Choosing and Architecting Storage for Your Environment

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Agenda

- VMware Storage Options
  - Fibre Channel
  - NAS
  - iSCSI
  - DAS
- Architecture Best Practices
- Sizing
- Case Study: Impact of Architecture on Performance

Storage Mechanisms

Technology	*Market*	*Transfers*	*Interface*	*Performance*
Fibre Channel	Data Center	Block access of data/LUN	FC HBA	High (due to dedicated network)
NAS	SMB	File (no direct LUN access)	NIC	Medium (depends on integrity of LAN)
iSCSI	SMB	Block access of data/LUN	iSCSI HBA	Medium (depends on integrity of LAN)
DAS	Branch Office	Block access	SCSI HBA	High (due to dedicated bus)

Storage Mechanisms (Topology Comparison)

DAS vs NAS vs SAN

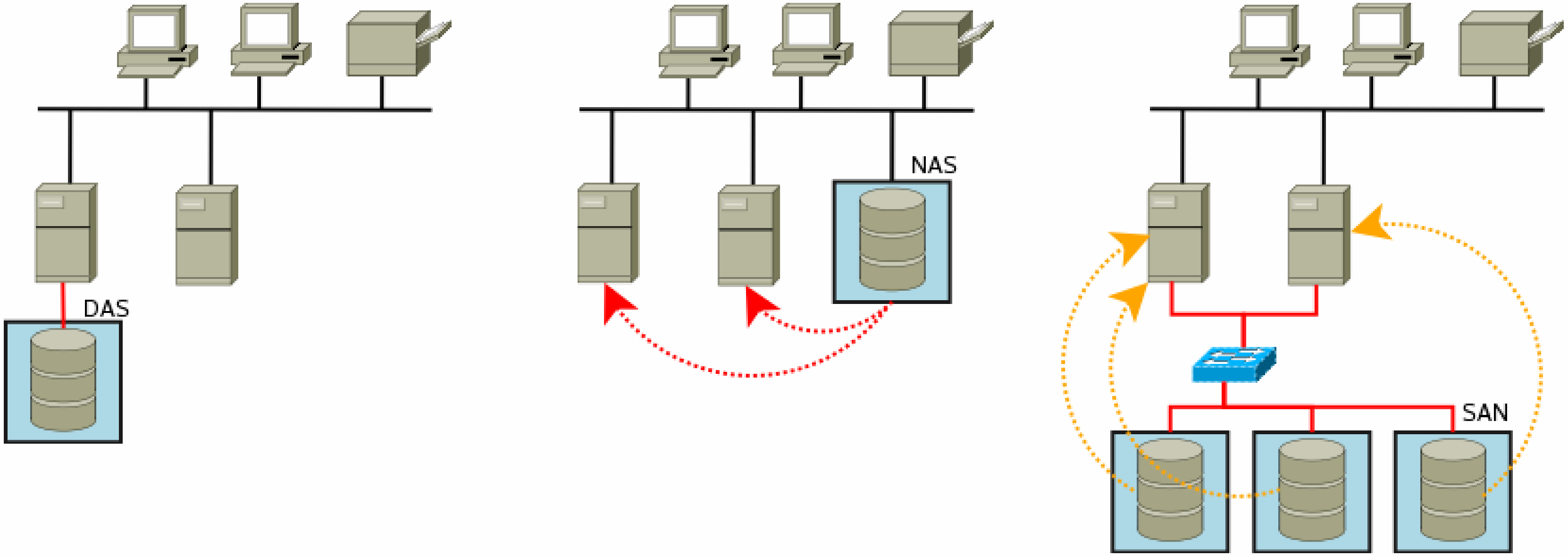
Branch Office | **SMB Market** | **Data Center**

DAS → NAS → SAN

DAS — Direct Attached Storage

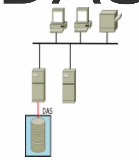
NAS — Network Attached Storage

SAN — Storage Area Network



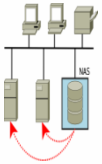
Storage Disaster Recovery Options

DAS



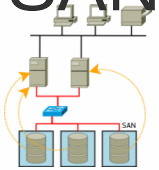
- Tape / RAID
- S/W Cluster

NAS



- Tape / RAID
- NIC failover
- S/W Cluster
- Filer Cluster
- LAN backup
- Data Replication

SAN



- Tape / RAID
- HBA / SP failover
- Fabric / ISL redundancy
- Data Replication technologies
- S/W Cluster within Virtual Machine
- LAN backup within Virtual Machine
- VMware HA
- VMware Consolidated Backup

Choosing Disks

- Traditional performance factors
  - Capacity / Price
  - Disk types (SCSI, ATA, FC, SATA)
  - Access Time; IOPS; Sustained Transfer Rate
  - Reliability (MTBF)
- VM performance gated ultimately by IOPS density and storage space
- IOPS Density -> Number of read IOPS/GB
  - Higher = better

