File Server Scaling with Network-Attached Secure Disks (NASD)

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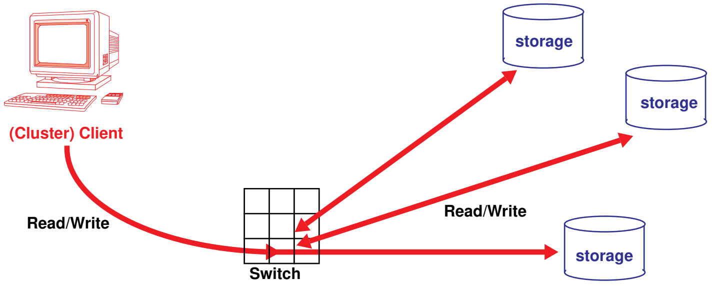
Meet scaling compute needs with storage striped over scalable client network



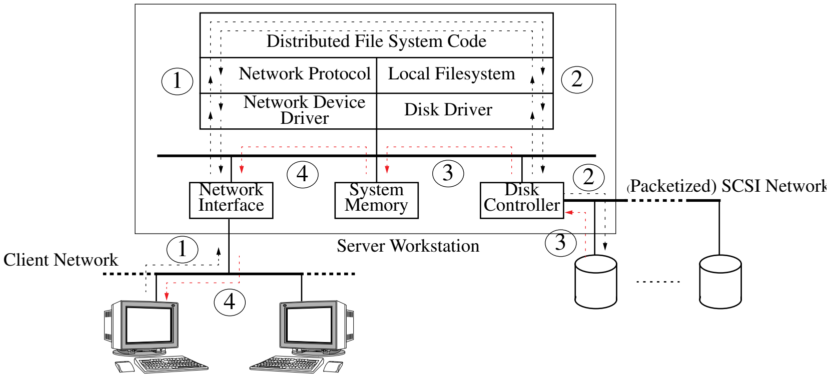
Problems with current Server-Attached Disk (SAD)

Store-and-forward data copying thru server machine

- translate and forward request, store and forward data

Limited bandwidth, slots in low-cost server machine

- server adds > 50% to $/MB and can't deliver bandwidth



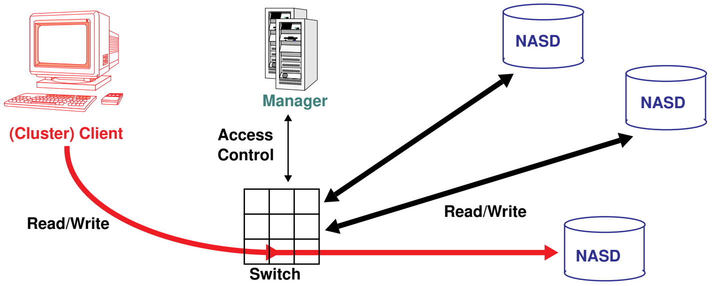
The fix: partition traditional distributed file server

High-level striped file manager

- naming, access control, consistency, atomicity

Low-level networked storage server

- direct read/write, high bandwidth transfer
- function can be integrated into storage device



Storage industry is ready and willing

Disk bandwidth: now 10+ MB/s; soon 30 MB/s

- Disk-embedded, high-speed, packetized SCSI
- Eg. 100+ MB/s Fibrechannel peripheral interconnect

Disk areal density: now 1+ Gbpsi; growing 60%/yr

- Reducing TPI demands more complex servo algorithms
- RISC processor core moving into on-disk ASIC

Profit-tight marketplace exploits cycles to compete

- Geometry-sensitive disk scheduling, readahead/writebehind
- RAID support to off-load parity update computation
- Dynamic mapping for transparent optimizations
- Cost of managing storage per year 3-7X storage cost

NSIC working group on Network-Attached Storage

- Quantum, Seagate, StorageTek, IBM, HP, CMU

What function should be moved?
Taxonomy for Network-Attached Storage (NAS)

Server-Attached, Server-Integrated Disk (SAD, SID)
- (specialized) workstation running file server code

Networked SCSI (NetSCSI)
- minimal differences from SCSI; manager inspects requests

Network-Attached Secure Disk (NASD)
- new (SCSI-4) interface enables direct, preauthorized access

Contrasting extremes: NetSCSI vs. NASD
- both scale bandwidth with large, striped accesses
- what impact on workloads of current LAN file servers?

