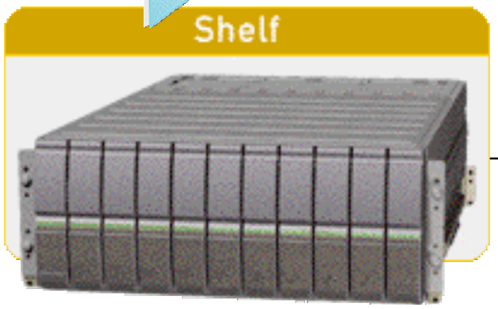
Wide variety of Object Storage Devices

- Disk array subsystem
- Used with Lustre

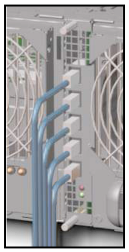
- Smart disk holding objects
- Panasas StorageBlade uses Serial ATA disks for up to 500 GB

- OSD research at Seagate
- Highly integrated, single disk

- Orchestrates system activity
- Balances objects across Object Storage Devices



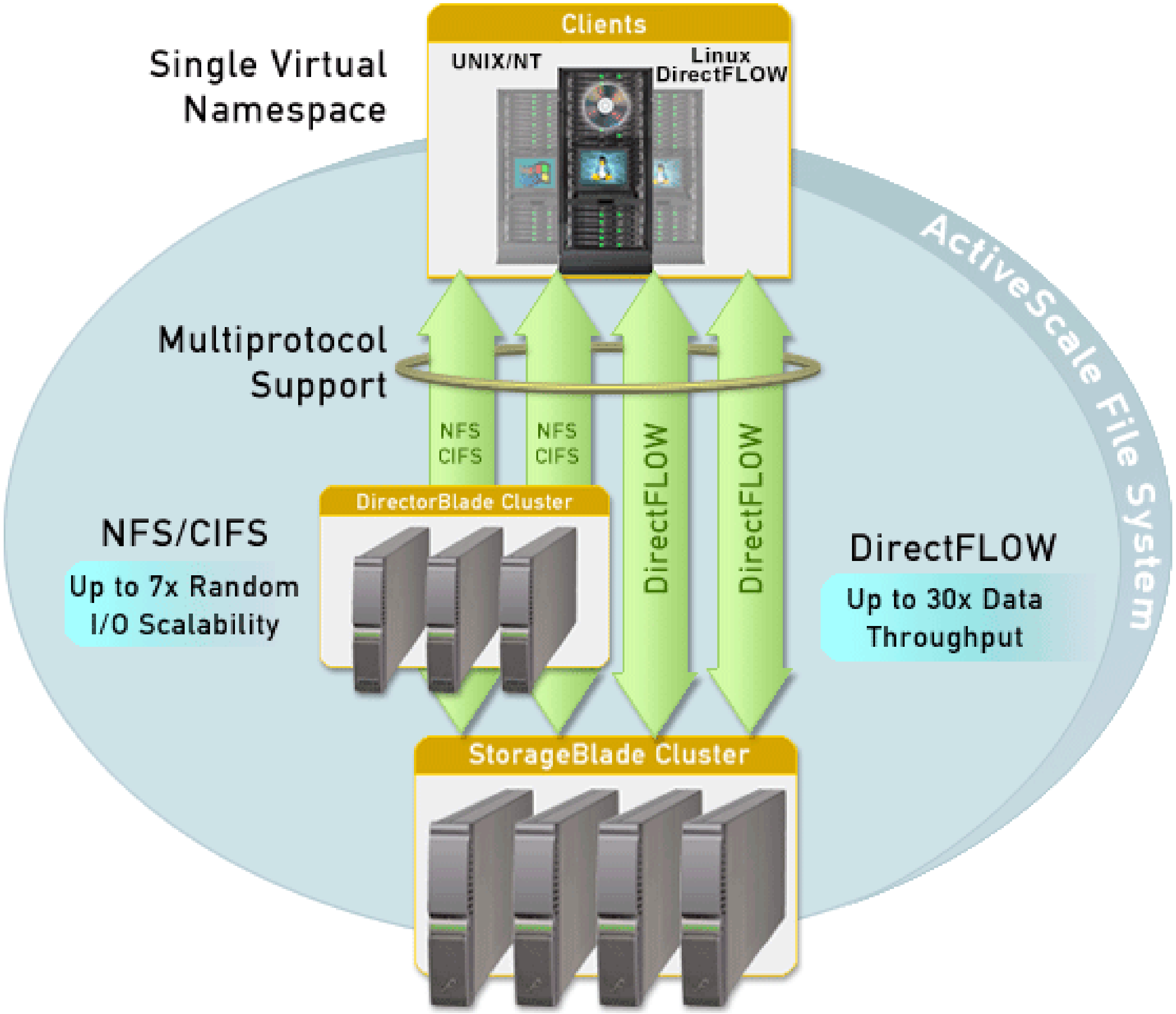
- Stores up to 5 TBs per shelf
- Battery-backed redundant power



