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Scalable filesystems boosting Linux storage solutions

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Motivation

- User's view:
  - Storage is a scarce resource that is always
    - too small
    - too slow
  - If it isn't today, it will be in shorter time than expected
- Admin's view:
  - Storage is a precious resource that is always
    - too unreliable
    - too inflexible
- Boss's view:
  - Storage is a necessary evil that is always
    - too expensive

Motivation

- Ideal storage solution
  - can grow in capacity and bandwidth
  - allows to transparently move around data
  - is cheap
  - is easy to use
  - doesn't fail
- Scalable filesystems can't do miracles, but they get you closer

Agenda

- Storage solutions that scale (and those that don't)
  - Terminology
  - Theory of operation
  - Implementations
- Case study
- Present and future developments

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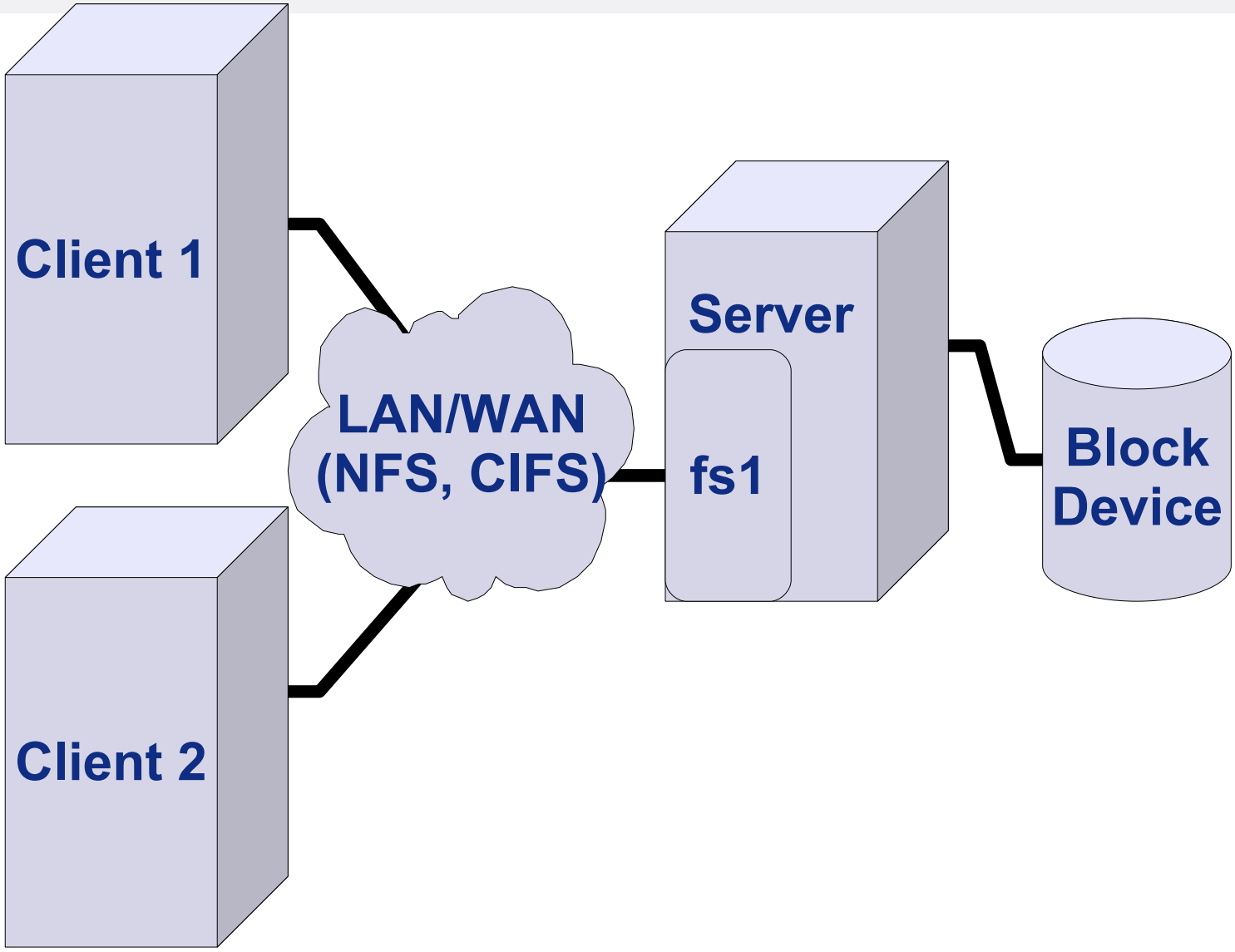
„I need this future-proof storage infrastructure – what are my options today?“

Grandma's networked storage (NAS)



Traditional NAS: Properties

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- **Re-exports** of local filesystems
- „Proxy filesystem“
  - **Network protocol** only, no dedicated on-disk data layout
- Concurrency of local and remote access
- Implementations: NFS, SMB/CIFS