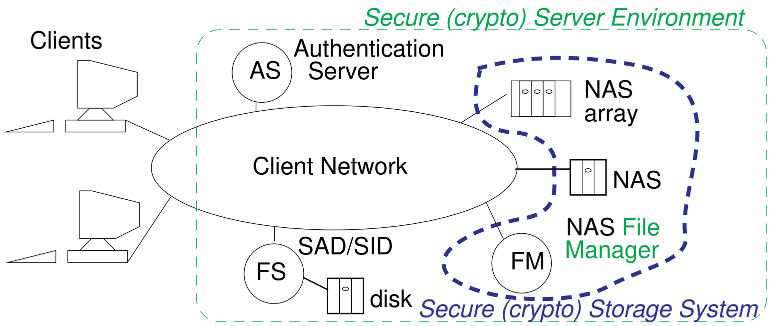
Security implications of network-attached storage

SCSI storage trusts all well-formed commands !

Storage integrity critical to information assets

Firewall is bottleneck, costly, ineffective

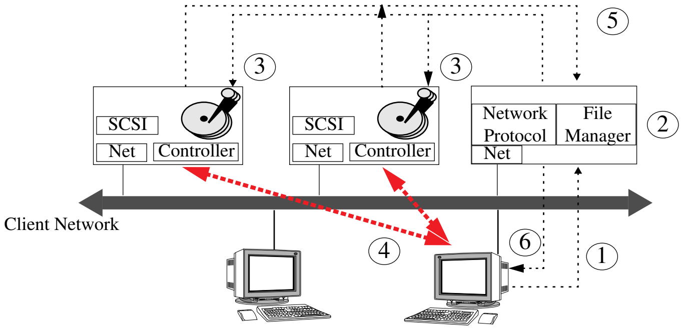
Assuming cryptography used in same way as ECC



Networked SCSI (NetSCSI)

Minimize change in drive HW, SW, IF: RAID-II
- server translates (2) and forwards (3) request (1)
- drive delivers data directly to client (4)
- drive status to server (5), server status to client (6)

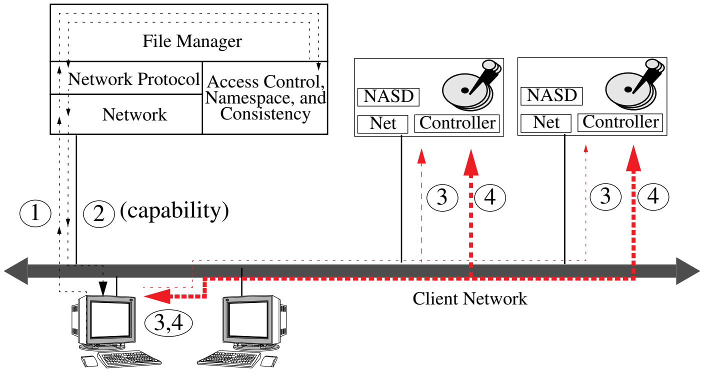
Scalable bandwidth through network striping



Network-Attached Secure Disk (NASD)

Avoid file manager unless policy decision needed
- access control once (1,2) for all accesses (3,4) to drive object
- spread access computation over all drives under manager

Scalable BW, off-load manager, fewer messages



Impact of NASD vs. NetSCSI on current file systems

Analytic & trace-driven agree; talk presents analytic

Analyze FS traces; instrument SAD server, count instrs

Model change in operation counts and costs at manager

For SAD, use numbers as measured

For NetSCSI, data transfer is off-loaded

- manager does work of 1-byte access per request
- attribute/directory assumed no less work

For NASD, off-load file write and file/attr/dir read

- updates to attributes/directory are no less server work
- manager must do new “authorization” work when file opened (synthesized as first touch after long inactive)

NFS on network-attached storage projections

Berkeley NFS traces [Dahlin94] (230 clients, 6.6M reqs)