Disk Drive Statistics

Application Attribute	*High-Performance Enterprise*	*Typical 2006 Desktop*
Rotational speed (rpm)	15,000	5,400–7,200
Interface	FC, SAS	SATA
Avg Power: operating idle	 18–20 W 12–14 W	 8–12 W 6–9 W
Nonrecoverable read errors per bits read	1 sector per 10^{15}–10^{16}	1 sector per 10^{14}
Serial link rate (Gb/s)	2–4 FC, 3.0 SAS	1.5–3.0 SATA
Noise (ISO 7779, bels) idle performance seek	 3.5–3.8 4.3–5.9	 2.5 3.1–3.7
Capacities (2006)	37–174 GB	160–320 GB
Performance: sustained transfer average seek	 58–98 MB/s 3–4 ms	 32–58 MB/s 8–10 ms
Relative price per GB	5–10x	1x

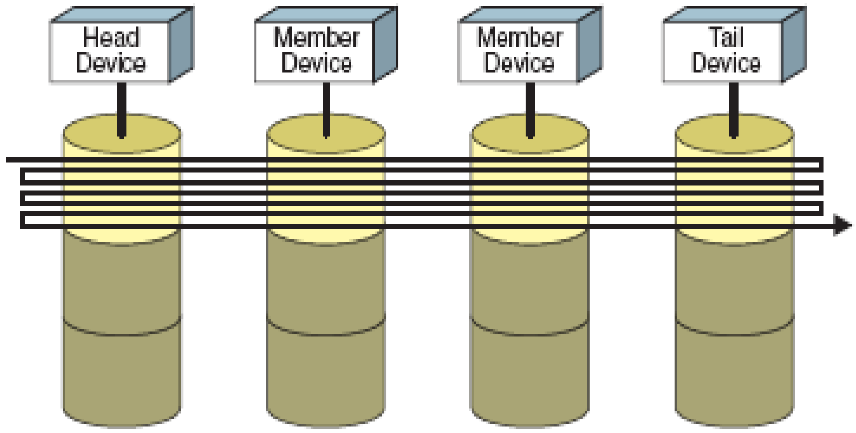
Source: Comparison of Disk Drives For Enterprise Computing, Kurt Chan

Typical IOPS Density

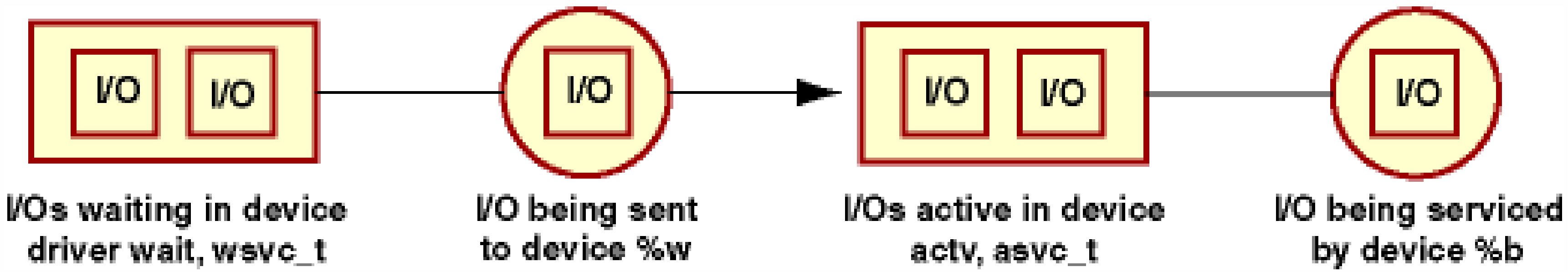
- Tier1 -> 144 GB, 15k RPM->180 IOPS/144GB = 1.25 IOPS/GB
- Tier2 -> 300 GB, 10k RPM-> 150 IOPS/300GB = 0.5 IOPS/GB
- Tier3 -> 500 GB, 7k RPM -> 90 IOPS/500 GB = 0.18 IOPS/GB
- Relative Performance
  - Tier1 -> 1.0
  - Tier2 -> 0.4 (40%)
  - Tier3 -> 0.14 (14%)
- Potential choices -> FC, LC-FC, SATAII

Volume Aggregation

- Stripe virtual LUN across volumes from multiple RAID 5 groups.
- Some storage platforms only concat, but striping is preferred.
- Aggregate across volumes in the same ZBR zone.
- Do not mix volumes from different disk sizes, rotational velocity, or volume sizes.
- It is OK and preferred to stripe within the same volume groups.
- End result is **one LUN** presented to VMware spanning many physical disks.