Traditional NAS: Pros and Cons

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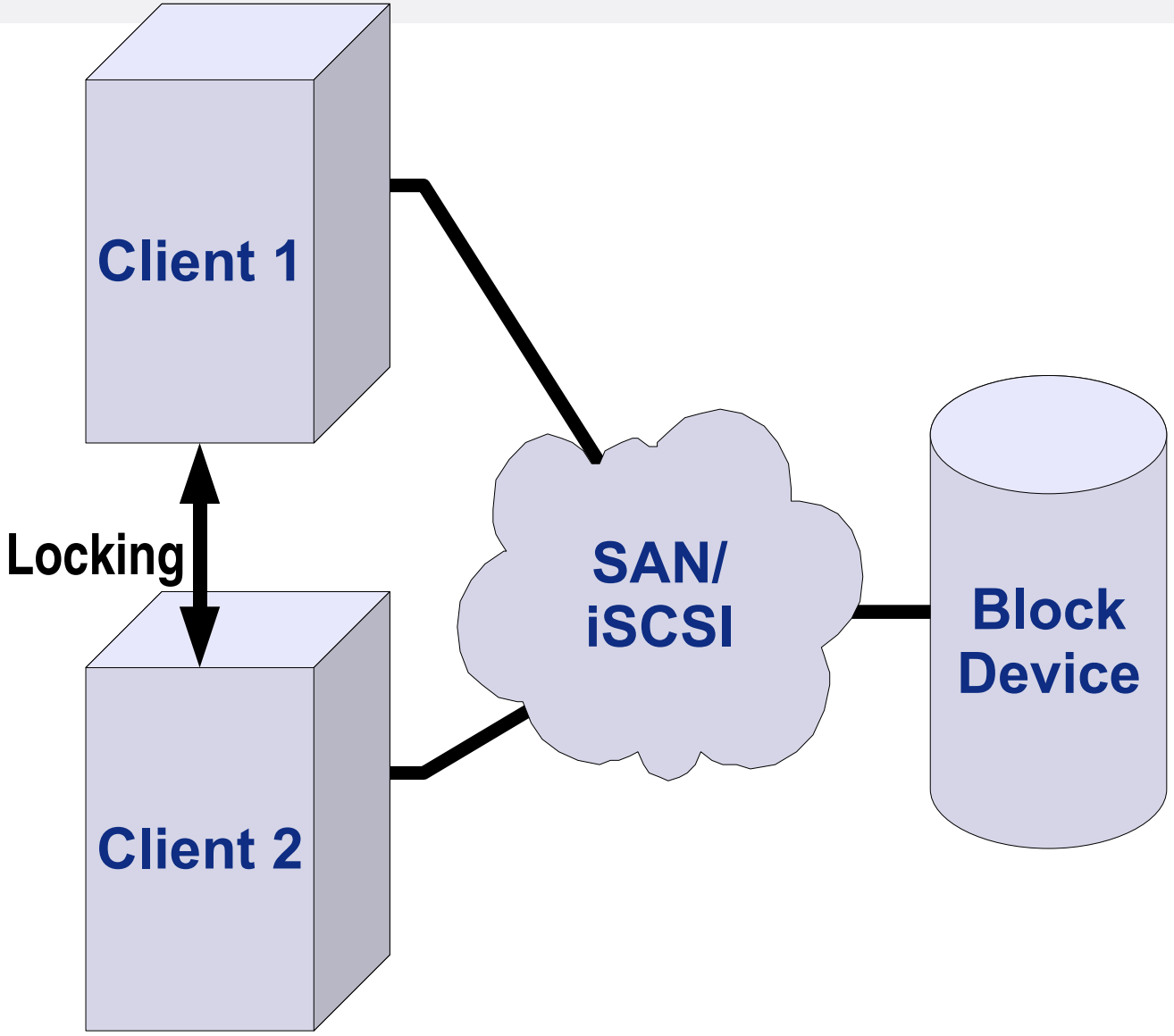
- **Mature** concepts and implementations
- **Ubiqitous**, usually part of standard installation
- **Convenient** integration
- Single fileservers **cannot scale** with rising demands on bandwidth and capacity
- Multiple fileservers **partition namespace** at physical boundaries
- Client-side virtualisation techniques (autofs, amd, DFS) mitigate problem, but still are subject to partition boundaries
- Virtualisation of backend storage (SAN) solves capacity constraints and increases reliability, but still requires access through conventional fileservers

Clustered storage in the SAN age



SAN-based filesystems: Properties

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- Access same filesystem on **shared block device** from multiple hosts
  - Filesystem manages concurrent access through **locking service**
  - **Dumb „server“** (block device), complexity handled on client side
- Terminology: SAN filesystem, cluster filesystem
- Free implementations: OCFS2, GFS
- Proprietary implementations: mostly from major storage vendors (cXFS, MPFS, PolyServe, TotalStorage SFS, Veritas CFS, ...)

