



Education

Latency: The Heartbeat of a Solid State Disk

Levi Norman, Texas Memory Systems

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➤ Latency: The Heartbeat of a Solid State Disk

- ♦ This SNW tutorial session is about the number one reason an IT manager would move away from HDDs and towards solid state disks (SSD)...latency. More importantly low latency. Latency becomes less of just a number and more an important metric when considering implementing any serious performance storage related solution. Today low latency can only effectively be addressed by one particular type of storage architecture and that's an enterprise SSD design. Latency in a technical environment is synonymous with delay. More succinctly latency in terms of a SSD is how long it will take for a request to complete its round trip cycle from the time the request enters the device to the time that it leaves the device with the "payload" in tow. In a storage world where metrics such as \$/GB are entrenched as a de-facto standard of measurement, and \$/IOPS has arisen to become a "relevant" metric, we continue to miss a critical discussion point. And that is that low latency is the most important thing that can be delivered to a performance sensitive application or a workhorse database environment. In this session we will discuss the merits of low latency solutions and what they mean when coupled with a high IOPS and a large bandwidth design. From a business perspective, low latency will be discussed in terms of how it saves money, makes money or ideally does both for an enterprise organization. Learning Objectives • Latency, what is it? • Why does latency matter, no one seems to be really talking about it? • How coupling low latency to high IOPS and generous bandwidth creates true performance solutions.

- Latency: The Heartbeat of a Solid State Disk
- What is Latency and why does it matter?
- Disk drives and Latency
- Resolving Latency
- Business Examples
- The “Net, Net” of it all

➤ Why does this subject matter?

- ◆ “Can’t I just keep doing what I’ve always done and buy some more disks?”

➤ The underlying concern of:

- ◆ The CEO
 - Business Efficiency & Performance
- ◆ The CIO/CTO
 - Managing Constrained Resources
- ◆ The Datacenter Manager
 - Balanced Architecture: “Chasing the Bottleneck”
- ◆ The Business Group
 - Application Performance to meet Business Goals

- We must first define performance in the context of this discussion
- Three basic metrics are applied to describe the performance aspects of any storage system:
 - ◆ IOPS
 - › The number of Input or Output (IO) requests per second
 - ◆ Bandwidth
 - › The number of bytes transferred per second
 - ◆ Response Time (**Latency**)
 - › The amount of time each IO request will take to complete

- And let's define latency
 - ◆ AKA “response time” or “wait time”
- Within a computing system it is the amount of time between a request to a resource being issued, and when that request is served
 - ◆ Consider a support call center for an elementary example. “Latency” is the amount of time a customer has to wait after dialing the support number until a representative is available to service the call

➤ System view

- ◆ It's an integral part of the pre-described recipe that makes performance feasible. The latency of any “system” is a critical factor in the performance of that “system.”

➤ As such latency has a dramatic impact on the customer's experience of an application

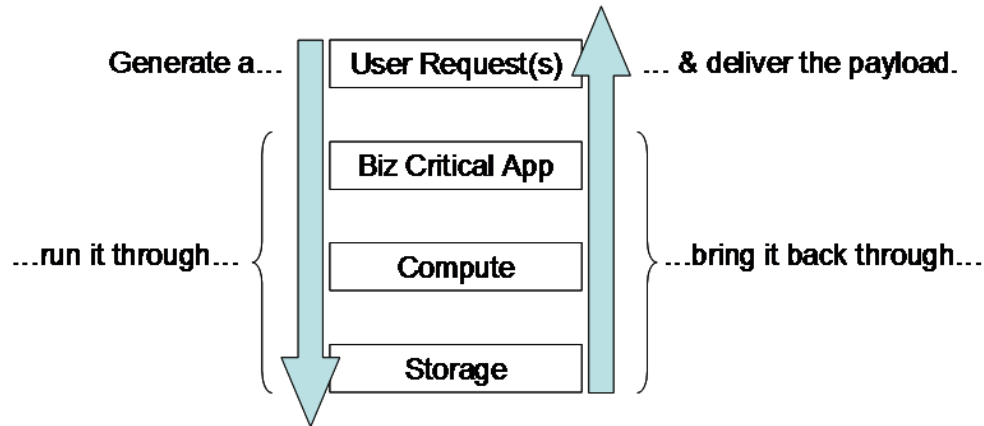
- ◆ Consider again the call center example...
 - The customer will have a radically different perception of the service if they wait 1 minute vs. if they wait 30 minutes.