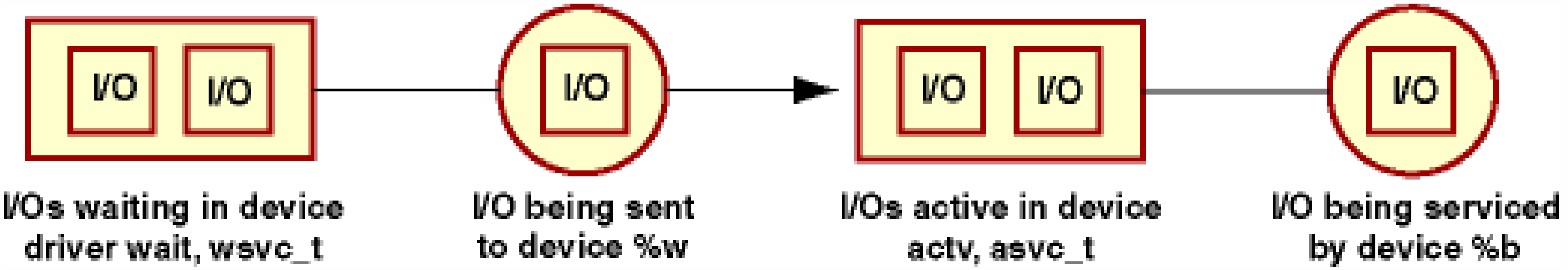


Understanding SCSI Queuing and Throttling



- Service Time: time for disk to complete requests
- Response Time (or **svc_t**) = wait time in queue + service time
- I/O active in device = actv
- Average wait queue response time = wsvc_t
- Average run queue response time = asvc_t

Understanding the Network Storage Stack
SCSI Queuing and Throttling



- SCSI is a connect/disconnect protocol so the array can make certain optimizations
- Wait queue - I/O's buffering in the HBA/sd queue - bad
- Active queue – I/O's buffered in the storage array
- Service queue – I/O's being serviced on the disk (read miss) or cache (read hit, or fast write)

SCSI and Storage Optimizations – Keep that disk busy

- Array writes – written to hardware cache, destaged to disk with SCSI write buffering disabled
- Array reads – Array can reorder reads to minimize storage contention
  - SCSI tag queuing can optimize reads on active disks
- Why is this important?
  - A moderately busy disk services requests faster on whole than an inactive disk

Busy, but not backed into the HBA wait queue

- Average I/O 80-100 ms which is very slow (>50 ms)

R/s	w/s	Kr/s	kw/s	wait	*actv*	wsvc_t	*asvc_t*	%w	%b	device	Utilization	Throughput (IOPS)	Av Read Sz (K)	Serv Time
215.6	2.0	5799.1	29.5	0.0	*20.0*	0.0	*91.8*	0	88	c7t1d0	0.88	217.60	26.90	4.04
215.8	2.4	5814.6	38.5	0.0	*15.3*	0.0	*69.9*	0	84	c7t2d0	0.84	218.20	26.94	3.85
216.0	1.9	5814.9	30.1	0.0	*15.4*	0.0	*70.6*	0	84	c7t3d0	0.84	217.90	26.92	3.85
217.6	2.1	5820.9	32.0	0.0	*25.0*	0.0	*113.9*	0	92	c8t9d0	0.92	219.70	26.75	4.19
216.3	2.0	5803.8	31.0	0.0	*18.6*	0.0	*85.1*	0	89	c8t10d0	0.89	218.30	26.83	4.08
216.4	2.0	5801.3	29.8	0.0	*18.1*	0.0	*83.1*	0	88	c8t11d0	0.88	218.40	26.81	4.03

Flooded, I/O serialized in wait queue

- Average I/O 200+ ms

r/s	w/s	kr/s	kw/s	*wait*	*actv*	*wsvc_t*	*asvc_t*	%w	%b	device	Utilization	Throughput	Av Read Sz	Svc Time
Dua411	Dua461													
121.3	0.7	5677.3	10.9	*41.3*	*13.4*	*338.0*	*109.7*	79	98	c6t0d0	0.98	122.00	46.80	8.03
121.2	0.6	5648.6	9.1	*43*	*13.2*	*353.5*	*108.6*	79	97	c6t1d0	0.97	121.80	46.61	7.96
120.6	0.4	5654.6	5.7	*34.6*	*12.9*	*285.9*	*106.9*	75	96	c6t2d0	0.96	121.00	46.89	7.93
121.8	0.0	5781.2	0.1	*29*	*11.9*	*238.4*	*97.3*	67	92	c6t3d0	0.92	121.80	47.46	7.55
123.0	0.0	5796.8	0.3	*23.3*	*11.2*	*189.0*	*91.2*	62	90	c6t4d0	0.90	123.00	47.13	7.32
123.8	0.0	5834.6	0.1	*25.1*	*11.4*	*202.8*	*92.0*	64	90	c6t9d0	0.90	123.80	47.13	7.27
94.9	1.1	2915.4	17.2	*15.3*	*7.9*	*159.0*	*82.6*	41	67	c6t16d0	0.67	96.00	30.72	6.98
94.6	0.8	2905.1	12.1	*14*	*7.8*	*146.5*	*82.1*	41	67	c6t17d0	0.67	95.40	30.71	7.02
95.4	0.9	2937.1	13.6	*14.6*	*8*	*151.2*	*82.9*	42	67	c6t18d0	0.67	96.30	30.79	6.96