SAN-based filesystems: Pros and Cons

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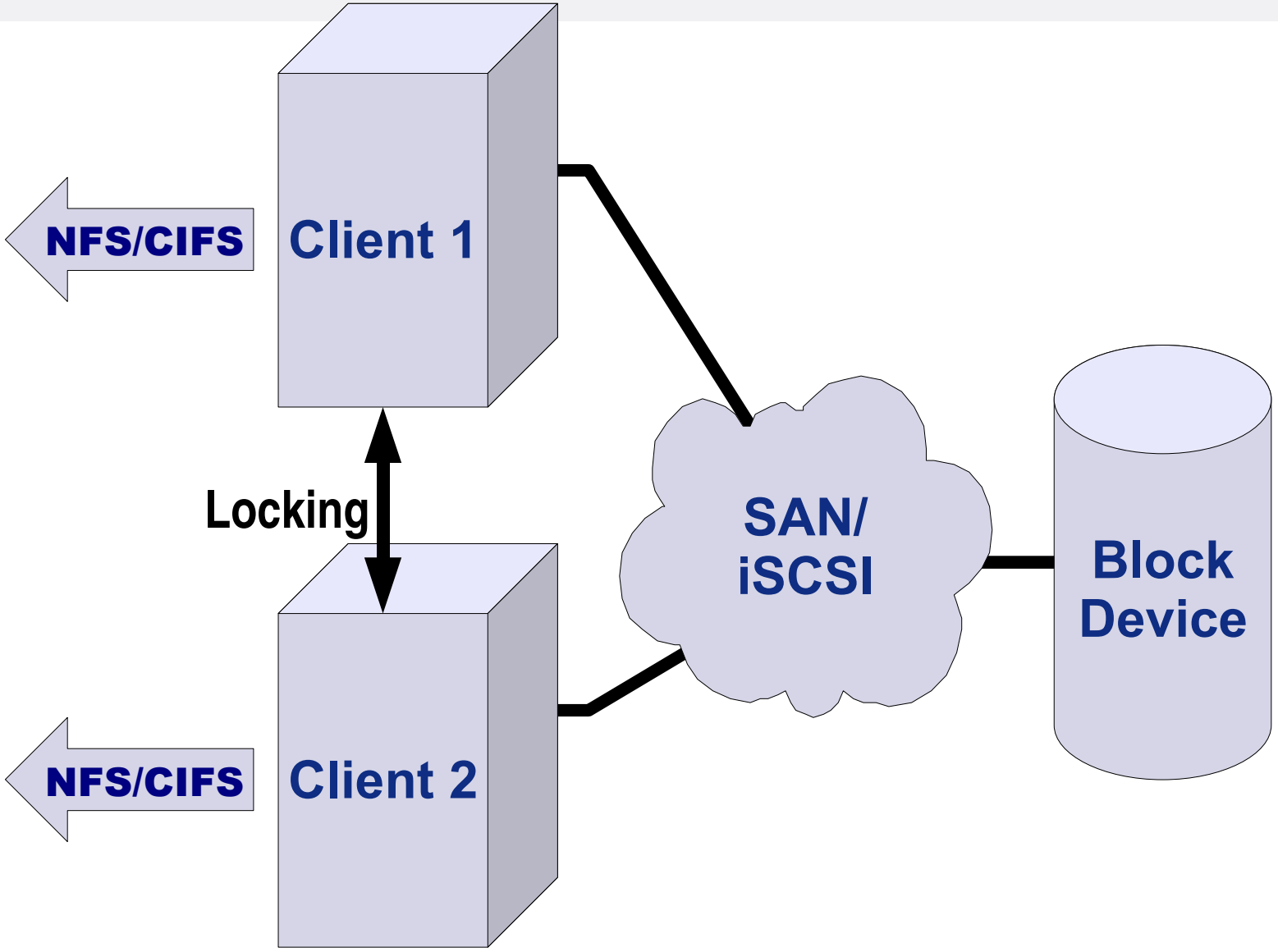
- Requires SAN (or SAN-like) infrastructure
  - additional fabric (FibreChannel)
  - suboptimal fabric (iSCSI over Ethernet, etc.)
- Virtualized backend storage allows
  - Replication
  - Relocation
  - Resizing
- Typical problems:
  - Quorum of clients needed for filesystem operation
  - Limited scalability, dependent on implementation characteristics of locking service and supported access patterns