16-Port GE Switch Blade

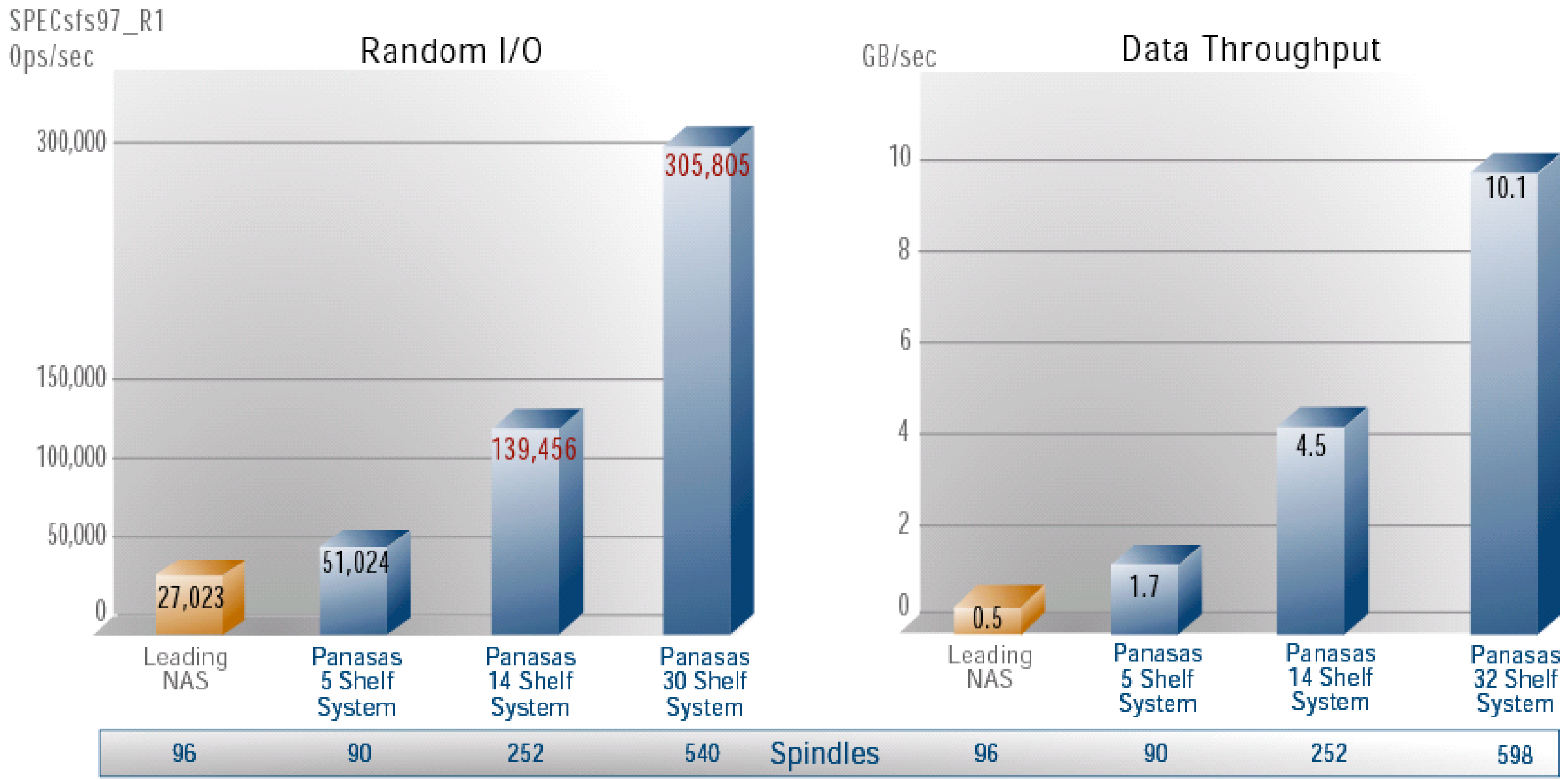
- 4 Gb/sec per shelf to Linux cluster

Full Function Storage Cluster



Objects: Performance & Scalability

Breakthrough Data Throughput AND Random I/O



Object Storage:

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