LUN Queuing for VMware

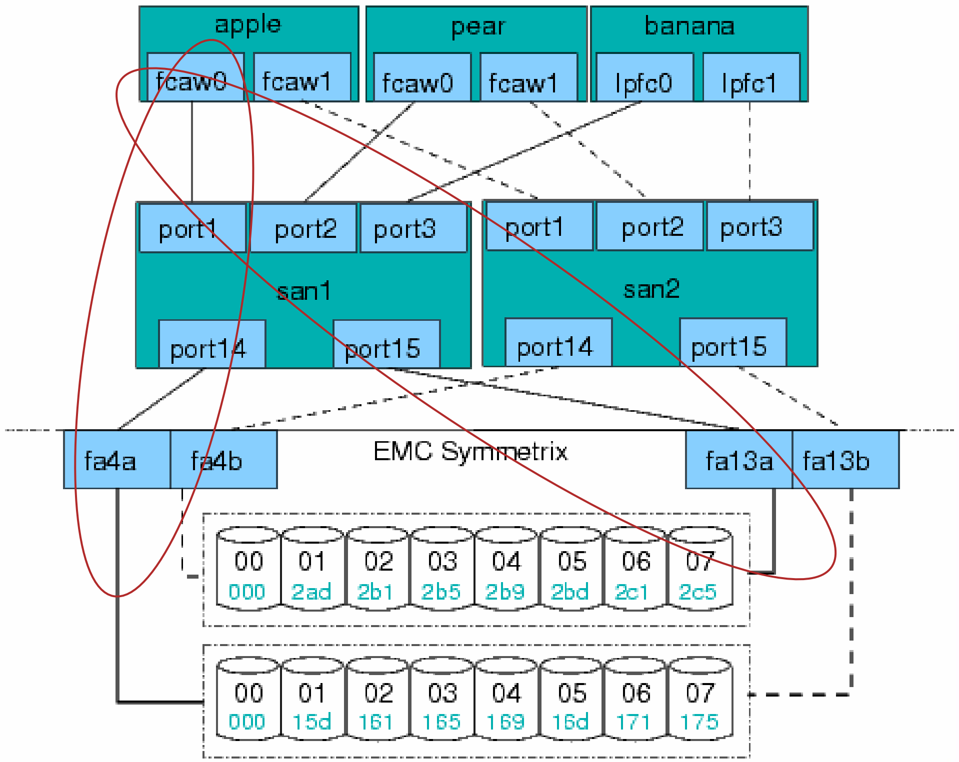
- Queuing techniques <u>different</u>
  - In symmetric storage, path software can spread I/O's to different adapter ports (LUN queues in adapter ports)
  - Typical open system can have several LUNs
- VMware
  - LUN/VMFS active on one path (active/passive arrays) only
  - VMFS volume much larger than typical OS LUN
- Why is this important?
  - Default HBA queue depth usually too small

Controlling VM's from flooding your storage

- Easiest method is setting the maximum outstanding disk requests
  - This setting can slow a read I/O intensive VM, but will protect the farm. Problems usually surface during backup/restore
    - Advanced Settings → Disk.SchedNumReqOutstanding (Number of outstanding commands to a target with competing worlds) [1-256: default = 16]: 16
  - Do not set this to the queue depth as this is intended to throttle multiple VM's

LUN Presentation – SAN Zoning

- Use WWPN zoning and zone the initiator (HBA) to the FA (storage port) in a 1:1 relationship
- This minimizes RSCN disruptions, device LI/LO, fail-over host based confusion



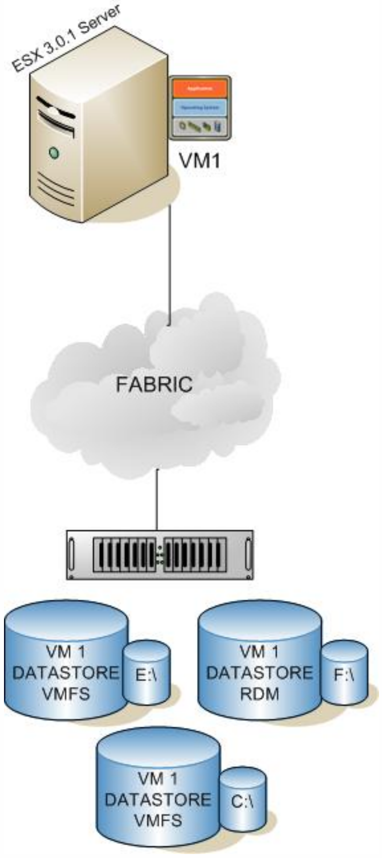
CASE STUDY

Impact of Architecture on Performance

Background

- Architecture can have huge performance implications
- Every environment will be different
- Use tests in your environment to find bottlenecks