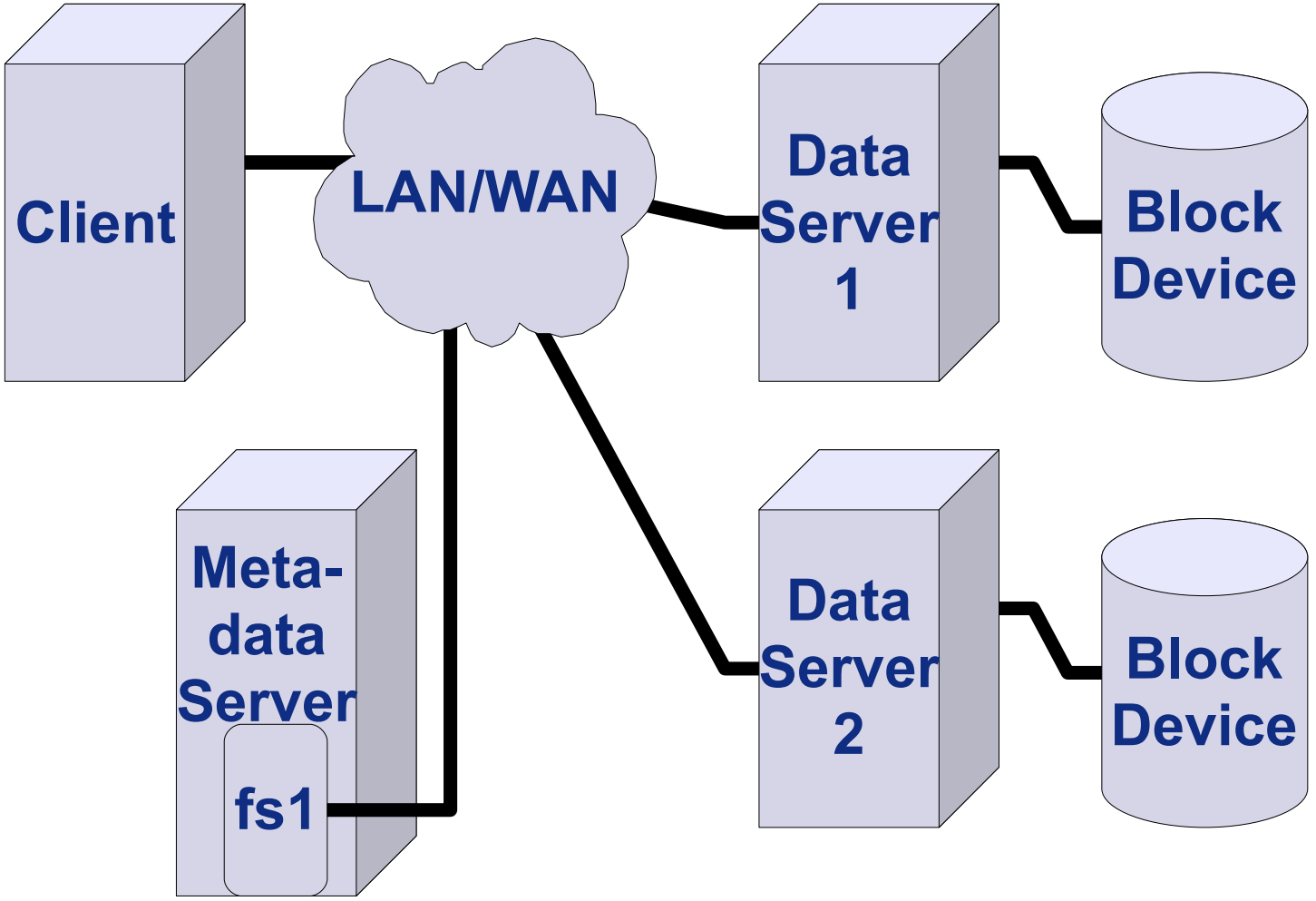
➔ Usually limited to servers, uncommon on end-user machines

- NFS/CIFS re-export necessary

SAN-based clustered storage



Serving files from a distributed system



Distributed Filesystems: Properties

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- Data distributed to **local storage** on multiple servers
- **Metadata service** ties distributed data into single filesystem
  - decouples namespace from physical layout
  - metadata either on single server, or distributed across several nodes
- Implementations:
  - Special purpose: Hadoop, GoogleFS, ...
  - Open Source: AFS, Lustre/HP SFS, Ceph, PVFS2
  - Proprietary: GPFS, PanFS, FhGFS

Distributed Filesystems: Pros and Cons

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- Complex system on client and server side
- High **scalability:** additional servers increase bandwidth and capacity
- High **flexibility** due to decoupling of namespace and physical storage
- Data servers: „Block devices with intelligence attached“

→ Some locking complexity can be offloaded on single server instance, allowing to serve high numbers of clients

→ Ubiqituous deployment to all servers and end-user systems possible

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„I fancy my data - does it work for real?“