Directory/attributes dominate SAD manager work

NetSCSI, therefore, little benefit for manager load

NASD off-loads over 90% of manager load

NFS Operation	Count in top 2% by work (thousd)	SAD		NetSCSI		NASD	
		Cycles (billions)	%of SAD	Cycles (billions)	%of SAD	Cycles (billions)	%of SAD
Attr Read	792.7	26.4	11.8%	26.4	11.8%	0.0	0.0%
Attr Write	10.0	0.6	0.3%	0.6	0.3%	0.6	0.3%
Block Read	803.2	70.4	31.6%	26.8	12.0%	0.0	0.0%
Block Write	228.4	43.2	19.4%	7.6	3.4%	0.0	0.0%
Dir Read	1577.2	79.1	35.5%	79.1	35.5%	0.0	0.0%
Dir RW	28.7	2.3	1.0%	2.3	1.0%	2.3	1.0%
Delete Write	7.0	0.9	0.4%	0.9	0.4%	0.9	0.4%
Open	95.2	0.0	0.0%	0.0	0.0%	12.2	5.5%
Total	**3542.4**	**223.1**	**100.0%**	**143.9**	**64.5%**	**16.1**	**7.2%**

AFS on network-attached storage projections

CMU AFS traces (60-250 clients, 1.6 M reqs)

Data transfer dominates SAD

NetSCSI is able to reduce manager load by 30%

NASD is able to reduce manager load by 65%

AFS Operation	Count in top 5% by work (thousand)	SAD		NetSCSI		NASD	
		Cycles (billions)	%of SAD	Cycles (billions)	%of SAD	Cycles (billions)	%of SAD
FetchStatus	770.5	98.6	37.9%	98.6	37.9%	0.0	0.0%
BulkStatus	91.3	36.6	14.1%	36.6	14.1%	0.0	0.0%
StoreStatus	16.2	3.1	1.2%	3.1	1.2%	3.1	1.2%
FetchData	193.7	83.7	32.1%	24.8	9.5%	0.0	0.0%
StoreData	23.1	15.1	5.8%	3.0	1.1%	3.0	1.1%
CreateFile	12.1	3.7	1.4%	3.7	1.4%	3.7	1.4%
Rename	6.4	1.8	0.7%	1.8	0.7%	1.8	0.7%
RemoveFile	14.6	4.8	1.9%	4.8	1.9%	4.8	1.9%
Others	57.3	13.0	5.0%	13.0	5.0%	13.0	5.0%
Open	480.8	0.0	0.0%	0.0	0.0%	61.5	23.6%
Total	**1665.9**	**260.5**	**100.0%**	**189.4**	**72.7%**	**90.9**	**34.9%**

Recap fundamental modelling results

Network-attached storage offloads file manager
increase manager ability to support storage/clients

NetSCSI offloads transfer only
manager capacity up: 1.6x NFS, 1.4x AFS

NASD offloads transfer, common command processing
manager capacity up: 14x NFS, 2.9x AFS

Implication:
lower overhead cost for manager machines

Related work

Network-attached (secure) storage

- **Baracuda, Seagate; DVD, van Meter**

Third-party transfer

- **RAID-II, Drapeau; PIO, Berdahl; MSSRM, P1244; SCSI**

Richer storage interfaces

- **Logical Disk, deJonge; Petal, Lee; Attribute Mgd, Wilkes;**

Server striping

- **Zebra, Hartman; xFS, Dahlin**

Capabilities

- **Dennis66; Hydra, Wulf; ICAP, Gong; Amoeba, Tanenbaum**

Application-assisted storage

- **Mapped cache, Maeda; Fbufs, Druschel; Cooperative caching, Dahlin, Feeley**

Summary: moving function to storage is multi-win

Network-stripe storage for scalable bandwidth

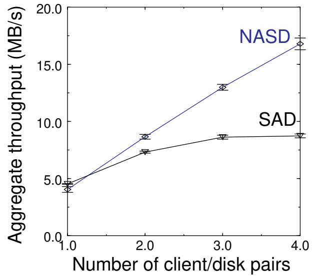
Industry open to evolving functional interface

NetSCSI: server-mgd SCSI; NASD: server-indep access

Both lower manager work; NASD by up to 3-10x

Recent work: prototypes of NASD drives, file systems

Striped NASD/NFS - raw read benchmark



Striped NASD/NFS - file search benchmark