Our Current Architecture

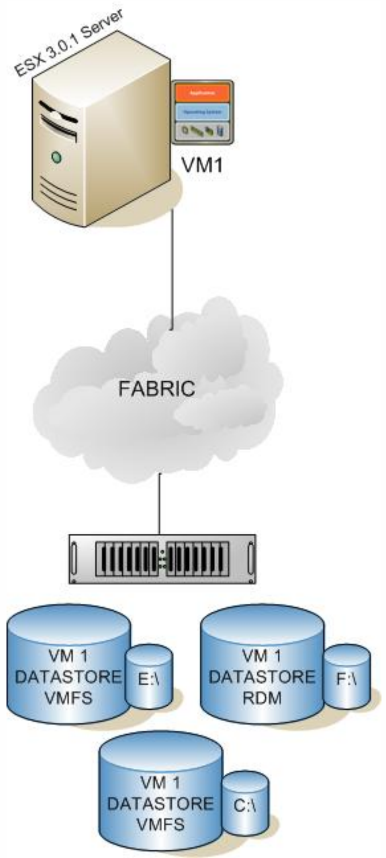


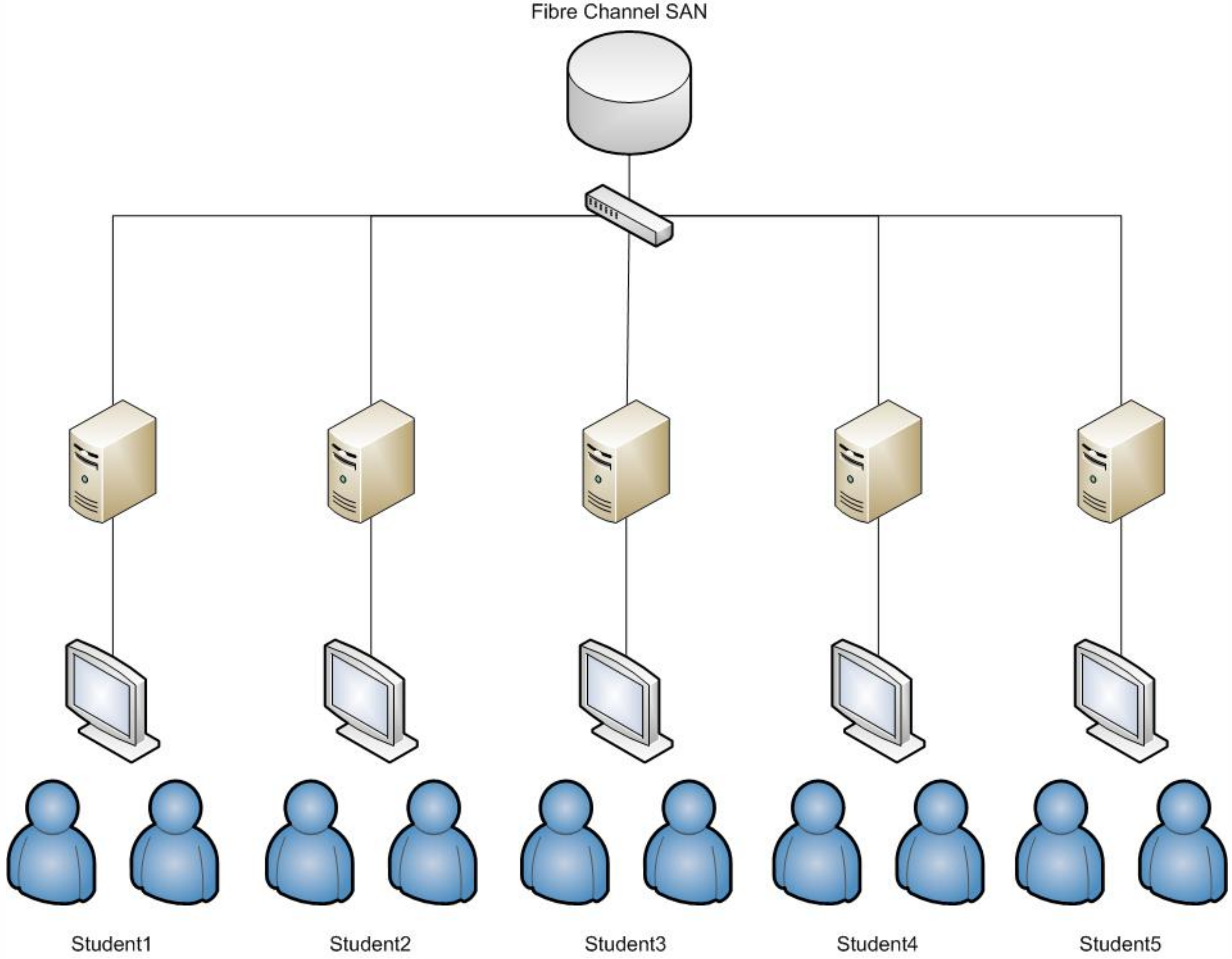
Tests Run

- IOMeter
  - 70% Random, 70% Read, 64k Block
  - 5 Minute run
  - 10 GB disk

	Fibre Channel Student Results		Fibre Channel Pre-Run		iSCSI Pre-Run		NAS Pre-Run
	VMFS	RDM	VMFS	RDM	VMFS	RDM	VMDK
Total I/Os per Second (IOPS)			3294	3353	1813	1865	1691
Total MBs per Second (Throughput)			206	209	113	116	105
Average I/O Response Time (ms)			1.21	1.19	2.20	2.14	2.36
% CPU Utilization (total)			33.87%	27.26%	24.00%	19.40%	23.00%

Scale Out Architecture





Results

- Students got worse performance
  - Where's the bottleneck?