Case study: Scalable filesystem setup

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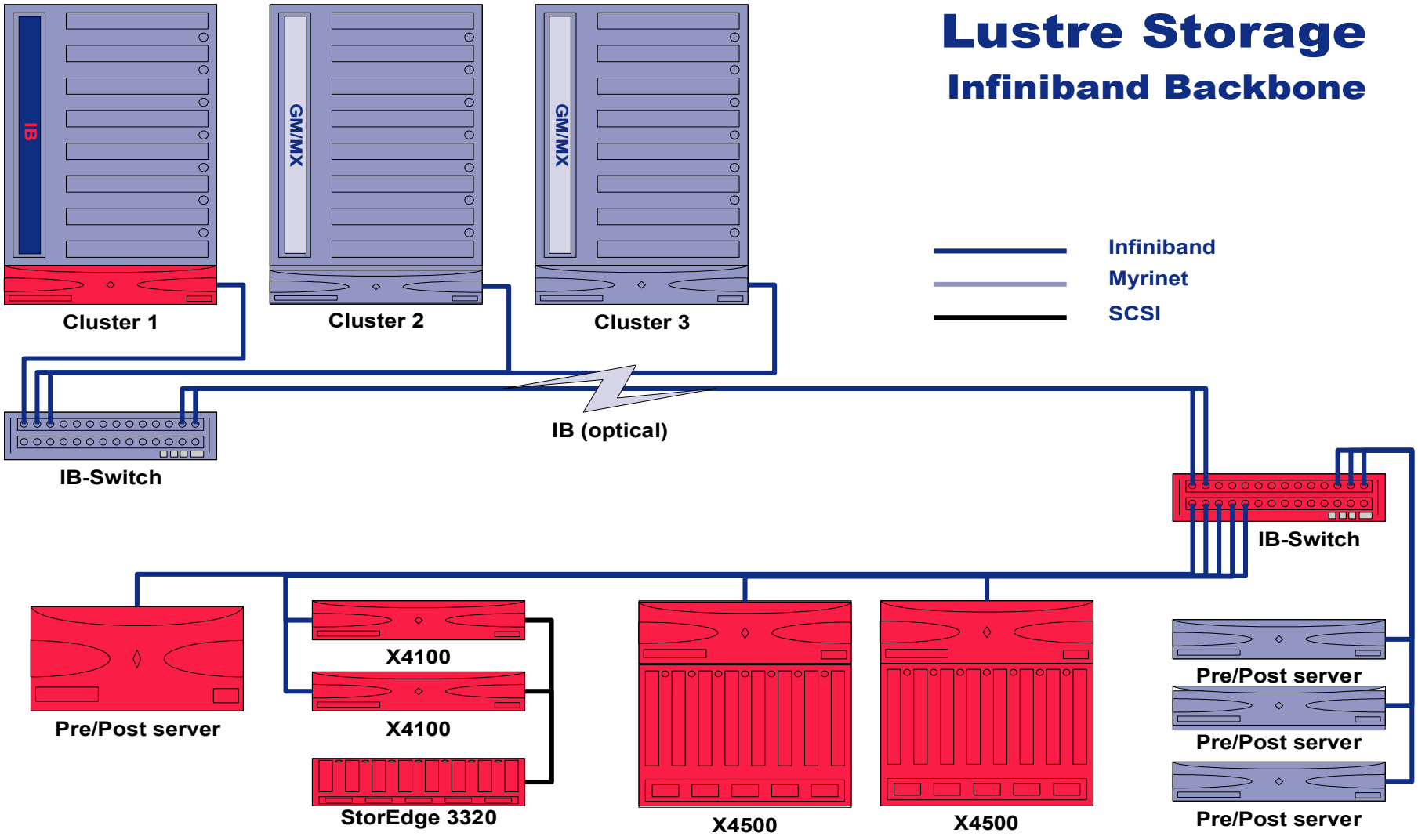
- Automotive engineering, computational fluid dynamics
- Pre-existing storage:
  - Stand-alone Linux servers
  - local storage
  - NFS/CIFS export
  - partitioned namespace
- New storage solution:
  - Single Lustre filesystem
  - Linux cluster nodes, servers, workstations as Lustre clients
  - CIFS export to Windows clients
  - 2 redundant metadata servers, external SCSI storage
  - 2 data servers (Sun „Thumper“)