➤ Business view

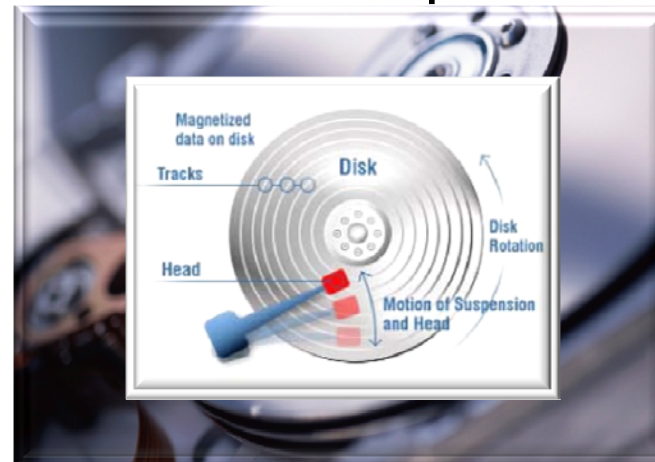
- ◆ Creates competitive advantage
- ◆ Optimized system/architecture performance
- ◆ Best case use of available resources
- ◆ Hugely favorable TCO/ROI versus alternative

How to make Latency

Conceptually...



...at the HDD component level



Hard Disk Drives & Latency

- What have hard disk drives attempted to do to avoid the latency penalty?
- Lower access times via mechanical improvement over time...
 - ◆ From drive inception (in 1956) we have lowered access from seconds to milliseconds, while CPU's and memory are performing in nanoseconds...
 - ◆ Design improvements
 - › Spindle
 - › Actuator
 - › Media
- Short stroke
- Dual actuators
- Split actuators
- Ratchet up the RPMs
 - ◆ 15K first introduced in 2000
 - ◆ Rotational speed increases hit a performance wall at 22K
- Play “tricks” with the RPMs
 - ◆ Virtual RPM



Caching as a Solution

➤ Adding RAM to the server

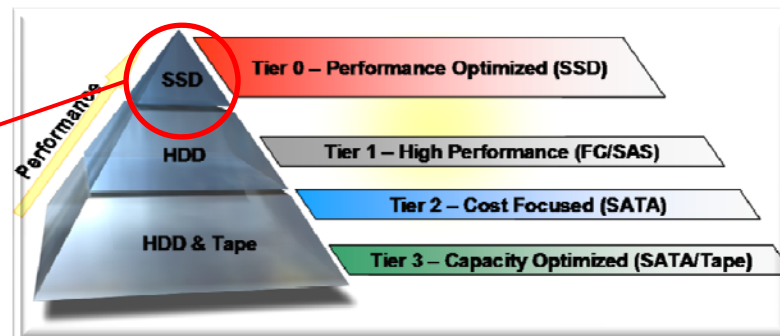
- ◆ Volatile
- ◆ Only accelerates reads
- ◆ Only useful if reads quickly follow writes
- ◆ Limited capacity
- ◆ High cost per capacity

➤ Adding Cache to the disk array

- ◆ Helpful for accelerating bursts of writes
- ◆ Sustained writes overrun cache and slow to speed of disk
- ◆ Controller architectures tend to mitigate effectiveness
- ◆ High cost per capacity

- Best method revolves around the idea of balance or optimization
- So what accomplishes that goal?
 - ◆ SSD/SSS where storage (direct or network) is concerned
 - › Manage, move & store data without moving parts
 - › Do it in MICROseconds, not MILLiseconds

Form Factor	Latency
RAM Rack Mount SSD	.015ms
Flash Rack Mount SSD	.07ms
PCIe SSD	.05ms
Hard Disk Drive	4-7ms



Back to Storage Performance

- Again, three metrics are used to describe the performance aspects of a storage system:
 - ◆ IOPS
 - › The number of Input or Output (IO) requests per second
 - ◆ Bandwidth
 - › The number of bytes transferred per second
 - ◆ Response Time (**Latency**)
 - › The amount of time each IO request will take to complete
- Creating a low latency solution
 - ◆ Disks are many
 - ◆ Wide is the path
 - ◆ Performance is slow...

- If you really didn't care about latency or IOPS how would you get the best bandwidth?
- ◆ Fibre Channel?
 - ◆ Infiniband?
 - ◆ iSCSI?
 - ◆ Something else?



- Place 10,000 1TB tapes in a truck and move it all to a remote site in 8 hours
 - ◆ The Bandwidth of the transfer is **460 GB/s**
- Setting up a DR site often involves this exact process, as the bandwidth required is far greater than networks can provide
- The **latency** of the transfer is *~8 hours*
 - ◆ Severely limits the effectiveness of this type of transfer



But is the Bottleneck Bandwidth?

- Storage bottlenecks are rarely bandwidth related...
- Why?
 - ◆ Disk Bandwidth has increased at a much faster rate than disk latency
 - ◆ Ex: 1987 to 2005
 - › Bandwidth Improvement - 30x
 - › Disk latency improvement - 3x
 - ◆ Combining disks in a RAID set is an easy way to increase bandwidth.



Obviously not just Bandwidth

- Is **latency** where I should focus?
- Look at the server statistics
 - ◆ Average Queue Depth: this is the average amount of IO requests outstanding.
 - ◆ CPU Utilization: this is how much of the time the processors are processing data numbers verses waiting for data to process.
- If the Average Queue is one or higher and the CPU utilization is low, you are the proud owner of a storage bottleneck

- Why is the response time (latency) of varying SSD design types different?
 - ◆ “The response time of SSDs from different vendors seems to vary dramatically.”
- Depends on two main factors
 - ◆ The type of chip used
 - › RAM vs. Flash
 - ◆ The design of the chip controllers and the array
 - › Where is the logic of the design focused?
 - Certain vendors focus storage management features
 - Other vendors focus on performance

➤ Queue = Response Time * IOPS

- ◆ The Queue is the number of parallel IO requests
- ◆ This formula is simply known as Little's Law

Increasing Queue Depth?