	Fibre Channel Student Results		Fibre Channel Pre-Run		iSCSI Pre-Run		NAS Pre-Run
	VMFS	RDM	VMFS	RDM	VMFS	RDM	VMDK
Total I/Os per Second (IOPS)	1894	1868	3294	3353	1813	1865	1691
Total MBs per Second (Throughput)	110	113	206	209	113	116	105
Average I/O Response Time (ms)	1.19	1.24	1.21	1.19	2.20	2.14	2.36
% CPU Utilization (total)	22.73%	21.72%	33.87%	27.26%	24.00%	19.40%	23.00%

Analysis

- iSCSI and NAS give good performance
- Tier your storage
- RDMs do not always give better performance than VMFS
  - (1894, 3294) for VMFS (1868, 3353) for RDM

	Fibre Channel Student Results		Fibre Channel Pre-Run		iSCSI Pre-Run		NAS Pre-Run
	VMFS	RDM	VMFS	RDM	VMFS	RDM	VMDK
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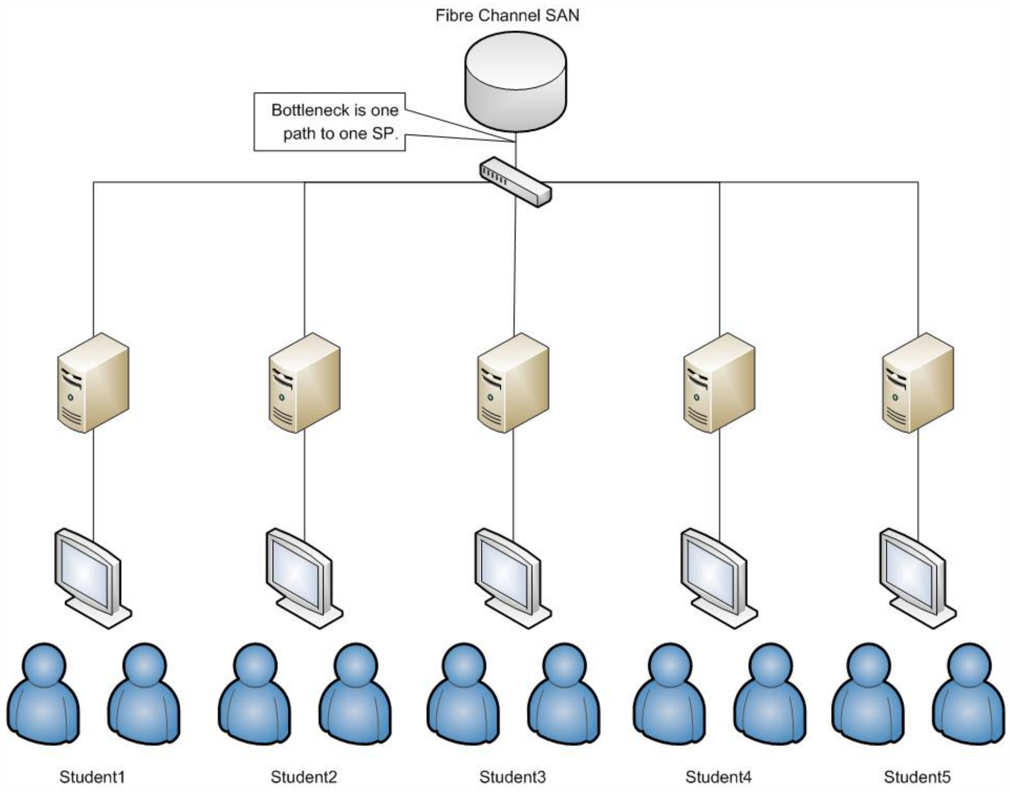
% CPU Utilization (total)	22.73%	21.72%	33.87%	27.26%	24.00%	19.40%	23.00%

Analysis

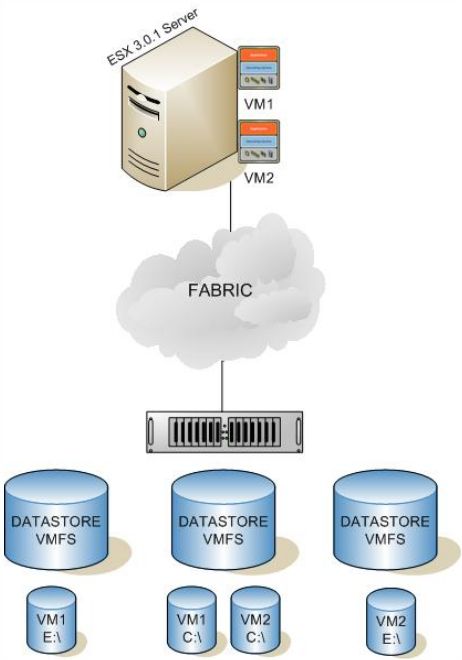
- Located a potential bottleneck – SP path



- How could you improve performance?