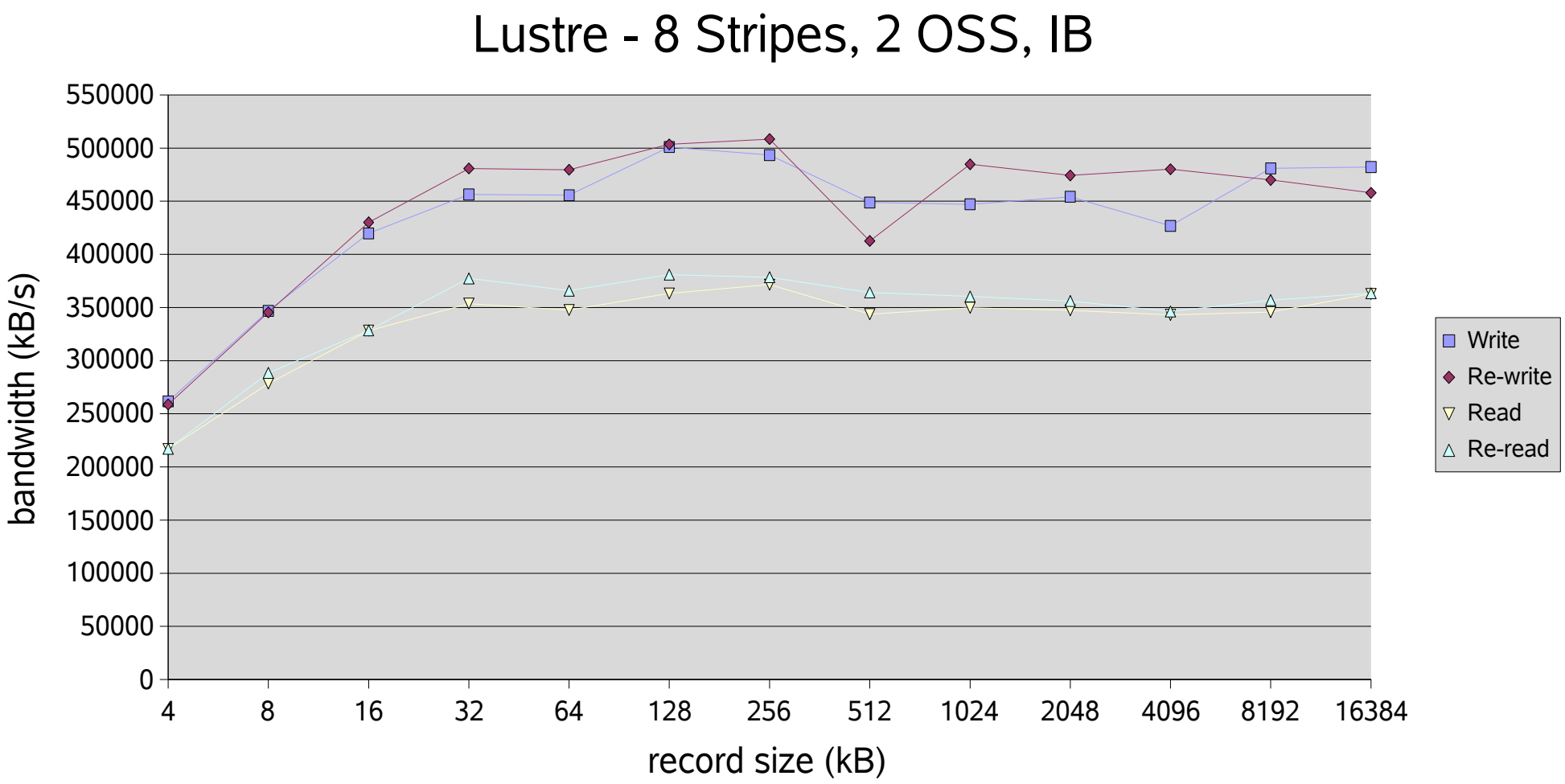
Case study: Benefits

- Scalable storage link for compute clusters
  - extensible capacity
  - extensible bandwidth
- Single, unified filesystem for clusters and workstations
- Avoids temporary local storage on cluster nodes to prevent data loss on node failure
- Simplified workflow due to central storage
- Increased job turnaround times as copy processes become superfluous