- The queue depth of a storage bound application is dictated by the code of that application
- Altering the queue depth requires altering the code
 - ◆ This may not even be possible if the business logic and requirements involve interrelated data.
 - Ex: Inventory updates in a database need to be updated as soon as a purchase order is received if a business wants to implement a just in time inventory system.

What does that mean for IOPS?

- $\text{IOPS} = \text{queue} / \text{response time}$
 - ◆ That means the IOPS of a storage device can be independent of its response time!
 - ◆ This is why adding spindles to an array increase the IOPS

- Solid State Disks are equivalent to extremely large arrays of normal disks when it comes to IOPS
 - ◆ It is just easier to hit high IOPS numbers with a lower queue!

- Applications have a limited amount of storage queuing they can tolerate before the processor has to sit idle waiting for data
- Lowering the response time allows the storage to return more data to the server while remaining under the queue limit
 - ◆ This replaces the time the CPU sat idle with time spent processing data
- Solid State Disks that are purchased to accelerate applications should be compared on a response time (latency) basis

Can I Keep on Queuing?

- If your application can queue at extremely high levels
 - ◆ Keep queuing and adding disks until your server is processor bound
- In a case where you can queue indefinitely, look at SSDs if the IOPS/GB reach a level that makes SSDs the least expensive option

- If you are still not convinced that addressing latency isn't incredibly valuable and worthy of time invested...
- Let's work through a couple of business examples
 - ◆ Effect on
 - › An e-Commerce environment
 - › A data warehousing/data processing environment
 - › An OLTP environment within a financial trading organization
- Each example is an environment where it doesn't matter how many disks you put in...IOPS grows, bandwidth grows, but latency bottoms out at around 5ms with disks

➤ ABC, Co. & an e-Commerce environment

- ◆ Industry – e-Commerce
 - Application – Inventory Database
 - 40 million line items
 - 3,000 customers that need to be kept up to date
- ◆ Challenge – Improve inventory database by eliminating backlog of updates
- ◆ Solution – RAM SSD rack mount system
- ◆ Result – 400% performance improvement
- ◆ Cost differential
 - RAID storage system at \$51k
 - 128GB of rack mount SSD at \$50k



“Monolithic RAID is very expensive and we were not seeing improved performance.” ABC President

➤ DEF, Co. & a data warehousing environment

- ◆ Industry – Database enterprise co-op
 - Application – Data warehousing, data processing
 - 10-15 million transactions
 - Processed daily
- ◆ Challenge – Address the bottleneck caused by processing and consolidating huge volumes of transactions into a production data mart
- ◆ Solution – Flash SSD rack mount system
- ◆ Result – Batch processing that runs 3x faster
- ◆ Cost differential
 - 60 15K FC spindles at \$125k
 - 1TB of rack mount SSD at \$80k



“The [SSD]...outperforms traditional disk storage, and was more cost-effective than our interim disk solution.” DEF CTO

➤ XYZ Online & an MMORPG environment

- ◆ Industry – Online gaming
 - Application – Massively multiplayer online game (OLTP) on a SQL Server
 - 300,000 dedicated subscribers
 - Single, connected online environment
- ◆ Challenge – Scale to over 25,000 users with instant response times
- ◆ Solution – RAM SSD rack mount system
- ◆ Result – 4000% (40x) performance improvement delivers immediate satisfaction and a new record for more than 53,000 simultaneous users
- ◆ Cost differential
 - Displaced big iron RAID at \$175K
 - 64GB of rack mount SSD at \$36k



“The effect of the [SSD] was immediate on both system performance and customer satisfaction.” XYZ CEO

Sum of the Business Examples

➤ So what was gained?

- ◆ Competitive Advantage
- ◆ Balance
- ◆ Throughput
- ◆ Efficiency

➤ And what was saved?

- ◆ Time
- ◆ Resources
- ◆ Energy

- IOPs, bandwidth, and CPUs have all been on a performance growth trajectory that is truly impressive
- Storage has been unable to keep up due to mechanical latencies that remain today in the low milliseconds
 - ◆ Can increase IOPS and Bandwidth
 - ◆ But can't decrease latency with disks
 - ◆ Can only decrease latency by eliminating mechanical devices
- The key to balancing today's architectures lies within latency
 - ◆ Latency is the single most important aspect that solid state storage delivers to enhance performance
- Solid State Storage Technology has an answer for your performance needs!
 - ◆ Latency is the heartbeat of that answer...

- Looking for something on the features, relative costs, and performance characteristics of the different solid state architectures?



**Check out SNIA Tutorial:
Solid State Storage
Architectures**

by Jamon Bowen

- Please send any questions or comments on this presentation to SNIA: tracksolidstate@snia.org

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