Discover a Down Stream Bottleneck

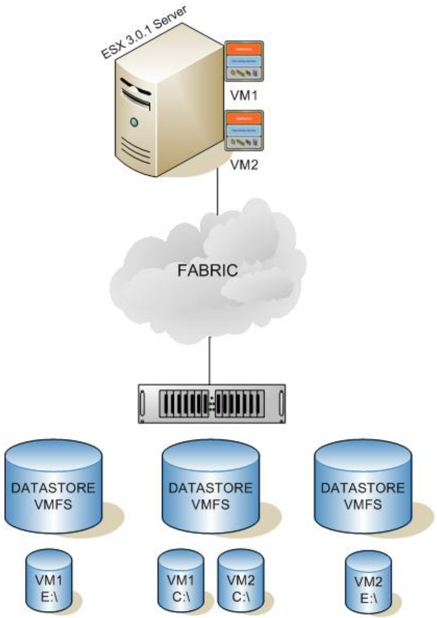
- Test to see if our path is the bottleneck
  - Use more downstream destinations
- 1 ESX Server – 1 Array – 2 Datastores



Discover a Down Stream Bottleneck

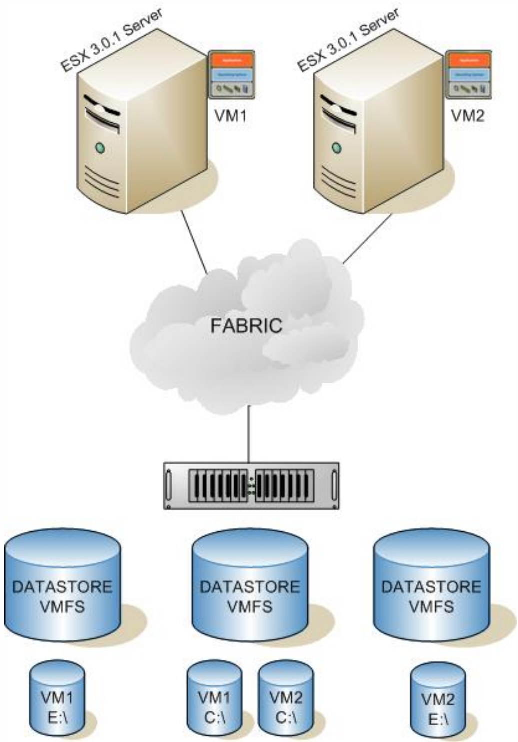
- Split datastores give better performance because of more work queues
  - Path was not our bottleneck

	IOPS	MB/s	Latency	%CPU
VM1	1961	123	2.04	22.27%
VM2	1983	123	2.01	22.37%
Total	3944	246		
Previous	3294	206		



Lab Session 4 – Storage Performance – Step 5

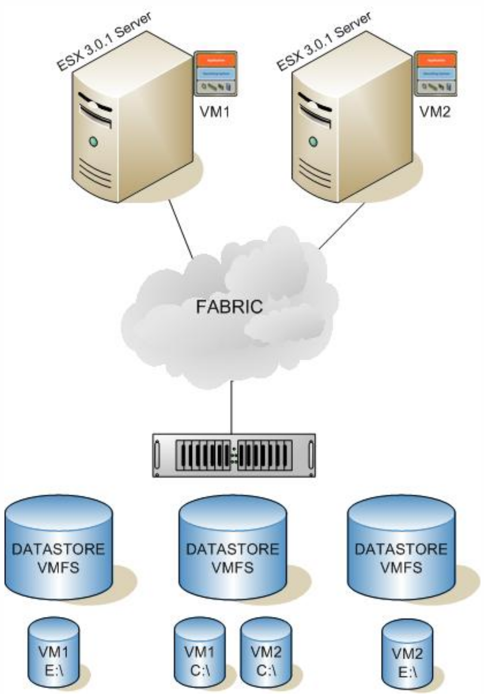
- Test to see if HBA is bottleneck
- 2 ESX Servers (2 HBAs) – 1 Array – 2 Datastores



Lab Session 4 – Storage Performance – Step 5

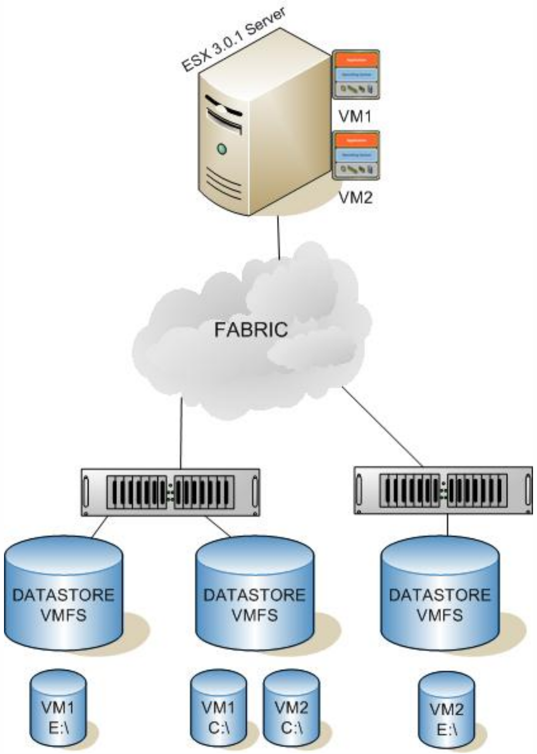
- Still bound at path to SP

	IOPS	MB/s	Latency	%CPU
VM-Host1	1980	124	2.02	20.30%
VM-Host2	1989	124	2.01	20.70%
Total	3969	248		
Previous	3944	246		