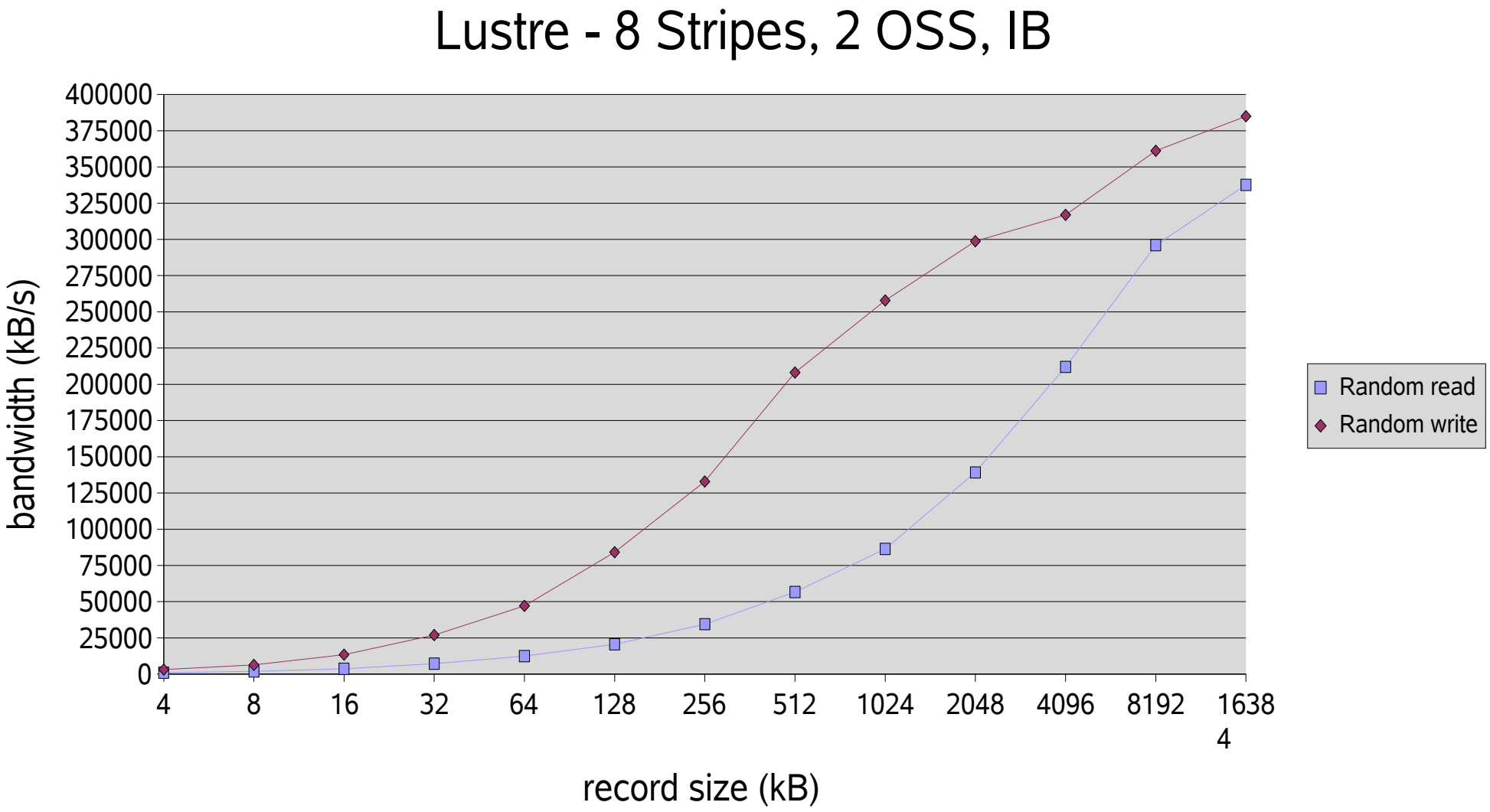
Case study: Network layout



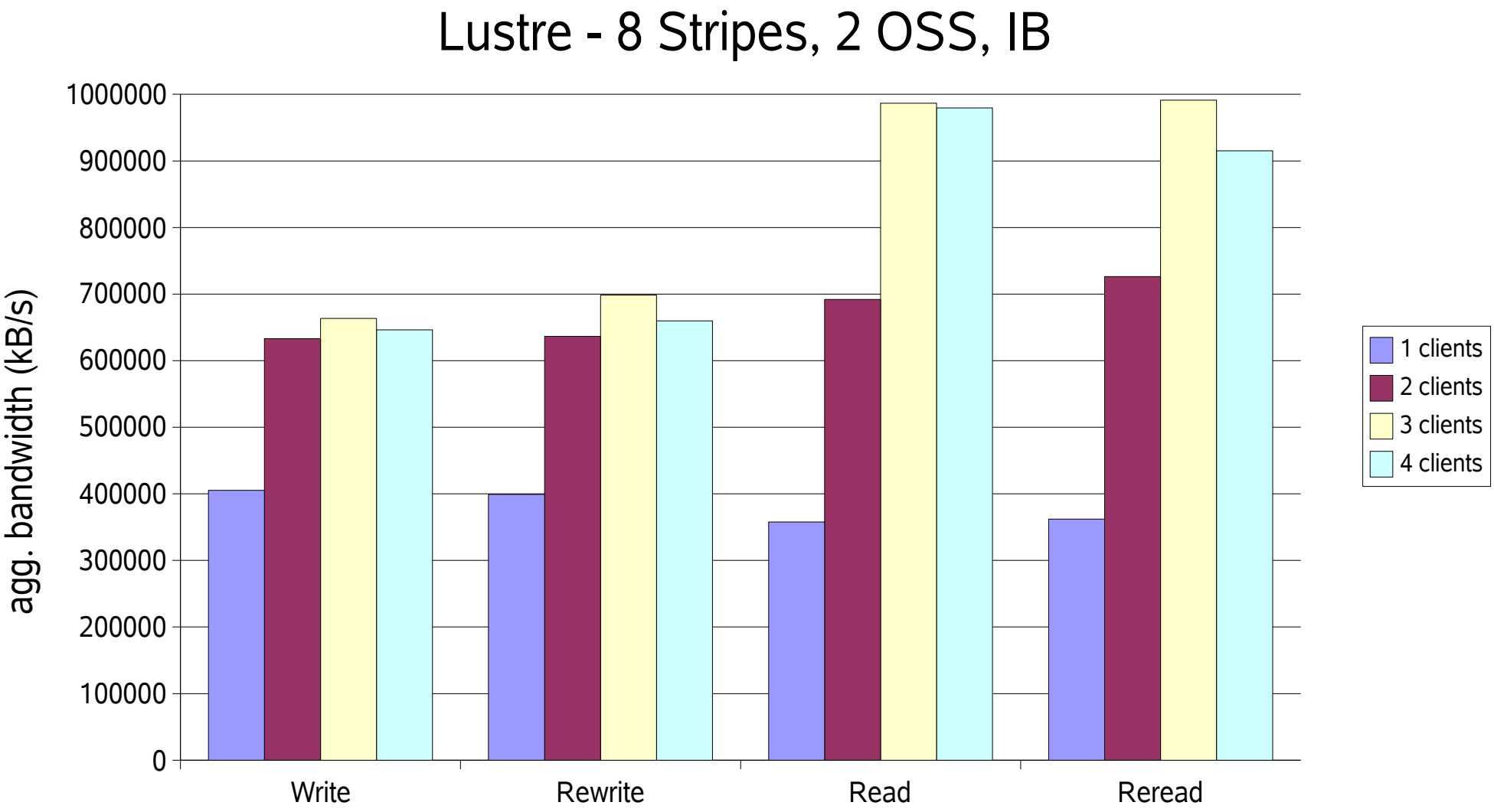
Case study: Lustre bulk I/O



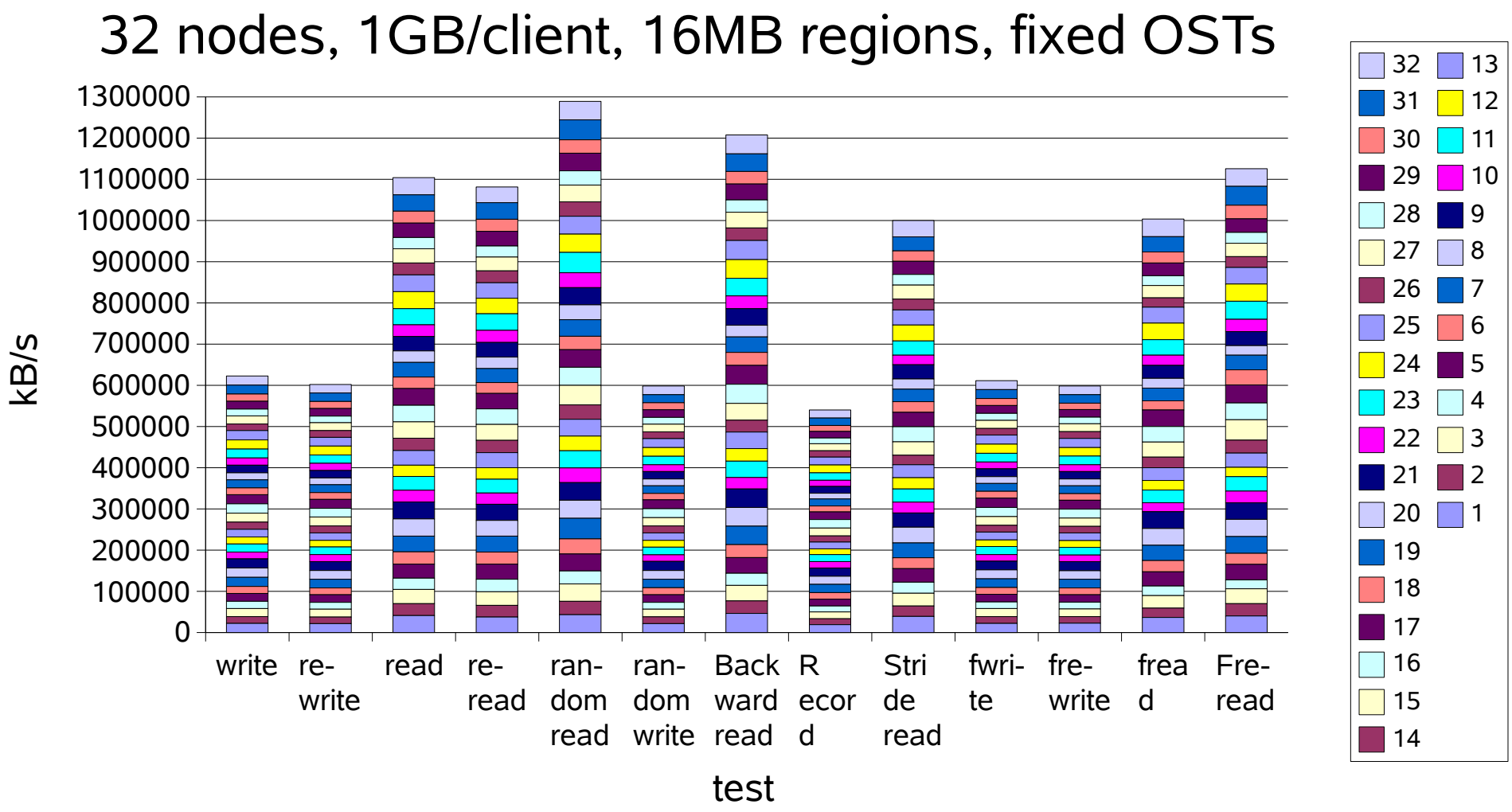
Case study: Lustre random I/O



Case study: Lustre scaling



Case study: Lustre scaling



Case study: Current status

- > 1 year in production
- Ca. 150 clients access filesystem
- > 1 GB/s aggregate bandwidth
- 33 TB net capacity
- ➔ Combination of open-source software (Lustre, heartbeat, Linux...) and (more or less) „standard“ hardware components!
- Central storage for all project data within workgroup
- Additional storage servers planned in the near future
- Similiar installations in several neighbouring groups have followed

Case study: Problem areas

- Storage servers: redundant hardware components, but system-level failure stalls filesystem
- No (trivially) scalable backup concept
  - Backup/restore via multiple filesystem clients possible, but requires manual tuning
  - Full/differential backups undesirable
  - → Backup software needs to support incremental-only schemes
  - → Integration with HSM systems desirable
- Client-side modifications required

„Does it get any more convenient?“

Scalable filesystems + NAS

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- Idea:
  - Install scalable filesystem on cluster of NAS servers
  - Re-export filesystem from all server nodes simultaneously to many clients
- Requirement:
  - Cluster-aware NFS/CIFS servers to ensure lock consistency
- Benefits:
  - Easy access from clients via native protocol to whole namespace
  - Scalable bandwidth and capacity
  - High availability
- Implementations:
  - CTDB (in Samba 3.2) with GPFS, GFS, Lustre...
  - Alternative: pNFS/NFSv4.1 (draft standard)

Wrapping it up

Scalable filesystems in a Linux world

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- For numerous scalable filesystems, Linux is the primary platform
- Linux-based scalable filesystems allow to build **fast**, **capable**, **reliable** and **affordable**, **custom-tailored** storage clusters from **commodity hardware**, and proprietary or open-source software components
- We've had this before: Beowulf clusters revolutionized high-performance computing, and made Linux the pre-dominant supercomputing platform
- Available software provides the potential for Linux to assume a similar role for scalable storage solutions in the near future

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Thank you for your attention.

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