Lab Session 4 – Storage Performance – Step 5

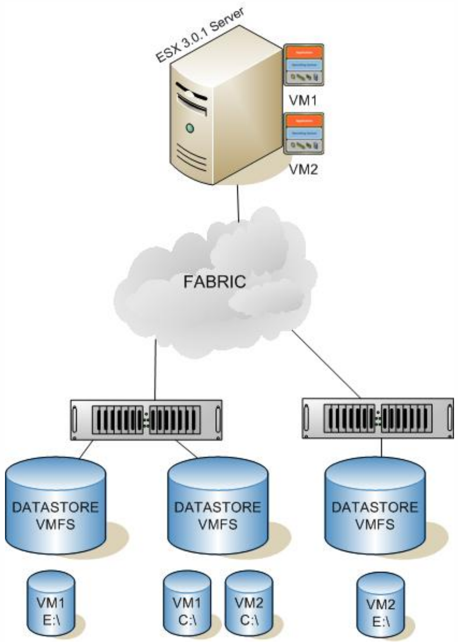
- Test to see where SP path is bottleneck
- 1 ESX Server – 2 Arrays (2 SPs) – 2 Datastores



Lab Session 4 – Storage Performance – Step 5

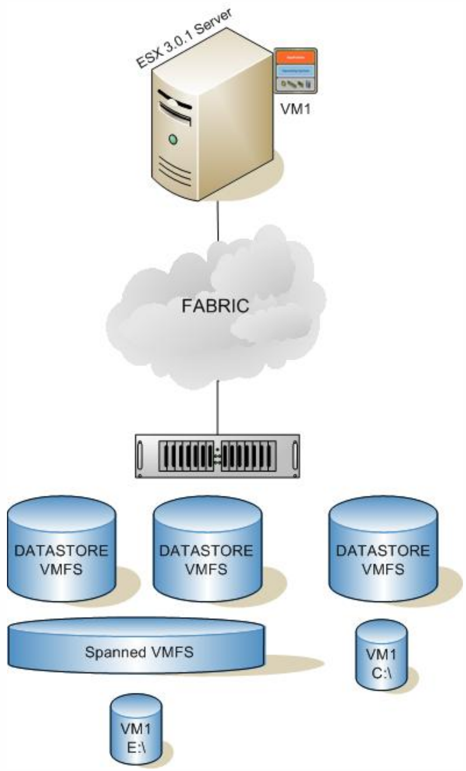
- Adding more SPs increased performance – Hit HBA bound
- Manually load balance LUNs

	IOPS	MB/s	Latency	%CPU
VM-Array1	2048	131	1.90	20.88%
VM-Array2	2153	134	1.86	20.08%
Total	4201	265		
Previous	3969	248		



Lab Session 4 – Storage Performance – Step 5

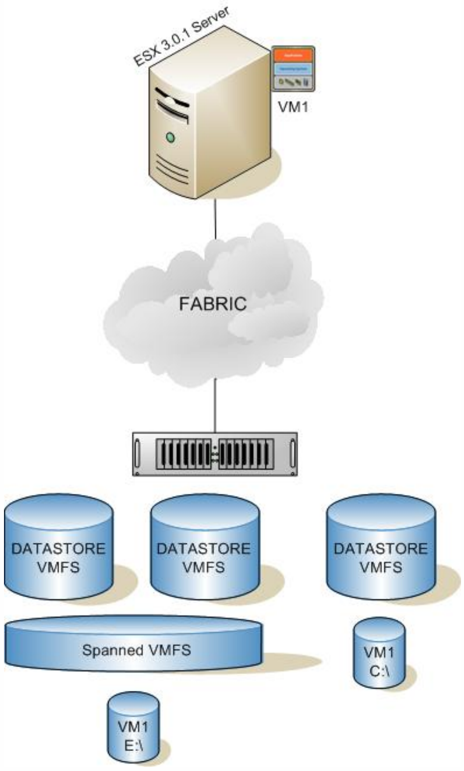
- Test spans across volumes
- 1 ESX Server – 1 Array – Spanned Volume



Lab Session 4 – Storage Performance – Step 5

- Spanned Volumes **DO NOT** increase performance

	IOPS	MB/s	Latency	%CPU
Student#-Storage	3328	208	1.20	32.74%
Original	3294	206		



Lab Session 4 – Storage Performance – Step 5

- NOTE: Every environment is different. If you decide to run this test in your environment your numbers may be different for a variety of reasons. Many things will change the results of your tests such as SAN fabric architecture, speed of disks, speed of HBAs, number of HBAs, etc. The numbers introduced in this lab are by no means meant to be an official benchmark of the lab equipment. The tests run were simply used to create a desired performance issue so that a point could be made. Please consult your storage vendor contacts for official benchmarking numbers on their arrays in a number of environments

Questions?

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